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WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

A. General Section

- Letter of Welcome
  giving details of Monday November 13th arrangements
- Questionaire Personal Details
- List of Participants

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ir. E.L.P. Hessing	Programme Coordinator
ir E.H.A. Hofkes	Programme Officer
Ms. M.M. Heseltine	Project Assistant

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DRAFT AGENDA

SUNDAY 12, NOVEMBER

17:00	Registration and Issue of Workshop Documents at Park Hotel (Lounge).

MONDAY, 13 NOVEMBER

9:30 - 10:30	Opening Session
10:30 - 11:00	COFEE BREAK
11:30 - 12:30	Introduction of Reference Documentation Review of on-going and planned programmes
12:30 - 13:30	LUNCH
13:30 - 15:00	Introduction of Guide on Laboratory Testing Introduction of Guidelines for Field Evaluation
15:00 - 15:30	TEA BREAK
15:30 - 17:00	Presentations General Discussion on Handpump Selection for Rural Water Supply Programmes.
17:00	DRINKS

TUESDAY, 14 NOVEMBER

9:00 - 12:30	Laboratory Testing of Handpumps detailed review of Working Documents; reference to other sources of knowledge and determination of outline for code.
12:30 - 13:30	LUNCH
13:30 - 17:00	Field Evaluation of Handpumps detailed review of Working Documents; reference to other sources of knowledge and determination of outline for guide.
20:00	JOINT DINNER

WEDNESDAY, 15 NOVEMBER

9:00-12:30	Working Session: a) Handpump Laboratory Testing Code b) Handpump Field Testing Guide
12:30 - 13:30	LUNCH
13:30 - 15:00	Introduction and review of the draft Plan of Action
15:00 - 15:30	TEA BREAK
15:30 - 17:00	Finalization of the Plan of Action

THURSDAY, 16 NOVEMBER

9:00 - 10:30	Review Working Session Report. General discussion on further development of selection methodology
10:30 - 11:00	COFFEE BREAK
11:00 - 12:30	Review of the Plan of Action
12:30 - 13:30	LUNCH
13:30 - 14:30	Recommendations for development of Plan of Action
14:30 - 15:00	CLOSING SESSION
	TEA

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WORKSHOP

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HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

GENERAL OBJECTIVES

1. To survey and review current and planned handpump evaluation and testing programmes.

2. To define a suitable methodology for handpump evaluation and testing, and to formulate guidelines for the set-up of programmes.

3. To review the draft protocol for field evaluation of handpumps, and to state the direction further development of these guidelines should take.

4. To review the draft guide for laboratory testing of handpumps, and to state the direction further development of this guide should take.

5. To prepare a draft Plan of Action for international collaboration on hand-pump evaluation and testing, including the development of mechanisms for the systematic exchange of information and the coordination of on-going and planned programmes, and arrangements for funding.

6. To formulate recommendations for further work and future activities.

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B. Working Documents section

W.D. 1 Draft "Guidelines for Field Evaluation of Handpumps"
W.D. 2 Draft "Handpump Laboratory Testing Guide"

C. Background Information Section

B.P. 1 Shallow Handpump Design : Summary
B.P. 2 Bangladesh Rural Water Supply Programme
B.P. 3 Evaluation of Simple and Inexpensive Pump for Community Water Supply Systems : South-East Asia
B.P. 4 Field Testing of Hand-operated Water Pumps : Costa Rica; Nicaragua
B.P. 5 Evaluation of Deep-well ("Dempster") Handpump - Indonesia
B.P. 6 Handpump Evaluation and Testing : Thailand
B.P. 7 Development India Mark II Pump : India
B.P. 8 The Bangalore Pump : India
B.P. 9 Shallow Well Pump Improvement Research Project on Stage I of Project : Malawi
B.P. 10 Report Format for Field Testing of Handpumps
B.P. 11 Reciprocating Pumps Test Code
B.P. 12 Comparative Testing of Consumer Products ISO Guide 12
B.P. 13 Format "Work-bench Inspection"
B.P. 14 Directory of Handpump Manufacturers
B.P. 15 Hand Pumps for Drinking Water Wells
B.P. 16 Rate of Wear of PVC Pump Cylinders.

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WORKSHOP
on
HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
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ADDITIONS TO LIST OF BACKGROUND DOCUMENTS

B.P.	17	Development of Handpump for Rural Thailand
B.P.	18	Inexpensive Plastic Hand Pump and Well
B.P.	19	Report on the Final Evaluation of the Pilot Project for Maintenance of Handpump Tubewells with people's participation.
B.P.	20	Survey of Boreholes in Mtchfu District (Central Region).

ADDITIONS TO WORKING DOCUMENTS

W.D.	1	Reliability - F.E. McJunkin
W.D.	2	Notes on Field Testing of Pumps - J. Cuthbert

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HANDPUMP EVALUATION AND TESTING

The Hague 13-16 November 1978

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WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

The Hague, 13-16 November 1978

The departure times for the KLM coaches from Schiphol to The Hage Central Station are as follows:

The first coach departs at 06.55 in the morning. The following ones leave every 40 minutes, the last one departing at 12.01 at night.

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WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

SCOPE AND OBJECTIVES OF WORKSHOP

by

E.H.A. Hofkes

SCOPE AND OBJECTIVES OF WORKSHOP

1. Introduction

Any international statistic will necessarily be crude, and with a large margin of error. However, a not unreasonable assessment could be that, at present, some 400-500 mln people depend on handpumps for their drinking water supplies. The drinking water programmes envisaged by the developing countries in fulfillment of their commitment to the targets set for the Drinking Water Decade 1980-1990, would when implemented according to the present plans, have - at least - another 200-300 mln people served with handpump water supplies. In the same period, very conservatively estimated, handpumps serving some 200-300 mln people will need to be replaced by new ones.

Pursuing, for a moment, the fugitive - and meanlingless - figure representing a global requirement of handpumps (shallow well, deep-well, all types) the above population figures indicate that a number of handpumps equivalent to a population served of between 600 and 800 mln people will have to be selected, produced and installed, and - last but not least - maintained during their service life.

With each pump serving say 120-160 persons (averaged for all sorts of situations), the global requirement of handpumps for the 1980-1990 Decade would seem to be: over 5 mln

Handpump costs, of course, do range considerably; say from $ 25 for a very simple shallow well unit to about $ 800 - $ 1.000 for a deep-well Mono pump. Again, for the sake of arriving at a global figure, the total sum of the funds required for meeting the handpump requirements of the 1980-1990 Decade, a weighted average could be assumed at a level of $ 100 - $ 140 per pump.

A conservative estimate, then, of the amount to be spent on handpumps of all types and makes, over the coming ten years or so, would be: $ 500 - $ 700 mln.

We all realise that a well or borehole fitted with a handpump is no good unless the pump is operative. Pump costs in the total capital investment for a handpump/well system rarely exceeds 20 %. Occasionally, one finds cases with ratios as low as 5, or even, 1 %. The reliability of the entire handpump/well system is dependent on the pump, and unjustified attempts to cost savings on the pumps may compromise the very purpose of installing pumps and wells; to bring a reliable supply of safe water.

Using a 10 % ratio for the handpump cost in the handpump/well system, we arrive at a figure of $ 5-7 billion indicating the monetary value associated with the many choices of handpump which are to be made in the coming ten years or so.

2. HANDPUMP SELECTION

Some official, or group of officials in the water supply agency of the developing countries concerned, or a planning commission, national budget bureau, or whoever, in consultation with representatives of any international or bilateral organization involved, will have to select a pump or a number of pumps for particular projects and, in effect, for the national water programmes. One may think of the Director and his staff in a Rural Water Supply Division in the Ministry of Health of a particular country, the Chief Engineer in the Water Department of a Public Works Ministry, the Director of a Public Health Engineering Department, and officials in similar positions. Often committees or consultative groups are formed to have representation of all interests involved in the selection of handpumps for water programmes.

Chosing handpumps is difficult. The so called handpump solution to the rural water supply problem is complex. Experience shows that the use of handpumps in community water supplies presents serious problems, with regard to design, quality of manufacture, installation and maintenance, spare parts provision, and administrative organization.

Handpumps are used under a wide variety of conditions. They may serve on shallow or deep wells, with many or few users. Operation may range from almost continuous to infrequent and maintenance from adequate to none at all.

Numerous handpump models are on the market; others may be obtained from non-commercial sources, or assembled from generally available "off-the-shelf" materials.

Proper selection of handpumps, of course, is crucial to the success of any handpump programme. Looking at the water supply officials, water authority committee, or planning commission officers charged with the task of selecting the pumps to be used in their countries water programmes, the question is: what sort of guidance and assistance from the international community would be helpful and instrumental.

These would be inputs to help achieve a balanced and well structured handpump selection process based on careful consideration of all pertinent factors such as:

- pump technology and design
- hydraulic capacities, and costs
- installation practise
- maintenance requirements
- possibilities of indigenous manufacture.

I should like to mention the following instruments/tools of handpump selection:

1. Handbook giving state-of-the-art of handpump technology; plus information on handpump programme organization, research and development work, indigenous manufacture etc. (IRC Technical Paper No. 10).

2. Catalogue of Handpumps, and Directory of Handpump Manufacturers.

3. Field Evaluation and Laboratory Testing.

4. Systematic Consideration of Handpump Maintenance; organization; institutional set-up, etc.

5. Assessment of Potential and Possibilities for Indigenous Manufacture of Handpumps.

6. Handpumps Selection Process Flow-Chart.

Thes are instruments of handpump selection to serve those facing the manifold complex questions associated with chosing handpumps for water supply programmes. Evaluation of pump field performance, and laboratory testing feature high amongst these instruments.

3. FIELD EVALUATION AND LABORATORY TESTING

Surely, evaluation of field performance of handpumps supplemented by field tests, confirmed and supported by laboratory testing as appropriate, are important instruments to support the selection process of handpumps.

Several projects of this type are underway both in developing countries themselves, and in certain industrialized countries. All are conducted with the active support of international or bilateral agencies. The methodology used in these projects is as yet not very well established. The improvement of this methodology should be the object of international collaboration.

Comparison of handpumps on an international basis will require common criteria, definitions and methods. Uniformity in the collection and recording of pump performance data is required.

Therefore, it is very desirable to establish a standard protocol for field evaluation, and a standard code for laboratory testing.

Establishing methodology for field evaluation and laboratory testing of pumps, means breaking new ground. The requirement is there, but the body of knowledge and experience must grow; and this is only possible, if inputs are received from various sources including:

- those working in international organizations supporting the development and implementation of national water supply programmes;
- supply programmes, and familiar with the role played by handpumps;

- those involved in planning and research pertaining to the use of handpumps in rural water supply;
- those having in-depth knowledge of handpump technology and a wide range of related subjects;
- those having extensive knowledge and experience in the fundamentals and methodology of testing; of numerical ranking through weightable attributes.
- Those working to develop appropriate technology in water supply and sanitation.

All such sources of knowledge and expertise have an essential contribution to make, and I am glad to know that the participants to this workshop, as a group, represent all the sources just listed.

So, although the task in hand may seem a large cup full, I am confident we may make progress towards the establishment of a field performance evaluation protocol and a laboratory testing guide. Supplemented, I would expect, with direction as to other instruments of handpump selection, and an action plan for international collaboration.

<u>I hereby submit the draft general objectives of the Workshop</u>

Working Documents Section

RID 165/5000/78-820509*-3

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DRAFT

"GUIDELINES FOR FIELD EVALUATION OF HANDPUMPS"

PRELIMINARY

DRAFT GUIDELINES

FOR

FIELD EVALUATION OF HAND PUMPS

BY

F. Eugene McJunkin

Ebbo H.A. Hofkes

prepared for

Preparatory Meeting
(November 13-15, 1978)

for

INTERNATIONAL WORKSHOP

on

HAND PUMP EVALUATION & TESTING

at the

International Reference Centre for Community Water Supply

The Hague

CONTENTS

BACKGROUND

A recent survey by the World Health Organization found that over one billion people living in rural areas of developing countries lack reasonable access to safe and adequate drinking water. The importance of water supplies in transmission and control of enteric disease is well established; in the countries surveyed, waterborne diseases are generally among the leading causes of sickness and death, particularly among children. Even the unsafe waters now in use frequently require many hours daily toil and travel for their collection.

To bring ready access to safe water by 1990 for these rural peoples would require an investment of over 40 billion dollars (U.S.) at U.S. $26 per capita. Alternatively expressed, the current rate of investment would have to be multiplied four-fold and sustained through 1990. These estimates, prepared by the World Health Organization in collaboration with the World Bank, indicate that use of low cost water supply technology will be mandatory for many years to come in these areas.

Many knowledgeable observers agree with a recent analysis by the World Bank that "In areas where groundwater is readily available at moderate depth, constructing a number of wells fitted with hand pumps is by far the cheapest means of providing a good water supply." (IBRD, PUD Rpt. 793, p. 16, 1975).

Although community water systems piped under pressure to households and public standposts are an ultimate goal, many of the unserved billion will realistically have to seek hand pumps as an interim if not an ultimate measure.

Unfortunately the record of most present hand pump programmes is not good. Serious problems exist in hand pump technology, design and selection; quality of manufacture; installation, operation, and maintenance; and organization and administration of hand pump programmes generally. The number of successful hand pump programmes extant for community water supplies is very small. Unfortunately the hand pump "solution" to rural water supply problems poses some major problems on a worldwide scale.

Hand pumps are used under a wide variety of conditions. They may serve on shallow or deep wells, with many or few users. Operation may range from almost continuous to infrequent, and maintenance from adequate to none at all. Numerous hand pump models, from many different manufacturers are on the market. Frequently, the pumps are imported from distant countries on the basis of very limited information. Comprehensive and reliable information on hand pump manufacturers and their pumps and pump components is lacking.

Evaluation of field performance of hand pumps, supplemented by field tests, and laboratory testing of pumps are very useful tools to support the selection of suitable pumps for rural water supply programmes. This type of work is currently underway or being planned in several developing countries, with active support from a number of development assistance agencies. There have been earlier investigations on hand pumps but the findings have tended to be inconclusive. The current field evaluation and testing programmes seem to be more systematic and a sound methodology may now be developed to provide better technical assistance than heretofore possible. Comparison and evaluation of hand pumps on an international basis will require common criteria, definitions and methodologies. More uniform collection and recording of hand pump performance data will benefit all. Internationally recommended guidelines for field evaluation and for laboratory testing of hand pumps are necessary and desirable for systematized collection and analysis of results, for the improved exchange of information and experiences, and for better evaluation and testing of hand pumps.

The establishment of a widely accepted methodology for hand pump evaluation and testing should be made an international, collaborative effort. The purpose of the forthcoming international workshop on hand pump evaluation and testing is to structure and support the development of standard procedures for better, more appropriate selection of hand pumps based on objective and realistic evaluation in the laboratory and in the field.

GENERAL

Purpose of Guide

Field evaluation of hand pumps in the proposed guide means the subjecting of different pumps to systematic assessment of field performance in order to provide unbiased information on the characteristics and on-site performance of hand pumps to agencies responsible for the procurement and use of pumps in water supply programmes or for providing financial aid to such programmes.

The purpose of the guide is to present methodology and procedures which may be internationally applied in the set-up and conduct of hand pump field evaluation projects. Technical characteristics and performance data should be so recorded that evaluation project results will be internationally comparable. Results obtained in a particular country would supplement results from similar evaluation projects carried out in other countries.

The information so assembled from various evaluation projects, and presented in an agreed format, should better enable hand pump buyers to make a rational choice of pump that best meets their particular needs and budget. Assessment should be made in accordance with widely-accepted methods and criteria judged adequate to provide objective comparison of pumps under field conditions. Of course, costs of pumps and specific technical characteristics are important criteria in the evaluation process.

Hand pump field evaluation projects will vary in size in experience and in the resources available to them. Not all agencies commissioning such evaluation work, whether in-house or contracted out, will want to or be able to follow the proposed guide through all stages and to the same degree of thoroughness.

However, the scope of a hand pump evaluation project should always be consonant with the hand pump programme it supports, and measured in terms of the number of pumps to be used, number of population to be served, and financial resources required.

If hand pump evaluation projects are to yield reliable results, certain requirements of methodology will have to be satisfied. This guide's purpose is to describe suitable methods and procedures.

In setting-up projects for field evaluation of hand pump performance, where necessary supplemented with laboratory testing, the aim should be to meet, within staff and budgetary constraints, the following objectives:

- to provide unbiased information on hand pump field performance to the national agencies and the international organizations involved in rural water supply programmes of that particular country to enable them to make a more rational choice.
- to contribute to an information bank storing results of hand pump evaluation projects conducted in accordance with an internationally agreed methodology to the mutual advantage of all.

- to establish acceptable standards of quality for manufacture of hand pumps.
- to assist governments and manufacturers in introducing standards where none exist, or to improve those presently in use.
- to determine any differences between actual field performance and hand pump characteristics as claimed in manufacturers' documents or quotations.

Purposes of Field Tests and Evaluations

Field tests and evaluations may be undertaken in order to:

(1) Select the "best" pump or pumps from numerous candidate models. As will be shown later, "best" has many dimensions, many of which cannot be measured quantitatively or in similar units.

(2) Provide guidance for improvement of existing pump models, particularly those of indigenous manufacture.

(3) Evaluate the suitability of a particular pump or pumps for local conditions.

(4) Test and refine new pump designs, improvements, materials, etc.

PARAMETERS TO BE EVALUATED

Costs

Capital costs for purchase of hand pumps are generally the paramount criterion in selection of hand pumps. However the criterion should be total costs, that is capital costs plus operating, maintenance, and replacement costs. These should be expressed in equivalent terms, either annualized or present value costs. Or alternatively as life cycle costs.

The common supplier claim that its hand pump will last for 15-20 years under normal operating conditions is a far too simplistic approach to maintenance and replacement costs. Each hand pump has a number of components. Several of these components will undoubtedly last many years with little or no maintenance. Others have a more limited life span because of wear caused by movement or vulnerability to breakage. As with any mechanical device, a hand pump has wearing parts which have to be replaced periodically in accordance with the number of cycles of operation. The life span of a pump refers not to the most rugged and longest lasting component but to the multitude of components as a whole which establish the <u>economic usefulness</u> of a pump.

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

Because of the long life of the pump relative to the field evaluation time span, a large part of such an evaluation must be based on value judgments of the probable performance of individual pump parts. Without any test data or historical records, the exercise is largely guesswork. Also note that the costs of spare and replacement parts may be as significant as the original costs.

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

It is therefore evident that to ensure the most economical pump is selected, a careful analysis of a number of factors must be taken into account. If such a hand pump could be found, the one with the lowest initial cost, fewest component parts, longest useful life for each part, and needing the least field maintenance, would obviously be the most economical unit. It is conceivable that such a pump may have a life span of only 10 years and be more suitable for the task than another expensive unit which has a few components with the capability of lasting 20 or 30 years.

Regardless of the hand pump selected, some maintenance costs will be involved in keeping it in satisfactory operating condition. Each pump has wearing components which periodically must be replaced. Vandalism and accidents result in the need to replace damaged units from time to time. To establish the relative level of long term maintenance required for the various pumps is difficult. The extent of maintenance required is related to such factors as the useful life of the various component parts of each pump, the relative number of pump parts involved with the alternative pumps under test, the frequency of service calls required for routine maintenance and parts replacement, and the type of equipment needed to service the pumps.

Many value judgments are involved. Field testing will assist with establishing the relative performance of component parts and result in more meaningful value judgments than if no test data were available.

Repeating, to the extent practicable the costs should recognize initial costs and continuing costs.

Reliability

Reliability can be measured as the percent of time the pump is in service. This is a function not only of the pump but of the maintenance system and of the conditions of use including number of users and depth and quantity of water pumped.

Maintenance Requirements

The resources and infrastructure required (and their availability) for equivalent levels of service for each pump should be evaluated.

Availability

Central to availability is the location of the manufacturing source. Other factors being equal, a local source is preferable.

The purpose of the pump test evaluation program is to select the hand pump which can best satisfy local conditions. However, it would be unwise to select a hand pump only on the basis of the field test. If the plant capacity of the supplier of this pump could not meet the project need for pumps, or if this manufacturer had a reputation for poor quality or poor delivery of spares, then the advantage of the field performance could be outweighed by the disadvantages of the after sales service. A selected supplier must be reputable and be in the position to fully warrantee its product. In addition, the prospective supplier should be willing to modify the design of its pump to overcome weaknesses identified in the test.

Standardization is generally accepted as an economical and practical objective for a water supply. However, if one hand pump were used to the exclusion of all others, the successful pump supplier would in effect have a monopoly. Through time, this could result in poor service from the lone supplier, and/or an unrealistically high pump cost due to the absence of competition, both highly undesirable. Having at least two acceptable hand pumps (which might be needed in any case because of the type of service involved) may be considered desirable.

Performance Requirements

As in designing a bridge the loading must be analyzed in order to design the structure. The "loading" conditions for hand pumps include:

(1) Depth(s) from which water must be pumped. Plus lift if elevated storage is used.

(2) Number of people (and livestock) to be served.

(3) Per capita water demand.

(4) Number of pump installations.

(5) Types of wells, e.g., drilled or dug, and diameters.

(6) Quality of water to be pumped - impurities such as sand, corrosivity, gases, temperature, etc.

(7) Altitude and temperature (as they affect suction lift).

(8) Reliability (availability of alternate water source in event of pump failure).

(9) Ergonomic and anthropometric characteristics of local "pumpers."

Pump Characteristics

The candidate pump(s) must be matched against the foregoing performance requirements. Parameters include:

(1) Pumping head. Deep or shallow well lift or force pumps.

(2) Discharge characteristics for head (1) and energy input available from "pumpers."

(3) Pump dimensions, compatibility with well dimensions.

(4) Materials. Resistance to wear or attack by water being pumped and by friction of moving parts. Resists breakage (metallurgy).

(5) Maintenance requirements - technological and institutional. Repairability. Compatibility. Stores. Lubrication.

(6) Ergonomic and anthropometric requirements. Mechanical advantage, handle load, handle height and arc, etc.

(7) Versatility. Range of cylinder diameters, pumping depths, etc.

(8) Mechanical efficiency and slip.

Sanitation

The pump should be designed, manufactured, and installed so as to prevent the entrance of contamination or objectionable material into the well or into the water being pumped. The following factors should be considered.

(1) The pump head or enclosure should be designed to prevent pollution of the water by lubricants or other maintenance materials used during operation of the equipment. Stuffing boxes are preferable to slotted

pump head tops. Pollution from hand contact, dust, rain, birds, flies, rodents or animals, and similar sources should be prevented from reaching the water chamber of the pump or the source of supply. The spout should be fully covered, open downward, and prevent solid objects from readily reaching the well.

(2) The pump base or enclosure should be built so that a sanitary well seal can be installed within the well cover or casing.

(3) When possible, the cylinder should be placed near or below the static water level in the well so that priming will not be necessary. This setting also keeps the pump leathers from alternate wetting and drying and increases their life and efficiency. The foot valve is less likely to leak with the resultant advantage of elimination of the need for priming.

Safety

Any undue hazards to operators, installers, maintainers.

Compatibility

Fits into existing systems - maintenance, stores, lubricants, etc.

EXPERIMENTAL DESIGN

General

Field testing of hand pumps is fraught with statistical difficulties. A few:

(1) The objective(s) are not clearly defined. Many are not subject to numerical analysis.

(2) The effects of many factors examined are obscured by other variables and "background noise."

(3) Conscious or unconscious bias in the experiment or on the part of the experimenters is difficult to eliminate.

(4) Random sampling is extremely difficult.

(5) Sample sizes, especially when a large number of candidate pumps are tested, are invariably too small to yield statistically meaningful results.

(6) Uniform conditions, controlled variables, factoral experiments, and replication are generally not possible.

The preceding comments are not intended to deny the value of field evaluation but to suggest caution in conducting and, especially, in interpretating and extrapolating results.

Sampling

In order to make valid nontrivial generalizations from sample pumps about characteristics of the pump populations from which they came, the samples must be randomly selected. For example, each pump must have an equal chance of being the first member of the sample. After the first pump is selected, each remaining pump must have an equal chance of being the second pump picked, and so forth.

Samples should preferably be obtained through the normal retail channels, and care should be taken to ensure that sample pumps for field evaluation have not been specially manufactured for testing purposes.

Sample pumps obtained directly from manufacturers or wholesalers are unlikely to be typical unless the evaluation project staff is allowed to select the samples from a large number.

Precautions to ensure that sample pumps are not atypical of the pumps on the market include:

- an assessment of whether or not poor performance was due to an exceptional product failure.
- the checking of inspection results against manufacturer's specifications.
- the substitution or repair of a sample pump.
- the presentation of certain field evaluation results individually to manufacturers, and
- the experiences of the hand pump users themselves.

Sample Size

One pump is hardly an adequate sample size although there are numerous studies with awesome extrapolations of data from a single pump. Four pumps would be an absolute minimum. Ten would be better. A two stage sampling procedure can reduce the number of pumps needed. If initial findings show little variability between the sample of four, then further sampling might be omitted. If variability is high, then more pumps should be tested. The attached chart is indicative. (N.B. This section will be expanded before the November meeting).

2-4 NUMBER OF MEASUREMENTS REQUIRED TO ESTABLISH THE VARIABILITY WITH STATED PRECISION

We may wish to know the size of sample required to estimate the standard deviatic certain precision. If we can express this precision as a percentage of the true (unk standard deviation, we can use the curves in Figure 2-2.

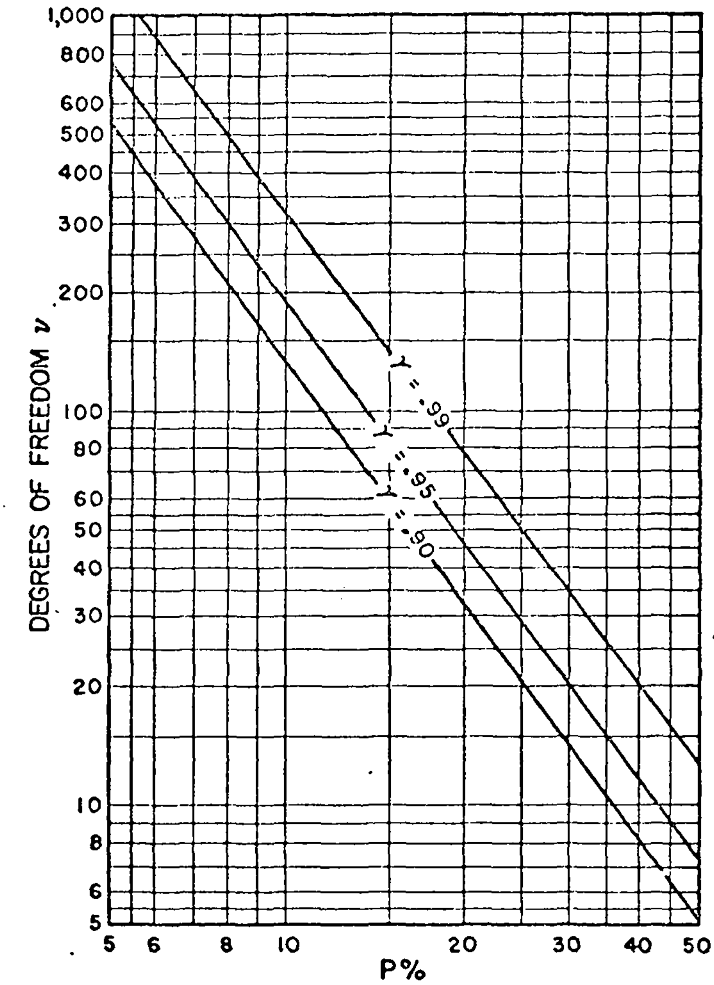

Figure 2-2. Number of degrees of freedom required to estimate the standard deviation within P% of its true value with confidence coefficient γ.

Adapted with permission from *Journal of the American Statistical Association*, Vol. 45 (1950), p. 258, from article entitle Size Required for Estimating the Standard Deviation as a Percent of its True Value" by J. A. Greenwood and M. M. . The manner of graphing is adapted with permission from *Statistics Manual* by E. L. Crow, F. A. Davis, and M. W NAVORD Report 3369, NOTS 948, U. S. Naval Ordnance Test Station, China Lake, Calif., 1955. (Reprinted by Dover Pı Inc., New York, N.Y., 1960.)

ORGANIZATION

General

It is assumed that the person responsible for the hand pump field evaluation project will have been able to familiarize himself with relevant standards, technical literature on hand pumps, and other relevant sources of information. Usually, one person, a Project Officer, is given responsibility for seeing the project through from start to finish.

Finding out which pumps are on the market, or can be obtained from non-commercial sources including overseas firms, and deciding which ones to subject to field evaluation, logically precedes working out the evaluation project. However, in practice, the two activities will often be done concurrently.

The conduct of a evaluation project will not necessarily require the set-up of a separate section in the water supply agency, and staffed by the necessary technical experts. University staff, technical colleges, official laboratories, standard institutes, or consulting engineers may be engaged to carry out the envisaged hand pump evaluation project.

The schedule which sets out reports planned submission to the responsible officials, and gives their timing, should reasonably allow for staff and budget constraints, market factors, model changes, and requirements relating to seasonal fluctuations.

Initial Inspection

Samples of all pumps to be tested should be examined and their dimensional and technical characteristics tabulated.

Pump cylinders, or equivalent, and material of construction (e.g. brass, last iron, welded steel, plastic, etc.) and their bore and maximum stroke should be described. Also the pump stand and material of construction, including dimensions and type of base for fixing cap, or equivalent provisions. Also the method of operation, e.g. lever and fulcrum hand-wheel and gear box, type of handle/pump rod linkage. Number and type and size of pins/nuts and bolts in linkages, size of coffer pins/fastenings, if any, dimensions of journal or the other bearings and bearing clearances.

If the cylinder is 'down the well', whether it is extractable through the pump head, or non-extractable. Closed or open cylinder. Where applicable, details of pump rods and couplings. Details of foot valve(s) and strainer, cup seals (size and material, number); method of assembly of plunger. Also internal diameter of suction pipe and length below foot valve. Details of any strainer fitted. Where applicable, internal diameter of drop pipe. If any borehole stabilizers required, list their wieght, state type, pitch, etc. List the total weight of cylinder (if down the well), the weight per metre of drop pipe and weight per metre of pump rods. Other features, e.g. bucket hooks. List faults on delivery or after initial assembly; including examination of stressed parts for incipient cracks or other damage.

Installation

All units should be installed strictly in accordance with manufacturers' instructions. The installation conditions should be carefully recorded, i.e., date, depth of cylinder setting, static water level, any modifications carried out, etc. Pumps should be fully serviced on initial installation.

Test hand pumps should be located with care. Pumps should operate under identical conditions (lift, users, etc.) as nearly as practical under field conditions. The pumps should also be readily accessible for monitoring throughout the test period, including rainy seasons. Locations near project offices and shops may be advantageous.

If possible the test pumps should be installed on existing wells which have had hand pumps in operation for some time. This will help ensure that the pump will be used and that the users are familiar with its operation. If the pump is obviously unsuitable, e.g. notoriously unreliable, it should be replaced promptly.

Performance Tests

Delivery into an open tank should be used for free discharge test. The depth to the water table should be measured for each pumping test.

Actual water delivery, expressed as water quantity pumped per unit time, should be recorded on all pumps surveyed, at 15, 30 and 45 (or maximum recommended) strokes/revolutions per minute. Temperature and barometric pressure should be noted for normalization of measured results. From these measurements and the calculated delivery the slip will be calculated and listed, for comparison with manufacturers' stated (or implied) slip. In particular, the possible rate of increase of slip will be observed over the period of evaluation.

Number of strokes or revolutions required to start pumping water will be recorded, together with information on actual use/non-use intervals of pump operation.

During performance testing, the maximum possible operating rate will be determined by speeding up until the running rate is no longer proportional to strokes per minute.

The methods of measurement should be reproducible, at least to the degree necessary to obtain results allowing the determination of a consistent and reproducible ranking order of the pumps. When pump characteristics can only be evaluated subjectively, the evaluation should be based on assessments made by experts or on surveys of the users of the pumps as appropriate. In the latter case, the survey should be conducted and analyzed in accordance with accepted statistical practice or the methods used and the limitations of the survey should be clearly stated.

User Trials

Subjective assessment of convenience, fatigue, physical effects (blisters, etc.); users to include tall, short, male, female, children. Left hand and right hand. Each person to operate the pump pumping water into measured volume buckets. Users will be asked to pump appropriate quantities for 60 seconds only; and, separately, to use the pumps for several minutes (up to 5) in order to discover any short term and longer term inconveniences.

All experimental runs are to be replicated by having several persons operate the pump for a number of times so that the results may be averaged with findings representing field use conditions rather than tests.

Unusual or severe stooping or bodily contortions should be noted and recorded. Pulse rate rise (above resting rate) during pumping will be measured for 10 percent of the sample. Ambient temperature and humidity should be simultaneously recorded.

REPORTING

Format

Findings will be summarized in a matrix array. Each row will represent a characteristic evaluated. The characteristics will be listed in order of importance with row 1 the most important characteristic. Columns will list rank from left to right, column 1 representing the highest ranking pump. Thus $cell_{11}$ will contain the assigned, unique number of the pump that ranks first in the most important characteristics.

The characteristics should be ranked by a locally established delphic panel. This panel may or may not wish to establish methods for weighting the various attributes or characteristics in order to numerically rank pumps on an overall basis.

Where desirable separate ratings may be established for pump stand assemblies, cylinder assemblies (or equivalent), and connecting assemblies.

The report should describe in narrative form the organization, conduct, and findings of the study. Complete data sets should be included as annexes. If voluminous, this could be bound separately in limited numbers. The complete report should be deposited with at least one library, accessible to the public, on each continent.

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W.D. 2

WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

DRAFT

"HANDPUMP LABORATORY TESTING GUIDE"

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CA
TESTING
AND
RESEARCH

PROJECT NO. Z.9977

TESTING AND RESEARCH ON HAND/FOOT WATER PUMPS

John Kingham - Project Controller, ODM Pumps Testing Project

Endellion Sharpe - Head of Survey Unit

John Cuthbert - Head of Testing

GUIDELINES FOR COMPARATIVE TESTING OF PRODUCTS

John Cuthbert - Head of Testing

OCTOBER 1978

Papers prepared for World Health Organisation, South East Asian Regional Office, Research Study Group on Appropriate Technology for Improvement of Environmental Health at the Village Level, New Delhi 16 - 20th October 1978.

and for

World Health Organisation, International Reference Centre for Community Water Supply, Conference on Hand Pump Testing/Methodology, UK, March/April 1979.

Copies of these Papers are filed with the authors in HRL Archives and with the Head of Research. We propose also to send copies to the UK Ministry of Overseas Development (which is funding our present hand pumps laboratory testing project No.Z.9923), to WHO-International Reference Centre in The Hague, Netherlands for its forthcoming conference, to other interested international agencies, such as the World Bank, UNICEF PAHO USAID CIDA IDRC and to Associated researchers such as Environmental Services Corp., (USA), Georgia Institute of Technology (USA), International Rural Water Resources Laboratory (University of Maryland, USA), S.B.Kirk and Associates (UK).

ISSUED BY : J. Cuthbert JOHN CUTHBERT, MA,DPhil,FInstP,FRIC,CChem,AMBIM
HEAD OF TESTING

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CONTENTS

I - TESTING & RESEARCH ON HAND/FOOT WATER PUMPS

1. RURAL WATER SUPPLIES : PROBLEMS AND APPROPRIATE TECHNOLOGY

1.1 Introduction

1.1.1 The supply of water in less developed countries, particularly in rural areas, has long been a serious problem. A supply of clean, potable water is the largest single contributory factor to the reduction of the high mortality rate encountered in such countries; nevertheless it was estimated that in the S.E. Asia region in 1975, eight out of ten people did not have reasonable access to a safe water supply.

1.1.2 In many countries much effort has been expended in attempts to alleviate the problem. The use of handpumps in either dug or tube wells provides perhaps the cheapest and most widely used form of water supply. Even so, the problems have not diminished, but are perhaps even accentuated. This is evidenced by the high percentage (sometimes $>$50%) of pumps in some areas (India has been particularly cited), which lie broken or fail to function properly. On the other hand there are pumps in other parts of the world which have given reliable service for decades. Further, hand pumps have been available for at least 200 years, and the technology is very well established. Why then do such problems persist one might ask?

The visible causes of these problems arise from several sources -

a. A pump used for a rural water supply may be used by as many as 1000 people. Many of these pumps were designed for use on farms in rural areas of industrial countries and simply cannot tolerate the intensive use required.

b. The manufacturing quality, particularly of cast iron pumps made in developing countries, is often poor.

c. The capital available for purchase of pumps is frequently severely limited. As a result, cheap pumps, which may be less reliable, are likely to be purchased.

d. There is often very little or no maintenance carried out on the pumps, resources to carry it out being severely limited. This is perhaps the major problem since others would be relatively less important if maintenance were carried out.

The reasons for improper maintenance vary considerably but are usually due to one or more of the following -

a. Poor availability of imported spares, and lack of skills to make spares locally.

b. Lack of local technological knowledge sufficient to provide adequate maintenance, often combined with remoteness of the pump from any servicing centre.

c. Difficulty of organising maintenance services.

d. Lack of awareness among villagers of the importance of clean water and the consequent vandalizing or neglect of pump installations.

e. Lack of clearly agreed and accepted responsibility for the pump.

1.1.3 The problems are thus well known and yet, despite much discussion, expense and new pump design they remain rife. One common answer is that the technology involved in the manufacture and maintenance of the pumps is not suited to the pump users. An appropriate technology must be used.

1.1.4 Before discussing what is meant by an appropriate technology it will be useful to consider the differences between the environments in which hand pumps were used in the nineteenth century in Western countries and those prevailing in many developing countries today.

When the Industrial Revolution swept through most countries in the western world in the 18th and 19th centuries, it had one characteristic trait: progress was achieved by the invention of new technologies. For example, a steam engine could not be built until its principles of operation were fully understood, and the necessary materials developed. An electric motor could not be made before the interactions between magnetic field had been determined experimentally. In brief, the uses of a new technology, and people educated to use it, were both known and available before the technology was applied. Thus, when a new machine was introduced, there were people who appreciated its value and could also maintain it. No machine can be utterly reliable and, however good and sophisticated the technology, some maintenance is always necessary.

This situation is as true for pumps as for any other technological product. Hence, even in the 19th century, pumps could be made using the then comparatively new technologies of machining, casting and forming metals, particularly wrought and cast iron. These pumps were frequently very reliable in the situations where they were used and many pump designs have changed little since then.

1.1.5 The situation in less developed countries today is very different; in particular, the level of technological expertise is generally much lower. The introduction of pumps made in the industrialized world to such countries immediately gives rise to a problematical situation. Firstly, and most importantly, the technology is not understood and thus it may not be possible to provide effective maintenance. Secondly the need for a pump (as opposed to e.g. a dirty water hole or a stream) may not be understood; this, in turn, will lead to neglect of a pump if other water sources are available, particularly if the attitude of the villagers is very conservative.

There seem to be two answers to these problems. The first is to educate the people to understand the basic principles of the need for clean water, to appreciate the benefits of a pump and to ensure that at least some of the users understand its operation and can maintain it

The second solution which is often proposed is that mentioned previousl i.e. the use of a technology appropriate to the pump users. As this is perhaps the solution most commonly suggested we will consider this for the moment.

1.2 Appropriate Technology

1.2.1 Appropriate technology can be described generally thus (cf WHO Document No.ATH/77.3).

"The word technology means not just a device, but any association of techniques, methods and equipment which together contribute towards solving a problem. 'Appropriate' means that the technology is not only scientifically sound but acceptable to users, providers and decision makers alike; that it fits within local cultures and that it is capable of being adapted, further developed, and manufactured locally wherever possible at low cost".

1.2.2 In this context, therefore, the hypothesis is that a pump should be made locally, of locally available materials, and of such a design that it is culturally, aesthetically and socially acceptable. It should also be cheap. This hypothesis however involves three (hidden) assumptions.

a. That appropriate technology is that which solves the problem of providing safe water supplies in the communities under consideration

b. That the community appreciates the need for safe water sufficiently to provide the motivation, and hence the necessary community structure and organisation, to deal with the problems. This may mean arranging manufacture of a locally made pump, or simply ensuring that maintenance can be done and is done (not necessarily by someone in the village).

c. Perhaps the most important assumption is that there is already in existence an appropriate technology which can solve the problems within the community that will use the pump (or that, at least, such an "appropriate technological" solution can be found).

1.2.3 In many places in the world these three assumptions are undoubtedly true, and there have been several examples of locally made pumps proving successful. In considerable areas (serving hundreds of millions of people) however one or more of these assumptions is probably not true. For example a rural agrarian community may be able to make basic farming implements from local materials (such as wood and rope) and may have an extensive knowledge of the flora and fauna of its region. The manufacture of a wooden boat would perhaps present no problem, but nowhere could the technology be found to manufacture a hygienic and efficient water pump. Moreover, if there are abundant rivers and streams, the need for a water pump would never make sense to it despite experience of ill-health (caused by polluted water) because it probably would not appreciate the connection. (The London Broad Street pump case is not much more than a century old)

1.2.4 Local manufacture of pumps or the designing of a pump to fit existing local skills may be unnecessary. There is no reason why a pump bought from abroad cannot be used with success in a less developed country, providing the conditions laid down in the 1.2.2.b are satisfied.

In a sense the technology can be appropriate even when there are no facilities to manufacture the pump in the country concerned. The words "appropriate technology" very often seem to be misused in referring only to technologies which are currently available in the local community.

1.3 The Water Supply Problem - Conclusions and Recommendations

1.3.1 In the final analysis therefore, there may be no answer to the problem as it stands, i.e. there is no 'appropriate' technology.

Every area of the world has its own peculiar cultural and sociological patterns and there cannot be a single, simple, all-embracing, definitive answer to the water supply problems. Some schemes have been reasonably successful and others have been almost complete failures. Indeed a prime reason for this paper and the numerous seminars and discussions around the world is that, despite many studies, trials, surveys, experiments and new pump designs, there is still no clear, common statement of direction. The reason perhaps is that studies have concentrated on only a part of the total situation and have failed to place the questions being asked and their answers in an agreed multidisciplinary framework (cf Mcjunkin, WHO IRC Technical Paper No.10, 1977; "Cross disciplinary studies have been rare. With a few notable exceptions, modern findings from such subjects as ergonomics, anthropometrics, metallurgy, lubrication, friction, materials science etc., have been ignored").

1.3.2 We stress the need for a common way of evaluating the problems of pumps-in-use-in-environment-in-community in order to point the way to successful practical solutions. The main points may be summarized thus

a. There must be the motivation amongst the pump users, both to use the pump and see that it remains usable. A good reliable pump which is relatively maintenance-free may give good service for a time even where this motivation is lacking, but it can never be completely satisfactory. If there is no motivation no technology, 'appropriate' or otherwise, can compensate for the education necessary to instil it in the users.

b. The pumps to be used in any water supply scheme must be carefully chosen to be compatible with the cultural and social habits of the users. They should be reliable, reasonably easy to maintain and perform acceptably. Manufacture within the developing country should be encouraged wherever possible as it contributes to the independence, self-sufficiency and educational level of the country concerned; it will also reduce the likelihood of poor availability of spare parts and prove cheaper, provided quality can be maintained.

c. The organisational infra-structure for installing and maintaining the pumps must be well defined and appreciated and made to work by those who are responsible for it.

At present however there seems to be a dearth of comparative information on the brands of pump available and we feel such comparative tests are very important.

2. THE PHILOSOPHY OF PUMP EVALUATION

2.1 Approach to Pump Evaluation

2.1.1 The basic need is for a common statement of the way to evaluate pumps in the context of their environment and the community which uses them. This must include developments in the pumps themselves, and the relationship between the pumps and the sociological, economic, cultural, anthropometric and geological parameters which influence their use. Any such statement must be wide enough to include all known influential parameters and yet not so definitive that it can only be applied in a few areas of the world. The real situation is extremely complex, and moreover is disturbed by observation. The best approach to the problem should include three studies viz. comparative testing of pumps available under the controlled environment available in a laboratory, field trials, and surveys. These three are inter-linked and should be organised in such a way that the results are comparable across the boundaries of each study.

2.1.2 Comparative tests on as many brands of pump as possible are important for several reasons.

a. These tests show up differences between various pump designs and hence conclusions can be drawn as to which type of pump might be most suitable in any given geological setting.

b. The pumps' ergonomic aspects can be evaluated and hence judgements made as to which might be easy to use.

c. Tests can highlight design features which are both sound engineering and have been proved in tests, and hence may be recommended for incorporation in existing pumps.

d. Pump characteristics which would cause problems under certain operating conditions, or could clash with cultural traditions or habits, can be enumerated.

e. An idea of the likely reliability of a pump can be obtained. The main advantage of such laboratory tests is that those factors which are random and varying in practice, such as climate and hydrology, can be closely controlled; i.e. results are truly comparative.

2.1.3 Field trials are difficult because they disturb the situation they are trying to test. They are necessary to test the conclusions reached by laboratory tests and to discover how theory corresponds to practice when the actual usage - environments are more complex than can be simulated in a laboratory. By their very nature the results obtained are only completely true when applied to the area(s) in which trials were conducted.

2.1.4 Surveys in the region where pumps are to be installed are essential to enable meaningful conclusions to be drawn from comparative tests.

They are of three types -

a. Geological surveys to determine particularly (from the point of view of the pumps) the acidity of the water, the type of impurities present and the characteristics of the aquifer throughout the year.

b. Surveys to determine the cultural - sociological habits of the users so that -

(i) The most efficient maintenance procedures can be formulated.

(ii) Due consideration can be taken of any socio-cultural habits which could affect pump performance. e.g. patterns of water usage, of water collection, other uses of the pump or its emplacement.

Many of these individual-users and user-group variables can only be studied in similar neighbouring communities which have pumps installed.

c. Surveys to determine the socio-technical situation so that the production engineering, production management, quality assurance possibilities for local manufacture of pumps, pump parts, or spares can be evaluated.

In less developed areas, the answers may be that little manufacturi[ng] capability exists but, in more industrially developed areas, such surveys could point the way towards gearing available firms, resources and skills to the successful manufacture of pumps. (For an expanded view of the concept presented here we refer readers to the work of Miller and Rice in Ahmedabad in the 1950's-1960's; "The Enterprise and its Environment".)

2.2 Comparative Testing and the Implications for Water Pumps

2.2.1 In any comparative brand test careful design of the test procedure is essential to make the results as reliable as possible. It is not intended here to go into a detailed discussion of comparative testing philosophy as this is the subject of a separate paper; in addition several booklets have been written on the subject (ISO Guide 12, IOCU Guide to Comparative Testing).

The more important principles are summarized below -

a. Testing must be independent of manufacturers, politics and any other external influence which could affect either the results or the conclusions drawn. This may be particularly difficult when the work relates to products for LDC use which are likely to be purchased in very large numbers by a few governmental and international agencies.

b. Testing must be objective as far as possible and unbiased i.e. independent of either the person carrying out the tests, or any previous test results.

c. Results of tests on any range of products must be comparable and be derived from realistic tests such that they can be used to draw useful conclusions.

d. Testing must be designed with the requirements of the product and its market in mind, and such that the significance and usefulness of the test results can be understood by the users. For example, a complex array of technical tests is of little use to a non-technically educated user unless their effect is shown by simple practical tests to back them up.

2.2.2 Designing a suitable test programme for hand-and-foot operated water pumps for use in developing countries presents some problems e.g.

a. The pumps vary widely in design so that comparison in some cases is difficult e.g. in comparing the comfort in use of a hand-operated and a foot-operated pump.

b. The physical, sociological and cultural environments in which the pumps are installed vary so that it is difficult to envisage and foresee every kind of problem which could occur and hence to test for it.

c. The interchangeability of components on some pumps makes it difficult to decide which combination to test. For example many pumps are supplied with several sizes and types of cylinder, and pumping depths quoted by manufacturers vary considerably even for one cylinder size on equivalent pumps. Ideally when testing a series of pumps, they should all be designed for a similar depth. In the authors' experience this has proved impossible and allowance has had to be made for this when testing. In our own tests we limited ourselves to deep well pumps to avoid comparison difficulties and because of funding limitations.

2.2.3 The next section explains the philosophical approach to the testing of pumps and section 4 how the tests have been carried out in practice. Some of the tests may require modification in the light of further knowledge, but most of them have been fully substantiated.

It is felt that the following are requirements if the pumps are to be tested successfully.

a. A wide knowledge of prevailing customs and cultural and sociological backgrounds in developing countries.

b. Experience of comparative testing and tried and proved methodologies for obtaining valid conclusions based on various usage/environment profiles.

c. The ability to call on a wide range of scientific and technical skills in the practical testing of the pumps.

this page should be on the end of section 2.4

The pumps can then be ranked according to their total scores. In practice it will probably be found desirable to examine also the ranking orders obtained by concentrating on the particular attributes specified by the "branches". In this case the score is the sum of (rating x weighting) for one "branch" only.

In general, conclusions can be drawn from the analysis described above, and although it is here applied to the comparative laboratory tests, the principles can be applied much more widely. In particular the analysis can only be as good as the weightings supplied, and to do this the results of surveys are necessary; those of field trials are a great help.

Having therefore shown briefly the main requirements of a pump, the next step is to consider in more detail the actual tests recommended. The next two sections deal with the details of our comparative laboratory tests and proposed field trials.

2.3 Requirements for Laboratory Testing of Pumps

In testing the pumps themselves, there are three particular areas for examination.

2.3.1 A thorough expert examination of the pump design, with confirmatory tests to establish -

a. Manufacturing quality and suitability of materials selected.

b. Adequacy of design to withstand the intensive use often encountered in LDC's.

c. Suitability of design for manufacture in LDC's; an assessment of the skills, facilities and materials required.

d. Likelihood of any corrosion or degradation due to the environment.

e. Foreseeable problems associated with the peculiarities of the mechanical design.

f. Feasible ways in which the product could be improved and/or made simpler and cheaper to manufacture and maintain.

g. The skills, facilities, tools and materials necessary for preventative maintenance and/or repair of probable breakdown or wear.

2.3.2 Testing by a variety of users in practical situations simulating norma use to establish the convenience and ease of use, and how these vary with the user's height, sex, age, fitness etc..

2.3.3 Thorough endurance testing in simulated environment and varying water qualities to reveal any areas likely to cause poor reliability.

Once the tests have been done, it is necessary to use the results to predict the likely cost effective performance of a pump in any given situation. In the final analysis it can only be done by the organisation buying the pumps, as such factors as price, spares availability, likely ease of maintenance etc., must be taken into account and these will vary both from country to country and also within various regions. The testing organisation, therefore, should report its results in such a way as to make this analysis as simple as possible for each water programme installation agency. Thus, though all results should be presented clearly and concisely, preferably in tabular or graphical form as appropriate, a further stage is desirable. The authors propose that at present the most suitable method is SMART (Simple multi-attribute ranking technique) a system where different weightings are given to a list of attributes combined with scores for each pump in the tests to given an overall score. The weightings can be supplied by the pump user purchasing agency to evaluate the most suitable pump for the situation where it is to be installed. The testing organisation should present typical weighting "trees", describing the kind of conditions in which they apply and give guidance to enable readers to select the weightings which apply in their own case.

2.4 Analysis of Results

The first stage in any multi-attribute utility analysis is to devise a weighting "tree", which effectively shows the features and test results to be considered when evaluating the pumps. The major areas of importance are decided first, which in this case are : design, ergonomics and user tests, performance, durability and safety; these are the "branches" which are subdivided into "twigs", and can then be further subdivided into "twiglets". The authors' suggested weighting tree for Harpenden Rise Laboratory's present tests is given in Fig. 1-3. This is a design mainly for deep well pumps, but would require only slight modification for suction pumps. For each individual item on the tree which is not further subdivided, a rating must be assigned for each pump. Normally this is on a 1-10 scale, 1 being poor and 10 very good. This rating is fixed and is dependent only on the test results or subjective assessments of experts based on corroborated data. In certain circumstances where one pump is exceptionally good or bad, it is permissible to give a larger positive or negative rating so as to bias the whole evaluation of that pump. For example, the efficiency of a pump would normally be rated on a 1-10 scale. If, however, it was found that one pump could only operate efficiently at a very fast speed, indeed at such a speed as would enable only the strongest men to use it, and that it was inefficient at the lower speeds at which it would normally be used, a large negative rating, say - 100, would be awarded and this would completely eliminate the pump from further consideration in the overall assessment, even though the pump itself performed well in other tests.

Weightings must then be attributed to each item on the "tree" which effectively indicate its importance. The total sum of all the weightings for each "branch" is normalised to 100. Similarly the sum of the weightings for the twigs on one branch must equal the branch weighting. The same is also true for twigs and twiglets.

The actual weightings will depend on the country and area in which the pump is installed, and can best be supplied by those with experience of the various factors which contribute to the success or failure of a water supply project in the area concerned. As an example consider a pump which is to be made in a less developed country, with no foundry facilities, and installed in a district where the culture, training and experience of the users is such as to make maintenance by a villager almost impossible. In such a situation high weightings would need to be given to simplicity in the manufacturing equipment necessary to make the pump, the ease of maintenance and the pump reliability.

If, on the other hand a pump is to be installed in an area where literacy and engineering skills and experience are high and, moreover, the pump is to be bought in from abroad, neither of the first two factors will be important, provided the reliability of the pump is acceptable. These factors can thus be given low weightings.

To show how this principle works, three specimen weighting "trees" are attached, together with a description of the kind of conditions in which they might apply. (Fig.1-3).

When all the ratings and weightings have been finalised, for each pump the sum of the products (weighting x rating) is found. Note that this product may be either (twiglet weighting x twiglet rating) or (twig weighting x twig rating) if there are no twiglets on any particular twig. Similarly for branches where there are no twigs. The resulting sum should give an overall rating out of a nominal maximum of 1000 (maximum rating of 10 x total weighting of 100). The overall ratings for the pumps are placed in descending order; the pump with the highest rating being considered the most suitable.

3. TEST PROPOSALS

3.1 Buying and Initial Inspection

All pumps should be bought, anonymously wherever possible, through the normal source of supply, ensuring that, in any case, the supplier does not know that these particular samples are intended for tests.

In the case of water pumps the normal purchasing channels would be a government department, International agency, or some other powerful public body, who would order large numbers of pumps from any one supplier, for a specific and defined rural water supply programme. In such a situation the purchasing power and leverage of the buying organisation, and the specificity of the conditions of end-use, coupled with the size of the order, can easily lead to particular modifications being requested, or particular features being incorporated into the pump design by the manufacturers. This, of course, would pose some problems in comparative testing of pumps. On the one hand, if poor results are obtained from two samples of a pump bought anonymously, the manufacturer may claim that special attention and special quality control applied to a large "governmental" order would remove the problems. Reasonable doubt however should remain about his organisational ability to fulfil such a claim. On the other hand there is a temptation to buy samples for testing openly through government/international agencies and to request such special features as would be appropriate. The difficulty then is that one will be testing specially prepared prototypes which might be expected to be very good indeed, but doubt remains about the manufacturer's ability to maintain such quality in pumps manufactured in routine production with less skilled labour. In the case of our present project it was decided to test only standard models of pump, remaining doubtful of the manufacturer's abilities to maintain any higher quality in special designs ordered in large numbers.

On receipt all brands should be inspected for any differences between samples of the same brand, for any similarities between different brands which would indicate a similar component source, and for any defects, damage and wrong or missing components. In general two samples of each pump will be sufficient for laboratory tests.

Where pumps have various cylinder sizes and types the choice will have to be made of the components to be tested. In our tests we selected a cylinder diameter of 57-64 mm, where this was appropriate, or otherwise a pumping element which could be used at a depth of 20-40 metres. It was felt that a larger cylinder of around 75 mm diameter would not provide so severe a test. The use of a narrower cylinder might introduce turbulence problems which are not typical of the larger cylinders.

3.1 (contd)

When removing the pumps from their packaging,an assessment of the suitability of the latter should be made, and the security of the pumps in it, and the protection which it affords, commented upon. The following information should then be listed.

(a) Brand

(b) Model

(c) Manufacturer/supplier and address

(d) Cylinder diameter (nominal), if appropriate

(e) Drop pipe and pump rod sizes, (where applicable)

(f) The range of well depths recommended by the manufacturer

(g) The type of pump

(i) deep well lift, reciprocating

(ii) shallow well suction, reciprocating

(iii) rotary type e.g. Mono

(iv) flexible membrane (diaphragm) type

If necessary, other types e.g. semi-rotary may need to be included

3.2 Construction

The purpose of this section is to describe the construction of the pump in such a way that the final user of the test report can understand fully the method of operation of each pump, and have sufficient information to organise suitable transport, equipment and labour for installation or repair.

Schematic drawings should be provided which show -

(a) The method of operation of the pump stand drive mechanism

(b) The type of pump rod, with couplings (where appropriate) to the pump head and plunger

(c) The types of cylinder and valve together with ancillary components such as suction pipes and strainers

Drawings should be labelled to show all relevant dimensions, and the materials of all important components should be specified.

The procedure necessary to remove the pump from the well should be described and the operations involved in replacing all valves, seals and cylinders. If the method of repair of any other component is not obvious e.g. the handle, this should also be explained. Information should also be provided about the tools required, sizes and types of any fastenings and details of the spare parts and materials commonly needed (.e.g gaskets, leathers).

Photographs should be taken to show the pump stand and all important components, as well as any other unusual or interesting features discovered during the tests.

Finally, the following information should be tabulated -

(i) The weights of the pump stand and cylinder

(ii) The weights per metre of any pump rod and rising main

(iii) Measurements of the surface roughness of the internal bore of the pumping cylinder (where this is applicable). The lay direction of any surface marks should also be stated and any other factors, which could affect the cylinder or seal wear, should be commented on e.g. non-circularity of cylinder and variations of this along the cylinder length.

3.3 Design

Because pumps are bought in large quantities and design modifications can be made, at least gradually over a number of years, it is important that any design assessment be constructive as well as critical.

An assessment of the design of the pump probably requires the greatest consideration of any part of a test programme, because it inevitably depends on the skill, knowledge and experience of the assessor. It should be carried out by at least two people who have a wide experience of engineering design, corrosion and ergonomics and who have the necessary knowledge of the sociological, economic and cultural backgrounds prevailing in different developing countries. Separate expert judgements by consultants may be essential in some cases, and tests may need to be conducted to verify both the tentative conclusions and those which are likely to have the most significant effects. It is impossible to indicate everything which should be assessed, but in general the following points should be taken into account -

a. The possibility of incorrect tolerances or clearances causing poor performance and whether these arise from a manufacturing defect or an inherent design fault. Particular areas to watch include seals, valves and bearings.

b. Whether any components are designed in such a way as would make it difficult to maintain a consistently high quality during manufacture.

c. Whether there are any parts of the pump which have a fundamental design fault which would result in either highly localized stresses leading to premature failure or rapid wear of a moving component..

d. How easily the pumps could be made in developing countries. That is: do any of the components require manufacturing processes of a high technology content which might not be available in developing countries? The types of manufacturing process, the materials and skills required should be considered.

e. The proper selection of materials. This may be important from an engineering point of view e.g. strength and impact resistance, and also from the point of view of corrosion and tribology. Particular attention should be given to bimetallic corrosion couples.

f. Whether the design makes repair and maintenance as simple as possible.

g. The adequacy of provisions to exclude foreign matter and surface water from contaminating the well.

h. The possibility of simple modifications to the pump which would enable it to be made more cheaply or would give a better performance without increasing the cost.

i. The resistance of the design to abuse which might be reasonably forseeable e.g. impact side loads on the handle, pilferage and removal of fastenings, and impact of the handle against any stops.

3.4 Ergonomics

A pump should be designed so that, within the limitations of its method of operation, it is as easy and comfortable to use as possible. In most cases in less developed countries, water is pumped into free standing receptacles positioned under the spout. Thus the spout height should be such that all likely containers can be positioned under it, and yet not so high that excessive splashing is likely to occur. Similarly the water flow pattern should be non-turbulent and suitable for filling narrow necked containers as well as wider ones.

The handle should be comfortable to hold and easy to operate by as many different types of people as possible. The handle should be of such a height that excessive stooping or reaching by the operator is avoided. Foot-operated pumps should always be provided with a suitable handle which the operator can use to keep his balance whilst pumping. Consideration must be given to ease of operation by children, handicapped people, the elderly, and pregnant women.

As individual pumps vary so much it is difficult to quote individual parameters which should be measured. The following however should be given where applicable -

(i) The maximum and minimum height of the handle above the ground

(ii) The mechanical advantage of the handle operation

(iii) The angular movement of the handle when operating a full stroke

(iv) The exit pattern of the water. Included in this description should be the spout height, the angle to the vertical at which the water emerges, the distance from the pump at which water hits the ground, the turbulence of the emerging water and the minimum diameter horizontal hole into which all the water can be directed assuming a constant pumping speed.

3.5 Installation of Pumps for Performance Tests

3.5.1 When testing pumps in the laboratory two requirements are found during installation which are not demanded in normal usage. Firstly the accessibility of all parts of the pump during the test without first dismantling the entire assembly. This is particularly relevant to the pumping cylinder where leakage rates, for example, must be measured with the pump intact. Secondly, the ability to alter the pumping head easily and over a wide range, e.g. 7-50 metres for a deep-well pump.

3.5.2 At the Harpenden Rise Laboratory, these problems were solved by building a tower on the side of the main building about 7 metres high with a hut 2.5 m x 4.3 m x 2 m high erected on the top of it. Six pumps were installed in the hut with the drop pipes inside the tower. The pumping elements were immersed in a large tank of water and all water raised by the pumps was returned to the tank via a recirculatory system. To keep the water level in the tank constant, a weir was fitted across the centre of the tank with the water flowing over the weir being pumped back into the main portion of the tank. There is also a facility for testing the pumping elements of two extra pumps without pump stand and handle assemblies.

To enable the effective pumping head to be varied, a specially designed head simulation valve was built and incorporated into the drop-pipe of each pump. By adjusting this valve the effective head could be varied from 7 to 60 metres without causing flow restrictions.

Into the bottom of the drop-pipe of each pump a 'T' piece with a valve was fitted. This served two purposes. Firstly a pressure gauge could be fitted to check the pumping pressure and the operation of the head simulation valves. Secondly the drop-pipe could be pressurized with compressed air to measure the leakage rates from the cylinders under different pressure heads.

As pumps vary considerably it would be tedious to describe exactly the details of installation for each pump. Figure 4 shows the set-up for a typical pump. Photographs of the head simulation valve are also attached (Figs. 13 and 14).

In order to analyse the forces involved during the pumping operation various parts of the pumps were fitted with strain-gauges, each pump individually as dictated by its construction. A typical reciprocating lift/force pump, for example, was strain-gauged, firstly on the handle to show the force being applied by the operator, secondly at the top of the pump rod where there is the maximum tension, and thirdly at the bottom of the pump rod to show the actual force applied to the plunger. At the bottom of the rod, a specially designed sealed proving ring type load-cell was used, as the whole system is immersed in water. The output from the gauges was taken out through a highly flexible flat ribbon cable via a water tight seal in the wall of the drop-pipe. Figures 5 to 12 show drawings and photographs of typical strain-gauged assemblies used in the tests. A displacement transducer was also fitted to indicate the relative movement of the pump.

3.5.3 Once installation of all the pumps is complete the pumps should be run-in for a short time by hand, and their operation checked. In particular the operation of all valves and seals should be verified, ensuring that there is no excessive friction or leakage.

At this point, while the pumps are still unworn and in good condition it is best to perform the user tests (section 3.8).

3.6 Performance Tests

Performance tests should now be carried out. Some or all of these tests may also need to be repeated at different stages during the endurance testing of the pumps in order to monitor the wear.

a. Leakage tests

The rate of water leakage through the pumping element in a reverse direction to normal flow should be measured. The relationship between leakage rate and pressure head should be shown. A convenient way of performing this test is to seal the water outlet and pressure the drop-pipe with compressed air.

b. Volume flow test

The amount of water pumped at varying stroke rates and using the full stroke length should be measured. The test should be repeated for various pressure heads; these will depend on the pumps being tested. For the deep well pumps tested at Harpenden Rise Laboratory (HRL) heads of 7 m, 25 m and 45 m were used.

c. Measurements

Measurements should be carried out on any part of a pump which is likely to show deterioration during endurance tests. Typical measurements might be the cylinder bore (diameter, eccentricity, cylindricity), seal dimensions, and the play in any bearings or pivots.

d. Operational characteristics

These are measured using the strain-gauges attached to the various pump components. In the tests done at Harpenden Rise Laboratory, the outputs from the strain gauge bridges were connected to a strain gauge amplifier. The gauged components were then calibrated and the gain of each strain gauge amplifier adjusted so that all outputs were matched. These were then fed into a high speed data logger which recorded the outputs digitally on cassette tape. The output from each transducer was sampled every 40 milliseconds. The data was then analysed by computer and graphs showing the forces in various parts of the pump against time and displacement were plotted directly by the computer.

A complete set o data should be recorded for each pump at fast and slow stroke rates (.e.g 20, 40 and 60/min) and for the various pumping heads which are relevant to the type of pump being tested. The authors used heads of 7, 25 and 45 m. A continuous data record for about 10 strokes was found to be sufficient. Further, the actual volume of water collected per stroke should be measured for each test condition.

3.6 (contd)

From the results the following should be given for each test condition :

(i) Graphs showing the variation of force with time and displacement for all the strain gauged components.

(ii) Actual work done (from integrated force-displacement graphs) by the pump operator and on the pumping element.

(iii) The efficiency of the pumping element and the pump as a whole.

For very high speed recording of the strain gauge outputs a storage oscilloscope may be necessary, but this is far less flexible than a data logger.

3.7 Endurance Testing

Endurance tests should be conducted using a pumping head suitable to each pump. Published data varies considerably and choice of the actual pumping head is probably best judged as a compromise taking into account -

a. the manufacturer's quoted pumping head(s)

b. the mechanical advantage of the handle

c. the cylinder diameter

d. the stroke length

e. the volume flow tests

The endurance rig to drive each pump should be made to reproduce as far as possible any side loads or twisting forces which could occur on the pump handle in normal use. A programmed variable stroke length should also be used where this is what would occur in practice. The speed can be varied but for our tests we used a fixed speed of 40 strokes/revs per minute.

At Harpenden the pumps are being tested for 4000 hours with a minimum break of 1 hour each day, in four stages of 1000 hours each.

1) For the first 1000 hours (running time), clean hard water is being used.

2) Acidified soft water is being used for the next 1000 hours. The pH should be checked frequently (every 2 days) and, if this increases significantly above 4.5, dilute hydrochloric acid should be added to bring the pH to the correct level.

3) For the third period of 1000 hours, soft water mixed with a very fine clay is being used. We used a natural grade of Keiselguhr as being a type of fairly consistent quality.

4) For the last 1000 hours small amounts of fine sand should be added to the water.

Any deterioration, breakage or wear should be examined when it becomes noticeable. Any repairs undertaken should be recorded. To monitor the wear it may be necessary at various stages in the endurance test programme to repeat some or all of the performance tests. At the end of the endurance all pumps should be dismantled and thoroughly examined and the effects of the test commented on.

3.8 User Tests

One intractable problem of user tests is the wide variety in the nationalities of people who use the pumps, as well as their different ages. When any test is conducted in one country, the most meaningful results are obtained by using people who live in that country. Trying to obtain users from different developing countries of the World would prove very expensive and, in the authors' view, of no significant extra benefit.

We suggest, therefore that user tests should always be conducted using people living in a country where the anthropometric data are well known and that only obvious extrapolations of data to other peoples should be made.

Our user tests involved sixty people in ten groups of six each, chosen as follows -

Group	Designation				
1	Women	Height (m)	1.695	-	1.90
2	Women	Height (m)	1.615	-	1.695
3	Women	Height (m)	1.45	-	1.615
4	Men	Height (m)	1.79	-	2.00
5	Men	Height (m)	1.68	-	1.79
6	Men	Height (m)	1.55	-	1.68
7	Children: Male	Height (m)	1.50	-	1.65
8	Children: Male	Height (m)	1.35	-	1.50
9	Children: Female	Height (m)	1.50	-	1.65
10	Children: Female	Height (m)	1.30	-	1.50

All children were aged 11-13 years.

The users were allowed to try out the pumps briefly before the test so that they could determine for themselves the most suitable method of operation.

They were then asked to use each pump to fill a bucket up to a mark on its inside which indicated a volume of 10 litres. A questionnaire, a copy of which is given here, was then filled in.

During the pumping, the user test supervisor recorded the number of strokes used and the time taken to fill the bucket to the required level. The purpose of this was twofold. Firstly, so that from a comparison of the volume pumped with the number of strokes, a judgement of a typical stroke length could be made and how it varied between types of user. Secondly, so that an estimate could be made of the typical stroke rate at which any pump might normally be used.

The results were statistically analysed using a specially devised system based on a two way analysis of variance so that differences between users and pumps could be found both in each individual group and between groups generally.

JUNE 1978 A.9923

WATER PUMPS

(Instructions to Users)

Thank you for coming to help with our test. We are asking you to try out 6 pumps for us following the order as given on the top right hand side of your questionnaires. We want you to use the pump until you are familiar with it, then, when you think you have discovered the best method for pumping, please fill up the bucket to the marked level. Do not start filling the bucket until the Laboratory Supervisor tells you to do so, as we want to record the time taken and how many strokes it takes to fill the bucket. This is a test of the pump, not you, so please don't feel you are trying to break any records!

When you have finished pumping please fill in the questionnaire and give it to the supervisor before going on to the next pump.

To fill in the questionnaire, ring the number applicable. If you make a mistake, cross it out and ring the right one.

(e.g.) Not at all easy Very easy

1 2 3 ~~4~~ 5

Please explain your ratings in the comments column, and comment as necessary.

JUNE 1978

A.9975

WATER PUMPS

USER QUESTIONNAIRE

Date ....

User's Name Mr/Mrs/Miss ....

User's Height ....

User's Age (if under 21) ....

User No ....

Pump Code ....

	QUESTIONS & INSTRUCTIONS	RATINGS	COMMENTS
Q1	How suitable was the handle height for you?	Much too high / Much too low 1 2 3 4 5	
Q2	How comfortable was the handle to hold in use?	Not at all comfortable / Very comfortable 1 2 3 4 5	
Q3	How much effort was required to work the pump?	A lot of effort / Very little effort 1 2 3 4 5	
Q4	Overall, how easy was the water pump to operate? (Please explain rating in the comments column)	Not at all easy / Very easy 1 2 3 4 5	

4. FIELD TRIALS

4.1 Introduction

Given that the aim of testing is to find out how pumps will behave in real use and how they will withstand real environmental conditions, field trials have an important place in the work which intermediate between controlled environment laboratory tests and the final use.

Field trials have the advantages over laboratory tests that they take place in environments and with users which are nearer to the eventual populations. Field trials have the disadvantages that the installation situations and environments are much less controlled and well-characterized than in laboratory tests and that the users and usage are completely uncontrolled. Attempting to overcome these difficulties is time consuming and costly.

4.2 Experimental Design

The purpose of field trials is to test the samples - pumps in this case - on criteria relating to the use they will have and the way they will be treated in real life. These criteria may have to do with environmental factors and/or human factors that cannot readily be reproduced in a laboratory or otherwise simulated.

By definition therefore, the conditions under which the samples are tested in field trials will be uncontrolled. The problem is to distinguish, in the results of the tests, differences between the samples which are inherent and those which have arisen due to the environment in which the tests were performed. If results are affected differentially by the test conditions, and these effects cannot be measured and accounted for, it will be impossible to predict how the samples will perform in different environments in the future, and if this is the case the test results will be useless.

So, the essence of good field trials is to organise them as a series of experiments designed specifically so that results due to the samples themselves, and results due to the (variable) conditions under which the tests are being held, can be distinguished. The rules for organising such a series of experiments come under the science of experimental design.

The principles of experimental design lay down that for each sample and each set of test conditions, either a test is performed or its results can be predicted, for every possible combination. (For example, if there are 25 brands and 4 sets of conditions, 25 x 4 = 100 separate tests are held, or at least enough to be able to predict what would happen in all 100 possible combinations).

The first stage therefore of any field trials on pumps would be to determine (empirically) how many different sets of test conditions would adequately cover all likely environments where pumps would be expected to operate.

Given the engineering problems of physically installing pumps and then replacing them with alternative samples, it would seem easier if possible to identify several separate locations which present the same set of test conditions. This, if it could be done, would enable the necessary number of combinations to be tested.

4.3 Carrying out the trials

4.3.1 In a field test of pumps, some of the main difficulties are connected with the essential fact that pumps are intended to be used by rural communities. Even taking 300 people per pump as a guide to pump density there will be few opportunities to vary the type of people using any one brand of pump (as would be normal in a laboratory user test). Furthermore, if a substantial number of brands is to be examined, the field trial may have to cover quite a large geographical area (which could lead to difficulties in inspection, non-comparable volume usage of the samples etc).

Several samples of each brand ought to be tested to increase the significance of the results by statistically removing the variables between different villages, (the objective being to evaluate pumps, not villages).

Installation is important and should be carefully controlled by the comparative testing organisation (CTO): there is little point in comparing some pumps which are installed in a hygienic, well-engineered, structurally sound way with others which are little more than "lash-ups". Obviously details of the installation should be appropriate to each brand, and any manufacturer's instructions should be considered but, at the same time, the installation methods must not be inappropriate to the region(s) in which the field testing is being done (presumably the same as, or related to, the region in which the eventual pump installation programme will be carried out).

4.3.2 Similarly, with regard to manufacturer's instructions for use and maintenance. Such instructions as are likely, in a normal rural water resources/pump installation programme, to be given to users/villages should be given: the CTO must avoid the situation where, because this is a test, exceptional care is lavished on users and/or pumps. One suggestion, however, is that the groups/villages available should be divided into two similar sections. Sufficient duplicate samples of each brand of pump should then be made available, so that it is possible to supply half the user group with the amount of instructions and maintenance help normally associated with a pump installation scheme in that area, while giving the other half more detailed instruction and help. In this way it should be possible to prove to what extent this is a limiting factor in the success of pump schemes, as has been sometimes suggested.

4.3.3 The CTO should not itself carry out skilled maintenance or repair over and above that which would be usual in the region, unless to investigate the value of such help, and evaluate it against the total costs. Attempts to use skilled engineers who may be available, because a comparative test is being done in the field, would invalidate the results of the test for use in choosing pumps for installation in the field without skilled engineering assistance for maintenance.

4.3.4 Measurements of pump performance (e.g. volume delivered per stroke, length of stroke, force needed on handle/pedal, wear in bearings, leakage, wear in piston seals etc.), observations of performance, wear, physical condition, etc., should be made at regular intervals by (itinerant) skilled engineers (or the like) : for example, such a person could travel regularly around a route taking in all the pumps. There are difficulties about the comparability of usage of differnnt pumps, so that, ideally, a volumetric meter should be attached to each : this could lead to problems when reading it (if it is a submerged meter) or vandalism/accidental damage (if it is easily accessible).

The engineer(s) probably should not attempt any observations of convenience/ease of use/user satisfaction (they are likely to encounter problems of the Hawthorne effect and other socio-cultural difficulties). They might attempt some discreet, unannounced, observation of intensity of usage (how many people per half hour, approximate quantity of water drawn, proportion of men/women/children, approximate size of users).

Since tests are comparative, certified instruments should be used in making any measurements. All observations, signed and dated, can be made on pre-written proforma, and all relevant detail must be recorded at the same time. All comments should be substantiated e.g. "pump not working", "light usage","two children needed to move the handle", are comments which are vague and useless by themselves.

4.3.5 The socio-cultural observations may be best made by people who are already in the villages concerned, rather than by highly educated, skilled, technologists (even of the same nationality). There is unlikely to be any point in trying to use detailed questionnaires with technical questions, but the observations are probably best made by someone who can deal with a relatively disciplined, orderly discussion, of the user groups' experience of the pumps intelligibly to "outside" pump programme managers/aid agencies/ pump designers etc.. This is an important cross-cultural/translation role and we consider that people such as the Peace Corps.,/WHO/UNICEF etc., workers who have been in the area for some time for reasons unassociated with pumps might be able to help.

4.3.6 Tests could also be carried out on different in-village maintenance systems e.g. appointing one man to carry out regular maintenance for a fee, for payment by users to have pump on his land etc.. However, it would be important not to confound the results of these tests (in the statistical sense) with comparative testing of pumps.

4.3.7 It is probably desirable to try to get information on simple, fairly cheap ways in which pumps could be improved to deal with some of their disadvantage (e.g. changing materials, enlarging bearing sizes etc.).

4.3.8 The analysis of the (copious) results and the evaluation of the pumps comparatively (e.g. by SMART or some other objective method) must be considered before the tests start. The appraisal of results of any experiment is inseparable from the design of the experiment itself (and often appraisal and usefulness is implied or entailed by the nature of the experiment); this is most particularly true for a field test in the conditions envisaged (which will be almost entirely limited to free-form usage).

4.4 Bias

Bias due to self-selection of the responding sample of users is most likely in field trials, or surveys of field operation, of water pumps in LDC's. Firstly there is likely to be a biased response to the test/survey administrators; since they may be either foreigners or substantially better educated and wealthier-and probably from an urbanised area - the village population may well select the most articulate, intelligent, and prestigious of its members to respond to questions or to operate the pump while observations are being made. Attempts to defeat such self-selection by arbitrarily plucking forward a reticent bystander are more or less doomed to failure, since the "bias" exists in the shared attitudes and feeling of the whole village group towards the survey-administrated field trial observer group; (e.g. C.Bion "Experiences in Groups" etc.).

In all user tests and surveys, (and, again, particularly in field observations or field trials carried out in communities which are not thoroughly used to th paraphernalia of surveys, experiments, and a surfeit of "mass media" communications) there is also a strong possibility of the Hawthorne effect (or "circus" effect). This arises when the mere fact of being observed/ being asked questions leads to a change in the behaviour/conscious thought of the subject. In user tests or observations of field trials, for example, the users may simply tend to "act out" an enhanced, dramatised version of previously sub-conscious attitudes to the product being tested. Being in in a user test, being observed as a user, may arouse in the user conscious thought about his/her treatment of the product. This could lead, either to careful usage and observance of instructions/"proper" modes of use (which might give better performance and longer product life") or to "harder" and mor punishing treatment of the product. Either way, effects on the product could be appreciably different from those in the "unobserved" situation, and the users' attitudes to the product are likely to be altered, so that answers to user test or field trial questionnaires may be biased. The Hawthorne effect may be minimised when there is minimum "distance" between the users and the organisers on any of the usual socio-economic dimensions, and when the users genuinely understand and believe that their personal (or group) performance is not being evaluated and they have nothing to gain or lose from the results, whatever they may be. It is clear that, in the case of field trials of water pumps in LDC's, these conditions are difficult to satisfy, but it is essential that the experimental design and the arrangements for making the necessary observations should take into consideration, and deal wit the difficulties outlined in this section.

5. FUTURE RESEARCH NEEDS

At present there seem to be quite a number of needs for further research work of widely varying complexities.

An attempt is made here simply to list some of the needs, as we see them.

5.1 Pumps which are Already Widely Available

5.1.1 Controlled and complete laboratory tests are needed to characterise more completely the advantages and disadvantages of the pumps. Their weak spots should be identified and the extent and importance of the weakness disclosed. This work should be done in conjunction with results from field trials.

Laboratory tests should cover as much as possible of the parameters which are important in, and would be observed in, the field. Although they can never equal results of good field trials, laboratory tests must include careful, comparative evaluations and tests of ergonomic/anthropometric factors, and the effects of environmental conditions.

Our own work is limited firstly to deep well pumps and secondly to only twelve of these: there are many more pumps which merit similar research, including shallow well types - with the pumping element above ground and generally giving a much greater volume-per-stroke than the deep-well versions Extending this work is mainly a question of finance.

5.1.2 Field trials and/or surveys of existing installations are needed to describe fully the performance and failures of these pumps in the field. Again their weak-spots should be identified and local reparative or preventive maintenance activities should be fully described. It is essential that field trials be designed carefully, including treatment of geological, social conditions, installation structures and maintenance/repair methods as parameters in the research, the effects of which should be measured in a clear and separable manner.

It is also highly desirable that the methods used in field trials and surveys of existing pump installations should be co-ordinated between countries and regions, in this way results could be "pooled" thereby giving the opportunity to treat them as one large experiment and providing valuable information about the effects of geographical, sociological, infra-structure-dependent variables. This co-ordination and co-operative use of common methodology is not easy; some of the detailed techniques which might be needed include the use of common pro-forma observation records, and free exchange of original data rather than of conclusions alone.

It is desirable that field trials and surveys should be designed to give as much information as possible about all attributes of pumps so that laboratory results and field test results can be compared as directly as possible. Of course there are parameters which are more easily measured in laboratory conditions than in the field (detailed chemical analysis and hardness measurements of materials are obviously two) but every effort should be made to obtain at least some measures of these parameters (a quick on-the-spot approximate analysis of metals can be done with a "pocket" instrument; substantial water analysis can be done with small portable battery-powered instruments, and hardness can be measured relatively simply - the limitations of measurements and observations which are made in the field (e.g in accuracy and precision) should always be stated of course).

If resources permit field trials preceded by laboratory tests on the same samples would be desirable, although - apart from proving the methodology of accelerated durability testing - there would be no need to carry out durability trials in the laboratory if the field trial design is adequate and the sample numbers sufficient.

5.1.3 Design improvements : wherever possible, if an existing established pump design can be improved by relatively minor design changes or additions these should be considered. Examples might be changes in diameter of pin bearings, changes in bolt size or in methods of fixing, changing the material of a handle (e.g. from cast iron to wood, anchored by metal), changes in piston washer material). Changes should only be considered where data obtained in well constituted tests clearly indicate a specific weakness. Changes should not be taken as far as redesigning castings or changing materials for major parts of pumps.
All such changes would require careful and repeated checking to ensure that they actually produce the improvements required. For example, changes to the diameter of pins for bearings in order to improve the load carrying ability of the bearings and increase life in the field should be monitored by measuring stress and wear under laboratory tests, by accelerated durability testing in the laboratory and by field trials - in all cases several samples of the original design and several of the new design would need testing together to ensure that the comparisons are correctly monitored. Care must also be taken in the testing of new designs or prototypes, by skilled staff in small teams; such pumps may not be representative of volume production by batch processing (or mass production) techniques.

5.2 Pumps which are New

5.2.1 Laboratory testing should be done (as 5.1.1) with the addition of possibly more effort to evaluate materials and design.
These pumps should be tested against more established designs. Careful note should be made of instances where efforts to simplify certain aspects of traditional pump design have entailed making other parts more complex; even if the simplifications are successful the complexities entrained with them in the innovative design may lead to the whole system being no better, or even worse, than the original.
An example might be the replacement of an expensive machined metal pump cylinder by plastic pipe, which might entail the use of expensive ABS pipe, and complex plastic machining of piston parts and cylinder valves. Generally speaking, assessment of the cost/benefit balance of innovatory designs can only be made after thorough testing and investigation of the pump as a whole, and probably specific subassemblies of it.

5.2.2 Field trials of new pumps should also be carried out with such an experimental design that the benefits of the innovations will be seen in relation to existing designs. Again care must be taken that the (relatively few) samples required for field trial experiments are not specially prepared prototypes unrepresentative of the quality which will be produced when large numbers are made. (The retrospective fitting of modifications to new designs in the field is an expensive, difficult and - to the users - demoralising procedure, which should be obviated by all possible means)

5.3 Usage Situations - Non-technical Factors

All testing (laboratory or field) of all pumps must pay particular attention to the usage-situation. That is to say, the sociological, geological, environmental, cultural and economic bounds of the regions for which pumps are being tested must be a priority consideration. If the region concerned is too large it will be necessary for the researchers to specify over what ranges of usage conditions a particular pump, or design, or sub-unit would be expected to function well. Since these considerations seem generally not to have been central in many extant research studies, it is the more important now to ensure that they are included in all present or future studies.

5.4 Appropriate Technology and its Social/Regional Setting

5.4.1 Since the durability, maintenance and local manufacture of water pumps are key considerations in successful pump programmes, and since these are all heavily influenced by sociological and cultural factors, particular research into these influences would seem to be indicated. It is all too easy to do technological research, the reporting of which contains plenty of statements which explain the paramount importance of social factors while actually largely ignoring them. Indeed it is all too difficult to deal with such factors.

5.4.2 Both maintenance of pumps and their manufacture entail a degree of technological understanding and a socio-technical "infrastructure" or organisation. Indeed, it might be the case that if pump programmes around the world were analysed, those found to be the most successful in dealing with manufacture/maintenance problems would be found in communities with the highest technical understanding, generally. On the other hand this correlation might as much be connected with economic factors or with ease of communication between the local region and the originators of pumps - who have generally been the capital-intensive-sophisticated-technology regions.

5.4.3 Good installation and maintenance of pumps, let alone local manufacture, require social organisation, administration, management, infrastructure, a system - or whatever one likes to call it. There seems to be a need for research into what social organisation or system can produce the best results.

It must be particular to the region concerned. There may be a need not so much for experimental research into what will work, as for actual direct development in situ of social organisations which do work. The only suggestion we have here is that perhaps it may be desirable to view the whole pump programme, and parts of it (e.g. manufacture, spares production, maintenance, a village, groups of wells/communities etc) as "socio-technical open systems" ("Systems of Organisation" - E.J. Miller and A.K.Rice Tavistock 1967, "Task and Organisation" - E.J.Miller, Wiley 1976), and to apply the methods, both of analysis and implementation, to the setting up of maintenance systems, malfunction warning systems, and where appropriate, manufacture.

"The Enterprise & Its Environment" AK Rice, Tavistock

5.5 Co-ordination

Whatever else may be needed, co-ordination of efforts is a "must". Design, technical testing, field trials, surveys, analysis and implementati of maintenance and manufacture probably amount to too large a package for any/most countries/agencies to cover completely. Much work has been done, and much is being done.

All too often co-ordination between different research programmes seems to be difficult. Co-ordination is necessary, so that commonality of aims, methods, and reporting may facilitate the transfer of conclusions from one programme to another, across the world.

In the context of co-ordination, it is quite important for the results and thinking of one conference to be available to others, and we end here in sincere hope that there will be full communication between the WHO/SEARO meeting in New Delhi (October 1978), the World Bank's meeting in London (December 1978) and the WHO/IRC meeting in England (March/April 1979), although the precise aims of each meeting are somewhat different.

FIGURE 1

WEIGHTING TREE

DESIGN OF ABOVE GROUND COMPONENTS 27	Manufacturing Equipment	0	Foundry	0
			Machining	0
			Cutting, drilling, welding	0
			Presswork	0
			Sheet metalwork	0
			Protective coatings	0
			Mouldings (Polymeric)	0
			Woodworking	0
			Fitting skills	0
	Adequacy of Design	0	Tolerances	0
			Clearances	0
			Dimensions	0
			Manufacturing requirements	0
	Design Complexity	0	---	0
	Materials Selection	4	Engineering	2
			Corrosion	2
	Simplicity of Repair	4	Hand/foot pedal	1·5
			Bearings	1·5
			Other components	1
	Sanitary Considerations	3	Spout design	0·5
			Resistance to contamination	2·5
	Robustness	8	General	3
			Resistance to impact loads	5
			Resistance to pilferage	0
	Maintenance	8	Extent of maintenance	6
			Ease of maintenance	2
DESIGN OF BELOW GROUND COMPONENTS 23	Manufacturing Equipment	0	Foundry	0
			Machining	0
			Cutting, drilling, welding	0
			Presswork	0
			Sheet metalwork	0
			Protective coatings	0
			Mouldings (Polymeric)	0
			Woodworking	0
			Fitting skills	0
	Adequacy of Design	0	Tolerances	0
			Clearances	0
			Dimensions	0
			Manufacturing requirements	0
	Design Complexity	0	---	
	Materials Selection	4	Engineering	2
			Corrosion	2
	Simplicity of Repair	4	Valves	1·5
			Seals	1·5
			Pumping element	1

FIGURE 1 (Cont'd)

WEIGHTING TREE

DESIGN OF BELOW GROUND COMPONENTS (cont)	Ease of Installation 7	General	4
		Likelihood of damage	3
	Maintenance 8	Extent of maintenance	6
		Ease of maintenance	2
ERGONOMICS AND USER TESTS 12	Spout Design (Ergonomic) 2	Height	0.8
		Exit water pattern	0.6
		Water turbulence	0.6
	Handle Height Suitability 4	Men (tall)	0.5
		Men (short)	0.5
		Women (tall)	1
		Women (short)	1
		Boys	0.5
		Girls	0.5
	Handle Comfort (Overall) 1	---	
	Ease of Operating Pump (20 m) 5	Men (tall)	0.5
		Men (short)	0.5
		Women (tall)	1.5
		Women (short)	1.5
		Boys	0.5
		Girls	0.5
PERFORMANCE 8	Leakage Rate When New 4	High head	4
		Low head	0
	Efficiency 4	High head	3
		Medium head	0
		Low head	0
		Stroke speed variation	1
ENDURANCE 25	Corrosion (Pumping Element) 2	Hard water	0
		Soft water	2
	Corrosion (Rising Main) 2	Hard water	0
		Soft water	2
	Corrosion (Pump Stand) 2	Hard water	0
		Soft water	2
	Mechanical faults (Pumping Element) 5	Clean water	5
		Sandy/silty water	0
	Mechanical Faults (Rising Main) 3	Clean water	3
		Sandy/silty water	0
	Mechanical Faults (Pump Stand) 5	Clean water	5
		Sandy/silty water	0
	Wear (Pumping Element) 3	Clean water	3
		Sandy/silty water	0
	Wear (Pump Stand) 3	---	
SAFETY 5		---	

FIGURE 2

WEIGHTING TREE

DESIGN OF ABOVE GROUND COMPONENTS 32	Manufacturing Equipment 10	Foundry 3
		Machining 1.5
		Cutting, drilling, welding 0
		Presswork 1.5
		Sheet metalwork 0
		Protective coatings 1
		Mouldings (Polymeric) 1
		Woodworking 0
		Fitting skills 2
	Adequacy of Design 5	Tolerances 1
		Clearances 1
		Dimensions 1
		Manufacturing requirements 2
	Design Complexity 2	---
	Materials Selection 3	Engineering 1.5
		Corrosion 1.5
	Simplicity of Repair 3	Hand/foot pedal 1
		Bearings 1
		Other components 1
	Sanitary Considerations 2	Spout design 0.5
		Resistance to contamination 1.5
	Robustness 5	General 0.5
		Resistance to impact loads 1.5
		Resistance to pilferage 3
	Maintenance 2	Extent of maintenance 1
		Ease of maintenance 1
DESIGN OF BELOW GROUND COMPONENTS 30	Manufacturing Equipment 10	Foundry 3
		Machining 1.5
		Cutting, drilling, welding 0
		Presswork 1.5
		Sheet metalwork 0
		Protective coatings 1
		Mouldings (Polymeric) 1
		Woodworking 0
		Fitting skills 2
	Adequacy of Design 5	Tolerances 1
		Clearances 1
		Dimensions 1
		Manufacturing requirements 2
	Design Complexity 3	---
	Materials Selection 3	Engineering 1.5
		Corrosion 1.5
	Simplicity of Repair 3	Valves 1
		Seals 1.5
		Pumping element 0.5

FIGURE 2 (Cont'd)

WEIGHTING TREE

DESIGN OF BELOW GROUND COMPONENTS (cont)	Ease of Installation	3	General Likelihood of damage	1·5 1·5
	Maintenance	3	Extent of maintenance Ease of maintenance	1·5 1·5
ERGONOMICS AND USER TESTS 12	Spout Design (Ergonomic)	2	Height Exit water pattern Water turbulence	0·8 0·6 0·6
	Handle Height Suitability	4	Men (tall) Men (short) Women (tall) Women (short) Boys Girls	0·5 0·5 1 1 0·5 0·5
	Handle Comfort (Overall)	1	---	
	Ease of Operating Pump (20 m)	5	Men (tall) Men (short) Women (tall) Women (short) Boys Girls	0·5 0·5 1·5 1·5 0·5 0·5
PERFORMANCE 8	Leakage Rate When New	4	High head Low head	0 4
	Efficiency	4	High head Medium head Low head Stroke speed variation	0 0 3 1
ENDURANCE 15	Corrosion (Pumping Element)	1·5	Hard water Soft water	1·5 0
	Corrosion (Rising Main)	1·5	Hard water Soft water	1·5 0
	Corrosion (Pump Stand)	1·5	Hard water Soft water	1·5 0
	Mechanical faults (Pumping Element)	3	Clean water Sandy/silty water	3 0
	Mechanical Faults (Rising Main)	0·5	Clean water Sandy/silty water	0·5 0
	Mechanical Faults (Pump Stand)	3	Clean water Sandy/silty water	3 0
	Wear (Pumping Element)	2	Clean water Sandy/silty water	2 0
	Wear (Pump Stand)	2	---	
SAFETY 3			---	

FIGURE 3

WEIGHTING TREE

DESIGN OF ABOVE GROUND COMPONENTS 37	Manufacturing Equipment 10	Foundry	2
		Machining	2
		Cutting, drilling, welding	0
		Presswork	2
		Sheet metalwork	0
		Protective coatings	1
		Mouldings (Polymeric)	1
		Woodworking	0
		Fitting skills	2
	Adequacy of Design 3	Tolerances	0.5
		Clearances	0.5
		Dimensions	0.5
		Manufacturing requirements	1.5
	Design Complexity 4	---	
	Materials Selection 3	Engineering	1.5
		Corrosion	1.5
	Simplicity of Repair 3	Hand/foot pedal	1
		Bearings	1
		Other components	1
	Sanitary Considerations 2	Spout design	0.5
		Resistance to contamination	1.5
	Robustness 6	General	1
		Resistance to impact loads	2.5
		Resistance to pilferage	2.5
	Maintenance 6	Extent of maintenance	4
		Ease of maintenance	2
DESIGN OF BELOW GROUND COMPONENTS 30	Manufacturing Equipment 10	Foundry	2
		Machining	2
		Cutting, drilling, welding	0
		Presswork	2
		Sheet metalwork	0
		Protective coatings	1
		Mouldings (Polymeric)	1
		Woodworking	0
		Fitting skills	2
	Adequacy of Design 3	Tolerances	0.5
		Clearances	0.5
		Dimensions	0.5
		Manufacturing requirements	1.5
	Design Complexity 3	---	
	Materials Selection 3	Engineering	1.5
		Corrosion	1.5
	Simplicity of Repair 4	Valves	1.5
		Seals	1.5
		Pumping element	1

FIGURE 3 (Cont'd)

WEIGHTING TREE

DESIGN OF BELOW GROUND COMPONENTS (cont)		Ease of Installation	4	General	2
				Likelihood of damage	2
		Maintenance	6	Extent of maintenance	4
				Ease of maintenance	2
ERGONOMICS AND USER TESTS	8	Spout Design (Ergonomic)	1	Height	0·6
				Exit water pattern	0·2
				Water turbulence	0·2
		Handle Height Suitability	3	Men (tall)	0·2
				Men (short)	0·2
				Women (tall)	1
				Women (short)	1
				Boys	0·3
				Girls	0·3
		Handle Comfort (Overall)	1	---	
		Ease of Operating Pump (20 m)	3	Men (tall)	0·2
				Men (short)	0·2
				Women (tall)	1
				Women (short)	1
				Boys	0·3
				Girls	0·3
PERFORMANCE	6	Leakage Rate When New	3	High head	1·5
				Low head	1·5
		Efficiency	3	High head	0
				Medium head	2
				Low head	0
				Stroke speed variation	1
ENDURANCE	15	Corrosion (Pumping Element)	1·5	Hard water	0
				Soft water	1·5
		Corrosion (Rising Main)	1·5	Hard water	0
				Soft water	1·5
		Corrosion (Pump Stand)	1·5	Hard water	0
				Soft water	1·5
		Mechanical faults (Pumping Element)	3	Clean water	0·5
				Sandy/silty water	2·5
		Mechanical Faults (Rising Main)	0·5	Clean water	0
				Sandy/silty water	0·5
		Mechanical Faults (Pump Stand)	3	Clean water	0·5
				Sandy/silty water	2·5
		Wear (Pumping Element)	2	Clean water	0
				Sandy/silty water	2
		Wear (Pump Stand)	2	---	
SAFETY	3			---	

ASSUMPTIONS USED IN FORMULATING WEIGHTING "TREES"

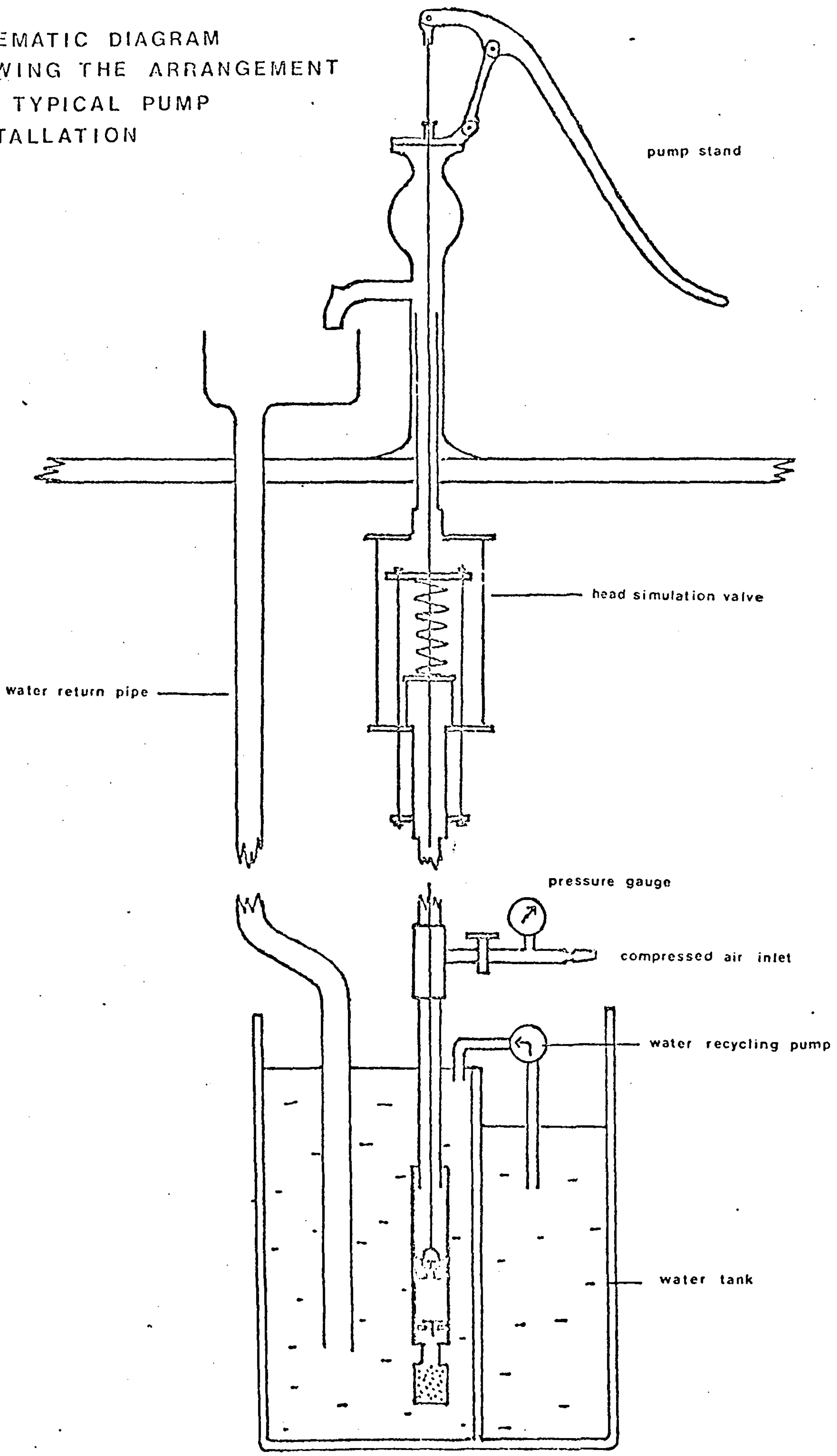
1. (a) Pump bought in from abroad
   (b) Maintenance difficult, level of technological know-how is generally low
   (c) Pilferage and vandalizing of pumps unlikely
   (d) Women are the main pump users
   (e) Deep well installations, > 30 m
   (f) Water is acid
   (g) No sand/silt in water

2. (a) Pump made in LDC
   (b) No foundry available and only limited skills
   (c) Pilferage and vandalizing common
   (d) Women are the main pump users
   (e) Simple maintenance is fairly easy
   (f) Well depth 15 m
   (g) Hard water
   (h) No sand/silt in water

3. (a) Pump made in LDC
   (b) Women are main pump users
   (c) Maintenance is difficult
   (d) Pump likely to be maltreated and pilfered
   (e) Well depth 20-25 m
   (f) Acid water
   (g) Some sand/silt likely to be in water
   (h) Only fairly simple manufacturing processes - no foundry and very little machining or press work.

FIGURE 4

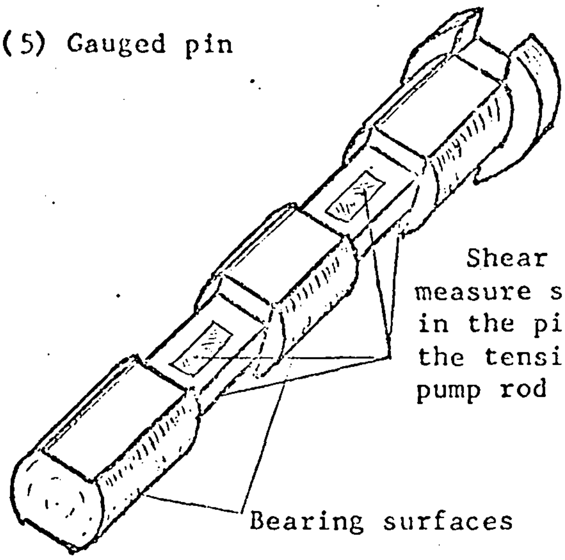
SCHEMATIC DIAGRAM
SHOWING THE ARRANGEMENT
OF A TYPICAL PUMP
INSTALLATION



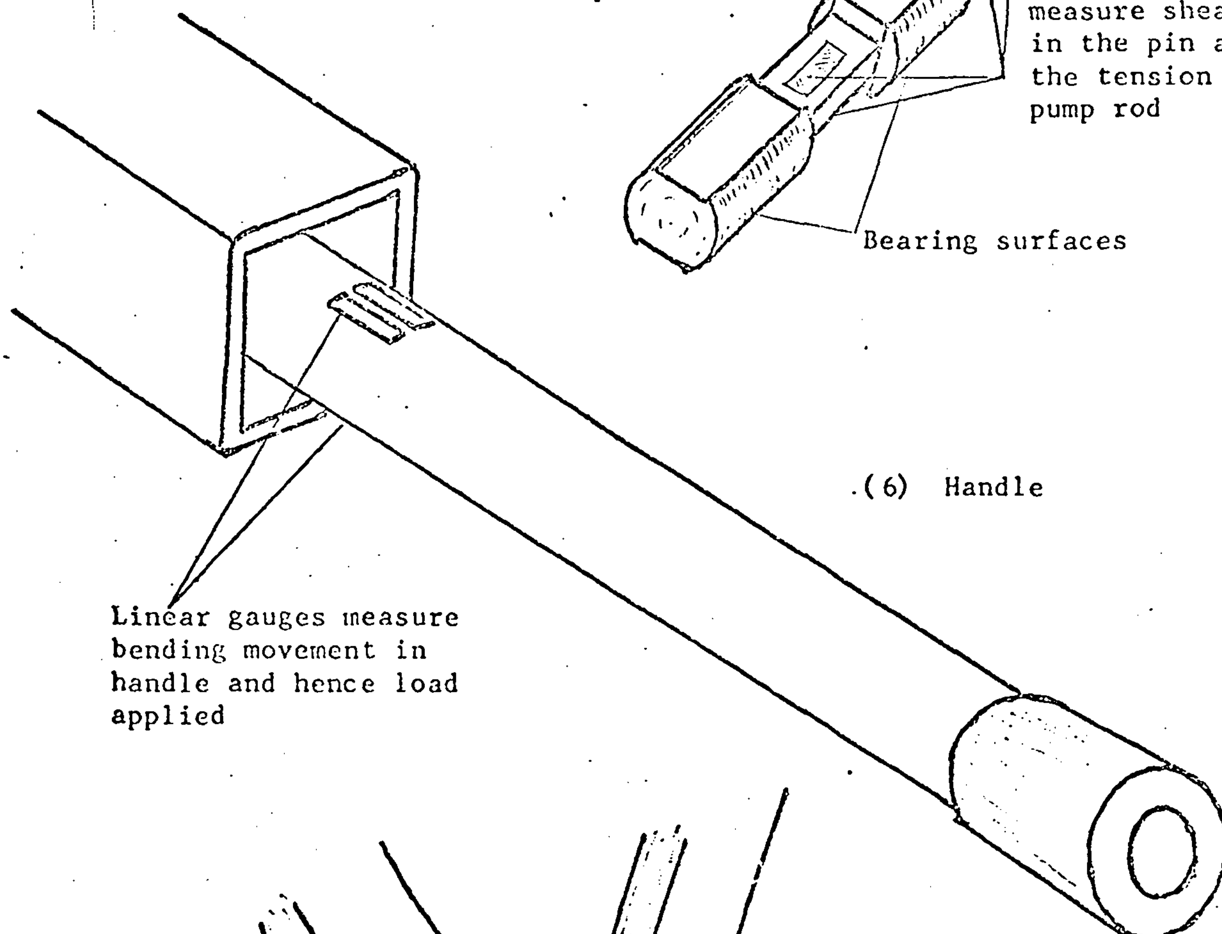
FIGURES 5-7

Examples of Strain Gauged Components Used to Measure Forces in Various Parts of a Pump

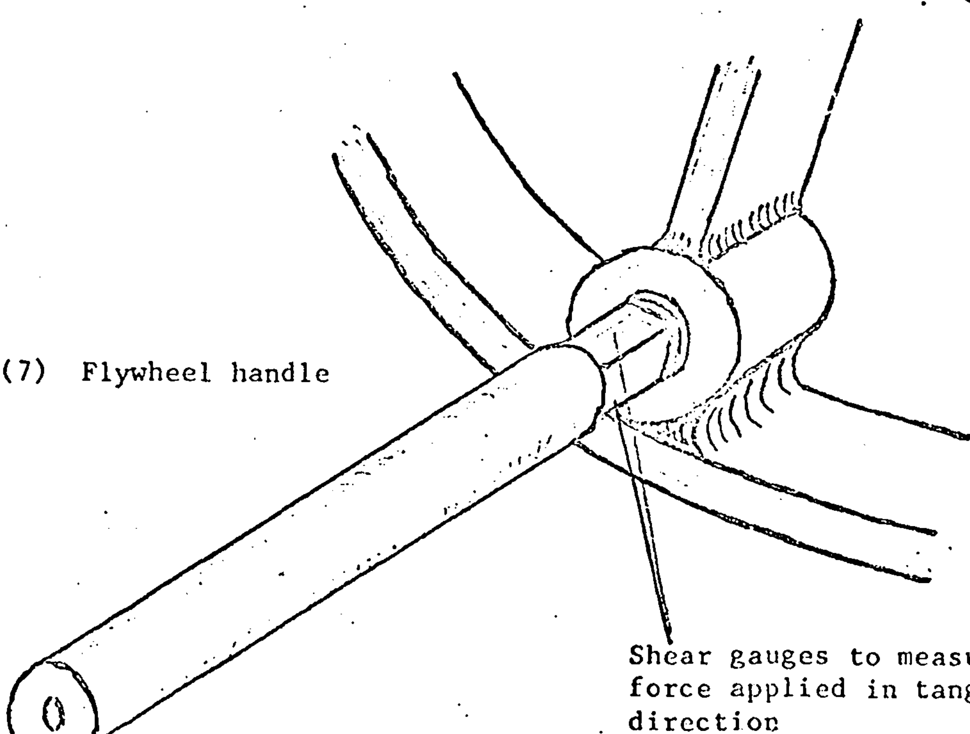
(5) Gauged pin



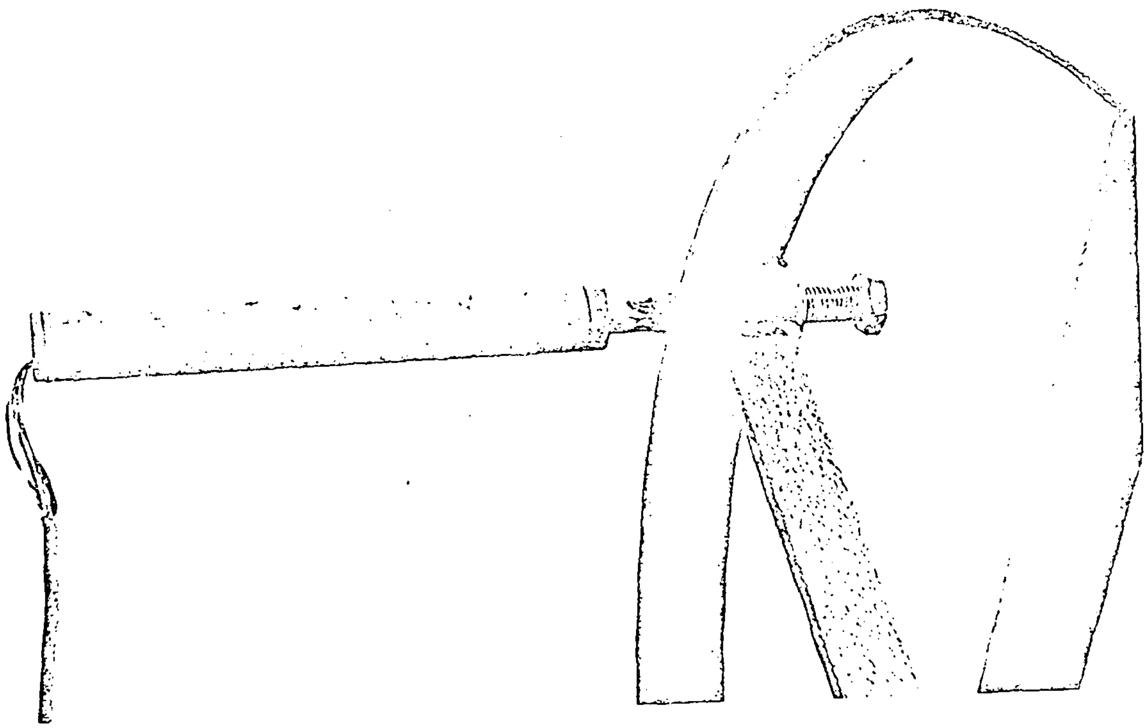
(6) Handle



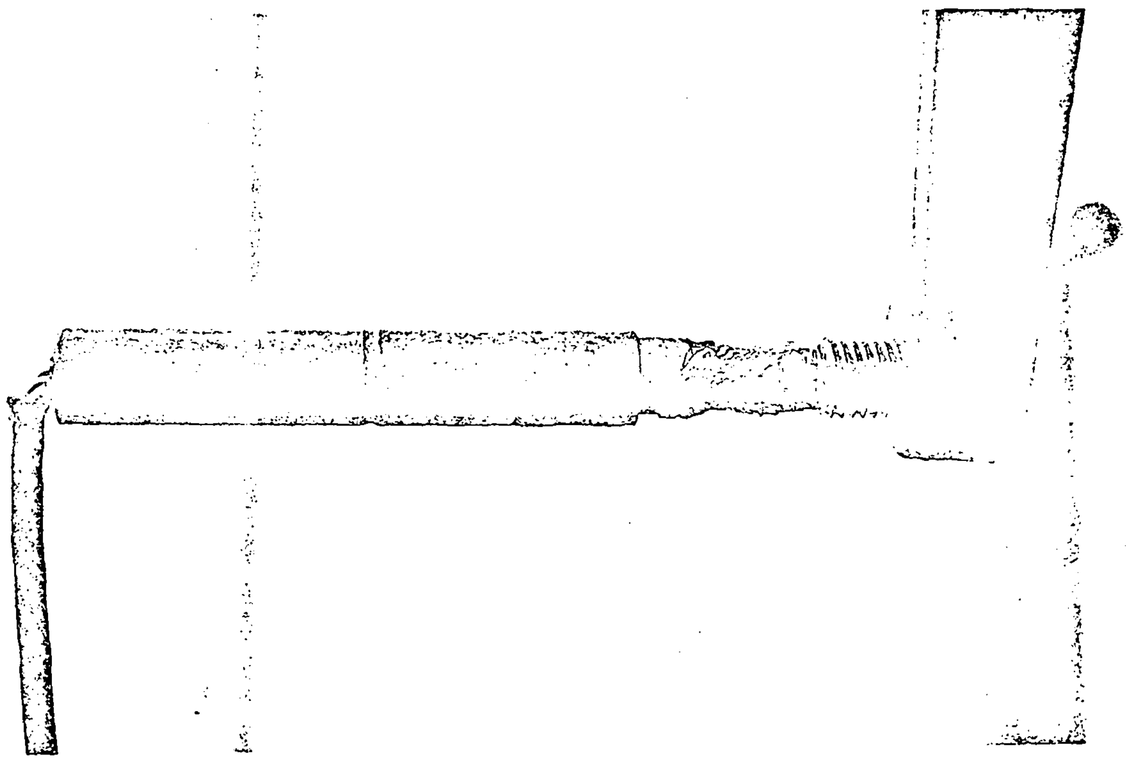
(7) Flywheel handle



Examples of Components Fitted with Strain Gauges

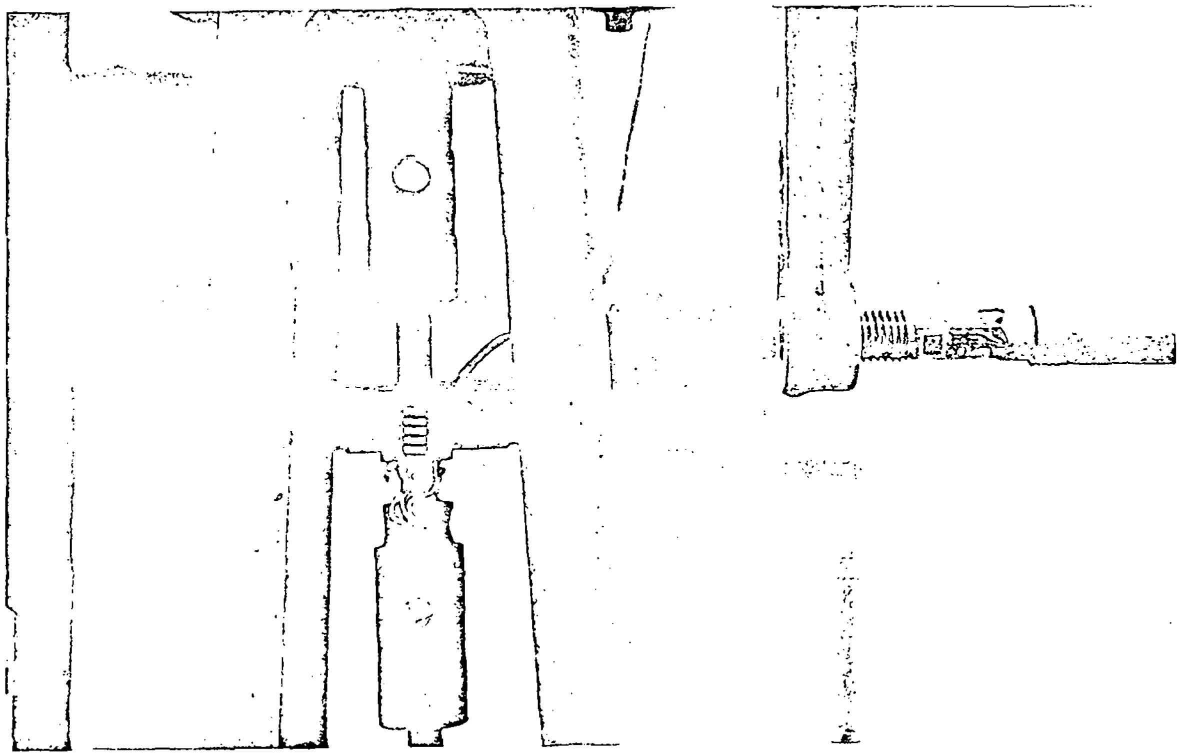


8. Flywheel pump with gauged handle for measuring handle loads (Godwin W1.H51)

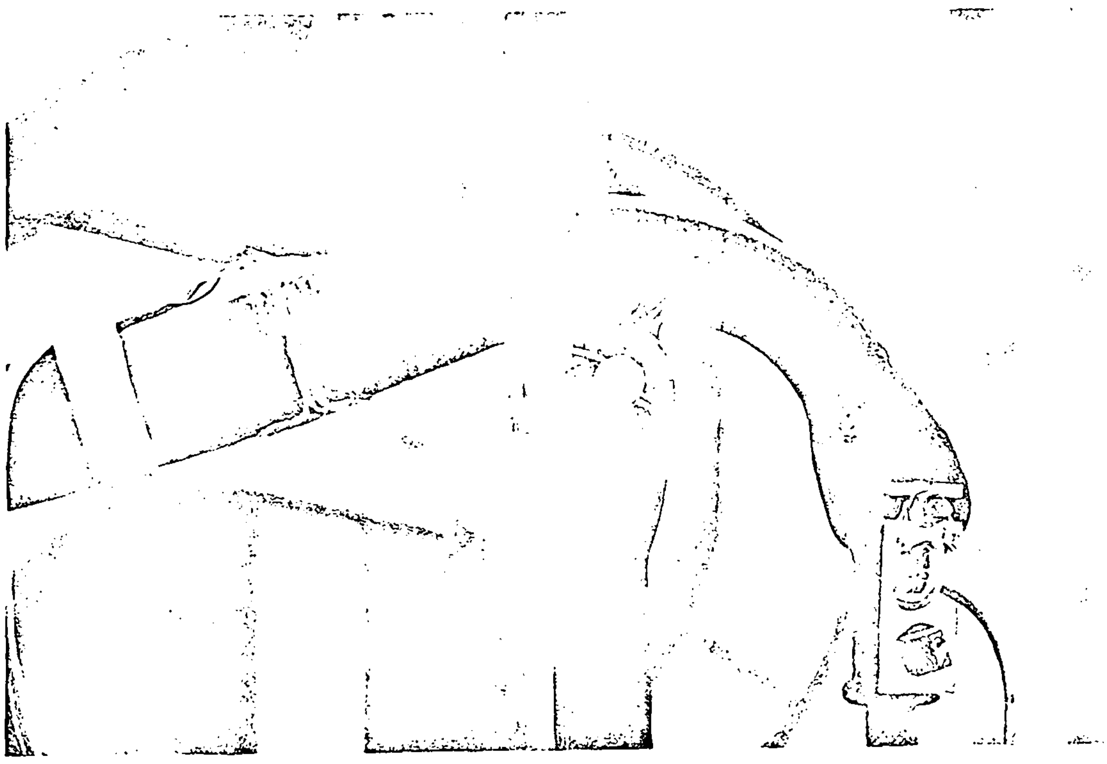


9. Gauged handle on rotary pump (Mono ES30)

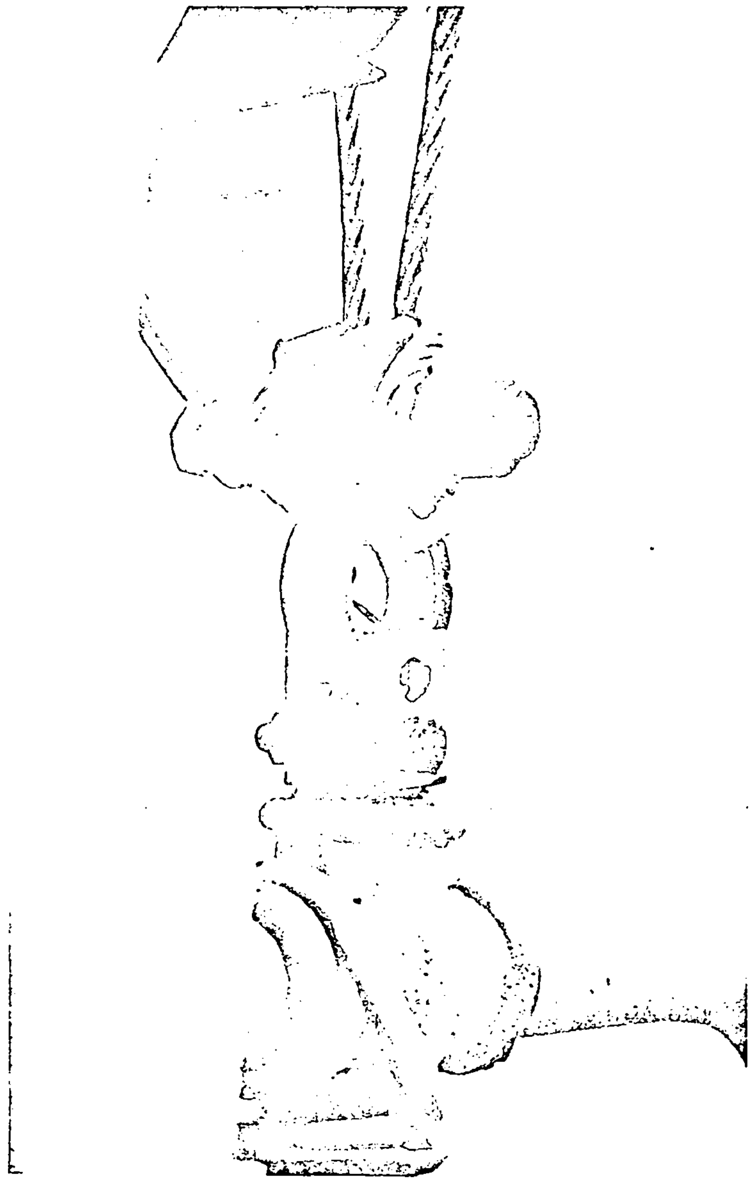
Examples of Components Fitted with Strain Gauges



10. Gauged rotating shaft and handle (Mono ES30)

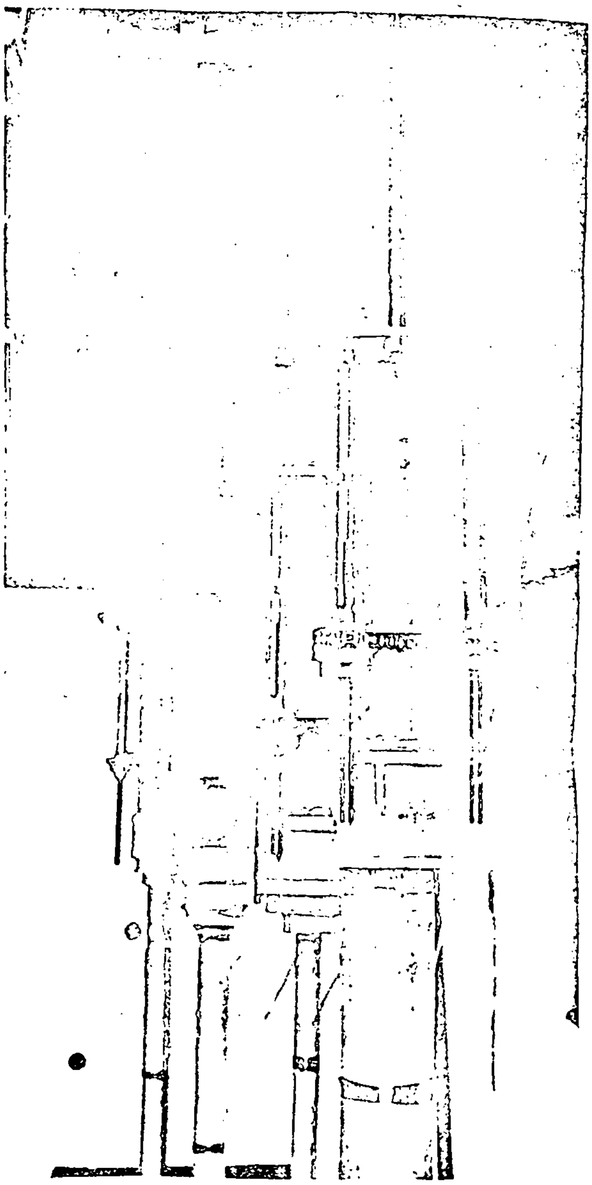


11. Gauged pin (for measuring force in the pump rod) and handle (Dempster 23 EX (CS))



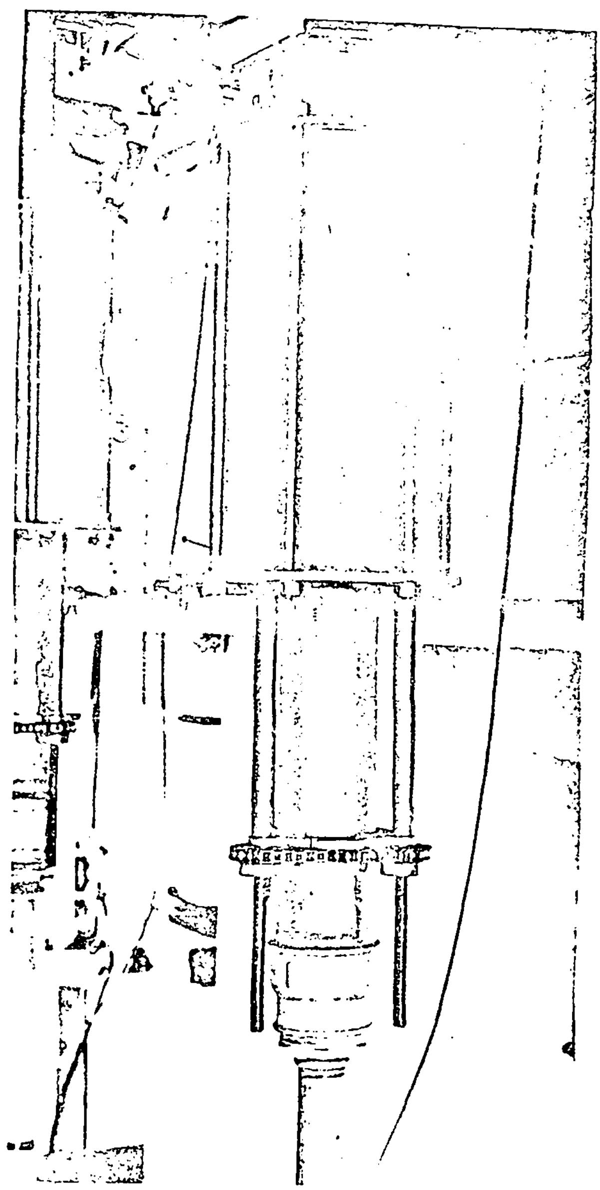
12. Stress proving ring fitted to a Petropump type 95

Photographs Showing the Head Simulation Valves



13.

14.



II - GUIDELINES FOR COMPARATIVE TESTING OF PRODUCTS

C O N T E N T S

II - GUIDLINES FOR COMPARATIVE TESTING OF PRODUCTS

GUIDELINES FOR COMPARATIVE TESTING OF PRODUCTS

1. INTRODUCTION

1.1.1 The best method of determining how particular brands of a product will perform and endure, in practice - and, therefore, of deciding which is the most suitable for purchase - is ~~be~~ to buy and use them in the normal way.

There are some major problems in such an approach, however If it is to avoid artificiality and produce real, useful answers, the users must know that the investigation is designed to simulate "real life". They will then treat the products normally - especially if reality is such that they have chosen and paid for the products in the normal way. Unfortunately, however, the answers will not be available for a long time, if they can be obtained at all.

1.1.2 Thus there arises the first dilemma of anyone who faces a buying decision - whether it be a personal choice about a product for personal use, or for use by family or friends, or a corporate/business decision about many products for use by others.

The problem is to obtain sufficient useful information about the brands available so that a sensible buying decision may be made. The dilemma is to obtain this information before committing one's funds to buying. The question is "where and how to get such information?"

1.1.3 At first sight it might be supposed that manufacturers are prime sources of the information one needs. What does the product do, how much, how well, and at what running cost, how safe is it, how easy is it to use, how noisy is it, how long will it last, what does it cost to buy/to repair etc.? Manufacturers who make their brands in thousands or millions must surely know the answers (?)

We all know that manufacturers' advertising literature, perhaps without being untrue, often avoid telling the whole truth; even technical brochures for engineering products, sent out by manufacturers' technical departments to the technical departments of buying companies, although more factual, tend to mention the more attractive aspects of a product rather than its drawbacks.

1.1.4 So, while we conventionally (and somewhat easily) reject manufacturers' published information as inevitably not-independent, and somewhat biased, what use is the fund of information which manufacturers must surely have from their customers through sales and field-service departments?

That information is certainly valuable but can it solve the problem? Is it for example, comparative, verifiable and usage-orientated? Unhappily, usually it is not. Not comparative because one manufacturer will seek, obtain and file different information in a different way from his competitors. Not verifiable because it often consists of opinions of users - genuine opinions, but often not helpful to potential purchasers (we are all familiar with the over-optimistic "testimonials" which are sent to manufacturers by users; no doubt there are equally over-pessimistic complaints and abuse received by manufacturers). Often this information is helpful, but incomplete and not a balanced picture.

1.1.5 So, we end up with a need for - Independent
Objective
Unbiased
Accurate
Reliable
Verifiable
Meaningful
Comparative
Usage-orientated

information about products.

This then, is the reason for the foundation of Consumer Unions throughout the World, and for the establishment of the technology of comparative testing : many users can band together to fund research into products-in-use which will provide answers to the above questions, and at a cost which is only a fraction of the cost of buying the products needed by these users. There is then a viable comparative testing organisation (CTO). Consumers' Unions perform that function for individual consumers (hundreds of thousands or millions of them in Europe and N.America). Governmental and international agencies may perform the research co-ordinating and funding role for their taxpayers or beneficiaries.

2. ORGANISATION OF COMPARATIVE TESTING

Comparative testing work in laboratories, or in the field, needs to be

2.1 Independent of manufacturers, of politics, of pressure groups, the Press, etc., for obvious reasons. The need for independence has implications when the choice of a testing organisation to carry out a project is being made. It also has implications for the staff of the testing organisation who themselves must not be subject to influences of the sort mentioned. Difficulties can also arise if the testing organisation itself is so small relative to a project that the organisation's financial viability rests on one project.

2.2 Objective

In that the results of any test must not depend on contingencies such as the place, time, and persons doing the job, except insofar as location is part of the test and particular skills are needed. The same testing procedure carried out by a different (but equally competent) team in a different place at a different time should produce the same results.

2.3 Unbiased

By memories of previous results and observations, whether these were obtained in the same project, or in previous projects, or even by other researchers. One helpful technique which can assist (but not ensure) lack of bias especially in recording and analysing data, is to code the brands with numbers or letters and refer to them only by codes and not by brands.

2.4 Accurate

Test methods must be designed and checked to ensure that results are correct enough and precise/reproducible enough to justify their use in evaluating the attributes of the product which the data purport to represent. Note that there is no need to measure anything more accurately or more precisely than necessary but that it is essential to know what the precision and accuracy of a test result is and that they are the same in all cases. It will be essential for test organisations to have regular procedures for checking the accuracy of their measuring instruments - including simple measuring rulers - against their own reference instruments and/or against national reference instruments.

2.5 Reliable

Attention to all the other points plus the reputation and experience of the CTO will generally assure reliability in its work.

2.6 Verifiable

Usually a test report on a product can have an effect on its sales; therefore, a critical report, especially of a product's safety or durability, may be damaging to its manufacturer. If the test report is misleading or inaccurate, or if testing has not been done properly or by suitably qualified staff, the manufacturers may in most countries be able to get legal re-dress. It is therefore necessary that the testing organisation take clear, and publicly available, steps to ensure that its report can be proved. Such steps include -

(a) The need for all data to be recorded as and when it is obtained, and for it to be clearly labelled with the date and the signature of the person recording the data. This original documentation must then be preserved so that it can be produced if necessary to justify the reported conclusions.

(b) If data are obtained which are likely to lead to substantial criticism of any brand under test (or which are in some other way "odd"), steps must be taken immediately to check such data by -

 (i) Repeating the test with other, more experienced/senior observers present.

 (ii) Checking the calibration of all measuring apparatus used and the validity of the test method.

 (iii) Obtaining further samples of the brand concerned and repeating the test on them.

 (iv) Obtaining the manufacturer's comments on the factual data (as in (c) below), and investigating thoroughly any reasons for disagreement.

It is desirable to inform the client after steps (ii) and (iii) and (iv) - unless he wishes to subcontract all the responsibility for even the most unusual results to the testing organisation.

(c) Even if (b) does not occur it is desirable, before issuing a final evaluation report, to check factual data for each brand tested with the manufacturers of that brand. He should only be given the factual data on his own brands, without indicating evaluat ry judgements as comparisons with other manufacturers' brands, and he should be invited to agree/disagree or comment. If he disagrees with the test data he should be asked to supply his own data to the testing organisation in order to demonstrate that its results were incorrect or that the test methods were unsuitable. Very often disagreements are minor and unimportant (e.g. a $\sim$1% difference in the measured external dimension of a product compared with the manufacturer's specification). Even when there are substantial differences in test results these will often be found to be due to different test methods, and, provided that the testing organisation can confidently justify its test methods and procedures in relation the criteria set out in this section (2), it need not be in any way bound by the manufacturer's measurements or views.

(d) Retaining test samples after presentation of the test report for a long enough period to deal with queries which may arise.

It is important that a comparative testing organisation has a full quality assurance system - which, as in good manufacturing industries, should report to the organisation's chief manager independently of managers responsible for finishing projects on time and within cost

2.7 Meaningful

Data should be analysed thoroughly and the significance evaluated - this includes assessment of accuracy and precision and other appropriate, statistically-based techniques. Only data which make sense to potential users/buyers should be included in the test report and indications should be given of the differences which will be perceptible to users and which matter in practice. These data - and, indeed, the whole report - should be presented in such a way that readers can understand and use the results. Without too much scientific detail it should be made clear how a reader can appreciate the results, in order to see for himself what his best choice of action is.

2.8 Comparative

The range of products/brands included in a test should be comparable - at least the brands included should be used realistically for comparable ends and they should present a real choice to users/buyers. Moreover all tests in the research programme must be equally applied to all brands without any differences in method or procedure.

2.9 Usage-Orientated

The test programme, the test methods and the evaluation methods should take into particular account the conditions in which the products are to be used, the level and nature of the users' skills and expectations, and the likely or inevitable abuse ("normal abuse").

3. THE TEST PROGRAMME

The attached flow chart gives an outline of the main steps in the execution of a comparative testing programme. Some points which should be noted are -

3.1 Choice of Brands

The budget may be a limiting factor but every effort should be made to include as many of the brands as are available on the market concerned, in a fully comparative test. However, there will also be occasions when one or two brands of special interest (innovatory designs, for example, or new local production in the country of interest) should be tested. It is also often helpful to include one or more brands of a different type or different price range in order to obtain comparisons and see whether, for example, price differentials or innovation are worthwhile.

3.2 Shopping

Should be done anonymously and through channels which are normal for sales of the product concerned. Care should be taken to ensure that samplesfor testing have not been specially prepared by some of the manufacturers since this would obviously invalidate test results. Shoppers should also collect, wherever possible, user and installation instructions, service manuals, guarantees and any other relevant documentation.

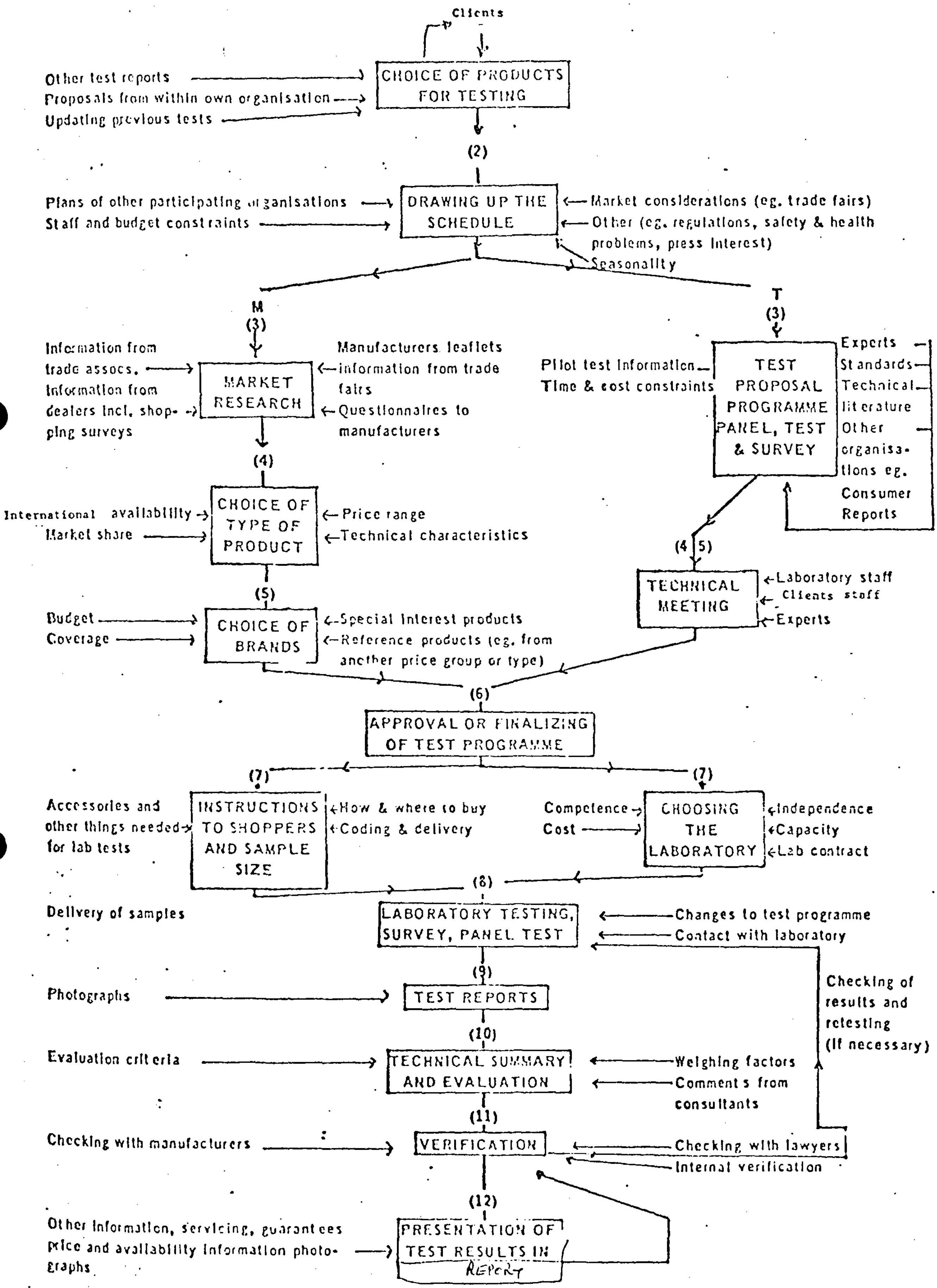
After delivery, samples and their associated literature should be checked thoroughly to ensure that what was ordered was, in fact, obtained, and also that the multiple samples of each brand are, in fact, similar.

3.3 Sample Size

It is rarely possible to take a purely statistical approach when determing sample size but, as indicated above, it is important to ensure that the way the samples are bought is much the same as the way in which users normally buy these products. Later on, precautions should be taken to ensure that the results obtained are not atypical of the products on the market. Such precautions may include an assessment of whether a fault is due to poor design or due to an exceptional product failure, the checking of results against manufacturers' specifications, the substitution or repair of a sample, the presentation of certain test results individually to manufacturers, and the experience of consumers themselves.

With certain products, such as perishable goods, particular attention should also be paid to the trading channels used for the purchase of the items, condition of sampling, transport and storing before test, in order to ensure the comparability of test results.

Samples obtained directly from manufacturers or wholesalers by the test organisation are unlikely to be typical unless a selection of samples from a large number is permitted.


Clients
Other test reports
Proposals from within own organisation
Updating previous tests
CHOICE OF PRODUCTS FOR TESTING
(2)
Plans of other participating organisations
Staff and budget constraints
DRAWING UP THE SCHEDULE
Market considerations (eg. trade fairs)
Other (eg. regulations, safety & health problems, press interest)
Seasonality
M
(3)
T
(3)
Information from trade assocs.
Information from dealers incl. shopping surveys
MARKET RESEARCH
Manufacturers leaflets
information from trade fairs
Questionnaires to manufacturers
Pilot test information
Time & cost constraints
TEST PROPOSAL PROGRAMME PANEL, TEST & SURVEY
Experts
Standards
Technical literature
Other organisations eg. Consumer Reports
(4)
International availability
Market share
CHOICE OF TYPE OF PRODUCT
Price range
Technical characteristics
(4 5)
TECHNICAL MEETING
Laboratory staff
Clients staff
Experts
(5)
Budget
Coverage
CHOICE OF BRANDS
Special interest products
Reference products (eg. from another price group or type)
(6)
APPROVAL OR FINALIZING OF TEST PROGRAMME
(7)
(7)
Accessories and other things needed for lab tests
INSTRUCTIONS TO SHOPPERS AND SAMPLE SIZE
How & where to buy
Coding & delivery
Competence
Cost
CHOOSING THE LABORATORY
Independence
Capacity
Lab contract
(8)
Delivery of samples
LABORATORY TESTING, SURVEY, PANEL TEST
Changes to test programme
Contact with laboratory
(9)
Photographs
TEST REPORTS
Checking of results and retesting (if necessary)
(10)
Evaluation criteria
TECHNICAL SUMMARY AND EVALUATION
Weighing factors
Comments from consultants
(11)
Checking with manufacturers
VERIFICATION
Checking with lawyers
Internal verification
(12)
Other information, servicing, guarantees price and availability information photographs
PRESENTATION OF TEST RESULTS IN REPORT

4. THE CONTENTS OF A TEST PROJECT

4.1 Assumptions

All comparative test programmes make assumptions about the identity of the user population, the nature of the usage and abusage applied to the products, and the value satisfactions to the user population of product attributes.

These assumptions are most often implicit rather than explicit, and an incomplete statement of the assumptions is one of the most prevalent reasons for disagreement (between users and comparative testing organisations, between one CTO and other.)

Users are populations; so are the characteristics of usage/abusage; so are product ranges. So comparative testing organisations are faced with investigating a statistically complex situation and presenting results in such a way that they are useful (typically to readers who are less sophisticated in comparative testing). Usually it is necessary to simplify the investigation by considering the most likely usage/abusage, the 'average' user, and the most available product range. However, it is desirable to indicate the limitations of these simplifying assumptions (e.g. how prevalent are 'fringe'/'alternative' patterns of use, or user groups?). and it is sometimes also desirable to consider evaluations of the same data relating to different profiles of user needs. The objective of a comparative testing programme is to work within a defined set of assumptions about users/usage and to disprove the hypothesis that there is no significant difference in value of the different brands of product examined in the testing programme.

4.2 Attributes Normally Considered

It is not the object here to prescribe comprehensive Terms of Reference for a product. Nonetheless some guidance can be given on those attributes of a product which are most often considered important.

4.2.1 Size, weight and shape : in some cases these are important to the user, because some brands may not fit the space available. The size and shape of any containers which are part of the product should also be measured and related to users' needs.

4.2.2 Delivery : Appraisals of transportability can be made, and related to packaging supplied, whose degree of protection should be assessed.

4.2.3 Installation : where the product requires installation, a description of the materials, skills, tools needed should be given together with an appraisal of the ease of installation, and whether it is reasonable to expect the user/purchaser to be able to do it. Instructions for installation which are supplied should be assessed for content, layout, intelligibility and clear separation of multiple languages (if relevant).

4.2.4 Design, construction and materials : where appropriate good and poor features of the design should be examined and explained. The manufacturing process, its degree of sophistication, the precision required in making various parts and whether it can readily be attained in batch or mass production (as appropriate) should be considered. Materials of construction should be identified and their appropriateness assessed to the design, to the manufacturing process and, especially, to the purpose and function of the product. The ability of materials to withstand the expected use/abuse should be assessed - the most frequent example here being corrosion resistance.

4.2.5 Running costs should be calculated based on the consumption of electricity, oil, water, gas, detergents, batteries etc. but actual consumption figures should always be reported so that readers can calculate running costs specific to their own area. It is important to comment on the nature of the energy input implications especially in relation to renewable energy sources.

Costs of regular maintenance and of likely repairs during the product's lifetime ought also to be calculated.

4.2.6 Performance is normally measured under carefully controlled conditions which are representative of normal use (finding such conditions can be quite arduous and may well involve surveys or field experiments e.g. in testing tools it is necessary to survey how people actually use them and, perhaps, to measure the loads which they apply). Often performance of products is measured under a single "standardised" set of conditions; when operating conditions are known or expected to vary substantially in practice, the performance should be measured over a range of appropriate conditions in order to find out what range the products can tolerate before giving poor results. (An example would be varying the voltage applied to electrical goods to see what line supply voltage variations they can tolerate). If people are needed to operate the product they should be skilled staff for performance tests (not "users" - see section 4.3); very often automated simulators are used (see section 4.4).

Any legal requirements that relate to the product should be taken into account. Standards organizations and manufacturers are understandably keen that where methods of measuring performance have been published in Standards, they should be used by comparative testing organizations.

Where possible, such Standards should be used: often, however, Standards Methods for Measuring Performance do not exist, and even if they do, it is possible that they consider only "average" usage conditions, perhaps determined by manufacturers. It is, however, recommended that testing organizations should be quite clear as to their reasons why any test method is used.

4.2.7 As well as measuring the desirable outputs of the product which the user wants (and for which he buys the product) it is necessary to measure the "negative' aspects of performance". These are undesirab outputs, such as noise and pollution (or factors such as the (undesirable) mechanical and chemical wear of the users' clothes which may accompany the (desirable) cleaning they receive in a washing machine). Adverse effects on non-users - e.g. neighbours - should also be assessed, and here again noise and pollution are the commonest factors.

4.2.8 Resistance of the product to normal abuse requires that it also be tested under conditions representing the inevitable, or likely, abuse to which users will put it. The fact that manufacturers may say that such use is extreme, or that the product is not designed for such use should be ignored, if it can be shown that users do actually so use the product. Examples of "normal abuse" include using screwdrivers to open paint tins (thereby tending to bend them), hitting wood chisels with a hammer instead of a mallet (thereby risking shattering the handle), using screwdrivers as cold-chisels (risking shattering the handle or blade tip), not levelling refrigerators, running small electric drills with sanding attachments for the time taken to sand the paint on a door, stalling electric saws, using too much detergent in washing and dishwashing machines.

Resistance to normal abuse includes the ability of the product to withstand extreme climatic and environmental conditions which are either inevitable or likely.

4.2.9 Safety of the product for its users and surrounding population must be investigated thoroughly. Safety aspects must include electrical, mechanical, chemical and potential dangers arising from heat,etc., All types of abuse must be considered. Safety under probable fault conditions should be reported and if users are likely to maintain and repair the product themselves, its safety under maintenance and repair conditions must also be reported. It is obviously desirable that products should be safe under all conditions but this is an ideal which may be unattainable in practice - safety being relative, not absolute.

Safety can be assessed both in terms of the likely damage to people, and in relation to the best available protection - for example in the case of electrically-powered hedgetrimmers, the moving blades represent a serious hazard in use which could result in loss of fingers but they are unlikely to kill, as inadequate electrical insulation could; moreover inadvertent starting of the hazardous blades can be prevented by interlocked switches and "deadmans" handles and any brand which fails to provide such precautions should be strongly criticised.

4.2.10 Convenience in use, and ease of use should be assessed. Any special demands which are made on the user in terms of anthropometrics and ergonomics should be highlighted. Such information is available for many if not most, countries and this should be considered before assessing ease of use and convenience. Ergonomists and experts on the product should collaborate in providing informed opinion. Hypotheses thus developed can be tested by user tests (See section 4.

In these assessments/tests it is obviously necessary to consider the control knobs/handles etc., which a user must operate, and any other parts with which (s)he will come into contact. The intelligibility of instructions, of labelling on the controls or other parts, and of the design itself should be assessed. Convenience and ease of use should be assessed/tested for the range of users likely to operate the product. It is often relevant to consider minority groups here, such as children, the aged, disabled or handicapped people (including pregnant women as a particular case of temporaily "handicapped" users) and the left-handed; with appropriate knowledge manufacturers can often design and make products which can be used by these minorities, but many of them often fail to do so. If there are even one or two brands in a comparative test which can be used more conveniently by some or all of the likely minority groups it is worthwhile to report this fact.

4.2.11 Durability testing often involves lengthy automated operation of the product, perhaps accelerated in time, in order to see the effects of substantial use of the product. Durability does not mean reporting only the life of the product: it should include finding out what factors limit the life (under use and abuse conditions), the most likely causes of failure (with an indication of expected frequency), how failures manifest themselves or can be detected and their consequences. The desirability and feasibility of users repairing failed parts should be assessed in terms of the supplies, tools and skills required and compared with repairs by regular service organisations (from the manufacturers or independent professionals).

It is most important that automated durability testing should represent as faithfully as possible the actual conditions of usage. An example of the differences which this can make was found in testing bicycles: in the past, durability testing in Europe had consisted of mounting the bicycle, with a weight on its saddle, on a moving "road" ("carousel" or "rolling road"), the surface of which was representative of real roads and kerbs/potholes. When Harpenden Rise Laboratory developed a machine which not only loaded the saddle-tube, but also pushed on the pedals to drive the bicycle (and the "rolling road") and also pulled and pushed on the handlebars and seat-tube as a rider would, results were obtained corresponding more to failures found by actual cyclists. As for performance testing, actual conditions of use probably have to be discovered by surveys and measurements in the field.

Corrosion resistance should be included in durability testing.

4.2.12 Although this is not intended to be an exhaustive, or prescriptive list of attributes to test, it is recommended that careful thought be given before omitting any, since an incomplete report may mislead readers (potential buyers). This could lead to inappropriate choices and loss of confidence in comparative testing (understandably but undesirably from the readers point of view).

4.3 User Tests

Many attributes are complex and may not be easy to measure. For example, noise is usually important as the perceived nuisance: visibility from a car is a complex function involving subjective impressions, as well as the topology of the design. Taste and other culturally dependent sensory perceptions usually cannot be measured objectively. Comfort and ease of doing something cannot be measured directly. Anthropometric and ergonomic studies, while necessary, provide only guides to the design of proper user tests.

Uuser tests are,therefore, designed to test the attributes, which cannot be measured objectively, using panels of people. Data are obtained by measurement and observation of the person/product system, by the users' answering pre-designed specific questions (e.g. on a prepared questionnaire, or under interrogation during or just after the test) and/or by collecting "free-form" responses from the users. User tests may range from carefully supervised operations in a laboratory to usage by individuals or groups in their homes. It is easiest to analyse data obtained from 'blocked' experiments in which each user uses each brand under comparable conditions and in the same way, (the brands being used in different orders by different users). If the tests have been designed by a team including an appropriately experienced and specialised statistician and survey sociologists, they should be able to eliminate the variance due to users/user groups.

Field tests can be particularly difficult because it may not be possible to change user group/brand combinations sufficiently and, therefore, it will be more difficult to distinguish between user group differences and real brand differences. User tests, unlike objective measurements, are subject to the same problems of reproducibility and accuracy as surveys. They are, in fact, sociological experiments as much as, if not more than, they are measurements.

It is necessary that the sample of people recruited as users is representative of the population of actual users; for most products the user-population is not the same as the population of the nation. The sample recruited for a user test must therefore take into account the characteristic of the real-user population (which can often only be discovered by a preliminary survey).

In the case of water pumps for LDC's recruiting a representative sample of people for a user test presents substantial difficulties. If the test is being done in a country other than that in which the results will be of interest, there are problems of matching the user-population anthropometricall as well as for sex and age.

A further requirement in user tests, as in surveys, is the avoidance of bias. Bias is not just a bad, subjective characteristic, (e.g. opinion) of the user which (s)he brings into the test. Bias occurs whenever some sub-groups of the user population are represented on the samples more than others (e.g. in a comparative test of cookers if there were substantially more owners of one brand than of any other brand the samples would be biased in terms of that brand - not necessarily in its favour). Bias may occur due to faulty sampling techniques on the part of the organiser, but is more likely to be due to limitations outside the organiser's control, since,for obvious reasons, his knowledge of the population is limited.

The organiser selects his sample of users from a section of the user population which (s)he knows and has access to. The assumption is that this section of the user population is itself representative of the total user population, and sometimes this assumption can be tested.

For example, at Harpenden Rise Laboratory, we normally select samples of users from a list of over 2000 Consumers' Association members who live within a few kilometres of the Laboratory. We are tacitly assuming, firstly, that Consumers' Association members are representative of the British users of the products being tested and, secondly, that those living in N.W, Hertfordshire are representative of the country as a whole. (The first assumption is not so important when we are testing products for reports in our own magazine to our own members). The assumptions could be tested by selecting samples of non-members in our area, and samples of members and non-members from areas far away, or likely to be different: such testing would be more difficult and costly and usually it is not judged to be necessary for CA projects, but the nature of the bias of our basic list of users must be considered in other projects.

Another common source of bias arises from self-selection: not everyone who is invited to respond to a survey or to help with a user test wishes to do so, and there is a possibility that the characteristics of being willing/unwilling to help in these tests may be associated with differentiation in user/usage characteristics. For most surveys in the UK it has generally been found that willingness to answer does not result in bias, but for some user tests (and, particularly for "free form" field trials) more caution is necessary in interpreting the results.

4.4 Accelerated Testing and Simulations

Often it seems desirable to simulate normal usage of products using mechanical/electrical/electronic machinery to 'operate' the products. One reason for this is the inherent irreproducibility and arbitrariness of human operators which might lead to non-comparable usage between the different brands being compared, (a simple example being the effects of fatigue on a human operator in testing the sharpness of saws, or the psychological effects on human operators in measuring the maximum braking performance of two-wheeled vehicles). The machine or 'rig' which replaces human operators needs to be well designed, taking account of the characteristics of human operation (e.g. a metal rod driven by a rigid ram does not adequately simulate the resilience of a hand pushing controls): if this is well done, a rig can adequately simulate normal usage and ensure that all brands are treated comparatively. It must also be remembered, however, that real usage of some products will be brand dependent (e.g. some cars will be driven 'harder' than others due to the psychological response of the driver to their combination of performance, ride, visibility etc.): in such cases the characteristics of the rig should be varied to match the expected human operation, while retaining the indefatigability, precision, reproducibility and comparativity of a rig.

Another frequent reason for using simulation is the variability in environmental and load characteristics of real usage; controlled environments and standard loads can be devised provided they can be shown to be representative of actual conditions (e.g. controlled climate chambers) or to give test results which are representative of real usage (a situation most thoroughly worked out for American/European domestic appliances).

The need to accelerate usage in order to examine wear, breakdowns and durability frequently leads to the use of continuous/programmed automated rigs. In some cases products can be operated in this way for 168 hours per week, but before doing such accelerated intensive testing it is important to consider whether rest periods between usage cycles in normal situations are actually important in contributing to longevity (e.g. when the rest period allows the product to 'cool off' as, for example, in an electric drill intended only for occasional, amateur usage) or to deterioration (where the rest period permits wear and degradation to set in as, for example, the corrosion which seems to occur in many machines while they are idle and static); in either of these cases, a too intensive durability test will produce unrepresentative results, and a 168 hour per week test may only answer the question 'What happens to the product (and its parts) in intensive use?

5. EVALUATION OF RESULTS

There are many short cuts to processing the data from appropriate tests to arrive at evaluated conclusions. But there is no substitute for the initial thinking about the product in its situation of usage, about the needs and values and (dis)satisfactions of the users, about methods of evaluating the product.

Ideally comparative testing results should be subjected to multi-attribute utility analysis though usually there is insufficient data to do a full analysis; for this reason we normally use a Simple Multi-Attribute Ranking Technique (see Appendix III), which facilitates going from the data obtained by measurements and tests to a ranking order for the brands tested.

Any evaluation makes assumptions about the needs of users; for this reason the future evaluation method must be considered when deciding the content and methods of the project, although modification may well occur as results become available.

6. ACKNOWLEDGEMENTS

Although I put together this particular text, I acknowledge my indebtedness to the accumulated experience and knowledge of those engaged in comparative testing, throughout the World. I would like to mention particularly colleagues on the Testing Committee of the International Organisation of Consumers' Unions, including -

Anwar Fasal (Director of IOCU S.E. Asian Regional Office, Penang, and present President of IOCU)

Monte Florman (Technical Director, Consumers' Union, USA)

Oscar Grosch (until recently Head of Technical Department, Consumentenbond Netherlands)

Roland Huettenrauch (Director, Stiftung Warentest, West Germany and present Chairman of the Testing Committee)

Peter Sand (Head of Research, Consumers' Association, UK)

and

Armand de Wasch (Head of Technical Department, Verbruikersunie Belgium)

Nonetheless I also acknowledge that this paper reflects my own views, and neither it nor the previous one is a normal CA Testing Report (which would be based on verifiable evidence).

APPENDIX I

Definitions

Test Programme	: Combination of particular terms of reference applied to particular products for use in particular situations.
T/R = Terms of Reference/Protocol	: Document outlining the extent and limitations of the testing.
Methodology	: Theory relating the ways of obtaining data to their significance.
Methods	: Description of how each attribute will be examined and measured.
Procedures	: What the people examining the tests actually do, in detail.
Attribute	: A property/parameter belonging to the product which relates to its usage.
Evaluation	: The process of arriving at conclusions representing the value of products to the user (and also the conclusions themselves)
Ranking	: A list of the brands examined placed in order of in/de-creasing value of defined attribute(s).
Weighting	: The relative importance/value of an attribute (often quoted as a % of the value of the whole product).
Scoring	: A measure of the degree to which one brand meets the ideal specification for an attribute.
Brand/Model	: One particular design of the product (different models from the same manufacturer/distributor are normally treated as different brands).
Sample(s)	: An individual example of a brand/model.
Expert Opinion	: The unbiased views of an independent assessor possessing the necessary qualifications, skills an experience relating to the products/attributes.
Rig	: Semi-or-fully-automated test equipment/machinery which operates the product and/or measures/observe the performance.

APPENDIX I (Cont'd)

'User' or Panel Tests	:	Practical tests carried out under controlled circumstances on products by a group of users.
Survey	:	The collection of information from a sample of users (members, subscribers, or the general public) either by interview, discussion, or postal questionnaire (See IOCU Guide on Survey Work).
Test Programme	:	The overall plan for comparative testing including choice of brands, test proposals, and proposals for panel test and survey work.
Expert	:	Anyone with specialized knowledge of the subject being investigated.
Test Report	:	Report of results of laboratory findings.
Project Controller	:	Person with responsibility for managing, co-ordinating, and seeing through the work on an individual project to its conclusion, including reporting the results and drawing evaluated conclusions from them.
Shoppers	:	The people employed by the testing organization to buy samples for testing.

APPENDIX II

CONDITIONS FOR TESTING BY CA TESTING DEPARTMENT
(HARPENDEN RISE AND GOSFIELD LABORATORIES)

1. We are able to perform INVESTIGATION AND TESTING OF PRODUCTS for some organisations other than CA (with the exception of manufacturers and traders), and this document summarizes the way in which we normally work with such clients.

2. Before starting any tests it is necessary to discuss and agree TERMS OF REFERENCE, which are the detailed instructions from the Client to the Laboratory, on which the work will often be based. Terms of Reference are written by the Client, but we can propose Terms of Reference for discussion. An appreciable part of the Laboratories' work is testing to relevant national or international Standards (e.g. BS DIN IEC CEE ISO), to manufacturers' specifications or against claims.

3. The Laboratory can give preliminary estimates of the COST OF TESTING to any Terms of Reference, but such estimates are not to be understood as firm quotations unless they are issued on a TESTING AUTHORISATION FORM or QUOTATION FORM over the signature of a Section Manager, and the initials of the Head of Testing. Quotations will normally only be given against specified, and agreed, Terms of Reference, for a specified number of samples of each of the specified number of brands to be examined, and for agreed dates for delivery of samples at the Laboratory and completion of the Laboratory Report. Obviously changes in any of these conditions may alter the actual cost of performing the work.

4. A QUOTATION issued and later accepted by a representative of the employing organisation (e.g. by signing Section 4 of the TAF) will be regarded as an official commissioning for the work to be performed and, unless there is any exceptional circumstance, this commission will be accepted when the Head of Testing signs Section 5 of the TAF, and acknowledged by return of a copy of the TAF to the client. There is then a CONTRACT between the employing organisation and the Testing Department. Payment for the work will normally be expected within one month of presentation of an Invoice (after delivery of the Laboratory Report, or other agreed termination of the Contract).

5. GOODS FOR TEST will normally be purchased by the Client and delivered to the Laboratory at the Client's expense, although we may be able to give advice and sometimes assistance in arranging transportation. Any spares, accessories or replacements which are necessary to fulfil the tests according to the agreed Terms of Reference, or because of faults in the samples as supplied, will also be supplied by the Clients and delivered to the Laboratory.

Appendix II (Cont'd)

All goods for test remain the property of the Client and we will ensure that all goods are returned to the Client after testing (unless otherwise instructed by him); (cif will normally be charged to the Client). The condition of tested goods will be notified to the Client as soon as possible after completion of testing, noting whether they are :

As new, Good (minor blemishes only), Repairable, Unsafe or Scrap.

Goods originating from outside the UK must be consigned to Consumers' Association, 14 Buckingham Street, London WC2N 6DS, and all transportation documents (delivery notes, bills of lading, customs declarations) and all packaging of the goods themselves must bear the legend 'Imported under Consumers' Association General Bond No : SOLR 2368/73).

6. The Laboratory will preserve until three months after delivery of the Report all packaging, instructions, labels, guarantees and other material that may be needed to identify products or to show the way in which they are intended to be used or prepared for use.

The Laboratory will, so far as it can consistent with the testing programme, take good care of and not make use of goods which are in its possession for testing. While on Laboratory premises, Goods for Test are covered by the Laboratory's insurance against fire and theft. The Laboratory does not accept any liability for risks inherent in the nature of the testing or which cannot reasonably be foreseen.

The Laboratory will, unless otherwise requested, keep tested goods until three months after delivery of the Report on its premises in the condition they were in immediately after testing, together with all component parts of tested goods, as well as the remnants of any goods damaged or destroyed in the course of testing, and will preserve appropriate means of identification of particular products in relation to the tests and the published report.

Appendix II (Cont'd)

7. It is usual for DISCUSSION to occur between representatives of the Client and the testing staff of the Laboratory as appropriate during testing and after completion and delivery of the Laboratory Report. Any significantly unusual results or occurrences during test, or points of principle about test methods will normally be notified to the Client as soon as possible, especially if criticism of product safety or performance is likely to ensue or if there is a likelihood that the Terms of Reference for testing might be changed in consequence.

The Laboratory will also inform the Client if any goods submitted for test do not appear to be as specified in the Terms of Reference or if there are any obvious similarities between different brands, or dissimilarities between samples of the same brand. The Client will be notified if any tests specified in the Terms of Reference appear to conflict with manufacturers' recommendations or instructions for use, or with relevant national or international standards.

Wherever possible the Laboratory prefers to use the Telex for such communications in order to combine speed with the availability of a written record.

(The Laboratory can accept letters or telex communications in French, German or Dutch as well as English. Other languages will require time for translation).

8. The Laboratory will carry out the tests described in the agreed Terms of Reference mentioned on the TAF and the results will be delivered to the Client in a CONFIDENTIAL LABORATORY REPORT (written in English), the copyright of which will remain with CA.

The Laboratory Report will contain estimates of the accuracy of all measurements and, where appropriate, statistical analysis of the results (e.g. in User Tests). Any major criticisms of products which during testing were notified to the Client will be marked in the Laboratory Report as 'Purple Alerts'; in such a case the appropriate original observations or measurements made by a Tester will have been checked by the Section Manager, the Quality Assurance Officer and, in the most serious cases, by the Head of Testing.

Appendix II (Cont'd)

9. ALL ORIGINAL OBSERVATIONS, MEASUREMENTS and RECORDS of communications between the Laboratory and the Client during testing will be retained in Laboratory Project Files for at least twelve months in order to provide original documentary evidence if required by the Client; this file will be treated as Confidential to the Laboratory and the Client. All original observations and measurements are recorded in Laboratory notebooks and are initialled and dated as the records are made. Measuring instruments are calibrated regularly against appropriate standards and full records of such calibrations are maintained.

The Laboratory Report is prepared from a draft which is examined and corrected by independent Checkers wholly employed by the Laboratory, whose comments are also retained in the Project File.

10. We will keep CONFIDENTIAL all matters relating to testing and reporting. This covers every aspect of the relationship between the parties, and nothing will be published or divulged to anyone (including, obviously the press and broadcasting authorities) without the Client's specific consent each time. This confidentiality will be kept both before and <u>after</u> publication of <u>any</u> report by the Client (where applicable).

Examples of things which we will keep confidential are -

(a) The fact of having been commissioned to do the work.

(b) The products tested.

(c) The methods of testing.

(d) The results of the testing, or of any other observations, of the goods for test.

(e) The contents of the test reports.

(f) The contents of any draft report for publication (where applicable).

(g) The nature of and reasons for revisions in the draft report.

These standard Conditions of Contract require the Client to maintain the same degree of Confidentiality. Either the Client or the Laboratory may break this confidentiality only by express agreement of the other, or if compelled to do so under, or by virtue of, an order or rule of court of law.

Appendix II (Cont'd)

11. When the TESTING is commissioned by the Client IN ORDER TO PUBLISH a report on the goods, either to the general public or to subscribing members of the employing organisation, the Laboratory can often help if a copy of the draft publication report is sent to the Laboratory as soon as possible for comments. In this case the Laboratory will comment on the factual statements, and interpretation; if the Client wishes the Laboratory to check any factual statements in the draft publication report, the words 'Please Verify' should be written on the draft clearly against the parts which are to be checked. The Laboratory will then indicate agreement disagreement on the draft and return it to the Client initialled and dated. If the Laboratory thinks that statements or interpretations in the publication report are accurate or reasonable but cannot take responsibility for them it will write 'Not Checked', '?', or some similar indication. Anything in the draft report left without comment is to be regarded as not checked specifically.

12. The Laboratory may be able to supply 'expert witnesses' and would normally expect to be able to verify the statements in the Laboratory Report. However the results of investigations and tests may not be used for the purposes of any civil dispute or criminal prosecution without the prior written agreement of the Head of Testing. If the Client requires the tests to be carried out in connection with any dispute (existing or contemplated) the details must be disclosed to the Laboratory before the Contract is signed. If Laboratory staff are required to prepare, or present, evidence in connection with any dispute or legal proceedings, whether instigated by the Client or anyone else, the Client will be charged for the costs of additional time and expenses involved over and above the original Contract for test work.

13. If any DISCOVERIES are made by Laboratory staff during an investigation or test we reserve the right, after consulting the Client, to secure ownership of the discoveries by patent, registered design or copyright in any countries. In this case the Client will be entitled to a free, non-transferable UK licence with limited period of exclusivity, and other licences on terms to be agreed.

14. The Laboratory is not obliged to allow Clients to witness the tests, or any experiments related to them, and reserves the right to exclude VISITORS, although this right will not be unreasonably used. If representatives of the Client do visit the Laboratory they will be restricted to the areas and staff concerned with work being done for them, in the interests of preserving the confidentiality of other work.

APPENDIX III

"SMART"

EVALUATED CONCLUSIONS FROM COMPARATIVE TESTS

(Multi-attribute utility analysis)

1. Comparative testing, whether it takes place in a laboratory, in users' homes or 'in the field' aims to assess products in relation to the needs of their users/prospective users.

2. In order to make the results of the tests meaningful and useful to the reader of the reports it is very necessary

   (a) to make the process of arriving at conclusions clear, objective, and reproducible.

   (b) to present the conclusions to the reader so that he can see how the conclusions follow from the objective data plus our assumptions about users' needs. Then, if he wants to change his own understanding of these needs it is not necessary for him to wade through all the mass of detailed evidence - he will be able to 'dial in' a new set of needs and obtain new conclusions.

3. Obviously we need to do two things :

   (i) think about our assumptions of the user's needs, expose them so that they are useful to the reader.

   (ii) develop and use consistently an objective 'calculator' for deriving evaluations of products.

   These need to be done at Terms of Reference stage, so that we can see that project resources are being put into obtaining data which is judged to be useful to readers.

4. We cannot draw any conclusions at all from our work without making some assumptions about the needs of a user; this follows from the aims of our work which are to evaluate and compare products in relation to their real usage and abusage. Obviously we should try to find out what real users actually want and expect from a product and how they will use and abuse it. Sometimes there is survey information, sometimes we depend on our client/project officer, (rarely) there is a specification for use, sometimes we are relying on our own experience as users (and perhaps our own prejudices and peculiar needs).

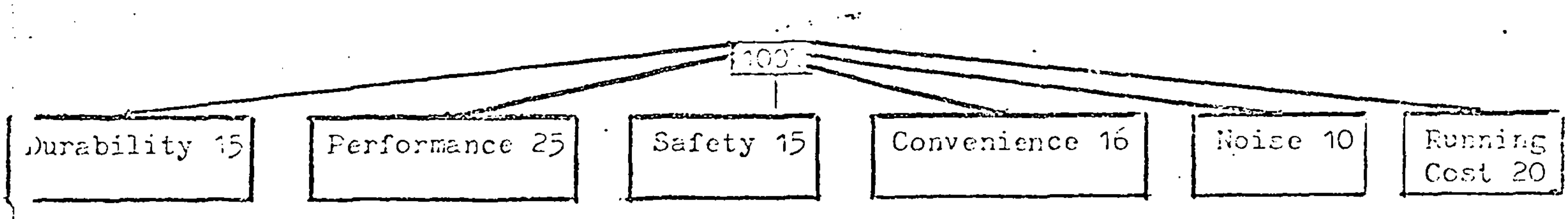
5. For a long time some consumer organisations (notably VU CB SW) have used an evaluation system which is relatively objective. While it is not totally beyond criticism, it has many advantages and is, in any case, one of the methods tried and proved by many non-domestic purchasing organisations on both sides of the Atlantic - the Americans refer to the problem of evaluating products for purchase as multi attribute utility analysis. This particular method is a simplified version called SMART (Simple Multi-Attribute Ranking Technique).

6. Starting with the whole product evaluation as 100, divide this into the main attributes which will be tested and assign weightings to each.

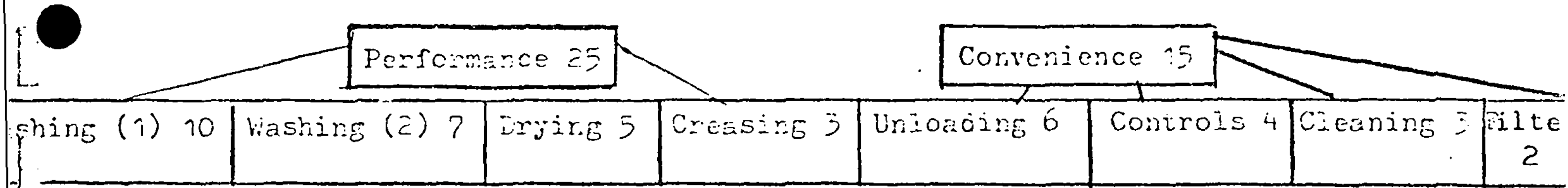
(It is helpful here to remember that attributes of most products can often be divided into <u>size</u>, and <u>shape</u>, <u>features</u>, <u>performance</u> in normal use, <u>negative aspects of performance</u> (cost, noise, vibration, environmental damage etc)., <u>safety</u> <u>normal abuse</u>, <u>ergonomics</u>, <u>durability</u>, and <u>maintenance.</u>

Obviously normal usage/abusage/users do cover a wide range of situations : in many cases it will not be sensible to decide on one "average" evaluation, and perhaps several different evaluation "trees" should be used to draw conclusions, for different segments of the user/usage population.

e.g. for Washing Machines



and subdivide these where necessary and appropriate e.g.



Further subdivision follows where necessary and possible, and the complete tree should be drawn (see over).

		Corrosion	5			
		Materials	3			
		Pump	2	Durability	15	
		Programmer	1			
Flexibility	2	Door seal	4			
Strength	1					
Degradation by solvents	1					
Result	8	Washing (1)	10			
Programme	2					
Result	5	Washing (4)	7	Performance	25	Total 100
Programme	2	Drying	5			
		Creasing	3			
		Electrical	10	Safety	15	
		Door lock	5			
		(Un)loading	6			
		Controls	4			
		Cleaning	3	Convenience	15	
		Filter	2			
				Noise	10	
Prog. (1)-6		Electricity	10	Running cost	20	
Prog. (4) 4						
		Detergent	7			
		Water	3			

(This is an artificial example which leaves out some attributes and the weightings are not right; it illustrates the principles however).

Method and scoring of results are inextricable.

7 - Deriving the conclusions from the results is then relatively straightforward.
Starting from the left hand side (or more detailed branch of the tree) one takes the test results and assigns a score on a ten point scale to each product.

(a) for some tests which are inherently scores (e.g. user tests, convenience assessments, instructions etc) it is obviously simple : if the original assessments by the tester/user are only on a five point scale (and should be) then just multiply by two to get a 2, 4, 6, 8, 10 scale.

(b) for other tests which produce an apparently continuous scale of measurements (e.g. 0-100 washing index, size, electricity consumption) it is necessary to think about a reasonable range over which a 10-point rating scale could sensibly be applied : also the widths of the 10 sectors of the rating scale do not have to be the same e.g.

0 10 20 30 40 50 60 70 80 90 100 working index

probable range of results

0 1 2 3 4 5 6 7 8 9 10 possible scoring (but value to the user and the needs of the user must be considered)

(c) there are some attributes which are measured on a continuous scale which actually is proportional (or inversely proportional) to value to the user (e.g. fuel consumption).

8 - There are some attributes which can rule out a product totally from further consideration (e.g. lack of adequate safety, or even very poor performance in some respects). In order that this real situation can be modelled correctly in the evaluation, the appropriate values of these attributes which would rule the product out of consideration can be given a score of -1000: the final score of the entire product will then be negative. For example, a scoring system for safety of :

Hazardous	=	-1000
Potentially hazardous	=	-1000
Unsatisfactory	=	0
Satisfactory with minor criticisms	=	6
Satisfactory within limits of tests	=	10

would delete all products found to be actually, or potentially, hazardous and highlight those which are unsatisfactory (perhaps for further examination).

9 - For each brand have a photocopy of the tree (section 6) with the weightings omitted. Starting from the branch ends enter on each 'twig' the score on the 10-point scale (section 7) multiplied by the weighting of the master tree (section 6). This is the brand's score on that particular attribute. Work up the branches, adding all the numbers from the previous sub-branches, to arrive at a total score out of 1000 (100 x maximum of 10 on 10-point scale).

10- It is now possible to draw up a ranking table for all the brands. Divide their final scores by 100 to get rankings on 10-point scale Obviously further condensation to a 5-point scale is possible, but not recommended for laboratory reports.

Including all the individual brand score sheets (section 9), the master weighting tree (section 6) and the bases on which measurements were converted to a 10-point sacle (section 7) as Appendices to the Report, will enable any reader who wants to use different weightings, or different scaling of particular measurements to do so quickly without having to read laboriously through every page of the Report each time.

11- The key task is to prepare the master weighting tree (section 6). This is where all available information (from surveys, client, consultants, previous experience, other publications) has to be incorporated and a judgement has to be made. Substantial discussion will be neccessary and is desirable (at least with the Client).

12- There is a difficulty about attributes which are judged to be important to the user (probably with good reason and evidence for the judgement) but for which there are no data available (either because the necessary tests have not been done or cannot be done within the limits of time and resources available). In these cases it is not satisfactory to omit these attributes from the weighting tree because that gives a falsely reassuring picture of the completeness of the information. These 'difficult to assess' attributes should be included in the weighting tree even though all scores for these brands will be zero, for all brands. At least all brands will be treated comparatively, though they will only be assessed against a maximum possible score of 10 - (0.1 x weighting of unmeasured attributes). For example, if the durability of dishwashers will is judged to be 30% of the value to the user, and we do not test durability (as is the case up to 1977) then dishwashers will only be scored against a maximum score of 7.

13- Finally it is worth stressing that, whether it is spelled out or not, the ways in which results will be appraised is inherent in the Terms of Reference and methods being used in the project - better, then, to be explicit so that Report readers may more easily see clearly what has been done.

Background Information Section

who international reference centre for community water supply

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WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

C. Background Information Section

B.P. 1	Shallow Handpump Design : Summary
B.P. 2	Bangladesh Rural Water Supply Programme
B.P. 3	Evaluation of Simple and Inexpensive Pump for Community Water Supply Systems : South East Asia
B.P. 4	Field Testing of Hand-operated Water Pumps : Costa Rica; Nicaragua
B.P. 5	Evaluation of Deep-well ("Dempster") Handpump - Indonesia
B.P. 6	Handpump Evaluation and Testing : Thailand
B.P. 7	Development India Mark II Pump : India
B.P. 8	The Bangalore Pump : India
B.P. 9	Shallow Well Pump Improvement Research Project on Stage I of Project : Malawi
B.P. 10	Report Format for Field Testing of Handpumps
B.P. 11	Reciprocating Pumps Test Code
B.P. 12	Comparative Testing of Consumer Products ISO Guide 12
B.P. 13	Format "Work-bench Inspection"
B.P. 14	Directory of Handpump Manufacturers
B.P. 15	Hand Pumps for Drinking Water Wells
B.P. 16	Rate of Wear of PVC Pumps Cylinders.

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B.P. 1

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SHALLOW HANDPUMP DESIGN: SUMMARY

Shallow Handpump Design : Summary

General Considerations

1. Pump cost should be related to the cost of the well, and the extent to which people depend on it for their welfare.

2. Designing a handpump tubewell is like designing a more sophisticated water system. Many of the same factors should be considered:- mapping the served population, (optimum site selection, drainage considerations) ground water resources (quality and quantity), alternative sources, total population per pump, water useage patterns, gallons per capita per day, peak demands, financial status of users/ local institutions/executing authority.

3. The output of a pump can not be considered independently of the design and construction of the well. The latter depends on ground water conditions (static water level, permeability of aquifer, variation of static water level); type, diameter, slot size, open area of well screen; and type and degree of development of the aquifer.

Getting Started

4. At the outset of a new handpump tubewell programme, improving the traditional pump design or introducing a new one may have high priority if shallow well pumps are usually out of order an unacceptably high % of time, (say 30%) or deep well pumps more than 10% of the time. (The latter because people normally depend more on a deep well pump). A relatively small amount of time and money spent at the beginning of a HPTW programme to introduce or develop an improved pump should reap manifold benefits in the long run. It might even be worth consideration delaying the construction of large numbers of new wells until at least an interim design is available. ("Why is it we always have enough time (money) to do it over again, but never enough to do it right the first time?").

5. It is normally preferable to separate the construction programme from the research programme, at least to the extent that a large programme is not held up waiting for a new design. Better to introduce a modestly improved traditional design, and then introduce improved models as they become available.

6. It is usually expedient to start a programme with a single design to serve a variety of uses. As time goes on, specialized designs can be developed for specific uses.

Design Objectives

7. The primary design objective is reliability. Most traditional designs provide sufficient quantities of water-when they work. Handpump programmes most often fail because pumps are out of order too often and too long.

8. Normally, to be reliable a pump design should be simple, i.e. few bearing surfaces, few numbers of parts, few kinds of parts, locally replaceable spares.

9. If the handpump programme is rather large, and there is wide use of private handpumps and sufficient capacity for local production, it may also be desirable to develop or introduce a design which is locally reproduceable - both technically and economically. For a large public handpump programme, local reproduceability may be a major objective in order to ensure ready supply of spare parts.

10. From the economic point of view, cost should be appropriate to the investment in the well. Avoid exotic materials or sophisticated technology, unless major gains in reliability are resulted.

11. Acceptability is important. The people who use, produce, purchase, install, maintain and repair the pump should all be considered.

How to Proceed

12. In pump design work, start small. Begin with existing models. Attempt modest improvements (larger bearing surfaces; smooth, large dia. pivot pins) etc. Experience will show what is best. Do not make major commitments to unproven or inadequate designs.

13. Unsatisfactory traditional shallow well pumps can often be made quite satisfactory by simple, common sense design improvements. (For deep set well pumps, however, especially for deep water tables of say 20 meters or more, innovative departures from traditional designs may be necessary to produce a reliable, economical pump).

14. Improvements can be graded as I - Urgent, Immediate; II - as soon as practical; III - for further consideration.

I. Increased bearing surfaces, bigger, smoother pivots, stronger structural design.

II. Simpler design, fewer parts, standard size of fasteners, reduced weight, less expensive material.

III. More efficient, reliable valve systems, hardened bearing surfaces, bushing or roller bearings, lubrication points, preventing pin rotation.

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15. Continuous observation of new or improved designs in actual field situations (both extraordinary and normal intensity) plus continuous observation of production processes will reveal design weaknesses needing further modification. Convergence towards a satisfactory design solution is a process of trial and success/error.

16. Only intensive field testing of a new design can reveal its real weaknesses. Mechanical tests conducted in laboratories often do not faithfully reproduce wear patterns produced by field use.

17. Local production problems often cannot be anticipated in the design office. They may become apparent only after large scale production is attempted.

Outline of Procedures

(1) Define project goals, purpose, objectives, outputs, inputs

(2) Develop pump design criteria

(3) Estimate basic pump dimensions, capacity

(4) Choose most appropriate materials and production process to achieve functional goals

(5) Sketch designs

(6) Prototype samples

(7) Field test

a) Normal use
b) Intensive use

(8) Evaluate wear patterns, performance, produceability

(9) Redesign

(10) Repeat 6-10 until design converges on acceptable solution

(11) Working drawings

(12) Tolerances

(13) Specifications

(14) Mass production

(15) Project implementation

(16) Refinement of design

General Observations

18. Handpump design, or redesign, is deceptively simple. One should proceed slowly, carefully. Systematically investigate effects of proposed changes on production and performance.

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19. Handpump design is not really that difficult. After all, the technology is relatively simple. The primary requirement is interest, followed by perseverance, patience and a willingness to work closely with local producers and people who use and maintain the pumps.

20. Pump designs can be continuously improved. "Can we do it better? Can we do it cheaper?" Should be asked continuously.

21. Adapt the technology to the people rather than vice versa.

22. Acceptability is important. The pump should be acceptable first of all to the users, also to producers, purchasers, installing agency and maintenance personnel.

Production of New Design

23. Traditional designs tend to be institutionalized. Great energy is often needed to catalyze a design improvement programme. The prospect of large sales of the improved design may be the only force capable of starting the process.

24. Choice of pump construction - (i.e. cast iron, fabricated from standard fittings at a central workshop, or fabricated of local materials at site) will depend on available technology, materials, and skills. Local acceptability is very important.

25. Tolerances should be neither too strict nor too lenient. Impractically strict tolerances may lead to high rates of rejection, low rates of production, high costs. On the other hand, tolerances must be strict enough to assure a relatively uniform standard of good quality, and interchangeability of spares and components produced at different times and places.

26. Drawings should be produced eventually, especially if mass production by more than one supplier is intended. But it may be possible to do most of the R & D work with prototypes and sketches. The use of drawings also depends on the sophistication of the design and the general use and comprehension of drawings in factories and workshops.

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B.P. 2

WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

BANGLADESH RURAL WATER SUPPLY PROGRAMME

UNICEF RURAL WATER SUPPLY WORKSHOP

Bangladesh Rural Water Supply Programme

An Outline of Choices Associated with Handpump Tubewell Programmes and Handpump Design

R. Phillips

UNICEF, Dacca

DACCA,
BANGLADESH

MAY 1976

OUTLINE

1. Health versus other sectors of development
2. Water versus other elements of health sector
3. Implementing agency choices
4. Funding sources
5. Personnel required : HPTW programmes
6. Sources of specialized personnel
7. Single wells versus piped systems
8. Handpump tubewells versus other wells
9. How to begin
10. Shallow, deep, or multi-purpose handpump
11. Output of pump desired
12. How much to spend?
13. Imported versus local pump
14. If local made pumps - then what?
15. Imported pumps
16. Handpump research and development work : who should do it?
17. Details of pump design
18. Considerations in site selection
19. Installation
20. Maintenance options
21. Continued development
22. Pump production

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N O T E

This outline may be helpful to UNICEF Programme Officers becoming involved with handpump tubewell programmes for the first time. Perhaps this type of outline could be amplified by others as time permits to include more details, and perhaps cover more topics.

Bangladesh Rural Water Supply Programme

Choices Associated with Handpump Programmes and Design

1. Health versus other sectors of development

   (a) Health and disease as a constraint on economic development.

   (b) Public demand for better health.

2. Water versus other elements of health sector

   (a) Disease patterns affecting children.

   (b) Proportion of water related diseases as percent of total.

   (c) Water resources available to supply safe, potable water.

   (d) Institutional arrangements to instal and maintain public water systems.

   (e) Public demand for and utilization of improved water systems.

   (f) Resources available - material, financial, manpower.

3. Implementing agency choices

   (a) National water authority

   (b) Provincial water authorities

   (c) Local water boards

   (d) Rural development departments

   (e) Cooperatives

   (f) Private sector

   (g) Public works departments

   (h) Health ministries

   (i) Others

4. Funding sources

   (a) UNICEF regular resources

   (b) UNICEF special assistance projects

   (c) Bilateral donars

   (d) Multilateral agencies

   (e) NGO's

   (f) United Nations or UNICEF special emergency appeals

   (g) Self-help, reimbursed payment schemes

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5. Personnel required : HPTW programmes

(a) Ground water engineers

(b) Tubewell technicians

(c) Managers

(d) Logistics: coordinators; procurement; follow up on end use - storage, books.

(e) Pump technicians - depending on type of pump

(f) Mechanical engineer, Metalurgical engineer for pump design, production.

(g) Communications, sociological, educators

6. Sources of specialized personnel

(a) UNICEF; country office, regional office, other country offices, NYHQ

(b) UN agencies; UNDP, WHO, FAO, ILO, etc.

(c) International Consultants: ground water, water resources planning, management

(d) Local consultants: technical, management, etc.

(e) Technical faculties of Engineering Universities and Technical Institutions.

(f) Government agencies, departments, resource centres, technical assistance centres, research organizations.

(g) Voluntary agencies; within the country, in developed countries but interested in development.

(h) Specialized personnel and consultants of bilateral donors and multi-lateral funding institutions.

(i) Foundations

(j) Retired personnel - especially logistics, retired from armed forces but anxious to work.

(k) Through advertisement

(l) Private industry: advice on a wide variety of technical matters related to supplies.

7. Single wells versus piped systems

(a) Demographic-sociological factors - how people are arranged in settlements. If highly compressed into concentrated settlements, then piped schemes feasible. If dispersed in hamlets, then single well systems preferable.

(b) State of technology - ability to maintain, operate and finance mechanized piped systems versus single well systems.

..... 3/

(c) Financial and other considerations:

1. Piped systems require relatively higher per capita capital investments, recovered over a long time, if ever.

2. Piped systems often take several years to instal.

3. Financial management/maintenance problems often mean low utilization of piped scheme investments.

4. Single well systems require smaller capital investment, short installation time, relatively easier to maintain and operate.

5. Access to piped water systems often restricted to those able to afford house connections.

6. Piped schemes often become disease distribution systems if contaminated by cross-connections.

7. Piped water system service is often intermittent.

(d) Hydrogeological factors:

1. Single well systems depend on availability of ground-water:

   a. depth
   b. quality
   c. aquifer yield

2. Where safe surface water is abundantly available under gravity pressure, piped systems may be the most practical solution.

8. <u>Handpump tubewells versus other wells</u>

(a) Handpump systems are relatively sanitary. Open wells are rather easily contaminated, either by the air, or water lifting device - bucket, rope, etc.

(b) Handpumps require more maintenance than some simpler, indigenous systems.

(c) In alluvial formations, HPTWs are easy to install, but require casing and filter.

(d) In rock, holes are harder to drill, but filter and casing may not be required.

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(e) Handpumps must usually be centrally manufactured, whereas some other systems can be made in the village.

9. How to begin

Whether you are choosing an imported pump, designing a new pump or redesigning an old one, there is only one way to start: start small. Experience by trial and error will then be the most reliable guide for further choices. Believe it or not the handpump choice problem is now very complicated - due to a veritable maze of options of designs, models, materials and assembly processes. To order large quantities of untried designs could lead to disaster.

An equal danger is to do nothing at all. One is apt to bog down in a quagmire of choices. It is necessary to make a start. Not all the factors can be known in advance. By proceeding slowly and cautiously, new factors can be dealt with as they arise. The main point is to avoid over commitment to one design, the performance and production problems of which are not fully known.

Perhaps the starting point should be the observation of available models already in use. Then choose an option which seems appropriate, order a few, field test it, produce a few, redesign, retest, etc., etc., etc., enough times until decision making becomes more refined. The design should gradually begin to converge around an appropriate solution.

10. Shallow, deep, or multi-purpose handpump

(a) Depends on depth of water table, and uniformity of ground water conditions.

(b) Where water level is normally 25' or less, shallow well may be used exclusively.

(c) Where water level is normally more than 30', deep well must be used.

(d) Where water table varies considerably - say between 10-40 feet within small geographical area, a flexible design, multi-depth setting pump may be used.

(e) Where water tables are likely to steadily drop, a design which can later be converted from shallow to deep may be worthwhile.

11. Output of pump desired

Designing a handpump tubewell is like designing a water system, because it is a water system - having inlet, rising main, pump, reservoir (the upper part of pump body) and distribution outlet (spout). Therefore, it is not too surprising that handpump design procedures should take into account criteria also considered in the design of piped water systems, such as mapping of the served area, ground water resources, local usage patterns, calculation of average demands and peak flows, financial status of the executing authority and the users, etc. These are outlined further below.

All these factors taken together will give an indication of the performance desired by the pump. Performance desired is determined by two factors:

(a) Water per person per day needed to satisfy optimum, minimum, or practical median water requirements.

(b) Persons per pump.

These two figures can be more clearly determined by consideration of the following:-

(a) <u>Intended water use</u>

1. Drinking water only
2. Drinking, cooking, washing utensils
3. Full domestic use
4. Micro-irrigation
5. Domestic use plus small garden
6. Or other combinations

(b) <u>Intensity of use</u>

1. Availability of other wells and/or other water sources.
2. Is well to serve 10, 50, 100, 1000 or more people?

   Type of site:-

   a) Single family unit
   b) Extended family, hamlet or small village
   c) Large village
   d) Urban fringe area
   e) Market place, bus station, boat landing, or other high density public site.
   f) School, health center or other institution

3. <u>Queue factor</u>: Will people draw water intermittently throughout the day, or will there be peak demands at sunrise, noon, sunset or other periods? If the queue factor is significant, as it is in most traditional societies, then the real test of how well the pump satisfies the performance criteria may well depend upon how well it can meet these periods of peak demands.

(c) Cultural factors

1. Will the pump be used by men, women and children alike?

2. Or will one sub-group predominate in well use? This determines the mechanical leverage desired, and volume of water which can be lifted per stroke.

3. How far are people willing to walk to draw water? Sometimes people will walk a great distance to fetch their minimal drinking water requirements, but will tend to use more convenient surface or other traditional water sources (if they exist) for other needs such as bathing.

4. Health awareness. The degree to which people will expend energy to obtain water from protected sources may depend upon their awareness of the cause-effect relationship between water and health/disease. In the overall equation, this factor is a variable, which may be increased by educational efforts.

(d) Depth of water table and water quality may determine the practical output of a pump, which may be much less than the total desired. That is, the performance of the pump cannot be considered independently of the design and construction of the well. A number of economic considerations influence this choice also. For any given set of ground water conditions, there is a maximum theoretical yield, but the optimum economical yield may be considerably lower. In well design in relation to HPTW programmes, three general levels of output should be defined:

1. Maximum possible
2. Minimum desirable
3. Maximum practical

The practical output would normally fall somewhere between the minimum desired and the maximum possible. Generally it is desired to provide as much water, as conveniently as possible, within economic constraints.

Within these social and economic considerations, the well design is normally determined by the following hydro-geological factors:

1. Depth to water table,
2. Aquifer yield,
3. Degree of development of well, if in unconsolidated formations,
4. Water quality may also be a factor in water use.

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The design considerations are as follows:

1. Diameter of filter
2. Diameter of rising pipe

   Technical considerations aside, these two choices are largely economic.

3. Filter slot size
4. Gravel packed, shrouded well or naturally developed.

   These are largely technical decisions, requiring the expertise of a ground water engineer. They will, however, have a direct bearing on the output performance of the pump.

5. Type, design and configuration of the filter. This is a rather complex interaction of technical and economic considerations. Generally, there are various trade-offs to be considered - largely economic - such as first cost versus yield and/or length of service. Water quality factors, such as encrustation by carbonates, bacterial slimes, or corrosion, acidity, etc. may be overriding considerations.

6. Most suitable aquifer. This is a complicated technical-economical decision. There may be a series of aquifers at different depths having various yields and water quality. It is normally desired to use the shallowest aquifer which will adequately satisfy the needs of the programme. Yield and water quality considerations may lead one to utilize a deeper layer.

   However, this is a self limiting process, economic considerations becoming overriding at a certain stated depth. At some point it may be necessary to choose a water quality or yield which is less than desirable, but is the best yield or quality practical within economic limitations.

   At this point, adaptability and taste preferences of the local people become critical. Most people are ready to make do with less if that is all which is available. They may also be willing to drink water of less than ideal taste.

(e) The static water level is an important factor in pump and well design. But equally, if not more important, are

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the annual fluctuations of the water table and/or special variations, i.e. the water table depth may vary considerably from place to place within a relatively small geographical area. Implications of these factors on pump design have been mentioned above (10).

12. How much to spend?

How much should be spent on the pump?

The amount should be related to how much has been invested in constructing the well. In Bangladesh, the materials used in constructing a $1\frac{1}{2}$" diameter tubewell 150 deep cost about \$60 - \$70. These wells are easily constructed, and are being installed by the tens of thousands in every village and for every two or three hundred people. The pump is presently costing about \$20 (after the recent devaluation of the Taka). This seems in line with the overall cost.

In other countries, water levels may be several hundred feet deep through solid rock requiring a major capital investment and the use of sophisticated drilling rigs to construct the well. In such cases the well may serve several hundred to a thousand people or more, some of whom may come miles to draw drinking water on which their life depends.

In Bangladesh there are usually many alternative sources of surface water or shallow ground water if the pump fails. But in many places, the UNICEF well may be the only source of water supply. Such wells will be severely stressed by intensive use.

Normally such wells would be constructed in relatively fewer numbers and it is imperative that a very high percentage of them be in good working order at all times. In such circumstances, a considerably higher investment is justified in the pump. The desirability of improving the design as much as possible would be equally great.

Possibly as a general rule of thumb for such deep well situations the amount spent on the pump should not become a major financial constraint significantly reducing the total number of wells. But on the other hand, the amount spent should be sufficient so that the pump is not out of order more than 10% of the time. If there is no existing design which fits within this criteria, then high priority may be given to developing an appropriate design, before mounting a major programme to construct new wells, which will then may be left without a satisfactory pump.

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13. Imported versus local pump

a) Ultimate goal of UNICEF assistance?

If the goal is to develop a self-sustaining water programme, local production of pumps may be a high priority.

b) Availability of local pumps : Industrial Base. Some countries have almost no industrial base whatsoever. In such cases, it may not be practical to hope for a locally produced pump. In such case, decision-making is limited to selecting the most appropriate import model.

On the other hand, even in countries with very little industry, it may be possible to develop a water pumping device fabricated out of locally available materials. In such cases, emphasis should be given to developing village level appropriate technology.

c) Foreign exchange position of the country.

d) Volume of demand : For a small number of pumps, it may not be worthwhile setting up local production.

e) Raw materials : Unavailability of raw materials should not necessarily prevent local development of a handpump industry, provided the necessary materials can and will be imported. Japan for example has very few raw materials. Interest, initiative and management are more essential.

14. If local made pumps - then what?

a) Use traditional design? Introduce brand new design? Or modify traditional design? A new or improved design may be needed if:

(1) Existing pumps are out of order more than 30% of the time (shallow wells), or more than 10% of the time (deep wells).

(2) There is no design available which can give 90% trouble-free operation within the price range appropriate for the investment made in constructing the well.

Depending on programme priorities, it may be necessary to begin with local varieties of pumps. Improvements can then be introduced gradually. If at all possible, design development should be separated from programme implementation, so that programmes do not become dependent on unproven designs still in the development stage. On the other hand, traditional pumps originally designed for single family use should either be replaced or reinforced as soon as possible, to prevent the institutionalization of an underdesigned pump.

Experience has shown that successful pump design is more often achieved by starting with an indigenous design and then improving it, rather than by trying to introduce a totally new design. In order to be successful, a design should be capable if being produced locally, and operatedd and maintained by the beneficiaries. Local acceptance, both by the user and the producer seems to play a key role in good design development.

Similarly, if redesign of an existing pumps is the order of the day, then improvements can be classified according to urgency: I - urgent-immediate; II - as soon as practical; III - for further consideration.

"Urgent-immediate" changes are usually also simple by nature - design aspects which can greatly improve the service life of the pump, but requiring little major changes. Using larger diameter pivots is an example. Enlarging castings for greater bearing surface or to reduce breakage is an example of category II. Redesigned valve systems may be category III.

Establishing such design priorities helps to bring greatest returns on time invested, while at the same time allowing major programmes to get off the ground. Further design work can proceed parallel to programme execution, rather than hold it up. Improved designs can be substituted as they become available.

b) Design objectives

The overall design objective is SIMPLICITY - the simplest, most economical design which will satisfy the functional requirements of the programme.

In general nearly all aspects of pump design fall into four general objectives. These categories can form the basis for the analysis of almost any pump design. They are not necessarily listed in order of priority. In fact, it is difficult to consider anyone aspect completely independently of the others. There is a high degree of interaction among them.

(1) Performance

Does the pump provide water easily enough, adequate to the needs?

(2) Maintainability

Is the design sufficiently robust to provide relatively continuous operation, presuming a basic routine maintenance service?

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There is an economic trade off here between first cost and overall service life. In situations where government maintenance systems are weak, and/or the local capacity to maintain and repair pumps is marginal, the long term objectives of the project will probably be better served by increasing first cost, to provide a more robust design which will minimize the maintenance problem over the years.

The performance of a pump from the maintenance point of view may depend significantly on the habits of the people. For example, if they are in the habit of lubricating mechanical equipment, the pump parts may last considerably longer than places where no lubrication is given. Also a conscientious caretaker who really looks after the pump, detering vandalism, arranging maintenance, etc. will help to improve the service of the pump.

(3) Cost

Is the cost appropriate to the amount of money invested in the well and the degree to which people depend on it for their welfare?

(4) Produceability

Can the pump be produced locally, relatively fast, easily and economically?

Specifically, a pump should be designed as follows:

(1) Reduce maintenance breakdowns to manageable frequency, so that maintenance system can keep pump in nearly continuous operation. Spare parts should be few in number, simple, easily replaceable.

(2) Design should be simple, economical, locally reproducable.

(3) Ease of lifting water may be a key objective.

(4) Minimize expensive, or imported materials.

(5) Discharge appropriate for needs in relation to water resources available.

c) Specific design improvements (mainly for shallow wells)

(1) Increased bearing surfaces (wider, bigger diameter). One practical tip is that in village use, nearly all parts move. A drawing may specify some parts as fixed and others as moving, but usually they all begin to shake loose sooner or later. Therefore, all parts of the design should be reinforced as much as economically practical. Field observations of pumps under very heavy use will reveal the most critical stress points requiring maximum reinforcement.

(2) Smoother bearing surfaces (round pins, instead of threaded bolts).

(3) Harder bearing surfaces (heat treatment).

(4) Lubricated bearing surfaces.

(5) Reduced number of parts.

(6) Standardized size fasteners.

(7) Stronger structural design to resist breakage.

(8) Reduced weight where possible.

(9) Use of most appropriate materials.

The design improvements needed may depend greatly upon whether a shallow or deep well pump is being used. Experience has shown that a shallow well pump can be made quite satisfactory by reinforcing bearing surfaces and other basic, common sense improvements of traditional models. However, in deep set well pump installations especially where the water table is particularly deep (say 100 feet or more), simply strengthening the traditional models may not be sufficient to prevent excessive breakdowns caused by the severe stresses on bearing points. For these situations more innovative approaches may be necessary to find a solution. (UNICEF New Delhi has done just this).

Also design objectives may be different if designing for micro-irrigation. Each person may use a public pump as little as five minutes a day. The objective is to have a pump producing 5-10 gallons per minute and which will need parts replaced less than once a year. The situation for a hand operated irrigation pump is quite different. One or two people may operate a pump continuously for 8-12 hours a day.

Therefore greater outputs will be required. Ease of pumping and mechanical leverage will be critical. Replacement of parts will be less of a problem because the pump is owned and maintained by the farmer.

Beware: Beware of new ideas advocated by "experts", but which have not been thoroughly tested under actual field conditions. Field tests almost always result in rougher, more excessive wear patterns than laboratory tests. It has been learned that there is generally no easy instant solution for handpump problems.

d) Design procedures

(1) Design criteria

(2) Sketch designs

(3) Sample prototypes

(4) Production models

(5) Analysis of production techniques

(6) Field test

(a) accelerated testing in high density use areas.

(b) normal testing in typical village site.

(7) Analysis of wear patterns.

(8) Modified-improved design

(9) Production drawings

(10) Tolerances

(11) Raw materials specifications

(12) Inspection guidelines. Quality control criteria.

(13) Tender documents

(14) Contract documents

e) Type of production

(1) Cast iron

(2) Fabricated from steel pipe, standard fittings, etc.

(3) Constructed at site

This decision will depend upon the type of industry in the towns, the raw materials available, and the skill of craftsmen at village level. A cast iron or pre-fabricated pump requires little engineering at the installation sight. Water pumping devices assembled or constructed in the village are able to utilize local skills and materials thus economizing on materials. The resulting unit is usually locally understood and maintainable.

f) Multipurpose unit versus single design options

It may be necessary to begin a programme with a single multipurpose design pump which will serve a variety of purposes, even if not particularly well. As the programme gains momentum, routine operational problems become reduced, R & D capacities expanded, it may become possible to branch out into several design options - each one appropriate for a single use. For example one pump may be designed specifically for single family use, another for small hamlets of say 50-100 people, and another more robust model for 100-200 people or more.

Also special purpose pumps, such as for micro-irrigation, can be designed as the need arises. Here again there is scope for variety. The aim may be to water a small vegetable garden plot with the household pumps, or micro-irrigate a small field crop of wheat, potatoes, sorghum, etc. with a special pump designed for that purpose.

15. Imported pumps

a) OLGA* may be helpful. But there are other pumps under development which are not yet in OLGA, particularly shallow well pumps in Bangladesh and Deep Well Pumps in India which may be more suitable. HQ may be able to give advice on the most appropriate model. Martin Beyer and Hans Lotje should be the best sources of information.

b) If local production is the ultimate project goal and import is a temporary expedient, then a simple design such as is being produced in a nearby developing country may be the most suitable design to begin developing local capacity.

16. Handpump research and development work : Who should do it?

a) International Consultants:- Tend to be expensive, and take a long time getting from the drawing board to prototype. Difficulties in communicating complex technical questions over long distances. May develop solutions which are

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* UNICEF GUIDE LIST (OSU-6400 May 1975, UNICEF HQ, NY)

neither technically, socially or economically appropriate. (But usually do have highly qualified engineers. Good for initial studies).

b) Government Agencies. Ideal to involve government in developing its own pumps. But often there is insufficient motivation or technical skill.

c) Local Industry. Usually has technical skill, but lacks initiative in developing improved, better-cheaper technology. Existing technology tends to become institutionalized, even though it may be more expensive, inefficient or both.

d) Beneficiary. For drinking water pumps, technical skills, motivation and resources are not usually available at village level. However, farmers in a famine situation often develop an uncommon ingenuity for developing appropriate means of getting water to the land.

e) UN Specialized Agencies. Do not normally purchase large quantities of final design units, and may have difficulty getting their ideas into production.

f) UNICEF Office. Normally does not have technical staff to initiate technical innovations and follow through into production.

g) OPTIMUM combination for success = purchaser + designer + manufacturer + beneficiary. That is, successful designs develop through continuous interaction between the agency responsible for purchasing the improved design, the designer, the manufacturer, and user of the pump in the field. It is sometimes most effective if the designer and purchaser are one in the same.

Another formula for SUCCESS = 90% perspiration and 10% inspiration. There does not seem to be any substitute for people. People willing to work closely with local manufacturers, make frequent visits to field sites, back to the drawing board, back to the workshops, back to the field, etc., etc., repeated enough times until an appropriate design is evolved. There is no easy solution to long range development.

Another way of saying this is that nothing happens automatically. An idea needs to be pushed and proded, revised and pushed again every step of the way until it actually reaches the field and produces results.

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17. Details of pump design

A. Dimensions

1. Cylinder size. Along with stroke length, determines the volume of water per stroke. The volume determines the weight of water lifted per stroke. $2\frac{1}{2}$", 3" and $3\frac{1}{2}$" are common pump cylinder diameters.

   A rather small increase in cylinder diameter may give a relatively large increase in discharge, since discharge per stroke depends on the cross-sectional area, which increases as the square of the radius.

   Combinations of diameters and stroke lengths are listed below. These discharges are not theoretical, but are general performance levels from existing designs operating under field conditions:

Cylinder dia.	Cross sectional area	Stroke length	Typical* discharge	Pump type
$2\frac{1}{2}$"	5.0 sq.in	4"-5"	4 - 5 gpm	Pak. G.I.
3"	7.1 sq.in	4"-5"	4 - 6 "	B'desh No.4
$3\frac{1}{2}$"	9.6 sq.in	6"-7"	6 -10 "	B'desh No.6

   * depends considerably on well.

2. Stroke length. A longer stroke length gives a greater discharge per stroke for a given cylinder diameter. A given unit of discharge may be achieved by either a fewer number of longer strokes, or a greater number of shorter strokes. From the operational point of view, the optimum configuration will have much to do with the size, strength and work habits of the users. From the maintenance point of view, it is thought that a smoother pumping action results in less wear on the moving parts.

3. Discharge. A combination of cylinder diameter, stroke length, number of strokes per minute, and number of cylinders.

   Note: The discharge of the pump can not be considered apart from the design characteristics of the well. These factors include:-

   a) Diameter of filter and rising pipe
   b) Slot size and open area of filter
   c) Transmissibility of aquifer
   d) Development of aquifer
   e) Depth to water level
   f) Fluctuations of static water level

4. Handle length. Determines the mechanical advantage, which, alongwith cylinder dia., and depth to water table, determines how hard it is to work the pump. Generally, the longer the better. The configuration of the handle also seems to be important in the overall use of the pump.

5. Overall size. Depends upon the size of the people using the pump, and the type of installation.

6. Thickness of bearing surfaces. $1\frac{1}{2}$" usually recommended as total breadth of C.I. bearing surfaces around pivot points.

7. Diameter of pivot pins. $\frac{5}{8}$" - $\frac{3}{4}$".

B. <u>Materials</u>

1. Cast iron 2. Plastics 3. Mild steel 4. Brass - Bronze 5. Wood	These all relate to the particular local economy/technology, and the particular engineering function which each is to perform.

C. <u>Assembly</u>

1. Foundry 2. Workshop 3. At site construction	Depends upon local technology, both in towns and at village level.

D. <u>Security</u>

1. "You can't pump the pump because the vandal took the handle".* Security problems vary from place to place, but are likely to be increased in exposed public places where there is no responsible caretaker. Lock and key arrangements can be devised locally.

2. Stones, pebbles, etc. There seems to be a human impulse to drop pebbles, etc. down a tube sticking up out of the ground. A wire mesh barrier placed in the pump cylinder, or sheet metal cowling over the top may be solutions. This problem is more critical for deep set well pumps where the cylinder mechanism is down the hole.

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* Song by R. Dylan

18. Considerations in site selection

a) Maximizing the number of beneficiaries

b) Responsible caretaker

c) Suitable drainage arrangement

d) Ground not too high to go beyond suction lift (for shallow pumps).

e) Site not too low to become flooded.

f) Far enough away from sources of pollution.

g) Maximizing possibilities of good ground water. (salt or iron concentrations may be localized).

19. Installation

a) A good concrete foundation and surrounding platform helps maintain a sanitary seal and healthy conditions around the pump, thereby increasing well use.

b) Details of design depend on local use patterns, available materials and skills.

20. Maintenance options

a) By caretaker: May be possible depending on skills, tools, spares available in village.

b) By local or union boards: May be able to manage finances and coordination, but may have difficulty arranging spares.

c) Centralized agency.

- Advantages : Bulk purchase of spares
- Disadvantages : Cumbersome, inefficient administration, financial burden on government.

21. Continued development

No design represents the "final" solution. The conscientious designer will restlessly be agitated by the questions.

Can we do it better ?

Can we do it cheaper ?

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Nearly always the answer is, "yes". Improved solutions are developed the same way as original designs : continuous interaction between designer - user - producer, as well as a restless look out on the horizon for better/cheaper materials, techniques, designs.

22. Pump production

a) One supplier or many?

b) Centralized production or regional dispersion?

This of course depends on the quantities needed by the programme against any one supplier's capacity to produce them. Dealing with one supplier may be preferable at the beginning since supervision and supply of raw materials and subcomponents is simpler. However having several producers improves UNICEF's bargaining position for price, frees programme of dependence on one source of supply, and helps to institutionalize the design. Possibly, production could start with a single supplier, centrally located and grow to include regional points as the demands of the programme and UNICEF's capacity to manage contracts increase.

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B.P. 3

WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

EVALUATION OF SIMPLE AND INEXPENSIVE PUMP FOR

COMMUNITY WATER SUPPLY SYSTEMS: SOUTH-EAST ASIA

15.

I.R.C.
Bijlage
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PROGRESS REPORT

EVALUATION OF SIMPLE AND INEXPENSIVE PUMPS FOR COMMUNITY WATER SUPPLY SYSTEMS

Submitted to

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March 1975

INTRODUCTION

Adequate supplies of safe water for their daily needs are beyond the reach of the vast majority of rural population in developing countries. The World Health Organization estimated that only about 12 percent of the rural inhabitants in the 90 developing countries surveyed in 1970 have access to regular water supplies of acceptable quality. Data published in the World Health Statistics Report (1973) reveals that the situation in the South-East Asian region is even worse than these average figures keeping in view of the limited financial and technical resources available in the region, the task of making wholesome supplies of water available to the majority of rural residents is indeed a difficult one.

The conventional approach to the solution of many rural water supply problems consisted in adapting a scaled down version of hardware and technology commonly adopted in the urban situation. In technologically developed countries which also had the advantage of a better economy, this adaptation process did not create any special problems. However, when the same was extrapolated to the relatively underdeveloped regions, it was seen that these solutions were seldom successful. For example, several rural areas in Thailand are provided with the conventional type of water treatment system consisting of coagulation, sedimentation, filtration and disinfection. A recent study on the Evaluation of the Effectiveness of the Community Water Supplies in North-east Thailand (FRANKEL, 1973) revealed that a large number of these plants were either inoperative or were performing defectively. Similar findings have also been reported by WHO. A major reason for the failure of many of these village systems is the lack of skilled personnel for operation and maintenance of sophisticated processes and equipment. It is then apparent that rural water supply problems as well as any other rural development program may require an entirely different approach from the urban situation.

A simple and inexpensive two stage series filtration system for treating surface water for rural communities has been developed at the Asian Institute of Technology and put into operation at several locations in Southeast Asia (FRANKEL, 1974). The units at present use a gasoline pump for lifting the water from the surface sources to the filter. Since pump repair facilities are not generally available in most rural areas in this part of the world, it was believed necessary to look for alternative pumping devices that are simple in design and construction and require little skilled attention. Furthermore, it was considered an added advantage from the point of view of poorly developed areas, to render the pump independent of conventional motive means such as gasoline and electricity. The principal objective of this work was, therefore, to identify and evaluate simple pumping techniques that would not be subject to same limitations as their more sophisticated and commercially available counterparts. The design, construction and performance evaluation of a simple and inexpensive pumping device that would be suitable for a rural water supply system serving a small community was to form the major part of the work. In order to maximize the benefits from the present research it was also desired to consider other simple pumping devices with a view to evaluate their suitability to rural service under different conditions. This latter aspect was accorded only secondary importance in this study consistent with available resources for the work.

The following sections briefly report on the early part of this investigation.

CRITERIA FOR SELECTION OF PUMP TYPES FOR THE STUDY

A water treatment system plagued with frequent breakdowns is as much of a threat to public health as no treatment at all. It has been reported that the most common cause of breakdown of small water supply systems is pump failure (WAGNER and LANOIX, 1959). Most community water supply systems currently operating in the rural areas use either gasoline or electric pumps. Occasional pump failures inevitably occur in all cases. Repair and maintenance of these pumps require the services of technically skilled personnel. Such specialized skills are, however, not readily available in most rural areas in the region. It, therefore, becomes necessary, when pump failures occur, to take the units to the nearest town where repair facilities are usually located. Experience indicates that quite often this entails total disruption of water supply extending over several days or even weeks. Provision of stand-by pumps is beyond the financial resources of most villages since these pumps, being mostly imported items, are rather expensive. In order to minimize disruption of water supply due to pump failure it appeared that the pump should be simple enough so that repairs could be carried out by the villagers themselves at the point of use.

As indicated by the WHO survey in 1970 only a minor segment of the huge rural population in developing countries have any form of an acceptable water supply. The importance of extending rural water service is well recognized. A major retarding factor is, however, the scarcity of available funds for such work. It has been estimated that to ratify the basic water needs of only 25 percent of the rural residents in developing countries would require a capital expenditure of about $2.8 billion (THANH, 1974). In view of the limited availability of finance it is not unreasonable to conclude that more emphasis should be placed on developing inexpensive systems. A pragmatic approach would be to encourage incorporation of locally made components to the maximum extent possible. To be practicable at the village level this would necessitate simplicity of design and construction, even at the expense of efficiency, and the use of locally available materials. In so far as the objective is to provide an acceptable service with available resources to the maximum number of people rather than to bring high quality service to a necessarily smaller number, such an approach would seem to represent a viable solution to the rural water supply problems in the South-east Asian region.

Many rural areas, even in the less developed parts of Asia, are, today, endowed with a supply of electricity and/or gasoline which are the most common power sources for the commercial pumps. Consideration of more primitive sources of energy such as human or animal power for purposes such as water lifting might, from this point of view, seem rather out of date. When one recognizes the fact that the hardware using electric or gasoline power as energy source necessarily consists of sophisticated components too complex for production and maintenance locally, it is seen that this is not the case. At present considerable interest is evident in the development and exploitation of naturally available energy in wind power, solar radiation etc. Because of the limited availability of funds needed for such work of a more fundamental nature, and a desire to expedite the availability of the results from this study, attention was concentrated in the search for a manually operable device. A supply of human labor can generally be relied upon in most areas of South-east Asia, where mass unemployment is a major problem.

Apart from the above criteria, dictated primarily by the technological and economic limitations of the rural areas, the pump selection process is also influenced by the specific requirement of the contemplated service to which it is to be put. The primary source of water in the South-east Asian region is surface water requiring some form of treatment. The water supply system can, therefore, be expected to incorporate a central treatment facility. Such indeed is the case in many of the existing systems. The service required of the pump is, then, to raise the water from the surface source to the inlet to the treatment unit. The volumetric capacity and lift of the pump should be such as to be suitable for this duty.

SELECTION AND PRELIMINARY DESIGN OF A MANUAL PUMP FOR RURAL COMMUNITY WATER SUPPLY

Having decided upon the essential attributes of the desired pumping device, a search was initiated to find a suitable pump that would best satisfy these constraints. Available information on the various types of pumping devices commonly recommended for rural water supply systems was collected. Pertinent characteristics of the different pumping devices were reviewed with a view to evaluate their conformance to the selection criteria. Table 1 presents a summary of the main characteristics and assessment of the more common varieties of surface-type pumps used in rural water supply systems.

Rural water supplies can be classified into two broad categories: (1) centralized systems which usually incorporates a water treatment facility located in areas where the natural supplies are not safe for direct consumption. A distribution system may or may not be available; (2) where individual users draw their own supplies from the source for direct consumption without treatment.

At many locations in Thailand and other parts of South-east Asia, the most readily available natural supplies of water are from surface sources and these waters usually require treatment to remove turbidity and harmful microorganisms. This would seem to require a central facility and therefore the pumping device to be selected should be suitable for incorporation in such systems. Of the commonly available types of pumps only the electrically or gasoline driven pumps with their relatively large capacities seemed to be suitable for such services. The hand-pumps, chain pumps and other varieties of rudimentary devices were more likely to be useful for supplying

Table 1 - Main Characteristics and Assessment of Surface-type Pumps and Lifting Devices

Pump type / Main Characteristics	CONSTANT DISPLACEMENT				VELOCITY
	Hand Pumps Plunger Type	Wind, Motor Driven Plunger Type	Chain or Continuous Bucket	Rotary Pumps	Centrifugal Action
Efficiency range	Low: 25%-60%	Low: 25%-60%	Low	"Good"	50%-85%
Operation	Very simple	Simple	Very simple	Relatively simple	Relatively simple
Maintenance	Simple, but valves and plunger require attention	Same as hand pump; Maintenance of Motor difficult in rural areas	Simple	Relatively easy, but requires regular attention	Requires skilled attention
Capacity liters/min	10-50	40-100	15-70	-	25-10,000
Head, meters	Low	Up to about 60 meters	Low	Up to 80 meters	Wide range
Power source	Manual	Wind or motor	Hand, animal, wind, motor	Manual, wind, motor	Combustion engine, electric motor
Cost	Low	Low	Moderate	Moderate	Moderate to high
Advantages	Low speed; easily understood by unskilled people; low cost	Low cost; simple; low speed	Simple; easy to operate and maintain	Reliable service life, relatively easy to operate and maintenance	Reliable service life; wide range of capacities and heads
Disadvantages	Low efficiency; limited capacities and heads	Low efficiency; maintenance of motor difficult in rural areas	Low efficiency; limited use	Moderately high cost	Unsuitable for manual or animal operation; high cost; difficult maintenance

water from source to individual users.

When the rural water supply literature failed to yield a suitable water lifting device fulfilling the criteria outlined in the previous section, the search was widened to the field of irrigation. A large number of devices widely used in various parts of the world were reviewed but none of them appeared to be adaptable for raising water above ground. A closer scrutiny of recent developments brought to our attention a manually operated foot-pump evolved at the Agricultural Engineering Department of the International Rice Research Institute (IRRI), Philippines. Being intented for irrigation use the pump apparently could deliver water at rates required in a community water supply system. The pump in the original design consisted basically of two canvas bellows reinforced with metal inserts, and a discharge box. When operated by one man it could lift 180-240 liters of water through 1 to 2 meters (KHAN and DUFF 1975). The basic configuration of the IRRI pump was selected for further development in order to design a pump for simple rural community water supply systems.

Even prior to adapting the IRRI foot-pump, a bellow type device driven by a bicycle-pedalling mechanism had been conceived and tested. Unfortunately, the collapsible rubber bellow which constituted the pumping element could not stand up to the pressures developed within during the pumping cycle for significant lengths of operation. In the IRRI basic design, this fundamental defect of a bellow has hopefully been corrected by use of a metal-reinforced canvas bellow which, according to the original designers yielded a rugged design with a long life.

Preliminary Design of Manual Pedal Pump for Rural Community Water Supply

The original IRRI pump was designed in such a way that the pump body needed to be partially submerged during operation. This feature was considered undesirable for the service contemplated in the present study and therefore the design of the pump was modified by providing external suction lines to deliver water to the bellows. Foot valves on suction lines were substituted for the original inlet valves in the bellows. Figure 1 illustrates a schematic of the pump configuration adapted for the present work. The basic pumping element consists of two canvas bellows reinforced with metal plates. The suction lines deliver water to the bellows. The bellows discharge into the discharge-box which is connected to the rising pipe. The bellows are supported at the bottom by a base plate which is fixed to a wooden frame. The box plate and the discharge-box could be made of metal plates, but sheet metal was desired as the construction material for the first model.

Pump sizing in the preliminary design was based on certain assumptions:

It was reasoned that the most likely use of the pump would be for village systems serving a population of up to 1,000. This does not, however, preclude use of the pump at least as a stand-by unit in larger systems to guard against possible disruption in service due to failure of the regular pump. If it is supposed that the per-capita daily consumption of water expected in the rural environment is 50 liters and that the average daily pumping hours could be something like 8 hours, then the capacity of the pump should be about 100 liters per minute. Assuming on an average 15 strokes per minute the pump should deliver approximately 7 liters per stroke. The volumetric capacity or displacement volume of each bellow then works out to be about 3.5 liters. The sizing of the pump was done to satisfy this requirement.

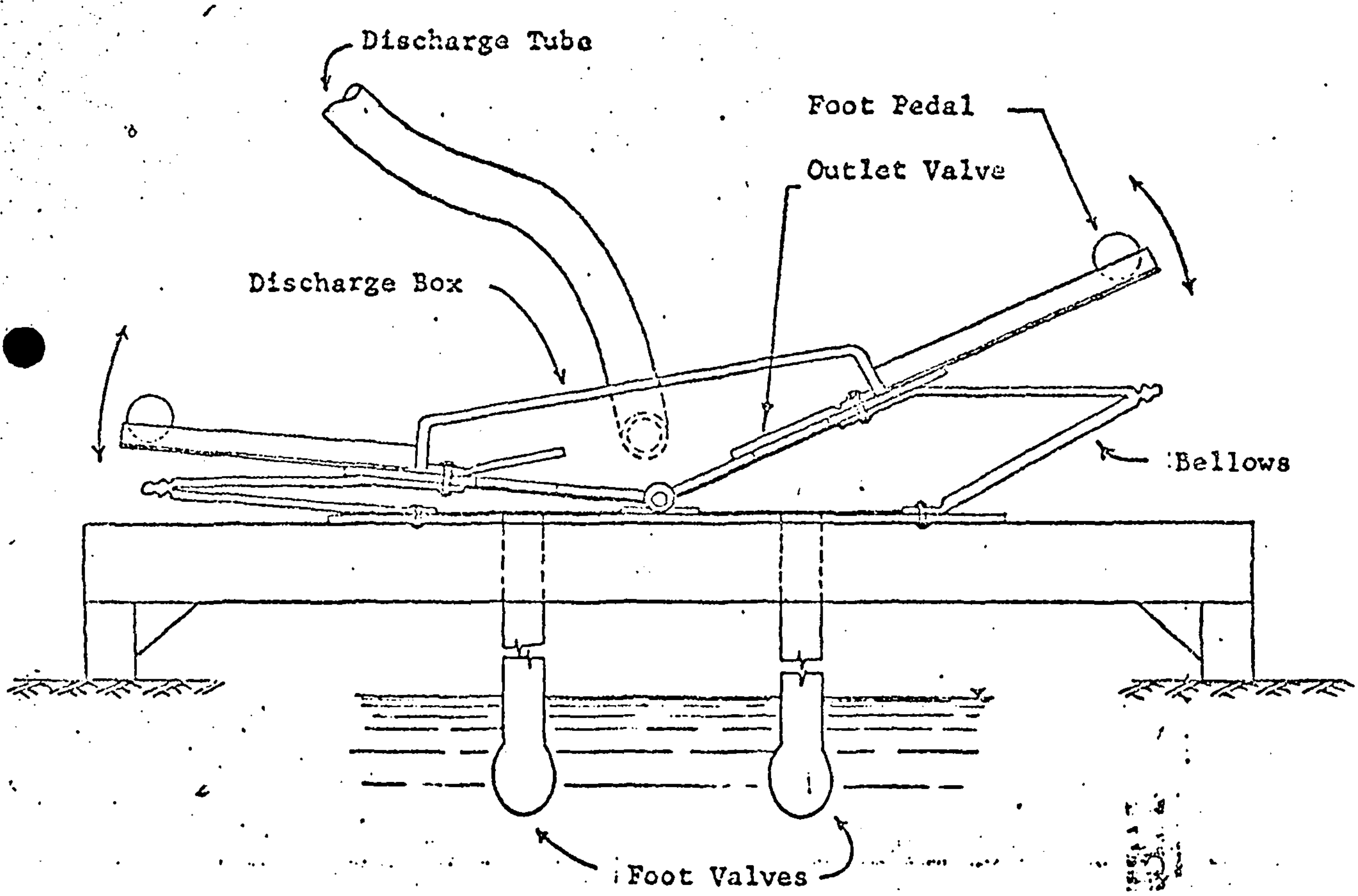

Fig. 1 - Manually Operated Foot Pump for Rural Community Water Supply

On the basis of existing water treatment systems of the two-stage filtration type it seemed reasonable to expect that the pumps would be expected to raise the water from the source through a head of about 5 to 7 meters. Assuming this lift the theoretical power requirement was about 0.1 to 0.15 HP. The actual requirement would be higher depending on the efficiency of the pump. Little reliable data was available on the rate of energy transfer possible through human labour. A range of possible values found in the literature is from 0.1 to 0.4 HP (VITA, 1973). It would then seem that one or two persons operating the pump could probably deliver the required volume through the 5 to 7 meter lift. The pump can indeed be worked by one or two persons. In the design of the preliminary prototype model it was assumed that two persons would be operating the pump simultaneously.

THE TESTING PROCEDURE

Pump testing in standard pump practice is carried out to determine the head-discharge relationship and the energy efficiency-discharge relationship which in turn can be used to define the optimal operating range for the pump. In the present context this standard testing procedure had to be modified because of the nature of the pump.

Because the pump belongs to the class of constant displacement devices it is to be expected that the volumetric discharge is directly related to the speed of operation or number of strokes per unit time rather than to the head. Assuming that the rate at which energy can be expended by a human being for sustained lengths of time to be more or less constant under standard conditions, variation in the number of strokes per unit time is to be expected for operation at different heads. In the experimental stage both variation in the frequency of pumping strokes and the discharge, will be studied for different pumping heads. For a given head the discharge as a function of hours of pumping will also be determined so as to obtain reliable data to estimate optimal pumping hours for the operator. All experimental runs are to be replicated by having several persons to operate the pump so that the results will represent average values to be expected in field use rather than an individual operator's performance. Despite these precautions the results, nevertheless, will remain to a certain extent qualitative.

ADDITIONAL STUDY: INERTIA PUMP

In addition to the foot-operated bellow pump, the study will also include investigations on the performance of a proposed modification of the simple inertia hand pump. The inertia pump (DAWSON, 1969, VITA, 1973) is an extremely simple device for lifting water from upto 3 or 4 meter depth. The proposed modification is with a view to recovering part of the energy that would otherwise be lost during the downward stroke of the pump. The pump configuration under consideration is shown in Figure 2. The flywheel is to be driven by a bicycle type drive.

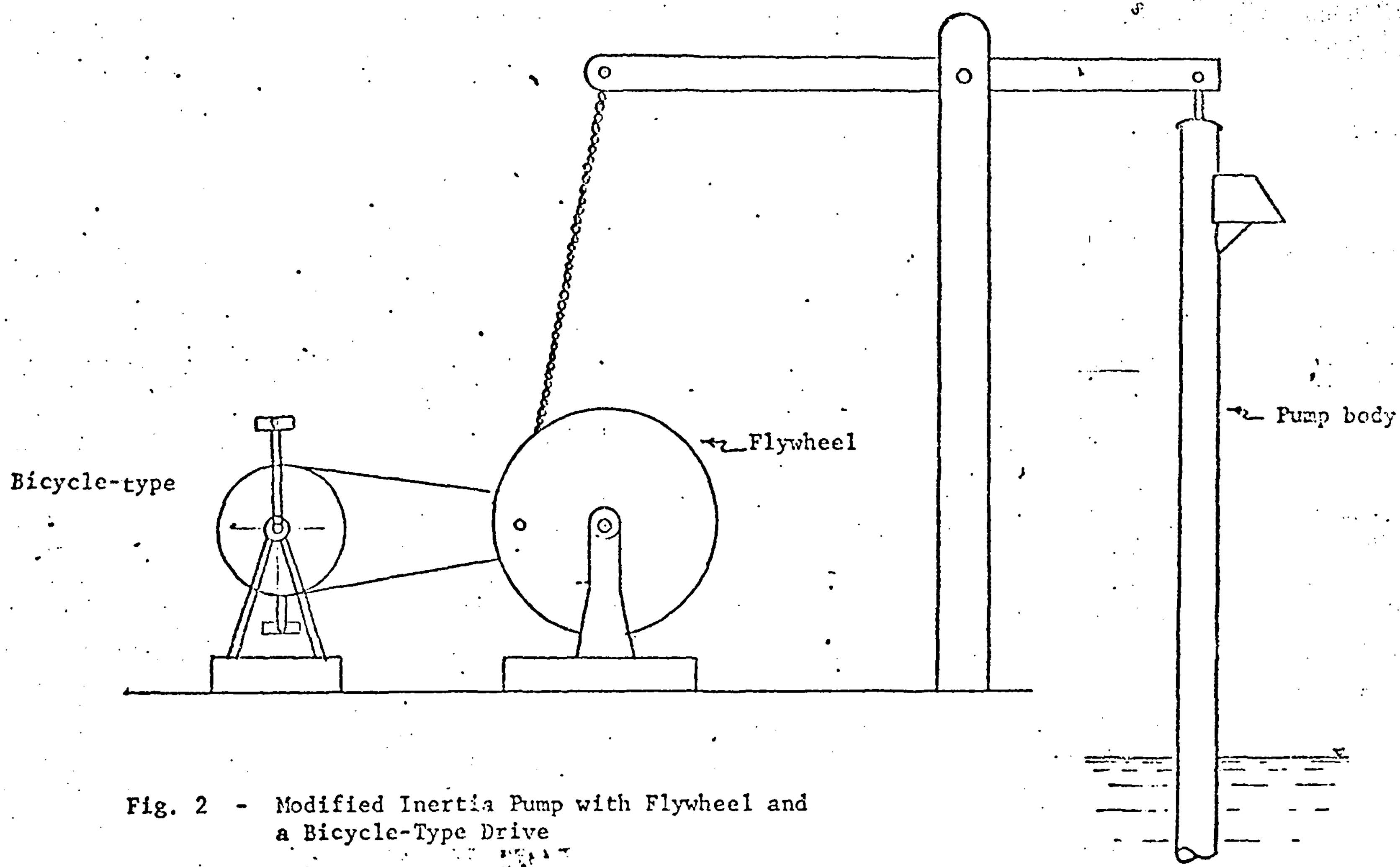

Fig. 2 - Modified Inertia Pump with Flywheel and a Bicycle-Type Drive

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B.P. 4

WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

FIELD TESTING OF

HAND-OPERATED WATER PUMPS: COSTA RICA; NICARAGUA

THE FIELD TESTING OF HAND-OPERATED
WATER PUMPS

by

Phillip W. Potts

Introduction

Estimates of inoperable water pumps in developing countries range anywhere from 50,000 to over 1,000,000 pumps, depending on the source of information. These pumps are poorly designed, poorly manufactured, poorly tested and poorly maintained, depriving the citizens of these countries of necessary potable water. As a result, much of the population suffers from the effects of intestinal parasites, mortality data revealing that enteric and other diarrheal diseases are among the leading causes of death in rural Latin America, Asia and Africa (with children suffering the most).

The impact of creating a more sanitary environment, however, extends beyond the reduction of gastrointestinal disease. The nutritional status of the population is also affected. As with infectious diseases, enteric and other diarrheal diseases drain the body's resources and create a need for increased caloric intake. The body cannot meet this need on the usual available diet, therefore, malnutrition results.

Because of the lack of sufficient potable water in many countries of the world, Georgia Tech has applied an established, proven methodology in Costa Rica and Nicaragua that stimulates small-scale industry, generates employment reduces the need for foreign exchange payments, upgrades local labor skills, educates rural villagers to proper sanitary habits, and provides installed, working, appropriate hardware (hand-operated water pumps) that eases serious water shortages.

The overall objective of such a program as just described is to improve the health of rural citizens by providing clean, safe water. However, the importance of the role of local manufacturing in stimulating small-scale industry and generating employment must also be emphasized. The program, more specifically, consists of the manufacture of water pumps, designed by the Agency for International Development (AID) through a contract with the Battelle

Memorial Institute (Columbus, Ohio), the purchase of locally available competitive pumps, installation of the pumps in rural villages, and evaluation of the field performance of the pumps over a one-year period.

The AID water pump was designed to contain many features (low production costs, long life under severe conditions, easy to maintain with simple tools and unskilled labor, suitable for shallow- or deep-well installations with only minor changes, capable of being manufactured by established firms within developing countries with a minimum of capital investment, easily operated by small people, and design features which discourage pilfering and vandalism). The attractiveness of local manufacturing has been noticeably an appealing feature because of the obvious economic benefits as well as the more readily available supply of spare parts. Also, a great deal of personal and national pride has been exhibitedby substituting "manufactured in Nicaragua" or "manufactured in Costa Rica" pumps for those traditionally imported from Japan, Brazil, Canada, Germany, the United States, etc.

Costa Rica

Costa Rica was chosen as a test country for the AID pump because of a sizable well and hand-pump loan that had been made to that country by AID and because of the country's need for an expanded water-pump program. Provisions of the loan specifically included installation of water pumps on a large-scale basis, and it was felt that assistance in such areas as pump selection, installation techniques, and pump maintenance, as a part of the field-test program, would greatly benefit the government of Costa Rica. Costa Rican Ministry of Health and AID officials also strongly felt that a locally manufactured hand pump had many advantages that should be included in the Costa Rican loan program.

One aspect of this project that has been obvious from the beginning is that, even though Costa Rica is a developing country, it is much more developed than Nicaragua, and this shows up in the availability of rural community water supplies for the two countries. For instance, based on recent surveys, representative test sites chosen for this project show an average daily usage by approximately 60 persons in Costa Rica and 170 persons in Nicaragua. In Costa Rica, most communities of 250 inhabitants or more have some form of piped water system, while in Nicaragua, the size of the community will usually exceed 2,000 inhabitants before piped water is found. In Costa Rica, most communities will have at least one well with a pump, if not piped water, and in Nicaragua, springs, rivers, and open, dug wells are the common sources of water. Costa Rica has a greater degree of electrification in rural areas, allowing the installation of motorized pumping systems that are not possible in many areas of Nicaragua. Further, the Ministry of Health in Costa Rica has had a limited hand-pump program for some 15 years, while Nicaragua is just now in the beginning stages of such a program.

This does not mean that Costa Rica is without a need for improvement in its potable water delivery system. The Ministry of Health, for instance, has estimated that as many as 47,000 hand-operated water pumps are needed to provide a suitable water supply to the country's rural citizens. Further, many existing water pumps are inoperable because of a lack of maintenance and, where there are functioning pumps, most of the well structures are poorly designed and completely ineffective in sealing out contamination. There is also a great need for a proper governmental organization infrastructure that does not now exist to carry out an effective rural water supply program.

Active work began in Costa Rica in January 1977, when AID/Washington and Georgia Tech jointly agreed that Costa Rica and Nicaragua should be the test countries for the program described herein. A machine shop, subcontracting to a local foundry for iron castings, was contracted with for the manufacture of 20 AID pumps, which were then produced and delivered to a Ministry of Health warehouse for installation. Two different kinds of pumps were chosen with which to compare the AID pump: a U.S.-manufactured Dempster and a Japanese-manufactured "Lucky" pump. Thirty-one sites, representative of Costa Rica, were chosen to receive the test pumps (16 AID pumps and 15 competitive pumps), most of which already had installed pumps varying in condition from broken to fully operational.

Wells were randomly tested by chemical and bacteriological analyses prior to test-pump installation and found to contain large numbers of intestinal bacteria, indicating that contamination was not being sealed off from the water. The pumps were installed by the Ministry of Health, the wells were disinfected with a chlorine-yielding compound, and attempts were made to seal off the contamination sources. However, subsequent bacteriological testing has shown no improvement in the quality of the water due to poor design and construction of the upper well structures by the rural villagers and Ministry of Health personnel -- a matter that has caused great concern within the Ministry of Health. As a result, internal organizational changes have been made and technicians and engineers are now being hired in an attempt to alleviate the situation.

Monitoring of pump performance has been carried out by responsible individuals in each test community with simple, printed report forms (see Form 1). designed to provide information covering community usage, pump physical condition, and functioning problems, if any. These forms are filled out and returned to Ministry of Health representatives every 15 days. If the returned forms show complaints of any type concerning pump functioning or condition, a repair truck is dispatched to the site for investigation and repair of the defect. Should a serious pump failure occur that cannot be corrected readily by Ministry personnel, the Ministry has been instructed to request, by telephone, immediate assistance from Georgia Tech or the Central American Research Institute for Industry (a counterpart organization of Georgia Tech that is a subcontractor for the program in Costa Rica and Nicaragua).

Copies of all report forms, as well as a record of any repair work done on either AID or competitive pumps, are maintained at the Ministry of Health. This information is reviewed periodically by Central American Research Institute for Industry personnel for inclusion in pump performance control charts. In addition to the above, a site-by-site inspection of all pumps has been made approximately every 60 days by Georgia Tech and/or Central American Research Institute for Industry personnel.

Pump Performance

To date, the functional performance and acceptance of the Costa Rican-manufactured AID pump has been satisfactory, but there have been casting defects encountered which have caused the replacement of handles, shallow-well caps and plungers (pistons). In all cases, these failures have been caused by a lack of quality control at the foundry, which is not possible without laboratory facilities for testing the cast iron. The foundry used for the manufacture of the AID pumps in Costa Rica was representative of what might be found in many developing countries, but was not considered by project personnel to be the best in Costa Rica. Better foundries were available; however, these foundries were not interested in initial small orders even though the potential for much larger orders existed for the future.

Leather cups have shown considerable wear in AID shallow-well pumps manufactured with metal cylinders and coated with epoxy. The cups appear to wear out for two reasons: first, the walls of the cylinders, even when the

Form 1

<u>Bimonthly Inspection Report</u>
<u>of Water Pumps</u>

Location: ______________________________

Water pump number: ______________________________

Date of inspection: ______________________________

Name of inspector: ______________________________

1. PHYSICAL CONDITION

Indicate the condition of the following water pump parts.

	GOOD CONDITION	WORN-OUT	BROKEN
Handle:	______	______	______
Plunger Rod:	______	______	______
Pins:	______	______	______
Nuts and bolts:	______	______	______
Pump stand:	______	______	______

2. PERFORMANCE

Indicate if there were a fault in the water pump in the last 2 weeks.

Yes	No
___	___

If there were a fault, describe the problem and action, if any, taken to correct it.

____

____

Indicate if there have been complaints about the performance of the water pump.

Yes	No
___	___

If there were, describe it.

____

Form 1 (continued)

3. USAGE

Indicate how many people use this well.

Less than 30	30 to 50	50 to 100	100 to 200	More than 200
______	______	______	______	______

Indicate approximately how many times per day the pump is used.

Less than 30	30 to 50	50 to 100	100 to 200	More than 200
______	______	______	______	______

4. GENERAL OBSERVATIONS

____

____

____

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epoxy coating is applied, are too rough and, second, the diameter of the metal base of the plunger where the leather cup sits was made too small (causing the leather cup to catch between the cylinder wall and the plunger, literally tearing the cup apart). The roughness of the cylinder disappears as the cups hone down the cylinder and corrects itself after several cups have been worn out. If two or three changes of the cups in the early in the early life of the pump are not acceptable, then the cylinder must have a PVC sleeve or be mechanically honed down during its manufacture -- an operation that may not be available in some developing countries. The smallness of the diameter of the plunger's metal base has been corrected by manufacturing units that are exact size or slightly on the plus side of specifications (in other words, closer quality control).

PVC cylinders for the AID deep-well pumps have performed exceptionally well, and there have been no leather cups changed in this type of cylinder (which seems to indicate that PVC or honed-down metal cylinders should be used for future pumps). There have been no significant problems with the U.S.-manufactured Dempster or the Japanese-manufactured "Lucky" pumps to date.

In order to determine further the durability of the different test pumps, attempts have been made to correlate the effects of different well depths and the number of people using the wells with the amount of total stress exerted on the test pumps. It is logical to assume that the greater the depth of the well and the greater the number of people using the pump, the greater the pump is stressed in pumping water over a given period of time.

Under normal operating conditions, a pump is never uniformly stressed, that is, the force per unit area varies throughout the structure of the pump. Due to the difficulty in calculating total stress for the entire pump, both theoretical and actual work (in foot-pounds force) was determined on the delivery system of the pump (the amount of work required to lift one pound of water one foot in height). Even though theoretical work and actual work are both directly proportional to stress, theoretical work increased with increasing well depth, while actual on-site work measurements randomly varied with depth (see Table 1).

No correlation could be made between depth and work. These data indicate that friction plays a dramatic role in the amount of work required to pump water. If a water pump is kept in a well-lubricated state, has a smooth cylinder, has a cup that fits snugly but not too tightly inside the cylinder, and

Table

WORK EXERTED ON FIELD-TEST PUMPS (COSTA RICA)
AS A FUNCTION OF WELL DEPTH (IN FOOT POUNDS)

Depth (m)	Site No.	Actual Work[1/] ($ft-lb_f$)	Theoretical Work[2/] ($ft-lb_f$)	Actual Work/ Theoretical Work	Type of Pump
3.20	10	39	6	6.5	AID-SW
3.25	31	54	6	9.0	AID-SW
3.85	11	23	7	3.3	Lucky
4.10	23	13	7	1.9	Lucky
4.20	13	11	7	1.6	AID-SW
4.50	8	70	8	8.8	AID-SW
4.90	22	30	8	3.8	Lucky
6.10	7	52	10	5.2	AID-SW
6.30	17	58	10	5.8	Lucky
7.61	18	21	12	1.8	AID-DW
9.60	29	39	15	2.6	Dempster
10.00	28	49	16	3.1	AID-DW
10.35	5	38	16	2.4	Dempster
10.50	19	46	17	2.7	AID-DW
10.80	6	38	17	2.2	Dempster
11.55	1	42	18	2.3	AID-DW
11.70	2	58	18	3.2	AID-DW

1/ Calculations for Actual Work. Actual work figures were ascertained, on-site, by measurement with a heavy-duty spring scale of the force required to lift water from each individual well. The force was then multiplied by the length from the plunger rod to the fulcrum point to determine the required work figures.

2/ Calculations for Theoretical Work. When calculations are made to find the amount of theoretical work on a hand pump lifting water, the theoretical force must be found. This is done by first calculating the total number of cubic feet of water from the pump to the water level. The equation used is the following:

$$V = \pi H \left[(R)^2 - (r)^2\right] + \pi h \left[(r^1)^2 - (r)^2\right]$$

where

V = Total Volume ($ft.^3$)
R = Radius of drop pipe (ft.)
H = Depth of the well to the water level minus the height of the water inside the pump assembly (ft.)
r = Radius of the plunger rod (ft.)
r^1 = Radius of the pipe inside the pump assembly (ft.)
h = Height of the water inside the pump assembly (ft.)

Table 8 (continued)

When V is determined, it is converted into pounds of water, assuming that one pound of water is equal to 1.603×10^{-2} cubic feet. The total number of pounds of water is then added to the weight of the plunger rod and the plunger assembly. The total amount of force is the result. If this force is multiplied by the length from the plunger rod to the fulcrum point, total theoretical work is ascertained. For example, at Bristol (Site No. 10) in Costa Rica, the variables are as follows:

$R = 0.625/12$ ft.
$H = (10.50 - 1.00)$ ft.
$r = 0.250/12$ ft.
$r^1 = 1.50/12$ ft.
$h = 1$ ft.
$V = \pi(9.5)\left[(0.625/12)^2 - (0.250/12)^2\right] + \pi(1)\left[(1.50/12)^2 - (0.250/12)^2\right]$
$V = 0.06801 + 0.04772$
$V = 0.11573 \text{ ft.}^3$

Therefore, the total number of pounds of water is:

$1 \text{ lb.}/1.603 \times 10^{-2}\text{ft.}^3 = x/0.11573\text{ft.}^3$
$x = (1 \text{ lb.})\ (0.11573\text{ft.}^3)/(1.603 \times 10^{-2}\text{ft.}^3)$
$x = 7.22$ lbs. of water

The total weight of the plunger rod and plunger assembly in this example is 6.75 pounds. The total force is then found to be 13.97 pounds (7.22 plus 6.75). With the distance from the plunger rod to the fulcrum point being 5/12 feet the total theoretical work is 5.82 ft.lb_f (5/12 times 13.97 lb_f).

NOTE -- THERE ARE WEAK POINTS TO THE ABOVE APPROACH BUT WE HAD TO TAKE THE FIRST STEP FOR ARRIVING AT SOME METHODOLOGY TO MEASURING STRESS. HOPEFULLY, PARTICIPANTS AT THE WORKSHOP WILL IMPROVE UPON OUR INITIAL EFFORTS!

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has no surfaces that grind against each other, the amount of actual work required to produce water will approach the theoretical work figure. If any of the above conditions are not met (which is almost always the case), the friction factor increases drastically and, as seen in Table 1, a pump operating from a depth of 4.5 meters (Site No. 8) can require 1.2 times as much work as a pump bringing up water from a well 2.2 times as deep (Site No. 2). Measurements will continue to be taken during the remaining monitoring period of this field-testing program to further analyze the relationship between stress on a water pump and the depth of the well.

At present, usage has not been included in the calculations in Table 1, since accurate water consumption per person per day in unknown. However, water meters have been installed on pumps at selected, representative sites in Costa Rica. After a period of four to six months, these meters will be removed and their data recorded. From this, and other daily, short-period data, the total work exerted on each individual pump over a fixed period of time will be examined.

Nicaragua

Nicaragua was also chosen as a test country because of a rural water supply and hand-pump program loan by AID to that country involving the installation of hand-operated water pumps. The loan provisions included potable water systems that will construct 300-340 wells by the end of 1979, which the AID/Georgia Tech program has complemented by providing technical assistance in pump selection, installation techniques, and pump maintenance, and which has enabled the Ministry of Health in Nicaragua to take advantage of locally manufactured hand pumps that can be produced at a cost lower then commercially available pumps, increases spare parts availability, contributes to a positive balance of trade, and stimulates local employment.

As in Costa Rica, program activities began in Nicaragua in January 1977. A local foundry was chosen to manufacture 20 AID pumps which were produced and delivered to a Ministry of Health warehouse for storage and installation. Two kinds of locally available pumps were chosen to compare the AID pump with: the U.S.-manufactured Dempster and a Brazilian "Marumby" pump. A pump developed by the International Development Research Centre (IDRC) of Ottawa, Canada, was also used for comparison. Thirty sites, representative of Nicaragua, were approved to receive the test pumps (15 AID pumps and 15 competitive pumps), and all of the sites required extensive preparatory work before pumps could be installed. Pumps were installed by a Ministry of Health installation team, and the wells were disinfected with a chlorine-yielding substance. As in Costa Rica, the sites had chemical and bacteriological testing prior to installation of test pumps and showed large concentrations of intestinal bacteria, requiring further testing to determine if the contamination is being sealed out by the addition of a closed well and the use of a hand pump for lifting the water.

As mentioned earlier, monitoring of pump performance in Costa Rica has been carried out by designated, responsible individuals (usually school directors or teachers) in each test community where they have been provided simple, printed report forms designed to provide information covering community usage, pump physical condition, and functioning problems, if any. These forms are filled out every 15 days and mailed to an AID engineer in San Jose for analysis, who then reproduces them and turns the copies over to Ministry of Health representatives. If any of the returned forms indicate that repairs are necessary, a maintenance team is dispatched to correct the problem.

The monitoring system in Nicaragua is similar to that in Costa Rica, except that all pumps are inspected every 15 days by Ministry of Health engineers who are permanently stationed in the field and are responsible for the completion of the report forms as well as initiating any necessary repairs. Information included in the report forms is reviewed periodically by Central American Research Institute for Industry personnel and recorded on pump performance charts. All Nicaraguan test sites have been inspected at two-month intervals by Georgia Tech and/or Central American Research Institute for Industry, also.

Two major problems with the AID pump in Nicaragua became apparent when installation of the pumps began. The most critical problem was that the deep-well cap's weakest point was where maximum stress was being applied by the handle fulcrum upon the pivot arm of the cap, causing the pivot arm to break off from the cap. This problem caused very close to a 100% pump failure and was partly the fault of the design and partly the fault of the manufacturer. ~~Because of the indented contour of the top plate of the pump body, it was not possible to cast the pump body as specified by the drawings (the patterns for the pump could not be removed from the molding sand without destroying the mold). Therefore, the manufacturer eliminated the indented contour of the top plate of the pump and~~

~~then did not have enough clearance between the pivot arm of the cap and the top of the pump body. In order to obtain a better fit between the pump cap and the pump body, the manufacturer milled away a fillet on the pivot arm, thereby leaving a notch and a weak link at the point of maximum stress.~~ To alleviate the entire problem, the pump cap was redesigned ~~by lifting the pivot arm up and away from the pump body and positioning it so that it does not absorb so much of the stress caused by the downward force of the pump handle (the fulcrum handle, naturally, had to be shortened). The redesigned cap was~~ and put into production at the manufacturer's foundry, installed on the pumps in the field, and has presented no additional problems.

The second major problem encountered with the AID pump in Nicaragua evolved when the manufacturer could not find 3-inch (inside diameter) PVC pipe for the deep-well cylinders. As a result, the manufacturer used 3-inch (outside diameter) PVC pipe and expanded it, by heating, to a 3-inch inside diameter. Quality control for such an approach was most difficult, and the results were unacceptable. While several of these PVC cylinders were installed in the field, it was decided that metal cylinders, coated internally with epoxy, would have to be used until the correct size PVC could be made available locally or imported from another country.

Excessive wearing of leather cups has also presented problems for the AID pump in Nicaragua. Battelle drawings specify a 3-inch diameter leather cup for a 3-inch cylinder, which would be satisfactory if leather did not expand when wet. To allow for expansion, the dry cups should have been made approximately 1/16-inch diameter undersized. A replacement order for the original oversized cups was filled by the pump manufacturer, and the wearing of these new cups has been considerably less due to the use of a blanking tool that improves the quality controls of the manufacturer. The blanking tool has proven to be very beneficial and is being modified to resemble a method suggested by Dr. Eugene McJunkin, in a recent publication:

> For "mass production," wooden forms can be used. To make the forms, use wooden boards about 3/4-inch (approx. 19mm) in thickness, having holes of the same diameter as the pump cylinders, and nailed to a stiff backboard. Cylindrical blocks, 3/8-inch (approx. 9.54mm) less in diameter, are bolted concentrically within the circular openings. The bolts should be long enough so that . . . wet and pliable leather, laid over the holes, can be drawn down by the bolts and blocks, forcing the leathers into position . . . let dry, remove and trim

the wrinkled edge with a sharp knif (including the center hole), soak for 12 hours in an edible oil (preferably neat's-foot), wax, and lightly apply graphite grease to the wearing surface.[1]

The Brazilian "Marumby" pump is beginning to have problems. The weakest point of the pump appears to be where the handle and the pump cap are connected. In three of the five pumps being tested, the pump cap has had to be, or needs to be, replaced due to breakage at this point. Spare parts are also difficult to find for this pump, and the local distributor does not carry a large inventory of extra pumps for replacement purposes -- a factor that enhances the argument for locally manufacturing pumps so that spare parts can be made readily available.

The Dempster pumps in Nicaragua, as in Costa Rica, have had no major problems. The IDRC pump has performed well but has had some difficulty with its foot valve sticking in the open position (allowing the pump to lose its prime).

Attempts also have been made in Nicaragua to correlate the effects of different well depths and the number of people using the wells with the amount of total stress exerted on the pumps. Because of the tremendous role friction obviously plays on the performance of the pumps (all types) and the many varying factors that change the amount of friction on an almost daily basis, no correlation could be made between the durability of the pump and the depth of the wells (see Table 3). Water meters also have been installed at representative sites in Nicaragua to study the effects of usage of the pumps and their respective maintenance requirements.

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[1] F. Eugene McJunkin, Handpumps for Use in Drinking Water Supplies in Developing Countries, (The Hague, the Netherlands: International Reference Center for Community Water Supply, 1977), p. 136.

Table 2

WORK EXERTED ON FIELD-TEST PUMPS (NICARAGUA)
AS A FUNCTION OF WELL DEPTH (IN FOOT POUNDS)

Depth (m)	Site No.	Actual Work (ft-lbf)	Theoretical Work (ft-lbf)	Actual Work/ Theoretical Work	Type of Pump
3.50	28	8	6	1.3	AID-SW
3.75	14	12	7	1.7	AID-SW
5.85	2	10	10	1.0	Marumby
5.95	29	24	10	2.4	AID-SW
9.46	22	64	15	4.3	AID-DW
10.16	21	34	16	2.1	AID-DW
10.42	4	77	17	4.5	Dempster
17.60	23	38	27	1.4	AID-DW
18.75	9	150	29	5.2	Dempster

Note: While the above data have been gathered from only nine of the thirty sites in Nicaragua, it is felt that the measurements are representative of all sites. In the next several months all sites will be examined and analyzed, however.

Conclusion

There are obvious indications at the present time that most definitely encourage further manufacture, installation, and use of the AID pump. The AID pump can be manufactured in a developing country at a competitive, profitable price and at an acceptable level of quality if adequate facilities (foundries, pattern makers, machine shops and skilled machinists, raw materials, etc.) are available; however, the availability of adequate foundry facilities with acceptable pump prices and quality controls are matters that must be determined for each individual developing country. Public acceptance by rural villagers has been good, both from an aesthetic standpoint and from a standpoint of the pump being used easily by men, women, and children. Further, the AID pump should have a positive impact in developing countries on the health of rural people, on employment generation, on a positive balance of trade, and on instilling national pride within the people when it is seen that these countries do have local capabilities for manufacturing a relatively complicated product rather than importing it.

As indicated above, the AID pump <u>is</u> adaptable to local manufacture in developing countries if adequate facilities are available. While numerous manufacturing problems have been encountered in both Costa Rica and Nicaragua, the majority of these problems are problems that are to be expected when a product such as the AID pump is introduced into production for the first time. As subsequent orders are processed through the manufacturer's plant and as personnel become more familiar with the pump itself, quality control should be refined to the point where the orders are considered to be normal production.

A slide presentation now follows which shows much more vividly than words the program just described. Please note that village labor was used for the preparation of all upper well structures with technical assistance from engineers representing Georgia Tech, the Central American Research Institute for Industry, and local Ministries of Health.

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HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

EVALUATION OF DEEP-WELL ("DEMPSTER") HANDPUMP - INDONESIA

Report on ~~investigation~~ evaluation of deep hand pump Dempster

Based on field study on locations of deep hand pumps 'Dempster' in East Java, Central Java, Yogyakarta, West Java and D.K.I Jakarta, which enclosed in this report, the team has concluded that :

1. About the efficiency of deep hand pump 'Dempster'.
   a. Dempster pump has a good efficiency, because it can lift up water from dug-well and piping-well, untill the total of head reach 30 meters.
   b. To supply water with a relatively large quantity between 9 liters per minute till 20 liters per minute with stroke between 30 till 40 per minute.
   c. Easy in operation and maintenance. Elementary school pupils and house-wives can easily operate this deep hand pump Dempster.
   d. It has a long time power (time service), proved by several pumps which installed in 1970, but now still running well. This fact depends on maintenance.
   e. Replacement of damaged part which generally caused by worn out cup seal, s easy and only takes time about 30 minutes by 3 persons.

2. The damage often experienced by hand pump 'Dempster'
   a. The damages of this pump which found out in this investigation (field study) are worn out cup seal, loosed rod, worn out hinge, loosed handle, get stuck and the water did not go out.
   b. The motive of damage are generally bad installing, straight in use and le.s careful, bad in maintenance,

- Lack of equipments and less in control (finished with installing, did not control again)

c. The mistaken in installing for instance ~~cause~~ the pump does ~~not~~ not stand perpendicular so that it works only half part, caused small quantity of water, a heavy pumping and a quickly worn out cup seal.

- The rod connection of pump are not tight, so that it often loosed.
- The rod holder is not screwed ~~[illegible]~~ tightly so that the handle often loosed.
- The foot valve is not separated from plunger when it's installed, caused a heavy pumping and it abnormally works.
- The plunger is not installed tightly, so that it causes the plunger loosed.
- The ~~p~~ length of pump's socket ~~handle~~ is not corresponded with the ~~depth~~ well's depth, so that for corresponding with the depth of the well, the handle has to be cut and to joint this it is made a new worm of a screw ~~[illegible]~~ with a different standard so that the joint is not firm and the under joint of the handle is loosed.

- The installed pump that implemented when the ground water is high, ~~[illegible]~~ is generally not deep, so the consequency is when dry season the position of pump becomes hanging.

- The zone where the ground consist of clay, the strainer of pump is pinned and the hole is surrounded by clay. In this condition like this the wells have to be made, used double casing.

- There is a case, this deep hand pump installed at a positive well where without water pump the water flow out by itself.

Surely with pumping the discharge of water would be increased.
Nevertheless it's not necessary to use deep hand pump but it's sufficient to use shallow hand pump that more economics and more practical.

d. Operation of pump

- In several place one pump has to serve a large number of consumer more than the power of pump (one pump serves more than 500 persons)
The pump is carried out night and day so that the pump is quickly damaged.

- Especially the pump that installed at frontyard of school or at public place, the consumer are children that carried out the pump careless so the consequency the pump is quickly damaged (play with pump)

e. Maintenance

- To forget to give oil and fat on pins so that the body of pins worn out and then the pins become spaciously and the pump cause unstable and give a noisy sound.
Besides the body of pins is quickly worn out and the pins is quickly damaged.

- If the cup seal is damaged, the replacement is not soon carried out so that the pump has no function.
This case often caused by the cup seals are not available (no reserve cup seal).
If there are available the quality is not same with the original.

- Once happen, because the reserve cup seal is not the original (the quality is worse), so after used for several times the reserve cup seal expand and caused the pump gets stuck (can not set in motion)

- There ~~are~~ is a case, the bolts that hold the cap's handle is slack, this condition ~~will~~ cause the movement of handle pump's position, ~~and~~ also the body and the bolt is quickly worn out.

3. Suggestions

1. To ~~be~~ attend an intensive training for installing worker and ~~controller~~ installing controller of this deep hand pump.
2. To prepare a complete equipment for installation and maintenance.
3. To prepare a sufficient spare parts and the quality is the same as the original, especially leather cup seals.
4. To prepare an operating and instructing manual in Indonesian language for each pump.
5. The size of rod with 6 meters long is too long and less practical.
   To suggest for order rod with 3 meters long.
   Thus also to suggest the size of rod's worm similar with the standard used in Indonesia.
6. ~~Improved~~ Controlling on the installing of pump has to be up-grade so that the pump installed as it should be (no mistaken in installing)

7. Controlling on the installed pump has to be ~~implemented~~ carried out periodically, for instance once in a month, so that if there are damages it can be repaired soon.

8. To carry out ~~on~~ the investigation on depth of ground water where the wells and pump with this type shall be installed, in order that the installed pump does not hang.
If the surface of ground water is high, it is not necessary to install this type of pump.

9. To suggest that this pump is only installed at place where it really need the support pump of this type.
Thus also the number of population that shall be served are limited not more than 100 persons per pump.

10. To give information to local community ~~has to be upgrade~~ so it has to be up grade in order that the community can appreciate how important and profitable ~~they~~ this type of pump for their living.
Thus it can be expected with consciousness that they will protect as it should be.

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HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

HANDPUMP EVALUATION AND TESTING: THAILAND

HANDPUMP EVALUATION AND TESTING IN THAILAND

FOR

IMPROVEMENT OF HANDPUMP DESIGN

prepared by

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The view and interpretations in this report are those of the authors. It does not necessarily represent the decisions or stated policy of either the Government of Thailand or United Nations Children's Fund.

1 Introduction

The handpump evaluation and testing in Thailand for the improvement of handpump design was undertaken by Office of Accelerated Rural Development (ARD) financially assisted UNICEF. The study had been conducted from June 1977 to September 1978, of which the final report is now being documented. This paper is an interim report to support the International workshop on handpump evaluation and testing and will be attached to the final report as the introductory and conclusion.

2 Background

The provision of clean water for rural areas in Thailand was initiated in 1964. The cabinet appointed the executive committee in 1965 with members represented from various departments. The target was to complete the supply of clean water to local inhabitants in 50,000 villages with several strategies as follows:-

a) Shallow dug wells and jet wells equipped with handpumps

b) Small diameter wells equipped with handpumps.

c) Deep wells equipped with handpumps.

d) Piped water supply.

e) Rainwater collection tanks.

f) Standard ponds.

g) Improvement of existing ponds.

h) Dykes and Reservoirs.

The first phase target was to complete providing clean water to local inhabitants in 20,000 villages within 6 years, from 1965 to 1970, which was the same year as the second National Economic and Social Development Plan ended. The target of the second phase which was added to the Third National Economic and Social Development plan was to provide clean water to the other 20,000 villages during 1971 - 1976. At the end of the Third Plan, the National Economic and Social Development Board had requested the National Institute for Development Administration (NIDA) to carry out the evaluation. It was found that only 9.3 per cent of rural population had water which is considered clean. There are many problems which obstruct the achievement, one of them is the failure of HANDPUMPS.

At the national level, the responsibility for providing clean water is shared by several agencies as follows:-

a) Department of Local Administration

This Department provides clean water to small communities through the provision of various types of rainwater collection tanks, improvement of existing ponds as well as support the construction of shallow dug wells and jet wells equipped with handpumps by local people and local contractors. At the end of 1977, a number of 32,410 shallow dug wells and jet wells had been constructed. Of these numbers, 5,820 handpumps had been installed. The survey conducted by NIDA on the Northeastern region indicated that 34.7 per cent of handpumps were inoperative during the investigation.

b) Department of Mineral Resources

The Groundwater Division of this department provides clean water through deep wells. The depth of the wells varies from 100 feet to 350 feet, while the average depth of the well is 185 feet. At the and of 1977, this Department has drilled 7798 deep wells all over the country. Of these numbers, 92.3 per cent of the wells were equipped with handpumps while the rest was equipped with motorpump. NIDA reported that 18.6 per cent of the handpumps installed by this Department was out of operation during the survey undertaken in the Northeastern region. Under the present plan, its target is to construct 720 deep wells annually.

c) Office of Accelerated Rural Development (ARD)

This Office was established to help develop the under-~~sewed~~ served areas which is now covering 53 provinces. The main task is to construct rural roads and provision of clean water in the underserved areas through construction of deep wells, shallow wells and standard ponds as well as improving of existing ponds. At the end of 1977 a number of 2,376 deep wells and 1,891 shallow wells equipped with handpumps had been constructed. It was found that 26.3 per cent of handpumps were out of operation during the survey undertaken by NIDA. Under the World Bank Loan Project from 1977 - 1981, the ARD plans to construct 3,500 deep wells and 520 shallow wells which will equip with handpumps.

Department of Public Works

The Provincial Water Supply Division of this Department constructed deep wells in other regions outside Northeastern region. Up to the present, 1971 deep wells have been constructed. However, the data on number broken handpumps are not available. Under the current plan, its target is to construct 200 deep wells each year.

Department of Health

The Department of Health has been providing clean water by pipe since 1966 through the national budget, community participation and also contribution from international agencies. From 1966 - 1977 539 piped water schemes have been constructed serving 1,438,100 rural inhabitants which is a small portion when compare to the total rural population. The Department of Health realized that in order to provide more clean water, a new approach must be considered. The small diameter well programme for the communities 500 - 1,500 was introduced in 1976 with UNICEF assistance. As of September 1978, 130 small diameter wells equipped with handpumps have been constructed.

It is planned to construct 350 small diameter wells equipped with handpumps annually.

There are also other agencies involved in the provision of clean water for the rural areas but their inputs are relatively small.

3 Problem identification

It is envisaged that handpumps play a major role in the provision of clean water for the rural areas in Thailand. The mentioned government operating agencies have installed approximately 19,000 handpumps all over the country. Based on the sampling survey conducted by NIDA, it is estimated that 5,000 handpumps are out of operation at any one time. It means that a wasteful capital investment at a given time for handpump itself will be US$ 400,000 approximately. Furthermore the wells equipped with inoperative handpumps will also be out of operation and the capital investment cost of the wells ranging from US$ 200 - 5,000 will also be worthless.

As a result of inoperative handpumps, the chance of maintaining rural people of using clean water will be lost. Morever, a great number of wells have been constructed with community participation in cash or in kinds or both, the villagers may view the loss of service as evidence their contribution was a poor investment and lose regard for the operating agencies and the Government.

The major causes of handpump failure are as follows:-

a) There are many different kinds of handpumps installing in the communities. It is very difficult for the local authorities as well as the villagers to maintain all of them since spare parts are not interchangeable.

b) Handpumps are not durable because of inadequate handpump design.

c) The quality of production is not good enough due to poorly quality control.

d) Lack of community participation in maintaining handpumps

e) Some agencies do not have maintenance unit at all, some do have but insufficient to service all handpumps provided for rural inhabitants.

f) There is no effective coordination on the maintenance of handpumps among operating agencies at the grass-root level.

g) The fund provides for each agency for running preventive maintenance programme was limited.

h) Spare parts are not available at the localities due to shortage of manufactures.

It may be concluded that what causes handpump failures are poorly handpump design, lack of effective maintenance strategies, lack of maintenance organization at a grass- root level, financial constraint and limitation of manufacture.

4 Scope of study

This study concentrates on the improvement of the existing handpumps' design particularly deep well reciprocating lift pump (cylinder is submerged in the water). The study on handpump made of PVC for shallow well (body of the pump contains a piston) is being undertaken by the Department of Health. The Asian Institute of Technology will carry out a research on designing and developing a typical handpump for Thailand in the future.

The study on the improvement of handpump design aims to solve immediate problem regarding the durability of handpump. It is hoped that the result of the study will lead to the standardization of handpump in the country and an improvement of handpump maintenance programme.

5 Objectives

a) To study of field performance of various types of handpumps which are being used in the country.

b) To improve the handpump design in order to:-

- be able to withstand rigorous usage
- perform consistently as long as possible
- operate easily

- be inexpensive
- maintain locally.
- be versatile.

6 Programme of work

The work programme for the improvement of handpump designs are as follows:-

a) Selection of location for testing and evaluating of various types of existing handpumps.

b) Installation of various types of handpumps

c) Collection and compilation of data on handpump performance under field operation in different static water level and different areas.

d) Data Analysis

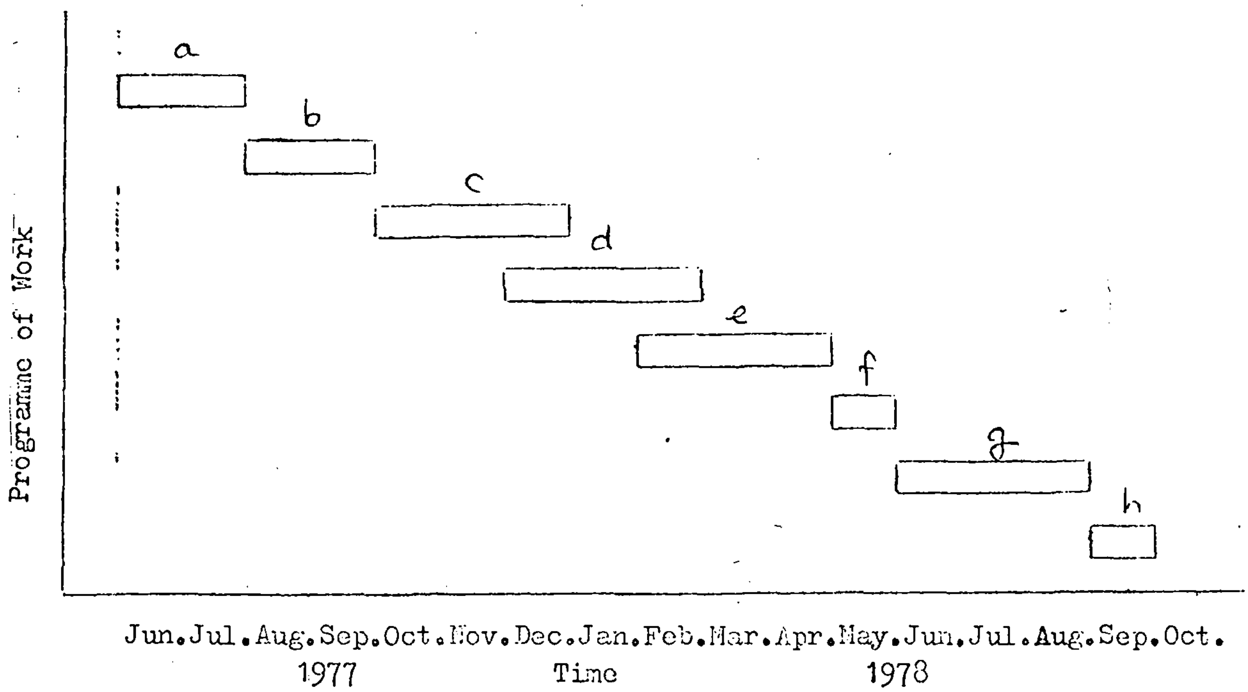
e) Improvement of handpump design based on the above data.

f) Field testing of the improved hamdpumps.

g) Monitoring and evaluation of hand pump performance

h) Report Preparation

The work schedule for the above programme is shown below:



7 Suggesting on testing of handpump under field operation

The handpump evaluation and testing for the improvement of handpump design in Thailand is conducted solely under field operation. There is no laboratory testing to confirm the result. It is therefore necessary to consider villagers behavior carefully besides technical components. There should be no attempt to change any behaviors of villagers during testing of handpump in order to have realistic data as close to local condition as much as possible. The followings are the behavior of villagers related to handpump operation and maintenance.

7.1 Handpump is one of playthings for children in communities.

7.2 The attitude and knowledge of villagers effect operation and maintenance of handpump. If villagers have good attitude towards handpump given by the government and considered it as community's property, knowing the value of clean water, handpump will be properly maintained.

In case villagers still feel that handpump belongs to the government and the government must take care of maintaining it, handpump will be broken easily and no one cares about it.

7.3 Village leaders such as Buddist monk and village headman play an important role in operation and maintenance of handpump. Most of them devote themselves for the community development and are respected by villagers. These people will take care handpump carefully. However some of them may lack of leadership ability, in this case it was found that the operation and maintenance of handpump is poor.

7.4 It was found that if handpump is the only water source, the villagers will give the priority to such a handpump and will operate it with special care. In case other sources are available, the priority of handpump will be decreased which will effect the operation and maintenance of handpump.

7.5 It was found that there is correlation between education background of villagers and maintenance of handpump. It shows that the villagers who have higher education background would understand the function of handpump and will be able to make minor repair and prventive maintenance better than those who have lower education background.

7.6 It was observed that handpump locates either in the temple or near the village headman's house would have better maintenance than located elsewhere.

7.7 The development programmes for community effect the operation and maintenance of handpump because all programmes require cooperation of village leaders. The village leader particulary village headman may not have time to pay attention to all programmes. If he does not understand the value of clean water, the maintenance of handpump even worse.

7.8 It is obvious that if the government operating agencies pay much attention to handpump operation and maintenance, the handpump performance will be good.

The above mentioned conditions will effect the testing and evaluation of handpumps's performance under field study. In running field testing, the factor of community leader, villager's education background, unity of villagers, tradition, custom, habit, handpump location and the priority of handpump in the village should be taken into account. It is proposed that the target villages should be left as naturally as possible. The following are some suggestions:-

a) There should be no attempt to prohibit or warning children not playing handpump.

b) The motivation programme and health education should not be launched during the testing of handpump.

c) There should be no promotion on leadership ability during the testing.

d) There should be no maintenance and adjustment of handpump during field testing by villagers or other volunteers. When it is damaged, the villagers should inform responsible government officials to inspect and making record and repair and replace it if necessary. It is suggested that a line of communication between villagers and responsible officials e.g. postcard be established.

8 Future Work Plan

a) The design of handpump has been finalized. The improved handpumps will be installed from 1979 onwards. The monitoring and evaluation of their performance under field operation will be conducted continuously as well as adjustment will be made if necessary.

b) It is expected that the evaluation and testing of handpump for shallow well undertaken by the Department of Health will be finalized soon. By that time, Thailand will have effective handpump which can be used under a wide variety of conditions.

c) The Asian Institute of Technology will conduct a research for a better and cheaper handpump. It is expected to be completed in one and a half years from now.

d) With regard to the maintenance of handpumps, each department uses its own approach. The Department of Mineral Resources takes all responsibility and assumes all costs for the maintenance and repair of its own installed handpumps. The system works successfully in keeping handpumps operate continuously, but the cost is a little bit high. With the increasing of the number of handpumps, the government may be inadequate to maintain all of them particularly in the remote areas. The Department of Health and ARD, therefore, introduce the new approach by training villagers to be caretakers for performing preventive maintenance and repair work on the upper part of handpump located above ground. The provincial mechanics will repair the lower part of handpumps located within the wells as well as supervise village caretakers. This approach will be monitored carefully and the result will be documented in due course.

e) It is planned to approach international and bilateral agencies to promote handpump manufacture so as to solve the problem of the availability of spare parts at the localities. It will be helpful if a manufacture of handpump could be established in the Northeastern region. It is calculated that more than 10,000 handpumps have already been installed in this region. With the present trend there will be more than 20,000 handpumps located in the Northeastern region by 1990.

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WORKSHOP

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HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

DEVELOPMENT INDIA MARK II PUMP: INDIA

12 August 1977

Development India Mark-II Pump

The purpose of this note is to record the salient points in the development of the India Mark-II, Village Deep Tube Well, Hand Pump. The design is now regarded as standard to the Government of India/UNICEF assisted, village water programme, where villages are being serviced by a deep tube well under the minimum needs programme.

UNICEF became directly involved in this project, to improve the village hand pump, in 1974, when surveys and feedback information indicated, that the locally produced and imported reciprocating hand pumps were unsuitable for the conditions found in the average village application.

For the sake of this record, it is not necessary to detail the problems, existent, within the programme in 74, save to say, that the situation was bordering on dissaster, and the drilling programme, UNICEF's prime responsibility, was in danger of being nullified, if a durable hand pump could not be supplied, as the end-result to the operation.

The following design criteria were established:-

1. The hand pump must have a trouble-free operational span, after installation, of at least one year, serving possibly a maximum of two-thousand beneficiaries, and drawing water from a static water level (SWL) of 150 ft. (Our average installation serves 500 beneficiaries and SWL would be approximately 60/70 ft).

2. The Pump Head, complete with 100 ft. of rising main, B class 1¼" BSP - connecting rod ½" and 2½" ID cylinder to cost less than US$ 200. (Appreciate that the programme calls for a total of 150,000 installations by the end of the next five year plan. Actual unit cost in production $ 182).

3. The design must be suited to local manufacture and not require any imported items or material.

4. Ease of operation to be a prime consideration, one adult must be able to operate the pump without undue effort at a SWL of 150 ft., if we are to encourage villagers away from their traditional unprotected water source.

5. The unit must be designed in such a way that maintenance can be effected by personnel having a minimum of engineering skill.

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6. The above ground mechanism, the pump head, must ensure hygienic standards; it's mounting to the platform must prevent any chance of pollution to the tubewell by surface water intrusion.

The voluntary agencies in Maharashtra, members of the AFARM Group, were aware of the problem within their own small scale village water programmes. They had, in fact, developed a simple design, based on the single pivot action, fabricated in steel; and in field reports, this "Jalna" unit was considered to be the most durable installation under village conditions. Further improvements were incorporated and from the "Jalna" the "Sholapur" design emerged. Adopting the "Sholapur" as a basis for our development, we established a working relationship with the AFARM Group and set up initial production. Our area of design improvement at this stage was concentrated on the handle mechanism, as field reports indicated that 70% of our breakdown factor involved failure of this component. To prove the principle, we developed an adaption of the single pivot handle, to the existing cast iron pedestal, to replace the original guided cast iron handle mechanism. The unit was commonly known as the "Sholapur Conversion Head" (Fig.2). Four hundred conversion heads were produced and fitted to existing installations throughout Maharashtra by the State Government Agency. With every conversion, cylinders were removed and reconditioned, platforms were constructed and drainage provided. Where previous cast iron pumps (Fig.1) failed within a period of one or two months, the conversion head, proved to be far more durable, as 80% were still operating without failure, at the end of a twelve months trial period. However, as expected, by eliminating the failure in the handle mechanism, and increasing the operational span of the complete unit, failures appeared in the cylinder, the connecting rods, the rising main and the pedestal mounting.

It must be appreciated that funds were limited, and we could see the necessity to convert the forty thousand cast iron units already installed in the programme areas. The original cast iron pedestal mounting to the casing pipe through a threaded flange could not survive the shock loading of extended operation now facilitated by the fitment of a conversion head. Once again, basing our development on a Sholapur concept, we designed a pedestal to be grouted into the concrete platform, completely independent of the casing for support. This pedestal has an internal diameter of 6 inches and fits over our standard 4" and 5" casing, forming a complete seal to any surface pollution. This three piece assembly (pedestal-water tank-head) is the India Mark-II Pump Head (Fig.3), now under mass production at Richardson and Cruddas, Madras (A Government of India Undertaking).

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Costing

Hand Pump complete with 100 ft. rising main, connecting rods and cylinder	Price	US $ 182
Pump Head only (Head-Water tank-spragged pedestal)	Price	US $ 63
Rising Main 1¼ BSP. B class GI Pipe To 100 ft (10' lengths)		US $ 71
Connecting Rod ½" Bright Round Bar (10' lengths)		US $ 20
Brass Cylinder Sholapur Type 2½ ID Ball Valves		US $ 28

Prices are ex-factory Richardson & Cruddas, Madras, and subject to change without notice.

Twelve pre-production India Mark-II pump heads were installed in the Coimbatore District of Tamil Nadu during the month of October 76. This area was selected because of its deep water table and high density population, to ensure that the test units would be exposed to the most extreme conditions. The workload would be two to three times our average factor. A period of nine months elapsed before a failure in a pump head was recorded; the unit in question was operating 19 hours per day serving in excess of one thousand people. The cylinder is at 150 ft. and the pump head is fitted with an extended Tee Bar handle, giving a twelve to one mechanical advantage. After nine months constant operation, the quadrant chain failed; with the shearing of a link pin. (There was some suspicion that the chain was faulty). The one year test period is now in its eleventh month and the above instance is the only failure recorded between the twelve pre-production units, that actually caused a unit to cease operation. Observations during the test have resulted in certain minor changes to the full production model. The appearance of fatigue cracks at the handle bottom stop, on some units, has been overcome by provision of two gussets to strengthen this area. The loosening of one unit in its mounting resulted in a modification to angle iron spragg legs for better bonding of the pedestal into the platform. The underside, opposite the handle, of the pedestal flange has been strengthened by heavier welding. Epoxy paint is now applied to the lower section of the handle head to ensure sealing against rust. The handle has now been standardised on an eight to one mechanical advantage, fabricated from 32 mm square bar. The handle, because of its solid construction, counter-balances to seventy feet, and facilitates ease of operation. Previous pumps in this area required upto five people to operate, however, now, under the same circumstances, the India Mark-II can be operated by a ten year old child. The pivot point

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of the handle is still to the standard,designed by Sholapur, and utilises two SKF 6204.Z. Ball Races locked into place by the axle pin. The bearings are grease packed, sealed, and should not require replacement for many years of operation.

The mass production of this unit must not be under-estimated, the design appears quite simple, however, there is a high order of accuracy required in its manufacture. Initially, we endeavoured to utilise the small scale manufacturers in the country, and establish production in each state, however, we found that basic engineering knowledge did not exist generally within this sector. To upgrade this sector, would in itself be a long term project, and our programme would suffer in the intervening period.

To establish a reliable production, we have placed orders with Richardson and Cruddas (A Government of India Undertaking) in Madras. They in turn have developed a production line utilising some sixteen jigs and fixtures, blanking dies, and backed by strict quality control inspection. Only in this way, can we ensure a 'first grade' item to the field.

With the production of a satisfactory heavy duty pump head, full concentration is now centred on developing a comparable standard cylinder. A project was established in Bangalore under a WHO Engineer to research hand pumps and develop a durable cylinder using plastic materials. Although we gleaned a lot of useful information from this experiment, and the Mechanical Engineering Research & Development Organization (MERADO), Madras, endeavoured to expand the concept, we eventually withdrew our support when we realised that it was impossible to control the quality of the plastic materials on a mass produced level. However, research is continuing on this cylinder with Richardson and Cruddas on an independent basis. MERADO also cooperated with us to complete the field testing of the pump head, and finali e a set of production drawings. The only obvious solution to the cylinder problem at this stage is to produce a first quality standard brass cylinder, possibly sleeved in cast iron to reduce the basic cost, fitted with a five web heavy duty piston and 1st quality leather buckets. We have, in fact, decided on a particular standard unit, and twelve pre-production cylinders and now ready for installation in the Coimbatore test area. It may be noted that various configurations of the positive displacement cylinder have been tested at Coimbatore, among them, the all plastic cylinder using nylon ball valves, nylon piston yoke and follower, neoprene buckets; the standard brass cylinder with rubber ball valves of various density,using a piston,machined from solid brass for added strength. All have been discarded in favour of the common design using flat or poppet valves and cast components, as this design proved, both in efficiency and durability, to be superior under

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the extreme conditions found in the test area. Because of a surge factor, we believe, the standard cylinder with poppet valves returns an efficiency in excess of 110% of the swept volume, as opposed to a cylinder using ball valves returning only the displacement of the swept volume. A ten per cent flow advantage is worth considering when one realises that a unit serving one thousand beneficiaries could be expected to deliver in the order of one and a half million gallons over a one year period. Similarly, it will work continuously for some 7000 hours and complete probably 17 million cycles, a far cry from the hand pump designed for one family as previously supplied to the programme.

New concepts are being developed overseas, and we will submit them to field testing, as and when they become available. A concept shortly to be tested in our application is the cylinder that allows for the removal of the piston and foot valve without the removal of the rising main. The added cost of providing 2" GI pipe instead of our standard 1¼" would be considerable, not to mention the installation factors. With the availability of High Density Polythylene (HDP) pipe in the country, we expect to test various configurations in the near future. (1) As a rising main to the removable piston foot valve concept (2) as an integral rising main and cylinder with a foot valve cemented in place, so that the piston can be removed separately for repair. (The wear factor HDP will be important, however, in theory the piston can operate in an unused area of the cylinder whenever it is replaced). This concept, if proved to be reasonably durable and by this we mean one year's trouble-free operation, could bring village maintenance within sight. In the meantime, we can only upgrade the simple positive displacement brass cylinder to a point where it matches the pump head in durability, by operating without failure for at least one year in the village.

Connecting rods, if manufactured to standard, are reasonably reliable. Our standard rod is ½" Bright Round Bar, with a coupling welded to one end and threaded to 50 mm depth. Providing the threads (std ½" BSW) are to recognized standards and lock-nuts are provided, the rods will not fail in operation.

The provision of a durable hand pump to the field is only the first step; equally important is the standard of the installation and the creation of a viable maintenance structure, to ensure that potable water is constantly available to the village. Our aim for a one year plus operational span, brings viable maintenance within the realms of possibility. Unlike the shallow well hand pump, where village level maintenance is possible, the deep well unit requires recovery equipment and tools to service the cylinder located at depths between 70 and 200 ft. below ground level. To this effect, we have organised mobile maintenance units at district level under government control. Sixty-two teams will be in the field by the end of 77, initially converting existing installations to the new

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standard. In excess of 5000 conversion heads have been fitted, however, government has agreed to use the complete pump head for all future conversions, and twenty thousand are now being produced and directed into the various states. With the completion of conversion, the team will cover routine maintenance, supported by block level and village level reporting. The two year time frame of the programme should see the introduction of a service exchange system, establishment of the district level workshop to recondition components, and if possible some concept of preventive maintenance. Service equipment is being developed to simplify the operation, and improve the safety factor. It is envisaged that the complete servicing of an installation by the mobile team, using service exchange components and improved methods, should be completed within one hour. All inclusive costing is expected to be in the region of twenty dollars (US$ 20) per unit per year, based on five hundred installations per mobile team. too technical an approach

Until the local bodies at block level are upgraded to cope with maintenance, or we can design a unit that they can maintain (ideally, we need a deep well hand pump that the village level can maintain) then there is no doubt in our minds that only a governmental structure at this point in time can successfully effect viable maintenance.

Ken McLeod
Project Officer
Water & Environmental Sanitation
UNICEF, New Delhi

DRAFT INDIAN STANDARD SPECIFICATION FOR

DEEPWELL HAND PUMPS

AS ADOPTED BY ADHOC PANEL ON 10. 3. 1978

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1. THE SCOPE

Specifies the technical requirements for hand pumps for lifting water from wells from a depth of not less than 8 m. Minimum depth at which the cylinder should be kept for satisfactory functioning of the pump is 25 m. The pump can be effectively worked for drawing water from depths upto 50 m.

2. UNITS AND TERMINILOGY

As given in IS: 5120-1977 "Technical Requirements for rotodynamic special purpose pumps", (first revision).

3. NOMENCLATURE

Figure 001 gives the installation details and the main components of a deep well handpump as under:

i)	Pump Head Assembly	:	The mechanism which is above the ground level and which operates the cylinder.
ii)	Cylinder	:	This contains plunger and valves, etc., which lifts the water upward in each stroke.
iii)	Connecting Rod	:	This provides linkage between pump head and cylinder.
iv)	Rising Pipe	:	This carries water from cylinder to the water chamber.

4. DIMENSIONS

4.1 Tables 1, 2 and 3 given below list the dimensions of the partes mainly used in connection with the deep well hand pump:

Description		Drawing No.
	TABLE 1 - PUMP HEAD ASSEMBLY	
	PUMP HEAD ASSMEBLY	001-1
A)	PUMP HEAD	002
i)	Pump head flange	002-1
ii)	Side plate	002-2
iii)	Back plate	002-3
iv)	Axle bush (right)	002-4
v)	Axle bush (left)	002-5
vi)	Guide bush	002-6
vii)	Bracket	002-7
viii)	Gusset plates	002-8
ix)	Front bottom end plate	002-9
x)	Front top end plate	002-10
xi)	Front cover	002-11
B)	HANDLE ASSEMBLY	003
i)	Handle bar	003-1
ii)	Bearing housing	003-2
iii)	Housing holder	003-3
iv)	Roller chain guide	003-4
v)	Chain coupling (forged)	003-5
vi)	Handle Axle	003-6
vii)	Spacer	003-7
viii)	Chain with coupling	003-8
C)	WATER TANK ASSEMBLY	004
i)	Tank pipe	004-1
ii)	Tank bottom flange	004-2
iii)	Tank top flange	004-3
iv)	Spout	004-4
D)	STAND ASSEMBLY	005
i)	Stand pipe	005-1
ii)	Stand flange	005-2
iii)	Leg	005-3
iv)	Gusset plate	005-4
v)	Collar	005-5
	TABLE 2 - CYLINDER ASSEMBLY	
	CYLINDER ASSEMBLY	006
i)	Plunger rod	006-1
ii)	Reducer cap	006-2
iii)	Sealing ring	006-3
iv)	Plunger yoke body	006-4
v)	Upper valve seat	006-5

vi)	Rubber seating	006-6
vii)	Upper valve guide	006-7
viii)	Pump Bucket	006-8
ix)	Spacer	006-9
x)	Follower	006-10
xi)	Cylinder	006-11
xii)	Brass liner	006-12
xiii)	Rubber seat retainer	006-13
xiv)	Rubber seating	006-14
xv)	Check valve guide	006-15
xvi)	Check valve seat	006-16

TABLE 3 - CONNECTING ROD - RISING MAIN

i)	Connecting rod	007
ii)	Galvanised rising main 32 mm (N.B.).	Shall conform to IS: 1239-1973 (Part I) Medium Series

5. GENERAL REQUIREMENTS

5.1 The material, tolerances etc., shall be as per the specifications in 4 above.

5.2 The bolts, nuts and washers used for assembly of hand pump shall conform to IS: 1367-1967 "Technical supply condition for threaded fasterners".

5.3 The chains shall conform to IS: 2403-1973 "Transmission steel roller chains and choin wheels".

5.4 The M.S. coupler welded in the storage tank shall be manufactured by forging and shall conform to Class II of IS: 2004-1970 "Carbon steel forgings for general engineering purposes".

5.5 The welding shall be done as per IS: 823-1964 "Code of Practice for use of metal arc welding for general construction in mild steel".

5.6 The CI castings shall conform to Grade 25 minimum of IS: 210-1970 "Grey iron castings (second revision)".

5.7 The G.M. castings shall conform to Class V of IS: 1458-1865 "Railway Bronze ingots and castins (revised)". The Brinell hardness shall be between 60 and 70.

5.8 The brass tube shall conform to Alloy No. 1 of IS: 407-1966 "Brass tubes for general purposes".

5.9 The connecting rods shall conform to Grade St. 42 of IS: 7270-1972 "Bright bars (standard quality)" and surface finish to Grade III of IS: 7270-1972 Bright bars (standard quality). The electro galvanising shall be done as per Grade III of IS: 1573-1973 "Electro plated coating for zinc on iron and steel".

5.10 The bearings shall meet the requirement of IS: 4025-1967 "Ball and roller bearings, gauging practice".

5.11 The steel plates/sheets, angle iron and square bars for fabrication of pump shall be as per St. 42 of IS: 226-1969 "Structural steel (Tendered quality)" or St. 42 of IS: 1079-1973 "Hot rolled carbon steel sheet and strip" and they shall be as tested quality.

5.12 The cold rolled sheets used for manufacture of cover for the Head Assembly shall conform to ordinary quality of IS: 513-1973 "Cold rolled carbon steel sheets".

5.13 The hot dip galvanising of storage tank shall be done as per IS: 4759-1968 "Hot dip zinc coatings on structural steel and other allied products".

5.14 All the bolts and nuts shall be electro-galvanised or zinc passivated.

5.15 The leather pump buckets shall conform to IS: 1273-1958 "Leather pump bucket made from chrome tanned leather".

6. PAINTING

6.1 The painting shall be done generally as specified under.

6.1.1 For surface preparation, one of the following methods shall be employed:

a) Sand Blasting

b) Phosphating to Class "C" of IS: 3618-1966 "Phosphate treatment of iron and steel for protection against corrosion".

6.1.2 All interior surfaces shall be given two coats of red oxide primer containing not less than 17% zinc chromats. The red oxide primer shall conform to IS: 2074-1962 "Ready mixed paint red oxide zinc chrome priming".

6.1.3 The exterior surfaces of MS/CI components shall be given the following treatment:

i) One coat of red oxide primer.

ii) One coat of surfacer.

iii) a) Two coats of synthetic enemel paint

or

b) One coat of harmertone finish paint of any colour to suit the requirement of the purchaser.

7 TESTING

7.1 SAMPLE SIZE

Ten percent of a production batch subject to a minimum of ten pumps shall be tested. If, however, the production batch is less than ten, the entire batch shall be tested.

7.2 Routine Test.

7.2.1 All the pumps shall be examined for finish and visual defects.

7.2.2 The dimensions of the assemblies shall be checked for conformity with the drawings.

7.2.3 The handle shall have reasonably good surface contact with the top and bottom portions of the bracket.

7.2.4 Coupler welding is to be checked for the verticality. Plain round mandrel of 300 mm length is to be screwed to the water chamber coupling and verticality to be checked with the help of a trisquare. For the entire length of the mandrel a maximum of 1 mm tilt may be allowed.

7.2.5 The flanges shall be reasonably flat to provide proper matching.

7.2.6 Alignment of the rod with respect to the guide bush shall be checked as follows: One 100 mm long 12 mm dia rod shall be fitted to coupler. The handle shall be raised and lowered gently. The rod shall pass through the guide bush freely.

7.2.7 The stroke of the pump shall be 100 mm ± 3 mm.

7.2.8 The connecting and plunger rods shall be examined for their straightness and the formation of the threads. The couplers shall also be subjected to similar checks.

7.3 TYPE TESTS

Two complete pumps out of the batch selected shall be subjected to the following tests in addition to the routine tests in 7.2 above.

7.3.1 The pumps and cylinder shall be dismantled and all the components shall be checked in detail for dimensions as per the drawings.

7.3.2 Performance of the pump shall be checked after placing the cylinder at 30 m below the ground level in a bore well the yield of which shall not be less than 20 lpm. The pump shall be primed and the tests shall start after there is continuous flow of water through the spout. The water shall then be collected in a container for forty continuous strokes. The discharge thus measured shall not be less than 12.5 l.

8. CRITERIA FOR CONFORMITY

The batch shall be considered as conforming to the requirements of the specification if the conditions given under 7.2 and 7.3 are satisfied.

9. GUARANTEE

The pump accessories shall be guaranteed for 12 months form the date of installation or 18 months from the date of supply whichever is earlier against bad workmanship/ bad material. The life of leather/rubber components shall however be guaranteed for only 6 months from the date of supply.

10. DESIGNATION

The pumps shall be designated by nominal size, stroke and number of this standard.

Example:

Deep well hand pump of N.B. size 32 mm having 100 mm stroke conforming to this standard shall be designated thus:

Deep well hand pump: 32 mm N.B. Stroke 100 mm.

IS ....

11. PACKING

Unless otherwise agreed to between the manufaturer and the purchaser, the packing shall be as under:

11.1 The cylinder shall be packed in wooden cases and nett weight of each case shall net exceed 50 kgs.

11.2 The pump head assembly shall be normally wrapped in paper and straw/woodwool to withstand road transit.

11.3 The connecting rods shall be packed in bundles of 30 rods. Each bundle shall be wrapped with two layers of hessian cloth.

12. MARKING

The pump head and cylinder shall be marked with manufacturer's name/trade mark serial number.

N.B. THE HOLE SIZE 13.5 mm AS SHOWN IN THE DRAWINGS SHALL BE ALTERED TO 14 mm AS RECOMMENDED FOR MEDIUM FIT UNDER I.S.

Water Supply

RID 163/5000/78 - 823889° - 3

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B.P. 8

WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

THE BANGALORE PUMP: INDIA

WORLD HEALTH ORGANIZATION

ORGANISATION MONDIALE DE LA SANTE

SOUTH-EAST ASIA REGION

SEA/Env.San./168
2 March 1976
RESTRICTED

THE BANGALORE PUMP

REPORT PREPARED FOR

THE GOVERNMENT OF INDIA

BY

SOUTH-EAST ASIA REGIONAL OFFICE

WORLD HEALTH ORGANIZATION

NEW DELHI, INDIA

1976

WHO Project: IND BSM 002

CONTENTS

I. INTRODUCTION

This document is based on reports emanating from the work carried out in Bangalore, Karnataka State, India, in 1973 to 1975 under the Government of India project "Village Water Supply". This project has received and continues to receive financial and technical assistance from UNICEF and WHO.

Within this national project, of which the objectives are primarily to provide safe drinking water to rural communities, a sub-project was specifically formulated to develop an improved deep-well handpump suitable for community use, and to investigate ways and means of reducing the cost of such a pump. A WHO sanitary engineer, Mr V.J. Emmanuel, acted as project co-ordinator and chief research officer, and he was assisted by national engineers deputed by the Chief Engineer, Minor Irrigation and Public Health Engineering Department, Government of Karnataka. Additional assistance was given in the collection, compilation and analysis of statistical data. The Mechanical Engineering Research and Development Organization, Madras, collaborated in the project, prepared certain working drawings, produced the prototype cylinder assemblies and executed the construction of the accelerated testing device. Support and financial assistance were provided by UNICEF. Annex 1 lists by name the various persons who have contributed directly to the project.

The data summarized in this report are taken principally from the "Report on Deep-Well Handpump Development: Project IND BSM 002", prepared by Mr Emmanuel. This draft report is in four volumes. Volume One identifies the problem, lays down the plan of investigation, analyses the statistical data, describes the development of the pump and analyses the results of the tests. Volume Two consists of detailed plans of all the pumps studied; Volume Three contains the statistical data collected in field surveys. The detailed drawings of the improved cylinder assemblies, improved hand-operated pump head and foot-operated pump head make up Volume Four. Volume One was prepared in eighteen copies for limited distribution to Chief Engineers of States in India,who have considerable requirements for deep-well handpumps,so that they could provide comments; copies were also provided to UNICEF. Very few copies of Volumes Two and Three were prepared, but they are available with the WHO Regional Office in New Delhi, India, for purposes of reference. Volume Four was distributed to a limited number of persons,but copies of selected parts were made available through UNICEF to a number of potential manufacturers in India. These volumes have not received general clearance from the Government of India, but it may be possible to distribute certain extracts to serious enquirers.

As a considerable part of the time spent on the project involved the study and evaluation of the different existing deep-well handpumps available, it was evident that the good features of several types would need to be combined in an improved version. As it turned out, the design of a cylinder produced by the project depended very little on existing models, as,for the improved cylinder,the use of plastic components was adopted and all parts in brass or machined metal were eliminated. However, for the pump head, the single pivot chain-link arrangement, first devised in India by the Jalna pump manufacturers and subsequently modified in the Sholapur pump, was adopted, some modifications being made to bearings and the roller chain. The origin of this design is recognized and acknowledged as being a considerable advance on older systems.

In recognition of the assistance given by the Government of Karnataka, the name "the Bangalore Pump" has been selected to designate the improved handpump system described in this document.

II. BACKGROUND

The need to develop a suitable deep-well handpump for use in the national, drilled-well, rural water supply programme become apparent early in the operation of the WHO/UNICEF assisted village water supply project. Starting in 1954, when the Government of India initiated its National Water Supply and Sanitation Programme with the objective of providing safe water supply and basic sanitation facilities to urban and rural communities of the country, assistance was provided to State Governments to take initial steps to identify the problems and draw up a phased programme of investigation, design and construction.

Since the beginning of the Fourth Five-Year Plan (1969-1974), the Government of India has placed increasingly greater emphasis on the need to provide safe water supplies - in the first instance, to all rural communities in the country. The concept of a safe water supply in the hard-rock areas had been to provide a piped community water supply, the quality of the water meeting accepted national standards. It was found, however, that the cost of constructing piped water supplies to all rural communities in India would be of such magnitude as to make it impractical to invest so much money in a relatively short period purely as a social service. A change of strategy was consequently required.

It was realized that meeting the basic water needs in rural communities would have to depend on the exploitation of ground water, as, in many areas, surface water sources were not available, were only seasonal or were grossly polluted. The development of ground water sources presented a problem in that most of the areas with acute water scarcity were underlain by "hard rock", thus making excavation of wells by hand practically impossible.

It had been feasible for many years to drill wells in such hard-rock areas using percussion or cable-tool rigs. Generally these methods required three to six months per well, depending on the nature of the rock and the depths drilled. Since these wells had to depend on the water contained in the faults and fissures in the rock, there was an element of uncertainty, and the success rate was sometimes of the order of only 30 to 40 per cent. Such a method was thus expensive and unsuited to a country-wide programme. The two difficulties faced were therefore: (a) the location of fissures containing the water, and (b) the drilling of holes to the depth required in a reasonably short time.

WHO and UNICEF, agreeing to increase substantially their technical and financial support to the Government for implementation of the rural water supply programme, signed a plan of operation with the Government in October 1970. Under this agreement UNICEF was to provide the equipment necessary for geophysical exploration of ground-water, special drilling equipment of the pneumatic hammer type and all the necessary ancillary equipment such as air compressors, laboratory field kits, etc., and transportation; in the past few years, the efficacy of using drill rigs of this type, capable of drilling wells in two to three days, had been demonstrated in connexion with drought relief programmes. WHO agreed to provide technical assistance to help the States develop their village water supply programmes based on drilled wells. Criteria for the selection of villages were: (a) preliminary surveys confirming the availability of water at accessible depth; (b) a chronic water scarcity or a high incidence of water-related disease in the area; (c) suitable locally manufactured rigs not being readily available, and (d) hand-dug wells being unable to meet the need.

The programme benefiting from this assistance has been in operation since mid-1970 and now involves ten States with extensive hard-rock areas. Several thousand wells have been drilled and put to use. In keeping with the Government's strategy of meeting the basic water needs of rural communities, the drilled wells were provided with deep-well handpumps, and by virtue of the depth from which water was drawn, it was expected that these wells would supply safe water at the pump.

Although considerable attention was paid to the technological aspects of the location of the wells and the drilling, insufficient thought was given to the means of extracting the water from the drilled wells, as it was assumed that the indigenously manufactured deep-well handpumps would be satisfactory for use in the villages. When the programme had been in operation for some time, however, it was found, to the consternation of those who were involved in the programme, that this handpump, which had originally been developed for household use, could not stand up to the wear and tear of use by a community.

It had been intended initially that one well and one handpump would be provided for about 250 persons. Subsequent studies showed, however, that, in practice, a single pump was sometimes used by as many as 500 to 1000. This situation arose from the Government's policy, which was revised during drought conditions to give priority to the drilling of one well in each stricken village irrespective of the population. The resulting strenuous use to which the pumps were put caused frequent breakdowns and considerable hardship, forcing people to travel long distances for water or to revert to other, polluted sources nearer at hand. Such a situation obviously defeated the objectives of the programme.

After about a year of operation, the percentage of pumps out of order at any given time rose to an alarming level. Several reasons can be given for the failure of the pumps, such as incorrect installation, inadequate (or non-existent) maintenance and lack of well-defined responsibility for carrying out repairs, but it became apparent that the one outstanding reason was the fact that the deep-well handpumps manufactured in India were not designed for the sort of duty to which they were being put. WHO and UNICEF were concerned lest the massive investment in expensive geophysical and drilling equipment be wasted, as all of the efforts would have been in vain unless the delivery of the water could be improved. It became apparent that the entire programme depended on the handpumps' being kept in working condition.

The State Governments themselves were confronted with technical and procedural difficulties in trying to choose one of the pumps available on the local market. These difficulties stemmed from the fact that there is no standard specification in India (or elsewhere in the world) for a deep-well handpump, and that the governmental tender procedure is cumbersome and does not lend itself readily to the purchase of the best equipment on the market; price is usually the overriding factor.

Thus the urgent need to develop a deep-well handpump suitable for use in the village water supply programme, as well as to standardize the pumps and to establish satisfactory testing procedures and facilities, was already apparent to the State Governments. At this point, the Government of Karnataka suggested that WHO and UNICEF set up a sub-project to look into this matter. When the State Government put forward this request, a WHO sanitary engineer was already working in Bangalore, and this study was therefore started with the State Government's agreeing to provide local staff and meet local expenses, WHO to provide the sanitary engineer's services to manage the project, and UNICEF to contribute up to $10 000 for the necessary materials and equipment.

III. PRELIMINARY ACTIVITIES

1 Review of Handpump Development

Before a new pump could be designed, a considerable amount of preliminary work was required: to study the existing reports on the subject; to make field observations of the problems encountered and of patterns of usage; to study the available indigenously made and imported pumps in order to identify strong and weak points in design and construction, and to analyse the data collected for determination of design criteria.

A study of the literature reveals that the reciprocating pump was invented by a certain Ctesibius in 275 BC[1], and that in the intervening period of some 2250 years, little has been done to improve it. This is particularly true in respect of the hand-operated reciprocating pump, which has found less and less use with the advent of the centrifugal pump, internal combustion engine and electrical energy. As industrialized countries have thus virtually lost interest in this type of device, there has not been much published on the subject, and it is now left to the larger developing countries, where there is still considerable need for such a pump for community use, to pursue its development.

The most significant contribution to the improvement of the deep-well handpump which has so far been seen has been the work done by the Batelle Memorial Institute, Ohio, for the U.S. Agency for International Development. This work is described in two reports, dated September 1967 and August 1970.[2,3] In these reports, the problems in connexion with the deep-well handpump have been clearly identified and design principles laid down. The studies made covered wear and tear on components using various types of cylinders, and identification of the reasons for the differences in performance. The project also experimented with plastic coatings on the cylinder walls and with synthetic cup washers. The information collected in this study in respect of the metallurgical aspects, particularly of the cast-iron components, is adequate, and no additional investigation is necessary. It was felt, however, that the reports did not contain adequate data on patterns of use from which design criteria might be derived and that this question needed further field investigation. Further, not much attention had been given to the improvement of valve performance. While the use of better materials in the flap valves was considered, the use of balls in the valves also was discussed, and the comment made that American manufacturers do not recommend ball valves because of the "distortion of the valve seats caused by the pounding of the heavy ball checks".

A further report of some relevance was the one prepared for WHO by the All-India Institute of Hygiene and Public Health, Calcutta,[4] in 1973. Although this report dealt with shallow-well handpumps for community

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[1]Eubank, The Story of the Pump and Its Relatives, 1972.

[2]Frink, D.W. and Fannon, R.D. Final Report on the Development of a Water Pump for Underdeveloped Countries, Batelle Memorial Institute, Ohio, 1967.

[3]Fannon, R.D. and Frink, D.W. Final Report on the Continued Development and Field Evaluation of the AID Hand Operated Water Pump Batelle Memorial Institute, Ohio, 1970.

[4]Majumdar, N. and Sen Gupta, J.N. Final Report on Study of Handpump (Shallow Tubewell) for WHO/UNICEF-assisted Projects and Other Rural Water Supplies, AIIHPH, Calcutta, 1973.

use, defects similar to those appearing in the deep-well handpump were found. This report, supported by work done at the Central Mechanical Engineering Research Institute in Durgapur, corroborates the findings about metallurgical aspects which were described in the Batelle studies.

2 Field Study

The initial purpose of the field study carried out was to obtain information on the way the pumps were being used, the principle defects and the requirements of the users. It was hoped that in the study it would be possible to collect data on frequency of stroke, length of stroke and diameter of cylinder, which would be useful as a basis for design.

A sample size of 100 pumps and 20 users per pump was decided on as being probably adequate to give representative information. All pumps had similar pump heads, and the cylinders were 2-1/2", 3" and 4" in diameter, the 3" size being the most common.

During the collection of field data, some modifications were made to the plan for the surveys, as other factors appeared to have some bearing on the investigation. (For example, the height of the individual user in relation to the height of the pump-handle fulcrum appeared to have a bearing on the efficiency of the operation of the pump.) An attempt was also made to measure efficiency, as it became evident that to operate different makes of pump a varying degree of effort was necessary.

Data collection was carried out for the field study over a one-month period, with the help of four junior engineers and twenty students employed by the State Government of Karnataka. Some delay was experienced through the need to repair a number of pumps which were out of order. The following data were collected:

(1) Number of users per pump (from 0500 to 2000 hours). Classified as men, women and children.

(2) Average length of stroke. Top and bottom of each stroke performed by the user in filling his pot of water measured, using a device attached to the pump rod.

(3) Frequency of stroke. Number of strokes performed by the user to fill the pot counted by means of a stroke counter fitted to the pump rod. The time taken checked with two stop-watches and the stroke frequency calculated.

(4) Rate of pumping. Quantity of water pumped in a given time measured.

(5) Height of user. Recorded for each user.

(6) Overall efficiency. An attempt made with each pump to make a comparison of efficiency by recording the dead weight necessary, when applied at 0.70m from the handle fulcrum, to move the handle through 0.25m in five seconds.

(7) Well data

(a) static water level in well
(b) make of pump

(c) diameter of cylinder
(d) depth at which cylinder was installed
(e) size of riser pipe.

In addition to these tests carried out on a sample of pumps and users, observations were made on the general problems being experienced in the field and on the cause of pump breakdowns. It was found that most of the breakdowns seemed to occur in the pump head. Wear and tear were made worse by the excessive tolerances at all the working or moving points. (This factor is dealt with further in Section 4 below.) It is apparent that the pump head must be a robust piece of equipment to be able to take the continuous daily use and abuse to which it is subjected in community life. At least for the time being, the inadequacy of pump maintenance organization must be accepted, and equipment should be designed so that it can operate with reasonable efficiency with a minimum of maintenance.

Cylinder problems arise mainly when cup or bucket washers wear out. Excessive wear and tear on the leather washers may be attributed to poor surface of the cylinder wall, incorrect treatment of the leather or tilting of the piston assembly in the cylinder. The leather washers examined do not conform to the standard specification of the Indian Standards Institution for these items, which states that the leather should be impregnated with wax which has a 60°C melting point. Such wax impregnation will produce a leather washer which is not water-absorbent and which will maintain its form and suppleness, wet or dry. The leather cup washers examined were water-soaked and pressure formed in hand presses. They absorb water and swell, adding to the friction and are too stiff when dry but too soft when wet.

Another serious defect in the leather washers is that they are not of uniform diameter, and the hole punched in the floor of the cup, to enable it to be mounted over the follower, is often eccentric, sometimes by as much as 1.5 mm.

Lack of guides for the connecting rod also causes damage to the cups. In operation, the piston assembly carrying the cup washers tilts in the cylinder, resulting in greater friction and uneven wear.

Pumps also fail through disconnexion of the long connecting rod within the rising pipe. The induced torque from the whip of the rod, combined with the impact at the end of each stroke, tends to unscrew a connecting rod at one of the connectors after some time. Such failure can occur even when the connectors are "locked" satisfactorily at the time of installation. The provision of guides at intermediate points on the connecting rod and at the top of the cylinder should overcome this problem.

Most Indian pump manufacturers have adopted a pump head design which uses guide pillars and a guide to prevent lateral thrust on the piston rod when the handle is operated over a long stroke. The fulcrum link compensates for this movement. (See Drawings Nos. 1 and 2, pp.9-10, showing typical handpumps and the names of the different parts. Plates 7 and 8 on p.16 may also be helpful.) It was observed in the field that this guide system produced considerable friction owing to poor accuracy in manufacture and that, in any case, the double-hinged fulcrum link could compensate for this thrust. As a check, the guide was removed on a few pumps, and the operation proved to be much smoother and to require less force. It is of interest that a recently manufactured pump head from the USA, which was received through UNICEF, no longer incorporates the guide and pillars, which were supplied with earlier models.

It was observed that the energy level required to operate a handpump was not excessive when the cylinder was no lower than 30 meters below ground level and the static water level in the well about 10 to 12 meters below ground level. At greater depths the pumps were difficult to operate, and where the pumps had to take this higher stress, applied to lift the water a greater distance, early failure often occurred. This observation was particularly true of the single-pivot, chain-link type of pump head (see Drawing No.2, p.10).

While most pump heads of the conventional design are of the same height, they are installed on foundations of different heights. When the pump handle is released at the bottom of its stroke, it rises sharply upwards to its highest position because of the dead weight of the connecting rod string. Apart from the potential accident hazard, it was found that often this top position left the handle beyond the reach of children. It seemed in the study that for each user there were two heights of pump handle which were comfortable, (a) when the handle was high enough for the user to apply body weight and (b) in the low position, when a "stiff-arm" operation could be used. Plates 1, 2 and 3 (p.11) show settings of the pump handle as high, low and intermediate.

In the course of the field study many faulty installations were noticed. As examples, Plates 4 and 5 (p.12) show where the incorrect mounting of the pump led to early breakdown by not having a solid foundation to which the pump was bolted. In both cases the foundation is crumbling, and there is no apron or leadaway drain for excess spill water. In such cases, the excessive movement of the pump, when used, contributes to early wearing out of parts. A further problem is shown in Plate 6 (p.12), which indicates a pump located in an insanitary position, which may create a health hazard.

3 Analysis of Field Study Observations

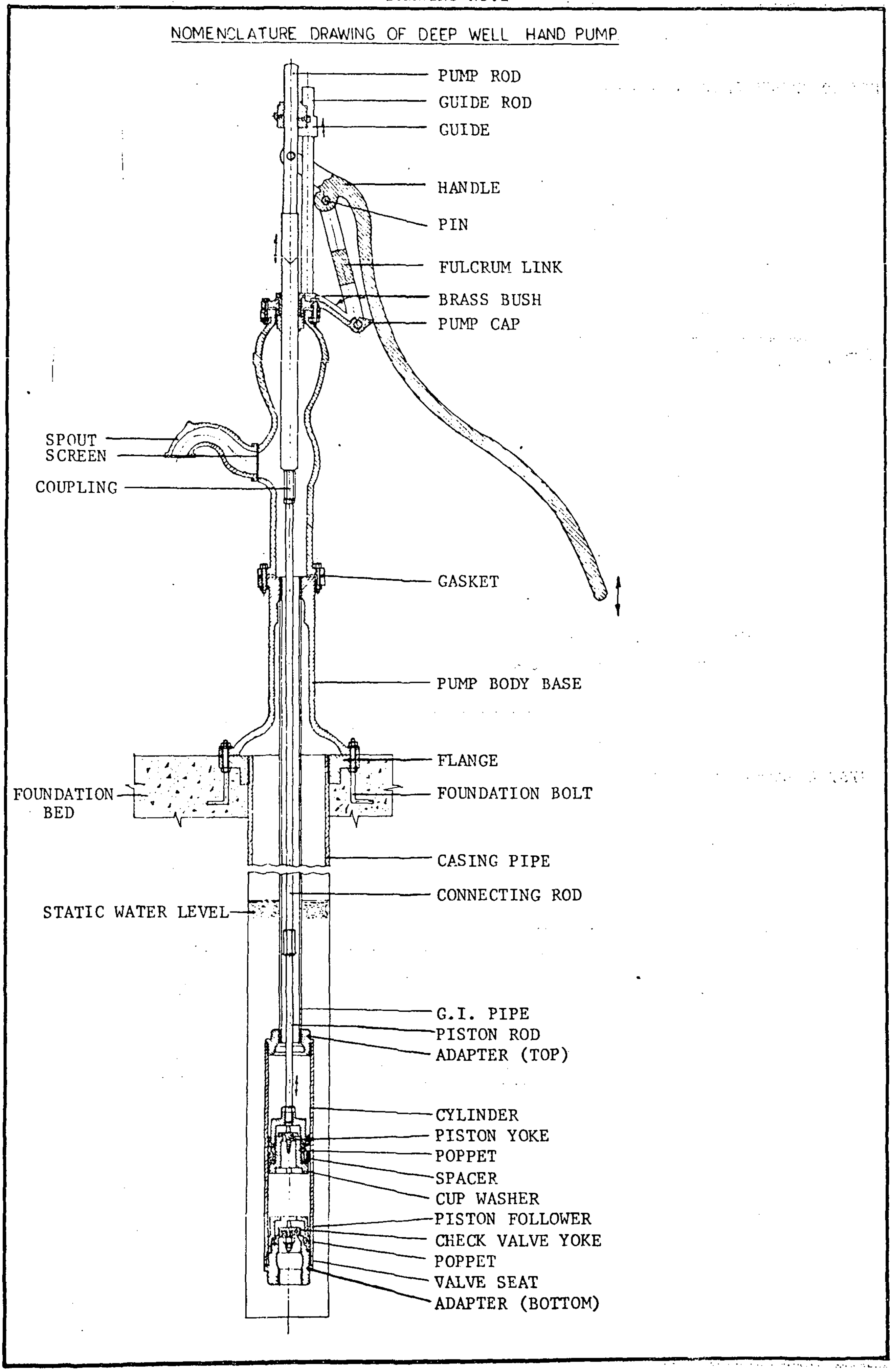
3.1 Height of user

The heights of 2000 users of handpumps were recorded. As was to be expected, there was considerable variation, between 926 mm and 1875 mm, with a mean value of 1512 mm. Although an attempt was made through an additional controlled experiment to establish a statistical relationship between the height of the user, the height of the pump fulcrum and the efficiency of the pump, this was not conclusive. It seemed that there was a human compensation factor which came into play, which made a purely statistical analysis unrealistic.

3.2 Stroke length

For the total number of observations, the average stroke length recorded was 114 mm. Some variation was measured in the mean stroke length

DRAWING No.1


NOMENCLATURE DRAWING OF DEEP WELL HAND PUMP
PUMP ROD
GUIDE ROD
GUIDE
HANDLE
PIN
FULCRUM LINK
BRASS BUSH
PUMP CAP
SPOUT
SCREEN
COUPLING
GASKET
PUMP BODY BASE
FLANGE
FOUNDATION BED
FOUNDATION BOLT
CASING PIPE
CONNECTING ROD
STATIC WATER LEVEL
G.I. PIPE
PISTON ROD
ADAPTER (TOP)
CYLINDER
PISTON YOKE
POPPET
SPACER
CUP WASHER
PISTON FOLLOWER
CHECK VALVE YOKE
POPPET
VALVE SEAT
ADAPTER (BOTTOM)

DRAWING No.2

NOMENCLATURE DRAWING OF DEEP WELL HAND PUMP.

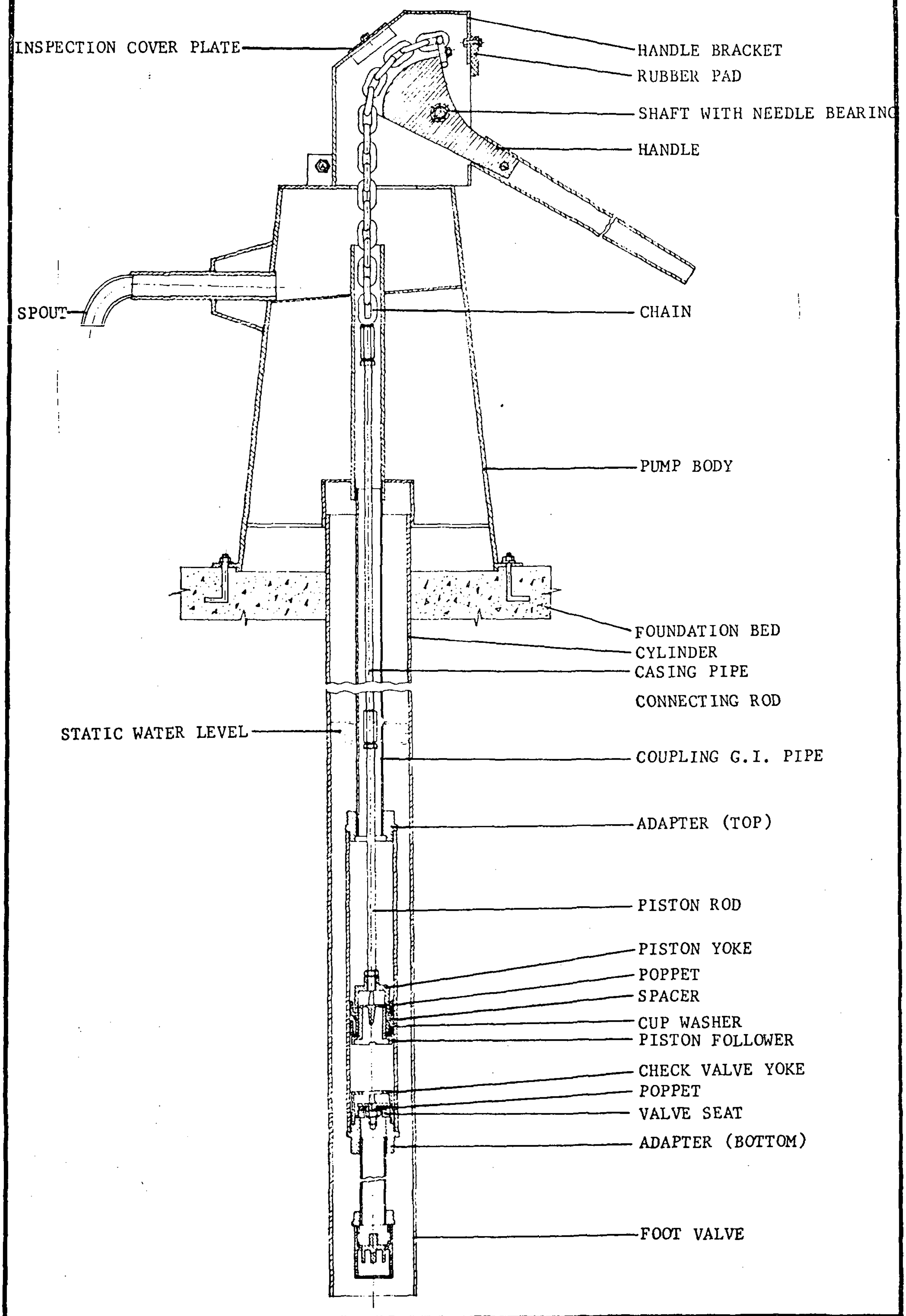


Plate 1

Pump handle with high setting.

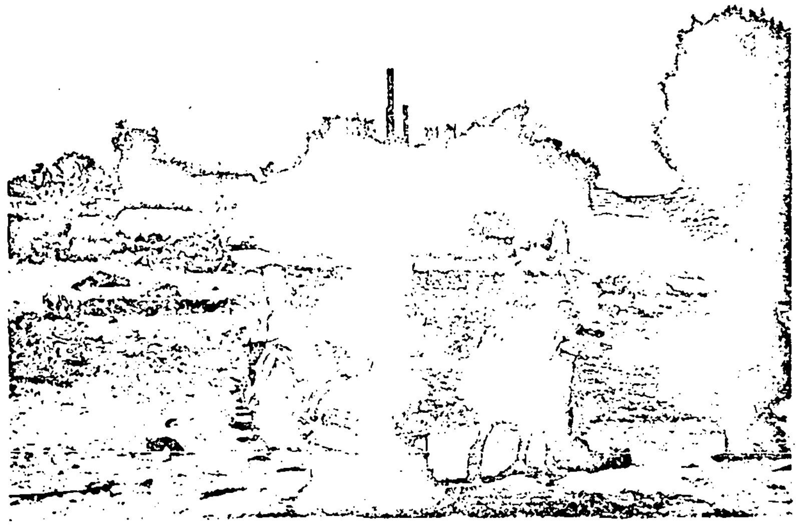


Plate 2

Pump handle with low setting.

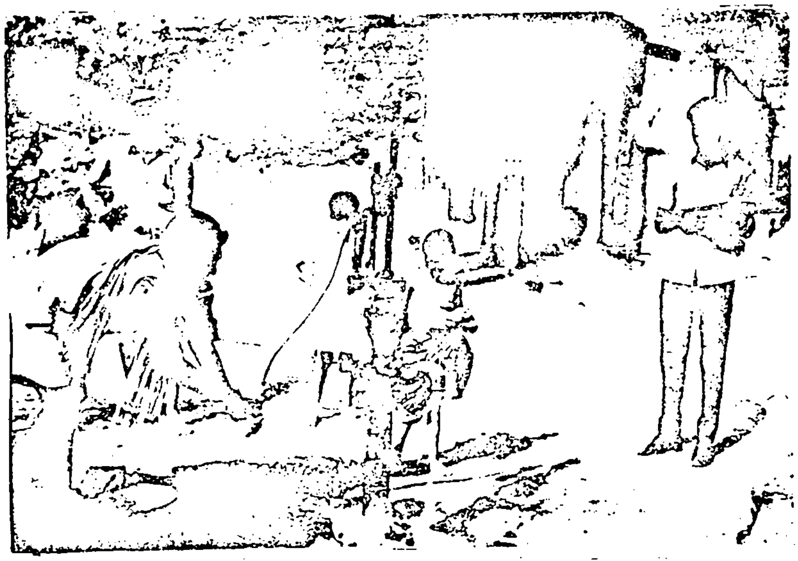


Plate 3

Pump handle with intermediate setting.

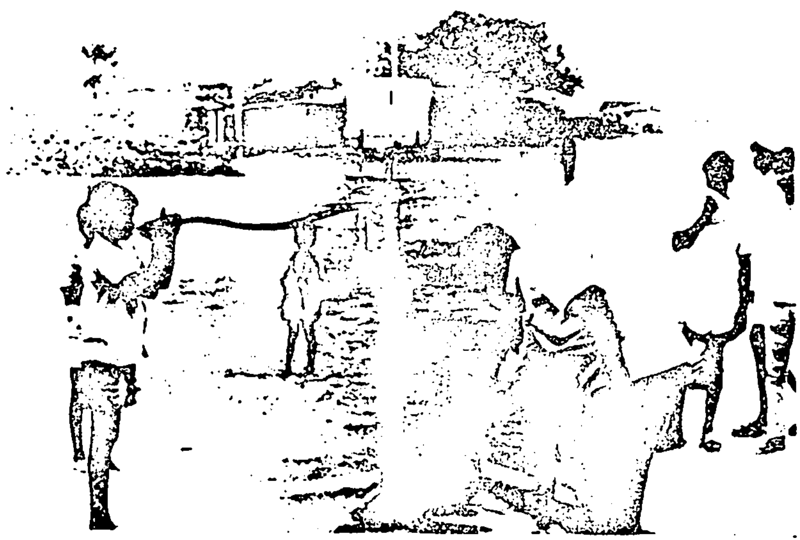


Plate 4

Poor pump foundation without apron and drain to soakage pit.

Plate 5

Crumbling pump foundation without bolts. No apron or drain.

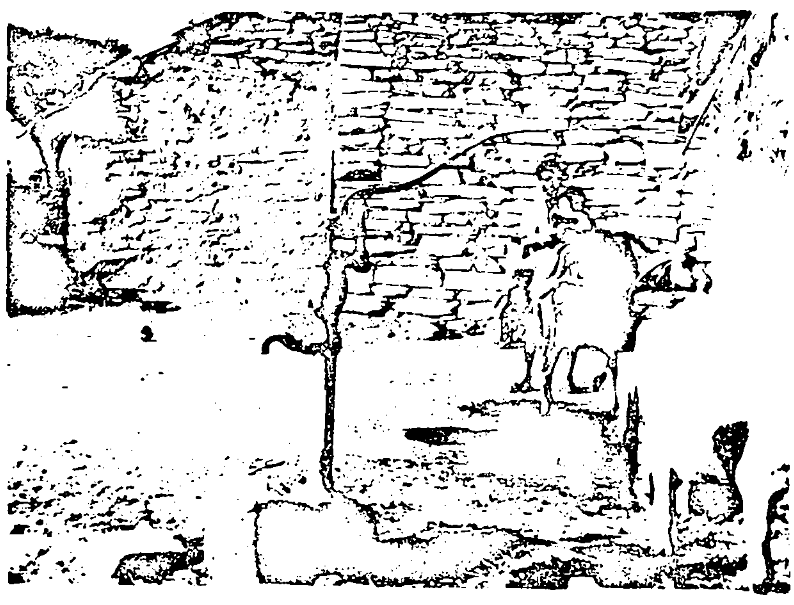


Plate 6

Insanitary location for well surrounded by animal dung.

according to the different cylinder size: for the cylinders of 2-1/2" diameter, the length recorded was 117 mm; for 3" diameter cylinders it was 116 mm, and for 4" diameter cylinders it was 101 mm. This indicates a further element of human compensation in reducing the length of stroke for the greater load to be lifted.

3.3 Stroke frequency

This was measured by counting the number of strokes taken for the pot to be filled and by timing this operation. Here again there was a natural tendency for the user to match his energy capacity to the rate of pumping, since mean frequencies for pump cylinders of 2-1/2", 3" and 4" diameter were found to be 64.0, 58.1 and 47.9 strokes per minute.

3.4 Time of pumping

The time of pumping ranged between 10 and 72.5 seconds. Averages for the different cylinder sizes were 26.0, 26.0 and 23.4 seconds for the 2-1/2", 3" and 4" cylinders respectively. The distribution tended to have a positive skew.

3.5 Pump output

The water delivered by the pump for each user was recorded, together with the time of pumping. The output was calculated for each of the three sizes of cylinder and was found to average 26.9, 30.0 and 34.8 litres per minute for the 2-1/2", 3" and 4" cylinders respectively. On this basis, considering the time of pumping calculated earlier, the average quantity of water drawn by villagers is about 13 litres. It is, perhaps, interesting to note that to draw as much water from a tap in the high-pressure area in Bangalore city would take more than twice as long.

3.6 Classification of pump users

It is generally believed that women and children make up the main body of users, and that men would not be expected to constitute more than 10%. According to the data collected between the hours 0500 and 2000 in this study, however, women made up 37.4%, children 34.8% and men 27.8%. The number of persons using the pump per day ranged from below 240 to above 1340, with an average of 683, for the 100 pumps studied.

3.7 Design criteria derived from the survey

The basic design criteria and conclusions derived from the field survey are as follows:

(1) It is obviously impossible to select a pump height which will suit the entire range of users. The most suitable height of pump for the average-size users was selected as 1.00 m, exclusive of the height of the foundation, which should be limited to 100 mm above platform level.

(2) Since there is undoubtedly an element of comfort involved in the relative height of the user and the pump, if one could evolve a pump head of which the operation was independent of the individual's stature,

this would seem to be an advantage. From this reasoning, the concept of a foot-operated pump head was derived.

(3) The most advantageous size of cylinder is 2-1/2" diameter. This conclusion is based on the following considerations:

(a) the smaller diameter cylinder has a strong cost advantage;

(b) this size appears to have the highest efficiency;

(c) the output is better matched to the energy which the user can supply, and

(d) field observations have shown that pumps with the smaller cylinders require less frequent maintenance.

(4) The stroke length should be about 114 mm (equivalent to 4-1/2").

(5) The stroke frequency for design purposes is taken as 50 strokes per minute (likely to be somewhat higher in practice, but this is not of particular consequence in the design of the pump).

Table 1. Summary of Analysis of Field Data

Item	Unit	Cylinder diam.			
		2-1/2"	3"	4"	Total
Number examined	No.	13	65	22	100
Average stroke length	mm	117	116	101	114
Average stroke frequency	Strokes/ minute	64.0	58.1	47.9	56.6
Average time of pumping	Secs.	26.0	26.0	23.4	25.4
Average collected output	l/min.	29.9	30.0	34.8	30.6

4 Workshop Study

4.1 Preparation

The workshop study was carried out on a series of sample pumps purchased and provided by UNICEF. It consisted of two parts. As a first stage, detailed drawings were made of the pumps and cylinders and of each component. (These, comprising nearly 200 sheets, are compiled in Volume Two of Mr Emmanual's report.) The second part of the study consisted of a critical analysis of the design and manufacture of available pump heads and cylinders.

The conventional pump head is shown in Drawing No.1 (p.9), which also gives the names of the component parts. This pump head has a cast-iron body, and the verticality of the pump-rod is maintained by a guide-pillar and guide arrangement. Drawing No. 2 (p.10) shows the components of a single-pivot chain-link type of pump head such as developed in India under the names"Jalna", "Jalvad" and "Sholapur". This type of pump has a body fabricated of mild steel sheet, and the pump handle is linked to the connecting rod by means of a roller chain which rides over a quadrant.

Typical examples of these pump heads are shown in Plates 7 & 8, and an exploded view of typical cylinder components is given in Plate 9 (see p.16).

4.2 Conventional pump head

The following defects were frequently recorded for pump heads similar to the one shown in Drawing No. 1 and Plate No. 7. (Plates No. 10 and 11 show some of the defects described):

(1) The moving parts are poorly matched. Tolerances and fits are excessive, allowing the handle and fulcrum link to rock sideways.

(2) The guide pillars are not fitted true to vertical. They are not locked in the pump head cap and therefore tend to work loose.

(3) The holes in the guide have too high a tolerance, with the result that the guide tends to tilt and foul the pillars.

(4) Some makes of pump have a forged 1" square section handle between the linkage with the piston rod and the fulcrum link. The fork at the point of linkage with the piston rod is formed by welding pieces of mild steel flats on either side of the square section. These strips are then spread to accommodate the pump rod, but the technique tends to distort the bearings and to produce uneven wear.

(5) The pivot pins are not truly horizontal in their bearing housings.

(6) The guide is held in position on the piston rod by a 6 mm set screw, which often works loose, allowing the guide to ride up and down the pillars, carried by the linkage point of the handle.

(7) The spout is shaped like an inverted P-trap to prevent the introduction of sand and pebbles by children. A piece of mesh screen is also included to protect the pump. The design is not effective in many cases, and sand, etc., can still be pushed inside until the spout is choked. Further, the off-set of the spout is often inadequate, causing spillage of water.

(8) The holes provided in the flanged base are generally for 10 mm diameter foundation bolts, which are not large enough.

(9) One of the imported pumps has a weak point where the pump rod joins the connecting rod. Failure at this point has been observed.

(10) In several models of one imported pump head, the nipple provided inside the pump body, to which the riser pipe is connected, has fractured. Since this nipple is threaded both inside and outside, the wall thickness is inadequate.

(11) One pump manufacturer provides a screw-type mounting flange for 4" and 6" diameter casing pipe to match the base flange of his pump head. This requires the end of the casing to be threaded to receive the flange. Certain serious difficulties are encountered, viz., (a) unless the casing pipe is perfectly vertical, the corresponding non-verticality of the pump head will create additional stress on the pump; (b) the provision of screwed ends on the casing pipe may involve having to weld on a special threaded piece. The threaded end is very susceptible to damage, resulting in poor mounting of the pump head.

4.3 <u>Single-pivot chain-link pump head</u>

The following points of critical observation are made on the models of this type inspected, similar to those shown in Drawing No.2 (p.10) and Plate 8 (p.17).

(1) The mild steel fabricated body is imprecisely formed. Welding runs are not continuous, and the base flange is not flat.

(2) Most ground waters from hard rock areas are slightly acidic, and the mild steel sheet forming the pump body is liable to become corroded.

(3) There is a mild steel sheet welded across the pump head section to serve as a stiffener and act as a discharge tray. The sheet is sloped, finishing 10 to 20 mm below the level of the spout, so that water collects at this point, which is particularly affected by corrosion.

(4) There is inaccuracy in the fabrication of the bracket carrying the handle, and frequently the pivot point is not located so that the chain is vertically central over the riser pipe.

(5) The quadrant is sometimes imprecisely formed, so that the pivot point is off-centre of the quadrant, resulting in malalignment in some positions of the handle.

(6) Mild steel sheet fabrication is not a manufacturing procedure or technique which is suitable for mass manufacture.

4.4 <u>Cylinders</u>

The cylinder provided by all manufacturers is of brass. The trueness and surface finish of these cylinders are not of a high order, and this has been commented on by the Batelle Institute, Ohio, and by CMERI, Durgapur (see Part III, 1). The poor surface finish of the brass cylinder produces rapid wear of the leather washers. The components such as the pump yoke, follower, check-valve body, etc., are crudely cast in brass and individually machined, with very little quality control in regard to dimensioning. The result is that manufacturers do not produce components that conform to reasonable tolerance limits. Castings are of poor quality, with blow holes and eccentricity as common features. Scrap brass is often used for these castings.

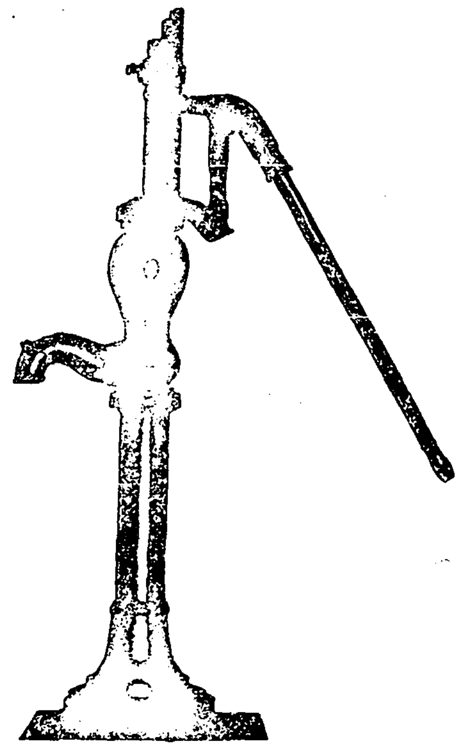


Plate 7

Example of conventional type of deep-well handpump pump head, of indigenous manufacture.

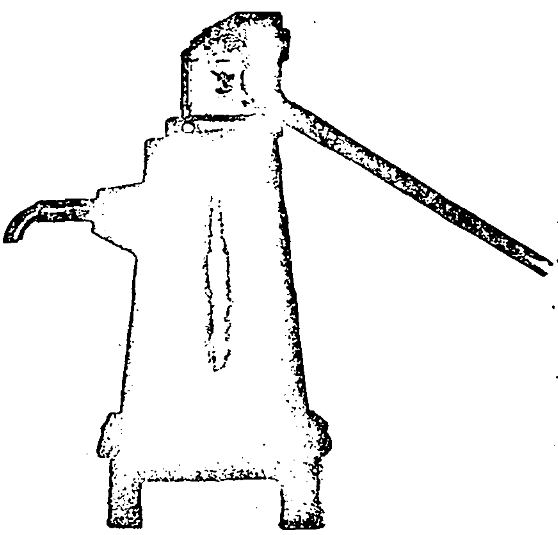


Plate 8

Example of pump head for deep-well handpump of single-pivot chain-link type, or "Jalna" type.

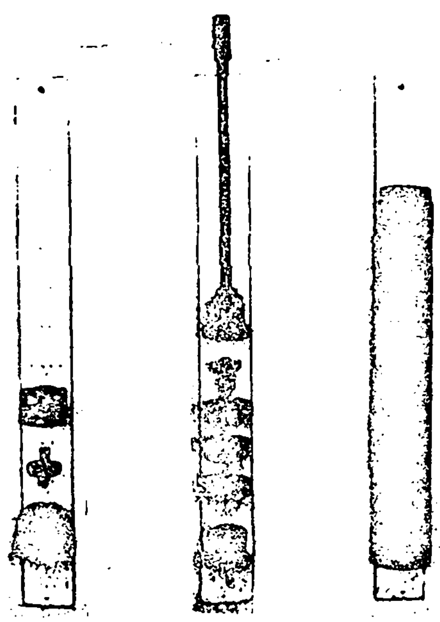


Plate 9

Exploded view of typical cylinder components.

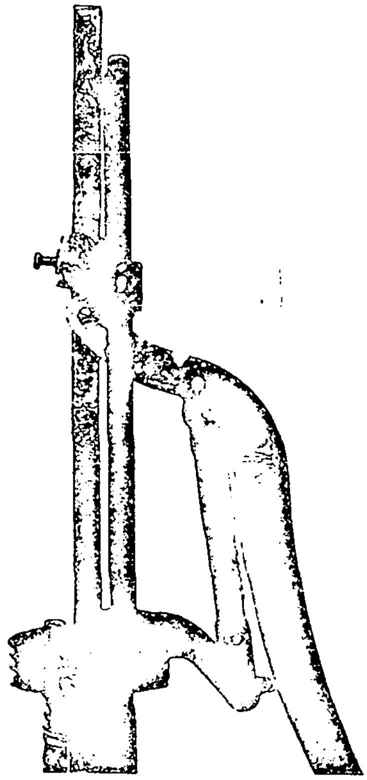


Plate 10

Manufacturing and design defects shown in locally manufactured deep-well handpump: non-verticality of guides and high friction on guide in upper position.

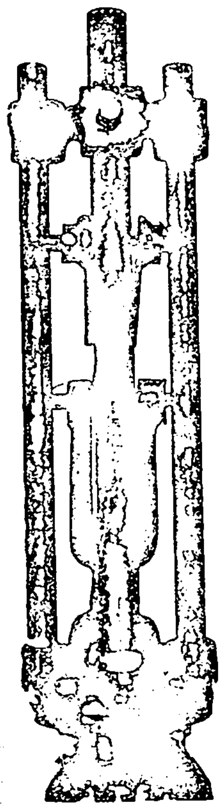


Plate 11

Manufacturing and design defects: pillars not vertical, high tolerance between handle fork and piston rod, pin bushes of handle fork poorly aligned, and pin not horizontal.

An additional factor is that brass is an expensive material in India, and the cost of the cylinder adds considerably to the overall cost of the pump. There is a great demand for scrap brass on account of the extensive cottage brass-foundry industry. It is a common experience for brass components to be "lost" when a pump is dismantled for repairs.

The leather bucket washers used are of very inferior quality, and the leather itself does not satisfy Indian Standards Institution (ISI) standards, as already mentioned.

IV. CYLINDER DEVELOPMENT

In developing a design which will perform the required duty, four aspects have to be considered, viz.,

(a) the fundamental design criteria based on usage patterns,
(b) the hydro-dynamic considerations effecting the design,
(c) the factors affecting mechanical design and
(d) the choice of materials of construction.

1 Design Criteria

The design criteria for the pump have been established by the field survey described earlier.

2 Hydro-dynamic Considerations

The hydro-dynamic considerations have been dealt with at some considerable length in Mr Emmanuel's draft report (see Introduction, page 1). The phenomena described are, however, rather complex, and there is some disagreement as to what forces actually come into play in the operation of the deep-well handpump. For this reason, and because the theoretical considerations do not appear to be as important as the practical ones in this instance, it has been decided not to include in this document any theory of the hydraulics involved, although it may be of interest to take this up elsewhere. In practice, the working of the valves is of major importance to the operation of the pump, and the two valves encountered in the single-acting deep-well handpump are the check valve and the piston valve.

The check valve, as indicated in Drawing No.1 (p.9), is at the bottom of the cylinder assembly. The conventional check valve uses a brass poppet with metal-to-metal seating or, in some cases, a rubber-to-metal seating, where a rubber lining is provided on the underside of the brass poppet. Since the specific gravity of brass is high (about 8), some advantage can be gained by using a material of lower specific gravity to facilitate the upward passage of water when the piston is raised. Further, it is generally agreed that a ball valve gives better performance than a poppet type, but some authorities have expressed the view that the pounding of the ball valve on closure may cause damage to the ball and to the seat. This would apply possibly to metal balls of high specific gravity, but by selecting a material of lower specific gravity this objection can be overcome. Nylon balls (imported), loaded to give an effective specific gravity of 4.5, have been used in the prototype experiment with excellent results. Equally good results could be expected from a synthetic rubber ball which could be formed over a steel core to give the desired composite specific gravity. The ball sits on a moulded synthetic rubber seat with inclined shoulders. The rubber ball could have a shore hardness 60, and the rubber seat could have a slightly higher shore hardness.

The piston valve is incorporated in the piston assembly, as shown in Drawing No.1 (p.9). A type of ball valve similar to that described above can be used. In this case the specific gravity could be lower (about 4.0), as the valve is actuated by the reciprocating motion of the piston itself.

3 Mechanical Design

The factors which require consideration, in so far as the mechanical design is concerned, are:

(a) preventing the piston assembly from tilting in the cylinder,
(b) dampening the impact of the piston at the top and bottom positions,
(c) preventing disconnexion of the piston rod from the piston yoke, and
(d) facility of dismantling the cylinder assembly.

The first requirement is met by providing a plunger rod guide at the top of the cylinder assembly. This guide may be of high density polyethylene (HDP) or unplasticized poly-vinyl chloride (uPVC), and may be bushed in resin-impregnated fabric. This material is water-lubricated, and the bush may be replaced as required.

The second problem may be solved in one of two ways: by providing a spring buffer over the piston yoke and rubber buffer over the check valve, or by so arranging the limits of the stroke that the piston does not hit the check valve at the bottom or the rod guide at the top.

Disconnexion of the piston-rod from the piston yoke has been overcome by moulding the first 25 mm length of the connecting rod into the piston yoke.

Dismantling is simplified by having all components of the cylinder assembly made so as to be fitted sequentially into the galvanized iron (G.I.) cylinder body. They are held in position by the G.I. reducing socket at the top and the G.I. cap at the bottom. Drawing No.3 (p.22) shows the component parts of the improved cylinder.

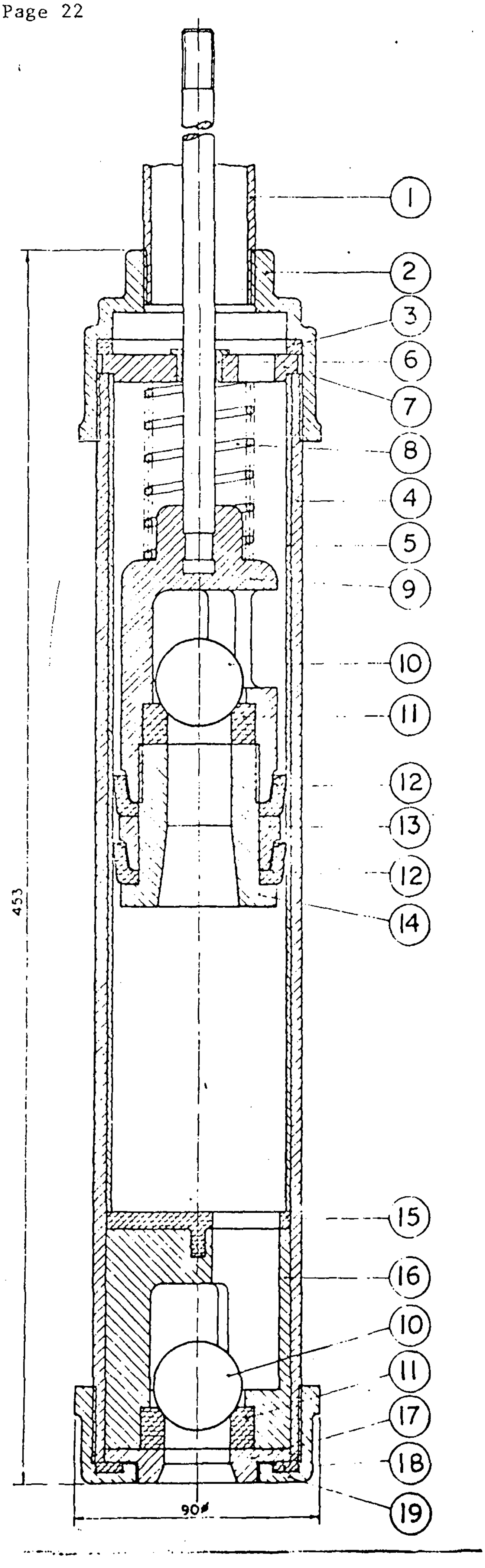
4 Choice of Materials

The guiding consideration in the choice of materials has been the unsuitability of brass for the cylinder and the cylinder components, partly on account of the cost and partly on account of the methods of production used. The fact that brass components are likely to be stolen has also been kept in mind. There is little doubt that mass production techniques such as die-casting and hot-stamping could be used in manufacturing some of the brass components, but this is not done in practice, possibly due to the high initial cost of the dies and the short production runs required.

The ideal cylinder sleeve should have the following characteristics:

(a) It should be non-corrodable since it remains immersed in water;
(b) It should have a good finish (smooth cylinder wall) at low production cost;
(c) It should have high abrasion resistance;
(d) It should have a low coefficient of friction against the material of the bucket washer;
(e) It should be water-lubricated;
(f) It should have adequate structural strength;
(g) It should have low water-absorption and should not swell;
(h) It should be easily available locally, and
(i) It should be relatively cheap.

DRAWING No. 3



CYLINDER ASSEMBLY FOR DEEP WELL HAND PUMP.

19	1	03·01·18	VALVE SEAT RETAINER CAP	GI	STD
18	1	03·01·17	SEALING RING.	HARD RUBBER (NEOPRENE)	
17	1	03·01·16	VALVE SEAT RETAINER.	HIGH DENSITY POLYTHENE	
16	1	03·01·15	CHECK VALVE BODY.	HIGH DENSITY POLYTHENE	
15	1	03·01·14	BUFFER	HARD RUBBER (NEOPRENE)	
14	1	03·01·13	FOLLOWER	[illegible]	
13	1	03·01·12	SPACER	HIGH DENSITY POLYTHENE	
12	2	03·01·11	CUP WASHER	[illegible]	
11	2	03·01·10	VALVE SEAT	HARD RUBBER (NEOPRENE)	
10	2	03·01·09	BALL VALVE	NYLON	
9	1	03·01·08	PLUNGER YOKE BODY	[illegible]	
8	1	03·01·07	SPRING (COMP.)	SPRING STEEL IS [illegible]	
7	1	03·01·06	PLUNGER ROD GUIDE	HIGH DENSITY POLYTHENE	
6	1	03·01·05	BUSH	NYLON	
5	1	03·01·04	CYLINDER SLEEVE	[illegible]	
4	1	03·01·03	PIPE 2-1/2"	GI	STD
3	1	03·01·02	SEALING RING	HARD RUBBER (NEOPRENE)	
2	1	03·01·01	REDUCER CAP	CI	
1	1	—	PIPE $1\frac{1}{4}$"ø	GI	STD

In considering substitute materials for the cylinder sleeve, it is evident that there is no justification for the cylinder body to have a longer life with respect to corrosion than the pipe string by which the cylinder is suspended in the well. Since the pipe string is generally of galvanized iron, the cylinder body could also be constructed in a standard size of G.I. pipe and pipe specials.

The inside finish of the G.I. pipe is unsuitable for use as the cylinder wall, and it is necessary to have a "sleeve" or "liner" which can be used inside the G.I. cylinder body to provide the desired surface. This arrangement has an added advantage in that the G.I. cylinder body provides structural support to the cylinder liner, thereby reducing the need for high structural strength of the liner. A cylinder liner capable of withstanding the wear and tear of about one year's use by a community would be satisfactory. The Batelle Memorial Institute, Ohio, has experimented on various coatings on mild steel pipe. These coatings have been bonded to the pipe to provide on integral cylinder body. Vinyl, epoxy and uralkyd coatings have been tried, and some have shown promise of long life. It has, however, been necessary for the entire cylinder body to be discarded when a replacement is required. There therefore appears to be a distinct advantage in using a cylinder sleeve with a sliding fit,which can easily be replaced in the field at a nominal cost. This approach has been used to produce a suitable cylinder.

The most common types of plastic tubing commercially available are poly-vinyl chloride (uPVC) and high density polyethylene (HDP). These materials do not have the abrasion resistance which is required in a community pump, although they could very well be suitable in a pump which is limited to single-family use. Such materials as acrylonitrile butadiene styrene (ABS) and epoxy resin-impregnated fiber-glass mat are good materials but have not been given serious consideration on account of difficulty of availability and relatively high cost. A rolled tube, based on medium-weave cotton fabric and impregnated with an epoxy resin, is manufactured in India on a commercial scale, is available in several standard diameters and wall thicknesses and could be made to any dimensions if the order were big enough. The greatest application of the epoxy-impregnated fabric is in bearings and bushes, where its water lubrication properties are needed. As the tubes are rolled on accurately machined mandrels, they can be produced to acceptable tolerance with good surface finish. This material, which bears the trade name in India of "Hylam TF 2211", has high tensile and cross-breaking strength. The tubes are produced in standard lengths of 1.09 to 1.25 metres, at a price of Rs 45.50 per length of 64 mm internal diameter tube (equivalent to approximately US$ 5.70). At this rate a cylinder sleeve would cost less than Rs 12 ($1.50). (For comparison, the cost of a brass cylinder of similar size would be about Rs 60 ($7.50).

This material thus satisfies most of the criteria laid down for the cylinder sleeve. The outside diameter of the tube required is limited by the inside diameter of the G.I. pipe, which would have to be rough-ground to remove beads of zinc. A slight increase in diameter may be expected. The outside diameter of the resin-impregnated fabric tube should lie within the limits of 0.23 and 0.34 mm less than the inside diameter of the G.I. pipe, which should be between 0 and 0.5 mm greater than the stipulated diameter.

The piston yoke is subject to considerable stress, mainly in tension, since it carries the dead weight of the column of water and the connecting rod, and is also subject to impact loads. The dead load may range to about 60 or 100 kg depending on the depth of the cylinder from ground level. A safety factor of 5 or 6 is desirable to ensure that this component does not suffer failure. The only materials which seem suitable for use in this component are glass-fibre mat impregnated with epoxy resin, and medium-weave cotton fabric impregnated with epoxy resin. The latter is preferred on account of its lower cost and greater ease in moulding. The structural properties of this material have been described above, and it will be seen that it is suitable.

The washer spacer, follower and check valve body are not required to take high stresses nor to have any special characteristics. The considerations of cost and mouldability are the most important factors. HDP and uPVC are both suitable for use in these cases.

While leather, properly treated, is an excellent material for the cup or bucket washer, the washers available on the Indian market are of very poor quality. The characteristics to be looked for in a good washer are:

- low water-absorption
- negligible swelling
- equal suppleness, wet or dry
- low coefficient of friction
- low cost
- availability
- ease of production and reproducibility to correct sizes.

Since plastics are generally being proposed for use in the cylinder components, it would be consistent to seek a plastic material which would be suitable. Neoprene and acrylonitrile rubber are both satisfactory, the latter with the advantage of having a good moulded surface. The process of manufacture of moulded items lends itself to a high level of quality control and the production of a perfectly concentric and accurately dimensioned component, thus overcoming the problems commonly encountered with the leather cup washer.

Details of the proposed new cylinder are shown in Drawing No.3 (p.22), and the choice of materials from the various components is given in Table 2 (see next page).

Table 2. Specifications for Materials

(Specifications laid down for the cylinder components, on the basis of this study)

Item	Material	Remarks
Cylinder top coupling	G.I.	Standard G.I. reducer socket, 2-1/2" x 1.25"
Cylinder body	G.I.	Standard G.I. Pipe 2-1/2" dia., medium quality
Piston rod guide	HDP or uPVC	Bushed in Hylam TF 2211 or nylon
Cylinder sleeve	Hylam TF 2211	Resin-impregnated fabric
Piston yoke	Hylam TF 2211	
Cup washer	Acrylo-nitrile rubber or neoprene	
Follower	Hylam TF 2211	
Valve seat	Butyl rubber or neoprene	Shore hardness 60
Ball (piston valve)	Nylon or rubber	Loaded to give Sp.Gr. of 4.0
Buffer	Rubber	
Check valve body	HDP/uPVC	
Valve seat retainer	HDP/uPVC	
Cylinder bottom cap	G.I.	
Ball (check valve)	Nylon or butyl rubber	Loaded to give Sp.Gr. of 4.5

V. PUMP-HEAD DEVELOPMENT

1 General

The breakdowns in the pump head may be classified broadly as being caused by either excessive wear at one or more of the pivot points, resulting in immobility or increased friction at these points, or fracture of the cast-iron components of the pump head.

Fracture of the cast-iron components has been reported in the handle and the pump-base flange. A few cases of failure of the pump body and the spout have also been reported. These fractures have clearly been identified as resulting from the high phosphorous content of the cast iron, and precautions should be taken to keep this below 0.2 per cent.

Most manufacturers do not now use cast iron in the handles, but have substituted a handle with a forged fork end and a pipe handle.

Since most failures occur in the pump head, no attempt has been made to reduce costs by cutting down on the sections. Rather, certain areas have been strengthened and the design altered to widen the base along the line of stress. Cast iron and sheet steel are the only possible materials in this case, and cast iron is considered to be better both from the corrosion point of view and from that of feasibility for mass production.

Although attempts were made to correlate efficiency of the pump with the height of the hand pivot above ground level and the average height of the user, these, as reported earlier, were not successful. For purposes of design, a pump height of 1.50 m is being used as being the most suitable height for most persons. This is based both on the data collected and the physical observation of the "human compensation factor" mentioned earlier. This is, of course, applicable only to the hand-operated pump head.

2 The Hand-Operated Pump Head

Field experience over the last three years, supported by the field and workshop studies undertaken under this project, has shown that the pivot points and moving points of the conventional pump head are weak points in the pump and are generally the points at which breakdowns occur. The conventional pump has shafting steel pivot pins riding in cast-iron "bearing" holes. Various reports have stressed that breakdowns are caused by poor maintenance. It has been found, in the course of the accelerated test conducted in connexion with proving materials and design for the improved pump, that even with good lubrication the type of pivot bearings provided shows relatively high wear.

The reduction of pivot points and moving parts has been achieved to a considerable extent in the Jalna and Sholapur type pumps (Drawing No.2,p.10), which use the single-pivot and roller-chain linkage arrangement, the chain riding over a quadrant placed tangentially to the connecting rod at the end of the handle. This type of pump, however, uses a mild steel-sheet fabricated body, which is not favoured for the reasons given in Section III, 4.2. The conventional pump, on the other hand, uses a tubular casting which requires higher machining costs.

The design evolved and proposed by this project utilizes the single pivot roller-chain linkage system with an open cast-iron frame. This frame simplifies casting, gives easy access to the pipe system and reduces machining costs to the minimum. The proposed improved pump head is shown in Drawing No.4 (p.29) and in Plate 12 (p.18).

3 The Foot-Operated Pump Head

It has been demonstrated that it is impossible to select a single pump height which will cater satisfactorily for the large range of user heights. A logical approach is to evolve a pump head which is independent of this parameter. A foot-operated pump head will not depend on the height of the individual and should give equally consistent performance over the entire range of heights of users. The foot-operated pump head also has an advantage in that the user brings to bear a part of his body weight to operate the pump and is not required to apply muscular energy. Since the pump will not require more than 5 kg. to operate, it will fall within the physical capacity of the average child who would be called upon to draw water.

The foot-operated pump head lends itself to a counter-beam arrangement for providing the reciprocating movement to the piston (see Drawing No.5,p.30). Such an arrangement reduces shock loads on the cylinder and pump-head components,thereby increasing their life. Since the stroke limits are controlled, the spring buffer could be omitted, thus effecting a slight reduction in cost.

The addition of a counterweight on the treadle beam actuating the piston rod will allow for smoother operation of the pump and make for better balance between the delivery stroke and suction strokes. The introduction of the counterweight greatly reduces the effort or pressure on the foot treadle of the pump which is required. A feature of the foot-operated pump head is that the drive is carried on an independent cast-iron T-section frame, while the riser pipe is screwed to the tubular pump pillar, which sits snugly in a socket in the base plate of the pump body. This gives accessibility to the riser pipe string and cylinder, without any need to dismantle the cast-iron frame.

4 Details of Components

4.1 Bearings

The conventional pump uses cast-iron bearing housings with shafting steel pivot pins, while the "Jalna" type pumps use either a heavy needle bearing (from a Willys Jeep water pump) or a pair of standard ball-bearings. Whereas the bearings in the conventional pump are very inefficient and show wear in less than 100 hours of use, the bearings in the Jalna pump are good, but comparatively expensive. Some problems with these pumps have been experienced owing to poor alignment or lack of horizontality of the bosses in which the shaft is housed.

Ball-bearings are generally used for high speed and high load conditions, neither of which requirements is found in the case of the hand pump. The principal objection to the use of ball-bearings is their cost, which could be justified only in the absence of an appropriate alternative, and there is such an alternative in this case. Both the hand and the foot-operated types of pump heads evolved in this project have been provided with sintered bearings, manufactured by Messrs Mohindra Sintered Products, Poona (Types MSP-409 and MSP-135), and provision has been made for oil reservoirs.

Sintered bearings, as manufactured in India, are quite inexpensive. They should give excellent service if the pivot pins are turned to the recommended tolerances and the bearings are lubricated twice a year. Grade SAE 30 oil, mixed with 5 per cent 300 mesh graphite powder, is recommended as lubricant. These bearings are mass manufactured in high precision dies by a process of powder metallurgy involving forming and sizing operations. They are guaranteed to close limits of accuracy on diameters, length and concentricity. The adoption of standard sizes of bearings leads to higher efficiency, greater economy and readier availability. The insertion and extraction of the sintered bushes can be carried out in the field,using simple tools developed for this task.

4.2 Pump base

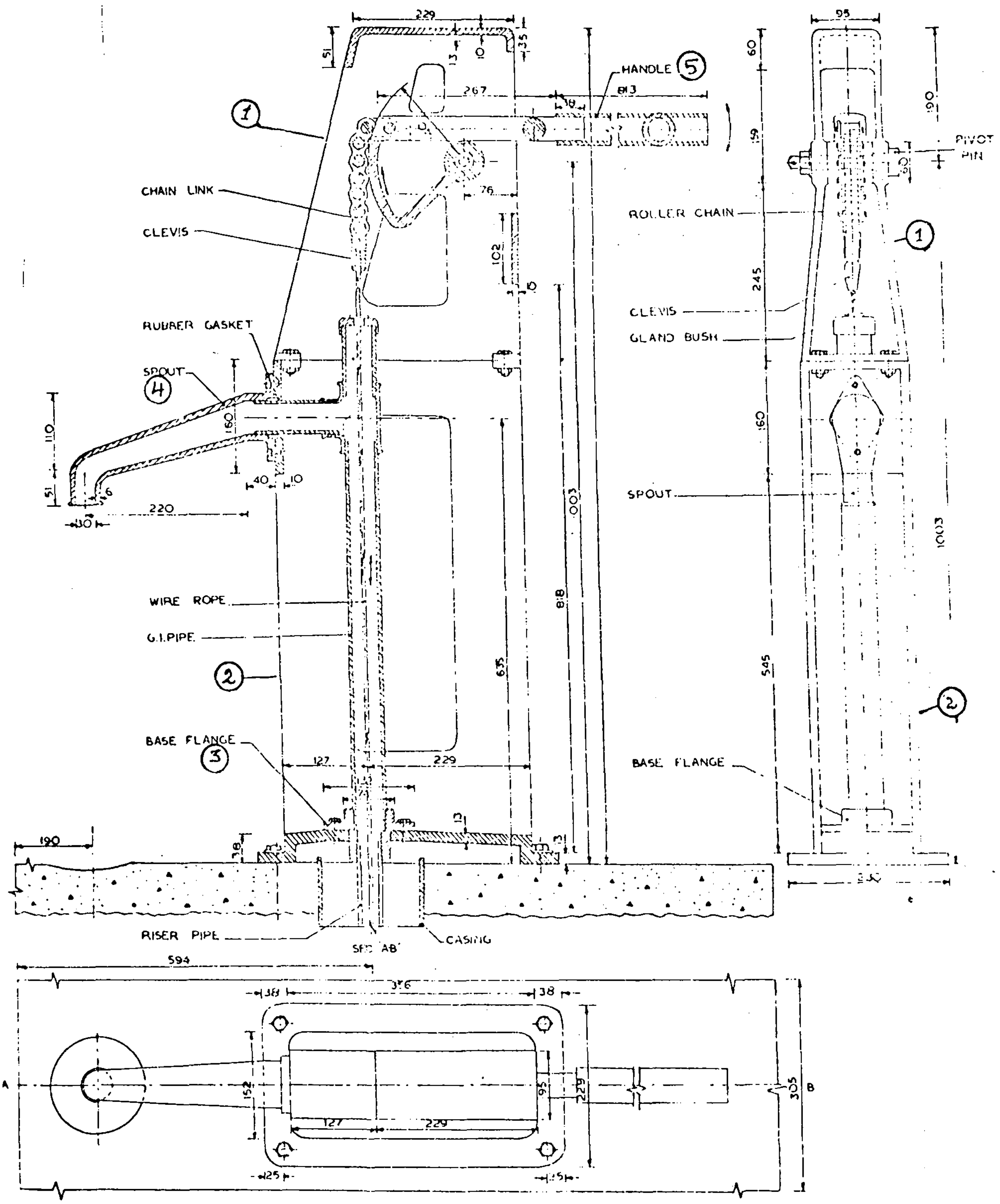
The base mounting for both the hand-operated and the foot-operated types of pump is rectangular in shape, with the axis of the longer side on the stress line. The larger bearing area provides stability for the pump head. Customarily 10 mm diameter foundation bolts are used for anchoring the pump to the foundation. These have been found to be inadequate, and provision has been made in the improved design for four bolts, 16 mm in diameter, to be used.

4.3 Pump spout

The improved design of the pump head provides a change of design in the pump spout. Of the pumps examined, both indigenous and imported, the outlet of the pump spout was only 150 mm from the pump pillar. This distance is inadequate to allow the centre-line of discharge to coincide with the centre-line of the water pot in common use in India. Considerable spillage occurs because of this fact, aggravating the problem of waste water disposal and increasing the energy input required of the user. The spout provided on the improved pump head stands 200 mm away from the pump pillar, overcoming this problem.

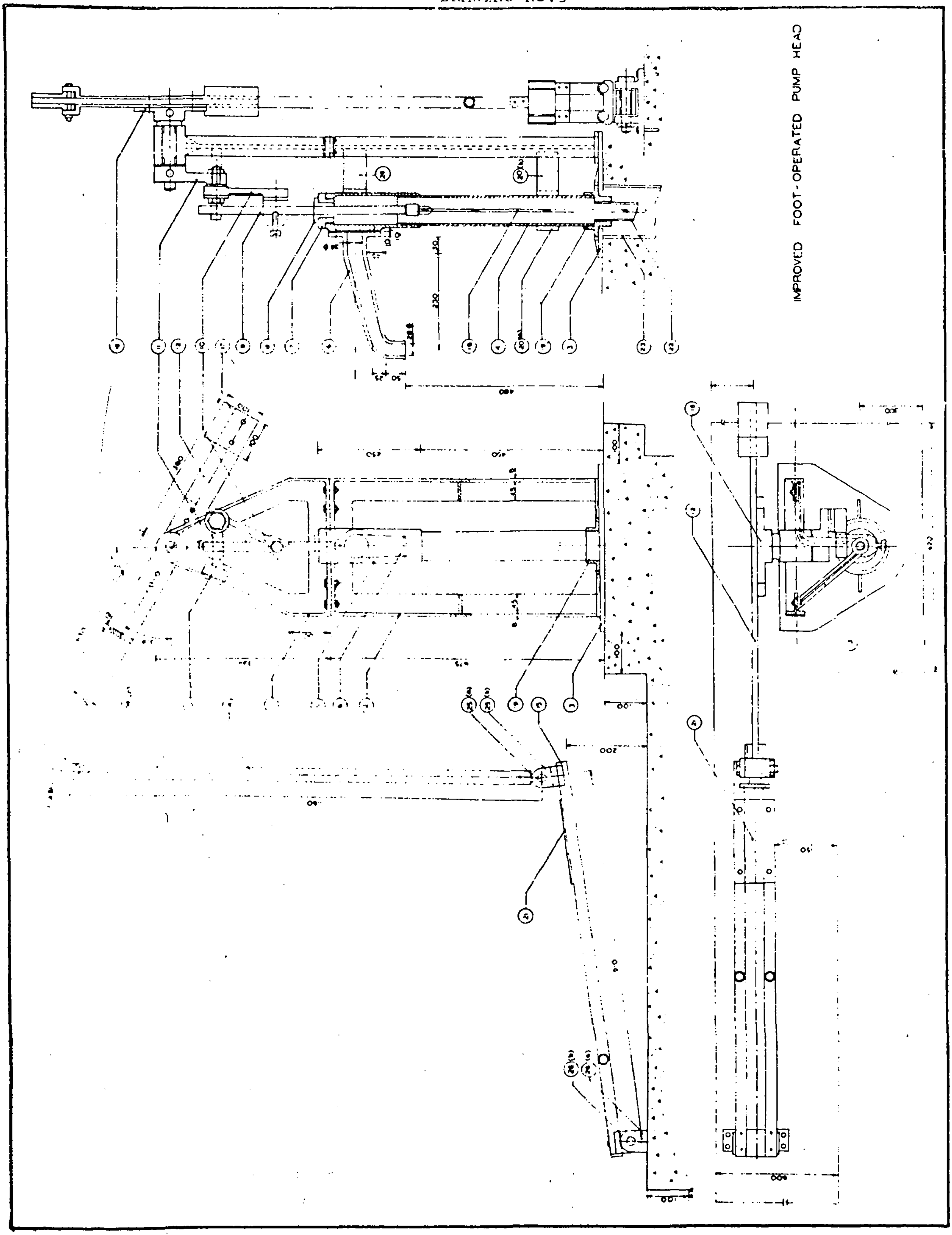
The earlier design of the spout had a "P" bend to prevent the introduction of sand or pebbles through the spout into the pump. In addition, a mesh screen was provided. This created a problem when the material inserted accumulated against the screen. The new design provides a spout that slopes away from its point of fixture to the pump head, ending in a vertical mouth which is 50 mm long. Any sand or pebbles shored upwards into the mouth of the spout will travel only part of the way and will then roll out of the mouth.

DRAWING No.4



IMPROVED HAND-OPERATED PUMP HEAD

DRAWING No.5



4.4 Connecting rod

Most pumps use a mild steel connecting rod of 1/2" diameter. These rods are generally supplied in short lengths of 10'-6" to facilitate installation. The G.I. riser pipe usually comes in 10'-0" lengths. Connecting rods are joined by couplings, and it is usual for a coupling to be spot-welded to one end of each connecting rod and to lock the other end to the next rod by means of a lock nut.

There have been so many failures of pumps caused by disconnexion of the connecting rod at one of the connectors that this source of failure is worthy of serious attention. In addition, the installation of the riser pipe in conjunction with the length of connecting rod makes installation cumbersome. It is also necessary for the overall length of the connecting rod to be of a specific length in order to be able to provide the maximum stroke with the handle travelling through the most convenient range of height.

When a connecting rod whips on the down stroke, inducing torque, it results in disconnexion of the connecting rod at a coupling when the rotation of the rod is anti-clockwise. This can be prevented by the use of intermediate rod guides, which may be placed 10 metres apart in the riser pipe string, wedged in a pipe socket on either side by the G.I. pipes. The rod guide is made of nylon, with a central hole fitted loosely over the rod.

The use of a steel wire rope (6 mm diam. 2-tonne breaking strain) is proposed as a substitute for the connecting rod. This substitution is possible because the downward movement of the piston is produced by the dead-weight of the water column in the riser pipe and the weight of the connecting rod (wire rope), and the stiffness of the rod is not a necessary factor. The downward drag can be improved by the use of counterbalance weights, as proposed for the foot-operated pump head described earlier. The wire rope can be cut to the exact overall length required, and fitted with a clevis at either end, enabling connexion to the piston rod at one end and to the pump rod at the other. The use of a wire rope as a substitute for the connecting rod has the following advantages:

(a) It can be cut to a pre-determined, exact length;

(b) Since it is in a single length, there is no problem of couplings, _in situ_ dethreading of connecting rods, or disconnexion;

(c) The installation of pipe lengths is made easier by the flexibility of the wire rope;

(d) Pipe lengths of standard length can be used, thereby reducing labour costs in threading and installation, and

(e) Intermediate rod-guides can be dispensed with.

There is very little financial advantage to be gained from substituting wire rope for the 1/2" diameter mild steel connecting rod, but the advantages listed above make wire rope a worth while substitute.

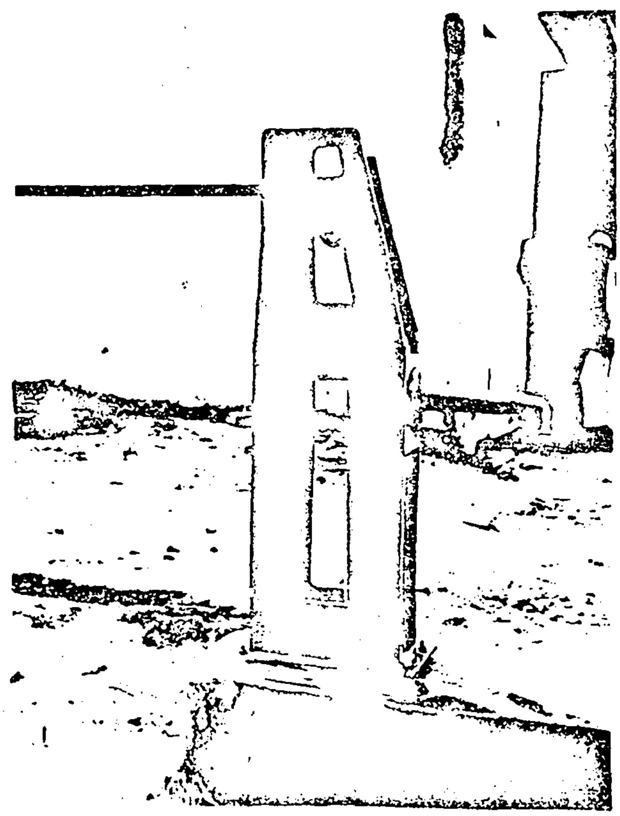
The use of the industrial-type roller chain to link the pump handle to the piston rod is an improvement, but a 200 mm length of 1" pitch roller chain costs over Rs 40, which is rather expensive, and it is difficult for government agencies to ensure that the chain provided is new. With a modified handle, in which the wire rope can be anchored directly to the quadrant, these difficulties can be overcome.

4.5 Riser pipe

Most state governments use 1-1/2" diameter G.I. pipes as the riser pipe. The argument generally given is that such pipes are sturdier than those of a smaller diameter and that there is less wear and tear on the threads when the pipe string is dismantled frequently for the repair of the cylinder. With the introduction of the improved pump, it is likely that the cylinder will not have to be withdrawn from the well more frequently than once (or, possibly twice) a year. In the circumstances, there is a strong cost advantage in using a 1-1/4" diameter pipe instead of the 1-1/2" pipe. From purely hydraulic considerations, a 1" diameter pipe would have been adequate if it were not for the space taken up by the connecting rod or rope.

Plate 12

The improved hand-operated pump head, prototype assembled from welded mild steel plate.



VI. TESTING

1 Testing of Cylinder Assembly

1.1 Preparation of the test

The prototype cylinder was manufactured by the Mechanical Engineering Research and Development Organization (MERADO), Madras, a regional branch of the Central Mechanical Engineering Research Institute, Durgapur, to designs and material specifications provided to them by the project. MERADO was also instrumental in preparing the draft detailed working drawings of the cylinder, as reproduced in Drawing No.3 (p.22). Their assistance was of great value to the development work.

Although the design provided for the compression/injection moulding of the cylinder components, the components for the prototype were machined out of solid stock. This procedure was adopted to avoid the initial expense of a manufacture of dies and tools which might have to be rejected on the basis of subsequently required modifications. The process of machining such a material as epoxy resin-impregnated cotton fabric greatly reduces the strength of the material in tension, as the continuity of the longitudinal fibres is lost. One must depend on the bonding strength of the epoxy resin for the necessary strength. Much greater strength of the components may be expected when they are compression-moulded.

For reasons of availability of material and machinability, many of the cylinder components, such as the washer spacer, the check valve body and the valve seat retainer, were turned out of resin-impregnated fabric. In production runs they would be injection-moulded in uPVC or HDP.

It was initially planned to manufacture two prototype cylinders and to test them both, one at MERADO and the other at the project office in Bangalore, and the assistance of the Chief Engineer, Tamil Nadu Water and Drainage Board, was obtained for drilling a tubewell in MERADO premises to serve as a test well. Unfortunately, several set-backs were experienced, and the well was not completed before the close of the project. It was decided, nevertheless, to proceed with testing one cylinder on the test well made available to the project in Bangalore by the Chief Engineer, Minor Irrigation and Public Health Engineering, Government of Karnataka. MERADO scientists were associated with the tests and made several visits to study the results.

1.2 Nature of test

The objectives of the test may be summarized as:

(1) to determine the suitability or otherwise of the various types of plastics selected for the components, and

(2) to check whether or not the changes in design provided the advantages expected and, if not, to determine the changes in design that would provide the desired results.

Since the purpose of the study was to determine how the improved pump would stand up in actual use, the test was devised to simulate, as closely as possible, actual field use. With this in view, the design criteria collected from the field survey were reproduced, i.e. the pump was arranged, by use of an electric motor and a belt drive, to operate at approximately 48 strokes per minute, with a 114 mm(4-1/2") stroke, the pumping pressure being applied at a point where the handle would be held by the average user. A conventional pump head was used for this exercise, and the pumping device was motorized to run continuously for 1000 hours, this period representing about four months of actual field use. The accelerated test took one third of this time.

The stroke frequency and output were measured every day at the same time, and the results recorded. The uniformity of output was used as an indirect index of pump efficiency. The experiment was held up several times by a breakdown in one component or another, but throughout the test the cylinder gave no trouble whatsoever.

The breakdowns did, however, provide an opportunity for examination of the cylinder during the trial.

1.3 Observations

During the course of the trial, the following observations were made:

(1) Although the conventional pump head used for this test was greased twice a day, measurable wear was noticed after 100 hours of running;

(2) The output of the pump increased slightly in the course of the test, from initially about 21.5 litres/minute to over 24 litres/minute, but was reasonably uniform throughout the 1000-hour test;

(3) Some variations in the stroke frequency were recorded, due partly to voltage fluctuation and partly to wear of the drive belt;

(4) The pump gave a lower output when motorized than when operated by hand, indicating that simulation was imperfect.

The connecting rod became disconnected after 534 hours of operation. At this time the cylinder was dismantled for inspection, and again this was done at the end of the test, after 1000 hours of use. On these occasions the following observations were recorded:

(5) There was no damage to the balls, valve seats or any other components as a result of pounding;

(6) Apart from a polished appearance, there was no alteration to the surface of the cylinder, and the wear was less than one thousandth of an inch, and

(7) On both occasions the diameter of both cup washers was measured as 79.80 mm, although initially one had a diameter of 80.70 and the other 80.40 mm. (It should be mentioned that the synthetic rubber washers, manufactured by the compression/heat technique, were initially made at 81 mm

diameter, whereas the internal diameter of the cylinder was 80.77 mm. As they fitted too tightly, they were ground down to about 80.7 mm to avoid the cost of a further set of moulds, and a slight difference in the finished diameters was observed.)

1.4 Conclusions

It was possible to draw the following conclusions from the test results:

(1) Epoxy resin-impregnated cotton fabric (Hylam TF 2211) is a suitable material for use as a cylinder sleeve;

(2) Epoxy resin-impregnated cotton fabric is a suitable material for use in the piston yoke;

(3) Neoprene is a suitable material for the cup or bucket washer (acrylonitrile rubber may be better). The diameter of the washers should provide a 0.2 mm clearance fit, as a closer fit retards efficiency rather than improving it. The design of the bucket washer and the seat should permit the washer to "spread" during the upward stroke, when hydraulic pressure is exerted on the lip of the washer, and it should retract on the downward stroke;

(4) Although nylon is quite suitable for the balls in the piston and check valves, synthetic rubber could be a good substitute (The Central Institute for Plastics Technology has undertaken to make the mould for this purpose, and MERADO will have the loaded rubber balls made outside. These could then be tested), and

(5) Although Hylam TF 2211 was used in the washer spacer, follower, check valve body and valve seat retainer, these components should preferably be injection-moulded in rigid PVC or HDP.

2 Testing of Pump Heads

2.1 The hand-operated pump head

The improved hand-operated pump head was installed over a pipe string with the improved cylinder located at 30 metres below ground level, connected to a "tandem" cylinder* placed 12 metres below ground level by the conventional 12 mm diameter mild steel connecting rod. The cylinder was connected to the pump rod by means of a 6 mm diameter wire rope, using a clevis as designed for the purpose.

It was found that installation of the pipe lengths, using the wire rope as "connecting rod", was decidedly easier. The installation of the pump head was found to be simpler than in the case of the conventional head. It was noteworthy that the new pump head was installed by mechanics who had considerable experience in installing the conventional head and that they were

*The project report, referred to earlier, deals at some length with the development of a "tandem" cylinder to be used when the static water level exceeds 18 metres below ground level. The components of this tandem cylinder are in most cases the same as for the improved cylinder. The details of this arrangement are omitted from this summarized report, but the use of a tandem arrangement when the water level is low deserves further investigation.

installing the new head for the first time. They agreed without reservation that the new pump head was easier to instal and take down than the conventional pump head.

The pump handle was connected to the accelerated testing device in the same manner as in the previous test, and the pump was run continuously for 100 hours. The pump gave a steady output of 15 litres in 35 seconds throughout the period of the test, during which there was no breakdown.

At the completion of the test the following examinations were carried out:

(1) Sintered bearings: no measurable wear in sintered bushes was found. The lubricant in the reservoir remained at practically the same level while the bearings were well lubricated.

(2) Clevises: both clevises were examined for possible failure of the clevis or the wire rope at this point. There was no evidence of any alteration or of pulling out of the wire rope.

(3) Cylinders: no measurable wear on cylinder lining or on valves.

It is claimed that, within the scope of the test conducted, the hand-operated pump head worked satisfactorily.

2.2 The foot-operated pump head

The model tested was a modification of an indigenous pump which had originally had a disc-cam actuating the pump rod with a wheel driving the cam-shaft. The unit was modified by providing a counter beam to actuate the pump rod, while the treadle was connected to a treadle beam loaded at the far end to compensate for the weight of the treadle arrangement. A counter-weight of about 8 kg was used.

The counter-beam rested at a lower position of 15° to the horizontal, and could be raised by the treadle to provide a 114 mm stroke. The treadle beam rested at 30° to the horizontal, the treadle travelling through 114 mms to produce a stroke of the same length. The pump output was comparable to that of the hand-operated pump head, but the operation of the treadle seemed easier on account of the application of body weight.

In this case, too, the cylinder was placed at 30 metres below ground level, connected to a tandem cylinder at 12 metres below ground level, which was linked to the pump rod by means of a 6 mm diameter wire rope. Because of shortage of time, this pump head was not put under continuous test, but the similarity of treatment in regard to design seems to indicate that it would work satisfactorily. Although this pump head will cost more than the hand-operated pump head, it is not unlikely that it would have application where water has to be lifted from depths exceeding, say, 45 metres.

VII. PRODUCTION AND COST ANALYSIS

1 Production

It is considered that the stage has now been reached where the pump should be manufactured in sufficient numbers to enable field tests to be conducted in a number of States, under varying conditions, over a long enough period for defects to become apparent and minor improvements to be made. Contact has been made with the Government of India undertaking, Messrs Richardson & Crudass Ltd., Madras, and this firm has expressed an interest in the manufacture of handpumps for rural areas on a commercial basis at nominal profit. The firm has good foundry and workshop facilities, and has experience in injection-moulding techniques.

If an initial batch of pumps can be produced for supply to the various States, they may be put into operation for a period of about six months, under careful control with regard to maintenance requirements, breakdown or wear of parts, acceptability to the user and general performance. After this period of field-testing, and after such modifications as may be found necessary have been made, the design could be passed on to any pump manufacturer who might care to produce it. It is desirable that at least one pump manufacturer in each State be encouraged to produce the pump.

It is suggested that assistance from UNICEF may be sought to support the manufacture of the first batch of pumps for free distribution to the States now involved in the drilling programme.

2 Quality Control

It is necessary that some quality control system be established to ensure that the quality of materials and quality of production are maintained. State government departments responsible for the village water supply programme are generally not equipped to carry out tests on quality.

As mentioned already, the Mechanical Engineering Research and Development Organization, Madras, which is a branch of the Central Mechanical Engineering Research Institute, Durgapur, has been associated with the project from its early days and was responsible for producing the prototype cylinder and the accelerated testing device. MERADO and other branches of the CMERI, located in different parts of the country, are equipped to undertake quality control tests. A possible solution would be for government departments to insist that all tenders for supply of the pump should obtain a certificate from any branch of the CMERI to the effect that their product conforms to specifications laid down on the basis of the recommendations made in this report. Any fees payable to the CMERI for this service should be borne by the pump manufacturer.

3 Cost Analysis

Though it is difficult to give accurate costs for the cylinder components of the improved pump, since the material costs are uncertain and the injection-moulding techniques to be employed become more economical when large runs of items are produced, fairly conservative estimates of the various parts can be made. Table 3 gives a list of cylinder components, recommended material and estimated cost based on die costs, where applicable, being amortized over a production run of 4000 of each item. The total cost of the cylinder comes to Rs 79.95, or approximately US$ 10.00. This compares very favourably with the costs of conventional brass cylinders, which, from five different suppliers, gave the following range:

2-1/2" cylinder	Rs 150 to 210
3" cylinder	280 to 320
4" cylinder	350 to 400

Table 3. Cost Analysis of Improved Cylinder Assembly

	Component	Material	Estimated Cost (Rs)
1.	Cylinder body	G.I. pipe	9.00
2.	Reducing socket cap	G.I.	6.00
3.	Sealing ring	Rubber or neoprene	1.50
4.	Spring buffer	Steel wire	3.00
5.	Piston rod guide	HDP	2.20
6.	Piston rod guide bush	Hylam TF 2211 or nylon	0.60
7.	Piston yoke	Hylam TF 2211	14.00
8.	Cup washers (2 No.)	Acrylo-nitrile rubber or neoprene	6.50
9.	Spacer	HDP	2.50
10.	Ball (2 No.)	Steel core, rubber covered	10.00
11.	Valve seat (2 No.)	Neoprene	6.00
12.	Follower	Hylam TF 2211	3.00
13.	Buffer	Rubber	1.65
14.	Check valve body	HDP	4.00
15.	Seat retainer	HDP	3.50
16.	Sealing ring	Rubber or neoprene	1.50
17.	Retainer cap	G.I.	5.00
		Total	Rs.79.95 = US$ 10.00

Likewise, an estimated cost analysis of the improved hand-operated pump head is given in Table 4, giving a total cost of Rs 306, or US$ 38.25. The comparable prices for conventional heads offered ranged between Rs 375 and Rs 425.

Table 4. Cost Analysis of Improved Hand-Operated Pump Head

	Item	Estimated Cost (Rs)
1.	Cost of casting pump head 50 Kg at Rs 3.50 per Kg.	175.00
	machining	25.00
2.	Cost of handle,including MSP bushes	60.00
3.	Cost of pivot pin and nut	10.00
4.	Cost of hex-head screws for spout	2.00
5.	Cost of pipe and tee	20.00
6.	Threading collar and providing bush	10.00
7.	Cost of 4 No. 16 mm dia. bolts and nuts	4.00
		Rs.306.00 = US$ 38.25

As mentioned earlier, little or no saving would be gained from the use of steel wire rope in place of the more conventional connecting rods, although use of the rope would have certain advantages in practice. With the proposed improved pump, however, and the thinner wire, it would be possible to make a saving by using 1-1/4" G.I. pipe in place of the more usual 1-1/2" pipe. At current prices of Rs 4.20 and 4.75 per foot run respectively, this saving could be considerable over a large number of installations.

To summarize, assuming a cylinder is installed at depths of 18 metres and omitting costs of foundation, platform and casing, the cost of an improved pump head and cylinder, with wire rope and 1-1/4" pipe, might be about Rs 770, and that of the conventional installation about Rs 1020. The saving might therefore be about Rs 250 in each installation.

VIII. ACKNOWLEDGEMENTS

Acknowledgements are due to the following individuals who contributed in one way or another to the development of the deep-well handpump project in India, which has resulted in the presentation of the system recognized as "the Bangalore Pump". Their contributions in support, interest, encouragement, comments and advice are recognized and appreciated. In addition, gratitude is expressed to many persons not mentioned here who have also given valuable service to the project in assisting with data collection, field testing, drafting, preparation of reports, etc.

<u>Government of the State of Karnataka</u>

S.P. Bhat	- Chief Engineer, Department of Minor Irrigation and Public Health Engineering
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A.G. Thimmappa Setty M.S. Gnanasambandan	- Junior Engineers assigned to the Deep-well Handpump project.

<u>Bangalore University</u>

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EPILOGUE

Since the preparation of Mr V.J. Emmanuel's report, which has been summarized in this document, further developments have taken place which require comment.

1 Bangalore Workshop

From 24 to 26 June 1975, a workshop was held in Bangalore at which the Chief Engineers of the States in which deep-well handpumps are used in large numbers assembled together with representatives from administrative and village organizations to discuss problems associated with rural water supply. In particular the objective was to study the improved Bangalore handpump which had recently been developed. Representatives of the Government of India, MERADO, UNICEF and WHO also attended. An opportunity was given to participants to examine the component parts of the prototype cylinder and pump head and, later to test the assembled pump.

At the end of the meeting the participants recommended, inter alia, that "a few hundred Bangalore pumps should be manufactured and distributed to the various States for carrying out extensive field trials for a maximum period of six months, to determine their suitability for large-scale use in the rural water supply programme in India"*.

2 UNICEF Assistance

The Government of India in July 1975 formally requested UNICEF assistance in the production of 1000 Bangalore pumps on the basis of the draft report and working drawings, which had been distributed to the Chief Engineers and discussed at the Bangalore workshop. UNICEF subsequently called for bids, and by November 1975 offers had been made. At the same time, however, a number of snags came to light, related to both the cylinder and the pump head, which made it necessary to carry out further development work before a large number of pumps could be manufactured. At the end of 1975, therefore, UNICEF agreed that Messrs Richardson and Crudass, in collaboration with MERADO, should prepare the necessary dies for the moulding of cylinder parts and should proceed with the manufacture of a number of complete cylinders for testing in Tamil Nadu State (Madras area). Subject to the satisfactory operation of these parts, detailed working drawings will be prepared and a sufficient number distributed to be tested in different parts of India. Initially, it is proposed that the cylinder be tested using the currently available Sholapur pump head, and the improved pump head developed separately.

3 Comments on the Bangalore Pump

Whereas all Chief Engineers and a number of other persons in India were invited to comment on the design of the pump as presented in the draft report, few written comments were received. The subject was, however, discussed at some length during the June workshop and subsequently, and comments have been received from WHO Headquarters in Geneva and from UNICEF.

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*Extract from mimeographed document entitled "Report on Government of India/ World Health Organization Workshop on Deep-Well Handpumps in the Rural Water Supply Programme", Bangalore, India, 1975.

As mentioned in Section IV, paragraph 2 of this document, the chapter on hydraulic phenomena in the draft report aroused some controversy, which caused a delay in the issue of this summarized report. At this stage no attempt is made to discuss the theoretical analysis of the hydrostatic and hydrodynamic forces which come into play. Certain issues are still unsettled and may be discussed in a later document.

Generally, comments were very favourable and complimentary to Mr Emmanuel and his co-workers. In particular, the improved cylinder has been seen to have considerable advantages in terms of economy, durability, need for maintenance, and replaceability of parts. The pump head has been criticised in some quarters as being:

(1) very heavy as a casting,
(2) easily cracked or broken if dropped or during fastening down,
(3) subject to breakage from the handle banging on the top piece, and
(4) subject to interference with the top being open.

It is expected that further trials will demonstrate whether these criticisms are valid and what modifications may need to be made.

Certain problems with the wire rope were noticed when the prototype pump was set up in Bangalore, but they were partially overcome when the rope was connected to one full length of pump-rod attached to the cylinder, thus giving it the necessary rigidity at the bottom. This modification seems to be justified.

Progress in the development of the pump for widespread use is, therefore, rather slow, but, with the enthusiasm of those directly concerned in the production and testing, it is to be hoped that, in due course, the first models of the Bangalore pump will be available to the public as an improved model and at a reasonable cost.

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who international reference centre for community water supply

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B.P. 9

WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

SHALLOW WELL PUMP IMPROVEMENT RESEARCH PROJECT ON

STAGE I OF PROJECT : MALAWI

THE UNIVERSITY OF MALAWI - THE POLYTECHNIC

ENGINEERING DEPARTMENT

SHALLOW WELL PUMP IMPROVEMENT RESEARCH PROJECT

REPORT ON STAGE I OF PROJECT

WKK

APRIL 1978

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THE UNIVERSITY OF MALAWI - THE POLYTECHNIC N.1227

ENGINEERING DEPARTMENT

SHALLOW WELL PUMP IMPROVEMENT RESEARCH PROJECT REPORT

REPORT ON STAGE I OF PROJECT : PRELIMINARY SURVEY OF SHALLOW WELLS

A. INTRODUCTION

The Wells Programme Project in Malawi was started in July 1975. The programme is organised by the Water Section of the Ministry of Community Development and Social Welfare.

A type of well which could be easily constructed by villagers themselves was evolved, with the Government providing cement, a concrete slab and a locally assembled hand pump. Since the project commenced the pump has been developed using PVC pipe, a perspex plunger, and a rubber or neoprene ball for the foot valve.

The Shallow Well Pump Improvement Project in Malawi started in December 1977 with a survey of some 68 shallow wells in the Dowa District of the Central Region of the country. The investigation was centred around Nambuma Village and the survey work was carried out by students from the Malawi Polytechnic under the supervision of the Ministry of Community Development and Social Welfare, and the Polytechnic. The students who were involved in the survey were those who are presently completing the course leading to the Diploma in Engineering (Mechanical) of the University of Malawi.

The survey of the shallow wells is Stage I of the Pump Improvement Project, which is funded by the International Development Research Centre, Ottawa, Canada. The project is a joint venture of the Ministry of Community Development and Social Welfare and the Malawi Polytechnic. The objectives of the project are:-

(i) to perfect the design of the existing hand pump so that it can be standardised for supply and future maintenance throughout the whole programme and in other parts of the world;

(ii) to introduce applied research related to rural development problems into the Malawi Polytechnic programme;

(iii) to develop close liaison between the technical education institution and the Government's development programme in rural water supply.

B. METHODOLOGY

A five-day intensive survey was carried out on 68 wells (during the period 16th to 21st December 1977). Inspection of the wells and pumps was carried out. Measurements were taken of the working components of the pump and details of any damage or wear were noted.

Appendix I shows the 'Site Visit Survey Sheet' which was used to record the findings of the investigation. The survey was carried out as follows:-

(1) Initial Findings: general observation of condition of pump and well surrounds before dismantling; operation of pump and measurement of discharge.

(2) Measurement and Inspection of component parts.

(3) General Findings: comments of villagers regarding the maintenance of pump, availability of water supply and frequency of faults, etc.

C. DETAILS OF SURVEY

(1) General: The location of each well visited is given in Appendix II together with the date of completion (where recorded).

Number of People served by Well: It was estimated that each well served about 40 to 120 people. A few wells served as low as 15 people and some served as many as 200 people.

Depth of Wells: Depth to water level : 0.5 to 3.5m+
Length of pump cylinder: 2 to 4 m (mostly in range 2.5 to 3.5m)

(2) Condition of Well Surroundings - well apron/concrete slab and drainage.

All of the wells had a good concrete apron. Attention was paid to the absence of stagnant water and good drainage, with signs that the surroundings were kept clean and tidy. It was considered that about 55% of the wells were acceptable on this criterion and 20% were not acceptable. The remainder were below average, but considered to be reasonably acceptable. The exact findings are:

Very Good	:	17%
Good	:	37%
Fair	:	26%
Not Acceptable	:	20%

(3) Condition of Well and Pump in General Terms

An initial assessment of the condition of the well and pump was made. This was simply based on whether or not the well/pump was in operation with the pump delivering an acceptable discharge for a given number of strokes/length of stroke.

It was found that on average the number of pump strokes of length 0.3 to 0.4m to fill a standard bucket (0.016m3) were 24 to 33. A pump delivering such a discharge was considered to be acceptable. This gives a volumetric efficiency of about 0.65. A pump giving a volumetric efficiency below 50% was unacceptable.
It was necessary to distinguish between a set-up which was either not operating or operating inefficiently due to (i) a pump fault; (ii) a well fault as follows:-

			No.	%
Operating Acceptably		:	28	41.0
Not Operating:	Pump Fault	:	5	7.5
	Well Collapsed	:	5	7.5
	Low Water Level	:	5	7.5
Operating at Low Efficiency:				
	Pump Fault	:	12	17.5
	Low Water Level	:	13	19.0
	Total	:	68	100.0

The above can be summarised: 41% of the pumps/wells were in an acceptable condition with 25% of them being in a poor condition due to the pump and 34% being in a poor condition due to the well/water level.

(4) Type of Pump (Mark 2 or 3):

The Mk. 2 pump has a steel pump rod. The Mk. 3 pump has a PVC tube as the pump rod which is reinforced at the top (normally with an inner PVC tube). Appendix III shows the pump details.

The total number of pumps which were actually inspected was 66.
48 pumps were Mk. 2 and 18 pumps were Mk. 3.

(5) Condition of Rubber Seal at Concrete Base

Good Condition	:	51
Poor (torn)	:	11
No Seal	:	2
Not Reported	:	2
Total		66

(6) Wear at Top Bush

The top bush consists of a PVC disc (63 mm o/d x 20 mm i/d x 7 mm thick) in the case of Mk. 3 pumps and a 2" x $\frac{1}{2}$" standard connection for the Mk 2 pump.

		Mk 2	Mk 3	Total (%)
Extremely Excessive Wear (bore : 30 to 40 mm)	:	18	7	38
Average - but Excessive (bore : 25 to 30 mm)	:	19	8	41
Slight Wear	:	8	3	16.5
No Wear	:	2	0	3
Not recorded	:	1	0	1.5
Total		48	18	100%

It was considered that the 'average wear' of the top bush was not acceptab hence only a small percentage of pumps had acceptable top bushes - many of these were pumps which had been installed recently.

(7) Footvalve Vibration

In operation the pump was subjected to vibration due to the ball footvalve moving in an erratic way in the cylinder. Vibration was significantly 'felt' at the plunger handle during both the delivery and return strokes. The reason for this phenomenon must be hydro-dynamic effect - the exact nature of which would become clear once the ball motion could be observed (using a clear perspex tube).

It was found that there had been a common fault experience in many pumps - that of the rubber or neoprene ball wearing to the extent of it falling into the well - having been forced through a 30 mm dia. hole in the footvalve seat. (Diameter of ball : 35 mm). In other pumps the ball had stuck in the seat. The local Community Development staff at Nambuma had attempted to reduce the occurrence of this fault by (i) inserting a PVC bush in the ball seat in order to reduce the bore diameter; (ii) inserting wire restraints through the pump cylinder just above the footvalve (it being assumed that the ball wear was due to a vertical bounce effect). This had certainly minimised/eliminated the problem of the footvalve ball disappearing - the vibration problem, however, was still present. During the course of the survey it was noted that some balls were becoming wedged in the wire restraints. The majority of the pumps had the above modifications impleme at the time of the survey. An assessment of the vibration of the footvalve is as follows:-

Excessive vibration	:	13
Average vibration	:	30
Below average vibration	:	15
Further faults:		
No ball	:	3

Ball worn excessively *	:	1
Pumps not in operation	:	2
	Total	68

* Note: It was not possible to take measurements of the diameter of the foot-valve ball because of the restraining wires fitted to the pump cylinder.

(8) Plunger Wear

The nominal diameter of the plunger was 56 mm. This gives a clearance of 1 mm in a pipe of 57 mm bore. The 59 plungers which were measured had the following dimensions:-

Mean Diameter (mm)	No.	Mean Diameter (mm)	No.
56.5	1	53.5	1
56.0	20	53.0	1
55.5	21	52.5	-
55.0	7	51.5	2
54.5	2	50.5	2
54.0	2	Total	59

Number of plungers broken (from 59) : 5 (about 8%)

Taking an acceptable limit of wear to be 0.5 mm then we may conclude that 17 plungers had excessive wear (about 30%).

Most of the plungers had uniform wear - about 30% of the plungers had variations in diameter of about 0.3 mm. (These were not limited to those which had excessive wear).

(9) Condition of Rubber Flap Valve (On Plunger):

The rubber flap valve had two faults - torn due to normal wear or an assembly fault of the rubber having been cut too small, so that it did not cover all the holes in the plunger. The condition of the rubber valve:

Satisfactory	:	47	80%
Unsatisfactory	:	12	20%

(10) Volumetric Efficiency:

Figure shows a graph of volumetric efficiency vs head for the pumps tested during the survey. The general trend of the results obtained is as shown with volumetric efficiency in the range 0.8 to 0.2 for heads between 1 and 3.5 m. In Section C. (3) the pumps which were considered to be acceptable had volumetric efficiency no lower than 50%.

It is clear from the volumetric efficiency figures that there is considerable piston leakage occurring in many of the pumps.

D. FURTHER ANALYSIS AND DISCUSSION OF SURVEY FINDINGS: :

(1) Wear at the Top Bush:

The wear at the top bush was unacceptable and is caused by:-

(i) the short bearing length (about 7 mm);

(ii) no leverage system on the pump which results in the pump rod being forced side-ways during pumping rather than being operated vertically. This results in oval wear (25 mm to 40 mm in extreme cases).

The bearing length should be increased to about two to three time the diameter of the pump rod - say 50 mm. This would encourage pumping in a vertical direction which in itself would reduce wear at the top bush. In addition the question of providing the pump with a leverage system should be considered.

(2) Foot-Valve Vibration:

A comparative analysis of the survey results with particular reference to foot-valve vibration and the discharge/stroke, length of stroke, etc. did not reveal any apparent correlation. In particular the reason for some pumps having negligible vibration while others had excessive vibration was sought. It did not appear to be a function of the discharge rate or the well depth. It was thought that the position of the plunger at the commencement of the delivery stroke might well be a contributory factor to the vibration phenomenon. Laboratory investigation would be required in order to resolve this particular problem.

(3) Plunger Wear:

An analysis of the plunger wear data revealed the following:-

(i) As expected the plunger wear is a function of the period of service of the pump. After a period of 5 to 8 months, with normal usage, it would appear that plunger wear was of the order of 0.5 mm. (the limit of 'acceptable wear'). Those pumps which had been in service for 1 to 1½+ years had unacceptable wear of 1 mm to 5.5 mm. (A few pumps which had been in service for about two years without plunger maintenance had the maximum recorded wear of 5.5 mm) Most of the older installations had wear of about 2 to 3 mm.

(ii) In the case of a well which frequently ran dry (daily, say mid-morning to mid-afternoon or seasonally) there was a tendency for wear to be accelerated. Reason: no water lubrication plus the possibility of sand, etc. being ingested.

(iii) Plungers which were not properly fitted to the pump rod - loose and had 'play' - had a tendency towards increased wear. This was not a very pronounced wear effect.

(iv) There did not appear to be any significant correlation of the wear at the top bush and the plunger wear. It was considered that due to the length of the pump rod and, in the case of the PVC rod, a certain flexibility of the rod, that the effect of any side-ways thrust at the pump handle was small at the plunger.

(4) Cylinder Wall Wear:

During the survey it was not possible to measure the internal diameter of the cylinder wall over the stroke length.

One section of a badly scored pipe was available for inspection. This pipe was cut into sections so that measurements could be taken of the bore diameter. It was found that there was little effective wear which would affect the clearance between the piston and the cylinder. Damage to the surface finish of the pipe consisted of several longtitudinal score marks. These were due to sand being trapped between the piston and the cylinder. Unfortunately the pump piston was not available for inspection. In the event of a perspex plunger being continued to be used then laboratory tests should be carried out to determine the wear characteristics of perspex on PVC.

(5) Major Faults (Over the past two years approx.)

Based on the maintenance requirements of the pump and well (past and present as at December 1977), the following major faults were noted:-

(i) Ball Foot-Valve disappearing or stuck in seat - at least one-third of the pumps had experienced this fault.

(ii) Plunger becoming loose or breaking - about ¼ of the pumps had a history of the plunger breaking or the securing nut (in Mk. 2 pumps) becoming loose. The latter problem is resolved in the Mk. 3 pumps as and end cap is solvent-cemented onto the end of the pump rod. The problem of the plunger breaking (1 in 13 chance of this occurring is linked to the plunger wear. As new, the minimum thickness between the plunger holes and theoutside diameter of the plunger is about 3.5 mm. Some of the older installations had plunger wear of 2 to 5.5 mm - i.e. 1 to 2.75 mm on the radius. The minimum thickness is therefore reduced to 2.3 to 0.75 mm. Breakage of the plungers took place around this thickness of the material. This problem can be remedied by either reducing the diameter of the holes in the plunger or reducing the pitch circle diameter of the holes together with a reduction in the number of holes.

(iii) Wear of Rubber Flap Valve - about 1 in 6 pumps experienced problems due to wear of the rubber flap valve. Other flap valve materials and arrangements should be investigated.

(iv) Low Water Level - At least ¼ of the wells had problems with daily or seasonal water shortage. A check should be carried out on all wells towards the end of the dry season and where necessary the well should be deepened.

(v) Well Wall Collapse: About 1 in 9 of the wells had problems of the collapse of the wall of the well.

The above were the major faults detected, some others include:-

(a) rust on the pump rod (Mk. 2 pumps);

(b) pump rod bent (or broken at the top - 2 cases) - Mk. 2 pumps;

(c) missing parts, i.e. self-tapping screws (top bush); steel backing plate (concrete base).

Maintenance had not been carried out on the top bush although this was clearly necessary.

E. CONCLUSIONS AND RECOMMENDATIONS:

The survey carried out on the shallow wells and hand pumps has shown that there is considerable room for improvement in both the pump design and in the well construction.

The introduction of the Wells Programme in Malawi has naturally made a significant contribution to the provision of safe water to the rural community. Furthermore, the development of the present PVC pump is a step in the right direction as it is clear that PVC pumps do have a considerable role to play in the water supply of rural communities worldwide.

The results of the survey show that about 78% of the wells inspected were in operating condition. However, about half of these were operating at low efficiency either as a result of a pump fault or a well fault such as the well not being deep enough. Hence only about 40% of the pumps were considered to be operating efficiently (see Section C(3)). It should be noted that about 15 to 20% of the pumps had been installed 6 to 7 months prior to the present survey - a relevant point to remember when the working life of the component parts is considered.

It was noted that $\frac{1}{4}$ of the faults were attributed to the pump while $\frac{1}{3}$ of the faults were attributed to the well. It is therefore just as important to ensure that the wells are dug deep enough and with acceptable walls as it is to improve the hand pump. A pump can only be as good as the well to which it is installed.

The major faults of the existing pump can be confined to the following components : footvalve, plunger, top bush.

The erratic behaviour (and the resulting wear) of the ball footvalve (neoprene) is a major drawback to the use of this type of valve. The present method of dealing with the problem (see Section C(9)) is far from satisfactory. Unless the ball can be contained in some way it would appear that an alternative footvalve arrangement will be required.

An analysis of the plunger wear shows that about 70% of the plungers had acceptable wear. Further laboratory tests are required in order to establish the wear characteristics of perspex on PVC. Indications at the moment suggest that such a combination may be acceptable. It has already been pointed out (Section D(5)) that the plunger requires modification - i.e. smaller holes. It is further recommended that, with the existing plunger set-up, the perspex disc be replaced (ideally) every six months. It should certainly not be allowed to exceed a period of 1 year without replacement.

Wear at the top bush is unacceptable as this gives rise to much leakage. The bearing length of this bush should be increased to about 50 mm. The possibility of using hard woods for the top bush should be investigated.

With regard to the plunger flap valve it is recommended that other materials and methods of fitting this valve be investigated.

F. PROVISIONAL WORK PROGRAMME FOR STAGE II:

The second stage of the project is concerned with the adaptation and modification of the pump. The existing pump will be critically reviewed in the light of the survey findings and other promising pump designs will be considered. In this context the work which has been carried out at the University of Waterloo on an inexpensive plastic hand pump and well (Waterloo Research Institute Project No. 609-01) is relevant and of considerable interest. Appendix IV gives some comments of the 'Waterloo Pump'.

The provisional work programme is as follows:-

(1) Foot Valve Development and Assessment:

(a) Ball Foot-Valve Vibration Problem:

Investigation of the vibration problem of the ball foot-valve will be carried out. This will involve laboratory tests with a perspex pipe section fitted to the bottom end of the pump cylinder so that the ball movement can be observed. The test variables will be: length of stroke, pumping speed, pump lift, relative position of the plunger above the foot-valve at commencement of delivery stroke and the ball size.

(b) Assessment of Alternative Foot-Valve Arrangements:

Plate-type foot-valve arrangements will be tested - especially the plate-valve which has been recommended by the Waterloo Research Institute. This seems to be an effective valve - especially the simple 'non-recoverable' type (Figure 3A of Waterloo report).

(2) Plunger Investigation:

Tests will be carried out to determine the pumping efficiency and the wear for various piston/cylinder clearances and pump lift/head. These will be obtained for the following plunger materials and arrangements:-

(i) perspex plunger;

(ii) PVC plunger;

(iii) PVC plunger with one polyethelene piston ring (this will be a simplified version of the Waterloo pump piston - it will have a short piston length - see Figure 1);

(iv) as for (ii) and (iii) but with a two stack arrangement (see Figure 1 with the addition of dotted outline).

The above work will be additional to the data which is already available (polymer on polymer wear tests carried out by Waterloo Research Institute - see above mentioned report, and the wear data obtained from the Malawi pump field survey). The aim will be to arrive at the optimum or acceptable clearance for a plunger without sealing rings - with wear of piston and cylinder taken into account. An assessment of the life of various arrangements will be obtained - based on the Malawi survey findings of the life of a perspex plunger.

(3) Top Bush Arrangement:

Various top bush arrangements will be assessed. One possibility which will be tested is to make the top bush from local hard woods. The length of the top bush will be increased (compared to the existing pump). A simple top bush-cum-casing cover made of wood along similar lines to the Waterloo design will probably be tested.

(4) Assessment of Pump Rod/Piston Assembly of Modified Waterloo Pump:

The proposed simplified version of the Waterloo Pump is shown in Figure 1. It is proposed that the pump rod/piston assembly be carried out by solvent cement bonding of the various parts. A load (tensile) test will be carried out on this assembly to ensure that this method of securement is feasible. If need be a pin may also be inserted through the pump rod and the piston securing spigot.

It will be noted that the single piston component can be used for the double bearing piston as well as the 'non-recoverable' foot-valve (which would be solvent cemented to the pump cylinder-or secured by screws or pins).

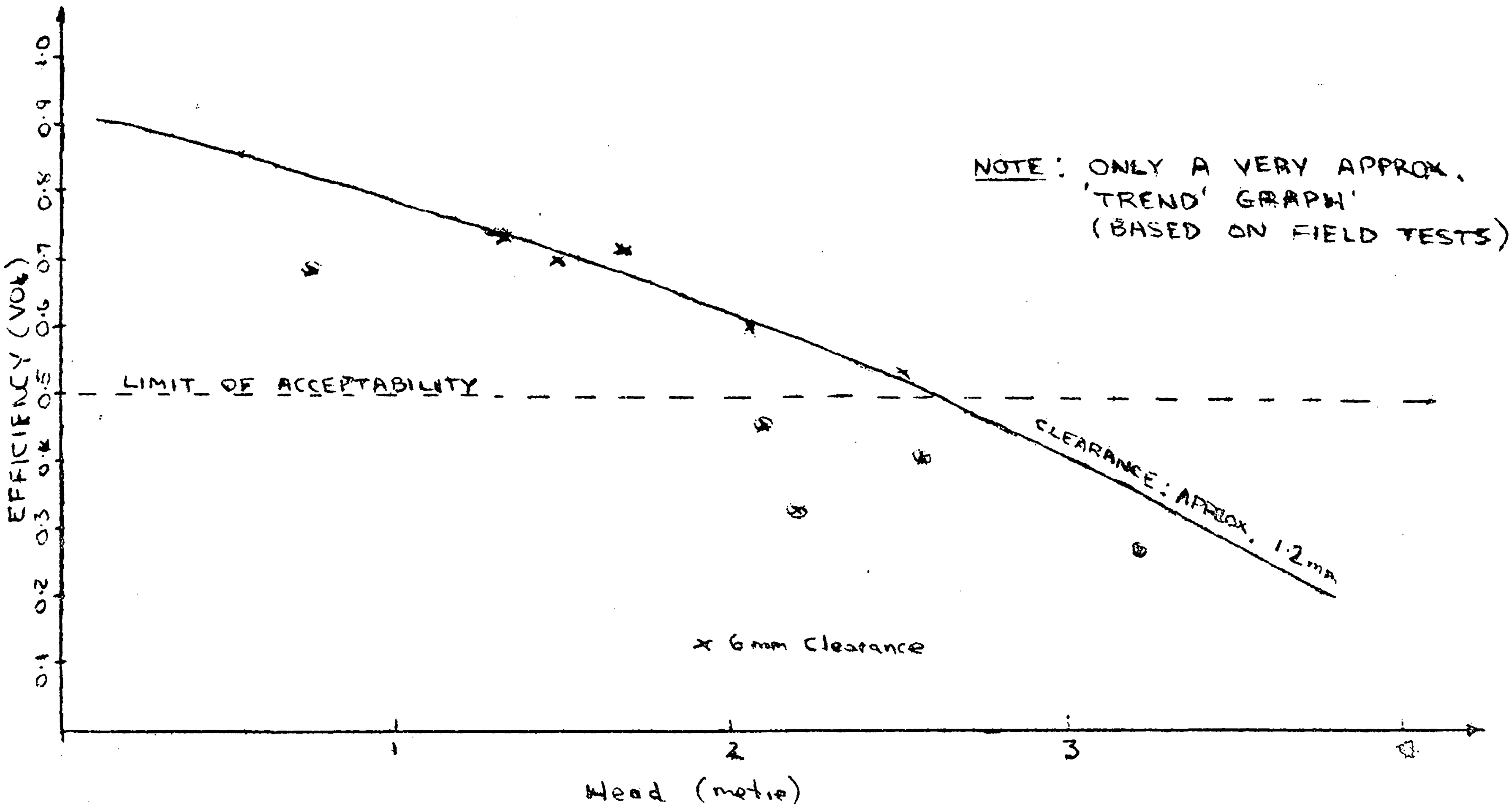
(5) Assessment of Final Design(s):

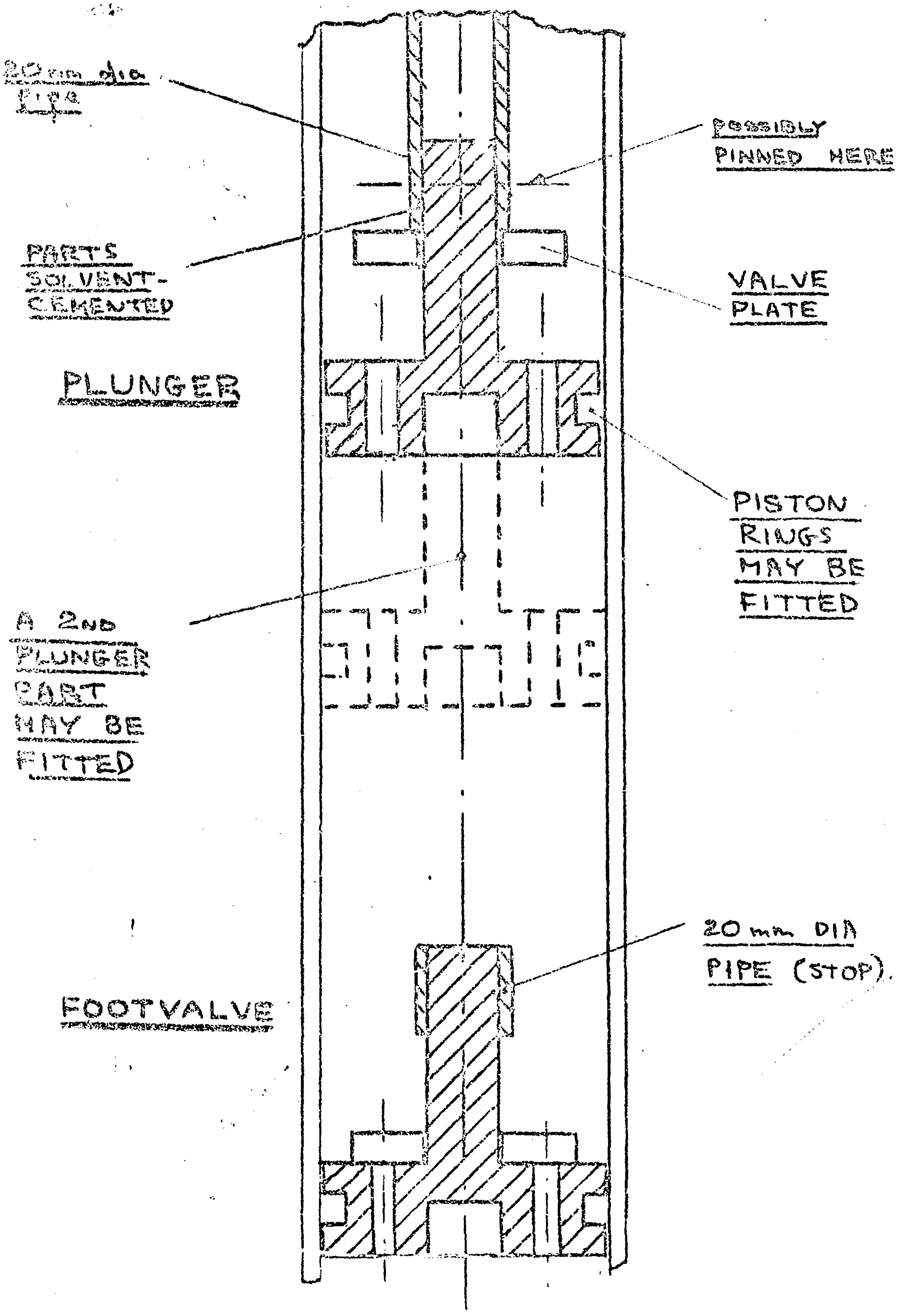
The measurements taken during the proposed work programme of laboratory tests will include wear and tear data and the maintanance requirements of the pump. The designs under test will take due consideration of the objectives of pump maintenance at the village level and the possible local manufacture of some components. After laboratory assessment one or two pump designs will be selected for field installation and evaluation.

WKK/MLC

7th April 1978

FIG 1. GENERAL TREND : VOL. 3 vs. HEAD





MODIFIED 'WATERLOO' PUMP

FIG 1

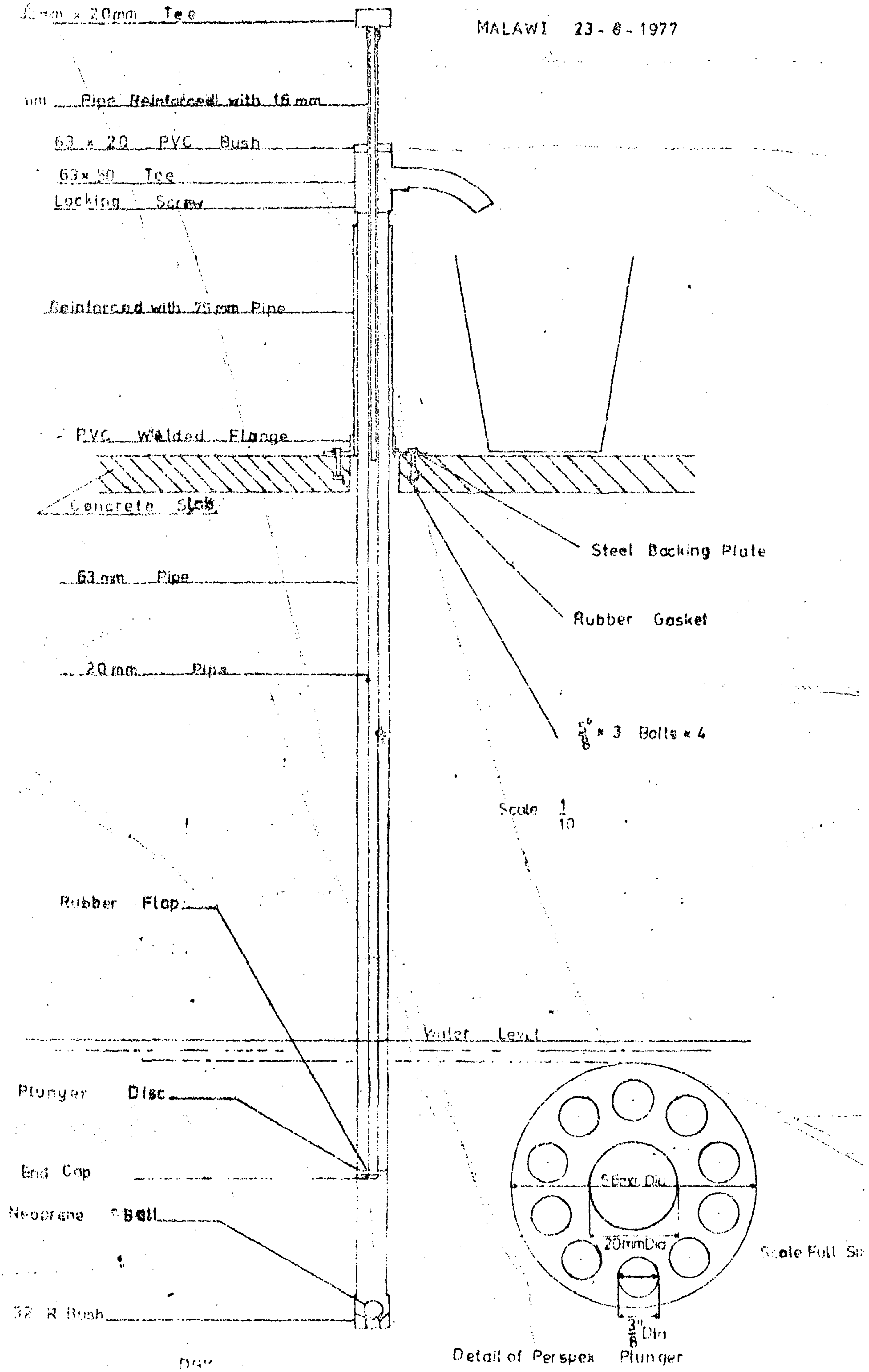
APPENDIX II

LOCATION OF WELLS

LOCATION	WELL NUMBER	INSTALLATION DATE
Mtsiro	51	
Katontha	16	
Kazulambonda	22	
Nthondo	27	
Mwitungwi	10	
Kasakali	39	
Chiwazula	45	
Siwinda (4)	66	
Njala (2)	14	
Chilemba	7	
Nsampha (2)	40	
Chiponda	52	
Nabwenje	19	
Nthondowa	34	16th May 1977
Mailoni	36	24th May 1977
Kasinja	23	
Nkwinda (2)	68	9th November 1977
Chiwoza	67	
Mphambonya	24	25th February 1977
Msampha (2)	40	
Mpopela (1) Kachitewe	54	
Mpopela (2) Kachitewe	61	5th July 1977
Khungwa	43	22nd June 1977
Malangwasira	6	17th May 1977
Msokonezi	2	
Chiwala	3	
Chisani (1)	17	
Chisani (2)	18	
Dzidzi (2)	38	
Chimdikeni (Kandiwo)	70	
Njala	63	2nd June 1977
Katikwa (Mbuta)	49	14th July 1977
Manyinda	24	24th February 1977
Malangwisila	21	8th January 1977
Mkwinda (1)	1	1st October 1976
Ndulu	6	
Matumatuwamba	46	26th May 1977
Msakadziko	60	
Msampha (3)	41	
Chimbalo	31	
Siwinda (3)	33	29th April 1977
Mzowa	20	15th December 1976
Mbuta (1)		16th June 1977
Mbuta (2)	47	16th June 1977
Kalungula	72	1st November 1977
Chidangwe	71	
Mbalani (Ngombe 2)	57	
Dzidzi (1)	37	
Kontho (1)		8th November 1977
Ngombe	56	18th June 1977
Sunche	9	
Masiwiti	8	
Mbuta (2)	49	
Chilemba	7	
Chulu	14	
Katontha	16	
Chitsotsa	48	
Siwinda (1)	29	
Mkulumimba (3)	11	
Malanda	4	
Kaphiza	53	
Mkulumimba (3)	13	
Mkulumimba (2)	12	
Swayi	55	
Katedwa/M'buta	42	16th June 1977
Mbuta	42	16th June 1977
Kanoto (1)	69	
[illegible] (2)	64	

SHALLOW WELL PVC HAND PUMP

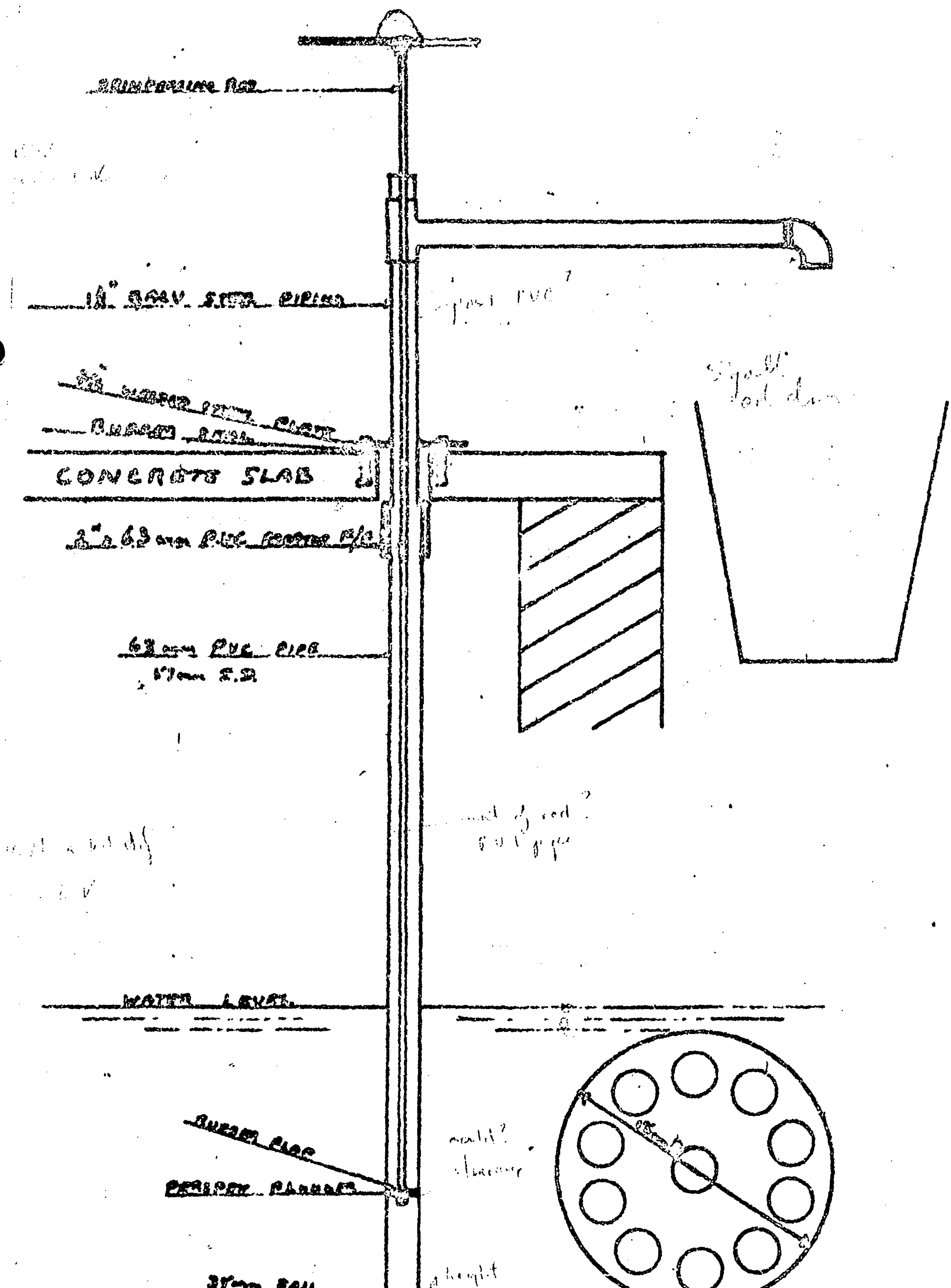
MALAWI 23 - 8 - 1977



SHALLOW WELL P.V.C. HAND PUMP
PARTS LIST

Item	Description
1.	Bush 63 x 20
2.	Tee 63 x 50
3.	Bend 45^{o}x 50mm
4.	75mm Class 16 pipe x 50cm
5.	P.V.C. Welded flange
6.	20mm P.V.C. bush
7.	Steel backing plate 3" table D
8.	5/8 x 3" Bolts Nuts and Washers x 4
9.	Rubber Gasket
10.	Self taping screw
11.	Perspex plunger
12.	Rubber flap
13.	end cap 20mm
14.	Neoprene ball 35mm
15.	Reducing bush 63 x 32
16.	16mm pipe x 1m
17.	20mm pipe x depth of Well + 1ft
18.	63mm pipe x depth of Well + 1ft
19.	Tee 32 x 20

SHALLOW WELL HAND PUMP



DETAIL OF PERSPEX PLUNGER

APPENDIX IV

COMMENTS ON THE 'WATERLOO' PUMP (REF. WATERLOO RESEARCH INSTITUTE REPORT ON PROJECT 609-01)

We feel that the 'Waterloo' pump has definite possibilities. At the moment for our purposes - shallow wells - we consider that several simplifications can be made.

We propose several modifications:-

(i) Non-recoverable footvalve (this agrees with one of the recommendations on page 57 of the report).

(ii) A simplified piston. A short-length piston is suggested of the same design as the above footvalve (see Figure 1). A piston ring may be fitted although we believe that this is not strictly necessary for low lifts. If no piston ring is fitted and the piston material is PVC (in a PVC cylinder) then the wear of the pump cylinder has to be considered (see later note).

Should our tests indicate some advantage of a longer piston then a second short-length piston would be fitted as shown in Figure 1.

(iii) Fitting of Piston to Pump Rod: Dispense with the need for a bolt and nut by solvent cementing the parts together. A pin may be fitted if necessary.

(iv) Leverage System and Casing Cover: These are interesting features and would probably be introduced at a later development of the wells programme. For simplicity we will omit them at present.

We are on the same lines as regard the following items: pump rod, top end and spout, and casing.

Polymer on Polymer Wear Tests:

These tests are interesting. We require information on the wear of perspex on PVC (our present plunger/cylinder combination). Field tests have established that a perspex disc plunger of diameter 56 mm in a pipe of diameter 57 mm wears by 0.5 mm in a period of 5 to 8 months. We do not have the corresponding wear data for the PVC cylinder.

The data in the Waterloo report on the wear of PVC on PVC is of interest. We are contemplating using the PVC piston without the polyethelene piston rings - giving wear of PVC on PVC. From the data in the Waterloo report - assuming an allowable wear for the piston to be 0.5 mm then (from Table 4 B of report) the wear of the PVC cylinder for this plunger wear would be:-

$$0.5 \times \frac{96}{4} = 0.0209 \text{ mm.}$$

If we assume that this wear would take place in 6 months then the wear of the cylinder in 1 year would be 0.0418 mm and in 10 years could be 0.418 mm. This is only a very simplistic calculation but it does indicate the possible adverse affect of dispensing with the polyethelene piston rings.

on PVC/ If comparable wear data for perspex on PVC and for PVC/were available then we would be able to come to a better estimate of the life of polyethelene rings or the PVC plunger (if no rings) as compared with the known life of perspex on PVC.

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B.P. 10

WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

REPORT FORMAT FOR FIELD TESTING OF HANDPUMPS

REPORT FORMAT

for

Field Testing of Hand Pumps.

Preamble : The ultimate criteria for choice of a hand pump would be :

(a). Performance in terms of longevity (measured in manhours of use between break-down).

(b). Ease of operation.

(c). Cost of pump.

(d). Simplicity of maintenance.

While these factors can be sub-divided with several sub-factors, the inter relation ships of which are quite complex, this study will limit itself to the more easily assessable components.

Two types of hand pumps are available for testing - viz : (a) shallow well pump, and (b) deep well pump.

Two sets of pumps are to be tested in different location, each set consisting of : 1 shallow well pump from India
1 shallow " " " Bangladesh.
1 deep " " " Thailand.

For ease of reference, the first set could be

I_1 , B_1 and T_1 with the 2^{nd} could be labelled.

I_2 , B_2 and T_2

For comparable results to be obtained, the four shallow well pumps, I_1 , B_1 and I_2 , B_2) should be installed under similar hydraulic conditions - i.e : where the depth from ground level to the water bearing stratum is the same and the seasonal drop in ground water is about the same. To ensure that the test is within these limits, the length of pipe installed on all 4 pumps should be the same.

Since the deep well pumps are of the same manufacture, they may be installed under different hydraulic conditions, so that their performance under these condition may be observed.
The two pumps may be installed where the ground water levels are at about 12 m and 20 m respectively below ground level.

Test procedure :

The study will consist of :

a) Inspection of the pump - cylinder and pump head in respect of materials of construction, physical and mechanical features. This information could provide some correlation with ultimate performance.

b) Longevity - this test would comprise of two parts -

i) Number of breakdowns is a given period (measured in actual man hourse of use).

ii) Fall-away in performance.

The first is a "Work-bench" inspection and a format is given under the heading "Work-bench inspection" (Form I).

Since a element of subjectivity is involved, the same investigator should inspect and report on all the pumps.

The second is a field performance test, carried out under actual - use conditions. This will consist of:

a. The measurement of output and its variations during the period of the test.

b. The assessment of man-hours of actual use.

c. A record of repairs / break-downs.

The test (a) will consist of the measurement of the time taken, under normal pumping use, to fill a bucket of 15 litre capacity. Three repetitive test will be run each time, 5 times during the entire period of the test. Assuming that the test will be run over four months, the timing of the test will be as below :

1. Day of installing pump	- Test	(a) :		secs
	Test	(b) :		secs
	Test	(c) :		secs
	Av.	:		secs
	Output	:		l/min.
2. 31st day after installation	- Test	(a) :		secs
	Test	(b) :		secs
	Test	(c) :		secs
	Av	:		secs
	Output	:		l/min

3. 62^{nd} day after installation -	Test (a)	:	secs
	Test (b)	:	secs
	Test (c)	:	secs
	Av.	:	secs
	Output	:	litre/min.
4. 93^{rd} day after installation -	Test (a)	:	secs
	- Test (b)	:	secs
	Test (c)	:	secs
	Av.	:	secs
	Output	:	litre/min.
5. 124^{th} day after installation -	Test (a)	:	secs
	Test (b)	:	secs
	Test (c)	:	secs
	Av	:	secs
	Output	:	litre/min.

The information obtained is filled into the form "Field test " (Form 2). The pumping should be done for all 5 tests by the same person to elimate the "human factor" in the test. (length of stroke & strokes/min).

The assessment of actual use of the pump will be made by an physical count of the number of users/day, and the average usage time/person.

The test should be done on at least 3 days during the entire period of the test, preferably, 5 days. The clocking of average time/user would be done at random over about 25 persons per test day. The information is filled in the format titled " Field test (b)' (Form 3).

A record will have to kept of all minor & mayor breakdown and a reliable reporting systems will have to be established to enable quick action to be taken to restore the pump to working order. The information on repairs required and effected is provided on the form with the heading " Record of Break-downs " (Form 4).

" WORK – BENCH INSPECTION "

G=good
F=fair
P=poor

	Pump Code No.					
	I_1	I_2	B_1	B_2	T_1	T_2
1. CYLINDER						
a. Body material	G	G	G	G	G	G
b. Cylinder material	[illegible]				PVC	
c. Cylinder surface smoothness	G		G		G	
d. Cylinder ovality	G		G		G	
f. Cup water material						
i) smoothness	G		Cleaned		G	
ii) tolerance to cylinder	G		G		G	
iii) pliability wet	G				G	
dry						
g. Piston valve						
i) material of valve	Leather		Rubber		Rubber	
ii) material of seat	[illegible]		Iron		Brass	
iii) type of valve	[illegible]		Iron		[illegible]	
iv) efficiency (leakage)	G		G		G	
h. Check valve						
i) material of valve	[illegible]		[illegible]		[illegible]	
ii) material of seat	[illegible]		Iron		[illegible]	
iii) type of valve	[illegible]		[illegible]		[illegible]	
iv) efficiency (leakage)	G		G		G	
i. Replaceability of components	G		G		G	
2. Pump head.						
i) type (integral/separate)	S		I		S	
ii) No. of pivot points						
iii) Material of pivot points	[illegible]					
iv) Tolerance / fit of pivot point.						
v) type of lubrication	[illegible]		Heavy oil		[illegible]	
3. Pump handle.						
i) material of construction	Iron		Iron		[illegible]	
ii) mechanical advantage	?		?		G	
iii)						
4. Pumping effort (low/moderate/ high).	H		H		L	
	INDIA		BANGLADESH		THAILAND	

Field Test (a).

1. Pump code No.
2. Location
3. Type of instalation : Open well / drilled well
4. Date of installation :
5. Date of test (i) :
6. Water level (below G.L.) :

Test consists of clocking time taken to fill a 15 litre bucket. The number of strokes taken aslo counted. Repeat 3 times for average)

I. day

	Time in secs	No. of strokes
Test(a)		
Test(b)		
Test(c)		
Average		

Output = l / min (litre per minute)

6. Date of test (ii)
Water level (below G.L.)

II. day

	Time in secs	No. of strokes
Test (a):		
Test (b):		
Test (c):		
Average :		

Output = l / min (litre per minute).

7. Date of test (iii).
Water level (below G.L.)

III. day

	Time in secs	No. of strokes
Test (a):		
Test (b):		
Test (c):		
Average :		

Output = l / min (litre per minute).

8. Date of test (iv)

Water level (below G.L.)

IV. Day

	Time in secs	No. of strokes
Test (a) :		
Test (b) :		
Test (c) :		
Average :		

Output = 1 / min (litre per minute).

9. Date of test (v)

Water level (below G.L.)

V. Day

	Time in secs	No. of strokes
Test (a) :		
Test (b) :		
Test (c) :		
Average :		

Output = 1 / min (litre per minute).

Signature : ____________

Investigator.

Form 3.

Field Test (b)

1. Pump code No.

2. Data of count.

3. Count of users.

TIME	USERS	TOTAL
05.00 - 06.00		
06.00 - 07.00		
07.00 - 09.00		
09.00 - 12.00		
12.00 - 14.00		
14.00 - 15.00		
15.00 - 16.00		
16.00 - 18.00		
18.00 - 20.00		

4. Av. time to fill 15 l. bucket

User No.	Time/secs	User No.	Time/secs
1		13	
2		14	
3		15	
4		16	
5		17	
6		18	
7		19	
8		20	
9		21	
10		22	
11		23	
12		24	
		25	

a) Av. time/user : secs

b) Output / min : litres

5. a) Total man - hour/day =

b) Total man hours for test period =

Form 4.

*

Record of breakdowns

1. Pump code No.
2. Date of installation.
3.

Date of breakdowns	Description of breakdowns	Date of repair.	Cost of Repair.
a			
b			
c			
d			
f			
g			

Signature ....
Recorded by

Equipment required

Item	Quantity
2 - 1. Stop watch	two
x 2. Steel mm Scale (30 cm)	one
x 3. Outside calipers 6"	one
x 4. Inside calipers 9"	one
2 5. Steel tape 30 m	two
x 6. 15 - lit, graduated plastic bucket	two
x 7. Tally counter	two

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HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

RECIPROCATING PUMPS TEST CODE

Scope

This Code establishes a procedure for conducting and reporting tests of metering, power and steam pumps to determine compliance with the provisions of the Standards.*

This Code specifies test conditions for measurement of metering pump capacity and provides limiting conditions for all methods of quantitative determination of power pump capacity and measurement of pressure and power input.

Except where specifically stated otherwise herein, this Code shall be understood to apply to tests of the pumps proper, and the terms "capacity", "total head" or "total pressure", "efficiency" and "power" are to be taken as referring to the pumps only.

While the pumps may handle a variety of liquids in addition to water, most pumps can be satisfactorily tested on water For those pumps where this is not practical and subject to specific agreement between manufacturer and purchaser, tests may be made with a clean petroleum oil of approximately 250 SSU viscosity at a pumping temperature between 60 F and 130 F.

This Code is not intended to cover tests where unusual liquids are handled. The methods of determining performance when pumping liquids other than water or oil are subject to specific agreement between the pump manufacturer and purchaser although the general procedure herein established may be used as a guide.

It is intended that the tests conducted under this Code shall be made and reported by qualified personnel, trained in the proper application and use of the various instruments and methods involved.

Test Tolerances
Metering Pumps

The test used to measure and time actual pump delivery should provide for the collection of a volume or weighted sample in a specified time period with a demonstrated variation of not more than one fourth of the percentage variation specified for repetitive accuracy of the pump.

* Test in accordance with these standards will normally be conducted by the manufacturer only when specified by the purchaser. Otherwise, manufacturers may conduct tests incorporating only those portions of these procedures which their experience with a particular type or model of pump has indicated are necessary to establish the suitability of the pump for the service intended.

The pressure measuring equipment should certified as having been calibrated to be with 0.5 per cent of the total pressure as determin by a "dead weight tester" or master referen pressures.

Power Pumps

Since the fluctuations in flow and pressu inherent to a power pump make it difficult obtain exact readings and since all measuri ments are subject to some error, a tolerance o plus and minus 2 per cent shall be allowed o all values directly measured and plus and minu 2 per cent on efficiency which is calculated fro the readings of capacity, pressure and powe In addition, a plus tolerance of 5 per cent ove rated capacity may be allowed, with a corre sponding allowance in horsepower input, pro viding the driver is not overloaded beyond it allowable service factor.

Production Test Procedure
Metering Pumps

Pumps to be tested shall be run in, and all conditions must be stable for each test, e.g.: suction pressure, discharge pressure, speed, liquid temperature, etc.

Each pump shall be checked for rated capacity and for repetitive accuracy by conducting two test runs which will be monitored at 100 per cent capacity and maximum rated or specified pressure under constant conditions without changing any pump controls. Pump delivery during each test run shall be equal to or more than the rated capacity of the pump. The difference in the delivery between the two tests represents the repetitive accuracy in which the difference is expressed as a percentage of maximum capacity.

All factory adjustments on relief valves, refill valves, and control accessories when furnished, are made to specified service conditions.

All assembled parts function normally without drive motor overload.

Pump Calibration. When pump calibration curves are required by the purchaser, the actual delivery at four capacity settings over the specified range (including maximum and minimum setting) shall be measured and recorded at specified or maximum rated pressure. These data shall be plotted as a percent capacity setting versus capacity curve with the test conditions as indicated.

Pump Witness Tests. When pump witness tests are required, the manufacturer should be consulted.

Test Procedure

Metering and Power Pumps

When acceptance tests are made, the purchaser and the manufacturer shall be represented and shall have equal rights in determining the conduct of the tests.

The plan of test and procedure shall be established by purchaser and manufacturer and shall cover the methods to be used in measuring all major quantities, including capacity, head, power input and speed.

The unit to be tested shall be run in and all conditions must be stable for each test point.

The results of the test shall be computed and found to be acceptable before the test can be considered terminated and the test equipment removed. The test report must be approved by both parties and, if published, shall follow the presentation explained in detail elsewhere in this Code.

Alternate Test Procedures

Metering and Power Pumps

Where the manufacturer's power supply is insufficient to test the pump at the maximum conditions or the motor, engine, turbine, etc., in the manufacturer's testing facility is not capable of operating the pump at the required conditions, the following procedure is to be used subject to specific agreement between manufacturer and purchaser:

Test pump at contract speed and capacity at maximum differential pressure that driver rating will permit.

Test pump at contract differential pressure at maximum pump speed and capactiy that driver rating will permit.

Corrections to specific pressure and capacity shall be made as explained later in this Code.

Steam Pumps

In many cases, the steam or air supply available at the manufacturer's plant is insufficient to test the pump at the contract conditions.

Under these conditions the steam pump shall be operated with steam or air at sufficient speed and pressure, pumping water at ambient temperature to assure proper operation of the pump.

No mechanical or volumetric efficiency tests are normally made on steam pumps.

Inspection

Metering and Power Pumps

Careful inspection shall be made before, during and after tests to insure the proper operation of the pump. Items 1, 2, 3, 5 and 6 should be inspected before the test and Item 4 during the test.

1. Alignment of pump and driver
2. Direction of rotation
3. Electrical connections
4. Operation of stuffing boxes and lubrication system
5. Clearances
6. Liquid passages

Hydrostatic Test

Metering, Power and Steam Pumps

Hydrostatic tests shall be made on all parts under hydraulic pressure using water at room temperature and at pressures equal to one and one-half times the maximum working pressure that a part is subjected to, unless specified otherwise.

Any casting (cylinder, chest, pot, pipe, etc.) that is under hydraulic, steam or air pressure when pump is in operation, shall be tested for five minutes and/or sufficient time to permit examination of the parts being tested.

Preliminary Tests

Metering and Power Pumps

It is advisable for the manufacturer to make one or more preliminary tests for the purpose of determining the adequacy of the instruments and apparatus and the training of the personnel.

When conditions do not permit such preparatory runs, operations may be started and the time at which conditions may become satisfactory can be chosen later as the starting time of a test.

Operating Conditions

Power Pumps

The most important factors affecting the operation of a power pump are:

Suction conditions

Total pressure

Effectiveness of pulsation damper on discharge side of pump

Unless suction line is short and unthrottled, effectiveness of pulsation damper on suction side of pump is reduced.

Where oil is used as the test liquid, viscosity shall be maintained within 10 percent of that specified for the duration of the test.

The total suction lift and total suction head are to be measured as specified on pages 236 and 237. During tests, the total suction lift shall not exceed that specified or, if a positive suction head is specified, the total suction head shall not be less than that specified. If the conditions set forth above are not immediately obtainable, the test shall be delayed until such conditions have been established.

If it is necessary that a valve in the suction line be closed partially to obtain specified inlet pressures, an effective pulsation dampener shall be installed at or near the pump to absorb the cyclical flow variation inherent to a power pump to prevent excessive pressure fluctuation, vibration, or noise.

When it is impossible to obtain the specified conditions of capacity, head, and speed, corrections to correspond to specified conditions shall be made.

In the measurement of capacity, corrections shall be made for the difference in temperature at the pump and at the measuring device to compensate for the volume difference.

Before the tests are begun, or before continuing the tests after an important change of conditions during operation, the apparatus shall be run under stable conditions for sufficient length of time to bring about equilibrium and steady readings.

Records
Metering and Power Pumps

Complete records shall be kept of all information relevant to a test. The suggested form for tabulating these data are given on pages 240 and 241.

The manufacturer's serial number, type, and size, or other means of identification of each pump and driver involved in the test, shall be recorded in order that mistakes in identity may be avoided. The dimensions and physical conditions, not only of the machine tested, but of all associated parts of the plant which have any important bearing on the object of a test, shall be determined.

While these records apply to the unit including the driver, the Code itsel only to tests of the pump.

Calibration of Instruments
Power Pumps

The supplier of all instruments shall evidence that they have been properly ca that they are being used under conditi responding to the calibration, and that in good condition corresponding esser that at the time of calibration.

Measurements
Power Pumps

The essential measurements for power pumps are:

- Capacity
- Total pressure or total head
- Power input to the pump
- Speed

Volume Measurements
Metering and Power Pumps

The standard unit of volume shall United States gallon or the cubic fo standard U.S. gallon contains 231. inches. One cubic foot equals 7.4805 The rate of flow shall be expressed in per minute (gpm), gallons per hour (barrels per day (bbl/day). A barrel, as these Standards, is considered to be ec to 42 U.S. gallons.

The preferred method of determining is by measurement of weight or volume of time.

Measurement of capacity by weight upon the accuracy of the scales used a the accuracy of the measurement of t the density of the liquid pumped.

Measurement of capacity by volume that sufficient measurements of the rese tank be taken to establish its volume acc When there is doubt as to the volur reservoir, it shall be calibrated by weig volume of liquid it holds.

Where it is impractical to determine by volume or weight methods, positive ment or volume meters may be used.

Venturi meters, orifices or nozzles used only with a large receiver, or a lo or a pipe with straightening vanes c ahead of the flow-sensing device so essentially steady flow exists as the liquid enters the measuring device.

The use of a venturi meter, orifice or nozzle, for capacity determination, requires accurate determination of the coefficient of the meter for the various characteristics of liquids.

Measurement of Pressure or Head Power Pumps

Accurate determination of the working pressure of a power pump requires the use of a receiver or pulsation damper of sufficient size to essentially absorb the cyclical variation in flow before throttling to establish the desired pressure. Throttling the line to a pressure gauge or the use of a damping device only in the gauge line does not insure an accurate pressure reading.

Head or working pressure shall be designated in pounds per square inch (psi). The relationship between pressure expressed in pounds per square inch (psi) and that expressed in inches of mercury (in. Hg) is:

$$\text{psi} = 0.49 \times \text{in. Hg}$$

In dealing with power pumps, it is customary to express head in pounds per square inch (psi) when referring to discharge head or suction head. Fig. 94 shows how measurements of head are made where the pressure is above atmospheric pressure. As the gauge reads psi, it is only necessary to correct for elevation (Z) and velocity head, both in terms of pounds per square inch.

Where there is suction lift or vacuum on the suction side of the pump, this is usually referred to in inches of mercury (in. Hg). Fig. 95 shows how measurements are made where the pressure is below atmospheric pressure. To find suction lift in terms of psi, multiply inches of mercury by 0.49, to which should be added the correction for elevation (Y) and velocity head, both in terms of pounds per square inch. (When calculating total differential pressure on a reciprocating pump, gauge elevation above or below datum and velocity head are negligible quantities and can be ignored.)

The datum shall be taken at the outlet port. In horizontal pumps this usually will be the lowest point of the discharge valve seat. In vertical pumps this may be, in the case of inverted pumps, the bottom of the plunger at the en of the suction stroke.

The gauge connection orifices shall be flus with and normal to the wall of the liquid passag and the wall shall be smooth and parallel wi the flow in the vicinity of the orifices. The or fices shall be from ⅛ inch to ¼ inch in diar eter, and their edges shall be free from bur or irregularities and shall be rounded to a radiu of 1/16 inch. All gauge connections shall be tigh

The following definitions apply to Figs. 9 and 95.

P_d = Total discharge head or pressure in pounds per square inch above atmospheric pressure at datum elevation.

P_s = Total suction head or pressure in pounds per square inch above atmospheric pressure at datum elevation.

P_g = Gauge reading in pounds per square inch.

h_g = Suction gauge reading in inches of mercury.

Y = Elevation of suction gauge connection to inlet port above datum elevation in feet. (Negative if the gauge connection to pipe lies below the datum elevation.)

Z = Elevation of discharge gauge zero above datum elevation in feet. (Negative if the gauge zero is below the datum elevation.)

V_d = Average liquid velocity in discharge pipe at discharge gauge connection in feet per second.

V_s = Average liquid velocity in suction pipe at suction gauge connection in feet per second.

g = Acceleration of gravity 32.17 feet per second per second.

sp gr = Specific gravity of liquid pumpe

In the case where gauge pressure is ab the atmospheric pressure and the connect line is completely filled with liquid:

$$P_d = P_g + .433 \times \text{sp gr}\left[Z + \frac{V_d^2}{2g}\right]$$

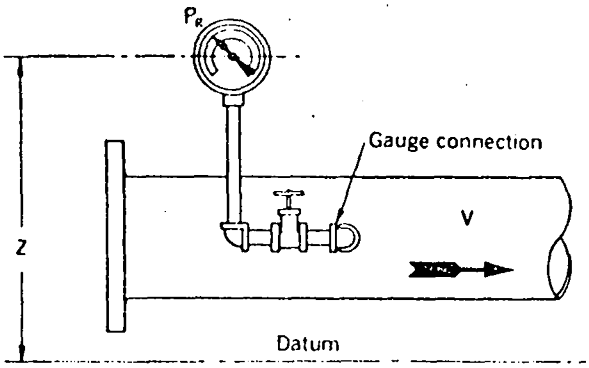

Fig. 94 TEST ABOVE ATMOSPHERIC

In the case where gauge pressure is below the atmospheric pressure and the connecting line is completely filled with air, with a rising loop to prevent liquid from passing to mercury column:

$$P_s = -.49\, h_g + .433 \text{ sp gr}\left[Y + \frac{V^2}{2g}\right]$$

The total pump head or pressure in pounds per square inch (psi) is given by the formula:

$$P = P_d - P_s$$

Note: P_s must be subtracted algebraically

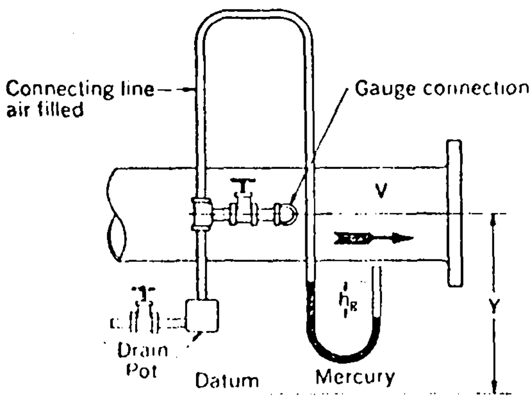

Fig. 95 TEST BELOW ATMOSPHERIC

Measurement of Power Input to Pump
Power Pumps

The unit of power input to pump is the horsepower.

1 horsepower = 550 foot-pounds per second
= 33,000 foot-pounds per minute
= 2545 Btu per hour
= .7457 kilowatts

Power Measurements
Power Pumps

Pump input horsepower may be determined from calibrated motors or from transmission or torsion dynamometers, if suitably damped.

Calibrated Drivers. When pump input horsepower is to be determined by the use of a calibrated motor, the following shall be applied.

All measurements of power input shall be made at the terminals of the motor to exclude any line losses that may occur between the switchboard and the driver itself.

Certified calibration curves of the motor must be obtained. The calibration shall be conducted on the specific motor in question, and not on an identical machine.

Such calibration curves must indicate the true input-output value of motor efficiency and not some conventional method of determining an arbitrary efficiency.

When the pump is arranged with a speed-changing device between the driver and the pump, the input to the pump shall be the actual output of the driving element less the loss through the speed-changing device. The value of this loss shall be certified by the manufacturer of the speed-changing device. If a speed-changing device is an integral part of the pump, the loss through this device shall be considered as part of the losses in the pump.

Transmission dynamometers may be used if equipped with a suitable means of damping out the cyclical variations inherent to a power pump. When pump input horsepower is to be determined by transmission dynamometers, the unloaded and unlocked dynamometer must be properly balanced prior to the test at the same speed at which the test is to be run, and the scales should be checked against standard weights. After the test, the balance must be rechecked to assure that no change has taken place. In the event of an appreciable change, the test shall be rerun. An accurate measurement of speed is essential.

Torsion dynamometers of the strain gauge type may be used if the electrical circuit effectively damps out the cyclical variations inherent to a power pump. Direct reading torsion dynamometers are not suitable for power pump tests. When pump input horsepower is to be determined by torsion dynamometers, the unloaded dynamometer shall be statically calibrated prior to the test by measuring the angular deflection for a given torque, the tare reading on the dynamometer scale being taken at rated speed with the pump disconnected. After the test the calibrations must be rechecked to assure that no change has taken place. In the event of an appreciable change, the test shall be rerun. An accurate measurement of speed is essential.

**Measurement of Speed
Power Pumps**

Measurement of speed shall be made by means of revolution counters or tachometers.

For speed measurements taken by means of a revolution counter, the timing period shall be of sufficient length to obtain a true average speed and the stopwatch used should be checked against a standard timer.

When a tachometer is used, it shall be calibrated against a revolution counter before and after test. Tachometer readings should be made at frequent intervals during each test point to obtain an accurate measurement of average speed over the reading period.

**Measurement of Viscosity and Density
Power Pumps**

While viscosity and density do not directly enter into the performance calculations when the capacity is measured directly in volumetric terms, as gallons per minutes, and the total pressure as a unit pressure in pounds per square inch, the density must be checked at suitable intervals if the capacity is determined by weight. Similarly, viscosity does not enter into performance calculations, but if a specific pump is tested on oil rather than water, viscosity should remain constant within the limits set in Operating Conditions page 234 and should be checked at suitable intervals.

Note: Refer to ASME, Power Test Codes, Instruments and Apparatus, for method of viscosity and density determination.

**Calculation of Output Horsepower
Power Pumps**

Since the total head is expressed in pounds per square inch, the formula for liquid horsepower, irrespective of specific gravity of the liquid, becomes:

$$\text{liquid hp} = \frac{\text{gpm} \times \text{differential pressure}}{1714}$$

**Calculation of Input Horsepower
Power Pumps**

The input horsepower (bhp), when measured by a transmission dynamometer, is calculated from the following formula.

$$\text{bhp} = \frac{2\pi LWn}{33{,}000}$$

where

L = Length of lever arm in ft.

W = Net weight in lbs.

n = Speed in rpm

π = 3.1416

The electrical horsepower input to an electric motor is given by:

$$\text{ehp} = \frac{\text{kw}}{.746}$$

where

kw = Kilowatt input

The input horsepower to a pump driven by an electric motor is:

$$\text{bhp} = \text{ehp} \times E_m$$

where

E_m = True efficiency of motor.

**Calculation of Efficiency
Power Pumps**

The pump mechanical efficiency is calculated from:

$$E_p = \frac{\text{output}}{\text{input}} = \frac{\text{whp}}{\text{bhp}} \times 100$$

The overall unit efficiency of a motor driven unit is calculated from:

$$E_o = \frac{\text{whp}}{\text{ehp}} \times 100$$

or

$$E_o = E_p \times E_m$$

**Correction to Constant Speed
Power Pumps**

Where specified speed cannot be reproduced during a test, corrections shall be made by using methods shown below.

This correction should be limited to plus or minus 20 per cent of the specified speed.

Correction of Capacity
Power Pumps

At constant pressure, the capacity will vary with speed as follows (plus or minus 20 per cent of specified speed):

$$Q_2 = \frac{n_2}{n_1}(Q_1 + S) - S$$

where

Q_1 = Capacity at test speed (gpm)

Q_2 = Capacity at specified speed (gpm)

n_1 = Test speed

n_2 = Specified speed

S = Slip (gpm), which equals the difference between the theoretical displacement and actual capacity at test speed.

Correction to Input Horsepower
Power Pumps

Input horsepower will vary approximately as:

$$bhp_2 = bhp_1 \times \frac{n_2}{n_1}$$

where

bhp_1 = Power at test speed

bhp_2 = Power at specified speed

n_1 = Test speed

n_2 = Specified speed

Plotting Results
Power Pumps

The capacity, efficiency, and input or bra horsepower, are usually plotted as ordinates the same sheet against total head as abscissa shown on Fig. 96.

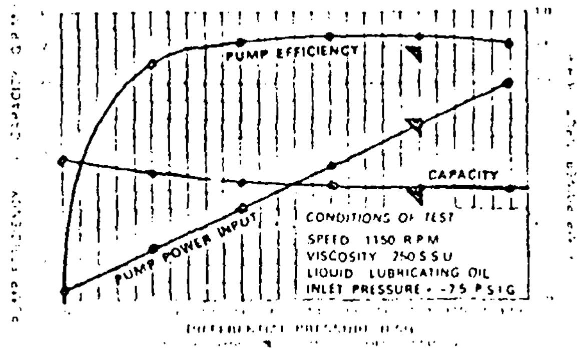

Fig. 96 PLOTTING RESULTS POWER PUMP

reciprocating pumps
test code

SUMMARY OF NECESSARY DATA ON PUMP TO BE TESTED

The necessary data on pump to be tested are as follows:

General:

1. Owner's name __________
2. Plant location __________
3. Elevation above sea level __________
4. Type of service __________

Pump:

1. Manufactured by __________
2. Manufacturer's designation __________
3. Manufacturer's serial number __________
4. Arrangement: horizontal __________ vertical __________
5. Inlet: single __________ double __________
6. Size suction: nominal __________ in., actual __________ in.
7. Size discharge: nominal __________ in., actual __________ in.

Intermediate Transmission:

1. Manufactured by __________
2. Type __________
3. Serial number __________
4. Speed ratio __________
5. Efficiency __________

Driver:

1. Manufactured by __________
2. Serial number __________
3. Type: motor __________ turbine __________ other __________
4. Rated horsepower __________
5. Rated speed __________
6. Characteristics (voltage, frequency, etc.) __________
7. Calibration curve __________

Specifying Rated Conditions

The necessary data on pump rated conditions are as follows:

1. Liquid, water __________
2. Liquid, oil, of __________ SSU; sp gr __________ at __________ F
3. Liquid, other liquids, of __________ SSU; sp gr __________ at __________ F
4. Pumping temperature __________ F

5. Capacity __________ gpm __________ gph __________ bbl
6. Total suction lift __________ ft __________ in. Hg (below atmospheric press
7. Total suction head __________ ft __________ in. Hg __________ psi (above atmospheric pressure)
8. Total discharge head __________ ft __________ psi (above) (below) atmospher pressure
9. Total head __________ ft __________
10. Liquid horsepower __________ v
11. Brake horsepower __________ t
12. Speed __________ r
13. Pump efficiency __________ per c

TEST INFORMATION

Test results, listed substantially in the following order, shall be given as:

General:

1. Where made __________
2. Date __________
3. Test made by __________
4. Test witnessed by __________

Capacity:

1. Method of measurement __________
2. Meter—Make and serial number __________
3. Calibration curve __________

Head:

1. Suction gauge—Make and serial number __________
2. Calibration curve __________
3. Discharge gauge—Make and serial number __________
4. Calibration curve __________

Power:

1. Method of measurement __________
2. Make and serial number of instrument __________
3. Calibration curve __________

Speed:

1. Method of measurement __________
2. Make and serial number of instrument __________
3. Calibration curve __________

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who international reference centre for community water supply

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telephone: 070 - 69 42 51, telegr.: worldwater the hague, telex: 33604

B.P. 12

WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

COMPARATIVE TESTING OF CONSUMER PRODUCTS

ISO GUIDE 12

GUIDE 12

First edition — 1977-02-15

Comparative testing of consumer products

UDC 641/648 : 620.1

Ref. No. ISO GUIDE 12-1977 (E)

Descriptors : tests, comparative tests, consumers information.

Price based on 3 pages

ISO GUIDE 12-1977 (E)

Comparative testing of consumer products

0 INTRODUCTION

This document sets out a number of principles relating to the operation of comparative testing programs. In these programs, different products offered for the same purpose are subjected to analyses and tests, the results of which provide consumers with information on the characteristics of these products, enabling them to make a choice among products offered to them on the market that best meet their particular needs and budget.

Comparative testing is usually undertaken by independent bodies specializing in the management and operation of consumer information systems.

Consumer information systems based on comparative evaluation of products are, however, often undertaken by bodies whose main activities are not necessarily directed towards consumer information systems.

In compiling this document, Technical Committee ISO/TC 73 carried out an extensive survey of the systems and procedures followed by bodies operating comparative testing programs, especially members of the International Organization for Consumers Unions (IOCU).

ISO/TC 73 also bore in mind the fact that ISO and IEC, through their technical committees, have launched an extensive program for the preparation of standard methods for measuring the performances of consumer products (SMMP). These methods are intended for technical testing of products for consumer information systems, including comparative testing.

Comparative testing programs usually consist of the overall evaluation of different products or services of the same kind. This involves the accumulation and recording of characteristics, many of which are non-technical and influenced by conditions prevailing in the particular country, region or market under survey. For this reason, comparative testing programs may be different from place to place and influenced by factors such as money and facilities available, market conditions and legislation in force, custom and tradition.

Technical test results obtained should, however, be based on test procedures which might be internationally applied, such as SMMPs. These SMMPs provide test results on the performance and durability of products that are technically comparable, irrespective of the country, region or market in which such a project is undertaken.

This document deals mainly with the technical aspects of the testing of products and gives only broad outlines of the non-technical aspects.

1 SCOPE AND FIELD OF APPLICATION

This document sets out guidelines for the conduct of comparative testing programs of products for the information of consumers.

2 DEFINITIONS

2.1 comparative testing : For the purpose of this guide, the subjecting to tests of different products offered for the same purpose, the results of which allow consumers to be provided with unbiased information on the characteristics of these products.

This information should enable consumers to make a rational choice, among products offered to them on the market, that best meets their particular needs and budget. Such information is supplied by making available, via publications or through other means, results of tests and, as the case may be, of subjective assessments made in accordance with methods and criteria judged adequate to provide a meaningful objective comparison of prices, specific performance characteristics and other complementary criteria of the products under review, including their likely effects on the environment.

In addition, the analysis may serve to give consumers more general information about products of the same kind.

2.2 body responsible for comparative testing (hereafter referred to as CTB) : The body which not only organizes and manages comparative testing programs but also arranges and accepts responsibility for the dissemination of information to consumers based on such comparative testing programs.

3 GENERAL PRINCIPLES

3.1 Body responsible for comparative testing

The CTB should ensure that all aspects of the work are carried out in a proficient and objective manner.

3.2 Choice of the type of products

The choice of the type of products to be tested must rest entirely with the CTB. This choice should, however, reasonably reflect the consumers' needs for information and take into account the possibility of conducting the test within the recommendations of this guide. Products submitted to tests should be sufficiently representative of the variety of products offered on the market for one and the same purpose. The CTB may also deal with a limited selection of products if there are unique or specific aspects of interest to consumers (for example safety or doubtful effectiveness) or may limit itself to a given price range.

3.3 Choice of the sample

The method used for the choice of the sample of products subjected to testing should ensure randomness of selection of products as far as possible in the same way as consumers normally select them on the market. The sample should be obtained through normal retail channels, and care should be exercised that special samples are not introduced for testing purposes.

The CTB should take reasonable steps to ensure that the models selected for tests will be available on the market when the test results are published.

3.4 Size of the sample

For the determination of the size of the sample, it is not always possible or desirable, in the light of 3.3, to take a purely statistical approach. In this case, precautions should therefore be taken to ensure that the results obtained are representative of the products on the market. Such precautions may include an assessment as to whether a fault is due to poor design or to an exceptional product failure, the checking of results against manufacturer's specifications, the substitution or repair of a sample, the presentation of certain test results individually to manufacturers for comment, and consideration of the experience of consumers themselves.

With certain products, such as perishable goods, particular attention should also be paid to the trading channels used for the purchase of the items, conditions of sampling, transport and storing before test in order to ensure the comparability of test results.

NOTE – The statistical techniques for the determination of samples are described in the reference standards ISO 2859, *Sampling procedures and tables for inspection by attributes*, ISO 3319,[1] *Guide to the use of ISO 2859*, and ISO 3951,[1] *Sampling procedures and charts for inspection by variables for percent defective.*

3.5 Choice of characteristics

Unless a special survey is made for a particular purpose, such as the investigation of safety or reliability, all characteristics of the product which are relevant to its use by the consumer should, as far as possible, be taken into account. These may include running costs and likely total cost for ownership, safety, health, the effect on the environment, the conservation of natural resources and energy consumption. Attention should also be given to other aspects which are relevant to product satisfaction, for example packaging, delivery, installation, instructions for use, guarantees, maintenance costs and servicing, including the availability of spare parts.

In order to further the exchange of information, the definition of characteristics should, whenever possible and appropriate, be those recognized by international standards organizations (in the form of SMMPs), by the national standards body, by government or by other qualified bodies.

3.6 Program of tests

The program of tests should particularly take account of any legislative requirements relevant to the product.

1) At present at the stage of draft.

3.7 Test methods

The test methods used should be, as far as possible, the SMMP provided by standards approved or recognized by ISO or IEC, or by the national standards body. If these standards are deemed not appropriate and alternative methods are used, it is recommended that the CTB give the reasons for this choice and indicate the methods it has decided upon to the national standards body.

The chosen test methods should be reproducible, at least to the degree necessary to obtain test results allowing the establishment of a consistent and reproducible ranking order of products.

NOTE – It is advisable to consult on this subject ISO 5725,[1] *Determination of the repeatability and reproducibility of a standard test method.* This document will be especially useful in cases of dispute, for it contains the description of a procedure for controlling test results by means of inter-laboratory tests.

When characteristics can only be evaluated subjectively, the evaluation should be based on assessments made by experts or consumer panels, or on surveys of ordinary consumers. In the latter case, the survey should be conducted and analysed in accordance with accepted statistical practice, or the methods used and the limitations of the survey clearly stated.

3.8 Verification of test results

The CTB should take steps to minimize errors in testing or results from faulty samples. One way of doing this is to inform the manufacturer of test results on his own product and to invite his comments in sufficient time before publication. The test results submitted to the manufacturer should be accompanied by the list of characteristics tested and the test methods used. If the manufacturer disagrees with the test results, it is recommended that he supplies data to the CTB to demonstrate that the test results are wrong or that the tests used were unsuitable. The CTB should give consideration to these comments but is not bound by them.

3.9 Evaluation and presentation of test results

The evaluation and presentation of test results should be made in a manner which is technologically sound but also in terms which can be easily understood by consumers. Where statutory units or symbols meet the latter requirement, they should preferably be used. In assessing all test results, care must be taken not to emphasize differences between products if they are of no practical importance or are relatively insignificant for ordinary consumers.

Without flooding the consumer with scientific details, the system of presentation of test results and overall evaluation should be clearly explained in so far as this knowledge is required for an appreciation of the test results (for example criteria for the choice of products, constitution of the sample, method of sampling, characteristics chosen and reasons for excluding certain characteristics, test methods or surveys used, with their limitations, relative importance attached to the different tests and characteristics, stating the reasons).

Price and running costs in relation to results of tests are essential elements of choice. This information should, as far as possible, be given and should reflect the market situation at the time of publication. In order to assist consumers in choosing products most suited to their needs and budget, the conclusion of the test report may suggest a number of best possible purchases.

These conclusions should leave the ultimate decision to consumers but may nevertheless stress those products that may represent best value for money in the opinion of the CTB.

3.10 Publication

CTBs should not accept commercial advertising in the publication used for the test report. Other channels of disseminating information may, however, be used at the discretion of the CTB, to reach as many consumers as possible.

CTBs may permit the use of test results by third parties only when this is done in a way which does not alter their meaning or affect their objectivity.

Although CTBs cannot be held responsible for reprints by third parties, they should take all possible precautions to ensure that breaches of these requirements do not occur.

---

1) In preparation.

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who international reference centre for community water supply

postal address: p.o. box 140, leidschendam, the netherlands
office address: nw havenstraat 6, voorburg (the hague)
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WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

FORMAT "WORK-BENCH INSPECTION"

INDONESIA

Form: 1

"WORK - BENCH INSPECTION"

(Pre-installation check)

HAND PUMP: Type: ______________________

Origin/Country: ______________________

Code: ______________________

Place of Installation: ______________________

1. CYLINDER:

   a. Body material: ______________________

   b. Cylinder material: ______________________

   c. Cylinder ovalty: ______________________

   d. Cylinder smootheness: ______________________

   e. Cup water material- smooth: ______________________

   f. Piston valve material: ______________________

   Type of valve: ______________________

   Efficiency of valve: (leakage) ______________________

2. PUMP HEAD:

   Type- integral/separate: ______________________

   No.of pivot points: ____________

   Material of pivots : ______________________

   Type of lubrication : ______________________

3. PUMP HANDLE:

   Material of handle: ______________________

   Type of handle: ______________________

4. PUMPING EFFORT:

   Low: ______________________

   Moderate: ______________________

   High : ______________________

Repair of the hand pump needed? : ______________________

Place : ____________ Date: ______________ 19____

Form: 2

FIELD TEST (a)

Type of pump ______________________

Code : ______________ Place : ______________

Date of installation: __________ Date of test : __________

Water level(below G.L.) __________ Type of well: Open/Drilled ?

Test consists of clocking time taken to fill a 15 litre bucket. Number of strokes taken also counted. (Repeat three times for average)

Date of test: __________

Water level: __________ m.
(below G.L.)

	TIME in sec.	No. strokes	
Test a.			1 Day
b.			
c.			
av:			

Output:lit/min: __________

Date of test: __________

Water level: __________ m.

	TIME in sec.	No. strokes	
Test a.			2 Day
b.			
c.			
av:			

Output:lit/min: __________

Date of test: __________

Water level : __________ m.

	TIME in sec.	No. strokes	
Test a.			3 Day
b.			
c.			
av:			

Output:lit/min: __________

Date of test: __________

Water level: __________ m.

	TIME in sec.	No. strokes	
Test a.			4 Day
b.			
c.			
av:			

Output: lit/min: __________

Date of test : __________

Water level : __________ m.

	TIME in sec.	No. strokes	
Test a.			5 Day
b.			
c.			
av:			

Output: lit/min: __________

____

(Signature insvestigator)

Form: 3

FIELD TEST (b)

1. Type of pump: ______________________
2. Code: ______________________
3. Place of installation: ______________________

TIME	No.of Users	TOTAL
5 - 6 hrs		
6 - 7		
7 - 9		
9 - 12		
12 - 14		
14 - 15		
15 - 16		
16 - 18		
18 - 20		
	Total users:	

Average time to fill 15 lit. bucket:

USER	Time/sec.	USER	Time/sec.
1		13	
2		14	
3		15	
4		16	
5		17	
6		18	
7		19	
8		20	
9		21	
10		22	
11		23	
12		24	
		25	

a) av.time/user : sec: ____________

b) output/min : litre : ____________

Total No.of man per day: ______________________

Form: 4

RECORD OF BREAKDOWNS

Type of hand pump: ______________________

Code: ______________ Place: ______________

Date of installation: ____________ 19____

Date of breakdown	Description of the breakdown	Date of repair	Cost of repair

Date: ____________ 19 ______

Signature: ______________________
(Recorded by:)

Equipment required for test:

Item	Quantity:
1. Stop watch	one
2. Steel tape +30 m	one
3. Caliper (out) or one double 4. " (in)	one
5. Tally counter	one
6. Bucket, gradusted,plastic, 15 lit, 1 pc.	

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B.P. 14

WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

DIRECTORY OF HANDPUMP MANUFACTURERS

HAND PUMP MANUFACTURERS

ARGENTINA

Fabrica de Implementos Agricolas, S.A.
AERMOTOR
Hortiquera 1882
Buenos Aires

("Lago")
("Piccolo")
("Brisa")
("Aermotor")

AUSTRALIA

Metters
Murray House
77-79 Grenfell Street
Adelaide

AUSTRIA

Moderne Pumpen Ernst Vogel
Prager Strasse 6
P.O. Box 42
A 2000- Stockerau

("Vogel")

BANGLADESH

National Iron Foundry & Engineering Works Ltd.
Station Road
Khulna

("MOSTI No. 6")
("New No. 6")

Essential Products Ltd.
186 Rayer Bazar
Dacca

("MOSTI")
("New No. 6")

Bangladesh Light Casting Co
429-432 Tejgaon Industrial Area
Dacca

("MOSTI")
("New No. 6")

General Engineering & Foundry Works
199 Nawabpur Road
Dacca

("MOSTI")
("New No. 6")

Unique Metal Industries
44/C Azimpur Road
Dacca

("MOSTI")
("New No. 6")

BELGIUM

Pompes Deplechin
Dept. des Ateliers Deplechin
Avenue de Maire 28
B-7500 Tournai

tel.069-228152
tx. 57369

Duba S.A.
Nieuwstraat 31
B-9200 Wetteren

("Tropic I")
("Tropic II")
("Tropic III")

SERTECO - Water Technology Dept.
446, Avenue de Tervueren
1150-Brussels

BRAZIL

Industrias Mechanicas Rochfer Ltd.
Caixa Postal 194
Franca, Sao Paulo

(water operated piston pumps)

Bombas Americana Ltd.
Av. Marginal de
Via Anhanguera 580
Pq. Sao Domingos
Sao Paulo
("M1400", "M 1500")

CANADA

Beatty Bros. Ltd.
Fergus, Ontario

("Beatty")
("Dominion")

GSW Pump Division
Hill Street
Fergus, Ontario N1M 2X1

tel. 519-8431610
tx. 06-956552
Mr. M.O. Hickman - General Manager

Monarch Industries Ltd.
889, Erin Street
P.O. Box 429
Winnipeg R3C 3E4

("Monarch")

Robbins & Myers Company of Canada Ltd.
Brantford, Ontario

("Moyno")

Tri-Canada Cherry Burrell Ltd.
Mississauga, Ontario

("Helical rotor-stator type")

CHINA (People's Republic)

China National Machinery and Export Corp.
Kwantung Branch
61 Yanjiang Yilu
Kwangchow

("Golden Harvest")
("YL series")
("SB 38-1")
("SB 40-1")
("S & SH")

CZECHOSLOVAKIA

Sigma Pumping Equipment and Valves Manufacturing Works
Vaclavské nám.c60
P.O. Box 1111
11187 Praha 1

("Intersigma")

FINLAND

Vammalan Konepaja Oy
38200 Vammala

tel. 2667

("Nira")

FRANCE

Les Pompes Andrè Bodin
Usine des Regains
B.P. 29
37150 Blère

("Solo")
("Majestic")
("Celtic")

Ets. Pierre Mengin
Zone Industrielle d'Amilly
B.P. 163
45203 Montargis

("Hydropompe Vergnet")

Ets. Pompes Guinard
B.P. 189
36004 Chateauroux

Mr. J. Cesbron

Gould's Pump Inc.
113, Ave. Charles de Gaulle
F-92200 Neuilly-sur-Seine

Briau S.A.
B.P. 43
37009 Tours

("Royale")
("Murale")
("Aral")
("Classique")
("Africa")
("Hydraulic Rams")

Ets. Champenois
Chamouilley 52710 Chevillon

("l'Africain", chain type of pump using a nylon band)

GERMANY (Federal Republic)

Preussag Aktiengesellschaft
Kunststoffe und Armaturen
Postfach 9, Eixer Weg
D-3154 Stederdorf, Kr.Peine

(PVC casing, screens, cylinders)

Pumpenfabrik Beyer
2400 Lubeck 1
Glockengiesserstrasse 61

INDIA

Balaji Industrial and Agricultural Castings
Hill Street
P.O. Box 1634
Secunderabad - 500003

("Balaji" - Jalna Type)

Charotar Iron Factory
opp. New Ramji Mandir
Anand. Gujarat

("Wasp" type)

Senthil Engineering Co.
49 A/21 Kamaraja Road
Tiruppur - 4
Coimbatore

Dandekar Brothers
Shivaji Nagar Factory Area
Sangli
Maharashtra

("Jal Javahar")

Central India Engineering Co.
2153/5, Hill Street
Ranigunj
Secunderabad - 500.003 A.P

("Banglore"; "India Mark II")

Gujarat Small Industries Ltd.
Nanavati Estate, near Chakudia Mahadeo
Rakhial, Ahmedabad-23

("Kirti")
("Kaveri", very similar to Dempster)

Inalsa
19 Kasturba Gandhi Marg
P.O. Box No. 206
New Delhi - 110001

("Mark II")

JPSR Company (Mittra Das Ghose & Co.)
Howrah, near Calcutta

(low-lift & deep well pumps)

Kumar Industries
P.O. Box 2
10/194 Shekkarjyothi
G.B. Road
Palghat-1, Kerala State

("Bharatt 4")

Lifetime Products Corporation
Industrial Area
P.O. Box 102
Jodhpur

(Wasp type)

Marathwade Sheti Sahayya Mandal
Jalna, Dist. Aurangabad
Maharashtra

(originator and non-commercial
manufacturer of Jalna type)

Maya Engineering Works Private Ltd.
200A Shyamaprosad Mukherjee Road
Calcutta-700 026

("Maya Nos. 4,5,6")

Mohinder & Co.
Kurali, Dist. Ropar
Punjab

(low-lift pumps)

Richardson & Crudass Ltd.
(A Fovt. of India undertaking)
Madras

("Mark II")

Rohine Engineering Works Ltd.
Industrial Estate
Miraj 416410
Maharashtra

Senco Industries
A-12, Coimbatore Private Industrial Estate
Coimbatore-21

("Senco", also "Jalna; Sholapur")

Sholapur Well Service
560/59 South Sadar Bazaar
Civil Lines
Sholapur-3 Maharashtra

(non-commercial manafacturer of Jalna type)

Vadala Hand Pump
Marathi Mission
Ahmednagar
Maharashtra

(non-commercial manufacturer of Jalna type)

Water Supply Specialists Private Ltd.
P.O. Box 684
Bombay-1

("Wasp")

IVORY COAST

Abidjan Industries
B.P. 343
45, Rue Pierre et Marie-Curie
Abidjan Zone 4c

(ABI-type "M")
("Africa")

SAFICOCI
B.P. 1117
Abidjan

("Africa", agent for Pompes Briau)

JAPAN

Kashima Trading Co. Ltd.
P.O. Box 110, Higashi
Nagoya

("Kawamoto")

Kawamoto Pump Mfg. Co. Ltd.
P.O. Box Nagoya Naka No. 25
Nagoya

("No. 2-C Dragon")
("No. 5-N Tomoe")

Tsuda Shiki Pump Mfg. Co. Ltd.
2658 Mimani-Kannon-Machi
Hiroshima Prefecture

("Keibogo")
("Delta")

KENYA

Atlas Copco Terratest Ltd.
Norwich Union House
P.O. Box 40090
Nairobi

("Kenya", previously "Uganda")

MALAGASY REPUBLIC

Comptoirs Sanitares de Madagascar
B.P. 1104
Tananarive

("Mandritsara")

MAROC

Ets. Louis Guillaud et Cie
31, Rue Pierre Parent
Casa Blanca

NETHERLANDS

Pijpers International Water Supply Engineering
Nijverheidsstraat 21
P.O. Box 138
Nijkerk

("Kangeroo Pump")

Van Reekum Metalen B.V.
Kanaalstraat 33
Postbus 98
Apeldoorn

tel. 055-213283

NIGERIA

DIY pump

PARAGUAY

~~Bombas Americana Ltd.~~
~~Av. Marginal de Via Anhanguera 580~~
~~Pq. Sao Domingos~~
~~Sao Paulo~~

(~~"M 1400", "M 1500"~~)

Kasamatsu S.A.
Comercial & Industrial
Chile 452 - Piso 20 Edificio Victoria
Casilla de Correo No. 52
Asucion

(Gera models "G-60", Gera models "M")

PHILIPPINES

Avenue Mfg. Co. Inc.
P.O. Box 3629
Manila

(Pitcher Pumps)

Dong Tek Foundry
699 Elcano Street
Manila

(Pitcher Pumps)

Seacom
M/S Sea Commercial Co., Inc.
3085 R. Magsaysay Blvd.
Cor. V. Cruz St.
P.O. Box 1489
Manila 2806

(Kawamoto Licensee)

Occidental Foundry Corp.
Km. 16 McArthur Highway
Malanday, Vanlenzuele
Bulacan

(Pitcher Pumps)
("England" deep well)

Triumph Metal Mfg. Corp.
P.O. Box 512
Manila

(Pitcher Pumps)

SENEGAL

SISCOMA
B.P. 3214
Dakar

(various pumps, some of French origin)

SOUTH AFRICA

Stewarts and Lloyds of South Africa Ltd.
Windmill Division
P.O. Box 74
Vereniging 1930

Southern Cross Windmill and Engine Co. (Pty.) Ltd.
Nuffield Street
Bloemfontein

Hidromite Pump Engineers
P.O. Box 160
Milnerton 7435

SPAIN

Bombas Borja S.L.
Calle Villa Madrid
Pareela 168
Peterua, Valencia

Bombas Geyda
Avda. Carlos Gens, S.L.
Burjasot 54
Valencia

("Geyda" mainly for Spanish market)

SWEDEN

Petro Pump
Carl Westmans Väg 5
S-13300 Saltsjöbaden

TANZANIA

Shallow Wells Programme
Shinyanga Region
P.O. Box 168
Shinyanga

UGANDA

Craelius East African Drilling Company Ltd.
P.O. Box 52
Soroti

UNITED KINGDOM

Autometric Pumps Ltd.
Waterside
Maidstone, Kent ME14 1LF

tel. 54728

(Rotary)

Barcley, Kellett & Co. Ltd.
Joseph Street
Bradford, Yorks. BD3 9HL

(Rotary)

Barnaby Climax Ltd.
Pump Division
6, Kenneth Road
Crayford, Kent

tel. 526715

Consallen Structures Ltd.
291 High Street
Epping, Esses. CM16 4BY

tel. 378-74677

("Consallen")

English Drilling Equipment Co. Ltd.
Lindley Moor Road
Hudders Field, Yorkshire HD3 3RW

tx. 51687

("EDECO")

H.J. Godwin Ltd.
Quenington, Cirencaster
Gloucestershire GL 7 5BX

("W1H")
("X")
("HLD")
("HLS")

Jobson & Beckwith Ltd.
62 Southwark Bridge Road
London SE1 oAU

tel. 01-928-7102/3/4

("Castle",full rotary)
("Norfolk", semi rotary)
("Major", diaphragm)

Lee, Howl & Co. Ltd.
Alexandria Rd.
Tipton, West Midlands DY4 8TA

("Oasis")
("Colonial")

Mono Pumps (Engineering)Limited
Mono House
Sekforde Street
Clerkenwell Green
London EC1R OHE

("Mono-Lift")

Saunders Valve Co. Ltd.
Grande Road
Cembran
Mon

(Diaphragm)

UNITED STATES

Baker Manufacturing Company
133 Enterprise St.
Evansville, Wisconsin 53536

("Monitor")

Clayton Mark and Company
143 E. Main Street
Lake Zurich, Illinois 60047

Colombiana Pump Co.
131 E. Railroad
Columbiana, Ohio 4408

Dempster Industries, Inc.
P.O. Box 848
Beatrice, Nebraska 68310

("23 F")
("23 F (CS) -EX")

The Heller-Aller Co.
Perrye Oakwood Streets
Napoleon, Ohio 43545

("Heller-Aller")
("H-A")

Kitrich Management Company
4039 Creek Road
Cincinnati, Ohio 45241

("Gem" chain pump)

Mark Controls Division
International Division
1900 Dempster Street
Evanston, Illinois 60204

("Clayton Mark" cylinders,
valves and leathers)

A.Y. McDonald Mfg. Co.
P.O. Box 508
Dubuque, Iowa 52001

("Red Jacket")

Rife Hydraulic Engine Mfg. Co.
P.O. Box 367
Milburn, New Jersey

("Rife Ram")

Robbins & Myers, Inc.
Moyno Pump Division
1895 Jefferson St.
Springfield, Ohio 45501

Sanders Company, Inc.
Industrial Equipment and Supplies
410 N. Poindexter Street
P.O. Box 324
Elizabeth City, N.C. 27909

tel. 919-338-3995

who international reference centre for community water supply

postal address: p.o. box 140, leidschendam, the netherlands
office address: nw havenstraat 6, voorburg (the hague)
telephone: 070 - 69 42 51, telegr.: worldwater the hague, telex: 33604

B.P. 15

WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

HANDPUMPS FOR DRINKING WATER WELLS

RID 133/5000/78 - 823889° - 3

Uncorrected

6.3.11.

Handpumps for Drinking Water Wells - A KSCST Project

I. Modes of failure of handpumps

After the project was sanctioned by the KSCST, Dr.J. Gururaja, the then Convener, visited 60 handpump installations with his colleagues in order to ascertain the failure patterns. Due to time limitations, this survey was necessarily confined to facts that could be observed or inferred without lifting the entire pump assembly. The failure pattern emerging out of this survey is as follows (figures on the right hand side indicate the percentage of pumps which failed in the mode indicated):

(i) Uncoupling of plunger rods and of the coupling between the plunger rod and handle, or breaking of the plunger rod at the top	...	64%
(ii) Wearing of the pivot and fork connection (Patel type) and axle bearing support (Jalna type)	...	18%
(iii) Malfunctioning of valves and leather buckets (washers)	...	11%
(iv) Disconnection of riser pipe at the pump body	...	7%

It is possible that some of the above figures are approximate, since firstly an element of inference is involved in ascertaining the failure mode and second, other modes of failure which have been observed recently by the present working group (e.g., uncoupling of strainer from cylinder, uncoupling of cylinder from the riser pipe etc.) are not included, since they could not be inferred from observations of parts above ground.

The above failure pattern is also confirmed by the notes prepared by the Executive Engineer, P.H.E.Division, Chitradurga, who attributes 70% of the failures to uncoupling of plunger rod and breakage of the rod at the top, 20% to malfunctioning of valves and leather buckets, uncoupling of G.I. pipes (probably below the ground), wearing of guide rods etc., and 10% to the uncoupling of the whole assembly from the pump body.

It is thus seen that between 70% and 80% of the failures are caused by uncoupling of the plunger rods and of the riser pipe.

II. Causes of failure

The basic causes for each mode of failure are considered below, since understanding of the cause is essential to find a solution.

(i) Uncoupling of plunger rods: Screwed connections tend to become loose under sufficiently strong vibration. In the case of plunger rods, this vibration is excited by the buffetting given to the assembly when, e.g., the handle comes to rest more or less abruptly at the end of the downward and upward strokes, or when it starts accelerating at the beginning of the strokes; if the piston strikes the top or bottom of the cylinder at the extremeties of its movement; even during normal operation if, for example, the axle supports have worn out a little. During half a cycle of vibration, the mating threads in a coupling will be relieved of pressure against each other, and if one part of the connection carries load, such as the weight of water and self weight in this case, it tends to unscrew.

(ii) Breaking of plunger rod at the neck: The rod carries a static load between 50 and 100 kg. depending on the depth of the well. This load is composed of the weight of water supported by the piston, and the self-weight of the assembly. The load is more at the beginning of the down stroke when the whole mass is being accelerated, and the inertia of the mass acts together with the static load, to make a total load of around 150 to 200 kg. as a conservative estimate. This gives rise to a tensile stress in the rod, of about 200 kg/cm^2 at the maximum, which is well within the allowable tensile stress of the rod material. Breakage of the rod could thus be due to an isolated defect in the rod, such as a crack. In the Patel type pump, this could also arise if the pump body is shaking or if the riser pipe coupling with the pump body has loosened. In that case, large bending moments may come at the top of the plunger rod eventually leading to fracture.

(iii) Pivot and fork connection (Patel type): Since all the Patel type heads are now being replaced by the Jalna type head, we will not concern ourselves with this in the future.

(iv) Wearing of the axle bearing support (Jalna type): This is due to insufficient thickness of metal used in making the head.

(v) Malfunctioning of valves and leather buckets: Malfunctioning of valves is mostly due to wear of the rubber seating with use.

The leather buckets often expand a little when submerged in water for a length of time, leading to increased friction and difficulty in operating the pump.

(vi) Disconnection of riser pipe: This is also due to vibration and buffetting arising in the pump operation. Apart from the reasons discussed under (i) above, an additional contributory factor in the uncoupling of riser pipes is that when the bolts securing the pump body to the casing pipe flange become loose, additional buffeting load comes on the riser pipe, leading to uncoupling.

III. Proposed methods of attack on the above problems

The present approach concentrates on the uncoupling of the plunger rods and riser pipe. As already stated, these account for 70% to 80% of the failures, and a successful attack on them will make the problem much more manageable. Further, replacement of the pump head by the Jalna type, and a slight chipping of the leather bucket before installation which makes it a bit loose, eliminates much of the remaining reasons for failure. As such, the following will be concerned only with the uncoupling of the plunger rods and riser pipe. Several alternatives are considered, which can be conveniently divided into (1) the simpler solutions and (2) the other alternatives. The reason for this division is that it is now proposed that the simpler solutions be incorporated immediately in the forthcoming pump installations without waiting for the results of the vibrations and buffetting tests of all alternatives, going to be conducted shortly.

(1) The simpler solutions: The basic principle behind the simpler solutions is to increase the friction between mating threads of the coupling, so that resistance to relative rotation increases. Increase in friction can be achieved in two ways.

(a) By increasing the pressure between mating threads: This can be achieved by using locknuts, spring washers etc. In fact, locknuts are already used in the present installations. The locknut is tightened against the hexagonal collar welded to the plunger rod length being coupled, so that a small axial strain is introduced in both the locknut and collar. This strain develops a permanent stress, which is balanced by the pressure developed between the mating threads. The frictional force between the threads is proportional to this pressure (the constant of proportionality being the co-efficient of friction). Therefore, the tighter the locknut is turned against the collar, the greater should be the resistance against relative rotation. In spite of this, why do the couplings keep becoming loose?

The answer is that the strain induced in the nut is extremely small, and is readily relieved by a slight wear or formation of rust at the interface. If this happens, the ordinary locknut becomes useless.

It is therefore proposed that commercially available spring washers (½" size) be used at all the couplings of the plunger rod: one spring washer will be needed at the connections to the piston and to the handle chain, and two at each intermediate coupling. The force needed to compress a commercial spring washer is 45 kg. This corresponds to the load carried by the plunger rod. A spring washer therefore guards against uncoupling due to accelerations of the order of 2g. Accelerations of a higher level are not of much importance, since they would be of a higher frequency and there would be correspondingly little time for relative rotation of the coupled parts to take place.

(b) <u>By increasing the coefficient of friction between mating threads</u>: This can be achieved by, for example, applying cotton thread and paint on the G.I.pipe thread before screwing the collar on. Friction between metal on the one hand and paint and cotton thread on the other is much greater than friction between metal and metal. Resistance to relative rotation is therefore increased compared to the present simple collar joints. The paint and cotton thread will have to be applied at both ends of each length of G.I.pipe, on the strainer where it is screwed to the bottom reducing nut, on both the reducing nuts where they are screwed on to the cylinder, and on the nipple at the pump body to which the entire assembly is screwed on.

It has already been said that the loosening of the bolts securing the pump body to the casing pipe flange could lead to fracture of the plunger rod at the top in the Patel type pump (though not when the Jalna type head is used). In addition, a shaking pump body will lead to the wearing out of threads on the nipple to which the pump assembly is screwed on, ultimately causing the entire set to fall into the well.

It is therefore important that loosening of these bolts should be prevented. It is therefore suggested that the nuts used on these bolts should be of the "nylock" type, which is commercially available. These nuts have a nylon brush at the top, which has a very large coefficient of friction against mild steel. As an additional safety measure, spring washers also should be used.

To summarise, therefore, the simpler solutions consist of the following:

(i) Use spring washers at each screwed connection of the plunger rod: one washer is needed at each screwed end of a length of rod. They should therefore be used not only at each coupling, but also at the connection to the piston at the bottom and to the handle chain at the top.

(ii) Use cotton thread and paint on the thread at each end of every length of G.I.pipe before it is screwed into the bottom reducing nut; on both the reducing nuts where they are screwed into the cylinder, and on the nipple in the pump body to which the pump assembly is screwed on.

(iii) Use spring washers and nylock nuts on the bolts connecting the pump body to the Casing pipe flange

(2) The other alternatives: These alternatives are more expensive to carry out than the simpler solutions, and are outlined below:

(a) For the plunger rod:

(i) use of nylock nuts and multitooth washers in addition to spring washers for the couplings;

(ii) use of a locking plate to secure the couplings. The locking plate will be screwed on to hexagonal ends welded to the plunger rod;

X (iii) use of flange couplings, the flanges being again connected by screws with spring washers;

? (iv) avoid a screwed connection altogether and use a pin connection between plunger rod lengths.

(b) For the riser pipe:

(i) use of flange coupling for the pipes;

(ii) modification of pump body design to prevent the falling of the pumpset into the well;

(iii) use of tie rods to prevent uncoupling of cylinder;

(iv) use of spring washers for the riser pipe couplings also.

IV. Laboratory tests

A programme of laboratory tests is drawn up to evaluate the various alternatives suggested to prevent uncoupling of plunger rods and riser pipes. All the alternatives will be subjected to vibration and repeated buffetting in a test rig designed for the purpose, over a length of time sufficient to eliminate the poorer alternatives. Since the rig is motorised, an accelerated test is possible and it is intended that operation of the hand pumps in the field over a period of several months should be simulated, as far as vibration is concerned, over a period of a few days in the rig.

V. Importance of field data

By the very nature of things, field phenomena cannot be simulated perfectly in the laboratory. If the field conditions are more severe than in the laboratory, the solutions given by the laboratory tests will not be satisfactory. If on the contrary, the laboratory conditions are more severe, the solution suggested would be more expensive than necessary. It is therefore essential to get a feedback from the field on how the solution will work out under actual operating conditions.

VI. Proposed immediate field programme

Feedback from field tests will be slow in coming, since operation over a period of at least one year will be necessary in order to get meaningful results. Moreover, the results can be relied upon only if a sufficiently large number of pumps is fitted with the suggested alternatives. This will be expensive both in time and money. One possible course of action would be to carry out the modifications suggested by the laboratory test results and then evaluate the performancein the field after a year. This would be reasonable since the laboratory results are expected in March.

However, in this particular problem, another course of action is possible. This is to go ahead and adopt the suggestions detailed under "The simpler solutions" (page 7) without waiting for the laboratory results, because of the following advantages:

(i) Similar methods have been successful in machines operating under high levels of vibration, e.g., diesel engine driven machinery, textile machiney etc.

(ii) The material cost involved is negligible, being of the order of Rs.10/- per pump. The cost of labour involved in carrying out the modifications is also negligible.

(iii) In the next two or three months necessary to get results from the laboratory tests, several hundred new pumps are going to be installed. If the suggested modifications are now incorporated in these pumps and if they are successful, the huge expenditure on later repairs will be avoided.

(iv) Finally, nothing is lost by carrying out these modifications, since the performance will not be worse than what it now is.

It is therefore suggested that as the immediate field programme, the "simpler solutions" be incorporated in all the new pumps to be installed from now onwards, as well as in those old pumps which have to be lifted out of the wells for repairs.

gpr/20.1.1977/

who international reference centre for community water supply

postal address: p.o. box 140, leidschendam, the netherlands
office address: nw havenstraat 6, voorburg (the hague)
telephone: 070 - 69 42 51, telegr.: worldwater the hague, telex: 33604

B.P. 16

WORKSHOP

on

HANDPUMP EVALUATION AND TESTING

Voorburg, (The Hague), The Netherlands
13th - 16th November, 1978

RATE OF WEAR OF PVC PUMP CYLINDERS

TESTING

RATE OF WEAR OF PVC PUMP CYLINDERS

(Conducted by Prussag, Kunststoffe u. Armaturen, Hannover, Germany)

Lengths of (3" Ø) sized PVC pipe are being tested for application as the working barrel of piston pump. The object of the test is to measure the wear (loss of material from the walls) of the pipe. Two test benches were built each with sixteen cylinders mounted as individual units with a gate valve and a manometer.

The system is driven through a transmission (at 30 cycles/minute) which alternatively lifts and depresses two transverse bars to which the piston push rods are connected.

Each piston consists of four PVC plastic discs with four 16 mm diameter holes at 90° around a center hole (occupied by the 40 cm long push rod); the holes are covered by a 2 mm thick flapper of nylon reinforced neoprene. Two leather cups make a seal against the cylinder walls.

The 30 cm long PVC cylinders were cut from randomly selected production pipe. The wall thickness was measured at selected points in the middle of the cylinders and each point was marked. The cylinders were installed in the test benches, the water tanks were placed under them and filled with water.

When the piston ascends water is lifted from the tank and pushed through the discharge pipe in which the gate valve is located. The gate valve is adjusted to provide an impedence to the egress of the water, thereby creating a pressure which is measured by the manometer. The water is then recirculated in the tank.

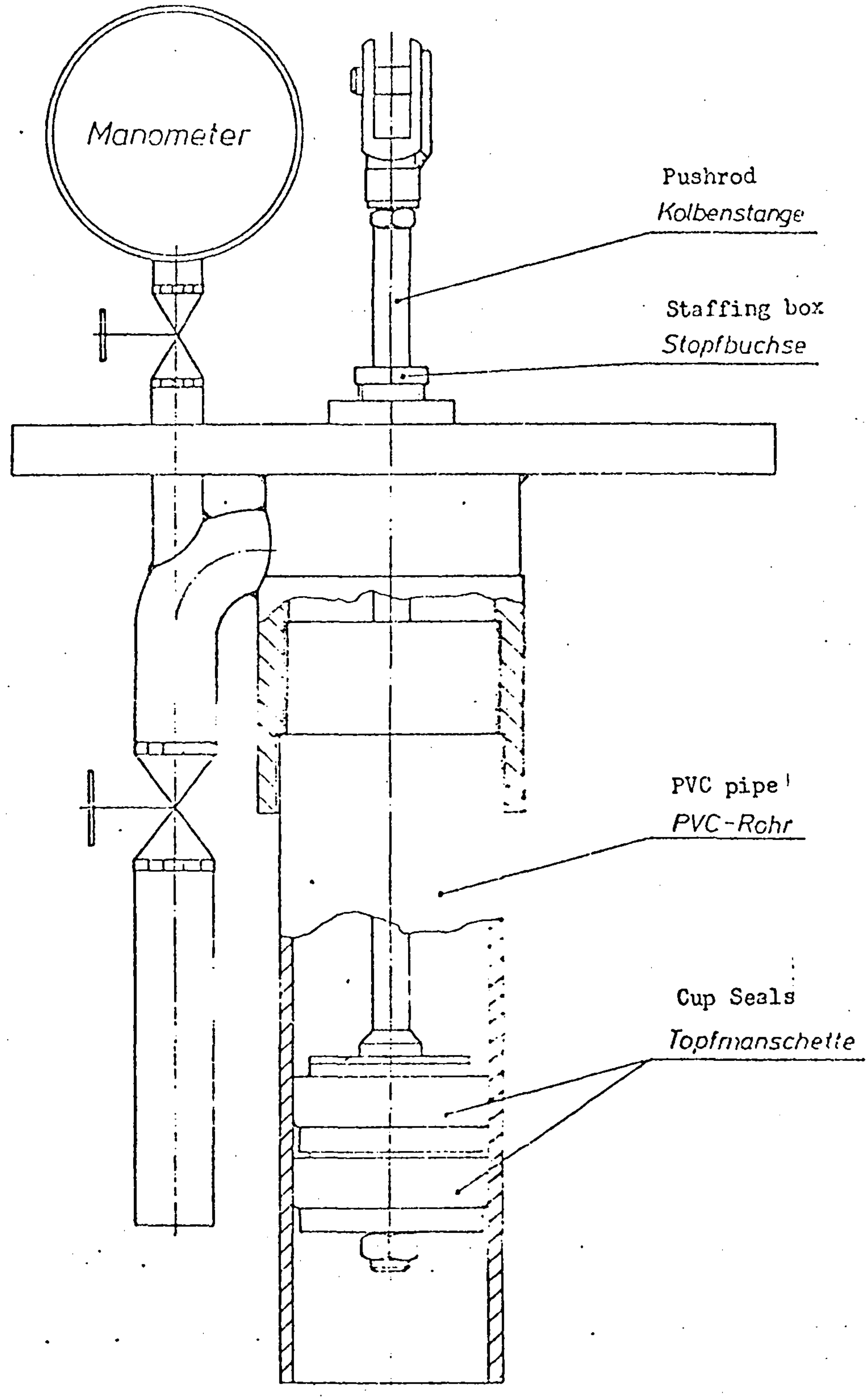
The water tanks are open topped, allowing atmospheric dust and foreign matter to enter the water. Periodically water is added to the tanks to compensate for evaporation.

The test benches simulate pressure heads ranging from 0,5 to 2.0 atmospheres (pumping depths of 15 to 200 feet).

The PVC cylinders were removed after 340,000 cycles and measured for wear at the marked positions. A maximum decrease in wall thickness of 0.10 mm was recorded. Pumping pressure was observed to remain constant.

After 500,000 cycles the cylinders were again measured for wear. A maximum decrease in wall thickness 0.15 mm was observed also with an unchanged pressure reading. The experiment continues.

ANNEX 4

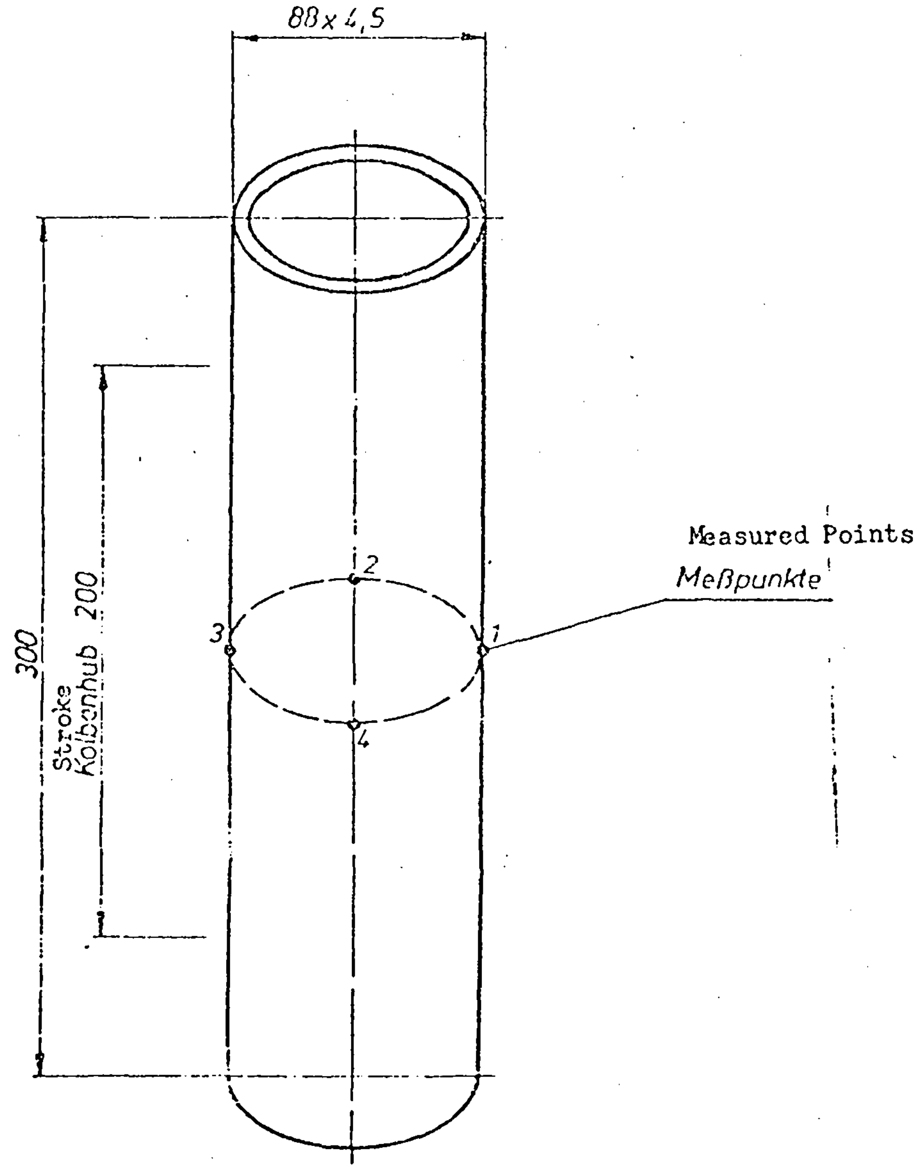


Test Stand for Rate-of-Wear Experiment

Prüfstand für Verschleißprüfung

gez.: 10. 2. 76 Klass

PREUSSAG AG
Kunststoffe u. Armaturen
Werk Siedersdorf



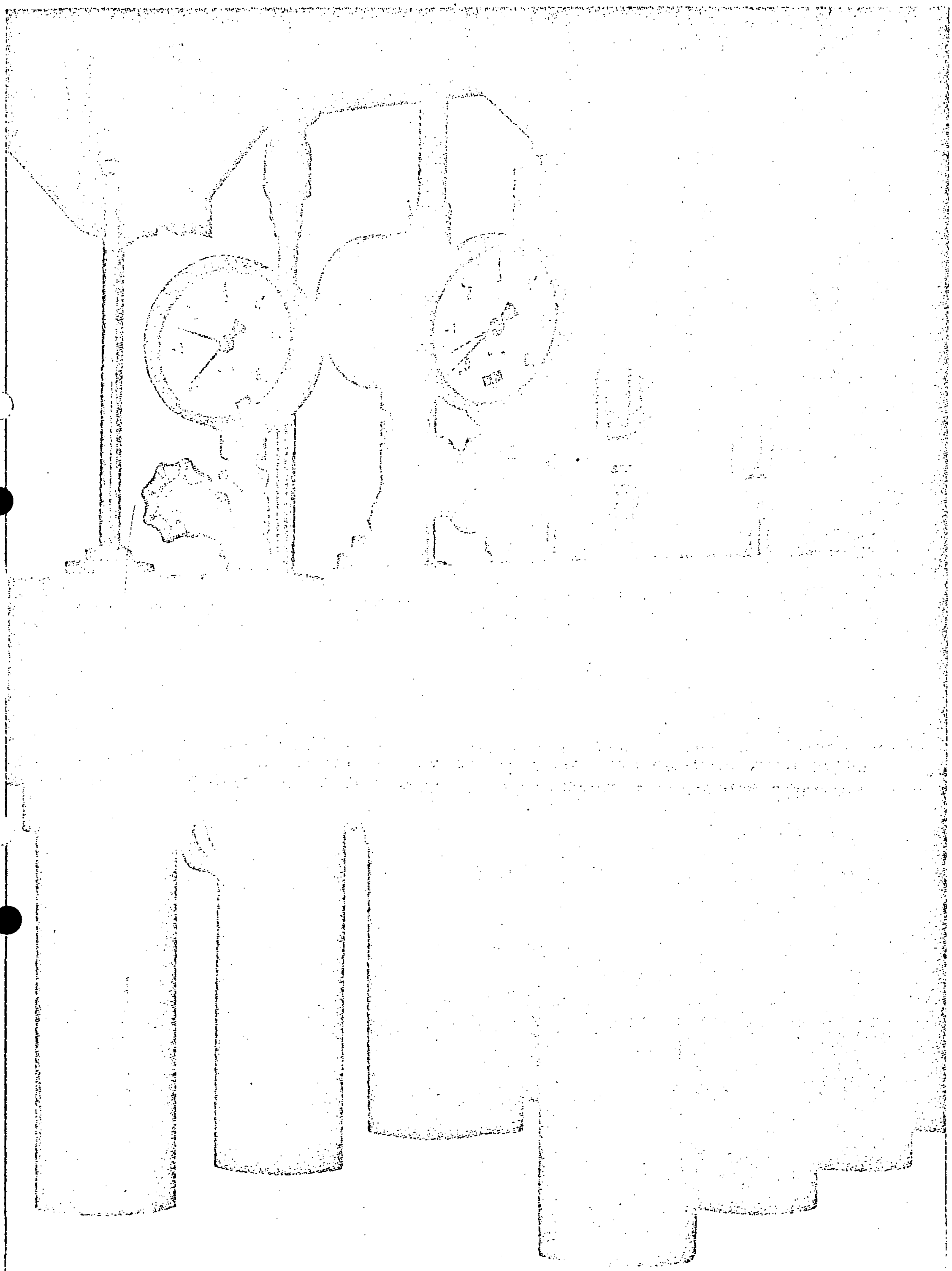
Location of the Measured Points along the Walls of 3" diameter for Pipe

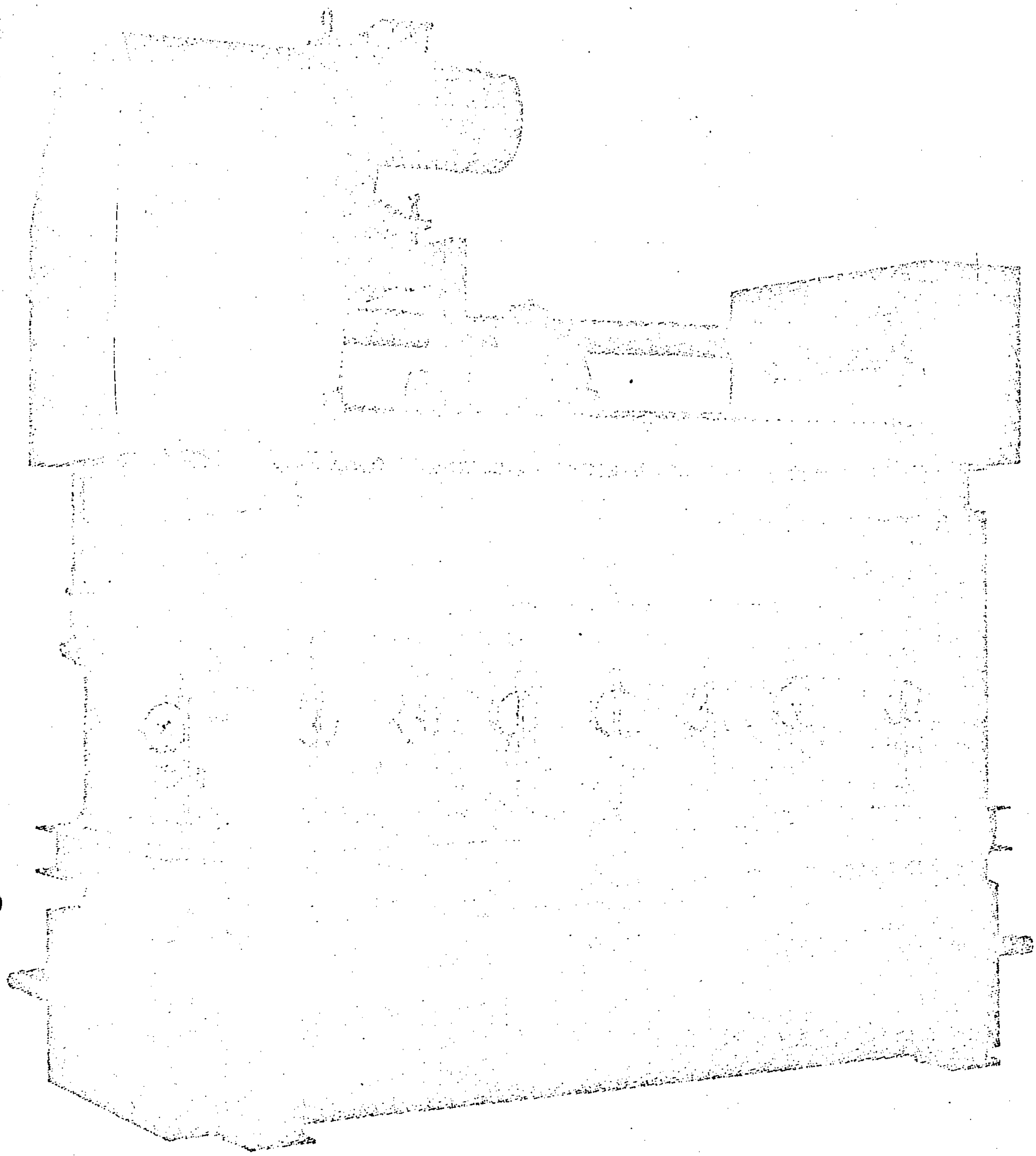
Anordnung der Meßpunkte für Rohr Φ88 x 4,5 / 300mm lg.

Anlage zum Prüfbericht vom 11.2.76

gez.: 13.2.76 Klass

PREUSSAG AG
Kunststoffe u. Armaturen
Werk Stederdorf





BP. 17

Development of Handpump for Rural Thailand

by

Suwanrat Limrat

Rural Water Supply Region 7, Ratchaburi

Rural Water Supply Division, Department of Health

Ministry of Public Health

Bangkok, Thailand

For presentation at the workshop on "Handpump Evaluation and Testing",
The Hague, 13-16 November 1978

Organized by WHO International Reference Centre for Community Water Supply, The Hague, The Netherlands.

Development of Handpump for Rural Thailand

by

Suwanrat Limrat

Rural Water Supply Division

Department of Health, Ministry of Public Health

Bangkok, Thailand

Introduction

The total population of Thailand was estimated at 44 million in 1976. Approximately 77%-80% of this total, or about 33-35 million live in rural areas where the problem of access to safe water supply still exists. The government of Thailand had set up a National programme on Rural Water Supply in 1965 to stimulate in providing access to safe water supply to all of this rural population. There are seven Government Agencies implementing for this National Rural Water Supply Programme of which five Agencies construct water supply systems and other two Agencies are associated with these activities through financial support to assist small communities and institutions. It is reported by the National Economic and Social Development Board (NESDB) of Thailand that in 1977 about 14 million of the rural population have been provided with water supply by various means implemented by these Agencies. Among these means, both shallow dug wells and deep wells incorporated with hand pumps contribute to a high percentage (about 32%) of the Programme's result. It is anticipated that the handpump will play a very important role in the achievement to the success of the proposed plan of the National Water Supply Programme which aims to fulfil the objective of the International Drinking Water Supply Decade (1981-1990) at the end of which all population of Thailand are expected to have access to safe water supply. Perhaps the significant role of handpumps will be better appreciated if it is realized that during the coming future an estimated of quarter to half of the rural population of Thailand will have to rely for the access to safe water on community sanitary dug-wells and tube wells equipped with handpumps.

Historical background and problems

The handpump has a long and successful history as a device for supplying water from a shallow family well. Most of the present day pumps are descendents of those earlier pumps. Several types of handpump for household use or farmyards namely Dempster pump, Red jacket, Myer Marine pump, etc. had been introduced to Thailand under the assistance of the U.S. Government to the Rural Health Development Project which started in 1959. From the field-experience, the RHDP had designed and developed a new model of handpump and named it 'Korat Pump' or '608 Pump' in 1964. It is a gear type reciprocating handpump that can be used either for shallow dug wells or deep wells. The 608 pump has been widely used for community handpumps in the Nation Rural Water Supply Programme by the Department of Local Administration (for shallow wells) and by the Office of Accelerated Rural Development (for deep wells). Presently there are two main types of handpump are being used by Agencies engaged in the National programme. They are as follow:-

1. Dempster's type, the Department of Mineral Resources and the Department of Public Works use this type for their deep wells.

2. 608 pumps or gear-type pumps are used by the Department of Local Administration for its shallow well with handpump project and by the Department of Health for its tube-well project.

The Department of Health also use market-type Japanese-design handpump which are contributed by local communities in some tube wells as a test.

The problems with the use of handpumps in Thailand as well as the problems of that on a global scale are associated with the community handpumps and are more or less similar in cause of problems such as quality of the hnadpumps due to inadequacies in design or manufacture, poor installation and lack of maintenance. Field investigations of the installation and use of shallow-well handpumps in Thailand were carried out by the Handpump Subcommittee of the National Rural Water Supply Programme in 1976. The result of the investigations indicated as follows:-

1. that approximately 75% of shallow-well handpumps installed by the Government programme in the investigated wells were not in operation.

2. that handpumps go out of action due to poor maunfacture and due to a lack of maintenance after varying periods of operation, which ranged between a few days and 5 years.

3. that with a few exceptions villagers were not able to repair and to maintain the hand-pump in operation.

4. that the shallow-well and handpump programme of the Government is being implemented by the administrators without adequate technical and financial support for installation and maintenance.

Research and Development Programme of handpump in Thailand

With a better view to the increasing important role of hand-pump to the success of providing access to safe water for all the rural population of Thailand, and with a better understanding of the problems of handpumps used in several water supply projects, the Executive Committee of the National Rural Water Supply Programme, in 1977, has set up a Working Committee comprising of all of the rural water supply implementing Agencies to study and develop one good typical model of handpump which will be suitable for use in either shallow dug wells or deep wells and also to develop a hand-pump managing scheme. The Hand-pump study programme is by now carried out by the Agencies engaging in the Working Committee having the National Economic and Social Development Board of Thailand act as the chairman and the coordinator.

The Department of Health, in answer to the request from the National Rural Water Supply Committee is preparing to conduct a field test and evaluation of handpumps currently in use in Thailand. All models of handpumps in use in community wells, both for shallow dug-wells and for deep wells or tube wells will be included in this programme. It is proposed to carry out this programme in Hang Chat District of the Lampang Province as a part of the preventive health measure projects in support of the Primary Health Care projects in this district. The work plan for the Hang Chat District is being prepared. Other handpump programmes which will be conducted by the Department of Health in preparation to support to the proposed objective of the National Rural Water Supply Plan for the coming International Drinking Water Decade (1981-1990) are:-

(i) Field testing of the PVC handpump for shallow dug-well

(ii) Development of PVC handpump for small diameter tube-well

(iii) Development and field testing of the handpump preventive maintenance scheme on a district basis.

The idea of having a handpump of reasonable low cost, light in weight, simple and easy to install, operate and maintain leads to the development of the PVC handpump. The Agricultural Engineering Division of the Department of Agricultural Technology had developed a PVC handpump in 1975 for the purpose to use in household. It was extensively tested in the laboratory. The Rural Water Supply Division of the Department of Health with the corporation of the Agricultural Engineering Division has later modified some features of the PVC handpump in order to be more suitable for installation and operation in the field test as a community handpump. In 1977, the Department of Health has secured a grant of US $10,000 from the World Health Organization (WHO) to have 400 PVC handpumps for the field testing. At present, trials are being conducted with the installation of this handpump in existing dug wells in some villages of the Rajburi Province, Saraburi Province and in Hang Chat District of the Lampang Province. It is expected that the field tests of this handpump will be commenced soon at the early of 1979.

The PVC handpump will also be modified, developed and tested for use in the tube well project of the Department of Health. A part of the subsidy from the 'WHO' for the production of 400 PVC handpump is also intended to enable the development of the PVC handpump for the tube-wells.

It is generally recognized that the major failures of community handpump are due to the lack of maintenance. This experience is shared by many developing countries. The handpump preventive-maintenance programme is being prepared to develop and to field test in some selected districts. The results will be evaluated and a suitable and efficient preventive-maintenance scheme will then be developed from the evaluation of this field study. This program is supported by the WHO and another part will be supported by the UNDP.

A field test programme on the use of handpumps for deep wells is also being carried out by the Office of Accelerated Rural Development in 1977-78 under the support of the UNICEF. The purpose of this field study are to improve the handpumps used for deep wells at the present time and to study the utilization of water from hand operating pumps. Four types of handpumps currently used by the Government Agencies in their rural water supply projects and one type of household shallow well handpump are being tested in selected deep wells of various conditions. The capability of each type of handpump tested and also the advantages and disadvantages of the handpumps are reported in the 3rd Progressing Report of this programme. This test programme is expected to give final recommendations on improving of the handpumps at the early of 1979.

A project on study, design and develop a typical handpump for rural Thailand is also being prepared to be conducted by the Asian Institute of Technology with the cooperation from various government agencies concerned namely the National Economic and Social Development Board, the Mineral Resources Department, the Department of Health, the Public Works Department and the Office of Accelerated Development, follow the Workshop on'Handpump and Drilling Rigs for the Rural Water Supply Programme'which were organized by the National Economic and Social Development Board (NESDB) of Thailand in cooperation with the International Development Research Centre (IDRC), Canada, in Chiengmai in January, 1978. The overall objective of the project is to design and develop a typical handpump which can perform consistently as long as possible, be inexpensive, operate easily, can maunfacture,maintain and repair locally, look good and be versatile. This project is expected to receive fund support from the IDRC.

Conclusion

Although handpumps had been successfully used as a device for supplying water from wells long time ago, the handpump is now still a very simple but increasingly important device which is significant to the achievement of providing access to safe water to all rural population in developing countries. In Thailand, shallow dug wells with handpumps and tube wells or deep wells with handpumps will share a major part to the success of the National Rural Water Supply Programme. However at present, the problems concerning with the design, manufacture, operation and maintenance of community handpumps still exist in Thailand. Several government Agencies engaging in the National Rural Water Supply Programme and institutions are carrying out research and field study on handpumps in order to improve the efficiency of the handpumps and also to develop an efficient handpump operation and maintenance programme which in turn will lead to the success of providing safe water supply to all population in rural Thailand. It is recommended that a good cooperation among the government Agencies concerned and the institutions conducting the research and field study be established.

In addition to the government/institution cooperation , it is necessary also to have the full cooperation of the communities involved, to ensure the success of the programme.

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OFFICE OF RESEARCH ADMINISTRATION

UNIVERSITY OF WATERLOO

INCORPORATING THE

WATERLOO RESEARCH INSTITUTE

PROJECT NO. 609-01

INEXPENSIVE PLASTIC HAND PUMP AND WELL

SPONSORED BY

International Development
Research Centre

A. Plumtree

A. Rudin

J. Tevaarwerk

SEPTEMBER, 1977

Contents

1.0 FINAL DESIGN

Figure 1 is an assembly and detail blueprint of the final recommendations which were reached after the research recorded in this report.

Some general remarks are prepared here before details of the various components are considered.

The guiding objective in this design has been the optimum usage of modern materials and production methods. The pump recommended here is extremely simple in concept. Our studies have shown that it is reliable and easy to operate under heavy usage conditions. Whatever repairs may be necessary are very easily made. The entire assembly is easily removed and replaced in the well. There are no important corrodible components and wear is localized in cheap, simple components.

A cost estimate is attached (Appendix II). This appears to be the least expensive hand-operable pump design, to the best of our knowledge.

Almost all the components are made of plastic materials. These have been selected for ease of manufacture and low cost, as well as for their efficiency in this application. Many of these parts are standard size, extruded items which are provided by many plastics suppliers. Special tooling is thus not needed. The relatively few special shapes which are required can all be injection molded quite easily. None of the moldings are complicated. All the recommended plastic parts are based on rigid poly(vinyl chloride) (PVC) or polyethylene. Both are low-cost commodity polymers. Exotic materials have been avoided.

Obviously it would be impossible to provide a universal design which uses strictly indigenous materials, since such products vary from country to country. The authors believe that local craftsmen will have little difficulty in understanding the operation of the pump and effecting repairs, when these are necessary, with alternative materials which may be at hand.

The pump design is particularly suitable for depths up to about 100 feet. The lever system is intended to limit the pumping force to about 40 pounds. Deeper wells should use smaller diameter casings so that the weight of water on the piston will not be excessive. The modifications for deeper well design will be obvious to people with a minimum of skill in this area. hm. P

The pump involves a submerged piston, with unique piston ring hydraulic seals and plastic pump rods. It has been extensively tested at simulated depths which are at least as deep as any that will be used in practice (~200 ft). The basic design is suitable for any depth, with human motive power.

Many different pump designs have been considered over the course of human history. In Appendix III we show the rate at which
basically determined
a human being can lift water from a given depth is limited entirely by this depth and the power of the operator. No pump can improve this performance so long as the human operator supplies the motive power. Of course, various pumps may vary in efficiency within this limit. The piston pump researched here appears to provide the best balance of low initial cost, reliability, ease of repair, efficiency and ease of operation.

As mentioned, the pump is based primarily on items which are "off-the-shelf", at least in countries with moderately developed plastics industries. Replacement parts are readily available in international markets and specialty items like metal castings are not used. Special plastic shapes are preferably injection molded, as noted above. In emergencies, however, these can be cut from stock shapes of the same or other plastics.

Although this report considers the pump operating in a new well, it is obvious that it can be adapted in a straightforward fashion to replace all or some parts of pumps which are in disuse on existing wells.

A separate report (1) has surveyed plastic well casings for this application. It was concluded that rigid PVC provided the best plastic pipe for present purposes, and this report assumes that the pump described here is to be used in such casings. Readers are referred to the original report (1) for details of polymer and pipe specifications,methods of handling and joining pipe sections, etc.

The present report first describes details of the various components in the recommended final design which is shown in the assembly drawing of Figure 1. Later sections of the report give experimental results which support this design choice, as well as descriptions of alternative components which may be equally satisfactory under some circumstances or which have been considered and rejected as deficient compared to the final preferred configuration.

This and the preceding report (1), provide a comprehensive summary of the background research together with the well design which resulted from this research.

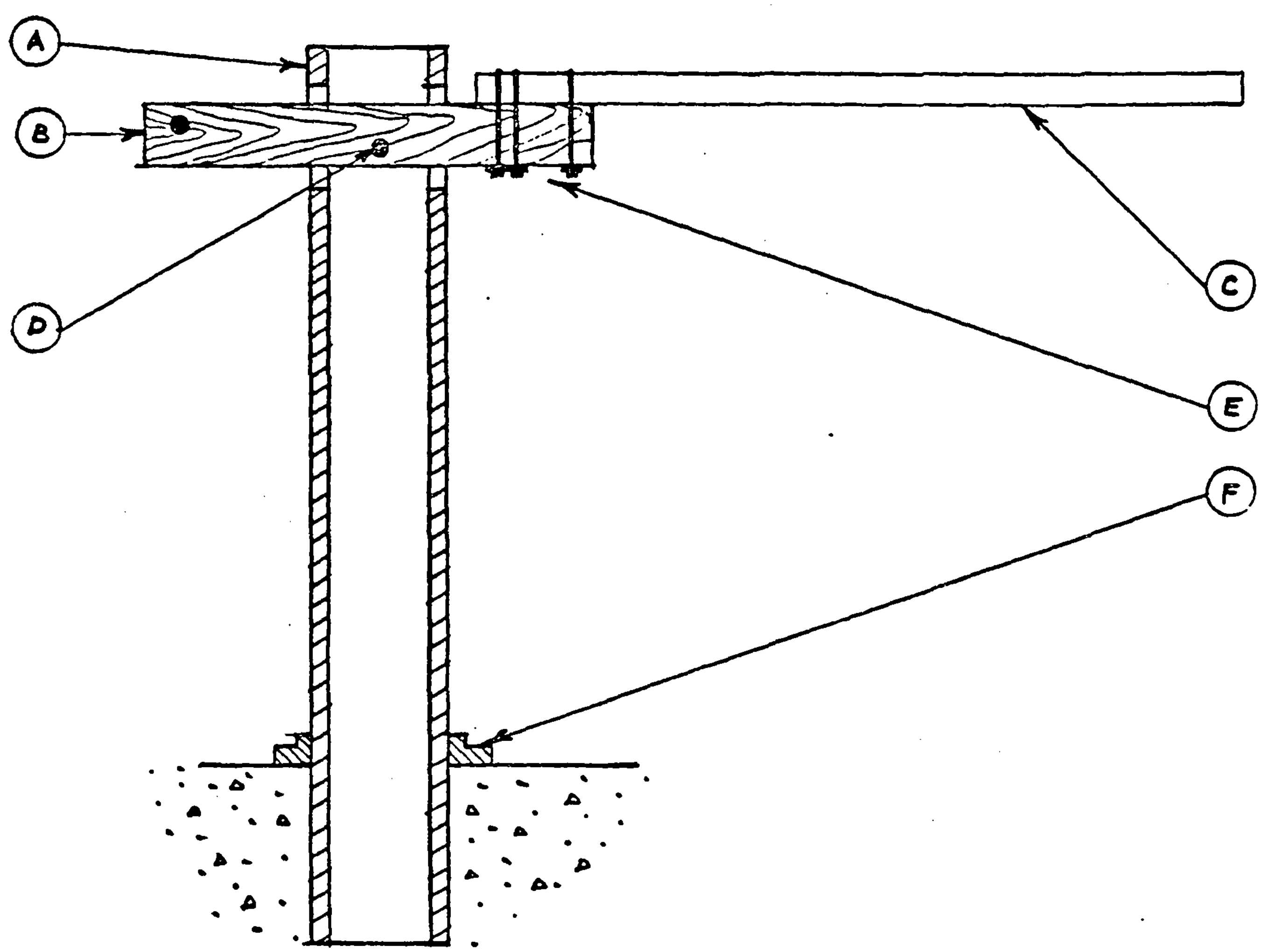
2.0 COMPONENTS

2.1 Leverage System

The leverage system consists of a very simple pedestal and lever arm. The pedestal shown in Figure 1(a) is a 6 inch series 160 high density polyethylene pipe. This particular casing has a wall thickness of 0.75 inch and this dimension and the polymer choice (PE3406, duPont of Canada Sclair polyethylene (1)) means that the plastic pipe is literally unbreakable.

FIG. 1(a)

LEVERAGE SYSTEM



(A) POLYETHYLENE PIPE 6" DIA.

(B) HARDWOOD 2" THK. x 4" WIDE x 26" LG.

(C) STEEL PIPE 1¾"

(D) GALVANIZED PIPE 1"

(E) U-BOLTS

(F) OPTIONAL FLANGE

This pedestal type is far more rugged (and expensive) than is actually needed. It is able to withstand prolonged and intensive abuse as well as normal use. A thinner wall, smaller diameter plastic pipe may well be suitable for this purpose in many applications. PVC and ABS (1) could also be substituted for the polyethylene. These are more rigid than polyethylene but are not as tough, in general.

In any event, the plastic pipe should be stabilized against ultraviolet light degradation. If this is not done the pedestal may become embrittled in locations where the sunlight is very intense. Adequate, inexpensive stabilization is provided by using about 3 per cent by weight of a small particle size carbon black which is well dispersed in the polymer. Raw material suppliers can provide suitable compounds.

It is possible to design for a particular use but not for abuse, since the stress levels under abusive conditions cannot be forecast. We have therefore selected this particular polyethylene pipe as the toughest pedestal material whose properties can be guaranteed by the designers.

Concrete pedestals are alternatives and it is also possible to encase the plastic pedestal and the top end of the well casing in concrete. This is not as reliable a procedure a priori as the plastic pipe since it is impossible for the well designer to anticipate variations in concrete quality which may exist between various locations.

However, if concrete is used, the recommended volume mix proportions for general use in regions where weigh patching is neither feasible nor desirable are ONE (bucket or shovel) cement: TWO fine aggregate-sand: FOUR coarse aggregate-gravel. Enough water should be added to produce a workable mixture. It is not necessary to use any reinforcing.

The plastic pipe pedestal shown in Figure 1a is secured by bolting it to the concrete pad (same volume mix proportions) through an attached plastic flange. Of course, an alternative is to cast the pipe into the concrete when the pad itself is being cast.

The polyethylene pedestal is provided with support holes for the galvanized iron pipe fulcrum pivot and is slotted to limit the piston stroke. The slot is sized also to restrict side play of the handle.

The handle shown consists of an oil-impregnated hardwood bearing section, bolted to a length of iron pipe to obtain the required leverage ratio. The fulcrum pivot and yoke pivot will turn in the wood section and will be stationery in the pedestal and yoke.

Galvanized steel in oil-impregnated hardwood provide a very long-lasting, low friction bearing (2). The wooden handle and bearing holes are sized to the recommendations of Professor Y. Sternberg to provide a larger bearing surface and avoid overstressing of the wooden handle. This component requires no lubrication and should last for a long time. The wood type and oil are not specified since products of the locality will very likely be satisfactory.

Oil impregnation is a simple procedure. The two holes shown should be bored undersize and the handle then immersed in oil. Both the handle and the oil should be heated until the gassing process due to release of air and water subsides. Of course, care should be taken not to char the wood. Finally, the holes should be rebored to size.

As mentioned, wear is restricted here to the oiled wood/galvanized iron interface and the bearings need not be sealed or lubricated.

The pipe strapped to the wooden handle limits the pumping force to a maximum of 40 pounds. In series 100 nominal 3 inch PVC pipe there is 3.775 pounds of water per foot of depth. Thus, a 9:1 lever ratio is needed for a 100 foot hydrostatic head and lower lever arm values may be used for shallower wells.

2.2 Pump Rod

The pump rod is required to be adequately strong, reasonably flexible, light and securely coupled. It is also an advantage if the rods float, so that sections which are inadvertently dropped into the well are easily retrieved. These properties can be combined with reliable performance and relatively low cost by using small diameter PVC pipe as the pump rod.

Besides giving buoyancy, a sealed pipe will be less likely to buckle than a rod of similar material with the same area. This can be shown by considering the Euler buckling load for the case of a column pinned at both ends (3) and often referred to as the fundamental case. The critical or Euler buckling load is given by

$$P_{Cr} = \frac{\pi^2 EI}{L^2} \qquad (1)$$

where I is the smallest or least moment of inertia, E is the modulus of elasticity and L is the column length. In cases where different restraints exist then instead of the actual column length, the effective column length is used, L_e. For the general case $L_e = KL$, where K is the effective length factor which depends upon the end restraints. In this instance for the pump rod, K is the same whether a solid rod or a pipe is used.

Considering a solid rod, the critical buckling load will be:

$$P_{Cr_R} = \frac{\pi EI_R}{KL^2} \qquad (2)$$

and for the pipe

$$P_{Cr_T} = \frac{\pi EI_P}{KL^2} \qquad (3)$$

if now equation (2) is divided by (3) we have for the same column length:

$$\frac{P_{Cr_R}}{P_{Cr_P}} = \frac{I_R}{I_P} \tag{4}$$

The moment of inertia for a rod is given by:

$$I_R = \pi R_R^4/4 \tag{5}$$

while that for a tube is:

$$I_P \cong \pi R_P^3 t \tag{6}$$

where R_R is the radius of the rod, and R_P is the average radius of the pipe and t is the wall thickness.

Substituting equations (5) and (6) into (4) thus gives:

$$\frac{P_{Cr_R}}{P_{Cr_P}} = \frac{R_R^4}{4R_P^3 t} \tag{7}$$

Now considering the areas. That for the rod is R_R^2 and that for the pipe is $2R_P t$. For the same area, then

$$R_R^2 = 2R_P t$$

hence $$R_R^4 = 4R_P^2 t^2 \tag{8}$$

Substituting equation (8) into (7) and rearranging:

$$P_{Cr_P} = \frac{R_P}{t} \cdot P_{Cr_R}$$

which shows that the critical buckling load of a pipe is greater than that for a solid rod of the same area by the rate of the average pipe radius to the wall thickness. For the 3 in. dia. pump, the average radius for the schedule 80 pipe used for the pump rod was 0.431 in. and the wall thickness was 0.177 in. Hence the critical buckling load for the pipe was 2.4 times (0.431/0.177) greater than that for a PVC solid rod of the same area.

The pump rod as shown in Figure 1(b) is made up of 20 foot lengths of 3/4 inch PVC pipe solvent welded together using PVC double socket couplings. Each pipe section has both ends plugged with a PVC plug, solvent welded into place. These will make the rod buoyant as well as strengthen the bolted connections at the top and bottom.

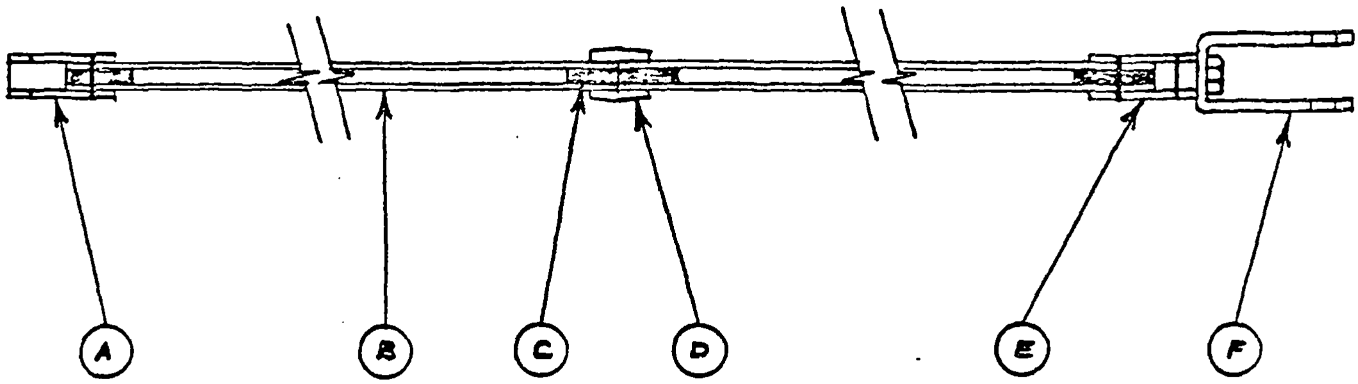
The end connections make use of two short lengths of galvanized steel pipe bolted to the pipe and piston at the bottom, and to the yoke and pipe at the top. The bolted connections are necessary to allow the piston to be removed and dismantled. The rod need not be dismantled as the pipe's flexibility allows it to be pulled from the well intact. It is recommended that slotted plastic or wooden spacers (see Figure 32) be placed on top of each coupling to prevent excessive lateral motion and to prevent wear of the coupling on the well casing.

The tensile properties of this rod were tested. The solvent welded coupling proved to be the weakest, but even then the strength averaged 2020 pounds. The water in a 200 foot well would subject the rod to a weight of 650 pounds. Therefore the rod has a factor of safety of 3.1. Although the fatigue properties were not tested the rod should last indefinitely as there are virtually no stress risers in the rod.

The bolted connections at each end can be made as strong as desired by increasing the bolt shear area of the plugged pipe. In this manner a safety device can be constructed by making the top bolted connection

FIG. 1(b)

PUMP ROD



(A) GALVANIZED PIPE 1" x 3" LG.

(B) PVC PIPE 3/4" SCHD. 80 x 20' LENGTHS

(C) PVC PLUG x 3" LG.

(D) PVC COUPLING SCHD. 80 SOCKET - SOCKET

(E) SAME AS (A)

(F) YOKE - 2½" x 3/16" FLATBAR

slightly weaker than the solvent welded PVC couplings. This will restrict any pump rod breakages to the convenient top coupling.

2.3 Top End and Spout

The top end and spout as shown in Figure 1(c) is one for a typical 3" well. The entire structure is made from 4" schedule 80 PVC pipe and connections, solvent welded together. The heavy duty components should be rugged enough but as a precautionary measure it may be encased in a concrete pillar.

A reducer coupling is used to connect the 3" well casing to the top end which is made up entirely of 4" components to allow the piston and foot valve to pass when dismantling the pump. The 4" pipe from the reducer is connected to the bottom of the tee joint. This tee joint acts as the outlet to the spout which is a 45° elbow. A small protrusion may be solvent welded on top of the elbow to enable a pail to be hung from it.

The joining pipe between the tee joint and elbow has a PVC grating solvent welded ahead of it in the tee joint to act as a strainer. Another short section of pipe extends from the top of the tee joint allowing it to be connected to the casing cover.

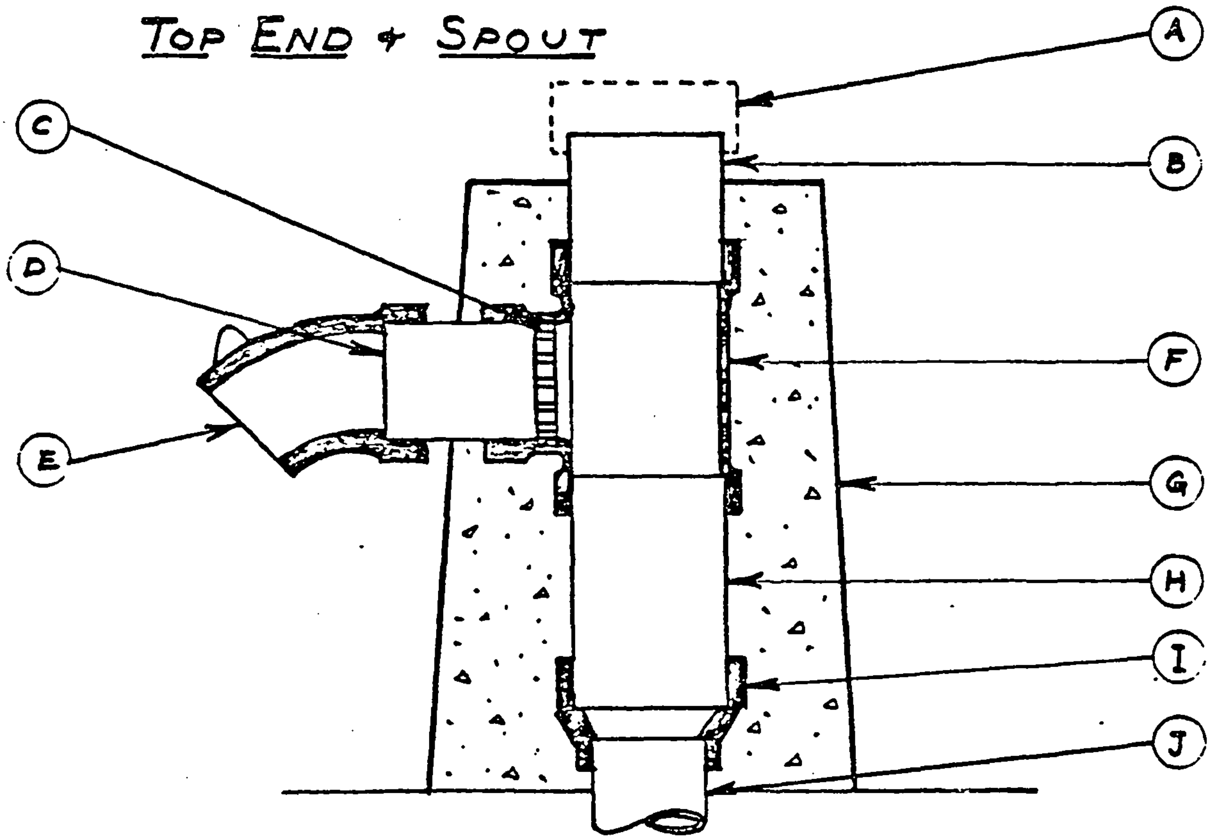
2.4 Casing

The casing for this particular pump will be a 3" series 100 PVC pipe. This pipe has many attractions since it is inert, easy to work with, inexpensive and has a very smooth inner surface (1). The only disadvantage is it has a tendency to take on an oval shape after being stacked in large piles (1). This would result in efficiency losses during operation.

The casing as shown in Figure 1(d) comes in 20 foot lengths and should be solvent welded together using double socket couplings. Care must be taken when making these joints as the piston with its rings will have

FIG. 1(c)

TOP END & SPOUT



(A) CASING COVER

(B) PVC PIPE 4" SCHD. 80 x 3½" LG.

(C) PVC GRATING

(D) PVC PIPE 4" SCHD. 80 x 3½" LG.

(E) PVC ELBOW 45° SCHD 80

(F) PVC 4" TEE JOINT SCHD. 80

(G) OPTIONAL CONCRETE PILLAR

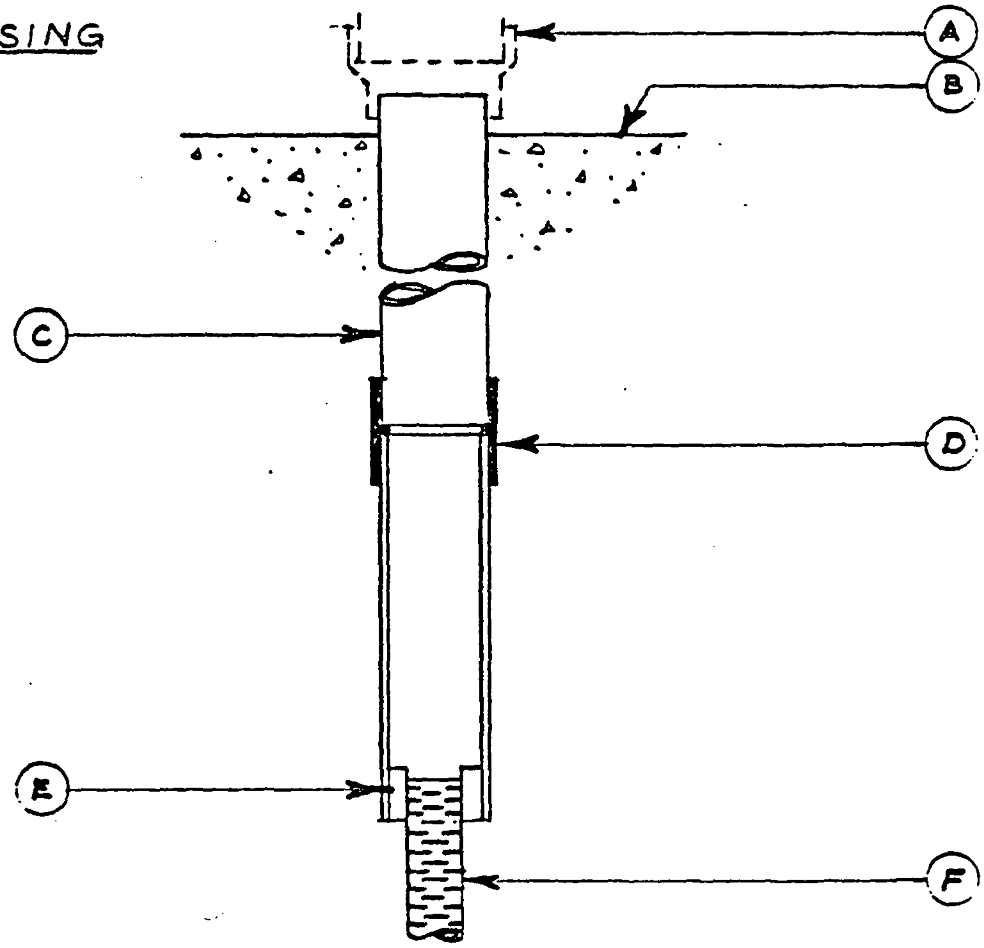
(H) PVC PIPE 4" SCHD. 80 x 18" LG.

(I) PVC REDUCER COUPLING 3" x 4"

(J) CASING

FIG. 1(d)

CASING



(A) TOP END

(B) CONCRETE BASE

(C) PVC PIPE 3" SERIES 100 x 20' LENGTHS

(D) PVC 3" COUPLING SOCKET-SOCKET

(E) PVC RETAINER RING x 2½" LG.

(F) PVC PIPE SLOTTED

to move freely. The inside edge of the pipe may have to be chamfered slightly and the inside diameter of the coupling must match the pipe's.

The bottom pipe will be fitted with a retainer ring. This ring can serve two purposes; first to support the foot valve and thus the column of water in the casing and secondly, the bottom strainer pipe may be chosen such that it can be solvent welded into the ring.

This casing of 3" pipe will be suitable for a well up to a 100 foot depth. Deeper wells will require a smaller size casing as the leverage ratio becomes too great if 3" is used.

When this casing is installed there should be approximately 3" protruding from the base to allow the connection of the reducer coupling for the top end.

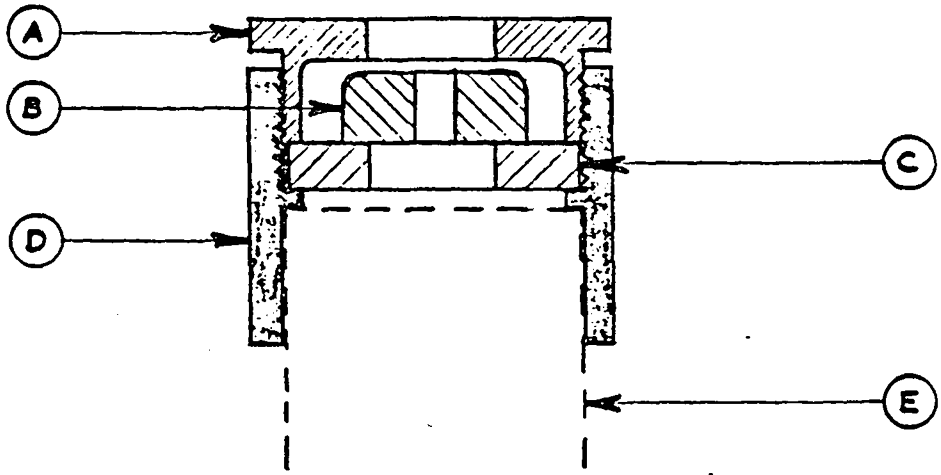
2.5 Casing Cover

The casing cover as shown in Figure 1(e) will allow the pump rod freedom of movement in two directions while keeping the top end closed off. This cover consists of one PVC coupling, one PVC threaded plug and two PVC washers. The coupling is a threaded-socket type with the socket end solvent welded to the pipe while the plug is threaded in the other. The plug has an oval slot allowing the rod to move back and forth from the pumping action. The bottom washer with an identical oval slot acts as a stop for the smaller washer. This small washer has a close clearance fit hole allowing the rod to slide through it but moves laterally with the rod thus covering the exposed opening of the slot.

The debris that slips through the slot in the plug can be removed by removing the threaded plug. The removal of the plug is also necessary when the piston or foot valve are to be removed. An additional plate similar to the sliding PVC disc may be placed on top of the whole assembly

FIG. 1(e)

CASING COVER



(A) PVC 4" PLUG 2" LG. OVAL SLOT IN TOP

(B) PVC DISC - CLEARANCE HOLE FOR PIPE

(C) PVC COLLAR - SLOTTED SAME AS (A)

(D) PVC 4" COUPLING SOCKET - THREADED

(E) PVC 4" PIPE - TOP END

to act as a cover plate and eliminate debris accumulating in the oval slot cut in the top PVC plug.

2.6 Piston

The piston as shown in Figure 1(f) appears to be somewhat complex but actually the majority of the components are stock items. These include a large bolt to hold the entire assembly together, a short length of 2-1/2 inch PVC pipe to act as a spacer between the top and bottom sections, a rubber washer for the plate valve, a short length of pump rod to guide the plate valve, two leather washers to seal the mid section and finally the polyethylene piston rings. The top and bottom sections are identical and must be injection molded or machined, whereas the remaining components can be cut from stock items. For example, the piston ring may be cut from a standard polyethylene pipe. The polyethylene was chosen as ring material due to its relatively low coefficient of friction on PVC (see section 4.0). Not only does this reduce the pumping force but according to the wear tests performed the wear will be limited to the rings.

Therefore the component requiring periodical replacement would be the ring which is both easy to make and relatively easy to install.

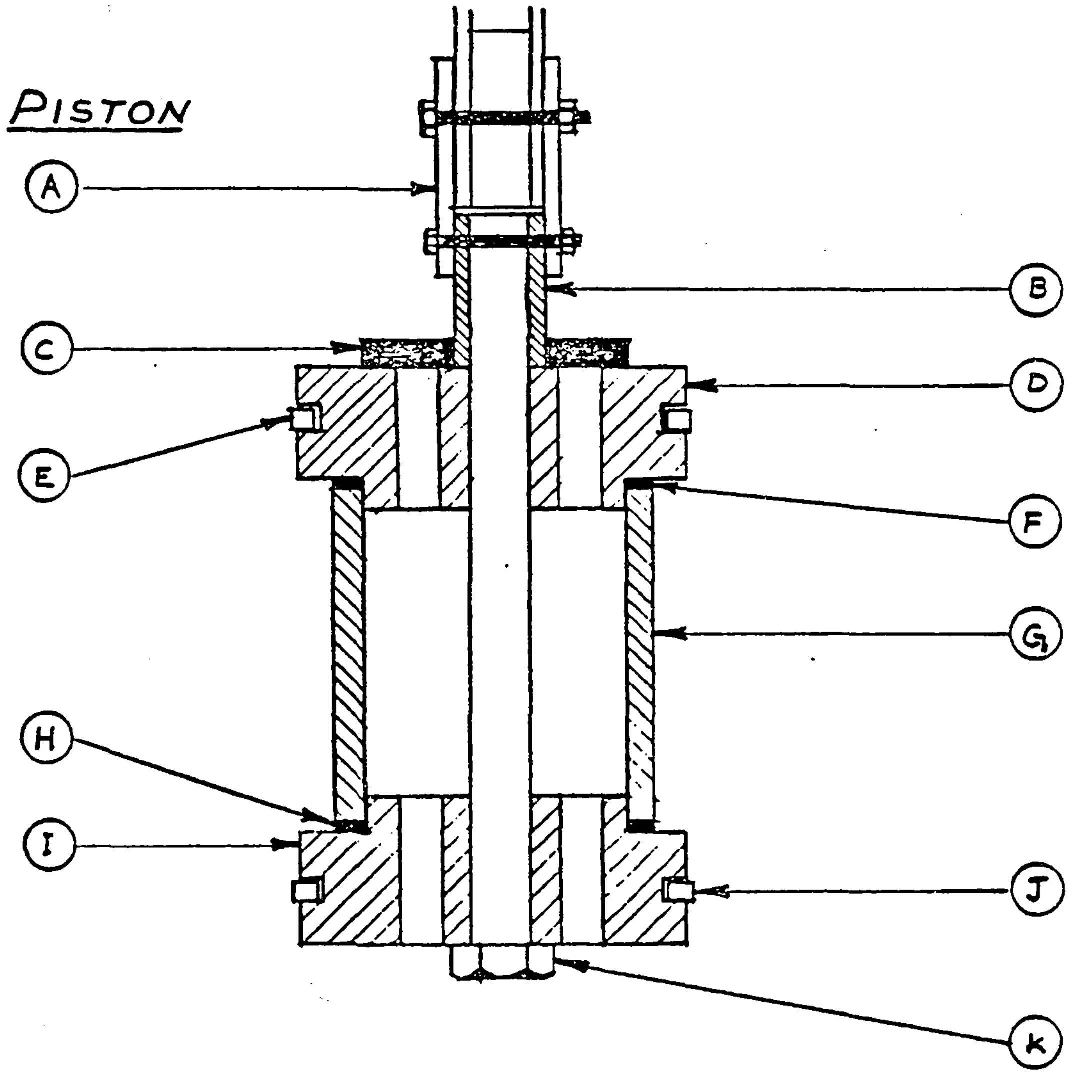
Since these rings seal only under a dynamic condition the piston, if withdrawn slowly, can be removed by hand. This occurs as a result of the water flowing past the rings thus allowing removal of the piston even when the pump has a full head of water.

Once the piston is removed it can be completely dismantled by removing the small bolt connecting the piston to the pump rod.

2.7 Foot Valve

The foot valve as shown in Figure 1(g) is very similar to the piston. The slight difference is the eyebolt holding the valve together and

FIG. 1(f)



(A) GALVANIZED PIPE AS COUPLING

(B) PVC PIPE 3/4" SCHD 80 × 2" LG.

(C) PLATE VALVE - RUBBER, LEATHER, PVC × 2½" O.D.

(D) + (I) MOLDED PVC

(E) + (J) POLYETHYLENE RING - CUT FROM 3½" PIPE

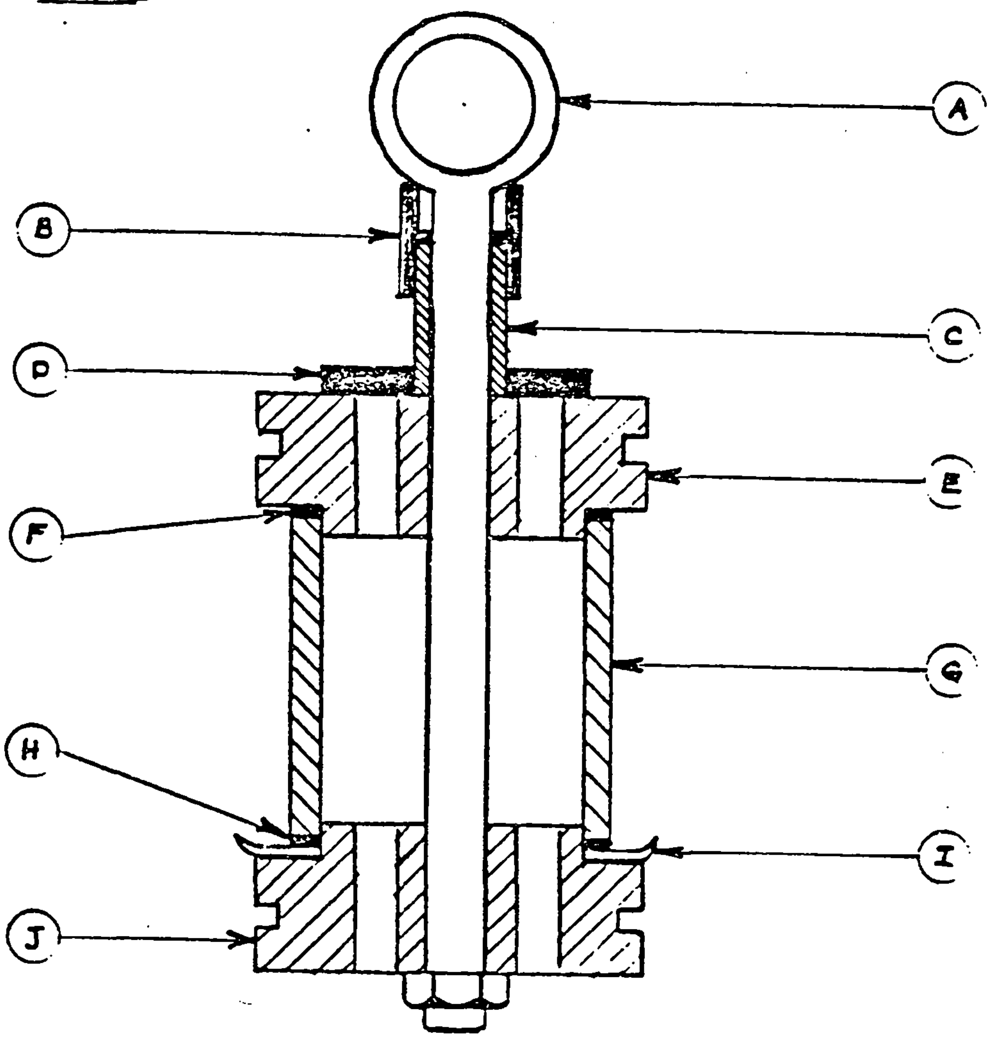
(F) + (H) SEALING GASKET - LEATHER, RUBBER

(G) SPACER PVC PIPE 2½" SCHD 80 × 4" LG.

(K) STAINLESS OR GALVANIZED BOLT 11/16" DIA. × 9" LG.

FIG. 1(g)

FOOT VALVE



(A) EYE BOLT 11/16" x 11" LG. STAINLESS OR GALVANIZED

(B) PVC COUPLING 3/4" SCHD. 80 SOCKET-SOCKET

(C) PVC PIPE 3/4" SCHD. 80 x 2" LG.

(D) PLATE VALVE - RUBBER, LEATHER, PVC

(E) + (J) MOLDED PVC SAME AS PISTON

(F) + (H) GASKET - RUBBER LEATHER

(G) PVC PIPE 2½" SCHD. 80 x 4" LG.

(I) POLYETHYLENE CUP

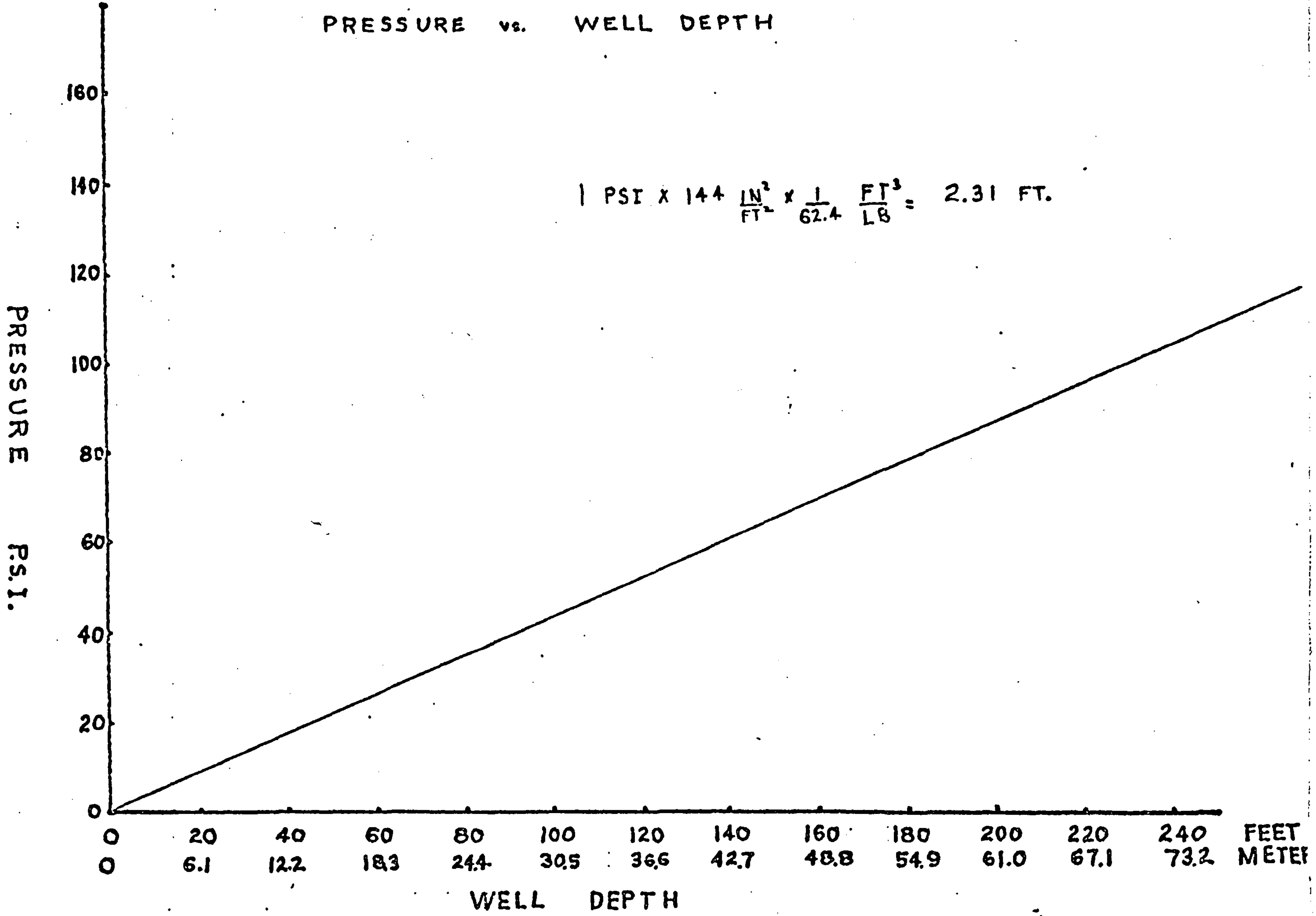

PRESSURE vs. WELL DEPTH
1 PSI X 144 IN²/FT² X 1/62.4 FT³/LB = 2.31 FT.
PRESSURE P.S.I.
0
20
40
60
80
100
120
140
160
0 20 40 60 80 100 120 140 160 180 200 220 240 FEET
0 6.1 12.2 18.3 24.4 30.5 36.6 42.7 48.8 54.9 61.0 67.1 73.2 METER
WELL DEPTH

Fig. 2

the polyethylene cup which provides a static seal thus eliminating the need for rings. Also the top coupling is a PVC double socket coupling which limits the travel of the plate valve.

The eyebolt will facilitate removal by using a hook on the end of the pump rod. The polyethylene cup offers little frictional resistance when being removed but provides an excellent static seal.

While in service the foot valve will rest on the retainer ring thus supporting the column of water. As the water rushes up through the valve during the pumping action the resistance of the polyethylene cup will be sufficient to hold it down in position.

3.0 PUMP TEST RESULTS

3.1 Two Inch Pump Tests

The main objective was to design a pump which would be virtually maintenance free and would have a maximum projected well depth of 200 feet. Simplicity was the keynote in designing the pump.

Materials that might fail should be easily replaced. Plastics such as PVC and polypropylene were investigated and on the basis of performance figures, a design could be recommended for field testing. Testing on shallow wells could be performed on an actual head model while deeper well testing could be performed on a simulated head pump.

3.1.1 Simulated Head Pump

Introduction

A simulated head apparatus was designed and constructed to perform deep well testing as well as providing an alternate means of testing shallow wells. Pressurized water (0-100 psi) acted on top of the piston to simulate a column of water (0-230 ft.) (Figure 2). A pressure chamber was mounted above the PVC casing and piston assembly (Figure 3). Upward movement of the simulated head pump

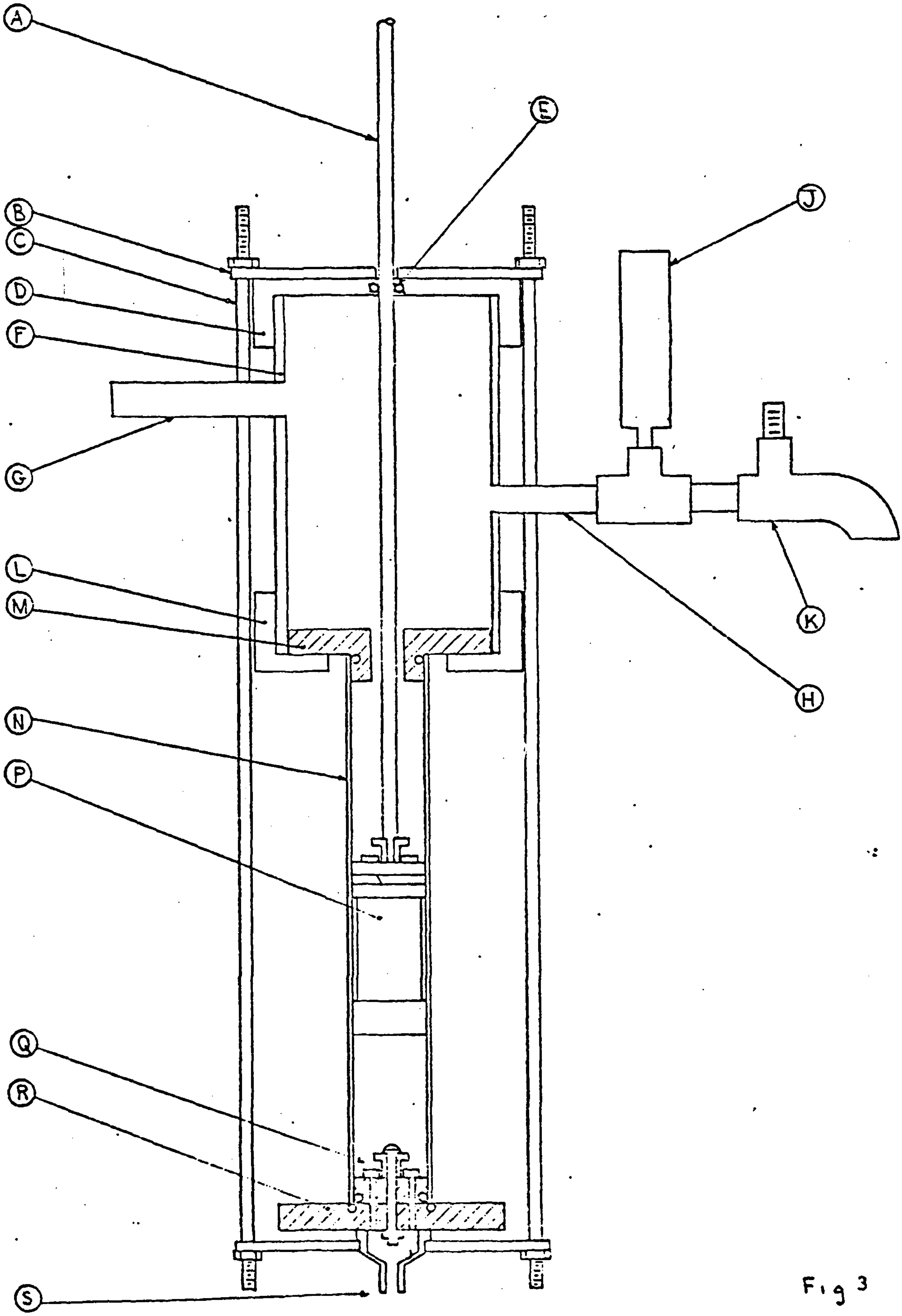


Fig 3

SIMULATED HEAD PUMP PARTS LIST

A - 3/8" Cold Rolled Steel Pump Rod

B - Restrictor Plates (2) - 9" dia. x 1/4" thick

C - Tierods (3) - 3/8" dia.

D - Aluminum Cap - 7-1/2 O.D.

E - O-Ring Seal - 3/8" I.D.

F - Pressurized Water Chamber - 6-1/2" O.D. x 1/4" wall thickness

G - Pressure Chamber Inlet Port - 1" dia. pipe

H - Pressure Chamber Outlet Port - 3/4" dia. pipe

J - Pressure Gauge - 0-100 psi

K - Pressure Relief Valve - 10-125 psi

L - Aluminum Cap - 7-1/2" O.D.

M - Upper End P.V.C. Plate - 7/8" I.D.

N - P.V.C. Casing - 2" SDR 26 x 16" long

P - Piston and Valve Combination

Q - Foot Valve-Plate Valve Assembly

R - Lower End P.V.C. Plate - 3/16" holes x 8

S - Water Inlet

piston drew water through a non recoverable foot valve (Figure 3(a)) from a water reservoir which is monitored to establish the total weight and hence the total volume of water displaced. During the upward stroke, pressure increases on top of the piston opening a pressure relief valve, allowing water to flow through the outlet. By measuring flow back through the foot valve a direct means of establishing leakage rates was possible.

The above ground section of the pump had a 4 inch schedule 40 PVC post. The handle consisted of a 2 inch by 4 inch spruce block with a 3/4" pipe attached with U-bolts. A 6:1 mechanical advantage was used for all tests conducted on the simulated head apparatus. A short section of chain link inserted in the pump rod insured a vertical path (Figure 4).

Pistons

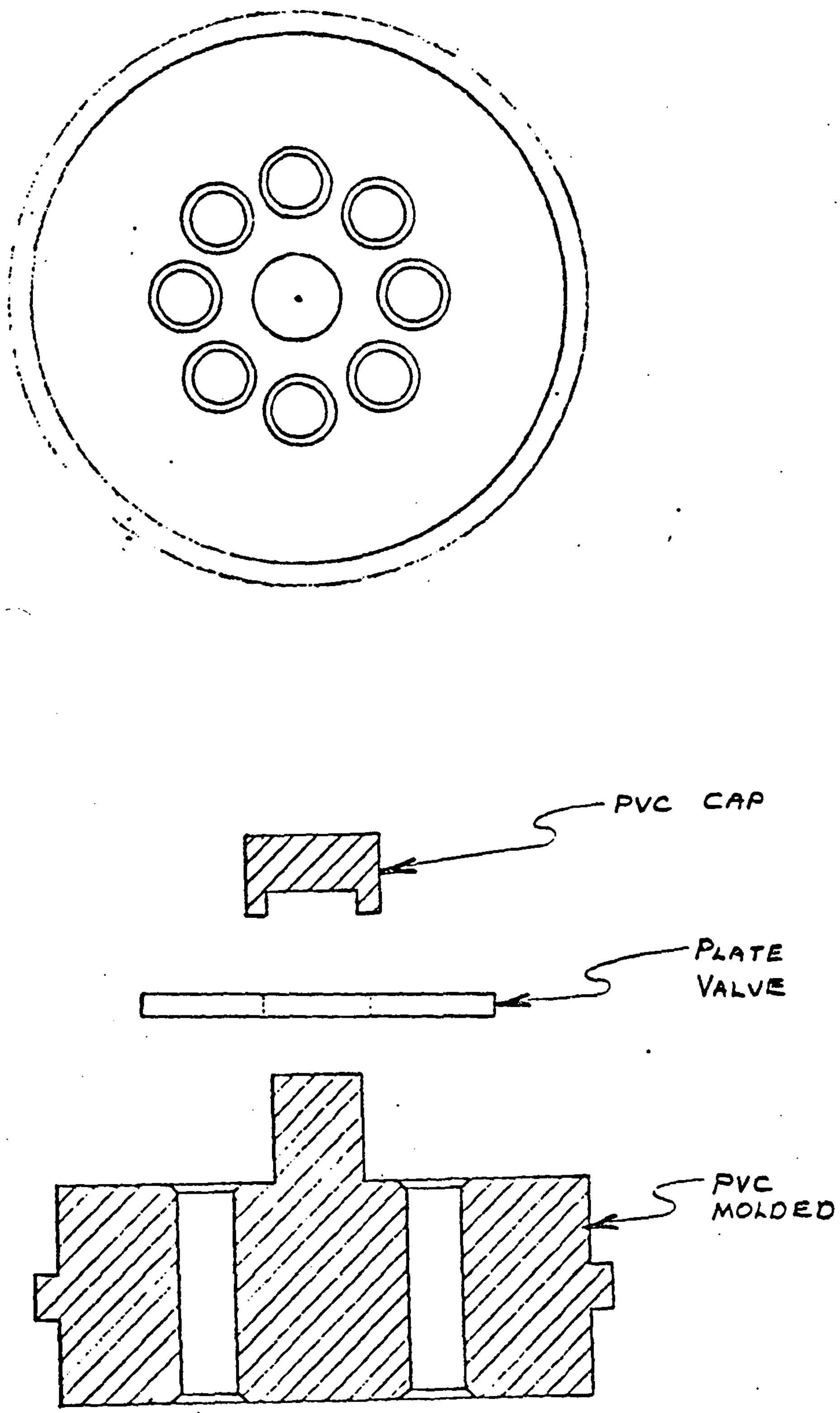
Pistons of similar material and dimensions but with different valve arrangements were used (Figures5-9). A PVC pipe 2.125 inches outside diameter and 5 inches long was used as the basic shell.

Centrally Pinned Flapper (Figure 5)

This piston consisted of a convex PVC cup with one piston ring on the upper section of the piston. The ring served as a hydraulic seal as well as giving guidance for the piston within the casing. The valve ports consisted of eight 3/16" holes countersunk slightly to reduce turbulence and insure proper seating of the rubber flapper.

Flapper Pinned at One Side (Figure 6)

This piston consisted of a concave PVC cup with a pin in the top section for mounting the piston to the pump rod. More freedom of movement was attained with such a setup. In this case the piston ring was on the lower section of the piston. The valve port was one hole 7/8 inch in diameter. A rubber flapper with a flat washer backing served as the check valve.



NON - RECOVERABLE FOOT VALVE

Fig.3 (a)

SIMULATED HEAD SUPER STRUCTURE

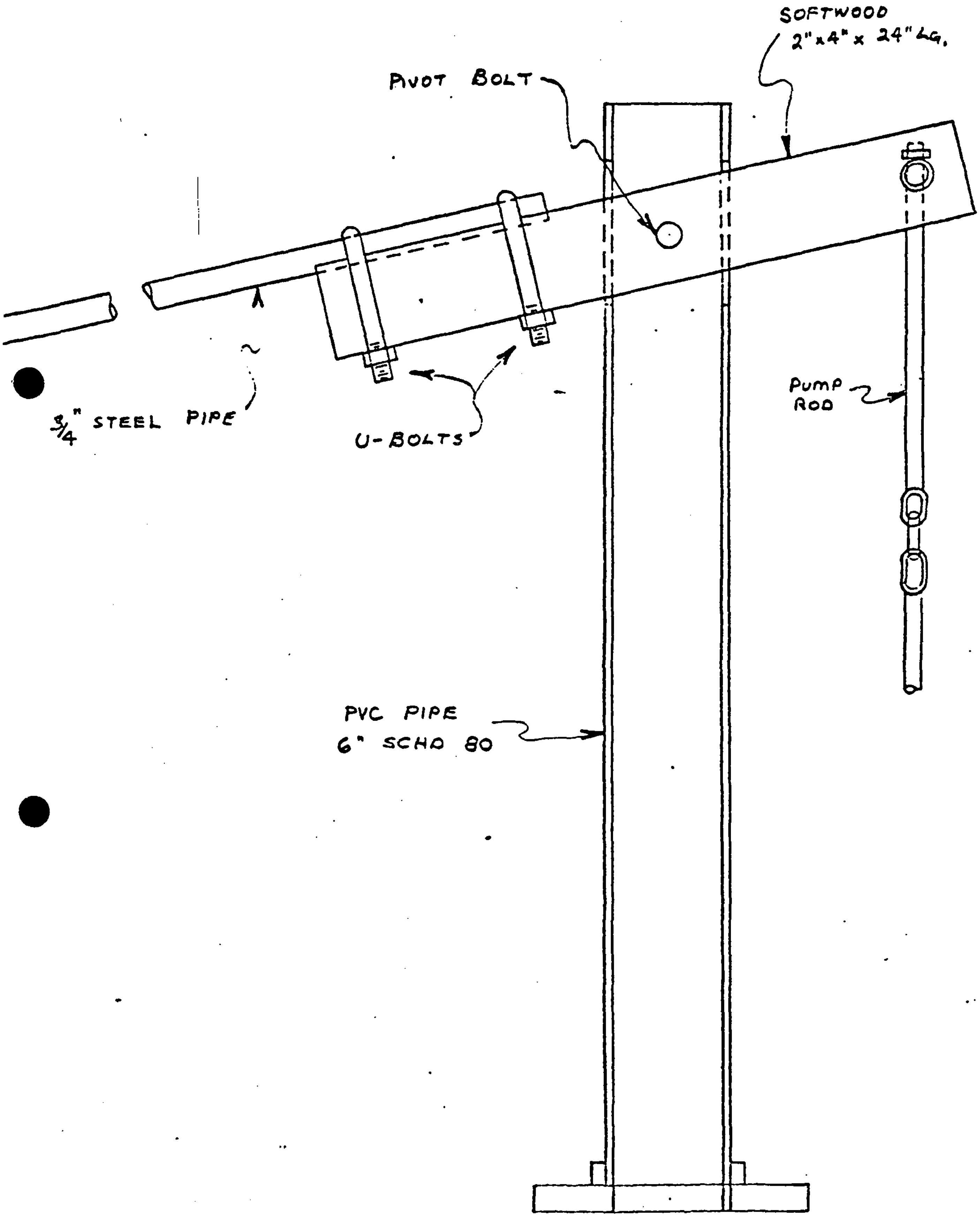


Fig. 4

RUBBER FLAPPER PINNED IN THE CENTER

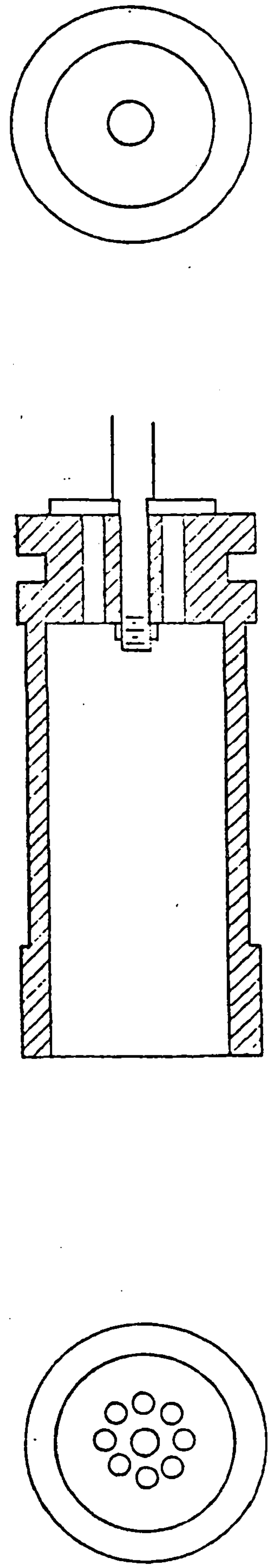


Fig. 5

RUBBER FLAPPER PINNED AT ONE CORNER

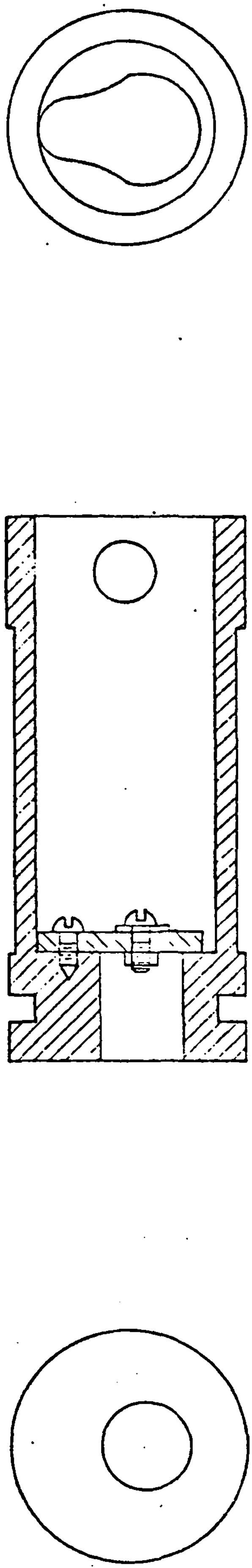


Fig.6

Ball Valve (Figure 7)

The shell was similar in nature to that of the piston with the flapper pinned at the side. The valve port was a 3/4 inch hole with a 3/16 inch deep countersunk shoulder. A standard 1 inch steel ball bearing completed the valve by sealing on the chamfered shoulder.

Plate Valve (Figures 8 and 9) (Preferred Design)

The shell was similar in layout to that of the centrally pinned flapper. Pistons with one and two rings were tested but the basic operating principles of the two valves were the same. A central sleeve acted as a guide for a washer shaped disc made of various materials. The washer had the freedom to travel 3/8 of an inch opening and closing. The valve ports were eight 3/16 inch diameter holes slightly countersunk to relieve turbulence. With the two ring layout the hollowed out middle section was slightly smaller in diameter to accommodate the second ring.

Testing Procedures

Tests for flow rate and static leakage rates were conducted at various pressures and various well depths. Flow rates were recorded and plotted versus stroke rate (Figures 10, 12-18). From these graphs theoretical flow rate, leakage rate past the piston, and actual flow rate can be observed.

$$\text{Theoretical Flow} - \text{Leakage Past Piston} - \text{Leakage Past Foot Valve} = \text{Actual Flow}$$

Polypropylene Plate Valve with Two Polypropylene Rings (Figure 10)

Polypropylene was ductile enough that the piston rings could be installed very easily. The rings were springy, a quality needed for efficient sealing. Although its ductile qualities were excellent machinability proved to be a problem. A perfectly flat surface free of ridges and burrs was impossible to attain. Hence the sealing properties of polypropylene

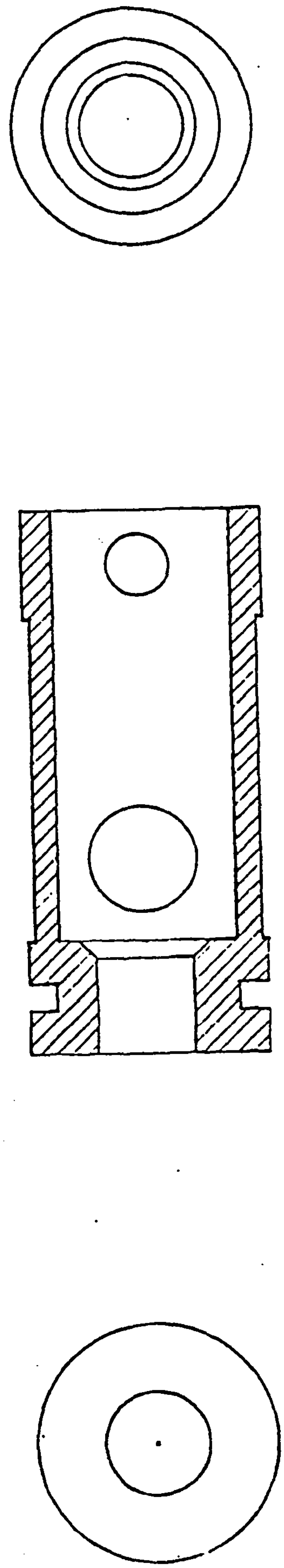


Fig. 7

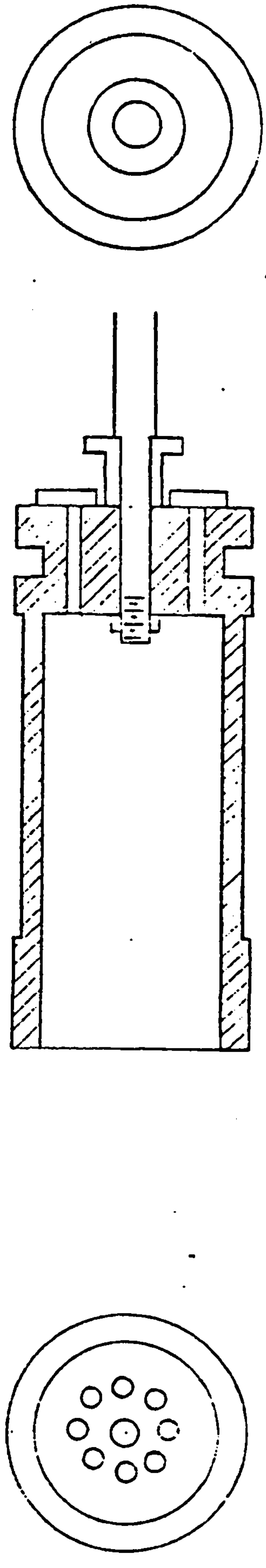


Plate valves

Fig. 8

PLATE VALVE - TWO RINGS

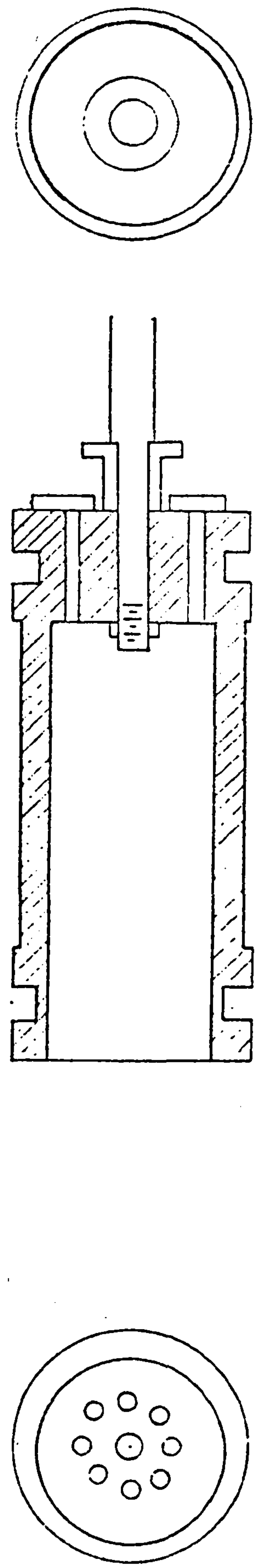


Fig. 9

SYMBOL	WELL DEPTH
O	25 FT.
□	50 FT.
△	80 FT.
O	140 FT.
X	220 FT.

— — — THEORETICAL VALUE - 100% HYDRAULIC EFFICIENCY

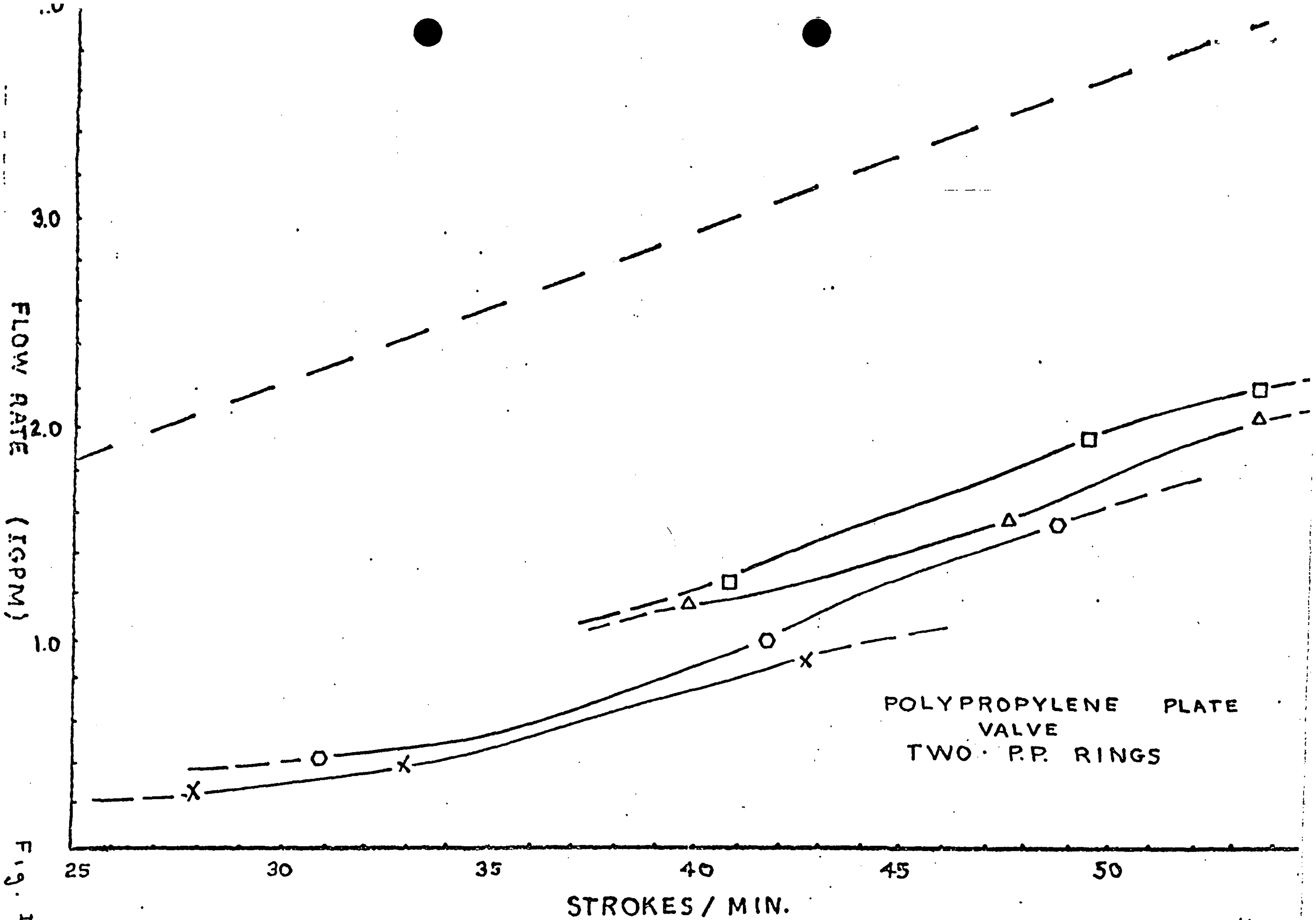

FLOW RATE (IGPM)
1.0
2.0
3.0
25
30
35
40
45
50
STROKES / MIN.
POLYPROPYLENE PLATE
VALVE
TWO · P.P. RINGS

Fig. 10

were erratic as evidenced in the irregularity of the flow rate curves (Figure 10).

The polypropylene was not flexible enough to conform to irregularities (i.e., waviness) in a mating surface. This lack of conformity results in a considerable static leakage rate past the foot valve (Figure 11).

TABLE 3.1.1.A Polypropylene Valve - 2 Rings

Well Depth (ft)	Flow/ Stroke (Igal/stroke)	Efficiency (%)
50	.037	51.0
80	.034	46.0
140	.024	32.0
220	.014	19.0

The polypropylene rings showed considerable wear after use. The outer bearing surface of the rings were scored through wearing on the PVC casing. The poor surface of the rings were another reason for the extremely high leakage rate past the piston.

Rubber Flapper Valve Pinned at a Corner - One PVC Ring (Figure 12)

The rubber flapper was 3/16 inch thick but to add stiffness a washer was bolted to the center of the flapper. Even with this added stiffness, at 60 psi or 140 ft. head of water, the flapper was forced through the hole due to the high pressure differential. This problem may be resolved by one of two methods:

1) Attach a large washer to the back of the rubber flapper. The washer should be larger than the valve port hole.
2) Have numerous smaller holes (1/8-1/4") rather than one large hole.

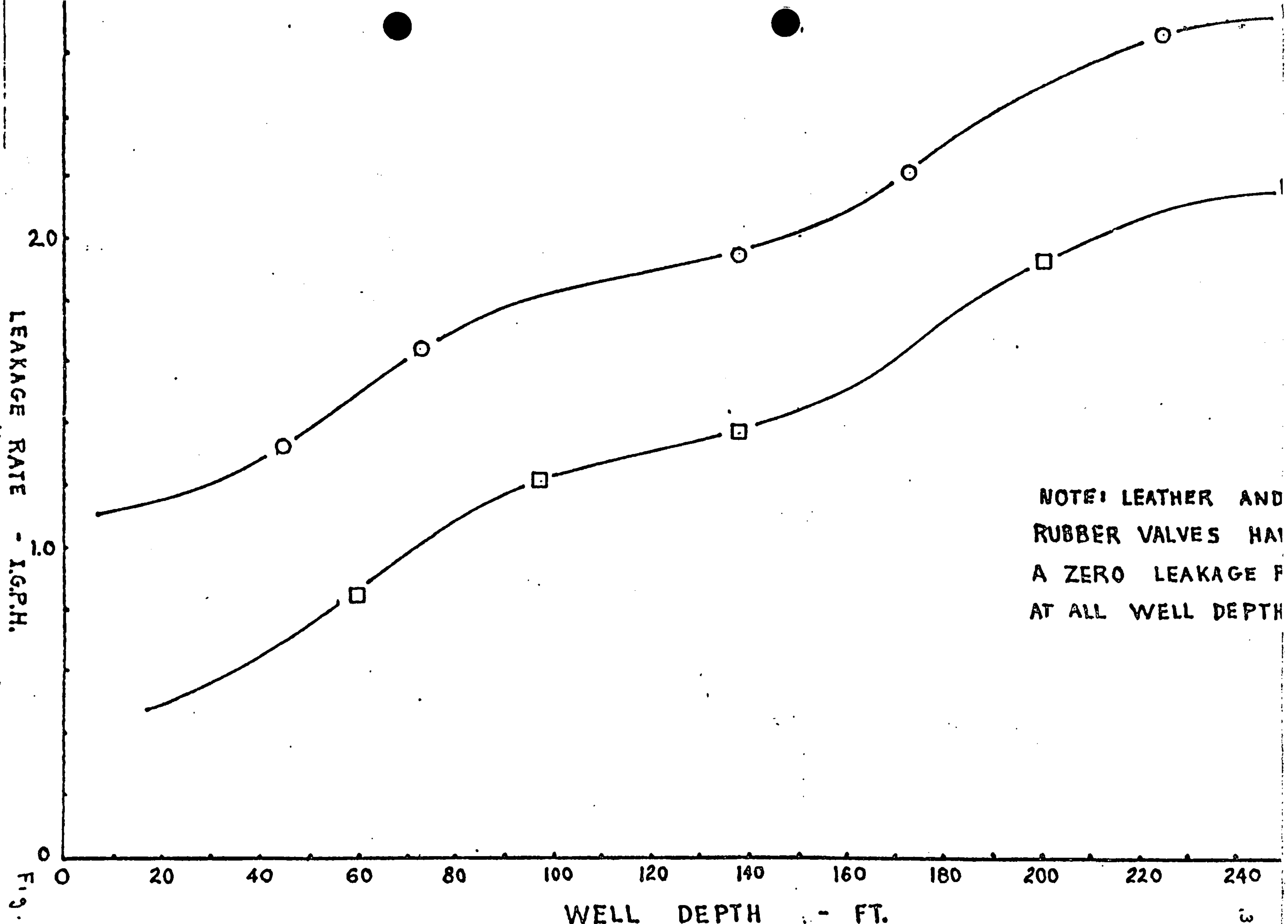

LEAKAGE RATE - I.G.P.H.
2.0
1.0
0
0
20
40
60
80
100
120
140
160
180
200
220
240
WELL DEPTH - FT.
NOTE: LEATHER AND
RUBBER VALVES HA
A ZERO LEAKAGE F
AT ALL WELL DEPTH

Fig. 11

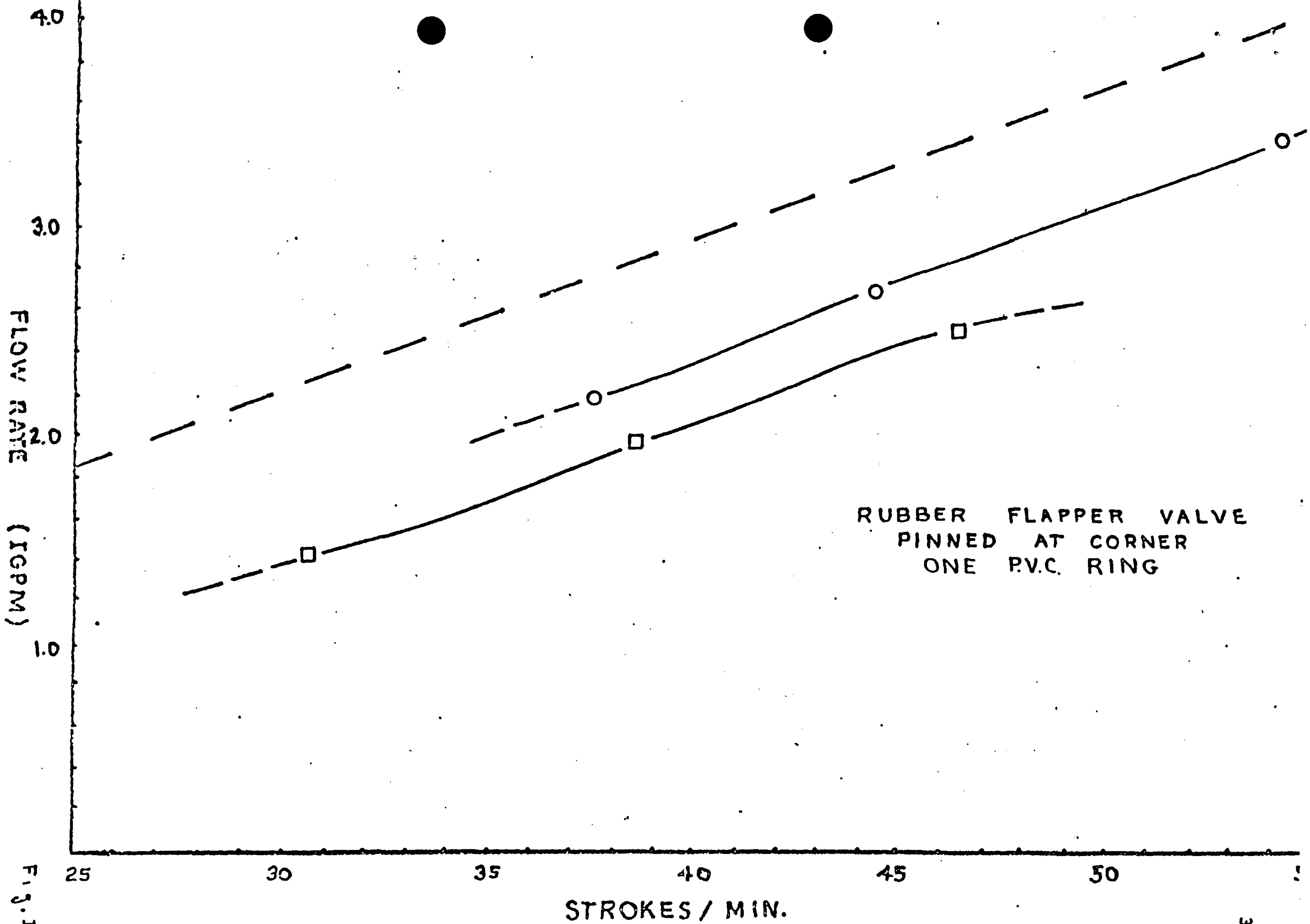

4.0
3.0
2.0
1.0
FLOW RATE (IGPM)
25
30
35
40
45
50
STROKES / MIN.
RUBBER FLAPPER VALVE
PINNED AT CORNER
ONE P.V.C. RING

Fig. 12

At shallow depths the valve worked efficiently and offered very little resistance to flow.

TABLE 3.1.1.B Rubber Valve Corner - One PVC Ring

Well Depth (ft)	Flow/ Stroke (Igal/stroke)	Efficiency (%)
25	.061	82.5
80	.051	69.0

With the flapper pinned at one corner there is not an even distribution of the pinning force over the entire flapper. Leakage rates past this type of flapper are higher than those of a flapper pinned in the center.

Rubber Flapper Valve Pinned in the Center - One PVC Ring (Figure 13)

An even distribution of the pinning force enables this type of valve to seal better at its extremities. This force while offering good sealing properties also offers increased resistance to flow. While no work should be done on the downward stroke this valve arrangement would not permit the water to flow through the valve fast enough at 60 strokes per minute without exerting some work. The hardness and the thickness of the rubber are important in this type of valve. A rubber which is harder than 60 Shore A or thicker than 1/8 inch would present too much flow resistance. Another problem with such an arrangement is the degree to which the pinning force is applied. If too much force is applied the rubber curls up at the edges increasing leakage.

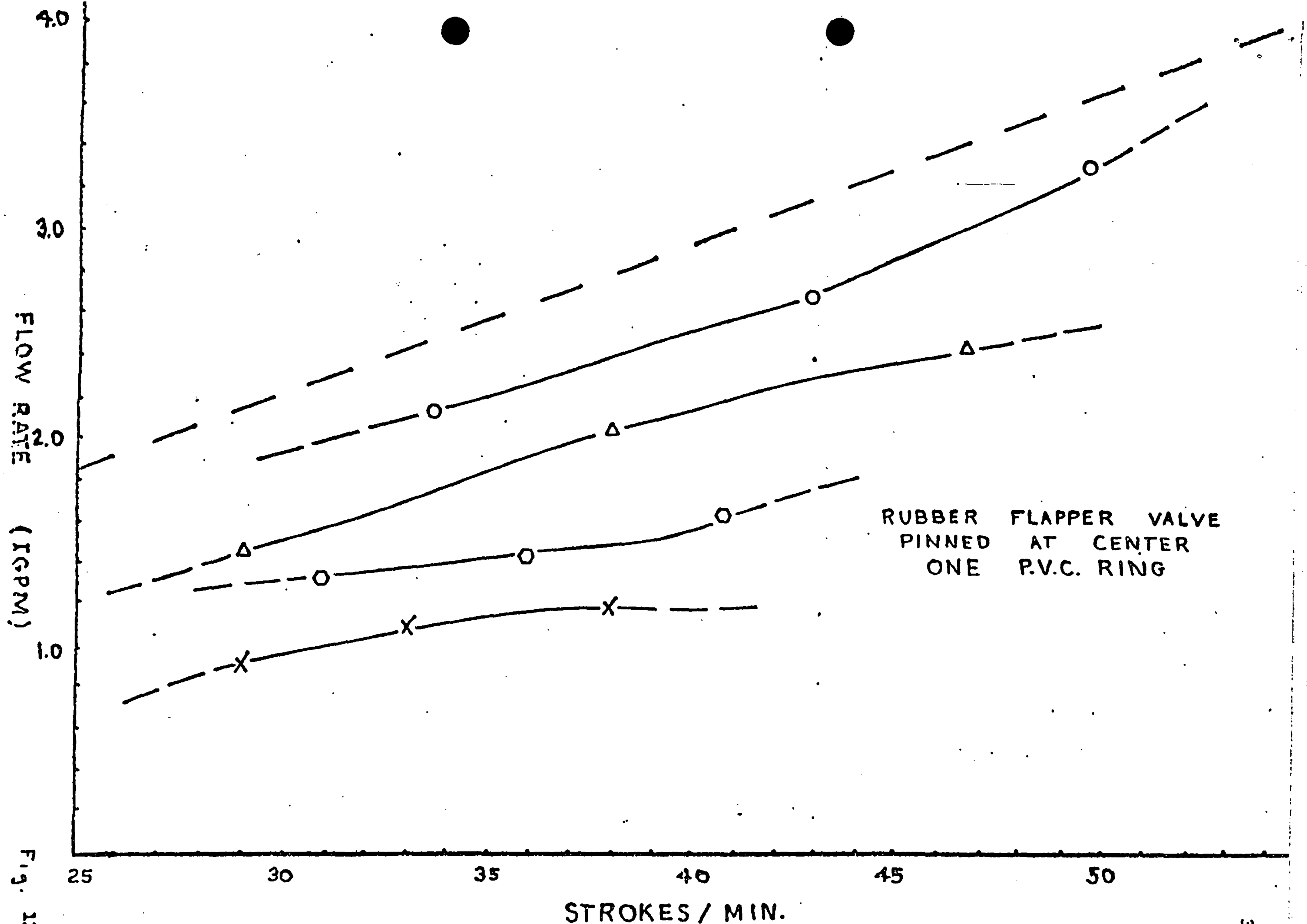

FLOW RATE (IGPM)
4.0
3.0
2.0
1.0
25
30
35
40
45
50
STROKES / MIN.
RUBBER FLAPPER VALVE
PINNED AT CENTER
ONE P.V.C. RING

Fig. 13

TABLE 3.1.1.C Rubber Valve Center - One PVC Ring

Well Depth (ft)	Flow/ Stroke (Igal/stroke)	Efficiency (%)
25	.066	89.5
80	.054	73.5
140	.043	58.5
220	.034	46.0

Ball Valve - 1 Inch Steel Ball Bearing (Figure 14)

Results obtained with this valve arrangement were quite inconsistent. A stroke rate of 35 strokes per minute could not be attained for well depths beyond 80 feet.

At high pressures a hydrodynamic boundary was set up between the ball and the seat. This cushion of water caused the ball to float on the seat rather than sealing immediately. When the boundary layer was broken down with the passage of time of a second or two, normal pumping action could be carried out for another couple of strokes until the layer built up again. The problem can be remedied by controlling the port hole size to be between 5/8 and 2/3 of the size of the ball. Restricting the vertical travel of the ball would help return the ball faster but may not correct the problem.

Flow resistance was very low and at shallow depths, pumping 60 strokes per minute or more was easily performed. The contact area between the ball and the PVC should be kept to a minimum for maximum sealing properties. Line contact is an ideal situation.

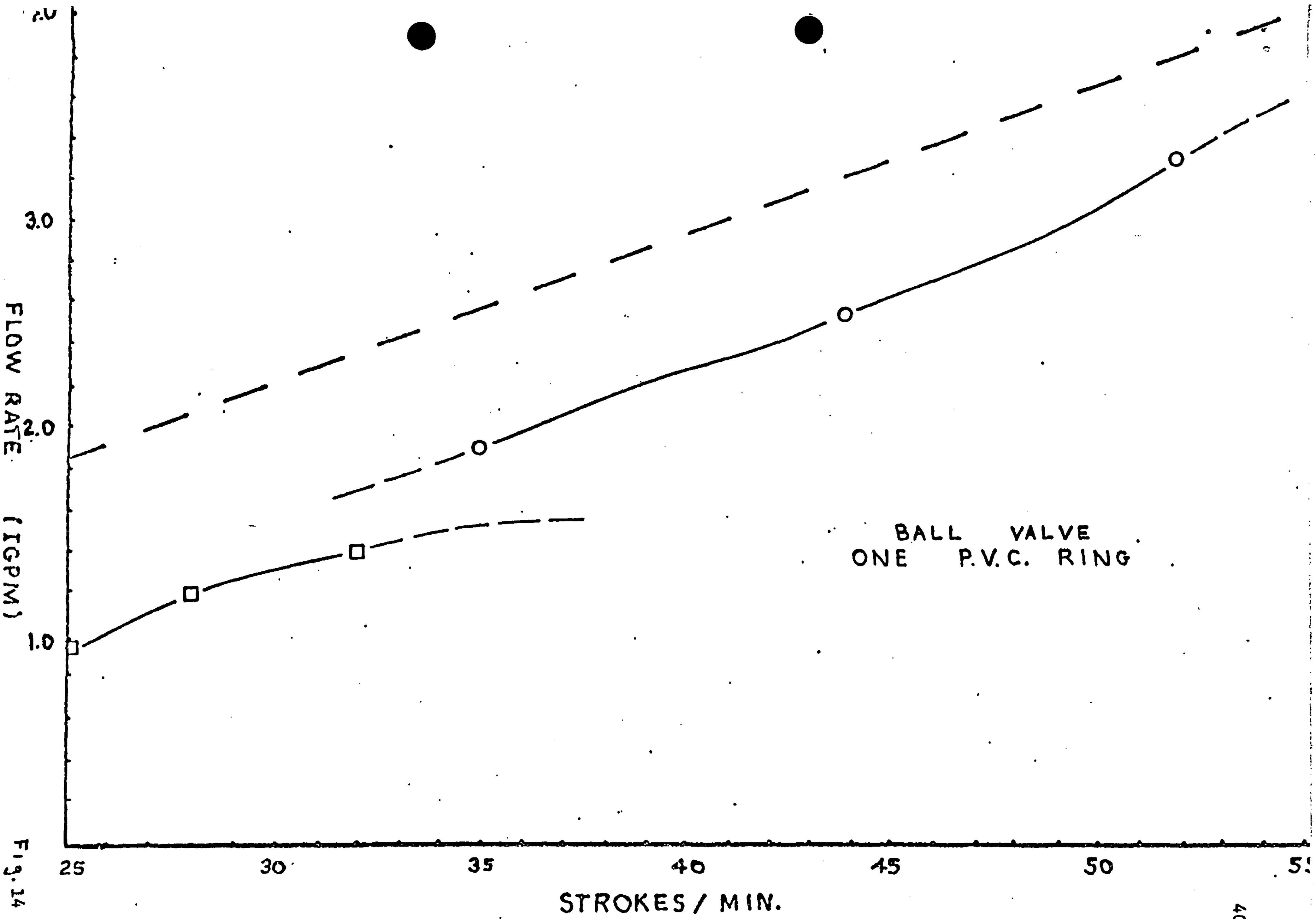

FLOW RATE (IGPM)
3.0
2.0
1.0
25
30
35
40
45
50
STROKES / MIN.
BALL VALVE
ONE P.V.C. RING

Fig. 14

TABLE 3.1.1.D Ball Valve

Well Depth (ft)	Flow/ Stroke (Igal/stroke)	Efficiency (%)
25	.060	80.5
80	.043	58.0

A steel ball bearing will corrode in time therefore a non-corrosive material would be required for the ball valve.

PVC Plate Valve (Figures 15 and 16)

PVC is much easier to machine than polypropylene but is still not flexible enough to conform to a mating surface. The smoother finish gives a more favourable leakage rate (Figure 11) but leakage past such a valve is still 2 gallons per hour at a well depth of 200 ft. In a 3 inch casing the head would drop 68 feet if left standing for a ten hour period.

PVC presented a problem when installing the piston rings. The rings had to be either heated in hot water to soften the PVC or small grooves on the internal diameter of the ring could be used to relieve stresses upon installation of the rings. This problem should only occur with piston rings smaller than 3 inches in diameter.

The clearance between the plate and the guide post has to be at least 1/16" to prevent cocking the plate. The plate must rise 3/16 inch to 1/2 inch off the seat to reduce flow resistance and allow free passage of water through the valve.

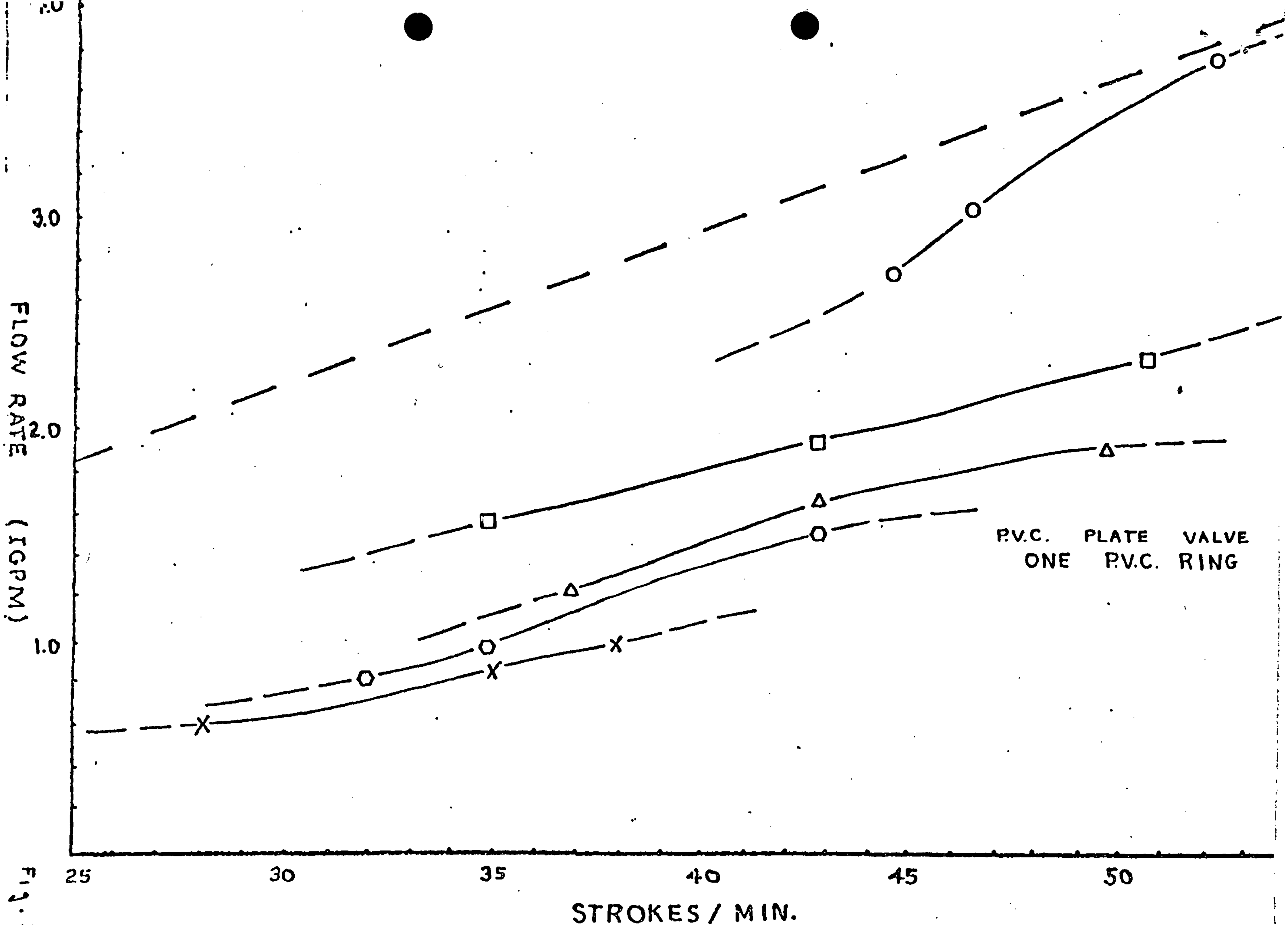
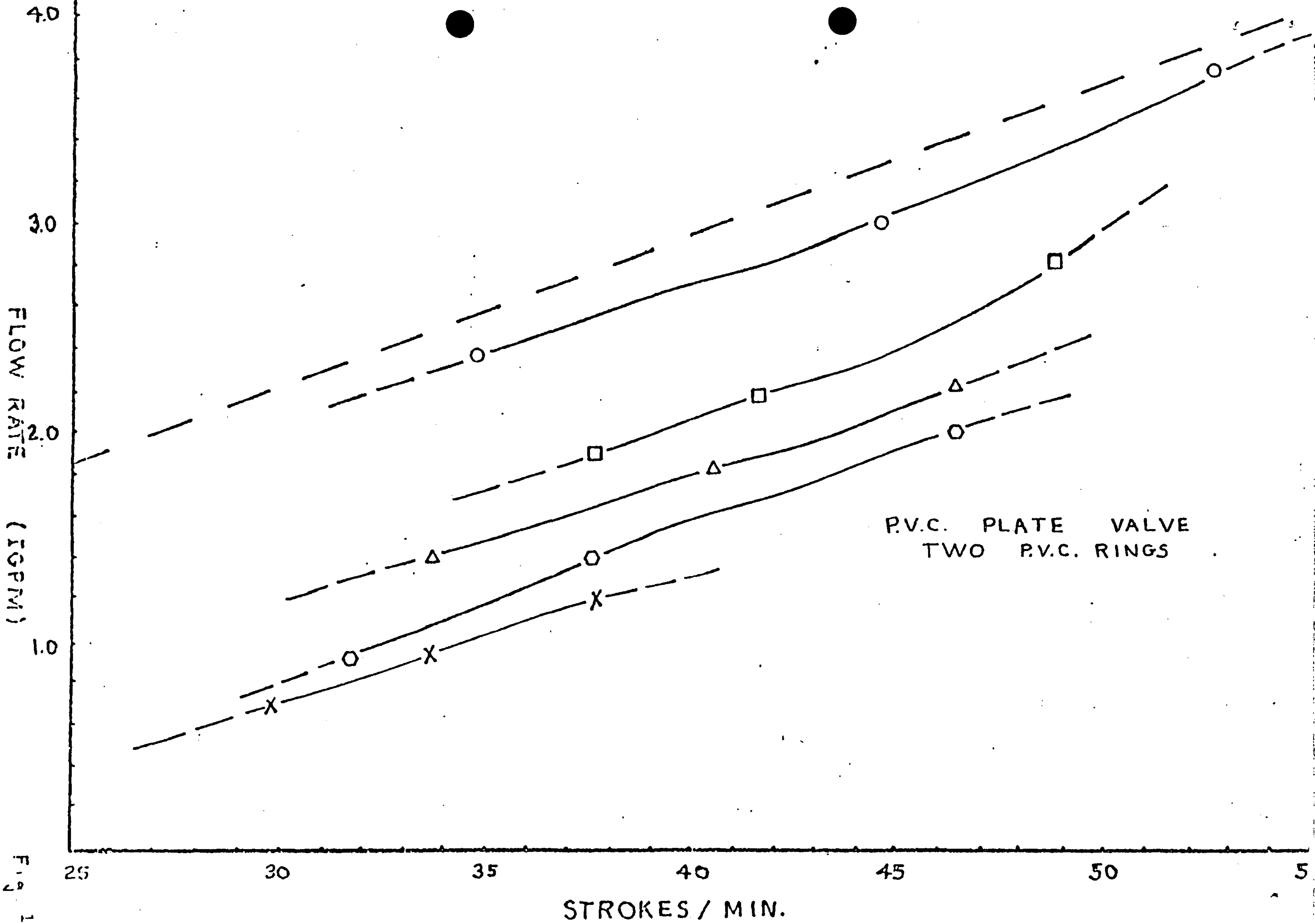

FLOW RATE (IGPM)
3.0
2.0
1.0
25
30
35
40
45
50
STROKES / MIN.
P.V.C. PLATE VALVE
ONE P.V.C. RING

Fig. 15



FLOW RATE (IGPM)
4.0
3.0
2.0
1.0
25
30
35
40
45
50
5
STROKES / MIN.
P.V.C. PLATE VALVE
TWO P.V.C. RINGS

Fig. 16

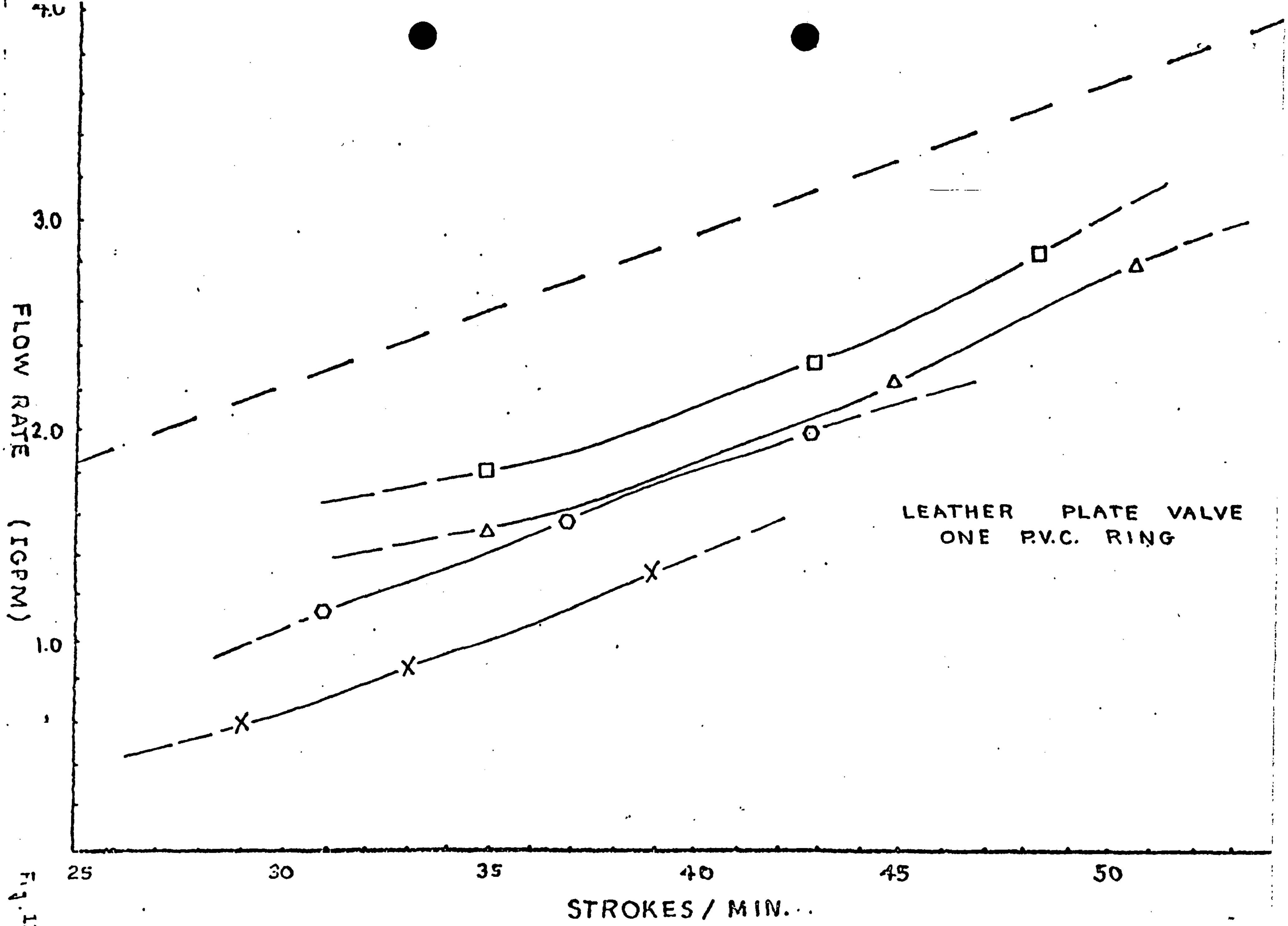
TABLE 3.1.1.E PVC Plate Valve - Different No. of Rings

Number of Rings	Well Depth (ft)	Flow/ Stroke (Igal/stroke)	Efficiency (%)
2 PVC Rings	25	.068	92.5
	50	.052	70.0
	80	.043	59.0
	140	.036	49.0
	220	.027	37.0
1 PVC Ring	25	.066	89.0
	80	.037	50.0
	140	.031	43.0
	220	.025	34.0
No Rings	25	.036	49.0

The efficiency for pistons with one and two rings is virtually the same. But with no rings the efficiency drops drastically. The port holes were the same size as those with the centrally pinned flapper but the flow resistance was reduced substantially with the plate valve.

<u>Leather Plate Valve (Figure 17)</u>

Leather 7/32 inch thick cut in the shape of a washer was used as the plate valve. The central hole required 1/16 inch clearance to prevent the leather from dragging on the central guide. Leakage past the foot valve was reduced to nil at all well depths. The leather became soft and gummy when exposed to water. This allowed the plate to secure itself to the top of the foot valve and piston forming an excellent seal. Although the sealing properties were excellent flow resistance past the valve increased


4.0
3.0
2.0
1.0
FLOW RATE (IGPM)
LEATHER PLATE VALVE
ONE P.V.C. RING
25
30
35
40
45
50
STROKES / MIN.
Fig. 17

accordingly. The strong attraction between the leather and PVC had to be overcome on the downward stroke requiring added work. The flexibility of the leather allowed it to conform to any waviness in the top of the foot valve and piston.

TABLE 3.1.1.G Leather Plate Valve

Well Depth (ft)	Flow/ Stroke (Igal/stroke)	Efficiency (%)
50	.054	74.0
80	.050	67.0
140	.042	57.0
220	.025	34.0

Any leakage past the piston would be by the rings and not through the valve on the piston.

Rubber Plate Valve (Figure 18)

The valve was a washer of 3/16 inch thick rubber with a hardness of 60 Shore A. The rubber possessed the ability to conform to its mating surface. Leakage past the foot valve was nil at all depths tested. The clearance between the rubber and the central post must be at least 3/32 inch and more if possible. The rubber dragged on the post and remained open if the clearance was any less. Flow resistance was minimal compared to that of the centrally pinned flapper.

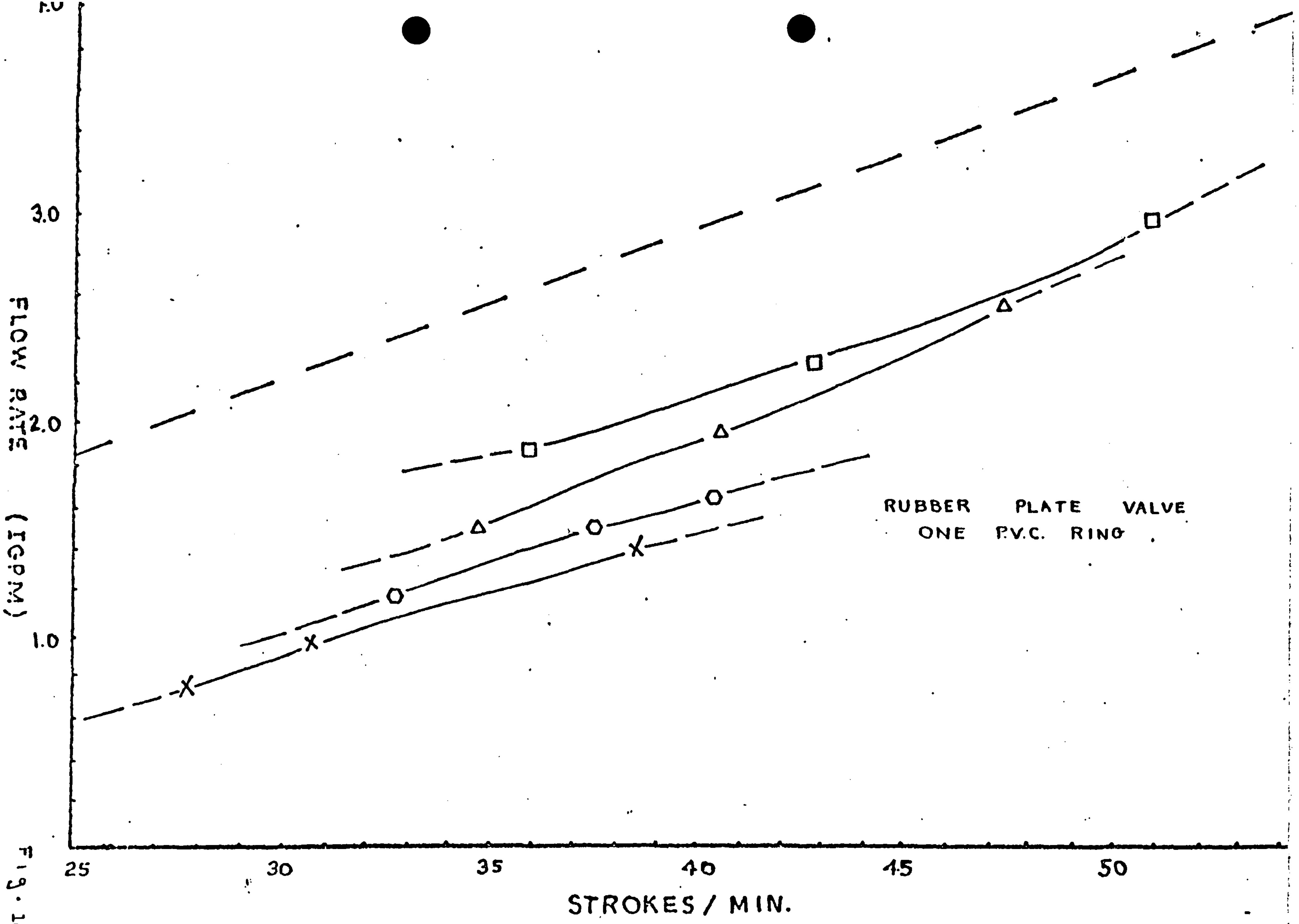

FLOW RATE (I.G.P.M.)
1.0
2.0
3.0
25
30
35
40
45
50
STROKES / MIN.
RUBBER PLATE VALVE
ONE P.V.C. RING

Fig. 16

TABLE 3.1.1.H Rubber Plate Valve

Well Depth (ft)	Flow/ Stroke (Igal/stroke)	Efficiency (%)
50	.053	72.0
80	.049	66.0
140	.039	53.0
220	.032	44.0

The problem of the plate securing itself to the surface did not occur, as with the leather plate.

Dempster Pump (Two Leather Cups) (Figure 19)

The Dempster Pump is a 3 inch diameter PVC casing with a brass-leather piston arrangement. The foot valve had a zero leakage rate at all well depths tested.

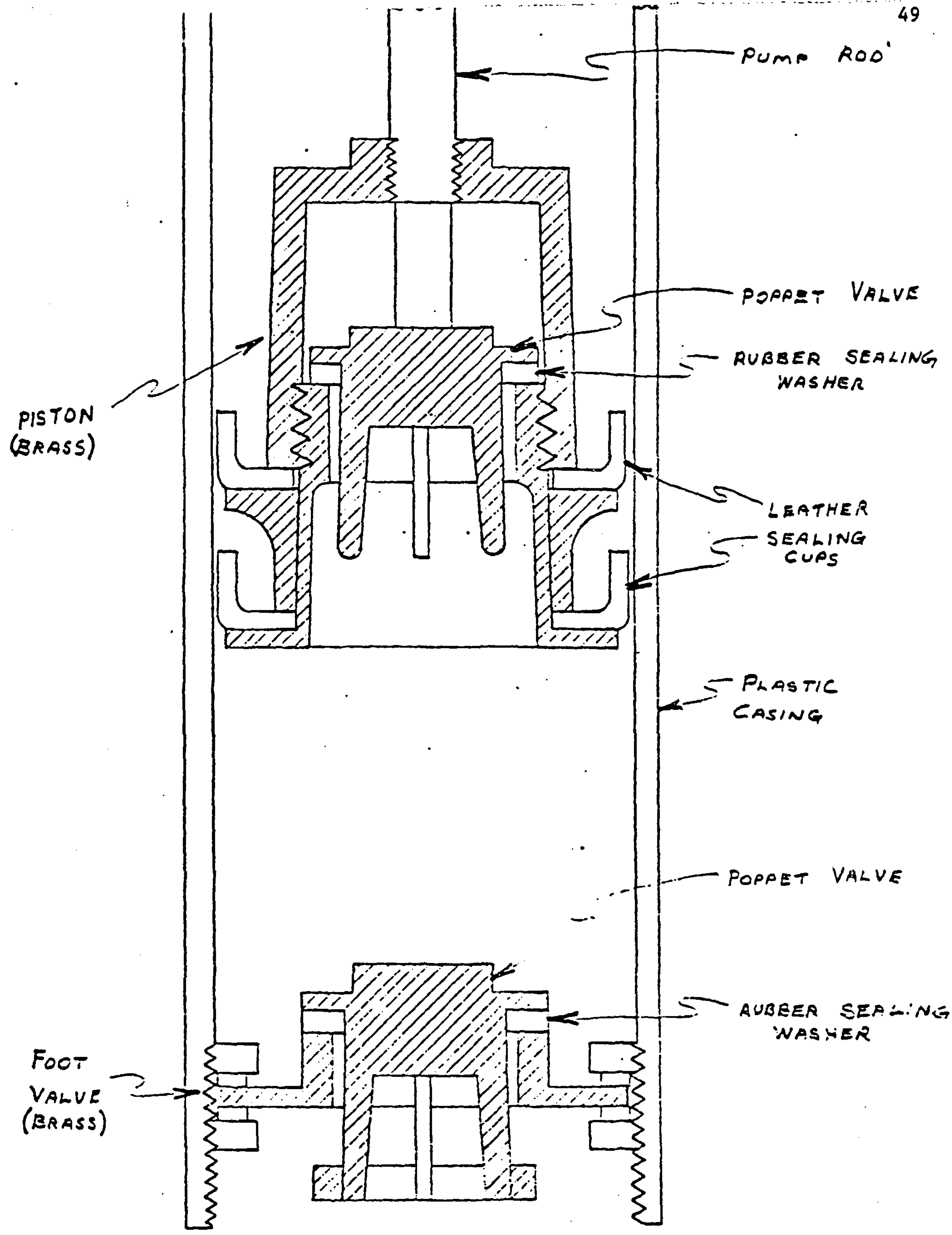
At a well depth of 125 ft. and more the piston required too much force to move with a 6:1 mechanical advantage in the lever arm. At 80 ft. leather cups offered three times the drag as that of the two PVC ring piston (Appendix I). The sealing properties of such a pump are extremely good but are limited by the depth at which they can be effectively used.

3.1.2 Actual Head - 25 Foot Pump (Figure 20)

Introduction

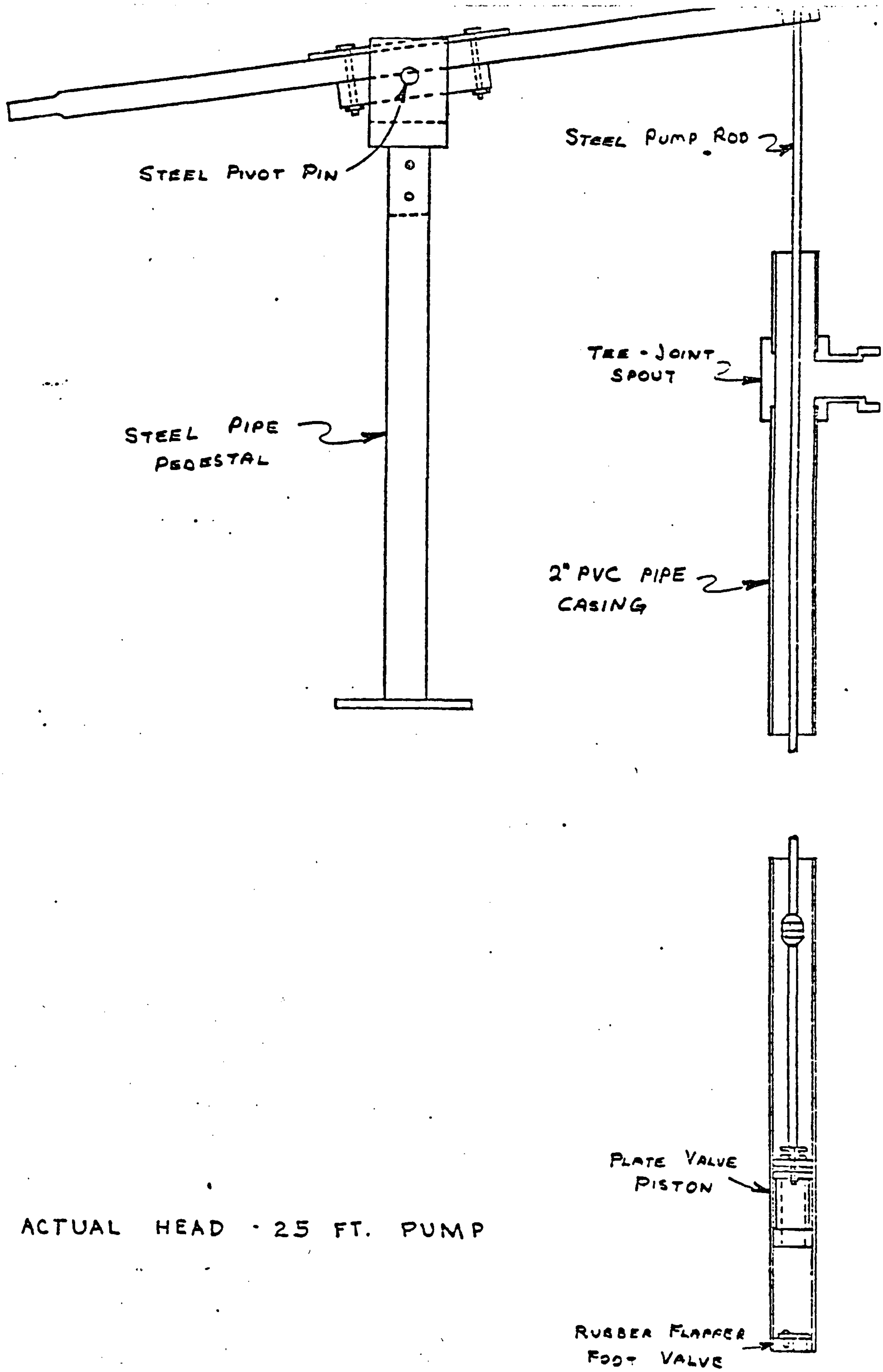
The piston and PVC casing were identical in material and dimensions to that of the simulated head pump (section 3.1.1). The casing was 25 feet from foot valve to exit nozzle. Three sections of 3/8 inch steel rod coupled with brass fittings were used as a pump rod. Due to the corrosive nature of the steel, rust appeared in the water after extended use.

The superstructure was similar to the simulated head with a few



DEMPSTER PUMP

Fig. 19



ACTUAL HEAD - 25 FT. PUMP

Fig. 20

minor changes. A 2 inch steel pipe was used as the post with a steel pivot point. The handle was one continuous piece of wood 60 inches long with a 1:1 mechanical advantage.

The piston remained at least 18 inches below the water level at all times. This insured the pump would remain a positive displacement pump at all times and not rely on suction.

Since the foot valve was submerged it was difficult to measure leakage rates directly.

Test Results

Rubber Flapper Valve Pinned at a Corner - One PVC Ring

Flow/Stroke (Igal/stroke)	Efficiency (%)
.065	88.0

Rubber Flapper Valve Pinned in the Center - One PVC Ring

Flow/Stroke (Igal/stroke)	Efficiency (%)
.066	90.0

Ball Valve - 1 Inch Steel Ball Bearing

Flow/Stroke (Igal/stroke)	Efficiency (%)
.060	81.0

PVC Plate Valve - One PVC Ring

Flow/Stroke (Igal/stroke)	Efficiency (%)
.065	89.0

PVC Plate Valve - Two PVC Rings

Flow/Stroke (Igal/stroke)	Efficiency (%)
.066	90.0

The flow rates for different stroke rates for the various combinations of valves and rings are given in Figures 21-25.

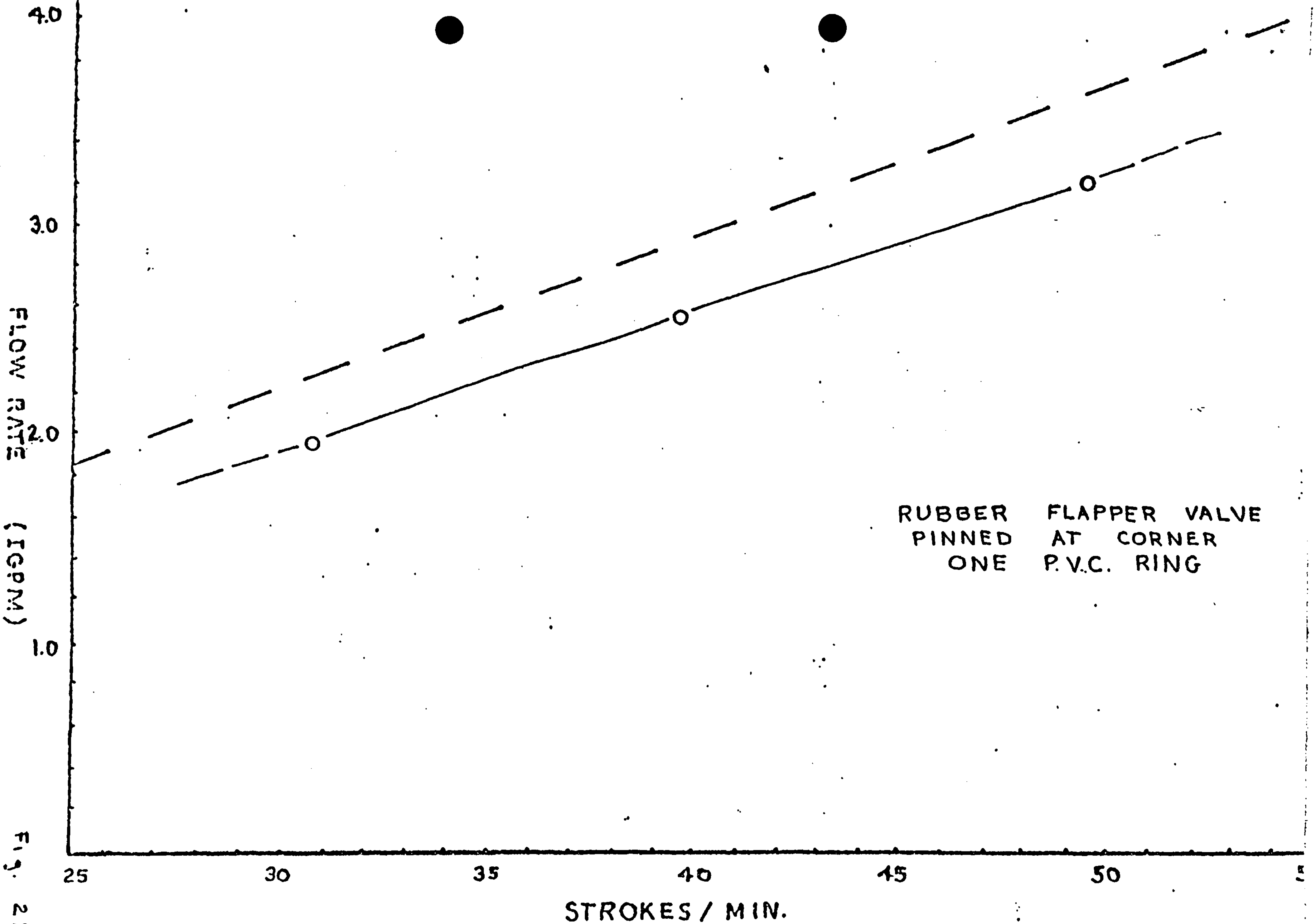
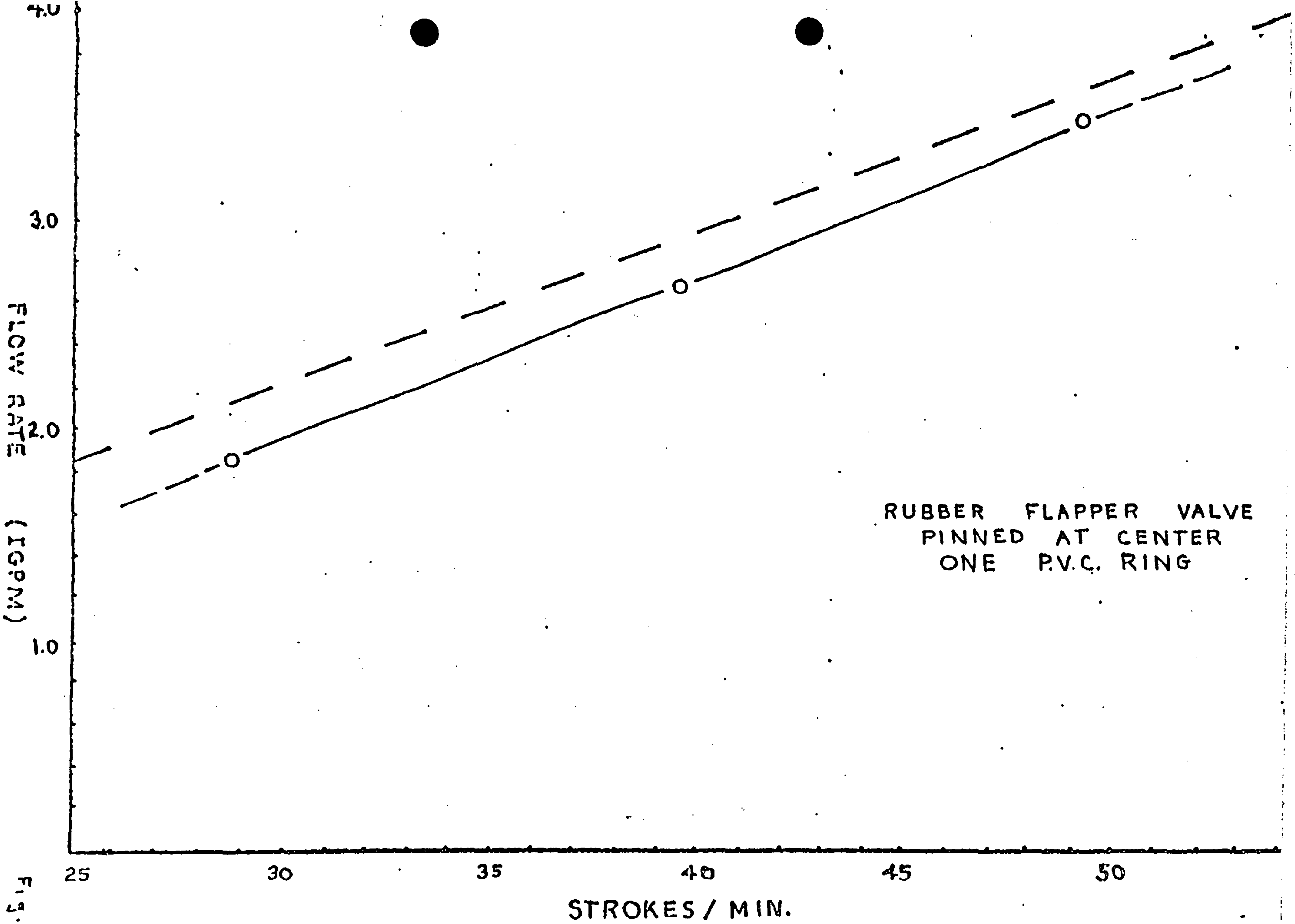
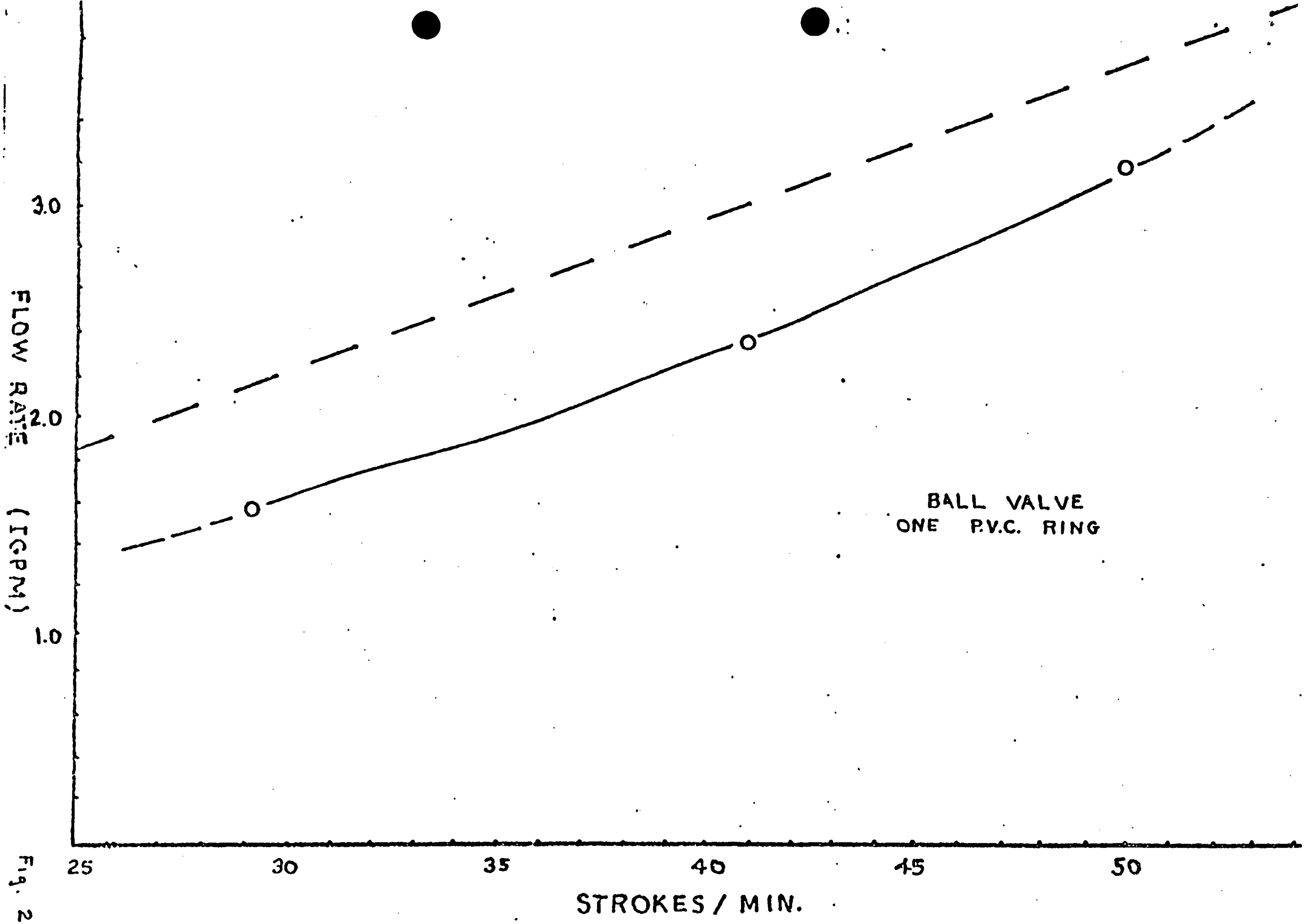

4.0
3.0
2.0
1.0
FLOW RATE (IGPM)
25
30
35
40
45
50
STROKES / MIN.
RUBBER FLAPPER VALVE
PINNED AT CORNER
ONE P.V.C. RING

Fig. 21



4.0
3.0
2.0
1.0
FLOW RATE (IGPM)
25
30
35
40
45
50
STROKES / MIN.
RUBBER FLAPPER VALVE
PINNED AT CENTER
ONE P.V.C. RING

Fig. 22



3.0
2.0
1.0
FLOW RATE (IGPM)
25
30
35
40
45
50
STROKES / MIN.
BALL VALVE
ONE P.V.C. RING

Fig. 23

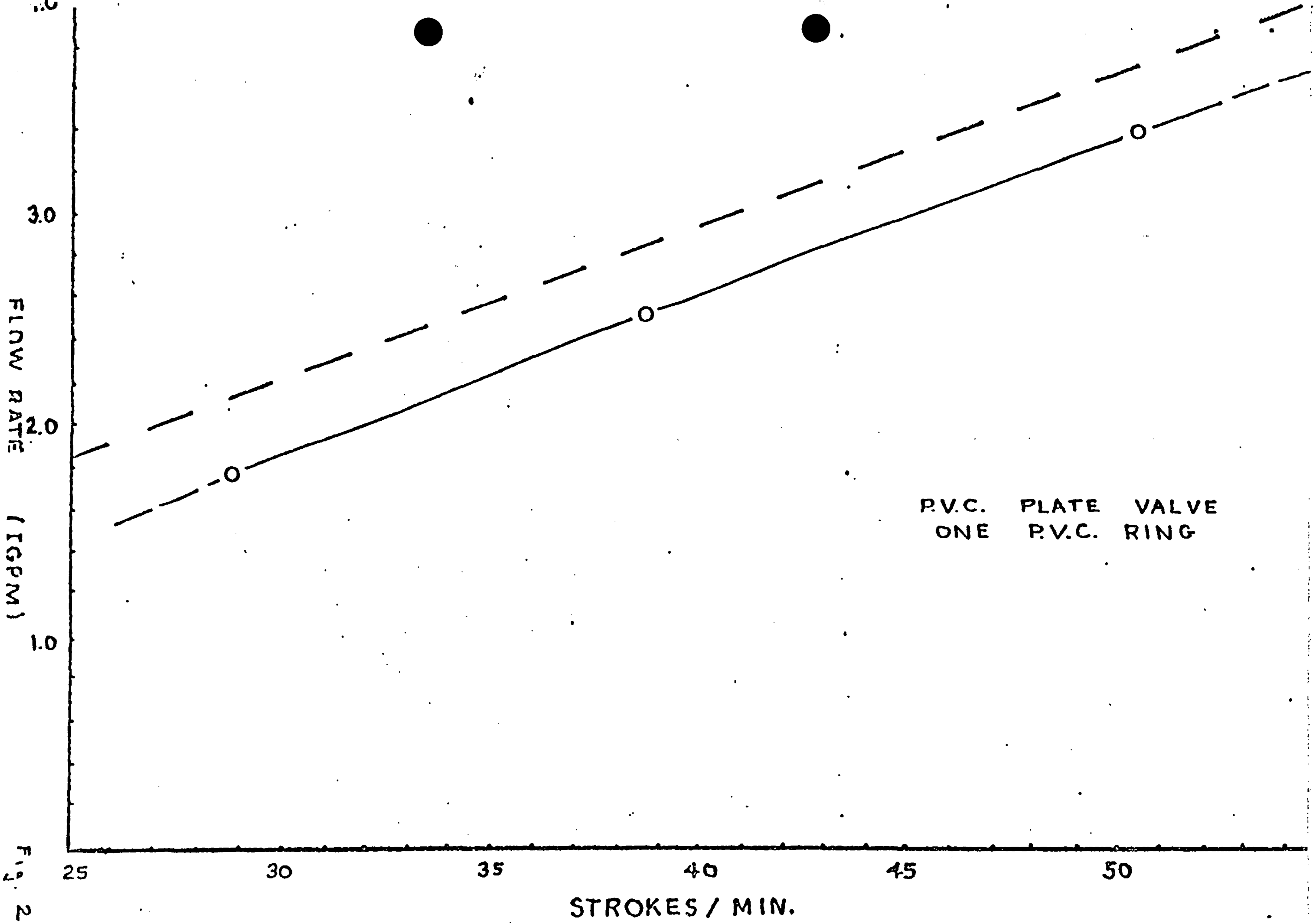

FLOW RATE (IGPM)
3.0
2.0
1.0
25
30
35
40
45
50
STROKES / MIN.
P.V.C. PLATE VALVE
ONE P.V.C. RING

Fig. 24

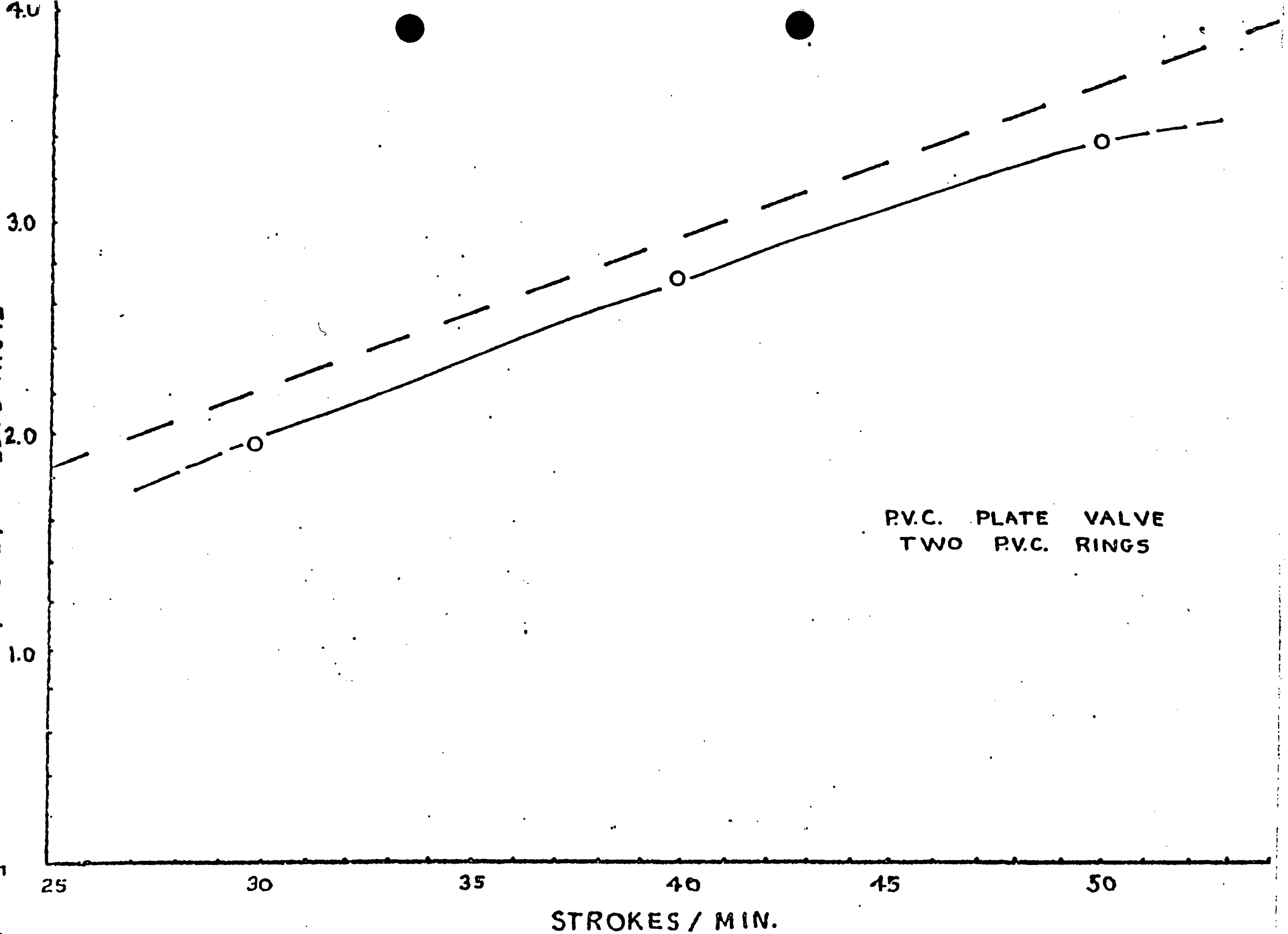

4.0
3.0
2.0
1.0
FLOW RATE (IGPM)
25
30
35
40
45
50
STROKES / MIN.
P.V.C. PLATE VALVE
TWO P.V.C. RINGS

Fig. 25

The overall difference between the values obtained with the simulated head and the actual head pump was about 1%. This error is attributed to many variables within the two systems which cannot be established exactly. These are pressure, flow, and stroke length.

Conclusions

1. There is very little difference between the efficiency of pistons with one or two rings. However, as expected a dramatic loss of efficiency occurs when no rings are used.
2. Leather rings or cups offer too much resistance to piston travel at depths greater than 100 feet.
3. The ball valve is too unpredictable at depths above 80 feet.
4. Plate valves exhibited high efficiency.
5. Leather and rubber plate valves displayed highly desirable properties for use as a plate valve.
6. The plate valve setup was very simple although it did not have the freedom of movement in the pump rod of the concave piston configuration (i.e., ball valve and rubber flapper pinned in one corner).

Recommendations

1. A non-recoverable foot valve (Figure 3(a)) could be injection molded easily. A minimum of three parts could give a very simple and efficient valve. The plate should be made of either leather or rubber for maximum sealing efficiency. Valve port holes should be countersunk to reduce turbulence and insure a surface free of burrs.
2. A plate valve piston (Figures 8 and 9) should be used as a final piston design. While giving maximum efficiency this setup also maintains maximum simplicity. One or two piston rings can be used with very little change in efficiency. Rubber or leather should be used as the plate itself.

3. A pump rod bolted directly to the piston (Figure 8) can be used effectively. The fixed position of the rod does not limit the lateral movement of the upper end of pump rod enough to cause problems. There are fewer parts than with the concave design (Figure 7), hence greater simplicity.
4. Leather cups while displaying excellent sealing properties, should not be used for wells deeper than 100 feet.
5. The total possible flow area past the valve should be at least 1/10 the total cross sectional area of the piston. This would amount to eight holes 7/32 inches in diameter if the piston is 2 inches in diameter. This helps reduce flow resistance and reduce work input on the downward stroke.

3.1.3 Kent Meter Test

The purpose of this test was to determine if the Kent water meter could be incorporated into the pump thus recording the total volume of water pumped. It was hoped that installed pumps could be accurately monitored in this manner.

Test Procedure

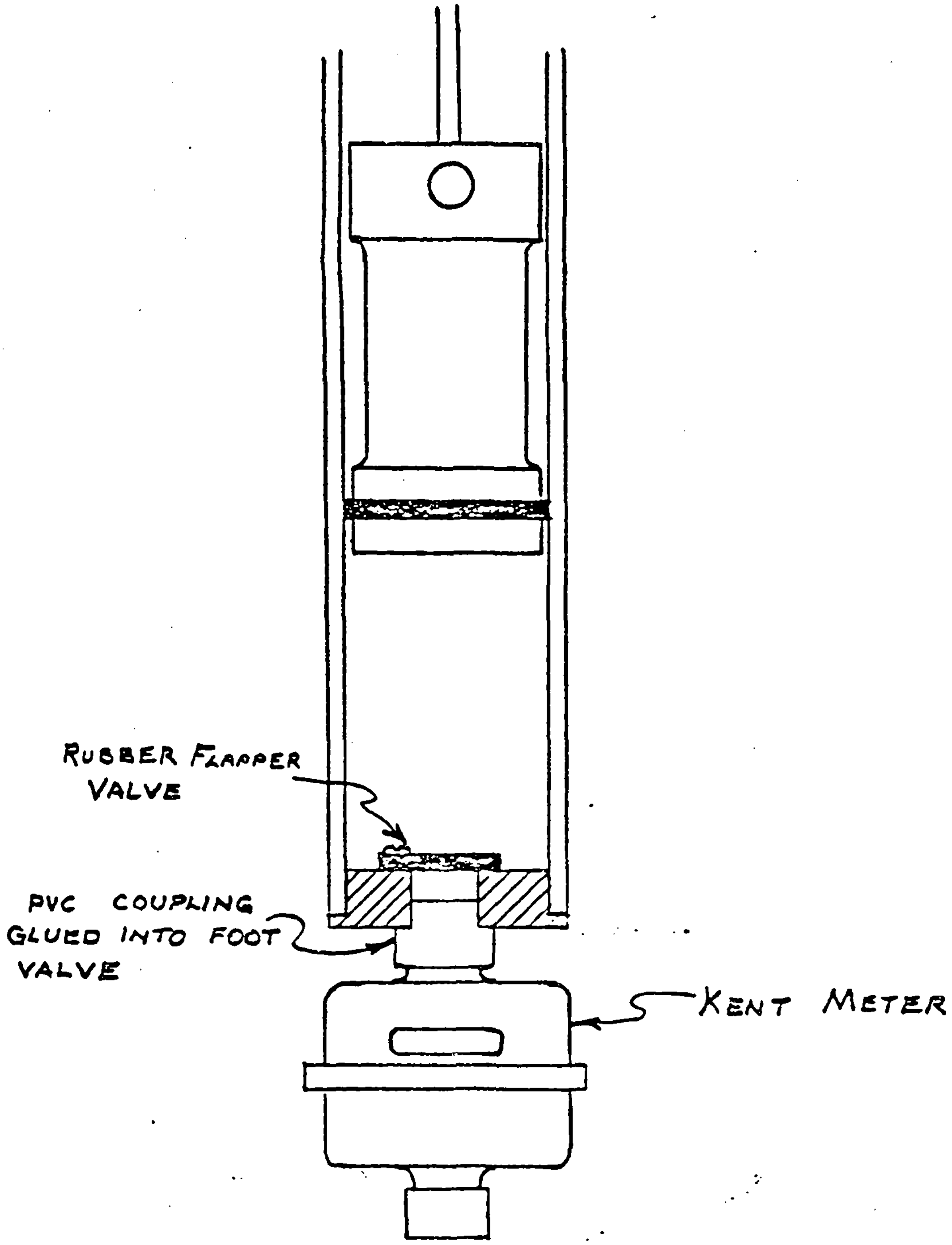
The meter was installed below the foot valve as shown in Figure 26 on the following page. The pump had a 2 inch casing with a 25 foot head. The foot valve was a rubber flapper type pinned at one side. Three pistons were used thus allowing the volumes pumped to be compared with previously measured volumes. The three type pistons were as follows:

(i) Piston - Rubber Flapper Valve - Figure 6
Polyethylene Ring

(ii) Piston - Same Valve
PVC Ring

(iii) Piston - Steel Ball Valve - Figure 7
PVC Ring

FIG. 26



EQUIPT. SET-UP FOR TESTS

Observations

Test (i)

A pumping rate of 30 strokes per minute was sustained for 3 minutes totaling 90 strokes.

The meter indicated a volume of 3.37 U.S. gal.

	Volume
Observed	778.42 in^3
Theoretical	1915.11 in^3
Efficiency	40.6%

Test (ii)

A pumping rate of 30 strokes per minute was sustained for approximately 7 minutes totaling 200 strokes.

The meter indicated a volume of 14.65 U.S. gal.

	Volume
Observed	3383.42 in^3
Theoretical	4255.8 in^3
Efficiency	79.5%

Test (iii)

A total of 200 strokes were carried out in 7 minutes with a pumping rate of approximately 30 strokes per minute.

	Volume
Observed	3095.08 in^3
Theoretical	4255.8 in^3
Efficiency	72.7%

Comparison

	Pinned Flapper Polyethylene Ring	Pinned Flapper PVC Ring	Ball Valve PVC Ring
Meter Indicated	40.6%	79.5%	72.7%
Previously Measured	N/A	86.1%	70.5%

As indicated by the ball valve results, the meter does not restrict the flow. The difference in the pinned flapper results can be explained by the fact that the meter will also read backwards thus any leakage past the piston and foot valve would lower the indicated volume. This fact was not discovered until the third test. Therefore the first two results are lower as the high leakage rate back through the foot valve decreased the indicated volume. The error was reduced in the third test by rapidly dismantling the pump to read the indicated volume.

3.1.4 Recoverable Foot Valve - Spool Type

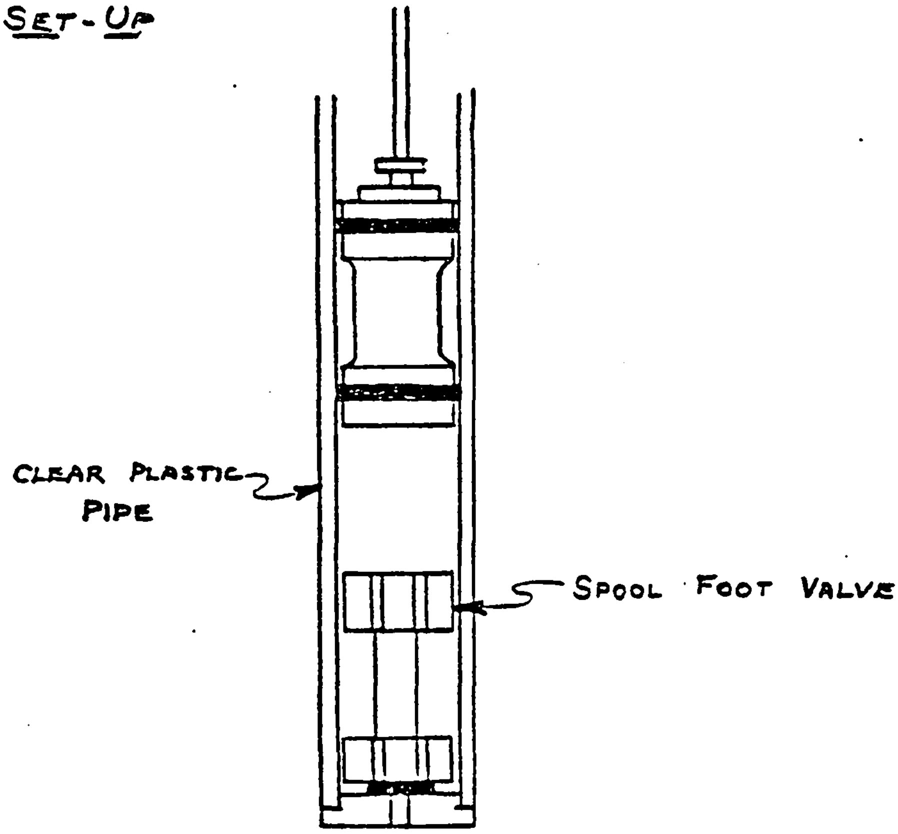
Experiments were conducted using a spool type foot valve in the hope of developing a foot valve that could be easily removed after the well was installed.

Test Procedure

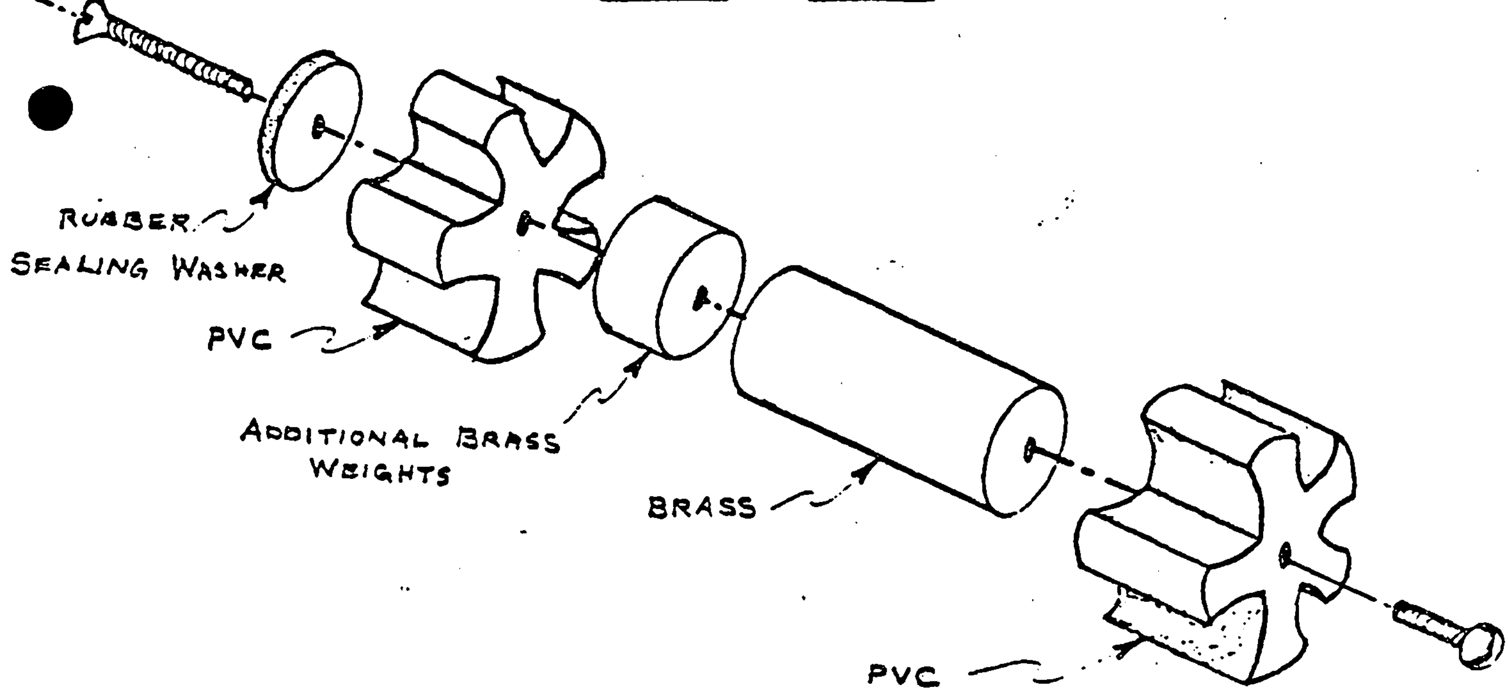
To check its feasibility, a spool valve of solid PVC was installed. This valving arrangement caused an excessive thumping during the pumping action. To determine the cause it was decided to install a clear plastic casing (PMMA) at the bottom end. This arrangement is shown in Figure 27 on the following page. It then became obvious that the spool was too light; therefore a solid brass spool was constructed and installed. This proved to be too heavy and caused excessive vibrations. Therefore a spool valve with interchangeable weights was constructed as shown at the bottom in Figure 27.

FIG. 27

EQUIPT. SET-UP



SPOOL VALVE



For the final test the weights and pumping rates were varied and the spool's upward displacement was recorded. The results are shown in the following Table 3.1.4.A and Figure 28.

TABLE 3.1.4.A Spool Valve Displacement

Strokes min	Spool 242 gm	Spool + 1 Weight 269.8 gm	Spool + 2 Weights 297 gm	Spool + 3 Weights 335.3 gm
30	1/8"	1/4" -slight clatter	1/8" -tips to one side	1/8" -tips to one side
40	1"	1-1/2"	1/4"	1/8" -tips -slight clatter
50	3-1/2" -varying, long then short	2"	1/4"	1/4"→3-1/2" -varies
60		3"→3-1/2"	3-1/2"	4"→4-1/2" -consistent

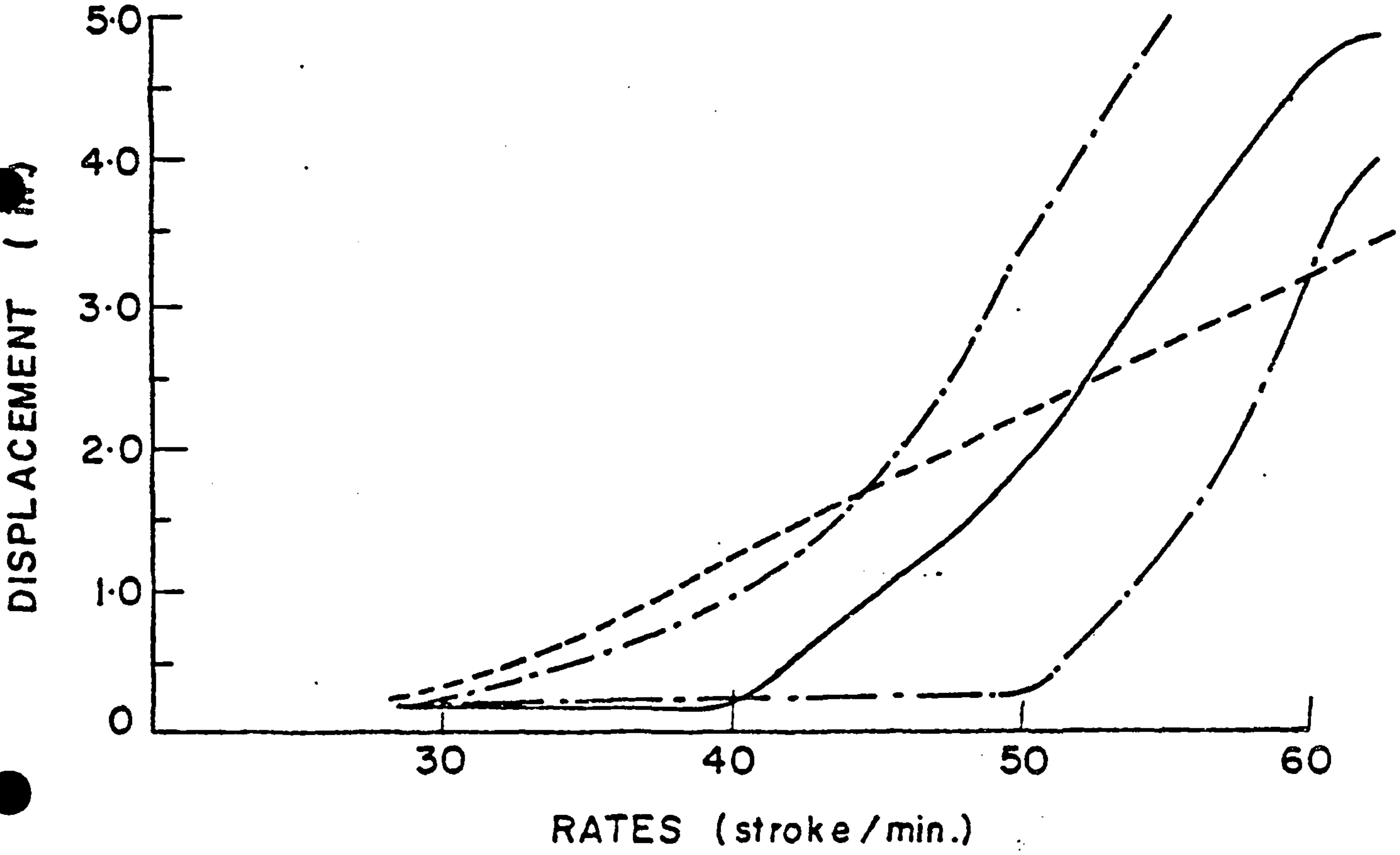
Figure 28 clearly shows that the displacement is not dependent upon the stroke rate but upon the upward velocity of the piston. Therefore an optimum spool weight would have to be determined by comparing the range of piston velocities to spool displacements. Although in this test, the spool with an additional weight seems to be the optimum.

Selection of a suitable spool weight is a touchy matter. It was also likely that a spool valve which had the right weight to respond quickly to piston movements would pound its retaining ring to pieces. It is not recommended that this design be used. It will work if made properly but maintenance costs are likely to be excessive.

3.1.5 Plate Valve Piston Test

The optimum design for the piston had been previously determined, but on inspecting the piston it was found to have a poorly fitted plate valve. This allowed considerable leakage and as a result the PVC plate valve was incorrectly judged as being inferior to rubber and leather. It was then decided to construct a new piston using a PVC plate valve and retest its feasibility.

VALVE DISPLACEMENT vs. STROKE RATE



SPOOL VALVE WEIGHTS

—·—·—·—·— 242 g

— — — — — — 269·8 g

———·———·— 297 g

—————— 335·3 g

Test Procedure

For this test a new piston was constructed and the clear pipe with the optimum spool valve was used. To measure the volume pumped, two water meters were coupled in series at the outlet of the pump. To insure the spool was functioning properly a slow upstroke was used. These results were then compared to those obtained earlier.

Observations

Trial 1

	Volume	
	Kent Meter	Badger Meter
Observed	18.363	18.132
Theoretical	18.85 in^3/stroke	
Efficiency	96.8%	

Trial 2

	Volume	
	Kent Meter	Badger Meter
Observed	18.294	18.57
Theoretical	18.85 in^3/stroke	
Efficiency	97.8%	

Comparison

Previous Measured Efficiency	New Piston Efficiency
89.8%	Trial 1 96.8%
	Trial 2 97.8%

By comparing these results, the rejection of the PVC plate valve is questionable and it was decided to carry out further tests using a PVC plate valve.

3.1.6 Water Pumping Efficiency Tests

These tests were conducted using a PVC piston plate valve and a 269.8 gm spool foot valve to determine the pump mechanical efficiency as opposed to the hydraulic efficiency.

Test Procedure

A strain gauge load cell was installed in the pump rod below the pump handle at the head of the experimental PVC hand pump. The output from the strain gauge ring was recorded by a strain gauge bridge and load cell. Samples of output are presented as Figure 29. The horizontal scale on the output graph is time, each mm representing 0.20 sec and the vertical scale is force, each mm representing 5 lb.

To determine the average force required to carry out the pumping task the area beneath the force curve for ten strokes was measured with a planimeter. Then this value was converted to equivalent product of time x force and the average force was calculated.

The average stroke length was found by dividing the average volume delivered per stroke by the area of the piston. For these trials the piston diameter was 2.125 inches. The weight of the piston rod is included in the efficiency calculations and the value used was 11 lbs net including buoyancy effects.

The efficiency was determined by calculating the power required to raise the water plus pump rod and dividing through by the average force x average stroke for the time period. The value for time was taken to be half the time taken for a stroke, the up and down portions being of equal duration.

Calculations

(1) PVC Pump Characteristics

Time to pump → 13.5 sec. Density of water 8.32/gal.

Time for power input → 6.75 sec.

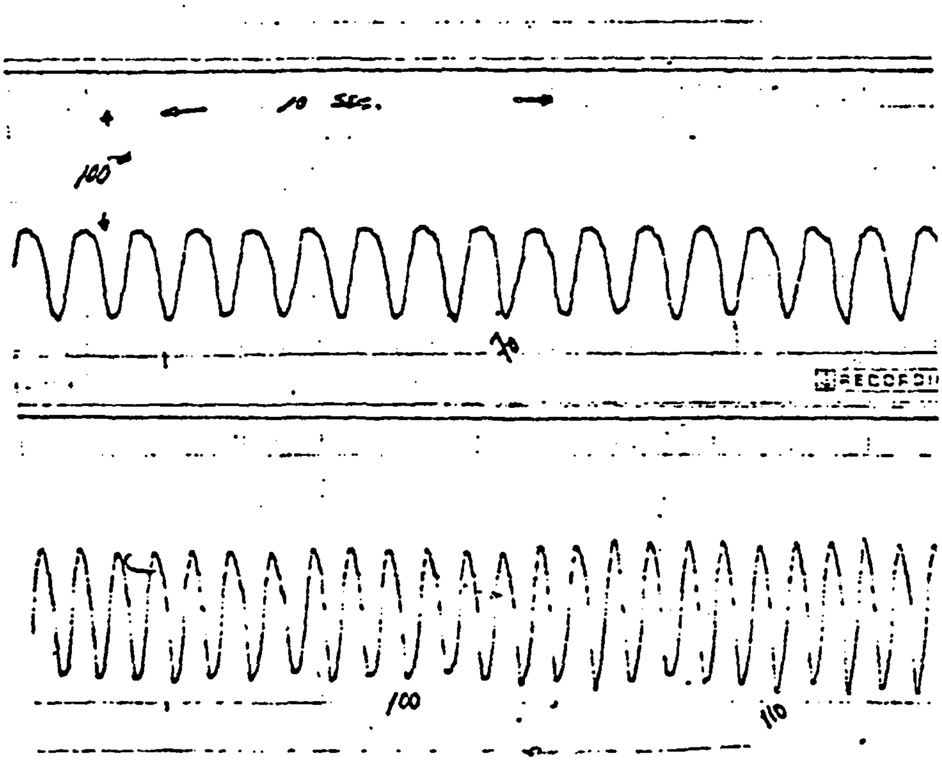


Figure 29

Water pumped 1.29 gal. @ 23.5 ft.

∴ Power required to pump water

$$P_0 = \frac{1.29 \text{ gal.} \times 8.32/\text{gal.} \times 23.5 \text{ ft.}}{6.750 \text{ sec.}}$$

$$= 37.36 \text{ ft.lb./sec.}$$

Power Input

$$Q \text{ Average Stroke} = \frac{1.29 \text{ gal./stroke} \times 8.32/\text{gal.}}{62.4/\text{ft.}^3}$$

$$= .0172 \text{ ft.}^3$$

$$\therefore \frac{1}{\text{Stroke}} = A/Q = \frac{1.0625^2}{144 \text{ in.}^2/\text{ft.}^3(.0172)}$$

∴ Stroke = .698 ft.

Average Force (by planimetry)

Stroke #'s 41→50

Measured 269 squares, 33 for time

∴ Force = 40.75

$$\therefore \text{Power}_{in} = \frac{40.75 \times .698 \times 10}{6.75}$$

$$= 42.14 \text{ ft.lb./sec.}$$

$$\therefore \text{Efficiency } \eta = P_{out}/P_{in}$$

$$= \frac{37.36 \text{ ft.lb./sec.}}{42.14 \text{ ft.lb./sec.}}$$

$$= 88.66\%$$

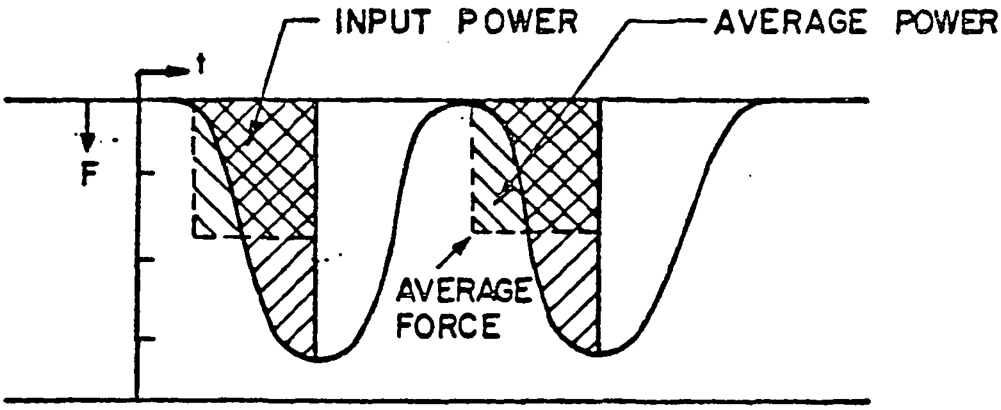
(2) PVC Pump Characteristics

Time to pump → 7.8 sec.

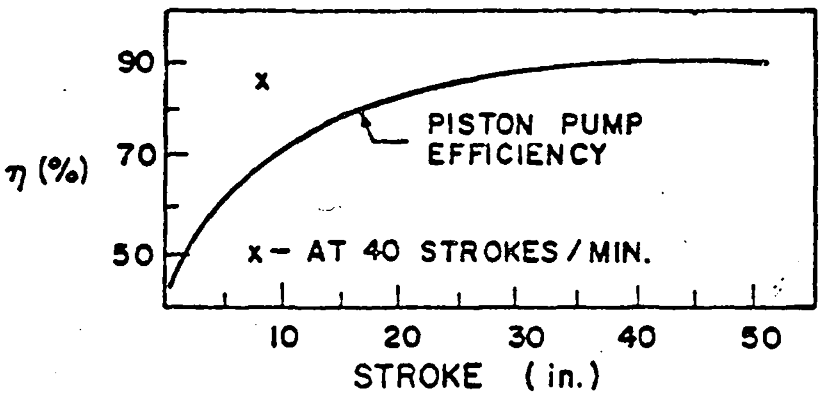
Time for power input → 3.9 sec.

Water pumped → 1.37 gal. @ 23.5 ft.

Power output required to pump water


INPUT POWER
AVERAGE POWER
t
F
AVERAGE
FORCE

30


90
70
50
η (%)
x
PISTON PUMP
EFFICIENCY
x – AT 40 STROKES / MIN.
10
20
30
40
50
STROKE (in.)

31

$$P_0 = \frac{1.37 \text{ gal.} \times 8.32/\text{gal.} \times 23.5 \text{ ft.}}{3.9 \text{ sec.}}$$

$$= 68.68 \text{ ft.lb./sec.}$$

Power Input

$$\text{Average Stroke} = \frac{\dfrac{1.37 \times 8.32/\text{gal.}}{62.4/\text{ft.}^3}}{1.0625^2 \ /144 \text{ in.}^2/\text{ft.}^2}$$

$$= .742 \text{ ft.}$$

Average Force (by planimetry)

Stroke 65 74

Area 287 sq. time 35 units

$\therefore$ Force = 57.4 + 21.42

$\therefore$ Power Input

$$= \left(\frac{57.4}{2.5}\right) + \left(\frac{21.42}{1.4}\right) \times .742 \times 10$$

$$= 283.88 \text{ ft.lb./sec.}$$

$\therefore$ Efficiency = 24%

The calculations for the first trial performed at a pumping rate of about 40 strokes per minute indicate that the total efficiency of the pump is between 85 and 90%.

The second trial was performed at a much more rapid rate, 60 strokes per minute average, showed a great reduction in efficiency using only 25% of the power input to raise water.

In both cases efficiency calculations used only the left side of the cycle to determine the time period for power input as shown in Figure 30.

Summary

Through the use of strain gauge ring the pump rod forces for an experimental PVC pump were measured. The results are inconclusive due to the difficulty in maintaining a constant input and the inability to determine the time over which input power was applied with any degree of accuracy.

Discussion

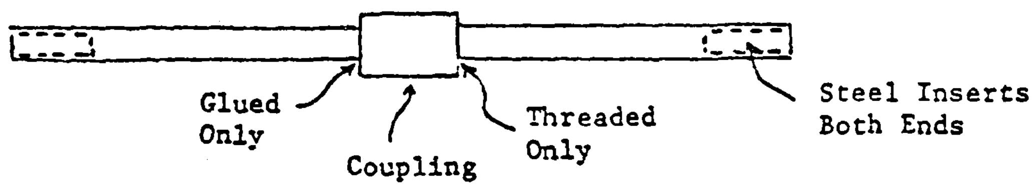
When pumping is performed at a comfortable rate of about 40-45 strokes per minute the efficiency is in line with normal efficiency expected from a piston pump. Figure 31 presents η as stroke length with the measured results included.

The lower performance of the trial carried out at the more rapid rate is due to the higher loses in the system and the inability to make very precise measurements on the output data. In both cases the results are very sensitive to measurement errors and so the results may not be reproducible. This may be seen in the first calculation where a small change in the time base greatly alters the efficiency calculated. As well, values such as average stroke distance and force may not be representative of the values over the entire pumping period. These variations will be difficult to eliminate as long as a non-mechanical input is used.

3.2 Pump Rod Tests

3.2.1 PVC Pipe Coupling Test

This test was to determine the strength of 3/4" and 1/2" PVC pipe and couplings. A socket-threaded coupling was chosen to determine whether a glued or threaded joint was stronger. The sample pipes were constructed as shown below.



The steel inserts prevented the pipe from collapsing in the jaws of the Tatnall testing machine. This machine has a dial readout and therefore only the ultimate strength is indicated. The results obtained are as follows in the table.

Pipe Size	Thread Engagement # Turns	Max. Load	Comments
3/4"	5	2000 lb	Glue Joint Failed
3/4"	5	2040 lb	" " "
1/2"	4-1/2	1380 lb	" " "
1/2"	4-1/2	1480 lb	" " "

From these results, it is obvious that either glued or threaded sections will be strong enough, as the weight of water in a 200 foot 3 inch well is approximately 650 lbs. The threaded joints may be susceptible to fatigue failure. For future reference, the shear stress of the glued joints were calculated.

Pipe	X-Sect. Area	Shear Area	Stress in Pipe	(Causing Failure) Shear Stress
3/4"	.5154 in^2	1.62 in^2	3880 psi	1234 psi
3/4"	.5154 in^2	1.62 in^2	3958 psi	1259 psi
1/2"	.3528 in^2	1.325 in^2	3911 psi	1041 psi
1/2"	.3528 in^2	1.325 in^2	4195 psi	1116 psi

The shear stress should be equal to that of PVC because the joints are solvent welded. The only possible explanation is that there was not 100% glue coverage in the joint.

3.2.2 Bolted PVC Pipe Couplings

Couplings which could be glued were bolted to the pipe and the tensile properties were tested. Since these were bolted together, there were many possible modes of failure. These included the following:

1. Bearing on pipe
2. Bearing on coupling
3. Shear of bolt
4. Shear tearout of pipe
5. Shear tearout of coupling
6. Tension failure of pipe
7. Tension failure of coupling.

To match the tensile strength of the pipe with the shear strength of the bolt, a 3/16" dia. stainless steel bolt was used. To attain the maximum strength the shear area of the pipe and coupling was made equal. To further increase the strength of the pipe, a PVC plug was solvent welded into the end. Since there was a limited supply of couplings, only one test on each pipe was carried out and the results are shown below.

Pipe	Max. Load
3/4"	1540 lb
1/2"	830 lb

The mode of failure proved to be shear tearout of the coupling in both cases. To increase the strength of a bolted connection a piece of galvanized pipe could be used as a coupling thus allowing the shear area in the PVC pipe to be made as large as possible, increasing strength as much as desired.

3.2.3 <u>PVC Rod - Piston and Pump Rod Connection</u>

Tensile tests were performed on threaded PVC rod to determine its feasibility as a connection to the piston. The first specimen had a national coarse thread on one end and a national fine thread on the other. This was simply to determine which thread was strongest. The coarse thread proved to be the weakest as it failed in tension at a load of 900 lbs. The second specimen was a 1/2" PVC rod threaded on both ends with a 20 National fine thread. Each end was engaged 1/2" in the holders. The ultimate tensile strength proved to be 1200 lbs as shown in Figure 31.

The strength of the PVC was sufficient to support the weight of the water but its fatigue strength may be greatly reduced by the threads. For this reason, it would be advisable to use galvanized or stainless steel connecting links.

3.2.4 Pump Rod Test in 2 Inch Well

A PVC pipe to act as a pump rod was constructed as shown in Figure 32. It was placed in the 2 inch well to test its feasibility.

The piston was a plate valve type with a PVC plate and the foot valve was the spool type. The results were as follows:

Trial	Strokes	Volume	Efficiency
1	100	7.85	93.5%
2	101	8.125	96.8%
3	100	8.23	98%
4	100	7.65	91.1%
5	100	8.1	96.5%

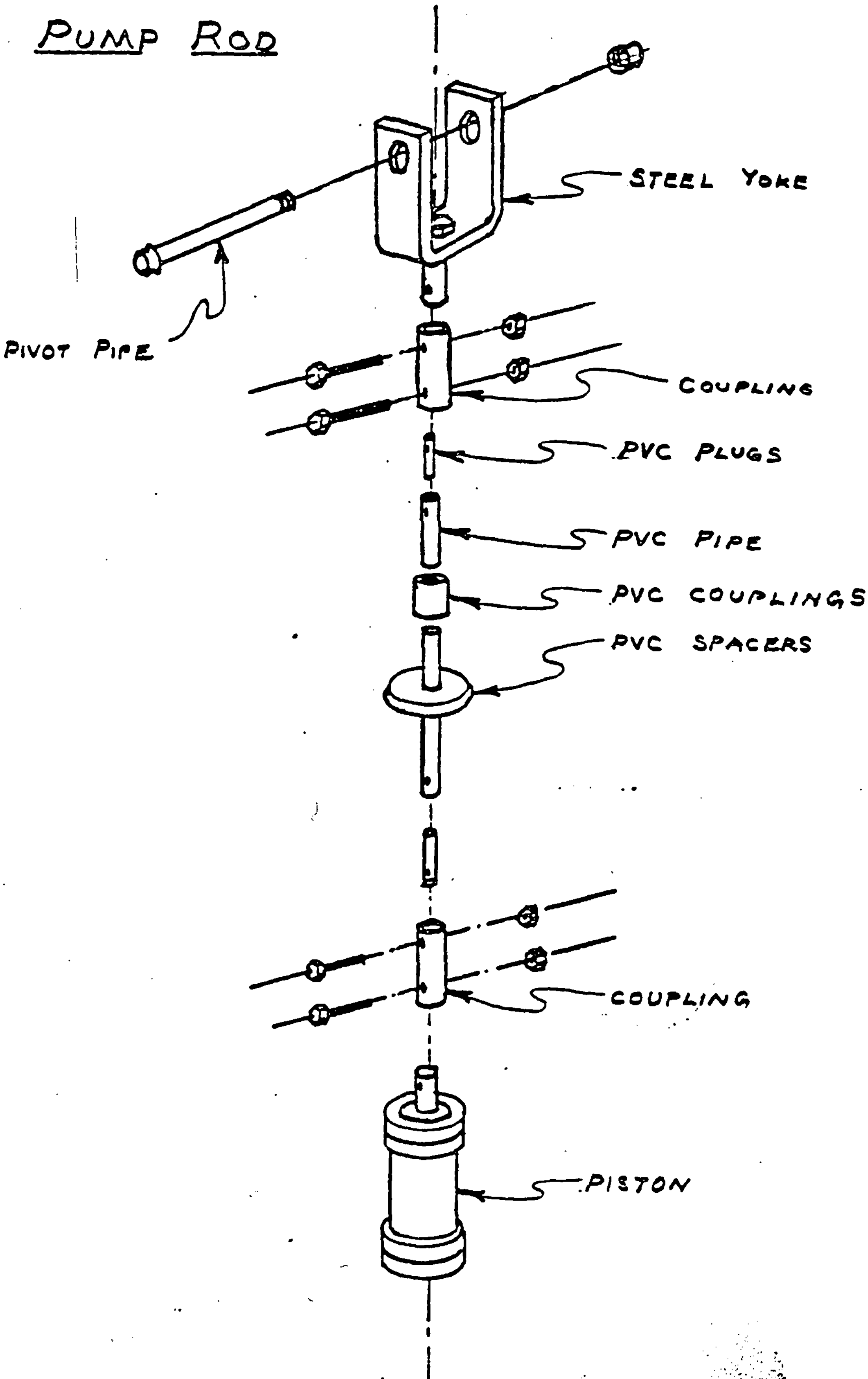
These results show that the PVC pipe will function adequately as a pump rod.

3.2.5 Pump Rod - Load Limit Device

In order to prevent the pump rod couplings from failing the surface, a short length of pump rod could be perforated to limit its tensile strength. The following are the results obtained from the tensile tests. Each pipe had four holes in it of the indicated size.

FIG. 32

PUMP ROD



Hole Size	Load
1/2"	1050
15/32"	1200
7/16"	1550
3/8"	1750

3.3 Three Inch Pump Tests

A three inch pump was constructed to test the feasibility of having the piston identical to the foot valve. This enables the piston and foot valve to be removed after the well is installed. Both can be easily repaired since the majority of parts are the same, the only difference being the sealing devices and the center bolts holding them together. This difference is shown by Figure 33.

3.3.1 Piston-Foot Valve Tests

Testing was performed in order to determine the optimum sealing components for both the piston and foot valve. For each test both components had a PVC plate valve.

Test #1

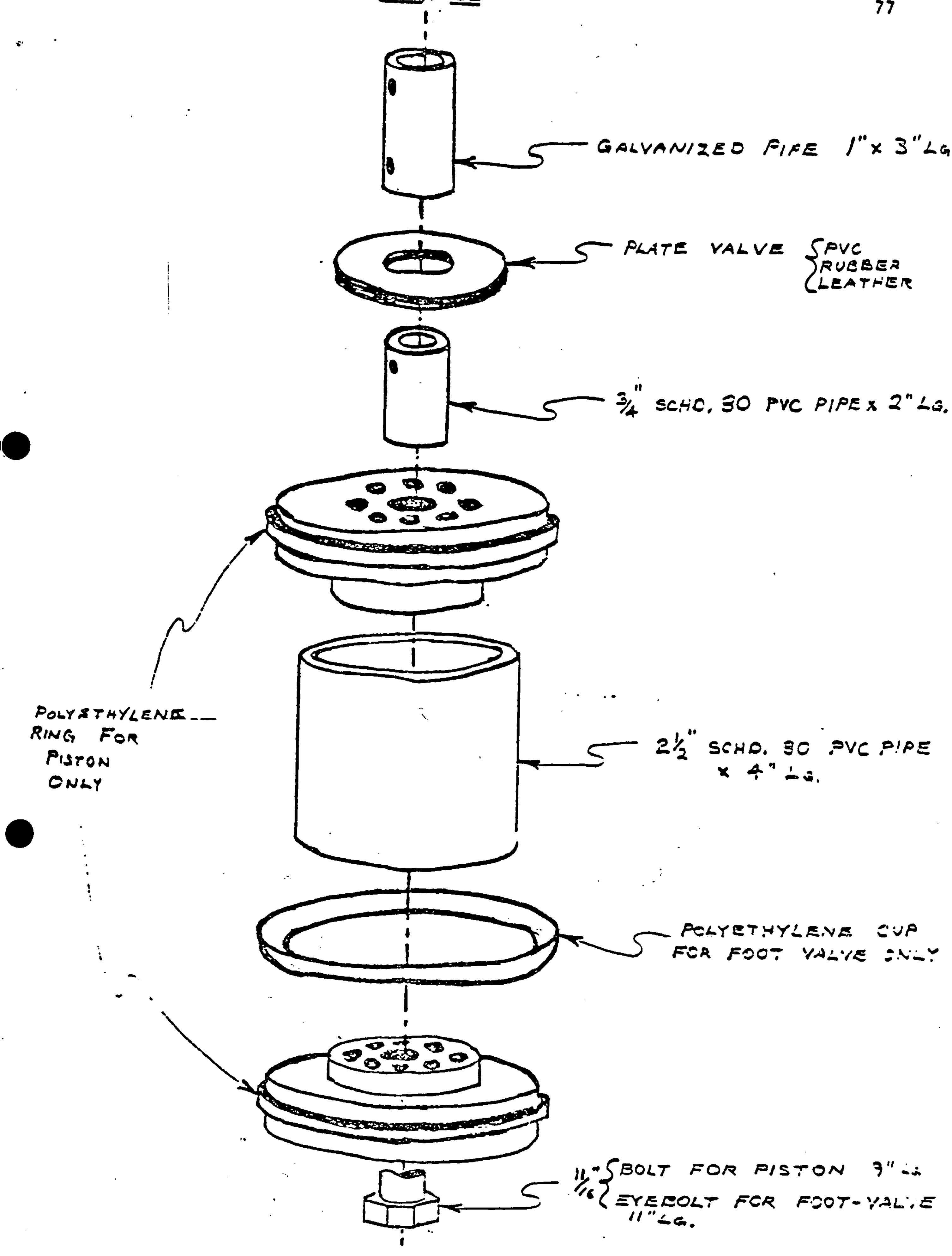
The piston had two PVC rings while the foot valve had a two layer leather cup. The results of the 4 trials made on this configuration are tabulated below in Table 3.3.1.A.

TABLE 3.3.1.A

Theoretical Volume per Stroke .22619 U.S. Gal/Stroke

Trail	Volume U.S. Gal/Stroke	Efficiency
1	.1689	74.7%
2	.1675	74.1%
3	.167	74%
4	.17	75%

FIG. 33


GALVANIZED PIPE 1" x 3" LG
PLATE VALVE PVC RUBBER LEATHER
3/4" SCHD. 30 PVC PIPE x 2" LG.
POLYETHYLENE RING FOR PISTON ONLY
2 1/2" SCHD. 30 PVC PIPE x 4" LG.
POLYETHYLENE CUP FOR FOOT VALVE ONLY
11/16" BOLT FOR PISTON 9" LG
EYEBOLT FOR FOOT-VALVE 11" LG.

These results indicate that on the average .059 U.S. gal of water leak past the piston on each stroke.

Test #2

For the second test a double layered leather cup was added to the piston. The results of this test are found below in Table 3.3.1.B.

TABLE 3.3.1.B

Trial	Volume U.S. Gal/Stroke	Efficiency
5	.22	97%
6	.2975	97.5%
7	.29	95%

Although the efficiency increased markedly the frictional restriction of the leather cup defeated its purpose.

Test #3

For this test the leather cup was removed from the piston and replaced with a polyethylene cup. The results are shown below in Table 3.3.1.C.

TABLE 3.3.1.C

Trial	Volume U.S. Gal/Stroke	Efficiency
8	.279	91%
9	.270	88%

The frictional resistance was greatly reduced but the efficiency was somewhat lower.

Test #4

For this test the leather cup on the foot valve was replaced by a polyethylene cup and the piston had PVC rings and a polyethylene cup.

TABLE 3.3.1.D

Trial	Volume U.S. Gal/Stroke	Efficiency
10	.30167	98.8%
11	.3033	99%

Test #5

For this test the piston had a polyethylene cup only and the foot valve had a polyethylene cup.

TABLE 3.3.1.E

Trial	Volume U.S. Gal/Stroke	Efficiency
12	.2675	88%

Test #6

For this test the piston had PVC rings with notched inner diameter and the foot valve had a polyethylene cup.

TABLE 3.3.1.F

Trial	Volume U.S. Gal/Stroke	Efficiency
13	.2875	91.5%
14	.305	97%

For trial 14 a faster stroke rate was used thus increasing the efficiency, as expected.

Test #7

For test #7 the piston had two high density polyethylene rings and the foot valve had a polyethylene cup.

TABLE 3.3.1.G

Trial	Volume U.S. Gal/Stroke	Efficiency
15	.290	95%
16	.3075	98%

The stroke rate was increased for trial 16 and again there is an increase in the efficiency. It was also noticed that if this piston was raised very slowly there was very little sealing of the rings. This will enable the piston to be raised slowly by hand as the water flows past it.

Since this arrangement was to be the final design its ability to retain a head was checked. The leakage rate proved to be .059 U.S. gal/hr. To put this in perspective this leakage rate means that overnight the level in a 3 inch well would drop 1 ft. 8 in.

3.4 Casing Coupling Tests

These tensile tests were performed to determine the optimum method for making joints in the casing. The most important aspect of the joint is to insure the inner diameter matches that of the casing. There must be a smooth interface to allow the piston and foot valve to pass freely. The couplings tested were a heat shrink sleeve and a bell type. The results are given in Table 3.3.1.H.

TABLE 3.3.1.H

Pipe Used	Coupling	Ultimate Strength
PVC	Heat Shrink	870 lbs
PVC	2 Layers Heat Shrink	1900 lbs
PVC	Plas-Tyton	50 lbs
Polyethylene	Heat Shrink	635 lbs

4.0 POLYMER ON POLYMER WEAR TESTS

Object

To determine the component wear rates in a hydraulic pump made from various plastic components.

Conditions of Tests

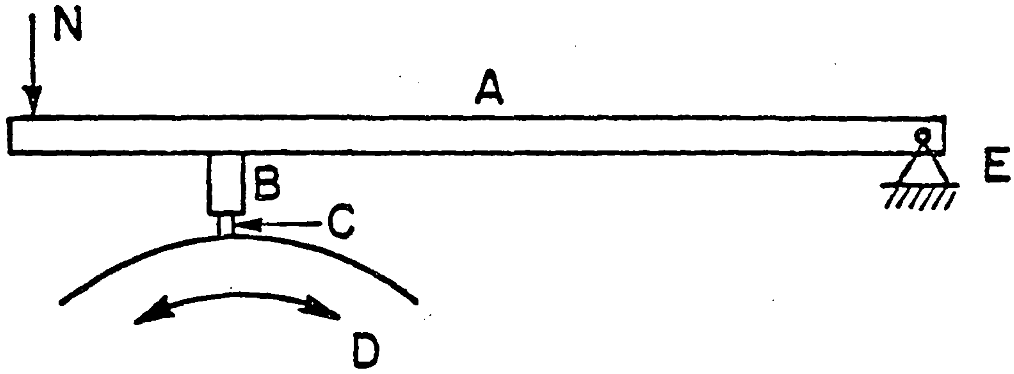
Close simulation of the normal stresses, sliding velocities, sand contamination, and stroke length as those observed by the pump elements.

Test Apparatus

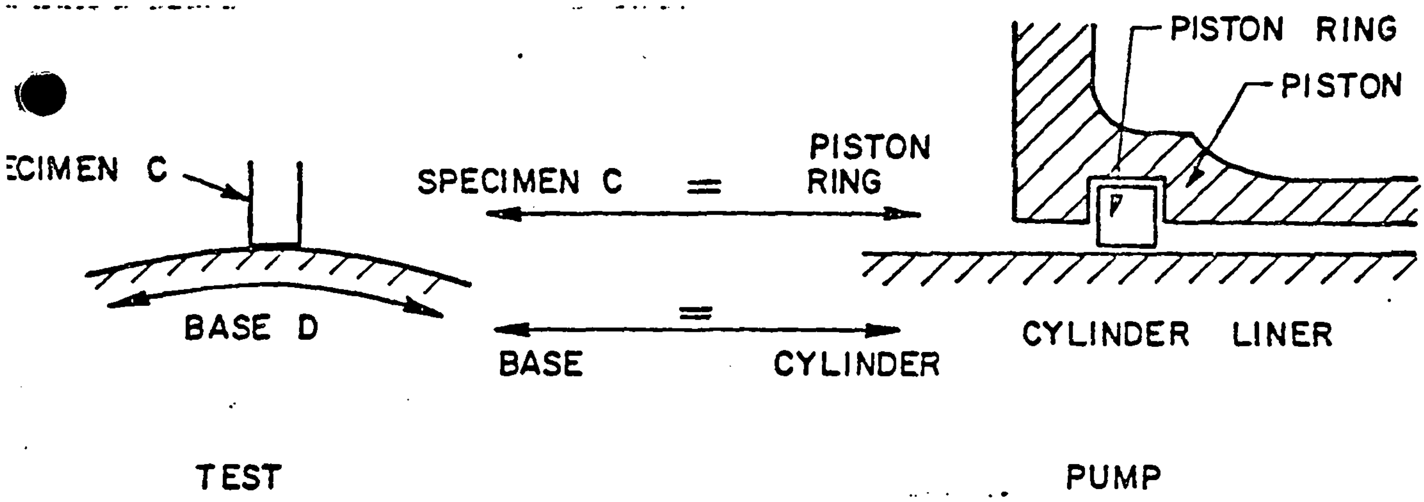
In order to simulate the pump motion and loads for different combinations of polymers and yet maintain identical contamination conditions, a nine stage reciprocal wear test apparatus was constructed. The features of this wear test apparatus are shown in Figure 34.

The arm A is pivoted at E and supports the specimen holder B. In this specimen holder B is the specimen C, which is referred to as the rider. At the end of the arm A a normal loan N is applied to simulate the various pump pressures. The specimen C is stationary and the frictional drag occurs on the same contact at all times. In this fashion it simulates the wear of the piston rings as employed in the actual pumps. The complimentary component to the rider is the semi circular block D also referred to as the base. This base undergoes an oscillatory rotation about its center of approximately 1.3 rads. In this fashion it simulates the wear on the cylinder wall of the pumps. A fresh patch of the base material was subject to the frictional forces. In diagramatic form the equivalence between these tests and the pump is shown in Figure 35.

The major dimensions of the rider and base are given in Table 4.0.A.



34


ECIMEN C
SPECIMEN C = PISTON RING
PISTON RING
PISTON
BASE D
BASE = CYLINDER
CYLINDER LINER
TEST
PUMP

35

TABLE 4.0.A

	Rider	Base
length	23 mm	75 mm ϕ
width	6 mm ϕ	13 mm
thickness	6 mm ϕ	25 mm

The rocking motion of base D was provided by a crank mechanism, operating at a fixed speed of 90 cycles per minute. This provided for two wear passes per cycle. The normal loads N were calculated to give equivalent pressures experienced by the piston ring for the following depths of water above the piston; N_1 for 20 m, N_2 for 40 m and N_3 for 60 m. All of the 9 test stages were completely submerged in water to which 10% "Ottawa River" grade sand was added. A special stirring vane on a rocking shaft prevented the sand from settling.

Wear Measurements

To measure the wear of each specimen the dimensions from the bottom of the rider to the top of arm A were measured with a micrometer. This provided for a linear wear measurement on the rider only. To determine the wear on the base it was necessary for it to be removed and measure the depth of the wear track. In order not to disturb the set up of the components, the wear on the base was only measured after each test was completed.

An appropriate measure of wear is given by the following expression:

$$w = \frac{\text{thickness of material removed per pass}}{\text{length of the pass}} .$$

The units of the wear measured are m/m or inch/inch. This wear measure is very suitable for the particular application of the pump because dimensional changes are more important than the net amount of material removed.

As a wear rate the following measure was used

$$\dot{w} = \frac{\text{total linear wear on rider and base}}{\text{number of passes}} \text{ [m/pass]} .$$

Table 4.0.B contains values for the measured total linear wear w_T, and values for the total linear wear rate $\dot{w}_T$ of both sides and base for the various material combinations tested. Also indicated is the percentage distribution of the individual component linear wear, $\%w_{rider}$ and $\%w_{base}$.

To calculate the total linear wear for any pump geometry the following formula is used

$$w_L = \{(\dot{w}_T \times \frac{\%w_{base}}{100}) \times (w_T \times \frac{\%w_{rider}}{100} \times \text{stroke length})\} \times \text{number of pumping strokes}$$

where w_L is the total linear wear for the pump. The formula is based upon the fact that the piston ring is total wear path length sensitive while the cylinder line is only pass sensitive. For example: A pump with a 60 m head and 20 cm stroke whose components are PVC throughout will have worn the following amount per one million pumping strokes. From Table 4.0.B under PVC-PVC for a 60 m head we find;

$$\dot{w}_T = 127 \times 10^{-11} \text{ m/pass}$$

$$w_T = 254 \times 10^{-10} \text{ m/m}$$

$$\%w_{base} = 6$$

$$\%w_{rider} = 94.$$

Substitution of this data into the above equation gives as a total linear wear;

$$w_L = \{(127 \times 10^{-11} \times \frac{6}{100}) + (254 \times 10^{-10} \times \frac{94}{100} \times .2)\} \times 10^6$$

$$= 4.85 \times 10^{-3} \text{ m.}$$

TABLE 4.0.B

Rider Material *	Base Material	Depth Simulator (m)	$\%w_{rider}$ (%)	$\%w_{base}$ (%)	w_T (m/m) $\times 10^{10}$	$\dot{w}_T$ (m/pass) $\times 10^{11}$
UHMWPE	PVC	20	≈100	≈0	5	2.5
UHMWPE	PVC	40	≈100	≈0	52	26
UHMWPE	PVC	60	≈100	≈0	23.5	11.8
PVC	LDPE	20	≈0	≈100	13.7	6.86
PVC	LDPE	40	≈0	≈100	9.94	4.97
PVC	LDPE	60	≈0	≈100	22.9	11.4
HDPE	PVC	20	≈100	≈0	42.5	21.2
HDPE	PVC	40	≈100	≈0	65.7	32.8
HDPE	PVC	60	≈100	≈0	115	57.5
LDPE	LDPE	20	86	14	545	273
LDPE	LDPE	40	58	42	1980	986
PVC	PVC	20	96	4	106	53
PVC	PVC	40	94	6	231	115
PVC	PVC	60	94	6	254	127
LDPE	PVC	20	≈100	≈0	62	31
LDPE	PVC	40	≈100	≈0	52	26
LDPE	PVC	60	≈100	≈0	158	79

*UHMWPE = ultrahigh molecular weight polyethylene. This is an extremely high molecular weight high density polyethylene.

HDPE = high density polyethylene.

LDPE = low density polyethylene.

The total dimensional loss would be approximately 5 mm with almost all the wear occurring on the ring.

Friction Measurements

Only very preliminary friction measurements were made at the highest loads. They were obtained by measuring the frictional drag on the arm from the crank-rocker mechanism and subtracting the frictional drag due to the rocker shaft bearings and seals. Drag forces were measured under dynamic conditions and the following friction coefficients μ were obtained.

(rider + base) + water and sand	
UHMPE on PVC	$\mu = 0.38$
PVC on LDPE	$\mu = 0.81$
PVC on PVC	$\mu = 0.25$
LDPE on LDPE	$\mu = 1.0$
LDPE on PVC	$\mu = 0.81$

There are two important observations to be made here

(1) The values of μ are high compared to metals and other solids. (This is common for plastics because of viscous dissipation in the matrix.)

(2) The value of μ is completely insensitive to the wear (rate). This is a well known fact in tribology.

Conclusions

The major conclusions to be drawn from the wear tests are as follows:

(1) Polyethylene piston rings on a PVC casing yield a situation in which all the wear is on the piston ring. This is desirable because the ring is a replaceable item.

(2) The wear on the polyethylene piston ring increases in the order

ultrahigh molecular weight > high density > low density polyethylene. The first material is obviously the best, but it is not generally available and either of the latter two is preferable from a cost/benefit point of view. The ring can be sliced from a polyethylene pipe with appropriate diameter and should cost pennies.

5.0 REFERENCES

(1) A. Rudin and A. Plumtree, "Plastic Well Casings for Use with Hand Operated Pumps", IDRC Project 609-01-02, University of Waterloo, August, 1977.

(2) Y. Sternberg, University of Maryland, Private Communication.

(3) E. P. Popov, "Introduction to Mechanics of Solids," Prentice-Hall, Englewood Cliffs, N.J., 1968.

6.0 APPENDICES

6.1 Appendix I

$$1 \text{ Gal. (U.S.)} = .13368 \text{ ft.}^3$$

$$1 \text{ Gal. (Imp.)} = .16710 \text{ ft.}^3$$

$$1 \text{ Gal. (U.S.)} = 8.342 \text{ lbs.}$$

$$1 \text{ Gal. (Imp.)} = 10.427 \text{ lbs. of water}$$

$$1 \text{ Psi.} = 2.31 \text{ ft. of water}$$

Maximum Possible Flow in a 6" Stroke

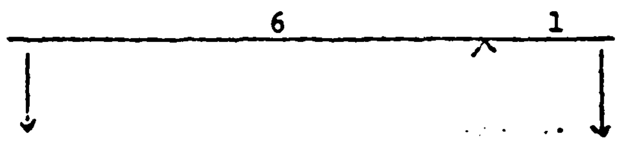
$$= \frac{\pi d^2}{4} \text{ ft.}^2 \times .5 \text{ ft.} \times \frac{1}{.1671}$$

$$= \frac{\pi\left(\frac{2.125}{12}\right)^2}{4} \times .5 \times \frac{1}{.1671}$$

$$= .0737 \text{ Gal. (Imp.)}$$

Drag Due to Leather Cups

Weight applied
60 lbs.
Weight of Handle
2.5 lbs.



245 lbs. water
40 lbs. rod + added weights
DRAG

Weight of Water @ 80 ft.

$$\frac{\pi d^2}{4} \times 80 = \frac{\pi(3/12)^2 \times 80}{40} = 3.93 \text{ ft.}^3$$

$$3.93 \text{ ft.}^3 \times 62.4 \text{ lb./ft.}^3 = 245 \text{ lbs.}$$

$$62.56 \text{ lbs.} \times 6{:}1 \text{ mech. adv.} = 375 \text{ lbs.}$$

$$285 \text{ lbs} + \text{Drag} = 375 \text{ lbs.} \quad \text{(for equilibrium)}$$

$$\text{Drag} = 90 \text{ lbs.}$$

Circumference of Dempster Leather Cups (Fig. 19) = 9.4 in.

Drag/In of Circumference = 9.6 lb./in.

6.2 Appendix II

Cost Estimate

It is not possible to estimate a cost which is applicable everywhere and at all times. The plastics used in this construction are commodity items and their prices vary with the periodic oversupply and shortage which is characteristic of this type of production. The following cost estimate is for a 60 foot well with casing and piston pump. Components are costed approximately at prices which would apply for large volume purchases in North America in 1977.

1)	Pedestal - 6 inch polyethylene pipe series 160 - 6 feet long	16.00
2)	Pump rod - schedule 80 PVC 3/4 inch pipe - 6 feet	13.50
3)	4 schedule 80 3/4 inch socket couplings	2.50
4)	60 feet series 100 3 inch PVC pipe	25.65
5)	Solvent cement	1.00
6)	1 increaser (3"-4") socket	2.30
7)	2 4" socket-socket couplings	5.00
8)	Spout and various top end items	15.00
9)	Piston	5.00
10)	Check valve	3.50
11)	Miscellaneous (bolts, PVC rod, wood)	10.00
		99.45

exclusive of costs of concrete.

This estimate can only be regarded as a "ball park" figure because very large discounts off list prices are available for volume purchases for export. A North American producer could make the product out of imported plastic resin which is available at very low prices in times of oversupply. He would be exempt from effective duty if the fabricated products were reexported and here cost could be substantially lower than that estimated here. Conversely, the price will be much higher for manufacture in countries with heavy import taxes and no local primary plastics production.

3P.19 30.8.96

UNITED NATIONS CHILDREN'S FUND(UNICEF)
DACCA, BANGLADESH

Report on the Final Evaluation of the Pilot Project for Maintenance of Hand pump Tubewells with people's participation

This has close reference to the interim evaluation(carried out at the end of one year of operation) report dated 2.7.77 submitted to the Chief Engineer by the committee appointed for the purpose.

As per recommendation(1) of the above report the pilot projects were continued and are still continuing. A final evaluation was conducted as per decision taken by the Technical Committee at their meeting held on 4 January 1977. The committee constituted originally for the purpose consisting of the following persons:

1.	Mr. V. P. N. Nayar, WHO	Chairman
2.	Mr. A. Awal, UNICEF	Member
3.	Mr. Matiur Rahman, DPHE	Member Secretary
4.	Mr. M. Asghar, DPHE	Member
5.	Mr. M. A. B. Siddique, DPHE	Member

was entrusted to do this evaluation.

The committee conducted field inspections of the project union hand tubewells, union offices etc. and also interviewed local villagers/, beneficiaries, union chairman, mechanics and caretakers.

A summary of the visits held on two days with a tabulated statement showing the condition of tubewells inspected is enclosed.

A divisionwise summary of the tubewells maintained in few of the project unions and a consolidated random survey of the same for the country as a whole is also enclosed.

The following are the observations the committee wish to make on the pilot projects covering the period from early January 1976 to end 1977.

Introductory

The country had as of end December 1977 approximately the following numbers of tubewells(shallow/deep set pump/deep wells) which are to be classified as public, besides the tubewells in the private sector as well as those constructed primarily for minor irrigation purposes.

Contd......P/2

For drinking and other domestic purposes:

End 1977		Shallow	Deep Set	Deep
Approx.	Public	3,30,000	2,000	9,200
	Private	3,00,000	-	-
	MOSTI (Irrigation)	22,000	-	-

With the ongoing programme of 155,000 shallow tubewells/5,000 deep tubewells of the current Plan of Operations and the number proposed under the approach plan period of 1978-80 the figures will still grow higher.

End 1980	Shallow	Deep Set	Deep
Public	4,88,000	9,000	16,200
Private	3,25,000	-	-
MOSTI	90,000		

With the projections contemplated as per C.H.P. exercise these will go still higher and by the end of 1985.

End 1985	Shallow	Deep Set	Deep
Public	7,38,000	14,000	21,000
Private	4,00,000	-	-
MOSTI	90,000		
	2,40,000 - (subject to funding by USAID)		

In summary, by end 1985 the country would have approximately the following numbers of drinking water and minor irrigation(used for drinking as well) shallow/deep tubewells that require the same kind and quality of maintenance.

1985	Public	7,73,000
	Private	4,00,000
	MOSTI	90,000
	Total	12,63,000
	MOSTI	2,40,000(US AID)
	Total	15,03,000

If the purpose of providing these wells is to supply water at least to a reasonable degree of satisfaction from considerations of convenience, comfort and health, at least 80% of the wells must be in working condition all the time. That such a state of affairs to be ensured needs tremendous efforts by way of trained manpower, spare parts, logistics, funds and administrative arrangements need not have to be emphasised.

It was only in this context the DPHE/WHO/UNICEF jointly decided to carry out a pilot project study on a country-wide basis.

The observations of the committee based on the compiled records, visits to various unions, interviews etc. are briefly narrated below:

1) The pilot projects have been run to better standard of record keeping, visits by AEs, conditions of maintenance of wells etc. over the period from January 1977 to December 1977.

2) Reporting by officers at various levels had also improved considerably.

3) Quite a few of the wells among those visited by the committee were found to need little or no maintenance at the hands of the union mechanics or by the beneficiaries.

4) Even on those that needed such maintenance, the off take of spare parts from the union mechanic(UP Office) has been generally low.

5) In most cases where repairs were needed, the people used to buy the parts, those readily available from the local market and have the wells repaired.

6) Caretakers were found to take an active role in routine maintenance of wells in at least 25% of cases.

7) In most cases mechanics did not do sufficient motivation to have the people agree to buy the parts from them and have the wells repaired.

8) A perfectly working pump with all parts intact was not often required by the people -all that they wanted was something that would somehow lift some water for them. In other words they preferred to have the minimum and not the optimum maintenance done, obviously to save cost.

9) Use of the tubewell water for purposes other than drinking was still rare except where other sources were totally absent/badly lacking.

10) Properly told and understood, the beneficiaries were prepared to pay for the parts.

11) In certain areas -few of course -the beneficiaries deserved special consideration as they were not in a position to pay for the parts at all they being extremely poor.

12) Chairman were not easily available in many unions as they were often called in for all kinds of thana/local meetings and functions most of the time.

13) Maps and records were found kept and maintained fairly well only in few unions. Any way a start on proper lines has been made.

14) Painting the number on the barrel of the pump for proper identification was [illegible] and done in most cases.

Findings

1. The availability of spare parts in the market at cheaper prices could presumably be only to the thana mechanics disposing the departmental free supplies for lesser consideration to them and thus making some extra money for themeselves.

?. It is also likely that a large quantity of spare parts are going into use with private wells, MOSTI wells etc. The expenditure of almost Tk. 25/- per well year in the adjacent unions as compared to Tk. 10/- to Tk. 12/- per well per year in the pilot project unions tends to indicate that large scale Government spare parts issued free of cost to the regular mechanics are finding an outlet in the local market through the mechanics.

2. Reaction of the Union Parishad - Chairman of the Union Parishad have generally accepted the system of maintenance, even though the people have to pay for the spare parts -despite the fact that the neighbouring unions do not have to pay. The system proves to be much suitable to the local people and local condition.

3. The appointment of the Tubewell Attendents one for each Pilot Union is found justified in view of the area of each union, number of tubewells, communication difficulties in the villages. This is considered a right step in bringing services nearer to the people of the rural areas.

4. This is perhaps the first and right step towards having participation of the people and the Government in the maintenance of rural water supply system which, however, may be ultimately taken over by the people fully. The system will possibly fit nicely into the maintenance of proposed rural sanitation system. Community participation will be elaborated further in booklets.

Recommendations

1. Adoption of the system for other unions

This system of maintenance of rural water supply should be adopted nationwide. Extension to all other unions should be made progressively -phase-wise.

2. Appointment of Tubewell Attendents

The pre-requisite for adoption of the above system is the appointment of Tubewell Attendents one for each union, the earlier the better.

3. Training - The Tubewell Attendents when appointed, will need comprehensive training on the basic principles of tubewells and their maintenance with tools and bicycles. UNICEF in the meantime has agreed to bear the cost of training, provide them with tools andbicycles.

4. Prices of Spares - The price of any spare parts should not exceed 10% of the purchase price of items from the manufacturers and the prices so fixed should be reviewed and revised if necessary at least once in 6 months.

5. Storing of Spare Parts - As in the case of pilot unions, spare parts must be made available by DPHE to all union offices as distance from villages to thanas are often too great.

6. Motivational Works - Until the 1,644 tubewell mechanics, the proposed 4,500 Union Tubewell Attendents and the Caretakers of each well are motivated properly -into the service aspects of the maintenance and until the DPHE thana set up with stores is fully established with adequate spare parts of standard quality, the technical control of the DPHE over the Union Tubewell Attendents must continue.

7. Standardisation of Pumps and Parts - To facilitate interchangeability and availability of pump parts, DPHE in co-operation with the Bangladesh Standard Institution should standardise the different types of handpumps and advise the private manufacturers to abide by the design while manufacturing them for private selling.

8. Stock Piling of Raw Materials - DPHE should prepare estimated requirements of raw materials necessary for manufacturing of the spare parts on annual basis and inform the Trading Corporation of Bangladesh for importing the raw materials especially the pig iron, coke etc.

STATEMENT OF SPARE PARTS USED IN THE MAINTENANCE OF TUBEWELLS IN THE PILOT PROJECT AREA

Pilot Project Area indicated by - A

Adjacent U.P. outside pilot project - B

Type of Project	No. of TWs	SPARE PARTS USED									Percentage of running TW at any time	Unit cost of repair for 1 year	REMARKS
		Bucket	Seat Valve	Plunger	Piston rod	Base	Head Cover	Handle	Barrel	Nuts & Bolts			
Name of subdivision:Jhenaidah Perood(Jan '76 to Dec '77)													
A. Porahati	87	33	49	14	5	1	-	-	-	186	96%	Tk.4.09	
B. Padmaker	55	93	107	13	5	-	2	1	2	243	100%	Tk.14.63	
Name of subdivision:Jessore Sadar Period(Dec'76 to Dec'77)													
A. Keshabpur	87	138	147	28	25	2	7	7	3	457	95%	Tk.18.26	
B. Trimohini	63	206	230	52	23	4	6	12	1	495	96%	Tk.34.10	
Name of subdivision:Magura Period(Jan '76 to Dec '77)													
A. Jagdol	83	54	96	22	20	-	-	4	-	205	96%	Tk.8.25	
B. Chulia	80	52	137	22	25	1	2	6	1	251	100%	Tk.11.58	
Name of subdivision:Narail Period(15 Jan'76 to 31 Dec'77)													
A. Auria	69	80	117	25	13	1	4	2	-	357	96%	Tk.12.87	
B. Bhaddrauila	55	117	140	48	34	3	10	15	2	490	99%	Tk.32.71	
Name of subdivision:Meherpur Period(17 Jan'76 to 31 Dec '77)													
A. Amjhuri	82	77	103	23	18	-	3	6	2	382	100%	Tk.12.35	
B. Kutubpur	97	265	323	75	74	5	10	18	1	964	95%	Tk.31.85	

STATEMENT OF SPARE PARTS USED IN THE MAINTENANCE OF TUBEWELLS IN THE PILOT PROJECT

Pilot Project Area indicated by - A

Adjacent U.P. outside pilot project - B

Type of Project	No. of TWs	SPARE PARTS USED									Percentage of running TW at any time	Unit cost of repair for 1 year	REMARKS
		Bucket	Seat Valve	Plunger	Piston Rod	Base	Head Cover	Handle	Barrel	Nuts & Bolts			
Name of subdivision: Mym. Sadar(S) From 19 Dec '75 ti 31 Dec '77													
A. Bailor	116	129	126	38	35	2	-	-	-	139	86%	Tk. 9.81	
B. Kanthal	96	276	319	76	39	3	2	13	9	1065	87%	Tk. 33.82	
Name of subdivision: Mym. Sadar(N) From Jan '76 to 31 Dec. '77													
A. Dowhakhala	76	36	45	10	10	-	-	1	-	110	73%	Tk. 4.68	
B. Tarundia	81	49	63	16	19	2	3	8	-	211	90%	Tk. 8.94	
Name of subdivision: Kishoreganj From Jan '76 to 31 Dec. '77													
A. Chowddasata	86	145	124	39	23	-	1	2	-	307	86%	Tk. 13.90	
B. Binnati	44	87	149	49	38	6	6	9	4	552	82%	Tk. 36.44	
Name of subdivision: Jamalpur From 1 Jan '76 to 31 Dec. '77													
A. Kendua	110	220	238	102	66	0	11	24	-	234	91%	Tk. 25.51	
B. Tilpullah	111	234	231	50	50	9	12	20	1	720	90%	Tk. 24.30	
Name of subdivision: Netrakona													
A. Challisha	59	91	59	22	19	-	5	6	-	168	98%	Tk. 12.21	
B. Rouha	63	139	144	38	38	3	7	12	4	419	89%	Tk. 29.45	

SUMMARY

STATEMENT OF SPARE PARTS USED IN MAINTENANCE OF TWs IN THE PILOT PROJECT AREA

Pilot Project area indicated by - A

Adjacent U.P. outside pilot project - B

Type of Project	Nos. of Project	Nos of TWs	SPARE PARTS USED									Percentage of running TW at any time	Unit cost of repair for one year	REMARKS
			Bucket	Seat Valve	Plunger	Piston rod	Base	Head cover	Handle	Barrel	Nuts & Bolts			
KHULNA CIRCLE														
A.	5	408	382	514	112	81	4	14	19	5	1587	96%	Tk. 11.10	
B.	5	350	733	937	210	161	13	30	52	7	2443	99%	Tk. 25.05	
DACCA CIRCLE														
A.	5	445	581	592	211	153	2	17	33	-	958	85%	Tk. 13.95	
B.	5	395	785	906	229	184	23	30	62	18	3925	88%	Tk. 25.64	
RAJSHAHI CIRCLE														
A.	2	160	95	100	21	9	1	2	1	-	362	98%	Tk. 6.86	
B.	2	128	172	188	47	37	2	7	17	1	359	100%	Tk. 21.30	
CHITTAGONG CIRCLE														
A.	5	354	236	192	45	16	-	5	1	1	522	100%	Tk. 8.30	
B.	5	284	304	234	51	37	18	13	18	-	935	82%	Tk. 14.36	
GRAND TOTAL	17	1367	1294	1398	389	259	7	38	54	6	3429	95%	Tk. 10.81	
	17	1157	1994	2265	537	419	56	80	149	26	7662	85%	Tk. 22.21	

STATEMENT OF SPARE PARTS USED IN THE MAINTENANCE OF TUBEWELLS IN THE PILOT PROJECT AREA

Pilot Project Area indicated by - A

Adjacent U.P. outside pilot project - B

Type of Project	No. of TWs	SPARE PARTS USED									Percentage of running TW at any time	Unit cost of repair for 1 year	REMARKS
		Bucket	Seat Valve	Plunger	Piston Rod	Base	Head Cover	Handle	Barrel	Nuts & Bolts			
Name of subdivision: Ctg. Sadar(N) (Period 5 quarter)													
A. Rangunia	64	25	30	8	4	-	1	-	-	99	100%	Tk. 6.07	
B. Hosnabad	61	128	125	23	22	6	6	7	-	456	100%	Tk.21.99	
Name of subdivision: Ctg. Sadar(S)													
A. East Gundandi	54	4	2	3	3	-	-	-	-	2	100%	Tk. 1.39	
B. West Gundandi	59	54	7	6	-	-	2	4	-	156	100%	Tk.10.41	
Name of subdivision: Syl.Sadar (Period 5 quarter)													
A. Tukker Bazar	80	58	72	11	1	-	-	-	1	117	100%	Tk.10.19	
B. Hatkhola	61	73	66	8	8	11	3	3	-	221	100%	Tk.21.56	
Name of subdivision: Habiganj													
A. Deorgachi	98	133	76	19	6	-	2	1	-	239	100%	Tk.15.98	
B. Paikpata	50	33	28	10	6	1	1	3	-	69	80%	Tk.11.53	
Name of subdivision: Sunamganj													
A. Lakhansree	68	16	12	4	2	-	2	-	-	65	100%	Tk. 3.72	
B. Aftabnagar	53	16	8	4	1	-	1	1	+	33	100%	Tk. 4.38	

STATEMENT OF SPARE PARTS USED IN THE MAINTENANCE OF TUBEWELLS
IN THE PILOT PROJECT AREA

Pilot Project Area indicated by - A

Adjacent U.P. outside pilot project - B

Type of Project	No. of TWs	SPARE PARTS USED									Percentage of running TW at any time	Unit cost of repair for 1 year	REMARKS
		Bucket	Seat Valve	Plunger	Piston Rod	Base	Head Cover	Handle	Barrel	Nuts & Bolts			
Name of subdivision: Pabna Sadar From 21 Apr. '76 to 31 Oct. '77													
A. Hamayetpur	106	59	53	17	6	-	-	1	-	284	96%	Tk. 6.21	
B. Maligacha	61	108	118	34	25	2	4	16	-	212	100%	Tk.29.67	
Name of subdivision: Serajganj From 19 Apr. '76 to 31 Oct. '77													
A. Ullapur	54	36	47	4	3	1	2	-	-	76	96%	Tk. 8.13	
B. Mohanpur	67	64	70	13	12	-	5	1	1	147	100%	Tk.13.68	

BP. 20

SURVEY OF BOREHOLES IN NTCHEU DISTRICT (CENTRAL REGION)

This is a second survey on CSC funded boreholes, following the first one done in Chiradzulu district - Southern Region - sometime in November and December last year. A total of 16 water sources of which all bar-one were boreholes (one was a safety well) were surveyed under the following guide lines:-

1. The condition of different parts of the pump
2. Distance to potential sources of pollution (latrines)
3. Condition of the apron/slab
4. Condition of the drainage system
5. Contamination of the water system by coliform bacteria
6. The use of the boreholes.

Objective

The main objective of providing the communities with boreholes is to improve the health of the people by providing them with clean and safe water. After the provision of these water sources it became essential to find out whether they serve the purpose they were meant for. It was also important to find out whether the communities served appreciate such services.

Method Used

The appropriate way to study the feasibility of a borehole and its service to the community is to study the social structure of of the community itself mainly the sanitary values it holds. This study would in most cases have an influencing factor to the better use of the borehole by the community.

1. Condition of the Pump:

This was determined by visual check of the pump-parts as well as measurement of the pump flow. Pumping rate of 30 strokes per minute was chosen as a standard. The quantity of water obtained indicated the condition of the cup-leathers, valves and the condition of the rising main or both in some cases.

It was found out that 88% of the pumps were of the climax (wheel-type) type, with average best performance of 14 litres per minute at the mentioned standard rate of pumping. The pump yield is direct propotional to the length of the stroke.

DISTANCE TO THE NEAREST SOURCE OF POLLUTION

The potential sources of pollution taken into account were pit-latrines. These are the main pollution sources in Rural Areas save septic tanks in mission stations where the survey was also done. The distances were determined in most cases by using a distrance metre gauge fitted on a fork of the bicycle with a wheel, so that by moving the wheel on the ground, distance was recorded. For accuracy, distances were run twice. i.e. to and fro the source of pollution and the average was regarded as the accurate distance indicated.

CONDITION OF THE APRON

After a successful drilling of a borehole and installation of a pump, the drillers construct a 2x3 ft concrete slab around the pump. Normally the community is asked to extend the slab into an apron as well as dig and line the drainage channel with a soak pit at the end, some distance from the pump. However, need to construct a drainage channel and a soak pit depends very much on the terrain where the pump stands as well as the kind of soil available. Where the pump stands on a hilly or domed place with adequate slopeness around the construction of the mentioned becomes but a formality. Likewise where the adequate slope is accompanied by clay soil which is impermeable. Therefore, the necessity to having an extended slab and drainage channel depends very much on the position of the borehole in relation to the surrounding.

2/......

Classification of the condition of the apron was done as follows:-

- Poor: The slab is worn out and suspended due to erosion; so that surface water soaks in around the hole. This condition is in most cases liable to contamination of the borehole water.

- Fair: The slab is well protected by surrounding it with stones and soil to avoid accumulation of water in pools around the slab. If the extended slab (apron) is cracked, the condition was regarded the same.

- Good: The slab has been extended into an apron of approximately 3 metre (10ft) diameter; hence giving the central point where the pump is installed some kind of a dome shape. This enables the water splashes from the pump to run-off into the channel whence into the soak pit.

The classification of the condition of the drainage system was based on the same pattern of the aprons.

- Poor: There is neither a drainage channel nor soak pit consequently - depending on the terrain - water accumulates around the slab into pools.

- Fair: There is either a cemented on uncremented drainage channel but with no soak pit or there is an uncremented/lined channel with soak pit at a reasonable distance of 15 metres. or more.

- Good: The drainage channel is lined with bricks or cement and ends up into a soak pit at equally reasonable distance of 15 metres or more away from the pump.

Bacteriological test

81% of the borehole (safety well inclusive) had their water tested for the presence of coliform bacteria; by means of a portable millipore incubator. Water is pumped from a sterilised pump outlet or tap into a steritised graduated cup. Whence 100cc of water is drawn through a tube fitted on the inlet side of monitor whose out-let end is fitted to a syringe. Water is drawn in via a filter- which has affinity to trapping bacteria by filtration - in the field monitor and finally out through the out-let end of the syringe. The appliance is then disconnected from the field monitor which is then incubated at $35^{o} \pm 0.5$ centigrade for 24 hours after introducing Endo-media on which the bacteria if any would feed on hence be able to multiply. After this period of incubation the monitors are removed from the incubator and colonies of coliforms are counted and classifed as follows:-

- Good: No colonies in 100 ml (100cc) of water
- Satisfactory: Less than 5 colonies of total coliform bacteria present in 100 ml of water (100 c.c.)
- Suspicious: Between 5 and 20 colonies of bacteria present in 100ml of water.
- Contaminated: Over 20 countable colonies present in 100ml of water.
- Badly contaminated: Uncountable number of colonies.

USE OF THE BOREHOLE:

To determine how much used the borehole is, is rather subjective and controversial; for it is mainly dependent on the time of observation. Observation at peak points give a rather true picture of how well used a borehole is whereas observation a low points could give a distorted picture of this. However; a few signs and details around the water source help to build or justify the use of the borehole. These are:-

1. Condition of the foot-paths leading to the water source.
2. Number of foot-prints the water source (This could be questionable as a few people could frequent the water source)
3. Pools of water and the wetness around the hole.

3/.....

The Criteria of classifying the degree of borehole use was based on the number of people found drawing water; although in some cases population figures of the villages served by the borehole give some impressiom of how well used a borehole is. Here we will base our classification on the former.

- Little used: Either no one or only one person was found at the borehole or arrived to draw water during our visit. The surrounding paths were overgrown with grass and absence of adequate wetness also indicated unpopularity of the borehole. Usually an alternative source with more palatable water compaired to the borehole existed within ear-shot of the community's premises. Salinity, smell and rust in the water are usually refraining factors to borehole water use.

- Fairly Used: More than one person was pumping water during our visit but less than five people. Paths and the drainage channel indicated that many people use the borehole regulary.

- Well Used: At least five people arrived at the site for pumping water during our visit. The sorroundings clearly indicated that many people use the borehole. Usually a village or villages were seen near the borehole at roughly 200 metres away.

OBSERVATIONS

In order to visualise our observation at a go, it would necessitate to put them in a tabulated form; thereafter detailed description would follow:-

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SURVEY OF BOREHOLES IN NTCHEU DISTRICT

BORE-HOLE NO.	LOCATION	POPULATION SERVED	YEAR DRILLED	PUMP TYPE	DONOR	FLOW IN LITRES/MIN	DISTANCE TO LATRINE	CONDITION OF APRON	DRAINAGE	RESULT OF WATER TEST	USE OF BOREHOLE	REMARKS
SM 22	Dombole School.	500 people	1975/ 1976	Climax	EZE	8	56m	Fair	Fair	Satisfactory	Well Used	Water very Rusty
L 243*	Senzani 1	-	-	Climax	-	4.2	70m	Fair	Poorly kept	Suspicious	Well Used	Pools of water around cattle drink from over-flows.
-	Ntonda (S.Well)	260 people	1978	President	Dev.of Health Centre Services	17.3	90m	Good	To be extended	Badly contaminated	Well Used	Water is clear
FP 161	Solomoni Lazaro	2,000 people	1974/ 1975	Climax	E.Z.E.	10	14m	Fair	Fair	Satisfactory	Well Used	Muddy + unkept
R 83* ?	Diwiza vge	553 people	197	Climax	?	9.4	14m	Fair	Poor	Suspicious	Well Used	Krall 5m away
PM 551	Khola H.U.	300 per day	1977/ 1978	Climax	ICCO	9.1	28m	Fair	Fair	Badly contaminated	Well Used	Weight misplaced hence pumping is difficult.
R 83? (SM 166)	Manjawira	1,246 people	1968/ 1969	B & C	Bread for the world	5.5	42m	Fair	Fair	Badly contaminated	Well used	Stroke been reduced
R 77*	Nsipe Mission	800 people	1969/ 1970	Climax +Lister Engine	E.Z.E.	-	270m	Fair	Poor	Badly contaminated	Well Used	Water tested from tap
FP 1	Senzani II		1973/ 1974	Climax	E.Z.E.	13.6	14m	Good	Fair	Suspicious	Well Used	Surrounding clean save for unlined drainage
FC 136*	Gongolo	399 people	1973/ 1974	Climax	Danchurch aid	6.7	91m	Fair	Fair	Badly contaminated	-	Very rusty water

BORE-HOLE NO.	LOCATION	POPULATION SERVED	YEAR DRILLED	PUMP TYPE	DONOR	FLOW IN LITRES/MIN	DISTANCE TO LATRINE	CONDITION OF APRON	DAINAGE	RESULT OF WATER TEST	USE OF BOREHOLE	REMARKS
R 86	Ganya School	-	1969/ 1970	Climax	EZE	9.1	100m	Fair	Poor	Badly contaminated	Well Used	Horehole pump frequently out of order
SM 23 A	Gowa School		1975/ 1976	Climax	ICCO	12.1	14m	Fair	Fair	Badly contaminated	Well Used	Newly replaced pump.
Y 155A	Penga-Penga	400 people	1970/ 1971	Climax	DANCHUR-CHAID	8.5	28m	Fair	Not essential Good	Badly contaminated	Well Used	Water is Clear
FC 78	Libvulezi School	502 people	1971/ 1972	Climax	DANCHUR-CHAID	-	60m	Fair	Poor	Not Tested	-	Borehole out of order
X 1	Muwalo School		1969/ 1970	Climax	EZE	-	12m	Good	Fair	Not Tested	-	Borehole out of order
R 88	Beni Chauya	1010 people	1969/ 1970	Climax	EZE	-	70m	Poor	Poor	Not Tested	-	Borehole out of order

Among the 16 boreholes surveyed, one is a safety well dug by C.S.C. well digging team. This project was not quite finished, what remained was sterilization of the well and pump and completion of the storage tank.

Of the 16 boreholes, borehole L243 is a D.D.C. borehole. The reason for having surveyed this borehole was the fact that it subsidises borehole No.FP1 within the same big village - Senzani. It was also found that the boreholes at Manjawira and Diwiza had the same number R83. We believe this was a mistake done by the drillers. Later on the office records showed that Manjawira borehole bears two numbers R83 and SM166 whereas borehole R83 at Diwiza is not a C.S.C. funded borehole. This is funny.

POPULATION

The population served by the borehole is in some cases the totals of the population of the surrounding villages served by that particular borehole and in some other cases the enrollment of a school where most of the pupils are day scholars. In most cases the population given give a general impression of how well used a borehole is. Although it does not necessarily mean that all the people would depend on the borehole for their water. Alternative sources are in many cases available and some people would depend on these because of either their nearness, quality of water in comparison to the borehole water.

(Note: The figures shown were obtained from population census records at the District Commissioner's Office).

PUMP TYPE

88% of the pumps were of climax type with $4\frac{1}{2}$" stroke. These are very durable pumps but expensive. Little problems could be expected from these pumps. A common problem observed during this survey was that the leathers of the glands were worn out in most of them; so that considerable amount of water was being wasted through the glands.

Of the 16 pumps observed one is a President (Limani) pump with 8" stroke fitted on a safety well. This is equally a durable and solid pump with the best observed flow. The other pump observed was a Brown and Clapperton hand pump at Manjawira. Normally this pump has a 3"-4" stroke. It was funny to find that this particular pump had $2\frac{1}{2}$" stroke.

Generally speaking most of the pumps looked well maintained for 81% of the boreholes were functioning. Thanks to the maintenance team.

YIELD

The best time to test borehole yield is during driest time of the year i.e. September to November. However tests done a few months after the rainy season would at least give some needed information.

The mean maximum yield for a climax pump is 14 litres per minute whereas the minimum could be taken as 4 litres per minute taking 30 strokes per minute as a standard. Only one borehole FP1 at Senzani II village indicated a yield rounded off to this; whereas the rest fell within the two dead-lines. The President pump fitted on the safety well showed a very high yied. This is obviously because of the longer stroke but could also be because of the reservoir in the safety well which does not exist in the boreholes. The Brown and Clapperton hand pump had one of the lowest yields despite the well maintaining of the pump because of the reduced stroke.

DISTANCE TO SOURCE OF POLLUTION:

The recommended distance to a source of pollution is 30 metres (100ft). However; this minimum distance is meant to be no more than a guide to good practice and may be increased depending on the position of the pollution source in relation to water source i.e. whether up or down slope from it, the kind of soil whether permeable or impermeable and underground streams.

25% of boreholes situated less than 30 metres from a pollution source were found to be either under suspect or contaminated. However 6 boreholes (38%) were found to be under suspect or contaminated despite the fact that they were situated beyond 30 metres from the source of pollution. This could be because of either soaking of dirty water through the unprotected surface or infiltration or seeping through of the bacteria in sandy soils run by underground streams.

POSSIBLE CAUSE OF POLLUTION

Ntonda Safety well - Lack of treatment of water with chlorine after completion. The pollution might have originated from the diggers.

PM551 Khola Health Unit - Lack of a proper apron and drainage channel.

R83 Manjawira - Pools of water around the borehole. Borehole situated down stream from some houses.

R77 Nsipe Mission - Borehole situated down slope from the school (and possibly septic tank)

FC136 Gongolo - Borehole situated downslope from houses nearby. The soil is sandy.

R86 Ganya - Waterpool around the borehole inadequate apron and poor drainage.

SM23A Gowa School - The short distance from teachers' houses and latrines, situated up-slope. The soil is sandy.

R83 Diwiza - A cattle Kraal situated some 5m . away from the source.

USE OF THE BOREHOLES

All functioning boreholes were well used save Borehole No. FC136 where we found no people at all; the reason being the water is very rusty. A few people were seen carrying water from the nearby river.

The following are the number of people we found drawing water at the boreholes during our visit.

SM22 Dombole - 40 people - at 11:12 a.m.
L 243 Senzani I - 20 people at 12:10
R83 Diwiza - 14 people at 12:05
PM551 Khola H Unit - 8 people at 4:50 p.m.
FP161 Solomoni Lazaro - 25 people - at 3:35 p.m.
R 83 Manjawira - 30 people at 11: 30
R77 Nsipe - No people because the engine was in operation. People draw water after the tank for the missionaries is full at 10:00 a.m.
FP1 Senzani II - 5 people - at 1:40 p.m.
FC136 Gongolo - No people - at 11:35
R 86 Ganya - 5 people - at 3:00 p.m.
SM 23A Gowa - rt pupils-at 1:00 p.m.
Y 155A Penga-penga - 10 people - at 5:40 p.m.
R88 Beni Chauya - No people. Borehole breakdown.
X1 Muwalo School - No people. Borehole breakdown.
FC78 Libvulezi School - No people. Borehole breakdown
Ntonda safety well - No people. Over head concrete tank under construction - at 1:50 p.m.

IMPRESSION FROM THE SURVEY

1. There is no feeling of ownership of the boreholes among the people.
2. In some cases people do not know who to approach in case of borehole breakdown.
3. Sanitary values are in most cases still less realised to communities provided with boreholes.
4. Hygine comparison between borehole water and other water from unreliable sources is very limited.

SUGGESTIONS AND FUTURE PLANS (Subject to discussions)

1. After a successful drilling of a borehole and installation of a pump, it would be important to hand over the borehole to the community in order to establish a sense of ownership among the people. This system has shown to be very effective in the Gravity piped water scheme. Most of the times people have a tendency to take care of their own property better than of others, it is for this reason that this point is emphasized.

2. The community should be informed of the responsible office who would be approached in case of pump breakdowns. Two fair examples of places where villagers had no idea of who to approach when their pumps could not work are:- Libvulezi School. Borehole FC78 and Muwalo School. Borehole X1. When the Ntcheu maintenance team was approached later it was found out that they never received any report from the villagers about that.

3. The community need to be educated in order to appreciate Sanitary values. The cleanliness of the borehole surrounding is very essential. There is equally need to warn the people of the danger of establishing pollution sources near the boreholes. This situation happened at Liwiza where a cattle kraal was about 5 metres away from the borehole. It is not suprising that the water there is contaminated.

4. People need to be discouraged from using water from Unreliable sources and be encouraged to use the borehole water despite some qualities in connection with unpalatability.

PROBLEMS:

1. Since some boreholes have been found to be contaminated, a way has to be found to get rid of this by means of treatment. However; this will not help if there is a permanent source of pollution nearby. In order to achieve this it would be necessary to improve the aprons and the drainage system of the boreholes.

2. One of the other problem to be looked at seriously is that of rust in the water due to oxidation of iron ions (Ferric ions) in the water. Although calcuim hydroxide is the thought of chemical for such a problem,method of application still remains a problem.

ACKNOWLEDGEMENT:

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CHRISTIAN SERVICE COMMITTEE
P.O. BOX 949, BLANTYRE.

10th July, 1978.