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WORKING MEETING ON HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

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WORKING MEETING ON HANDPUMP SELECTION AND TESTING

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OBJECTIVES
(proposed)

1. To assess the handpump requirements of rural water supply programmes;

2. To develop guidelines for the selection and development of handpumps for rural water programmes;

3. To establish guidelines for field evaluation of handpumps;

4. To establish a protocol for handpump testing;

5. To design a mechanism for international cooperation, and systematic exchange of results of testing and evaluation projects;

6. To develop a proposal for a programme of handpump field trial projects in selected countries.

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WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

LIST OF PARTICIPANTS

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Bangladesh

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Mr. T.B.F. Acquah	Ghana Water & Sewerage Corporation
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Philippines

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Thailand

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Mr. L. Surla	AID, U.S.A.
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Mr. C. Schippers	DTH, Netherlands
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Mr. J. Collett	Intermediate Technology Development Group, U.K.
Dr. W.K. Kennedy	International Development Research Centre, Canada
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Mr. J.S. Paulsen	W.L. Wardop & Associates, Canada

CONSULTANTS

Mr. F.E. McJunkin

Mr. C.K. Stapleton

SECRETARIAT

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WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden , Hertfordshire , U.K ,
29 May - 1 June 1979

PRELIMINARY AGENDA

MONDAY, 28 MAY		Registration at Glen Eagle Hotel Issue of Conference Documents	
TUESDAY, 29 MAY			
9:30	1.	OPENING SESSION	
	1.1	Opening	
	1.2	Scope and Objectives of the Meeting	Mr. E.H. Hofkes
	1.3	Adoption of Agenda	
	1.4	Presentation by Participants	
	1.5	Introduction of Background Documents	
	2.	GENERAL	
	2.1	Organizational Matters	
	2.2	Announcements	
10:30		*COFFEE BREAK*	
11:00	3.	INTRODUCTION TO SUBJECT AREA	
	3.1	Introductory Paper Handpump Requirements of Rural Water Supply Programmes	Mr. C.K. Stapleton
	3.2	Discussion	
12:30		*LUNCH*	

	4..	TESTING OF HANDPUMPS	
14:00	4.1	Presentation of Handpump Testing Guide (Working Document No. 1)	Dr. J. Cuthbert Mr. J. Kingham
	4.2	Statements and General Comments by Participants	
15:00		*TEA BREAK*	
16:00	4.3	Detailed Review and Discussion	
	4.4	Summary of Main Issues	
17:00		*Adjourn*	
		Cocktails	

WEDNESDAY, 30 MAY

9:00		*Daily Report Tuesday 29 May*	
9:15	5.	FIELD EVALUATION OF HANDPUMPS	
	5.1	Presentation of Guidelines for Field Evaluation of Handpumps	Dr. F.E. McJunkin
	5.2	Statements and General Comments by Participants	
10:30		*COFFEE BREAK*	
11:30	5.3	Detailed Review and Discussion	
	5.4	Summary of Main Issues	
12:30	6.	WORKING GROUPS	
	6.1	Terms of Reference	
	6.2	Formation and Membership	
13:00		*LUNCH*	
14:00	7.	VISIT HARPENDEN RISE TESTING LABORATORY	
		• Explanation of Methods and Devices for Comparative Testing of Hand/ Foot operated pumps for use in developing countries	
		• Inspection of Pump Testing Set-up/ Installation	
		TEA	
16:00	8.	WORKING GROUP SESSIONS	
	8.a	Handpump Testing Guide	
	8.b	Handpump Field Evaluation Guidelines	
17:30		Adjourn (to continue in the evening, if necessary)	

THURSDAY, 31 MAY

9:00		*Daily Report Wednesday 30 May*
	9.	FINAL REVIEW SESSION
9:15		*HANDPUMP TESTING GUIDE*
	9.1	Working Group Report
	9.2	Final Review and Discussion
	9.3	Recommendations
10:30		*COFFEE BREAK*
		HANDPUMP FIELD EVALUATION GUIDELINES
11:00	9.4	Working Group Report
		Final Review and Discussion
	9.6	Recommendations
12:30		*LUNCH*
14:00	10.	COUNTRY PROJECTS
	10.1	Country Projects for Testing, Field Trials and Evaluation of Handpumps
	10.2	Multi-country Cooperation Programme (Proposal) (TCDC)
15:00		*TEA BREAK*
	11.	COOPERATIVE ACTION
	11.1	Mechanism for Exchange of Results
	11.2	Coordination
18:00		*RECEPTION*
19:30		*CONFERENCE DINNER*

FRIDAY, 1 JUNE

9:00		*Daily Report Thursday 31 May*
	12.	EXTERNAL ASSISTANCE TO COUNTRY PROJECTS
9:15	12.1	International and Bilateral Assistance to Country Projects for Testing and Evaluation of Handpumps
	12.2	Recommendations
10:30		*COFFEE BREAK*
	13.	RESEARCH AND DEMONSTRATION PROJECTS (supporting Handpump Selection and Development) for Rural Water Supply Programmes
11:00	13.1	Priority Studies, Research and Demonstration Projects
	14.	*CLOSING SESSION*
		LUNCH
		Participants' Departure

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WORKING MEETING ON HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

QUESTIONNAIRE

SURNAME : ______________________

INITIALS, TITLE(S) : ______________________

FIRST NAME : ______________________

OFFICIAL POSITION : ______________________

INSITUTE : ______________________

ADDRESS : ______________________

P.O. BOX : ______________________

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ADDITIONAL INFORMATION : ______________________

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Please complete this form and return it to the Secretariate. Thank you.

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W.D. - 1

WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden , Hertfordshire , U.K ,
29 May - 1 June 1979

DRAFT

GUIDELINES FOR FIELD EVALUATION OF HANDPUMPS

0-0-0-0-0

MAY 1979

CONTENTS

8. REPORTING

8.1. Format

8.2. Ranking of Handpumps

REFERENCES

ANNEXES

- Directory of Handpump Manufacturers
- Specimen Forms
- List of Reviewers

1. INTRODUCTION

1.1 Background

A recent survey by the World Health Organization found that only 300 million (22 percent) of some 1,400 million people living in rural areas of developing countries have reasonable access to safe and adequate drinking water. Over a thousand million rural people lack such access to safe, reliable water (see Table 1).

The importance of water supplies in transmission 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. $25 per capita. Alternatively expressed, the current rate of investment would have to be multiplied fourfold 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 in these areas will be mandatory for many years to come.

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 handpumps is by far the cheapest means of providing a good water supply". (IBRD, PUD Rpt. 793, p.16, 1975).

TABLE 1

ESTIMATED POPULATION HAVING REASONABLE ACCESS[1] TO SAFE WATER[2] IN 1975 IN 71 DEVELOPING COUNTRIES[3]

WHO Region (countries)	Population					
	Urban[4]		Rural[4]		Total	
	Millions	Percent	Millions	Percent	Millions	Percent
Africa (16)	14,152	65	19,272	21	32,710	29
Americas (21)	145,650	81	21,753	30	104,091	57
Eastern Mediterranean (15)	46.272	80	23,955	16	67,673	34
Europe (2)[5]	19,980	81	20,180	63	40,160	71
South-East Asia (8)	127,521	68	145,118	19	272,639	29
Western Pacific (9)	36,036	91	18,046	30	54,082	54
TOTALS[6]	450,000	77	313,000	22	763,000	38

NOTES:

1 . "Reasonable access", in an urban areas, was defined as a public fountain or standpost located not more than 200 meters from a house. In rural areas, reasonable access impled that "the housewife or members of the household do not have to spend a disproportionate part of the day in fetching the family's water needs"

2 "safe water" supply includes treated surface waters or untreated but uncontaminated water such as from protected boreholes, springs, and sanitary wells.

3 Not including the population of China.

4 The national definition as determined by each country

5 Algeria and Turkey

6 Extrapolted to include the 95 countries survey in 1970.

SOURCES: Twenty-Ninth World Health Assemby. "Community Water Supply and Wastewater Disposal (Mid-Decade Progress Report)." DOC. A29/12 Rev.1. World Health Organization.
United Nations Water Conference. "Report on Community Water Supplies" E/CONF. 70/14. 1977.
World Health Organization. "Community Water Supply and Wastewater disposal (Mid-Decade)." World Health Statistics Report. Vol.29 No. 10. 1976
World Health Organization, Regional Office for South-East Asia. "Community Water Supply and Excreta Disposal in South-East Asoa." WHO Regional Publication, South-East Asia Series, No. 4 1977.

Although community water sytems piped under pressure to households and public standposts are an ultimate goal, many of the unserved thousand million will realistically have to seek handpumps as an interim if not an ultimate measure.

Worldwide estimates of handpump use are necessarily crude. A not unreasonable estimate could be that, at present, some 200 to 400 million people are served by handpumps for drinking water. The drinking water programmes envisaged by the developing countries, in fulfillment of their commitment to the targets set for the International Water Supply and Sanitation Decade 1980 - 1990, would serve - when implemented - an additional 400 to 700 million people with handpump water supplies. In the same period, very conservatively estimated, handpumps serving some 100 to 200 million people will need replacement. An additional 300 million population increase by 1990 must be taken into account.

Further extrapolating these estimates, with an overall average of 100 persons per handpump, the global requirement for new communal handpumps is on the order of 8 to 10 million handpumps. Handpump unit costs have a wide range, from about U.S. $20 for the simplest shallow well pumps to about $2,000 for sophisticated, imported, heavy-duty deep well pumps. Assuming a weighted average cost of $150 per handpump yields a conservative projected capital purchase of handpumps in excess of $1,200 million dollars.

Using a 10 percent ratio for the handpump cost in the handpump/tubewell system leads to a capital investment estimate of over 12 billion U.S. dollars. Added to these are operation and maintenance costs.

Handpumps are used in a wide variety of conditions. They serve on shallow or deep wells, with many or few users. Operation may range from almost continuous to infrequent, and maintenance from adequate to non at all. Numerous handpump models, from many different manufacturers are on the market. Frequently, pumps are imported from distant countries on the basis of very limited information.

Unfortunately the record of most present handpump programmes is not good. Serious problems exist in handpump technology, design and selection; quality of manufacture, installation, operation and maintenance; and organization and adminstration of handpumps generally. The number of existing, successful handpump programmes is small. It appears that the "simple" handpump "solution" to rural water supply poses some major, complex problems on a worldwide scale.

The causes of these problems arise from several sources:

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

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

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

d. Often, very little or no maintenance is 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.

1.2 Need for Evaluation of Handpumps

A common way of evaluating the problems of handpumps-in-use-in their community environment is needed, in order to point the way to succesful practical solutions.

Evaluation of field performance of handpumps, supplemented by field trials and testing of pumps, can provide the necessary basis for selection and development of suitable handpumps for rural water supply programmes. This type of work is currently under way or being planned in several developing countries, with active support from a number of international and bilateral agencies. There have been some earlier investigations of handpumps but their findings have tended to be inconclusive. Several current field evaluation and testing programmes appear to be more systematic, and a sound methodology may now be developed to provide improved technical assistance to decision makers.

If field trials and testing of handpumps were coordinated between countries and agencies, results could be "pooled" thereby giving an opportunity to treat them as one large experiment and providing valuable information about the effects of different variables. A broader body of knowledge would be available to each participating organization than it could afford to assemble on its own.

1.3 Purpose of Guidelines

Field evaluation of handpumps in these guidelines means the subjecting of different pumps to systematic assessment of field performance in order to provide unbiased information about the characteristics and on-site performance of handpumps to agencies responsible for the procurement, installation, maintenance and operation of handpumps in water supply programmes or to agencies providing financial and technical assistance.

Comparison and evaluation of handpumps on an international basis will require common criteria, definitions and methodologies.

The guidelines present methods and procedures which may be internationally applied in handpump field evaluation projects. Technical characteristics and performance data should be so recorded that evaluation project results can be internationally compared. The guidelines should also serve as a checklist for use in designing individual field programmes for evaluating and testing of handpumps.

The information so assembled from various evaluation projects, and presented in an agreed format, would better enable handpump buyers to make a rational choice of pump that best meets their particular needs and budget. Assessments should be made in accordance with widely-accepted methods and criteria so chosen as 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.

Handpump 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 methods through all stages, and to the same degree of thoroughness.

The scope of a handpump evaluation project should be consonant with the handpump programme it supports, as measured in terms of the number of pumps required, population and area to be served, and financial resources available.

If handpump evaluation projects are to yield reliable results, certain requirements of methodology will have to be satisfied. The guidelines describe selected methods and procedures.

1.3 Field Evaluation and Testing

Field evaluation and testing of handpumps may be undertaken in order to :

(1) Select the "best" handpump from numerous candidate models. As will be shown later, "best" has many dimensions, some of which cannot be measured quantitatively;

(2) Evaluate the suitability of one or more candidate pumps for local conditions;

(3) Evaluate effectiveness of maintenance system or systems;

(4) Provide guidance for improvement of existing handpump models, particularly those of indigenous manufacture;

(5) Test and develop new handpumps, components, materials, mechanisms, etc.;

(6) Establish acceptable standards of quality for local manufacture of handpumps;

(7) Assist governments and manufacturers in introducing standards where none exist, or to improve those presently in use;

(8) Determine any differences between actual field performance and the handpump characteristics as claimed in manufacturers' documents.

In a field evaluation programme for purpose (1) above, various pumps are compared, and implicitly, ranked. Purpose (2) evaluates one or more pump models under local conditions. The other six purposes affect the evaluation programme in different ways.

In summary, the purpose of field evaluation of handpump performance, supplemented by controlled testing if necessary, is to provide unbiased information to make better decisions about handpumps for rural water supply programmes.

1.5. Some Handpump Evaluation and Testing Projects

1.5.1 General

Very few handpump programmes have incorporated formal evaluation and testing of handpumps, although evaluation is obviously an integral part of all rural water supply programmes. Some evaluation/testing projects are described in the publication "Hand Pumps", (IRC Technical Paper No. 10), including laboratory testing of the AID/Battelle pump and field testing of the "Bangalore" (India) handpump, the DPHE/UNICEF New No. 6 shallow well handpump (Bangladesh), the Vergnet foot pump (West Africa), and others.

1.5.2 Harpenden Rise Laboratory Testing Project

A comparative testing programme for handpumps is being carried out by the Harpenden Rise Laboratory (U.K.), under contract with the Overseas Development Ministry (U.K.). Altogether 12 different pump models are submitted to laboratory testing under a scientific protocol.

The pump models presently under test are: Dempster (U.S.); Climax (U.K.); and Godwin (U.K.) wheel driven models; Mono (U.K.) helical rotary; Monarch (Can.); Beatty (Can.); Vergnet (France); Petro (Sweden); Mark II (India); AID/Battelle (Costa Rica and Nicaragua; Kangaroo (Tanzania) and Sholapur (India). Preliminary results are given in an interim report dated December 1978; the final report is expected in 1980. The reports are recommended sources of information for any organization with an interest in the 12 pump models tested. They should also provide much useful information to handpump researchers.

1.5.3 Ghana Water and Sewerage Corporation Evaluation Programme

The extensive comparative field tests of handpump undertaken in Ghana by the Ghana Water and Sewerage Corporation, assisted by the Canadian International Development Agency and Wardrop Associates, Consulting Engineers,has been completed in 1978. Eight different handpump models were field tested. The Ghanaian experience should be of particular interest to neighbouring West African countries.

1.5.4 India Mark II - deep well handpump

A promising new, indigenous deep well handpump, the India "Mark II", is undergoing field trials in UNICEF-assisted projects in the States of Tamil Nadu and Madya-Pradesh. Published findings are, as yet, not consolidated but they should be very useful. Development of local manufacture, quality control, and suitable maintenance schemes is particulary noteworthy.

1.5.5 Comparative Field Testing in Central America

Field testing of the AID/Battelle handpump is proceeding in Costa Rica and Nicaragua under agreements involving those countries, the U.S. Agency for International Development, the Central American Research Institute for Industry (ICAITI), and the Georgia Institute of Technology (U.S.). The AID/Battelle pumps under test were manufactured locally. Four other pumps are also under test for comparative analysis: Dempster (U.S.), Kawamoto Daiichi "Lucky" (Japan), Marumby (Brazil) and a PVC pump developed by the International Development Research Centre (Canada).

Complete documentation is available from the Office of International Programs, Georgia Institute of Technology, Atlanta, Georgia, 30332, U.S.A.

1.5.6 Other Evaluation and Testing Projects

Other projects underway or shortly to begin include testing of new handpump models in several Asian and African countries under the auspices of the International Research Development Centre (Canada). Similar work is planned or underway in the Dominican Republic, Indonesia, Thailand, the Philippines, Pakistan, India, Bangladesh, Tanzania, Ethiopia, Malawi, and several West African countries.

2. METHODOLOGY OF HANDPUMP EVALUATION

2.1. Approach

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 know 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 general approach to the problem might include three studies; field trials surveys, and (laboratory) testing of handpumps, where appropriate. These three are inter-linked and should be organized in such a way that the results are comparable across the boundaries of each study.

2.2. Definitions

In order to provide a common framework, the following definitions are offered, as used herein:

Test: An experiment designed to prove (or disprove) an hypothesis. Example hypotheses: (a) Pump X can be maintained by local villagers, (b) Pump Y will provide satisfactory service under local conditions. (c) Pump Z can be satisfactorily manufactured locally, (d) pump A is a better pump for local use than Pump B or pump C.

Comparative Test: An experiment designed to rank two or more handpumps in accordance with explicit criteria. The experimental design should enable the hypotheses to be proved/disproved and/or whether there are verificable differences between the pumps tested.

Laboratory Test : A test made under laboratory conditions in which the variables to be tested can be rigidly controlled and systematically varied. Although real-use conditions may be simulated, the test is still a model of reality. For handpumps, laboratory testing, thus far, has been useful but not fully adequate for field-level overall evaluation; These tests are often useful for improving particular models of handpumps and for screening out weaker candidate pumps. Some extrapolations from laboratory to field conditions have been disastrous.

Field Test: A test made under real-use conditions. Some attributes and variables can only be testing in community use, e.g., user acceptance. Field tests may verify the validity of laboratory tests. Field tests may be comparative tests on several pumps or one pump model.

Longitudinal or time-series field test: A test which evaluates pumps over an extended time period, typically a year or more, beginning with their initial installation or rehabilitation.

Cross-sectional field test or survey: A test (or survey) which evaluates the performance of a large number of handpumps at a common time, i.e., simultaneously.

User Survey: The collection of information from a sample of handpump users, by interviews, questionnaires, or other direct contact. Especially useful for socio-cultural information.

Field Trial: Somewhat synomymous with field test but often used to describe programmes when handpump evaluation is part of an on-going pump installation and operation programme, but without formal testing protocol.

Protocol: Formal document outlining the overall plan, scope and procedures for testing and evaluation of handpumps.

Attribute or Characteristic: The property of a handpump which influences its value in a programme and which, therefore, must be considered in evaluating the pump.

Parameter: (1) any set of physical properties whose values determine the characteristics or behaviour of the handpump or handpump system, e.g. water table depth.

(2) A characteristic element: factor.

Methodology: Description of how each attribute will be examined and measured. Part of the protocol.

Evaluation: The process of placing (objective) values on models of handpumps on a predefined scale, or in relation to each other. Criteria for evaluation should be established beforehand.

Ranking: A listing of handpump models or components on the basis of defined attributes -- either overall or singly. The first listed is the highest ranked.

Model: A particular design of handpump or handpump compenent. Differs from brand or manufacturer in that many manufacturers market several models.

Significance and Confidence: A difference (e.g., between models or between observations) is significant if statistical treatment of the data shows that this difference is probably correct. The degree of probability can be chosen and is called the level of significance or the confidence level. A confidence level of 95 percent means that any result which is significant at the 95 percent confidence level has only one chance in twenty of being wrong.

Other definitions appear under the relevant section. For definitions of handpump types and components refer to the publication "Hand Pumps" (IRC Technical Paper No. 10).

2.3 Surveys

There are several types of surveys.

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

(b) Surveys to determine the social and cultural habits of the users so that:

I) The most suitable maitenance procedures can be forumulated.

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, or the emplacement of the pump.

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

(c) Surveys to determine the socio-technical situation so that production engineering, production management and 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 manufacturing 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.

(d) Censuses including number of people, communities, existing wells, pumps, etc.

2.4 Field Trials

2.4.1 Introduction

The aim of field trials is to determine how pumps will behave in real use and how they will withstand real environmental conditions. Field testing has the advantage over laboratory tests that they can take place in environments and with users which may closely resemble the actual conditions of planned installations. Field trials have the disadvantage that the situations and environments are much less controlled and well-characterized than in laboratory tests and that users and usage may show wide varience. Attempting to overcome these difficulties is time consuming and costly.

In a laboratory test the influence of such factors as number of strokes, depth of pumping, pumping speed, length of stroke, etc., can be controlled by keeping them constant at one or several levels. In the field these factors are not under the direct control of the test agency and are generally much more variable.

2.4.2 Fundamental Aspects of Field Trials

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

When pumps are tested in field trials, the problem is to distinguish in the test results, the 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 are significant but cannot be measured and accounted for, it may be impossible to predict how the samples will perform in different environments in the future. If this is the case, the test results may be useless.

So, the essence of good field trials is to organize them as a series of experiments designed specifically so that the 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 organizing 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 relevant combination. For example, if there are 5 handpump models and 6 sets of conditions, 5 x 6 = 30 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 handpumps 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 technical problems of physically installing pumps and then replacing them with alternative samples, it would seem easier to identify several separate locations which present the same set (or closely identical) of test conditions.

2.5. Selection of Pumps for Evaluation and Testing

2.5.1 Introduction

With a hundred or more handpump models to select from the international market, the necessity of pre-selecting or screening the candidate handpump is obvious. Some initial steps might include:

(a) Review past experience of water supply programme or project itself, and other projects in the country or region concerned;

(b) Review literature on handpumps particularly the IRC publication "Hand Pumps" and test reports on handpumps;

(c) Review catalogue/directory of handpump maintained by the IRC, and write for manufactures' information;

(d) Determine which pumps are readily available;

(e) Investigate price, both of pumps and parts ;

(f) Assess potential for local manufacture. Other things being equal a local pump is preferable.

2.5.2 Handpump Specifications

Only those handpumps should be tested which will be technically suitable for local conditions. Thus a necessary step should be a survey of the technical specifications likely to be required by the programme.

The following notes provide a check list for preparation of general handpump specifications. For particular installations, data requirements are necessarily more specific, for example, the exact depth of the cylinder setting.

The specifications should be oriented towards a limited number of handpump models based on pre-qualification, preferably through field testing or proven experience under local conditions. This should be supplemented by a component by component review of the design. Proliferation of handpump models in a single programme can lead to difficult maintenance problems - inventories, spares, purchasing, lubricants, training, etc.

Use of a single handpump model would be the ultimate in standardization but should be avoided inasmuch as few pumps are fully suited to all installations and dependence on a single supplier may hamper price competition and factory service.

The performance requirements of handpumps within the programme should be identified, tabulated and categorized. An illustrative example is shown in Table 2.

TABLE 2

NUMBER CATEGORIZATION OF HAND PUMPS PERFORMANCE REQUIRED
(EXAMPLE)

PUMPING HEAD	POPULATION SERVED PER PUMP						TOTAL
Feet (meters)	Columns → / Rows ↓	50	100	300	500	1000	
		V	W	X	Y	Z	
15 (5)	A	5	20	250	6	1	282
50 (15)	B	8	160	27	2	1	198
100 (30)	C	40	23	3	2	4	72
150 (45)	D	0	12	6	4	0	22
200 (60)	E	0	5	2	0	0	7
TOTAL		53	220	288	14	6	581

Analysis of the Table indicates a need for about 282 good quality, durable shallow well pumps (row A) with special maintenance attention for 7 of them (row A; columns Y and Z, that is, blocks AY and AZ).

A moderately-priced deep well handpump can probably be used under blocks BV, BW, BX, VC and CW, about 258 pumps. Blocks CV and CW will require pumps with smaller cylinder diameters.

The remaining 41 pumps will require a heavy duty deep well pump, possibly with a rotary wheel handle and low-friction bearings.

Thus only three handpump models would effectively and economically serve the varied needs shown in the example of the Table.

With the needed inventory now established, the ergonomic (strength, power, etc.) and anthropometric (height, reach, etc.) requirements can be matched with the appropriate ranges of cylinder diameters, mechanical advantage, ahdnle dimensions, stroke lengths, and pumping speed as described earlier. This information should then be summarized and specified for each pump as an allowable range of discharge (Q) for a stated pumping head (H), pumping speed (N), and stroke length (S). Maximum slip and minimum mechanical efficiency can be specified <u>if</u> a means of verification is available. Slip and efficiency are measures of pump quality. A suggested matrix is summarized in Table 3.

TABLE 3

BLOCK DESIGN OF FIELD TEST

(Based on Example of Table 2)

PUMPING HEAD Feet (meters)		POLUATION SERVED	
		100	300
		Y_1	Y_2
15 (5)	X_1	Shallow Well	Shallow Well
50 (15)	X_2	Deep Well	Deep Well
100 (30)	X_3	Deep Well	Deep Well
150 (45)	X	Deep Well	Deep Well

The array above would cover nearly all conditions relevant here. Blocks X_1 Y_1 and Y_1 Y_2 cover nearly all the shallow well configuations. If 3 shallow well handpump models are to be tested, thus 3 models x 2 test conditions would require 6 tests. Two of each handpump model would be needed. A minimum sample size for each model would be X_1 but 8 or 10 would be preferable. When testing, say, 6 of each shallow well models, then (6÷2).(2x3) or 18 shallow well pumps would be required. By similar reasoning, for 3 candidate deep well handpumps (3x2) sets of conditions x 3 models = 18. combinations, requiring at least 6 of each model or a total of 18 deep well handpumps; using 2 of each model in each block would be preferable and the number of deep well pumps to be tested, would be 36.

The total programme would require 18 shallow well plus 36 deep well or 54 pumps in all. . Thus representing about 9 percent of the total project (581 installations).

2.5.3 Dimensional Requirements

In making the final selection, the dimensions and threading of pump rods, drop pipes, cylinders and cylinder caps should all be standardized and interchangeable even between pump models. (They can also be bid separately for the top of the well pump stand assembly). These dimensions must, of course, be compatible with the wells to be used. Additional guidance may be found in the publication "Hand Pumps" (IRC Technical Paper No. 10).

2.6. Sources of Handpumps for Evaluation and Testing

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 is one of the first steps in working out the evaluation project. However, in practice, the two activities will often be done concurrently.

Samples should preferably be obtained through the normal procurement channels, and care should be taken to ensure that sample pumps for field evaluation have not been specially manufactured for testing purposes. If necessary "blind" purchasing should be adopted, i.e., ordering of pumps through intermediaries.

3. CHARACTERISTICS OF PUMPS TO BE EVALUATED

3.1 General

In evaluating handpumps, several characteristics are important. A systematic comparison of each should be carried out. Of course, in reality the parameters are inter-related, and influence each other.

3.2 Costs

Capital costs for purchase of handpumps are generally the paramount criterion in the selecting of handpumps. However, the criterion should be total costs, that is capital cost plus operating, maintenance, and replacement costs. These should be expressed in equivalent terms, e.g. annual or present value costs, or alternatively as life cycle costs. Examples of this type of analysis may be found in the publication "Hand Pumps" (IRC Technical Paper No. 10). Where local currency and labour rates are overvalued relative to world prices, the use of shadow pricing may be necesary to reach sound conclusions.

It is common for a handpump supplier to claim that his pump will last for 15-20 years under normal operating conditions, but this is a far too simplistic approach to maintenance and replacement costs. Each handpump 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 handpump has wearing parts which have to be replaced periodically in relation to 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 determine the economic usefulness of a pump.

Theoretically, the usefulness of a handpump could be extended over a very long period of time by simply replacing worn out or damaged parts one by one as required. One could argue 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. In fact, this would be separate evaluation of each pump component over the project design period. Within this time frame, an estimate would be made of the number of times each component 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 other several times within a 20-year period. One should realise that the costs of spare and replacement parts may be as significant as the original costs of the whole pump. 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 judgements of the probable performance of individual pump parts. Without any test data or historical records, the excercise is largely guesswork.

Some of the most significant factors do not pertain to the handpump itself, but to the maintenance costs associated with the trucks, motorcycles, fuels and manpower required to inspect, service and repair defective pumps.

It is therefore evident that to ensure the selection of the most economical handpump, a careful analysis of all pertinent factors must be made. Obviously, the pump with the lowest initial cost, fewest component parts, longest useful life for each part, and needing the least maintenance, would be the most economical unit. Such a handpump may have a life span of only 10 years and still be more suitable for the task than another expensive unit which has some components capable of lasting 20 or 30 years.

Regardless of the handpump selected, some maintenance costs will always 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, the frequency of service call required for routing maintenance and parts replacement, and the type of equipment needed to service the pumps.

Many value judgements must be made. Field trials will assist in establishing the relative performance of component parts, and so result in more meaningful value judgements than if no test data were available.

Repeating, to the extent practicable the costs should recognize initial costs <u>and</u> recurrent costs.

3.3 Reliability

3.3.1 Introduction

A vital characteristic of any handpump model is its reliability. This factor is one of the major parameters to be measured (or validated) by field trials and tests.

Reliability can be measured as the percent of time the pump is in service. This is a function not only of the pump, but also of the maintenance system and of the conditions of use.

A surrogate measurement often used is the percentage number of pumps in operation at a given time. This is a convenient measurement but it offers the water supply agency no way to distinguish between inherent reliability of the pump and the reliability of the maintenance system. Breakdowns which the maintenance system takes a long time to repair may be "disguised" by blaming the poor quality of manufacture for the high percentage of inoperative pumps.

Reliability actually refers to satisfactory functioning of a handpump over a period of time, more precisely :

- *Reliability of a pump is the probability of its satisfactory performance without failure, under given conditions for a specified period of time.*

Failure is the inability of the pumps to meet the design function. Failure may be described as follows:

Critical	:	No discharge
Major	:	Reduced usability which could ultimately result in critical failure
Minor	:	Departure from established standards but without significant effect on function.

Given conditions relate to the total environment in which the pump is to work including not only the head and discharge but also the maintenance regime. Reliability incorporates both the physical characteristics of the pump and its supporting system, particularly maintenance. The test conditions should stimulate the actual conditions over the long term, not those during the testing period or installation phase.

The design maintenance interval period should be of a minimum acceptable duration to make maintenance feasable. Other things being equal the pump with the longest probable time period without failure obviously is the preferred choice.

3.3.2. Quantifying Reliability

Comparison of pump reliabilities may be enhanced by using, to the extent possible, numerical data. A useful measure is the mean time between critical failures, hereinafter termed the MBTF. Its determination is not easy, as both intensive record keeping and the participation of a reliable local observer, would be required.

In testing and evaluating handpumps, the size of the sample will determine the statistical "level of confidence" with which statements of reliability can be made. This is discussed in the section "sampling".

From a user point of view the pump is not performing its function during the time is unavailable to him because it is awaiting or undergoing repairs. This is often referred to as "downtime" or DT.

The availability (A) to the user can be expressed as a percentage of total time as follows:

Mean Time Between Failure	= MBTF
Downtime	= DT
Total cycle time	= MBTF + DT
Availability	= A

The A as a percentage:

$$A = \frac{MBTF}{MBTF + DT} (100)$$

Reliability can be measured over time in other ways than MBTF; frequency of different failures over a given period, for example. Whatever technique is used should be explicitly described in the testing protocol.

3.3.3. Destructive Testing

Because reliability is a very important parameter, there is considerable merit in "destructive testing". Therefore, it may be worthwhile to consider testing of a fraction of the sample to critical failure as quickly as possible.

To speed the process, these pumps might not receive any maintenance.

Information thus gathered might be used to screen out weak candidate pumps and to guide sample size in subsequent field trials and laboratory testing.

3.3.4. Importance of Record Keeping

Reliability testing and analysis requires good records. The design of reliability experiments should be done carefully, and the necessary data should be established. Because many people, of widely differing backgrounds will be involved, the development of standardized data recording forms and training in their use is mandatory. Some forms used in various field studies are annexed to this report.

3.4 Technical Performance

As in designing a bridge the loading of the handpump must be analyzed in order to design the structure. Factors relevant to the "loading" of handpumps 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) Types of wells, e.g., drilled or dug, and diameters

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

(6) Altitude and temperature (insofar as they affect suction lift).

(7) Availability of alternative water source in event of pump failure.

(8) Ergonomic and anthropometric characterisitics of pump users.

The candidate pump(s) must be matched against the foregoing technical conditions and requirements.

3.5 Acceptability to users

Factors influencing the acceptability of the handpump to the users, include:

(1) Population density
Village or city
Transportation means
Accessibility

(2) Economic Conditions
Caste or Class-system
Interactions between users

(3) Location and distance from pump users and of spare parts supplies and tools.

(4) Religious factors.

(5) Impact of health education if any

(6) Presence of caretaker

(7) Government facilities: offices, location and accessability to people.

(8) Alternative sources of water.

3.6 Maintainability

The resources and infrastructure required (and their availability) for equivalent levels of maintenance service for each pump are factors which enter into the evaluation. For example, will a tripod and/or vehicle be required to lift the pump in order to replace below-ground level pump components.

3.7 Availability

The availability of any handpump is often very much dependent on the manufacturing source. Other factors being equal, a local source has a great advantage.

The purpose of the pump evaluation programme is to select the handpump which can best satisfy local conditions. However, it would be unwise to select a handpump only on the basis of the field trials. If the plant capacity of the supplier of a suitable pump is insufficient to meet the project requirements, or if this manufacturer has a reputation for poor quality control, or slow delivery of spares, then the field performance would be outweighed by the disadvantages of the inadequate after-sales service. To be selected, a supplier must be reputable and be in the position to fully support his project. In addition, the prospective supplier should be willing to modify the design of its pumps to overcome weaknesses identified in the test.

Standardization of the handpump(s) for use in rural water supply programmes is generally accepted as an economical and practical objective. However, if one handpump 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 single supplier, and/or an unrealistically high pump cost due to the absence of competition. Having at least two acceptable handpumps (which might be needed in any case because of the type of service involved) may be considered as a matter of policy.

3.8 Sanitation

The pump should be so designed, manufactured, and installed as to prevent contamination of the well or 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. The spout should be open downward and so designed as to prevent solid objects from reaching the well.

(2) The pump base or enclosure should be so built that a sanitary well seal can be obtained 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 alternative wetting and drying and increases their life and sealing efficiency. The foot valve is less likely to leak with the resultant advantage of the elimination of the need for priming.

3.9 Safety

Any undue hazards to operators, installers and maintainers are to be prevented.

4. EXPERIMENTAL DESIGN

4.1. General

Field evaluation of handpumps if fraught with statistical difficulties. A few:

(1) Multiple objectives often not clearly defined. Many are not subject to numerical analysis.

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

(3) The experiment may have a bias (conscious or unconscious) on the part of the experimenters which is difficult to eliminate.

(4) Random sampling may prove difficult to achieve.

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

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

The preceding comments are intended to suggest caution in conducting and, especially, in interpretating handpump evaluation results.

Designing a suitable evaluation programme for handpumps for use in developing countries must take into account certain limitations:

(1) The pumps vary widely in design so that comparison in some cases is difficult, e.g. the comfort in use of a hand-operated pump compared to a foot-operated one.

(2) The physical, sociological and cultural environments in which the pumps are installed, vary so much that it is difficult to envisage and foresee every kind of problem which could occur.

(3) 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 installed at identical depths. However, in practice this is impossible when testing, this has to be allowed for.

4.2. Steps in Development of Experimental Design of the Evaluation Programme.

A. Explicitly state the handpump evaluation data sought.

- a. Identify the pump evaluation range
- b. Identify constraints
- c. Define scope of evaluation programme
- d. Determine who is to do what
- e. Determine relationship of the evaluation programmes, to the water supply programme it supports.

B. Collect available background information

- a. Identify information sources
  - (1) Publications
  - (2) Previous work
  - (3) Other agencies
  - (4) Pumps available
- b. Tabulate pertinent local information
  - (1) Physical parameters of groundwater resources
  - (2) Logistical and administration data
  - (3) Social and economic parameters
  - (4) Institutional structure
  - (5) Previous handpump experience.

C. Design of Evaluation Programme

a. Consultations with all parties concerned

(1) State handpump evaluation data sought

(2) Outline possible alternative evaluation projects

(3) Choose factors to be studied

(4) Determine practical range of factors, specific numbers and levels of tests, magnitude of difference considered worthwhile, approximate sample sizes

(5) Determine the measurements to be taken

(6) Review sampling variability and test precision

(7) Consider possible interaction of factors

(8) Determine limitations of time, cost, materials, manpower, transport, instrumentation and other facilities

(9) Determine limitations imposed by extraneous conditions, e.g., seasonal weather conditions

(10) Review human and social factors relevant to evaluation and testing

(11) Screen and select initial candidate pumps

(12) Establish major evaluation criteria.

b. Preliminary Design of Evaluation Programme

(1) Prepare a systematic evaluation project schedule

(2) Prepare a budget

(3) Prepare adaptive plans for variations in timing and budget

(4) Choose methods of statistical analysis

(5) Eliminate or reduce effect of variables not under study by controlling, balancing, or randomizing them

(6) Arrange for orderly accumulation of data

(7) Prepare written, detailed evaluation protocol.

b. Review Design with all Concerned

(1) Adjust Programme in line with comments

(2) Spell out the steps to be followed in unmistakable terms and in writing

D. <u>Plan and Carry out the Experiment Work</u>

(1) Develop method, materials, and equipment

(2) Train staff

(3) Select candidate pumps and sample size

(4) Collect evaluation data

(5) Monitor and modify work plans or necessary feedback

(6) Periodically assess and report progress

E. <u>Analyze the Data</u>

a. Reduce recorded data to numerical form

b. Apply proper mathmatical and statistical techniques

F. <u>Interpret the Results</u>

a. Consider all observed data

b. Test if necessary, the data by additional independent experiments

c. Arrive at conclusions on the technical meaning of the results, as well as their statistical significance

d. Describe results in quantitative terms

e. Interpret non-quantitative results

G. <u>Prepare the Report</u>

a. Describe work clearly, giving background, pertinence of the problems, and meaning of the results

b. Use tabular and graphic method of presenting data

c. Supply sufficient information to permit reader to verify results and draw his own conclusions.

4.3. Role of Statistics

4.3.1. *Introduction*

Statistics deal with the collection, analysis, interpretation, and presentation of numerical data. Statistical methods may be divided into two classes - descriptive and inductive. Descriptive statistical methods are those which are used to summarize or describe large volumes of data. They are the kind used everyday in newspapers and magazines. The central tendancy of the data may be summarized by its mean, average, median, or mode. Variations in the data summarized by its standard deviation, distribution, frequency or range.
Inductive statistical methods are used to generalize from a small body of data to a larger set of similar data. The generalizations usually are in the form of estimates or predictions.

4.3.2 *Populations, Samples and Distributions*

The concepts of a *population* and a *sample* are basic to inductive statistical methods. Equally important is the concept of a *distribution.*

Any finite or infinite collection of individual things - objects or events - constitutes a *population.* A population (also known as a universe) is not just a list of things specified by enumerating them one after another, but rather as an aggregate determined by some property that distinguishes between things that do end and thing that do not belong. Thus, the term population carries with it the connotation of completeness. In contrast, a sample, defined as a portion of a population, has the connotation of incompleteness.

Examples of population are:

(a) The workers in agriculture on January 1, 1979

(b) The handpumps within the country today.

Attention to some characteristic of the individuals of a population that is not the same for every individual leads immediately to recognition of the *distribution* of this characteristic in the population.

The distribution of some particular property of the individuals in a population is a collective property of the population; and so, also, are the average and other characteristics of the distribution. The methods of inductive statistics make it possible to predict such population characteristics from a study of samples.

4.3.3 *Statistical Inferences*

If we are willing or able to examine an entire population, our task will be merely that of describing that population, using whatever numbers, figures, or charts we care to use. Since it is ordinarily inconvenient or impossible to observe every item in the population, we take a sample - a portion of the population. Our task is now to generalize from our observations on this portion (which usually is small) to the population. Such generalizations about characteristics of a population from a study of one or more samples from the population are termed *statistical inferences*.

Statistical inferences take two forms: *estimates* of the magnatudes of population characteristics, and *tests of hypotheses* regarding population characteristics. Both are usual for determining which among two or more courses of action to follow in practice when the "correct" course is determined by some particular but unknown characteristic of the population.

Statistical inferences all involve reaching conclusions about population characteristics (or a least acting as if one had reached such conclusions) from a study of samples which are know or assumed to be portions of the population concerned. Statistical inferences are basically predictions of what would be found to be the case if the parent populations could be and were fully analyzed with respect to the relevant characteristic or characteristics.

4.3.4 *Sampling*

In order to make valid generalizations from evaluation results on sample pumps, about characteristics of the total 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 pumps 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 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 likely to be untypical unless the evaluation project staff is allowed to select the samples from a large number.

Precautions to ensure that sample pumps are not different from 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 handpump users themselves.

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.

4.3.5. *Statistical Analysis*

Both the experimental design and the evaluation of the data of the test programme require statistical analyses to ensure its validity. Much useful information on experimental design, sampling, inference technique, etc., is available in standard text books. Many engineers have had at least some formal training in statistics. However, most pump testing programmes should retain an experienced programmatic statistical consultant before, during and after the test evaluation programmes, to advise on the project design, to monitor data collection, and to statistically test its findings. In developing countries, statisticians with expertise in experimental design can probably be found in agricultural universities and experiment stations.

5. ORGANIZING THE HANDPUMP EVALUATION PROGRAMME

5.1 Organizational Set-up

It is assumed that the person responsible for the handpump field evaluation project will have been able to familiarize himself with relevant standards, technical literature on handpumps, and other relevant sources of information. Usually, one person, a Project Officer, should be given responsibility for seeing the project through from start to finish. He should have the necessary authority to carry out his responsibilities.

To carry out an evaluation project will not necessarily require the set-up of a separate section in the water supply agency, staffed by technical experts. It may be possible to engage university staff, technical colleges, government laboratories and experiment station, standard institutes, or consulting engineers to conduct the handpump evaluation project.

The schedule which sets out planned reports for 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.

5.2 Staff Preparations

5.3 Selection of Survey Areas

6. CARRYING OUT THE EVALUATION PROGRAMME

6.1 Initial Inspection

Samples of all pumps to be tested, should be examined. Dimensional and technical characteristics are to be tabulated. Pump cylinders, or equivalent, and material of construction (e.g. brass, cast 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-wheeel 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 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 stainer fitted. Where applicable, internal diameter of drop pipe. If any borehole stablizers required, list their weight, 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 pump components and parts for incipient cracks or other damage.

6.2 Installation of Pumps

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.

Where handpumps are placed for testing purposes, they should be located with care. Pumps should operate under condtions (lift, users, etc.) as nearly as practical to 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 handpumps 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.

6.3 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. 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 must 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. Any required priming should be noted.

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 standard statistical practice or the methods used and the limitations of the survey should be clearly stated.

All data are to be recorded on pre-printed standardized forms and the original copies should be regularly collected and reviewed by the project head office.

Copies of the Report of the Harpenden Rise Laboratory, and Georgia Institute of Technology laboratory and field testing programmes (respectively) may be obtained and reviewed for additional information on performance testing. It should be noted however that the use of electrical strain gauges, at Harpenden Rise, is not likely to be practical in most field situations.

As indicated previously, a small portion of the pumps may have to be tested until "destruction". If necessary this may be artificially accelerated, e.g., by lack of lubrication.

6.4. 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 lifting water into measured volume buckets. Users may 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 should 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 should be measured for 10 percent of the sample. Ambient temperature and humidity should be simultaneously recorded.

7. REPORTING

8.1. Format

The report should describe in narrative form the organization, conduct, and findings of the study. It is generally desirable to have a brief "Executive Summary" at the front of the report for the non-technical reader, administrator, or instructor. Complete data sets should be included as annexes. If voluminous, these could be bound separately in a limited number of copies. The complete report should be desposited with at least one Library, accessible to the public, and with the IRC, in The Hague.

The pumps should be ranked for each relevant category of use, e.g. shallow well, deep well, high intensity use. The operation and maintenance regime should be clearly described for each pump. Where these are no clear cut, significant differences between pump models, the operation and maintenance regime may be marked with identical rankings.

The criteria used for ranking should be clearly described, including the weight given to major factors, such as, costs, maintainability, local manufacture, etc.

8.2. Ranking of Handpumps

Some countries and organizations prefer to use group evaluation for ranking the handpump models. With proper selection of the group members, this practice may indeed result in superior decision-making. Further it relieves the Project Manager of what may be the burden of an unpopular decision with his superiors, aid donors, local manufacturers, etc.

The most informal technique is to have a committee of senior agency officers, deciding on the handpump test evaluation. They may represent different responsibilities within the government agencies, procurement, community relations, maintenance, well-drilling, sanitary engineering, construction, etc. Some officers may not have been directly involved in the testing programme but all should become familiar with it and be provided with the draft project report (excepting the pump rankings of course). They should agree on appropriate evaluation criteria before determining the actual ranking.

A somewhat more sophisticated group evaluation technique is that termed the "delphic panel". A matrix (table listing the pre-selected handpumps, the evaluation criteria, and the pump characteristics) is presented to the panel members who vote independently on each pump and each characteristic. The overall voting result is then reviewed by each panel member who is asked to reconsider his initial assessment in the light of the group evaluation, and then give his reconsidered voting. The "delphic panel" evaluation process may involve several rounds of voting.

Findings of the delphic panel can be summarized in the 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 pannel. 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 rating may be established for pump stand assemblies, cylinder assemblies (or equivalent), and connecting assemblies.

A similar weighting system , a method known as the Simplified Multi-Attribute Ranking Technique (SMART), is described in a companion document.*

*"Guidelines for Testing of Handpumps"

ANNEXES

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
("M 1400", "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

SPECIMEN FORMS

UNICEF WATER & ENVIRONMENTAL SANITATION PROGRAMME
DACCA, BANGLADESH

WELLS INSPECTION AND EVALUATION REPORT

Form RWS/05

1. IDENTIFICATION

Village :
Union :
Thana :
Sub-Division :
District :

2. PUMP

Date of Installation :
Water Discharge Rate
Depth (Well)

3. CARETAKER

Name :
Profession :

4. QUALITY OF SITE

(a) Distance of UNICEF/DPHE Well from :
- Caretaker's house ______ ft.
- a Cluster of houses ______ ft.
- a Tubewell (excl. privrte) ______ ft.
- a Latrine ______ ft.
- Standing water around ______ ft.

(b) Platform
Completed ? Yes [ ] No. [ ]
Intact ? [ ] Broken ? [ ]

(c) Well-
—subject to flooding (1) ? Yes [ ] No. [ ]
—installed on low ground ? Yes [ ] No. [ ]

(d) Slope-
—Sufficient slope to drain away water from
Platform- Yes [ ] No. [ ] and around
well- Yes [ ] No. [ ]

5. USE AND USERS

(a) Population of the Village ______
(b) Population of a cluster of houses where well installed ______
(c) Population using this well ______
(d) Population uses this well for
Drinking [ ] Bathing [ ] Washing [ ]
Other [ ]
(e) Population uses (3) ______ for Drinking
______ for Bathing
______ for Washing
______ for other need

6. WATER QUALITY

Iron content : ______
Chloride content : ______
Water Taste : ______
Cdor : ______

7. MAINTENANCE

a. Pump (2) Lubricated ? Yes [ ] No. [ ]
b. Spare readily available ? Yes [ ] No. [ ]
c. PHE Mechanic last attended the pump : Month______
d. No. of time pump repaired______

e. Pump ever repaired by
Caretaker ? Yes [ ] No. [ ]
Villager ? Yes [ ] No. [ ]

f. Platform maintenance
Satisfactory ? [ ] Poor ? [ ] None ? [ ]

8.

Well accepted ? Yes [ ] No. [ ]

If not, give reason : ______

WES Field Technician

Name : ______
Signature : ______
Date : ______

(1) Situation which will warrant pouring floodwater into the well (pipe).
2) Piston, pins, nuts, and bolts.
(3) Tubewell water, ring well water, pond water, or any other type of water for mentioned purposes.

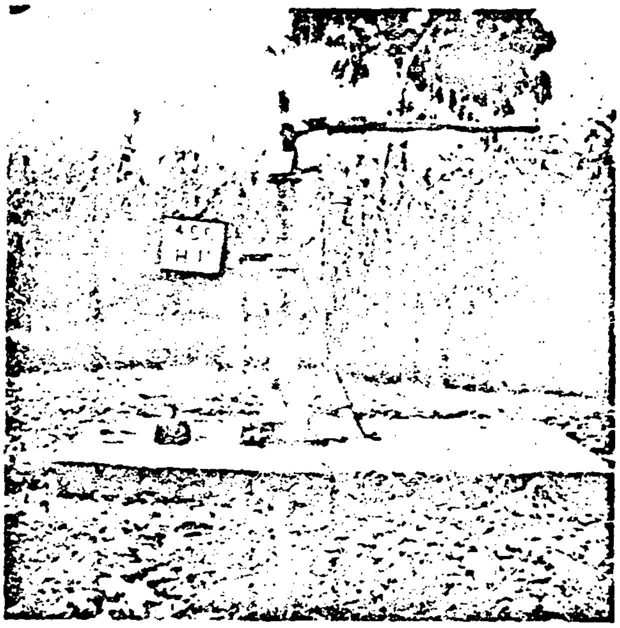
Contractor :	Work Order No : Date :

SEA/psb
7. 4. 78

HAND PUMP EVALUATION PROGRAM

Test Pump Data Sheet

Ghana Upper Region Water Supply Project



Well No. 455 H-15

Manufacturer/Model No. P-3
MONARCH INDUSTRIES LTD.

Pump Type
HAND OPERATED LIFT PUMP

Date Installed
MAY 29TH 1976

Static Level 13 FT.

Suction 45 FT.

General Description
THIS UNIT RECEIVED FOR TEST IN THE UPPER REGION,
TOTALLY NEW DESIGN BY MONARCH. THIS UNIT HAS BALL BEARINGS
AND IS DESIGNATED TYPE "C".
STD. EQUIP. = 1½"ϕ DROP PIPE, 7/16" SUCKER ROD & 3"x10" BRASS CYLINDER.

Prepared by

W. L. WARDROP & ASSOC. LTD.
Winnipeg, Canada

Ghana Upper Region Water Supply Project

HAND PUMP EVALUATION PROGRAM

Summary of Relative Usage Reports

WELL NO. 455 H-15

DATE:	JUNE 25.76	SEPT. 15.76	DEC. 29.76	JAN. 29.77	FEB. 2.77
* READING:	1361.	476.	523.	678.	482.

DATE:	16 MAR. 77	19 APR. 77	13 MAY 77	19 MAY 77	20 MAY 77
* READING:	817.	940.	601.	371.	359.
				1/2 DAY P.M. ONLY.	PART DAY. 8:30 → 16:-

* Represents total gallons per day

REMARKS

MAY 20TH HIRED TWO SMALL BOYS FOR BUCKET COUNTS - PLACED THEM @ WELL SITE FOR TRAINING BY MR. OBNEE.

Prepared by

W. L. WARDROP & ASSOC. LTD.
Winnipeg, Canada

HAND PUMP EVALUATION PROGRAM

Summary of Inspection Reports

Well No. 455 H-15

Pump Model MONARCH MODEL No B3 TYPE "C"

Date Installed MAY 29TH 76

Dates of Inspection Reports:

JUNE 10.76	JUNE 16.76	JUNE 25.76	JUNE 29.76	JULY 12.76	JULY 20.76
AUG 3.76	AUG.10.76	AUG 19.76	SEPT 1.76	SEPT. 10.76	SEPT. 20.76
OCT 1 76	OCT 12 76	OCT. 20 76	NOV 1 76	NOV. 11 76	NOV. 20.76
DEC. 1.76	DEC. 10 76	DEC. 20 76	JAN. 4 77	JAN. 11.77	JAN. 31. 77
FEB 8. 77	FEB. 21. 77	MAR. 1. 77	MAR. 14.77	MAR. 21. 77	MAR. 31.77
APR. 19.77	MAY 3.77	MAY 12.77	MAY 20.77	JUNE 7.77	JUNE 15.77

Prepared by

W. L. WARDROP & ASSOC. LTD.
Winnipeg, Canada

HAND PUMP EVALUATION PROGRAM

Summary of Relative Usage Reports

Ghana Upper Region Water Supply Project

WELL NO. 455 H-15

DATE:	23 MAY 77	24 MAY 77	25 MAY 77	26 MAY 77	27 MAY 77
READING:	451.	587.	774.	752	678.

DATE:	28 MAY 77	29 MAY 77	JUNE 6.77	JUNE 7.77	17 JUNE 77
READING:	673.	421. RAIN	382.	301. RAIN	519.5

Represents total gallons per day

REMARKS

TOTAL FOR ONE WEEK = 4336 GALLONS.

[illegible] 566 [illegible]

Prepared by
W. L. WARDROP & ASSOC. LTD.
Winnipeg, Canada

ข้อมูลการใช้น้ำจากบ่อบาดาลที่ทดลอง

(Data on the use of testing well)

Thailand Handpumps Evaluation and Testing Project

หมู่บ้าน ดงช้าง ต. บัวแดง อ. ปทุมรัตน์ จ. ร้อยเอ็ด

(Village name)

ระยะทางโดยเฉลี่ยจากบ้านผู้ใช้น้ำมาถึงบ่อบาดาล ....200.... เมตร

(Average distance from each house to deep well)

ระยะทางไกลสุดจากบ้านผู้ใช้น้ำมาถึงบ่อบาดาล ....250.... เมตร

(Maximum distance from each house to deep well)

ลำดับที่ (No.)	วัน,เดือน,ปี ที่เก็บข้อมูล (Date)	จำนวนผู้มาใช้น้ำ (No. of Villagers)					ช่วงเวลาใช้น้ำมาก (Period of peak load)				จำนวนครั้งที่โยก (No. of operating stroke)	ปริมาณน้ำที่ได้ (Quantity ลิตร (Litre)
		หญิง (Female)		ชาย (Male)		รวม (Total)	เช้า (Morning)	จำนวนคน (No.)	เย็น (Evening)	จำนวนคน (No.)		
		เด็ก (Children)	ผู้ใหญ่ (Adult)	เด็ก (Children)	ผู้ใหญ่ (Adult)							
1	8 พย. 20	-	-	4	4	8	-	-	15.10-17.51	8	380	
2	9 พย. 20	13	-	5	2	20	6.00-9.61	10	16.05-18.35	9	922	
3	10 พย. 20	10	5	5	5	25	6.00-8.15	14	14.40-17.45	6	920	
4	11 พย. 20	5	-	7	8	20	6.00-7.35	8	16.00-18.10	8	925	
5	12 พย. 20	2	-	9	8	19	6.07-6.20	4	16.10-17.25	8	911	
6	13 พย. 20	2	2	15	8	27	6.14-8.45	8	16.05-18.10	16	1,265	

สรุปข้อมูลการใช้น้ำจากบ่อบาดาลที่ทดลองทั้งหมด

(Data on the use of all testing well)

Thailand Handpump Evaluation and Testing Project

ชื่อหมู่บ้าน (Village - name)	แบบของเครื่องสูบน้ำที่ติดตั้ง (Type- of installed hand pump)	ช่วงเวลาที่เก็บข้อมูล (Data recording period)	จำนวนผู้มาใช้น้ำเฉลี่ยใน 1 วัน (Average daily user)					ช่วงเวลาใช้น้ำมาก (Period of peak load)				จำนวนครั้งที่โยกเฉลี่ย/วัน (Average - operating	ปริมาณน้ำที่ได้ Quantily (litre)
			หญิง (Female)		ชาย (Male)		รวม (Total) (คน)	เช้า (Morning)	จำนวนคน No. of user	เย็น (Evening)	จำนวนคน No. of user		
			เด็ก Children	ผู้ใหญ่ Adult	เด็ก Children	ผู้ใหญ่ Adult							
มลาก	กรมโยธา ฯ	1 กค. 20 1 พย. 20	28.10	55.69	4.61	11.60	125					5,685	4,061
ยโจด	อนามัย 608	25 กย. 20 23 ฦค. 20	57.00	31.38	3.39	8.23	35	5.57–7.27	9	16.46–18.10	20	3,693	1,996
นเซิ่ง	กรมทรัพย์ ฯ	11 กค. 20 9 พย. 20	10.63	51.60	9.22	28.55	26	6.05–7.08	8	17.06–18.28	10	3,042	3,042
ยฝาน	กรมโยธา ฯ	30 กย. 20 22 กค. 20	31.82	57.96	3.66	6.56	118	5.48–7.42	40	16.05–17.26	39	8,299	5,928
นขมิ้น	กรมโยธา ฯ	10 พย. 20 3 ธค. 20	36.61	43.17	15.71	4.51	39	6.01–8.02	15	16.10–19.37	17	1,794	1,281
บสนุก	กองควบคุม ฯ	9 พย. 20 1 ธค. 20	12.33	15.75	13.02	58.90	6	9.20–9.09	3	16.18–18.19	3	547	281
นสมบูรณ์(ขก)	กองควบคุม ฯ	6 พย. 20 30 พย. 20	42.39	42.81	9.45	5.35	40	–	–	–	–	3,752	1,924
ะพานทอง	น้ำกิ้น	7 พย. 20 3 ธค. 20	21.11	70.34	3.46	5.09	120	6.47–7.78	32	16.18–17.56	42	5,000	
ช้าง	น้ำกิ้น	8 พย. 20 6 ธค. 20	12.83	7.21	38.84	41.12	22	6.22–7.07	7	15.33–17.66	11	1,293	
วนาคำ	กรมทรัพย์ ฯ	25 กค. 80 5 ธค. 20	31.23	50.88	10.62	7.27	49	6.18–8.21	19	16.50–17.44	17	1,275	1,275

Form 1

Bimonthly Inspection Report of Water Pumps

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

____

____

____

____

____

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.

WORKSHOP

on

HAND PUMP SELECTION AND TESTING

Harpenden, Herts., U.K.; 29 May through 1 June 1979

Introductory Paper Presented by C.K. "Roger" Stapleton,
I.R.C. Consultant

"Hand Pump Requirements of Rural Water Supply Programmes"

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INDEX

Introductory Paper Presented by C.K. "Roger" Stapleton,
I.R.C. Consultant

"Hand Pump Requirements of Rural Water Supply Programmes"

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1. Introduction

The I.R.C. in particular has been successful in creating an awareness among the international communities of the urgent necessity to tackle the problems associated with hand pumps as a means of making groundwater available to the rural communities. Workshops and Seminars have, in recent times, concentrated on particular aspects of hand pump usage. These are dealt with in I.R.C. Technical Paper No. 10 entitled "Hand Pumps", a report prepared for I.R.C. entitled "Hand Pump Maintenance" also reports emanating from other organisations and international bodies.

However, it is felt that the subject of "Hand Pumps" has not been fully exploited, in that important issues still remain unresolved or that such issues are not universally understood concerning principally: the criteria for selecting hand pumps; factors affecting their selection; and uniform procedure which could be adopted for standardizing monitoring and evaluation of performance.

2. General

In this day and age when much attention is being focussed on man and his environment, it is understandable that water should have a place of prime importance. That every person should have sufficient safe (potable) water for his daily needs is his fundamental right. This is the goal which we would like to see realized today. We have been talking about the increased awareness among rural communities, that to have "good" water readily available is the most important amenity or element in the quest for better health. This has become manifest in real and tangible terms as the ever-increasing number of requests and proposals are emanating from the rural communities themselves for an improvement in their water supply and sanitary conditions, as an initial step to bring about an overall up-grading of their general living standards. This "bottom-up" approach is basically a natural phenomenon and is usually accompanied by a cooperative and voluntary offer by the community to participate at all levels in water supply and sanitation programmes.

Undoubtedly the rural communities are becoming stimulated in their demand for "good" water as a result of the publicizing of proceedings of major events, such as the International Conference on "Water for Peace" which took place in Washington D.C., U.S.A. in 1967;

recommondations which evolved from the World Water Conference held in Mar-del-Plata, Argentina in 1977 which also carried an endorsement of the HABITAT recommendation that safe water and improved sanitation should be available to all by the year 1990; and perhaps to be further influenced by the focus on the "Year of the Child", an event being marked in almost every country in the world this year. Furthermore, the period 1981-1990 has been publicized as the "Water and Sanitation Decade".

Taking water supply on a global scale it is estimated by WHO that in 1975 some 1,200 million people living in rural areas of developing countries lacked reasonable access to safe and adequate drinking water. To attempt to rectify this situation in the simplest of terms might cost in the order of U.S. dollars 40 billion if the task could be completed by 1990. Or realistically appraised by WHO in collaboration with the World Bank, it would require an investment rate amounting to four times the 1971-1975 investment rate maintained through 1990.

3. A Case for Hand Pumps

3.1 General

It is a common understanding that the utilization of hand pumps to deliver water from shallow ground water sources is the simplest, most economical and a readily acceptable form of rural water supply. This is the opinion of a writer in the World Bank publication "Village Water Supply" in which it is quoted "Groundwater, which requires little or no treatment to make it safe, is preferable to surface water. In particular, in the poorest countries shallow wells with handpumps should be used whenever possible. In areas where groundwater is readily available, shallow wells with handpumps are by far the cheapest means of providing a good water supply".

This philosophy is borne out by the fact that hand pump programmes of magnitude are being implemented in such countries as Bangladesh, Pakistan, India and Ghana to mention but few. Sizeable and important hand pump projects are underway in Afghanistan, Kenya, Tanzania, Thailand, Ethiopia, Malawi and other countries. In point of fact, it would be difficult to name a country that has not had hand pumps at one time or another, to provide water.

Hand pumps in general are referred to as simple water lifting devices, which basically is true when compared with most reticulation systems, deepwell power pumps and the like. But in common with all water supply systems, evaluation of a certain amount of basic data of a fundamental nature is necessary to ensure that the most suitable type or model is selected, first having established that the water is potable. The criteria upon which to base the selection of hand pumps, will include:-

- water sources (wells/boreholes), depth to water and yield.
- cost of constructing wells or boreholes.
- estimated average number of people who will use each hand pump.
- who will be responsible for installation, servicing and maintenance?
- financial arrangements for purchase of pump and replaceable parts.
- the feasibility and practicability of local manufacture.
- installation and maintenance procedures - easy or complex?

    etc. etc.

More in-depth selection, will include:-

- an appraisal of specifications collected from a broad spread of manufacturers.
- low production or purchase cost matched with the efficiency desired.
- long life expectancy under severe operating conditions.
- ease of maintenance with simple hand tools.
- simple to operate, especially by women and children.

    etc. etc.

3.2 <u>Selection Process</u>

The selection of the most suitable hand pump is essential and should be thorough, but by the same token it is not desirable that the process should be regarded as formidable. Local situations and circumstances greatly affect or influence the ultimate selection, such as social attitudes of the people who will use the hand pumps, local tradition, local production ability and prospects, types of hand pumps already in use to promote the possibility (and often desirability) to standardize, etc.

In Pakistan, as much data as could be found was researched and criteria for selection was applied by WHO and UNICEF, at a time some three years ago, when the latter organization was requested to assist the Government in the provision of large numbers of hand pumps for an emergency relief programme in rural water supplies. Even then, this proved inadequate, because on this occasion additional assurances had to be sought from the principal manufacturing company that they could locate sufficiently competent small firms to fabricate certain component parts so as to maintain production targets of complete hand pumps. This exercise was also further complicated by the necessity to involve the small firms in the legal aspect of honouring delivery dates for production. Inspection of the completed hand pumps and quality control of component parts did not prove to be an easy matter to arrange and execute.

In Tanzania, UNICEF's assistance to Government coupled with a bi-lateral donor, aimed at producing hand pumps indigenously, has been a protracted association which has resulted in considerable delay in producing the first few hand pumps. Unfortunately the test results showed them to be unsatisfactory due principally to structural weakness in the headmounting. This has been rectified, but subsequent production models are being fitted with some components which are imported. It is believed that the locating of a suitable workshop and tooling it up to produce the prototype hand pumps have been the major set-backs to the programme.

Observations on the Bangladesh Rural Water Supply Cyclone Reconstruction Programme in which UNICEF assisted the Government earlier in this decade, pointed to the necessity to alter the design of the hand pump which was already being produced in large numbers for on-going projects. This decision was reached following an appraisal of all relevant factors in the hand pump selection process. The adviseability of installing more pumps of the same design seemed questionable in view of the volume of parts which would be necessary to maintain them. It was revealed that some vital components wore out in 3 months or less and that many hand pumps were out of commission for periods of 3 to 6 months. This situation gave rise to speculation that the hand pumps were out of order at least half of the time.

The production model of the U.S.T. hand pump in Ghana in 1976 was the outcome of five years intermittent work involving research and testing of prototypes. Even then it was considered to be an advantage to modify the production model, by re-designing the bottom valve to facilitate its withdrawal through the rising main. This modification, together with the ensuing operational testing period, needed a considerable period of time to prove its reliability.

3.3 Technical Factors

Although criteria upon which to base the selection of hand pumps and basic data have been mentioned previously, it is thought necessary to enter into more detail under the headings of technical and non-technical factors in hand pump selection.

Dealing with technical factors, the following headings are relevant:-

a. Hydrogeological considerations. It would be correct, and in some countries it is mandatory, to have the area of a proposed hand pump programme hydrogeologically surveyed prior to constructing wells or boreholes, to ascertain, among other requirements the level of the water table, source of re-charge, safe extraction rate, etc. Institutional capacities for management of ground water resources are ineffective in some countries, therefore programmes for rural water supply which have a high priority rating are (of necessity?) frequently implemented without sufficient hydrogeological understanding.

b. Design characteristics. The depth to water or lift required by the pump is of major importance and will greatly influence the robustness of the design of the hand pump. Yield requirements will also contribute to this aspect and additionally to the dimensions of the barrel and plunger. Water source (well, borehole, etc.) will determine the design of the base. Water quality (mineral and chemical constituents, plus any presence of suspended solids, silt or sand) will have a bearing on the selection of materials to be used for the barrel or liner, plunger, rising main, etc. Physique of the users, plus the lift of the water, will, in part, detail the design of the handle or foot pedal. Receptacles in which traditionally, water is collected, will determine the position and design of the delivery point, spout, etc. Local resources of beneficiaries in terms of ability to instal and maintain hand pumps and, within the country, the possibility to manufacture the pump complete or certain component parts needs careful investigation.

etc. etc.

c. Quality of manufacture. The prevalence of poor quality pumps or a relatively high proportion of those, being defective as supplied in new condition can be traced invariably to a few developing countries which manufacture indigenously. This does not imply that developing countries should not be encouraged to manufacture hand pumps or component parts - rather the opposite is the case. But it does point to the need for tighter design and quality control during the manufacturing process. Common defects are: faulty screwing of threads, rough bores in the casting or the liner, incorrectly balanced constituents in the cast iron, poor quality leather for cups and valves, variables in standard dimensions of component parts, etc.

d. Maintenance requirements. The relationship between new well construction and hand pump maintenance frequently receives insufficient attention when new projects are planned. A hand pump well construction project requires a long-term commitment to maintaining hand pumps and providing spare parts. Whether the financing for new construction comes from internal or external sources, the relationship between construction and maintenance exists and should be considered from the start if the investment is not to be wasted.

There are many reasons that the relationship between construction and maintenance costs is not fully considered. Sometimes the organization responsible for well construction is different from the organization responsible for hand pump installation, which is again different from the organization responsible for hand pump maintenance. Sometimes, without any real justification, it is hoped that the local community will somehow maintain the well. However, experience has shown that maintenance is of paramount importance in a hand pump programme.

Whatever maintenance strategy is adopted, be it government controlled, the three tier system, Thana Stores System[1], village self reliance system or others the underlying aim should be for efficiency. Simplicity must be the keynote to repair and maintain the hand pumps. There is a strong recommendation to standardize the model or type and arrange courses of instruction for those responsible for the repair and maintenance, to teach them to undertake this function efficiently and with dedication[2]. Hand tools will need to be provided to those undertaking repair and maintenance.

e. <u>Guidelines.</u> There are two basic types of hand pumps:-

- the shallow well pump with the pump cylinder above the ground.
- the deep well pump with the pump cylinder below ground and normally submerged in the water.

A rule-of-thumb guide on performance of a typical hand pump is 30 to 40 strokes per minute giving a yield of approximately 30 litres per minute. There are, however, numerous factors which affect the capacity of a pump, such as the lift, strokes per minute, dimensions of the barrel (cylinder), etc.

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1) Described in the Draft Report "Hand Pump Maintenance" by John F. Shawcross for I.R.C.

2) Described in a UNICEF paper "Motivation of Pump Operation and Maintenance Training Programme for Rural Water Supplies in Kenya" by C.K. "Roger" Stapleton, Nairobi, 6 May 1976.

For the shallow well pumps, barrels are often made of cast iron and, to avoid excessive wear on the cups, have a brass or P.V.C. liner. In some instances G.I. pipe is used with a liner inserted. Single cups are mostly fitted, originally made of leather, but now manufactured from neoprene and possibly other plastics. The rods are mostly of steel. Popular barrel diameters vary between $1\frac{3}{4}$ ins. and 3 ins. and from 9 ins. to 18 ins. in length.

Deep well pumps usually have a brass barrel, but P.V.C. barrels are now used extensively. Cast iron barrels with a brass or P.V.C. liner are used to a lesser extent. Double cups made of leather or neoprene are widely used. Popular barrel diameters are similar to the shallow well pump, although due to a longer stroke being preferred, the barrel is necessarily longer, some 2 to 3 feet in length. There are two basic types of deep well pumps: the "closed type" which requires the rising main (or riser pipe) and barrel being withdrawn to replace worn cups, and the "open type" which, because the barrel is of a smaller internal diameter than the rising main, the plunger only need be withdrawn to replace worn cups. The rising main, popularly 2 ins to 3 ins. diameter is either G.I. pipe or P.V.C. - the latter used especially when the water level is not deep. The rods are mostly of steel.

Appropriately classified under the heading of Guidelines can be data derived from the testing of hand pumps. When such data is available, it will contribute to the collection of base line statistics which can greatly influence the selection of hand pumps. Evaluation of reports on the monitoring of pumps under normal operating conditions can be constructive in determining a type or model to suit a specific programme, whilst the reports of laboratory tests might be beneficial in providing design characteristics, strength and chemical constituents of the material for the component parts.

3.4 Non-Technical Factors

Such factors may be difficult to define, but they are inherent in most rural water supply programmes and become manifest during the decision-making phase. For instance, non-technical factors will include:-

a. Acceptance by the rural communities. The introduction of a hand pump, or even a particular type or design must be acceptable to the people, otherwise there is a grave risk that the hand pump will not be used. There are a number of reasons which could lead to rejection, including cultural, lack of health education, or simply that the community anticipated a different water supply system.

b. Responsibility for installation and maintenance. It is not yet a universal understanding or a commitment, as desirable as it might seem, for the beneficiaries to accept this responsibility, even when suitable training is available.

c. Institutional arrangements. There have been instances where the institutional organizations were not orientated or were too inflexible to accept a hand pump programme. In some cases this is because governments have not decentralized their administration.

d. Finance. The sources of finance, level of funding and financial arrangements have a direct impact on the choice of hand pumps, often of a limiting or restricting nature.

e. Political pressure is occasionally associated with the source of funding, especially when foreign assistance is involved.

4. Observations

This workshop is meant to provide a forum for the exchange of views and discussions on the results of pump evaluation and testing; to establish a guide for hand pump testing and a protocol for field evaluation of pumps. In producing this abridged paper it is anticipated that it will provide background information, placing into an overall context the various aspects connected with hand pump requirements of rural water supply programmes. Particular subjects such as maintenance, laboratory and field testing, evaluation, etc., which are supported by independent documentation will be treated as separate entities in the first instance.

The general inference throughout this paper has been for the reciprocating type of hand pump. It is envisaged that the rotor and stator positive displacement type of hand pump will figure in the discussions at this workshop.

Buxton
23 May 1979

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ABBREVIATIONS

I.R.C.	International Reference Centre for Community Water Supply.
WHO	World Health Organization.
UNICEF	United Nations Children's Fund.
G.I.	Galvanised Iron or Steel.

who international reference centre for community water supply

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W.D. - 2

WORKING MEETING ON HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K.,
29 May - 1 June 1979

DRAFT

GUIDELINES FOR THE TESTING OF HANDPUMPS

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1. The Purpose of this Guide

Testing of handpumps in some form or other has often been performed in the past. Frequently, however, the complaint is made that the results of such tests are not borne out in practice, and if the success of many hand pump programmes is any measure of the usefulness of testing, the comment is often true. Nevertheless, many of the tests seem to have been carried out without due consideration for either the methodology of testing or the limitations of such testing, and all too often invalid conclusions have been drawn.

The purpose of this guide is to show the kind of approach that should be used, the principles involved, the uses and limitations of such testing, and how it should be used in the final decision-making process of a handpump programme. The kind of tests to be carried out and the equipment and skills required are enumerated, together with a suitable method of analysing the results.

Moreover, it is hoped that this guide to introduce a standard series of tests, whereby pumps tested by different organisations can be compared directly.

2. INTRODUCTION

2.1 Background

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.

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

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 and consequent lack of, 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.

The problems are thus well known and yet, despite much discussion, expense, and new pump design, remain rife. If a "distilled" reason for the problems were required, it could be stated as "the introduction of ideas and technologies into cultures which have no previous knowledge of them".

Cultural traditions die hard: changing from a dirty water supply, which has been used for centuries, to a clean water supply which must be looked after requires motivation. The absence of this, which may be due to lack of education, tradition of personal hygiene, or to some other reason is the root cause of the appearance of many of the other problems.

Since the problems are predominantly sociological in origin, whence does the need for handpump testing arise? Handpump testing is important for two main reasons -

(a) To enable international and government organisations to purchase pumps suitable for installation in a given area so that capital costs, maintenance costs and overall pump acceptability can be combined to give the best value for money.

(b) Because wise selection of pumps can considerably reduce the impact of those problems which in themselves are extraneous to the pumps. For example, a pump which can operate with practically no maintenance will be of considerable benefit in an area where maintenance services are very poor. At the same time it is essential that the root problems are dealt with as well, rather than placing the whole blame for the failure of a pump programme on the pumps themselves.

2.2 Pump Evaluation

In an ideal situation one could choose a pump which, merely on the basis of its technical performance, price, and maintenance costs, could be manufactured and used anywhere in the world. In the experience of comparative testing organisations it has been found that occasionally one does find a brand of product of sufficient superiority to all others that, it can be considered a "best buy" within a limited geographical area. In the testing of pumps, however, the situation is very different and presents some intractable problems when one considers that the results of such tests should be applicable world wide. In particular three things must be considered, i.e. that -

(a) The costs of installing and maintaining the same pump in different areas of the world will be completely different.

(b) The sociological and cultural traditions of certain people may completely rule out a pump which, from a technical viewpoint, is very good: e.g. It is almost impossible to use brass pump components, particularly cylinders in some parts of Africa, and India as they are likely to be stolen to make jewellery.

(c) The climatic and hydro-geological conditions in which the pumps are installed can vary so widely and affect different pumps in different ways: e.g. a pump may perform well in neutral waters and yet fall apart through corrosion in a water of pH 5.5

A final answer to the question of which pump(s) would give the best overall combination of performance, durability and cost can only be obtained by testing the pump(s) in the situation in which they will be used. However, such field tests are difficult and very expensive if carried out properly with large numbers of pumps. Laboratory testing of the pumps can give indications of those pumps which could perform well, but, to make any decision whatever based on such result, the kind of socio-economic and geological conditions prevailing must be known. Surveys are therefore often a necessity especially in regions where handpumps have not been used before.

Laboratory testing, therefore, can only be regarded as a tool in the final evaluation of a pump and should always be considered as such. It can be especially useful in comparing larger numbers of pumps so that those which obviously will not fulfil the required conditions can be screened out. Field tests can then be performed on a few selected pumps which seem likely to meet the necessary standard.

In brief, therefore, the uses and limitations of laboratory testing can be summarized as follows.

The uses -

(a) The performance of the pump can be determined with regard to efficiency measurements, forces required for operation and stresses in the pump components.
(b) The ease of use of the pump by different users, and the ergonomics of that pump can be investigated.
(c) The design of the pump can be assessed both critically and constructively.
(d) Endurance tests can be performed under a limited range of conditions to give an idea of the components likely to cause failure or require frequent maintenance.
(e) All investigations can be carried out at varying pumping depths. This is a major advantage of laboratory tests over field tests.

The limitations -

(a) Handpumps are tested under standard conditions which, although making comparison between pumps much more reliable, may not correspond to those found in the field in one particular area.
The differences could cause significant problems.

(b) Laboratory testing cannot completely take into account the cultural and social effects on the pump-users, though in many cases one should be able to predict likely consequences if the users way of life is known

(c) Life cycle costs cannot be properly analysed, firstly because of their very wide variation in different parts of the world. Secondly because the life of some pump components is user dependent and cannot accurately be predicted in a laboratory test.

(d) The number of samples which are tested (usually only 1) cannot take account of sample variation or give any information regarding the quality control capabilities of the manufacturer.

As long as the limitations of laboratory tests are realised, very useful results can be obtained which can considerably reduce the decision-taking risk involved in a large handpump programme. It is important however to combine the results of laboratory testing with those of field tests and surveys if meaningful conclusions are to be drawn.

2.3 Current Pump Testing Projects

There are several testing projects known to the authors which are in progress at the present time. These are as follows:-

2.3.1. A full set of tests based on those in this guide is being undertaken by the Harpenden Rise Laboratory of Consumers Association, U.K. the project being funded by the Overseas Development Ministry of the U.K. A total of 12 pumps are being tested in two batches of 6 each. The project is due for completion in March, 1980.

3. THE APPROACH TO TEST DESIGN

3.1 Selection of Attributes

The first stage in any comparative test design is to find out those attributes which the purchaser/user considers to be important when choosing a product to suit his needs. The relative importance of each attribute will vary according to the country and area of application, but they can be divided roughly under five separate headings as follows.

3.1.1 Pump Design

Under this heading can be considered such questions as -

(a) Is the design easily manufactured in a developing country?

(b) Is the pump adequately designed to withstand the heavy usage encountered in developing countries?

(c) Does the pump have sufficient resistance to contamination by external/surface water?

(d) Is the pump robust enough to withstand a certain amount of abuse, attempted vandalism and pilferage?

(e) How easy is the pump to repair and maintain?

(f) Are the materials used in the pump compatible between themselves and with the environment in which the pump will be used?

(g) How easy is the pump to install?

3.1.2 Ergonomic Suitability

This includes such items as -

(a) Is the spout designed to be able to accommodate the use of as many types of container as possible without splashing or otherwise wasting water?

(b) Is the handle height suitable for the majority of the people who will use the pump?

(c) Is the pump reasonably easy and comfortable to operate by the usual drawers of water, who will be women and children in many cases?

(d) What forces are necessary to operate the pump?

3.1.3 Performance

In LDC applications, it is probable that the efficiency of a pump is not particularly critical, provided it is above an acceptable limit. Two items which will be of more than academic interest however are -

(a) How fast water leaks from the pumping cylinder when the pump is not being operated. In practical terms this is "For how many strokes does the pump have to be operated before water appears at the spout?"

(b) What is the volumetric and mechanical efficiency of the pump? In more simplistic terms this reduces to "How much energy is needed to fill a bucket of water?"

3.1.4 Endurance

The main question here is one of reliability and can be summarised in three questions thus -

(a) How often is the pump likely to break down and why?

(b) Which parts are likely to need periodic replacement?

(c) How much preventative maintenance is needed to reduce the frequency of breakdown to a minimum, or at least an acceptable level?

3.1.5 Safety

This last attribute can be quite simply stated "How safe is the pump in use?".

3.2 Discussion of Attributes

The above attributes, considered as questions, comprise the primary considerations when evaluating a pump. When the answers to these have been found for any pump, the overriding questions then become -

(a) How much will be pump cost to buy or to make?

(b) Can the manufacturing quality of the pump be maintained consistently?

(c) How much will the pump cost to maintain in working order and what facilities are needed for this?

Having listed the questions which must be answered it is apparent that many can be resolved by simple laboratory tests, some may require access to more information, (such as might be obtained from surveys) before they can be answered; and some can only be satisfactorily answered by field testing. In particular, the economic constraints and those which may arise from political and cultural environments can only be judged by the organisation installing the pumps on the basis of information from all sources.

The next stage perhaps is to decide which questions can be answered by laboratory tests and to arrange them in such a way that, knowing the kind of tests which can be carried out, they provide a meaningful basis on which the pumps can be assessed. Table 1 shows all the attributes before mentioned, each subdivided into the important component parts which can be more easily recognised. It will be noticed that the design section has been split into two parts viz above ground components and below ground components. This is to make comparison simpler, because on many deepwell pumps the pumpstand, cylinder and connecting assembly can each come from a different source of supply. Some pump characteristics are difficult to confine to one heading and it will be noticed that in some cases there is a slight overlap.
Having laid out in the form of Table 1, all the facts we need to know, and which we hope can be answered at least in part by laboratory tests, the next stage is to discuss how the pumps can be evaluated on a satisfactory basis.

TABLE 1

PUMP ATTRIBUTES TO BE CONSIDERED IN LABORATORY TESTING

PRIMARY ATTRIBUTE	FIRST SUBDIVISION	SECOND SUBDIVISION
How well is the pump stand designed?	How easily can the design be made in a developing country?	What type of equipment is required:- Foundry? Machining? Cutting, drilling, welding? Presswork? Sheet metalwork? Protective coating application? Plastic and rubber mouldings? Woodworking? How much skill is needed to assemble the pump?
	Is the pump adequately designed to withstand the heavy usage encountered in developing countries?	How well does the pump resist external impact loads? Are momentary high stresses possible in any pump component (eg by banging against handle stops)? Are the dimensions of all components, particularly bearings, suited to the applied loads. Are any parts (eg bearings) likely to deteriorate rapidly as a result of airborne dust and/or lack of frequent lubrication. Are all clearances and tolerances consistent with the design specification.
	Does the pump have sufficient resistance to external contamination	Is the spout designed so that external water and other contaminants cannot reach the drop pipe? Is the pumpstand base provided with an effective seal against surface water?
	Is the pump robust enough to withstand a certain amount of abuse, attempted vandalism and pilferage?	Can any pump components be removed without using any tools? Are fixings proof against removal using commonly available implements? Are any fixings or fittings likely to become loose due to vibration, impact etc?

TABLE 1 (Cont)

PUMP ATTRIBUTES TO BE CONSIDERED IN LABORATORY TESTING

PRIMARY ATTRIBUTES	FIRST SUBDIVISION	SECOND SUBDIVISION
(cont)	How easy is the pump-stand to repair and maintain?	
	Are the materials used in the pump compatable between themselves and with the environment?	Are the materials' mechanical properties consistent with the intended use of the pump? Do the materials used, either by themselves, or in combination, pose any likely corrosion problems?
	How easy is the pump to install?	
How well are the below ground components designed?	How easily can the components be made in a developing country?	What type of equipment is required:- Foundry? Machining? Cutting, drilling and welding? Presswork? Sheet metalwork? Protective coating application? Plastic and rubber moulding? Woodworking? How much skill is required to assemble the cylinder and associated components?
	Are the below ground components adequately designed to withstand prolonged use?	Are all clearances and tolerances consistent with the design specification? Are dimensions of all components fitted to the applied loads? Are there any parts likely to deteriorate rapidly if there are small amounts of solid impurities in the water? Is there sufficient resistance to man-handling encountered during installation?
	How easily are the below ground components repaired?	

TABLE 1 (Cont)

PUMP ATTRIBUTES TO BE CONSIDERED IN LABORATORY TESTING

PRIMARY ATTRIBUTES	FIRST SUBDIVISON	SECOND SUBDIVISON
(cont)	Are the materials used compatable between themselves and with the environment?	Are the materials' mechanical properties consistent with the intended use of the pump? Do the materials use, either by themselves, or in combination, pose any likely corrosion problems?
Is the pump ergonomically acceptable?	How well is the spout designed from an ergonomic point of view	Is the spout height correct? Does the water emerge from the spout turbulently, thus causing splashing? Is the water exit pattern predictable and narrow enough to enable the use of narrow-necked receptacles?
	How suitable is the handle height	Suitability for:- Tall men? Short men? Tall women? Short women? Boys? Girls?
	Is the handle comfortable in use?	
	How easy is the pump to operate overall?	By:- Tall men? Short men? Tall women? Short women? Boys? Girls?
	What forces are required to operate the pump?	At:- 7 m? 25 m? 45 m?
How well does the pump perform?	How fast does the water leak from the pumping cylinder when static?	At:- 7 m? 25 m? 45 m?
	What is the overall pump efficiency	At:- 7 m? 25 m? 45 m? Does efficiency vary significantly with pumping speed, or temperature?

TABLE 1 (Cont)

PUMP ATTRIBUTES TO BE CONSIDERED IN LABORATORY TESTING

PRIMARY ATTRIBUTE	FIRST SUBDIVISION	SECOND SUBDIVISION
How durable and reliable is the pump?	What corrosion problems are experienced on	
	Pumping cylinder?	In: Neutral waters? Acid waters?
	Connecting assembly?	In: Neutral waters? Acid waters?
	Pump stand?	In: Neutral waters? Acid waters?
	What mechanical faults occur and how frequently on	
	Pumping cylinder?	In: Clean water? Sandy/silty water?
	Connecting assembly?	In: Clean water? Sandy/silty water?
	Pump stand?	In: Clean water? Sandy/silty water?
	Which components are most liable to wear? on	
	Pumping cylinder?	In: Clean water? Sandy/silty water?
	Pump stand?	In: Clean water? Sandy/silty water?
How safe is the pump to use?		

4. TESTING PROCEDURE

4.1. Scope of Tests

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

4.1.1. 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 breakdowns or wear.

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

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

4.1.4. Performance testing with the pumps instrumented where possible to determine stresses in moving components, efficiency, leakage rates etc.

4.1.5. Within this broad outline it will be best to consider the tests in the order in which they are carried out. The tests described are those which it is felt must be performed if the most reliable conclusions are to be obtained. If any tests are omitted, care should be taken not to extrapolate results beyond their limitations to account for tests not performed or to exclude the possibility of those tests which are not performed, affecting the overall ranking of the pump.

4.2 Buying and Initial Inspection

The first stage in any test is to purchase the pumps themselves. In many cases the choice will have already been made but, if not, some form of market survey and selection procedure will be necessary.

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.

One must be careful, therefore, when ordering a small number of pumps for testing, because, if special modifications are requested with a view to future application in larger numbers, there is a danger that the test samples will be specially prepared prototypes and hence not representative of a larger sample.

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.

It is suggested that a cylinder diameter of 50-63 mm is used for deepwell pumps, if this is appropriate, or alternatively a pumping element which can be used at a depth of 20-40 metres.

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

  (iv) flexible membrane (diaphragm) type

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

It is common practice among consumer organisations, who perform extensive comparative laboratory testing, to code all pumps, usually with a letter or number, and after initial inspection to refer to brands only by their codes, e.g. "Code A". This system defines each pump exactly and avoids confusion when two slightly different models by one manufacturer are tested. It also helps to alienate in the minds of the testers the relationship between a given pump and its manufacturer, thus reducing the possibility of pre-conceived opinions affecting results in any way. It is suggested that this

4.3 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 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 measured e.g. non-circularity of cylinder and variations of this along the cylinder length.

4.4 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 the following points should be taken into account, and the assessment generally should follow the lines of the list of attributes discussed in 3.1.

(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.

All tests and assessments up to this stage can be performed without installing the pumps. Installation is discussed in more detail in Section 4. In brief, though, the pumps must be installed in a suitable tall building (around 10 m), and be provided with a suitable valve in the connecting assembly for simulating different pumping heads. At the installation stage too, all the instrumentation for measuring forces in various pump components should be implemented. The pumping cylinders (or suction pipes in the case of shallow well pumps) should be immersed in a constant level water tank, all water raised by the pumps being returned via a recirculatory system.

4.5 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 stoooping 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.

4.6 User Tests

One intractable problem of user tests is the wide variation 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. Each pump should be tested by 60 people in 10 groups of 6 each, chosen as follows -

Group	Designation			
1	Women		Height (m)	← 1.695 →
2	Women		Height (m)	1.615 - 1.695
3	Women		Height (m)	→ 1.615
4	Men		Height (m)	1.79 →
5	Men		Height (m)	1.68 - 1.79
6	Men		Height (m)	→ 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

The height ranges should be adhered to where possible, but some deviation may be unavoidable in some countries where the anthropometric data of the inhabitants is considerably different from that shown. Children should be aged from 11-13 years and literate. It has been found difficult to get children much younger than this to answer questionnaires

Each user should be allowed to try out the pumps briefly before the actual tests so that they can determine for themselves the most suitable method of operation. They should then be asked to fill a bucket up to a mark on its inside which indicates a volume of 10 litres. A questionnaire concerning the pump is then filled in.

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

Results should be analysed statistically using a two-way analysis of variance applied to each individual group to the overall group means, and to every data item. In this way differences between groups and within groups can be found. Details of this method are given later.

A sample user questionnaire and user instructions are appended at the end of this paper. In the user instructions it is worth emphasizing that one is not testing the users, but only the pumps. Otherwise some users may tend to give biased results.

4.7 Performance Tests

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

4.7.1. Leakage Tests

The rate of water leakage through the pumping element in a reverse direction to normal flow should be measured. The purpose of the test is to determine how much pumping is likely to be necessary before water is obtained at the spout, after the pump has been left standing for somet time.

To carry out the test, for deepwell pumps, the pumps should be operated to make sure that they are full of water, and then the tank should be emptied and the water outlet sealed. Usually the simplest way is to use a securely fixed rubber bung or, if the spout has a tap, simply to close the tap. If neither of these are possible, the head simulation valve should be screwed right down so that it simulates a pumping head of 50 m. The drop pipe will then be effectively sealed at pressures less than this. The drop pipe is then pressurised with compressed air to simulate various heads of water, and the leakage rate of water from the suction valve is measured by collecting the water over a given period (usually five minutes). It is suggested that the test is performed at 7m, 25m and 45m simulated heads.

Measurement of the leakage rate on shallow well pumps is more tricky. The leakage problem is often more important on shallow well pumps and has different characteristics. On deep well pumps the cylinder should always be immersed in water, and thus leakage is always due to water pressure above the valve - i.e. water leakage always occurs.

On shallow well pumps, water leakage only occurs when there is water in the cylinder. After this point it is actually air leaking past the suction valves which causes a further drop in water level.

To carry out the test on shallow well pumps the water tank should be emptied and a displacement can placed underneath the suction (drop) pipe. This should be filled with water and maintained full while the pump is being operated. When water flows from the spout of the pump, the pump operation is halted and, with the displacement can full, a measuring cylinder is placed under the overflow spout of the displacement can. The amount of water collected over a given period of time can then be ascertained. If the water leakage is significant, e.g. such that the pump would lose its prime in a period of 24 hours, it may be advisable to continue the test and plot graphically the leakage rate against time. Any obvious reasons for high leakage rates should be explained in the report.

4.7.2. Volume Flow Test

The purpose of this test is simply to determine how much water is raised by the pump in each stroke, and how this varies with the well depth and the pumping speed. The amount of water collected over a fixed number of strokes is measured at varying speeds (these may depend on the pump being tested, but on average will be between 10 and 80 strokes/min). If the stroke length of the pump is not fixed, then the maximum stroke length should be used. Heads of 7m, 25m and 45m are suggested, the latter two for deepwell pumps only.

4.7.3. 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 dimentsions, and the play in any bearings or pivots.

4.7.4. Operational Characteristics

The purpose of the tests in this section is to determine -

(i) The loads in various pump components, particularly the handle (or foot pedal), and the pump rod, and how these vary with time and pump rod displacement.

(ii) The work done by or on various parts of the pump, particularly that done by the user on the handle, the work done on the pumping cylinder, and how these compare with that theoretically necessary to lift the amount of water actually pumped as found from the volume flow tests. The actual measurements taken will vary according to the pump being tested. The method of measurement can vary considerably but to perform the tests in the best possible way requires the use of complicated electronic equipment. Details of these methods are given in Appendix I and it is suggested that these tests should be performed whenever possible. If simpler and more error prone methods are used, care must be taken in the interpretation of results.

It may seem that the tests in this section are of little more than academic interest, and in the case of a good pump, this may well be true. They can however show up effects which would be difficult to demonstrate by any other means.

e.g. a) high momentary stresses in the pump rod when banging a handle against its stops.

b) high frictional forces in a system, perhaps due to a leather jammed in cylinder.

c) sever flow restrictions in poorly designed valves.

4.8 Endurance Tests

The purpose of the accelerated endurance tests described here is to try and simulate the cumulative effect of a total of around 3 years of pump use (assuming pump is used for 4 hours per day). One must be wary when using such accelerated tests, since results can be different from (usually better than) those obtained in practice. This is because some effects (e.g. metal corrosion and deterioration of plastics) are time dependent. A frequent rest period is thus useful to encourage those effects which occur more during such times (e.g. sedimentation of impurities), but care is still necessary in interpreting the results.

Prior to endurance testing, all pumps should be rigged so that they may be driven mechanically. The drive should reproduce as far as possible the forces on the handle which would be applied in normal use. The suggested speed is 40 strokes/min.

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

(f) the opinions of the users as to the ease of operation.

Endurance tests should continue for a period of 4000 hrs. (running time) with a break of around 1 hour/day and are divided in four stages of 1000 hours each.

(i) For the first 1000 hrs. pumps should lift clean, hard water of a pH around 6.8 - 7.2

(ii) For the second 1000 hrs. soft water of a pH of 5.5 should be used. The pH should be checked regularly (every day or two) and dilute hydrochloric acid added if the pH rises noticeably above 5.5 The chloride concentration of the water should not be allowed to rise above 1 gm/litre.

(iii) For the third period of 1000 hrs, hard water mixed with a very fine abrasive should be used. A natural grade of Kieselguhr (diatomite or diatomatious earth) is suggested which has a particle size of . This is standard, and fairly widely available commercially, being used as a filter particularly in food manufacturing processes. 1gm of Kieselguhr per litre of water should be used. The water must be agitated.

(iv) For the last 1000 hrs. hard water with 1 gm/litre of fine sharp quartz sand should be used. The particle size should be in the range 75-500 μm.

The pumps should be dismantled where appropriate at the end of each stage of the endurance and any wear, corrosion or other deterioration noted. Care must be taken to reassemble the pumps in the exact position in which they were previously. Apart from lubrication, as required, at the start of the test, no preventative maintenance should be carried out. Breakdowns should be rectified as and when they occur and documented fully. The volume flow test (or a check test using the endurance rig speed and pumping head) should be repeated at the end of each 1000 hrs. as should any relevant measurements. At the end of the tests, all pumps should be dismantled and thoroughly examined.

4.9 Other Tests

Occasionally other tests will be required to validate the opinions formed in the design assessment. The most important, which will almost always be required is the impact test on the pumpstand.

The easiest way to apply an impact of the magnitude necessary (up to 500 joules) is to use a swinging pendulum. The pumpstand should be mounted in the normal way. The impact weight can be made in various ways - we suggest a strong leather bag filled with smaller bags containing lead shot. The total weight of the bag should be 50 kgf. The bag should be suspended by a strong rope from a point about 3-4 metres above the pump, so that the weight is level with the central portion of the pump body. The test is then performed by pulling the weight to one side by a predetermined amount and letting it fall back against the pump. By varying the angle to which the weight is pulled it is suggested that the impact load is increased in steps of 100 joules up to a maximum of 500 joules.

It may also be helpful to perform impact tests on the handle of a pump when it is held out approximately parallel to the ground. The impact should be applied at the centre of the handle and limited to a maximum of 200 joules.

Other tests may be required to further investigate any failure which occur on the endurance tests. Examples might be fatigue tests on handles, abrasion tests on certain cylinder materials and special corrosion tests to assess the susceptibility of certain materials to stress corrosion cracking.

5. IMPLEMENTATION OF THE TEST PROGRAMME

5.1 Installation of Pumps

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.

To enable the head to be varied, a special head simulation valve must be fitted in the drop pipe/connecting assembly of deep well pumps. The details of this are given in Appendix II. The valve simulates only the force in the pump rod on the working part of the stroke (i.e. the upstroke on a conventional cylinder). As some pumps rely on the water pressure for correct closure of valves and/or the weight of the pump rod for the movement of the plunger on the return stroke, it is not advisable to have a pump raising water from only a short distance below "ground" level, with the actual head simulated. It has been found that a distance of around 7m from the water level to the pumpstand is much better, with higher heads provided by the head simulation valves. This same height can also be used for testing shallow well pumps. Installation of pumps with around 7m of drop pipe obviously requires a tall building with the pipes passing through several stories. If such a building is not readily available, of adequate size to test a given number of pumps, then a tower built e.g. of scaffolding could be used. In any case access to facilities such as electricity, compressed air and water should be available.

The pump environment must be capable of being temperature-controlled preferably the "above ground" and "below ground" regions of the pumps separately .

As endurance tests must be carried out using several different water qualities, merely pumping water from the domestic supply to waste is out of the question; some form of recirculatory system is necessary. The pumping cylinders of all pumps must therefore be immersed in a tank of water to which all water raised by the pumps is returned. The level of the water in the tank should be kept constant, either by using a weir to provide a constant level or else by using simply a ballcock and overflow pipe.

Some form of internal access to the drop pipe just above the cylinder is also necessary. This is, firstly, so that the pumping pressure of the water can be measured and hence the operation of the head simulation valve checked. Secondly, so that the drop pipe can be pressurised with compressed air, thus simulating the pressure of water on the pumping cylinder seal when measuring leakage rates. This is most easily provided by using a "T" fitting in the drop pipe. A diagram of the overall arrangement of a typical installation is shown in Figure 1 . It should be noted here that strain gauged components will need to be fitted prior to installation of the pumps, and may require slight modification of the drop pipe.

5.2 Organisation of Testing

The actual organisation of the testing of pumps will vary somewhat depending on where the pumps are tested. The plan outlined here is a typical one, though, in some cases, more than one function may be accomplished by one person.

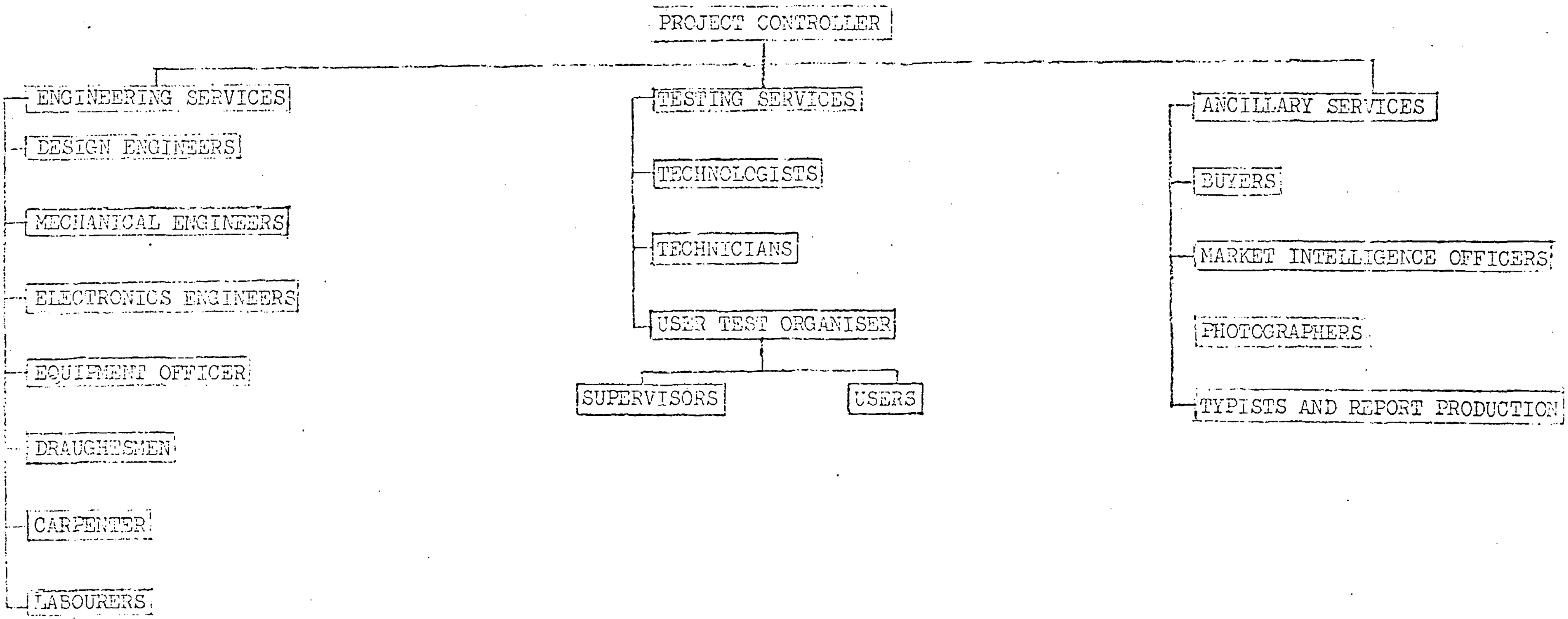
The testing project should be in charge of one person - a project controller, who is responsible for seeing that all the work is accurately carried out within the time allowed and that the report is written correctly. The same person is also responsible for co-ordinating the work delegated to other departments.

The building work, pump installation and all rig work, including design and building of all instrumentation, is undertaken by the Engineering Services department. The actual testing is carried out by the Testing Department, primarily by technologists and technicians.

At various times assistance from ancillary services will be necessary, such as buying, market intelligence, photography and typing and report production. Table 2 shows a typical organisational chart.

TABLE 2

ORGANISATIONAL CHART FOR TESTING



5.3 Equipment Requirements

Much of the equipment required for testing handpumps will need to be made specially. Such items include.

(a) The head simulation valve (details of this are given in Appendix II)

(b) The instrumentation for the pumps. As all the transducers for any one pump must be specially designed and built, one cannot give general details. Appendix I , however, gives examples of the type of equipment which has been built in the past.

(c) The mechanical drives for the pumps on the endurance test. Again these must be designed separately for each pump.

The following list gives a guide to the remaining types of equipment which will be needed for testing only. It does not include equipment for manufacture of rigs.

(a) Measuring vessels (10 ml - 15 litres)

(b) Various sizes and types of containers (50 ml - 15 litres)

(c) Measuring equipment - micrometers
- dial calipers
- bore gauges (25 - 90 mm)
- measuring rules and tapes etc.

(d) Compressed air equipment (valves, taps, pressure reducers, pressure gauges).

(e) Water pressure gauge (0-500 kN/m^2)(0-5 bar)

(f) Stopwatches and timers

(g) Data aquisition and analysis equipment eg highspeed data logger, storage oscilloscope, computer with plotting facilities etc.

(h) Such tools as are commonly used for the installation and servicing of pumps eg spanners, pipe wrenches.

6. ANALYSIS OF THE RESULTS

6.1 Ranking

A selection of pumps can be ranked in with respect to any attribute of the pump. For example the pumps can be ranked based on their efficiency, the pump with the highest efficiency being at the top of the list, and that with the lowest efficiency being at the bottom.

Such a simple, single attribute ranking presents few problems. What happens however when all the attributes of the pump are brought together? How can one reach a valid judgement as to the overall merit of each pump?

There are several ways of doing this, all of which involve personal judgement of some kind, particularly with respect to the relative importance of different pump attributes. One possibility is the Delphi technique which simply involved discussion amongst all interested persons of the test results, and the merits and demerits of each pump. Eventually some conclusion is reached as to which would be the best pump to use. The main disadvantage of such a method is that one tends to disregard results which are neither bad nor good, and merely take notice of those which are outstanding. Hence a pump which does fairly well in all tests may be rejected in favour of one which may be very reliable and yet have many ergonomic disadvantages. One best way to overcome this is to use some form of mathematically based multi-attribute utility analysis. Multi-attribute utility analysis can be very complex and here we will consider what is commonly called SMART (Simplified multi-attribute ranking technique). We suggest this is perhaps the most suitable method of analysis.

6:2 Multi-attribute Ranking

The basis of SMART is a "Weighting Tree".

A weighting tree is quite simply a list of attributes, such as has already been described, with all the main attributes subdivided successively so that they are as unambiguous as possible. When talking of weighting trees it is common to refer to the main attributes as "branches", the first subdivision as "twigs" and the second subdivision as "leaves". The "trunk" of course is the overall merit of a product; in our case, "How good is the pump". Simply having a "tree" of attributes is not sufficient, however, unless we know how important each attribute is relative to the whole pump. In LDC applications, reliability for example may be far more important than performance. Moreover the relative importance of different attributes may be completely different in different countries. In one country, a pump may have to be bought in from abroad, simply because there is no adequate manufacturing facility locally. In this case anything which refers to LDC manufacture is cimpletely irrelevent. In another country, completely the opposite may be true. It can thus be seen that any weighting tree can be strictly true only for a given area in which all the constraints, economic, cultural, social and political combine to affect the balance of the attribute weighting. The logical result is that the "best pump" in one environment will not be the same as the "best pump" in another environment. Weightings can be assigned in two different ways, which are basically similar and produce similar results. Only one will be considered here i.e. the method which is easier to understand and which simplifies subsequent numerical manipulation.

Firstly we set the overall weighting for the pump (simply by convention) to 100. The branch attribute weightings are then selected so that they add up to the total, i.e. 100. In the current example we might have weightings of -

Design of above ground components	=	13
Design of below ground components	=	12
Ergonomics and User Tests	=	10
Performance	=	10
Durability	=	50
Safety	=	5
TOTAL		100

Similarly, the twig weightings are selected so that the sum of the weightings for all twigs on one branch add up to the weighting for that branch. The leaf weightings are similarly chosen.

It can be seen that these weightings, which ideally should be supplied by those with experience of the various factors which contribute to the success or failure of a water supply project, require considerable expertise in accurate judgement of a situation. In general, however, the relative importance of each attribute is obvious, and in the final analysis it is usually a matter of tidying up the relative importance of the less aquatable twigs and leaves. These usually have low overall weightings and thus a comparatively large variation in them affects the overall ranking very little. Ideally a computer program is very useful where one can vary the weightings to determine the overall effect on the rankings.

Having decided the weightings, the next stage is to fit the test results into the weighting tree and to combine them to give an overall score for a given pump. To do this each pump attribute which is not further subdivided (into twigs or leaves) is given a rating, nominally on a scale of 0-10, 0 being poor and 10, very good. This rating is of course based on the test results, or on expert opinion supported by other evidence where possible. The product of weighting x rating is then found, and these products summed for all rated attributes to give an overall score out of 1000 (overall weighting of 100 x maximum rating of 10). When all the overall scores have been determined for each pump, they are placed in descending order; the pump with the highest rating being considered the most suitable on the basis of test results. When other factors, such as the economic and political constraints are taken into account, or results of field tests are known, the pump selected may not be the one which is the highest in the ranking. At the same time it is also true that the pumps at the bottom of the ranking order should not take preference simply because they may be cheap.

The principle of SMART is thus fairly simple. There is one problem which sometimes arises however which will be illustrated by an example.

Suppose that we consider that performance as an attribute is not very important and assign it a low weighting of, say, 10, and that durability and reliability are very important and merit a high weighting of 60. We Could meet with a pump which is very durable and performs adequately at low-medium heads when the water temperature is constant, although, if the water temperature drops by 10°C, we find that the pump performance drops dramatically so that even at fairly low heads a considerable amount of effort is required to produce a trickle of water from the spout.

In an area where the ground water temperature was constant and fairly high, such a pump would pose no problems and the performance could be rated in the normal way. But what if the ground water temperature should vary by as much as 10-15°C during the year? Even if we gave a rating of 0 for performance, the excellent reliability could still make the pump appear high in the overall rankings. At the same time it is obvious that the pump would be unacceptable. The answer to this dilemma is simply that, on such occasions, a rating is awarded which is outside the normal range of 0-10, e.g. in the above case we could give a rating of -50 for performance. This would completely eliminate the pump from further consideration in the overall ranking.

Table 3 shows a typical weighting tree based on Table 1, but with the attributes simply in the form of statements rather than questions.

The assumptions used are -

(a) The pump will have to be bought in from abroad.

(b) The well depths are in the order of 30-40m.

(c) The water is slightly acid and will be free from contaminations such as silt and sand.

(d) Women and children are the main pump users.

(e) Pilferage and vandalism are almost absent.

(f) Village maintenance will prove difficult - a centrally based service team will be provided.

TABLE 3

SAMPLE WEIGHTING TREE

"BRANCH"	BRANCH WEIGHT-ING	"TWIG"	TWIG WEIGHT-ING	"LEAF"	LEAF WEIGHT-ING
Pumpstand design	27	Manufacturing	0	Foundry	0
				Machining	0
				Cutting, drilling, welding	0
				Presswork	0
				Sheet metalwork	0
				Protective coating application	0
				Plastic and rubber mouldings	0
				Woodworking	0
				Skill required for assembly	0
		Adequacy of Design	10	Resistance to impact loads	1.5
				Possibility of high momentary stresses	2
				Dimension/load compatability	1.5
				Resistance to dust and lack of preventative maintenance	3
				Clearances	1
				Tolerances	1
		Sanitary Considerations	3	Spout design	1
				Resistance to contamination	2
		Robustness	2	Resistance to vandalism	0.2
				Resistance to pilferage	0.3
				Security of fixings	1.5
		Ease of Repair/Maintenance	5		
		Selection of materials	5	Engineering	2.5
				Corrosion	2.5
		Ease of installation	2		

TABLE 3 (Cont)

SAMPLE WEIGHTING TREE

"BRANCH"	BRANCH WEIGHT-ING	"TWIG"	TWIG WEIGHT-ING	"LEAF"	LEAF WEIGHT-ING
Design of below ground components	23	Manufacturing Equipment	0	Foundry Machining Cutting, drilling, welding Presswork Sheet metalwork Protective coating application Plastic and rubber mouldings Skill required for assembly	0 0 0 0 0 0 0 0
		Adequacy of Design	11	Clearances Tolerances Dimension /Load compatibility Resistance to man-handling during installation	1 1 1.5 3.5
		Ease of repair/ maintenance	6		
		Materials selection	6	Engineering Corrosion	3 3
Ergonomics	12	Spout Design (ergonomic)	2	Spout height Water turbulence Use of narrow - necked containers	0.8 0.6 0.6
		Handle height suitability	3	Tall men Short men Tall women Short women Boys Girls	0 0 1 1 0.5 0.5
		Handle comfort	1		
		Ease of operating	4	Tall men Short men Tall women Short women Boys Girls	0 0 1.5 1.5 0.5 0.5
		Forces required to operate	2	7 m 25 m 45 m	0 0 2

TABLE 3 (Cont)

SAMPLE WEIGHTING TREE

"BRANCH"	BRANCH WEIGHTING	"TWIG"	TWIG WEIGHTING	"LEAF"	LEAF WEIGHTING
Performance	8	Leakage rate when new	2	7 m 25 m 45 m	0 0 2
		Overall efficiency	6	7 m 25 m 45 m Efficiency variation (with speed or temperature)	0 0 3 3
Endurance	25	Corrosion (cylinder)	2	Neutral waters Acid waters	0 2
		Corrosion (connecting assembly)	2	Neutral waters Acid waters	0 2
		Corrosion (pump stand)	2	Neutral waters Acid waters	0 2
		Mechanical faults (cylinder)	5	Clean water Sandy/silty water	5 0
		Mechanical faults (connecting assembly)	3	Clean water Sandy/silty water	5 0
		Mechanical faults (pumpstand)	5	Clean water Sandy/silty water	5 0
		Wear (pumpstand)	3	Clean water Sandy/silty water	3 0
		Wear (cylinder)	3	Clean water Sandy/silty water	3 0
Safety	5				

6.3 Transfer of Raw Data to the Ranking System

One part of the SMART system which can involve some subjectivity is the transfer of the data as derived from the tests into the form of a 10 point scale. In order to reduce this as much as possible it is desirable to standardise on the way the rating is decided from the results. Appendix III gives guidance as to how this should be carried out where this is feasable. There are however, areas, where simply due to the wide variation in pump design, this is not possible, and some form of expert judgement is necessary.

7. REPORTING RESULTS

7.1 Format

Writing any report involves the author's personal stype, and in some cases it may be difficult to be specific as to the layout of a report, without intruding on this. Considering the wide readership of a test report, and the desire to have some consistency between reports issued by different laboratories, some type of standard format is necessary however. Since such a report is designed to be used in conjunction with this guide, detailed description of tests will not be necessary. The following layout is therefore suggested for the final report on any test programme, though an interim report many, of necessity, depart somewhat from this.

(1) Summary

Every report should carry a summary of the findings for every pump tested so that a casual reader can quickly obtain an overview of the test programme.

(2) Introduction

Contains general background information relative to the project, the choice of pumps for test and relevant information concerning the buying of the pumps for the tests. Pump costs as bought should be given.

(3) Inspection

Gives details of inspection carried out, a list of the pumps tested ... codes stated specifications and manufacturers.

(4) Installation

A brief description of the installation where necessary.

(5) Pump Features and Construction

The purpose of this section is to show the important features of the pumps and their construction in such a way that the reader can understand the method of operation of each pump and have sufficient information to organise suitable transport, equipment and labour for installation or repair. Photographs and schematic drawings of each pump should be given together with brief descriptions of the pumps and any distinctive features which could affect installation requirements. Also, all relevant dimensions, weights etc.

(6) Design

A full description of the design assessment should be given here. Results are best presented based on the weighting tree with ratings for each item and suitable comments. Also given should be the results of any tests carried out to validate opinions formed on examination of the pumps eg impact tests.

(7) Ergonomics

The ergonomic assessments and measurements should be described and recorded here together with the ratings for the SMART.

(8) User Tests

The organisation, design and results of the user tests should be described. For each question on the questionnaire the mean result for each pump in each group should be given and mean result overall. Least significant differences at a 95% confidence level should be given and a list of those pumps which are significantly better or worse than average. The relevant ratings for use with the weighting tree should also be recorded.

(9) Performance

All performance tests carried out should be described. Leakage test results can be tabulated directly, as can any cylinder measurements. Volume flow tests are best given graphically, i.e. graphs of volume/stroke against pumping speed for all relevant pumping heads. The force/time and force/displacement graphs obtained from the instrumented pumps may be given if desired but the results will be so numerous that a summary may be better. In addition, the ratings for the performance section of the weighting tree should be given.

(10) Endurance Tests

The design of the mechanical rigs should be enumerated, together with the pumping heads used for the endurance tests and the reasons for the choice of the latter. A full account should then be given of everything which took place during the endurance tests, the results of all examinations and any confirmatory evidence, e.g. wear measurements. The ratings for the durability section of the weighting tree should also be given.

(11) Safety

An assessment of the safety of each pump should be given, based on the experiences of the test programme.

(12) Analysis of Results

In this section the ratings for every relevant pump attribute should be brought together and tabulated, complete with the ranking results for the sample weighting tree given in Table 3. Results for other weighting trees may also be given

(13) Conclusions

Attention should be drawn to pumps which are likely to prove particularly good or bad in any situation, simply from their mechanical construction. Any likely problem areas with pumps should be described, especially any which are unusual (e.g. if the performance of a pump varied with temperature).

7.2 Verification

Because of the importance and financial implications which the test results have, it is common practice among Consumer Organisations to send "data checking sheets" to the manufacturer.

A data checking sheet is a list of the test results for one pump, with a brief description of the tests carried out where necessary, together with any suitable comments.

By this means the manufacturer has the opportunity to comment on the results before the final report is issued.

If any adverse comments are received, the testing organisation has the option to repeat tests where necessary, or to reject the comments, if it has full confidence in the results.

7.3 General Hints

To enable consistent comparisons between different reports, it is essential that units should be consistent. SI units should be used in all cases. The most important units in the case of pumps will be -

Length	metres (m) or millimetres (mm)
Time	seconds (s)
Pressure or stress	Newton/metre^2 (Nm^{-2})
Force	Newtons (N) or Kilogrammes force (kgf) if necessary
Torque	Newton metres (Nm)
Volume	Litres (L)

8. CONCLUSIONS

This paper has attempted to show how pump testing in controlled environments should be approached, the kind of information which can be obtained and the pitfalls to avoid. The methods which can be used have been enumerated, but these are not necessarily mandatory; the final aim is results which are consistent, repeatable and comparable. There are details which may need to be altered in the light of subsequent experience, but it is hoped that in the main it will help in running of test programmes and hence bring nearer the final goal - the availability of clean water for the vast majority of the worlds population.

APPENDICES

APPENDIX I

INSTRUMENTATION OF PUMPS FOR PERFORMANCE TESTS

It is difficult in a guide of this type to specify how a pump should be instrumented, especially since every pump will be different. The aim however is to be able to measure the forces on the pump (handle or foot pedal) exerted by the user, and how these forces are transferred through the pump linkage to appear at the pumping element. Using calibrated strain-gauged pump components is the easiest way of determining forces accurately and with a high resolution with respect to time.

On a typical, conventional hand-operated pump there would normally be three strain-gauged components. viz

(i) the handle, to measure the forces applied by the user,

(ii) the bearing pin at the top of the pump rod, to measure the force applied to the top of the pump rod,

(iii) the bottom of the pump rod, just above the plunger, so that the force on the plunger can be found. (On deepwell pumps only).

A linear transducer is also fitted to the pumpstand so that the pump rod movement can be determined using an analogue electrical output.

The transducer at the bottom of the pump rod is difficult to make because it must be immersed in water and, moreover, the electrical output must be taken outside the drop pipe from a moving pump rod. Details of this and various other types of instrumented components are given at the end of this appendix.

Some form of data acquisition system is necessary for the instrumentation This can vary considerably. Ideally, all outputs should be capable of being recorded simultaneously and at a fast sampling rate. A good system might consist of a suitable multiple input strain gauge bridge, each input with its own operational amplifier so that the outputs can be calibrated and matched, connected to a high speed data logger. The sampling interval should not be more than 80 milliseconds and should preferably be much less e.g. 10 ms. The data can then be recorded on magnetic tape and analysed directly by a computer. If a suitable datalogger is not available, a storage oscilloscope could be used but this is far less flexible.

It is suggested that data should be recorded for a 10 second interval while the pump is operated (preferably manually) at fast and slow speeds and at pumping heads of 7m, 25m and 45m where applicable. From the recorded data the following can be produced.

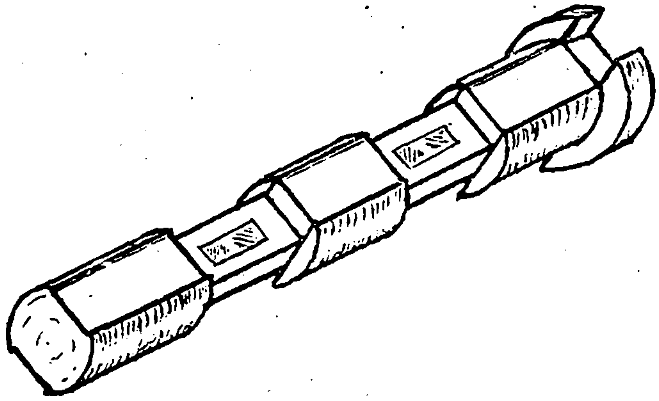
(i) Graphs showing the variation of force with time for each pumping condition and for each instrumented component.

(ii) Graphs showing the variation of force with pump rod displacement for each relevant condition.

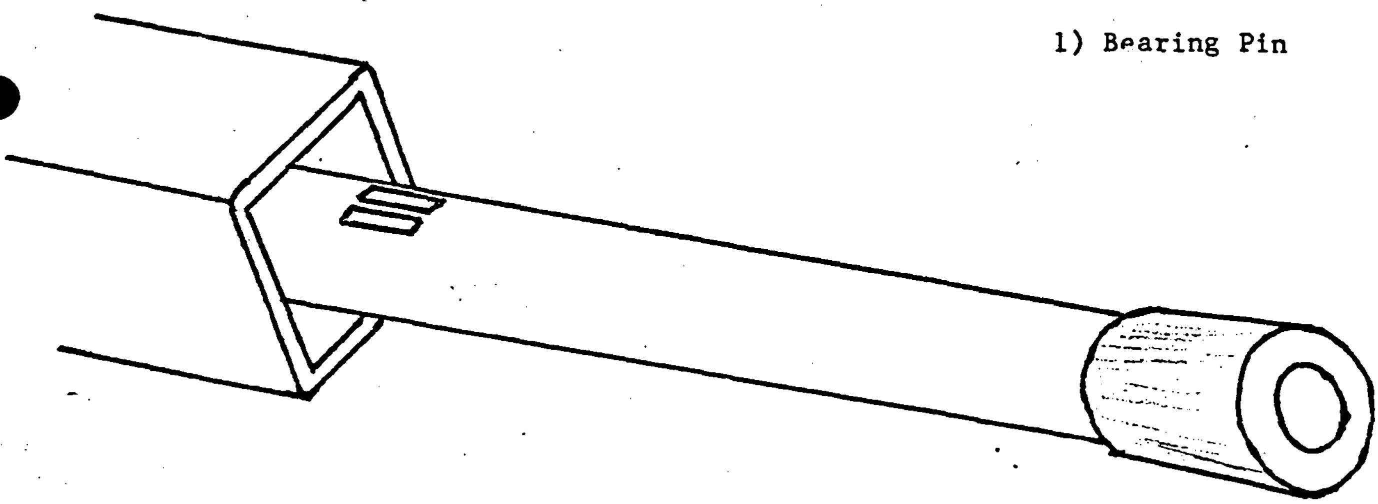
(iii) Actual work done for each situation, by integration of the force displacement graphs.

(iv) Calculations of the efficiency of the pump for each situation.

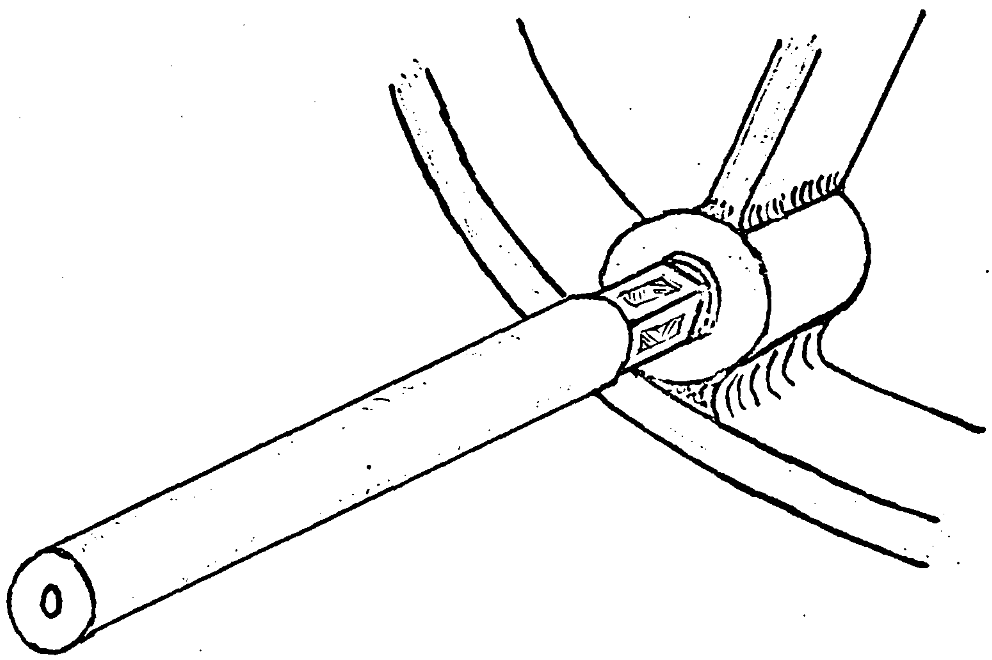
EXAMPLES OF STRAIN GAUGED COMPONENTS USED IN PUMP TESTING



1) Bearing Pin



2) Handle (reciprocating)



3) Handle (rotary)

APPENDIX II

THE HEAD SIMULATION VALVE

The purpose of the head simulation valve is to enable different pumping depths to be simulated easily without having to pump water from the actual depth concerned. The design shown here is one which has been fully tested and proved. It is in effect a modified safety valve, with the addition of a long sleeve to accommodate the pump rod, the sleeve providing a labyrinth seal. Figures 2 and 3 show respectively a drawing of the valve and a photograph of the valve components prior to assembly. Full drawings and a list of components are available from the publishers if required.

The use of such a valve requires certain precautions to be observed. Firstly, the valve simulates only the water head on the working stroke. Since some pumps required the waterhead on the return stroke to close valves, or a long pump rod length to give sufficient weight to return the plunger, it is not advisable to use the valve to simulate fairly low pumping heads. It is suggested that at least a 7m static head should be available as under normal pumping conditions, and the valve used only to simulate heads greater than this. Secondly, the valve cannot simulate the inertial effects of water in the drop pipes. One should therefore be careful particularly when examining the performance/efficiency measurements done at high speeds and high heads, as it is possible that the instantaneous forces recorded may be rather low owing to this limitation.

Figure 2

WATER HEAD SIMULATOR

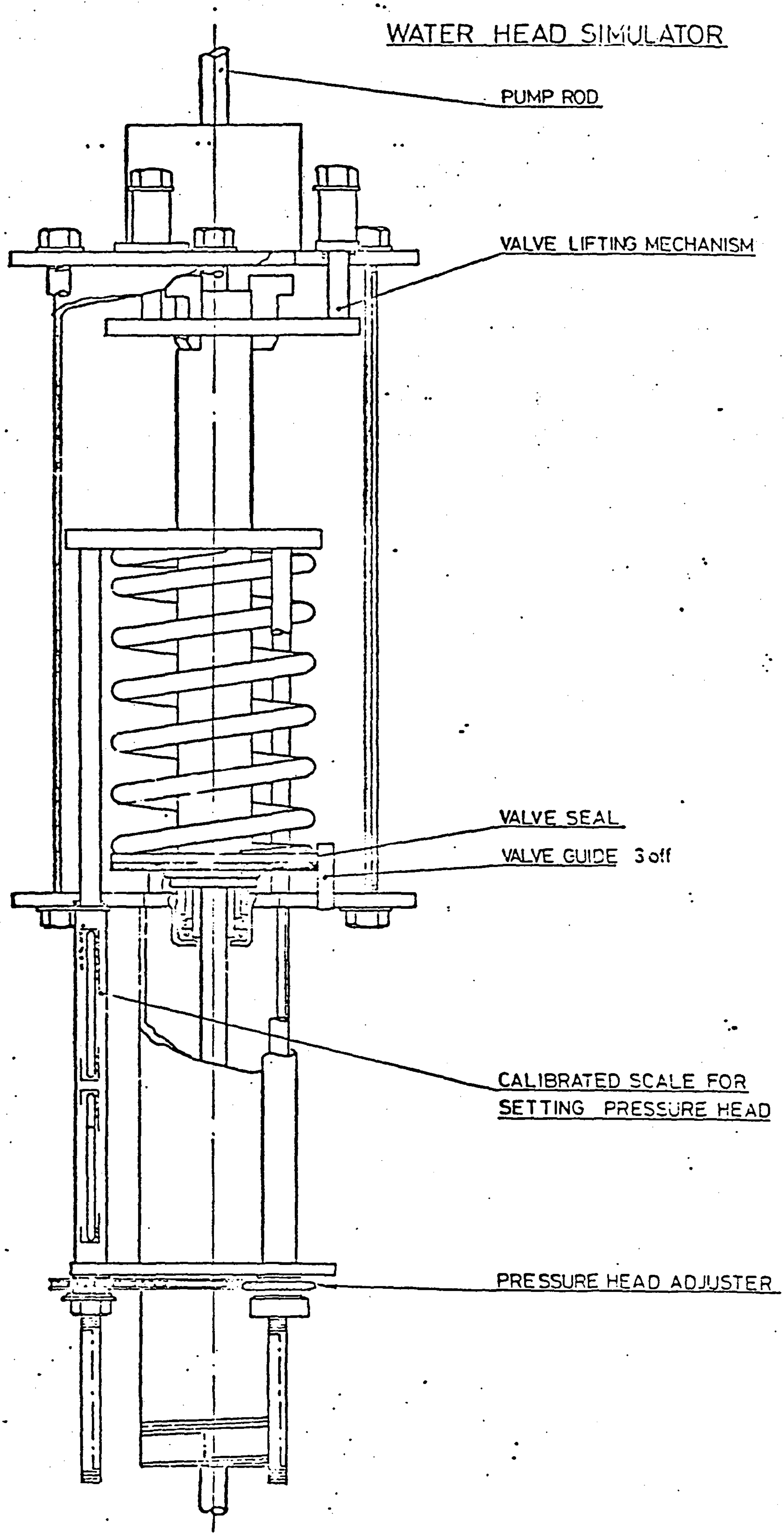
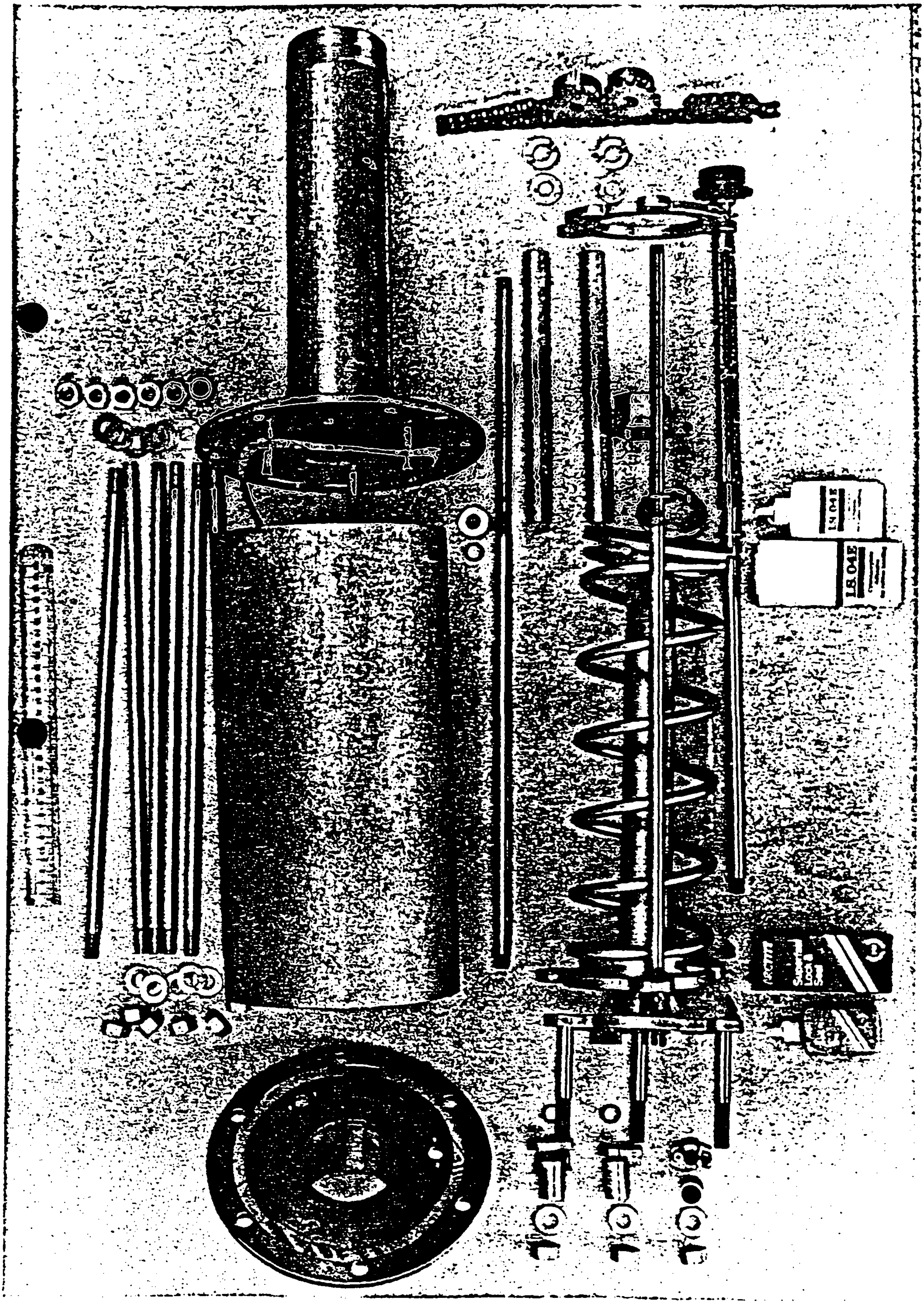


FIG. 3

PHOTOGRAPH OF DISMANTLED HEAD SIMULATION VALVE



APPENDIX III

TRANSFER OF TEST DATA TO A TEN POINT SCALE

"BRANCH"	"TWIG" OR LEAF"	SUGGESTIONS FOR SCALING OF DATA
Pumpstand Design	Manufacturing	For any of the manufacturing method in Table 2 a rating of 0 is given if the particular method is used extensively, and 10 if it is not required. A suitable rating between 0 and 10 can be given under the heading "Protective coatings" depending of the ease of application and the equipment required. We suggest e.g. 8 for a painted finish, 0 for a galvanised finish. For the heading "skill required for assembly" the ratin is inevitably subjective. A pump should be down rated when e.g. a) Accurate hole alignment or positioning is required. b) Complex and error-prone foundry work is required. c) Very accurate dimensions are required. d) Pump mechanism is complex.
	Resistance to impact loads	This rating should be based on impact tests. The following scale is suggested as a guide. 10 - No damage to handle or pump body likely by impacts up to 600 joules. 8 - No damage to body by impacts up to 600 joules or handle impacts up to 200 joules 6 - Some damage likely by higher impact energies. 4 - Some damage likely by medium impacts under certain operating/handle positions. 2 - Damage likely by fairly low impacts in certain operating/handle positions. 0 or less - Impact damage likely by low impacts under any conditions.
	Possibility of high momentary stresses	This rating can be determined from the design and comparison of this with the graphs showing the pump rod stress or load with time during pumping. The following scale is a guide. 10 - No high momentary stresses possible (e.g. rotary pump with low inertia handwheel). 8 - Momentary stresses possible, but fairly limited (e.g. high inertia flywheel where high handle loads are needed for starting and stopping). 6 - Momentary stresses possible, and can be fair high but only if harsh pumping action used. (e.g. conventional reciprocating pump with rubber stops). 4 - Momentary stresses likely but limited by some form of cushioned stop.

APPENDIX III

TRANSFER OF TEST DATA TO A TEN POINT SCALE

"BRANCH"	"TWIG" OR "LEAF"	SUGGESTIONS FOR SCALING OF DATA
Pumpstand Design (cont'd)		2 - Very high momentary stresses possible but only with harsh pumping (e.g. metal to metal stops). 0 or less - Very high momentary stresses almost impossible to avoid. (e.g. metal to metal stops with banging occurring on almost every stroke).
	Dimension/ Load compatability	It is difficult to specify a scale here because of the wide differences in pump design. Pumps should be down rated if projected bearing areas are too small for the actual load, if pump rods are too small or connections inadequate, metal thickness too small etc.
	Resistance to dust and lack of preventative maintenance	Again, a scale is difficult to specify. Pumps should be be downrated if there are e.g. a) unsealed bearings (especially ball and roller bearing. b) sliding joints which are difficult to seal c) sliding joints which require occasional lubrication. d) plain bearings which require lubrication. e) stuffing box requiring checking of packing.
	Clearances Tolerances	Ratings for these parameters are difficult to lay down. Generally however: 10 = all clearances/tolerances (especially on pinned on plain bearings) are correct. 1 = clearances/tolerances on at least one important moving part are excessive.
	Spout Design	The rating should be the sum of the following, given if the statement is true. 3 - spout points down (at least 45°) 3 - spout has bend to prevent sticks being pushed in 2 - spout cannot be moved by hand 2 - spout is not excessively wide (i.e. not greater than 30 mm internal diameter
	Resistance to contamin-:ation	The following is a guide to the rating scale. 10 - Very good seal against surface water (well casing protrudes within the pump stand). No possibility of contamination from the pump itself. 8 - Seal good in most cases, but a cracked concrete apron could allow slight contamination by surface water. 6 - Adequate seal possible if well apron smooth and flat and pump secured properly 4 - Contamination possible either from an inadequate base design or from within the pump. 2 - Well contamination likely due to poor pump design. 0 - No attempt made at sealing the well head -

APPENDIX III

"BRANCH"	"TWIG" OR "LEAF"	SUGGESTIONS FOR SCALING OF DATA
Pumpstand Design (cont'd)	Resistance to vandalism	This is difficult to specify as it has so many aspects. Pumps should be downrated if, e.g. a) any parts are easily removable without tools or using simple widely available implements b) The pump is weak in any way such that it can be broken using the muscle power of one man only. c) Dirt and other abrasive material can be easily placed on or near moving parts (e.g. bearings) so as to reduce their working life.
	Resistance to pilferage	Again rather difficult to specify. Pumps should be down-rated if e.g. a) Fixings are easily removable (e.g. split pins) b) Nuts and bolts are of common, easily accessible sizes. c) Any part is likely to have a wide alternative use d) There are many external fixings. N.B. Socket head screws should be more highly rated than hexagon head ones.
	Security of fixings	This can overlap slightly with the last rating. Pumps which are highly rated should have very few fixings and these should be very secure (e.g. locked nuts either using jam nuts, self locking nuts or locking washers). Pumps which have simple nut and bolt fixings, especially when these are on a cast iron surface should be poorly rated.
	Ease of repair/ maintenance	Rather a difficult assessment. Pumps highly rated should be capable of being maintained/repaired within about 15 minutes using a few simple hand tools only (this refers to the pumpstand only of course). Pumps should be downrated if:- a) Special tools are required. b) Worn or broken bearings require the replacement of a complete unit (e.g. a handle) c) Replacement of any part involves critical realignmer d) Any repairs are likely to require joining processes (e.g. welding) not easily available in the field. e) any breakage of the concrete apron could be necessar
	Selection of materials (Engineering)	Pump can be given a rating of 10 if all materials used are suitable for the use intended. Pumps can be downrated if e.g. a) brittle materials are used in places likely to receive impact loads (e.g. white or grey cast iron for a handle) b) Like materials are in moving contact (e.g. chromium plated steel), and hence are likely to spawl. c) Materials have the wrong engineering properties for their application (e.g. natural rubber in atmospheric conditions).

APPENDIX III

TRANSFER OF TEST DATA TO A TEN POINT SCALE

"BRANCH"	"TWIG" OR "LEAF"	SUGGESTIONS FOR THE SCALING OF DATA
Pumpstand Design (cont'd)	Selection of materials (corrosion)	A rating of 10 can be given if all materials used have either by themselves, or in contact with other parts of the pump, a low rate of corrosion. Pumps should be downrated if any corrosion can occur, dependent on its likely effect e.g. the use of improtected, or inadequately protected iron or steel. The use of metals such as copper or brass in contact with galvanised steel can also cause problems.
	Ease of installation	Again a rather subjective assessment. Any pump which can be installed completely by hand without any lifting equipment and by two people only should be highly rated (9 - 10). Pumps which are fairly simple to secure, which require some lifting equipment, but have a fairly small rising main (1¼ - 1½") should be rated average (4 - 6). Particularly heavy pumps with large rising mains (2½") should be rated poor. Other features may serve to downrate a pump somewhat. For example, poor pump rod threads, or rising/main pump rod mismatch could cause cylinder/plunger alignment problems.
Design of below ground components	Manufacturing Equipment	This should be rated similar to that for the manufacturing equipment required for the pumpstand.
	Clearances Tolerances	Ratings for these parameters are difficult to lay down Generally however 10 = all clearances/tolerances correct 1 = many incorrect clearances/tolerances e.g. leathers incorrect sizes/thickness incorrect valve lift incorrect valve side play excessive resistance to water flow
	Dimension/ load compatability	A specifications of ratings is again very difficult here because of wide variation in design. Generally pumps should be downrated if valve design is inadequate, cylinder wall thickness too small (particularly on PVC cylinder), screw threads too small etc.
	Resistance to man-handling during installation	Pumps should be downrated if there is anything which could be easily damaged during installation e.g improtected external plastic components, easily dented cylinders etc.
	Ease of repair/ maintenance	Inevitably a somewhat subjective assessment, similar to that for the pumpstand. Below ground components are always more difficult to repair than above ground component and therefore the scale should not be directly comparable. The following is a guide:-

APPENDIX III

TRANSFER OF DATA TO A TEN POINT SCALE

"BRANCH"	"TWIG" OR "LEAF"	SUGGESTIONS FOR THE SCALING OF DATA
Design of below ground components (cont'd)	Ease of repair/ maintenance (cont'd)	9 - 10 - Pumping element can be removed by hand from all but the deepest wells. Repair of cylinder is easy. 5 - 6 - Both plunger and footvalve are extractable without moving the drop pipe. Pump head easil removed to access drop pipe without lifting equipment. 3 - 4 - Lifting equipment required to remove cylinder from well. Time consuming operation but cylinder repair not difficult once removed. 1 - 2 - Heavy lifting equipment required. Time consuming, and cylinder repair difficult once removed.
	Materials Selection (Engineering)	Rating should generally be on the times specified under Pumpstand Design - materials selection. Especial notice should be taken of valve seat materials, especially with ball valves.
	Materials Selection	Again rating should be as defined under pumpstand design. Two common corrosion defects found in pumps are the use of galvanised rod and pipe in contact with brass pumping cylinders, and the use of brass which is not resistant to dezincification.
Ergonomics	Spout height	The optimum spout height may vary with the location and car be altered by the type of pump mounting. Generally however the optimum height is in the range 480 - 550 mm. The scale suggested is: 480 - 55 mm - 10 550 - 600 or 440 - 480 - 9 600 - 650 or 410 - 440 - 8 650 - 700 or 380 - 410 - 7 700 - 750 or 360 - 380 - 6 750 - 820 or 345 - 360 - 5 820 - 900 or 330 - 345 - 4 900 - 1000 or 320 - 330 - 3 1000 - 1150 or 310 - 320 - 2 >1150 or <310 - 1

APPENDIX III

TRANSFER OF DATA TO A TEN POINT SCALE

"BRANCH"	"TWIG" OR "LEAF"	SUGGESTIONS FOR THE SCALING OF DATA
Ergonomics	Water Turbulence	This is of necessity a subjective assessment. A rating of 10 should be given for a very stable, smooth water flow, around 4 - 6 for an unstable and inconsistent, slight spreading flow, and a very low rating, 1 - 2 for a very turbulent flow which spreads considerably from the spout causing considerable splashing.
	Use of narrow necked containers	This is simply a subject ease of use assessment on a scale of 10 - very easy to use to 1 - very difficult to use. The rating really takes into account the spout height, the water exit pattern and the turbulence.
	Handle height suitability	The ratings here can be taken directly from the statistical analysis of the user tests. As results are unlikely to show sufficient statistically significant variation for a ten point scale in full it is suggested that the mean results for each group of users are transferred to the following scale. 8 - handle height just right 6 - handle slightly too high or slightly too low 4 - handle too high or too low 2 - handle much too high or much too low.
	Handle comfort	The rating here should be based on the overall handle comfort results (i.e. analysed over all groups of users) The following scale is suggested 9 - handle much more comfortable than average 7 - handle significantly more comfortable than averag 5 - average comfort 3 - handle significantly less comfortable than averag. 1 - handle much less comfortable than average.
	Ease of operating	Ratings for this attribute can again be taken from the results of the user test question "How easy is the pump to use". The following scale is suggested:- 9 - much easier to use than average 7 - significantly easier to use than average 5 - average 3 - significantly less easy to use than average 1 - much less easy to use than average.
	Forces required to operate	The ratings should be based on the graphs obtained showing handle or foot pedal operating force against time. The following scale is suggested, based on the maximum force required to operate the pump at a fairly low speed.

APPENDIX III

TRANSFER OF TEST DATA TO A TEN POINT SCALE

"BRANCH"	"TWIG" OR "LEAF"	SUGGESTIONS FOR SCALING OF DATA
Ergonomics (cont'd)	Forces required to operate (cont'd)	

Rating	Force on handle (hand pump) Kgf	Force on pedal (foot pump) Kgf.
10	< 8	< 20
9	8 - 10	20 - 24
8	10 - 12	20 - 28
7	12 - 15	26 - 32
6	15 - 18	32 - 37
5	18 - 24	37 - 44
4	24 - 34	44 - 50
3	34 - 46	50 - 60
2	46 - 60	60 - 72
1	> 60	> 72

"BRANCH"	"TWIG" OR "LEAF"	SUGGESTIONS FOR SCALING OF DATA
Performance	Leakage Rate when new	These ratings are based on the leakage test as follows:-

Rating	Leakage Rate (ccs/minute)
10	unmeasurable
9	up to 0.1
8	0.1 - 0.2
7	0.2 - 0.35
6	0.35 - 0.50
5	0.50 - 0.70
4	0.70 - 1.00
3	1.0 - 1.5
2	1.5 - 3.0
1	> 3

"BRANCH"	"TWIG" OR "LEAF"	SUGGESTIONS FOR SCALING OF DATA
	Efficiency	Based on mechanical efficiency measurements at a medium operating speed and water temperature of 18°C. Scale as below:-

Rating	Efficiency %
10	> 90
9	83 - 90
8	76 - 83
7	69 - 76
6	62 - 69
5	55 - 62
4	48 - 55
3	39 - 48
2	30 - 39
1 or less	< 30

APPENDIX III

TRANSFER OF TEST DATA TO A TEN POINT SCALE

"BRANCH"	"TWIG" OR "LEAF"	SUGGESTIONS FOR SCALING OF DATA
Performance	Efficiency variation with speed/ temperature	Temperature dependent variation in efficiency is not normally a problem with reciprocating pumps, but can be with rotary pumps. Variation in efficiency with speed can occur with any type. It is difficult to define scale exactly since for example a variation of ± 10% around a mean efficiency of 80% is hardly important, whereas a similar variation around a mean of 35% would be. The extent of the variation should therefore be compared with the mean efficiency. If at any time the efficiency drops below 20% under a normal operating conditi then a negative rating should be considered.
Endurance	Corrosion	The following scale is suggested as being generally applicable as a guide. 10 - No significant corrosion 8 - Slight corrosion unlikely to cause failures. 6 - Some corrosion which could possibly cause failure over a long time. 4 - Considerable corrosion during tests, no failures though this is likely over a fairly short timescale. 2 - Pump failure during tests due to corrosion. 1 or less - Frequent corrosion failure.
	Mechanical faults	Again, a scale which should be generally applicable 10 - No mechanical faults 8 - Slight mechanical fault(s) which could be prevented by attention to detail (e.g. during installation) 6 - Minor faults occurred, but easily rectified (e.g. loose bolts and nuts) 4 - Serious faults possible, but rarely. Minor components only required for repair. 2 - Breakdown of pump during test requiring major part replacement 1 or less - Frequent serious breakdown.
	Wear	The following scale is a guide based on the endurance tests 10 - No significant wear 8 - Slight wear but which is unlikely to have any effect on reliability. 6 - Some wear which would require attention at infrequent intervals, but which is unlikely to cause pump breakdown. 4 - Some wear which could adverse affect pump reliability. 2 - Noticeable wear requiring attention at not infrequent intervals if pump is to remain useabl 1 or less - Considerable wear requiring frequent replacement of parts.

APPENDIX III

TRANSFER OF TEST DATA TO A TEN POINT SCALE

"BRANCH"	"TWIG" OR "LEAF"	SUGGESTIONS FOR SCALING OF DATA
Safety	-	The safety hazards associated with a pump are a matter of both judgement and experience. The following is a guide 10 - No obvious safety problems 8 - Some possible safety hazards (e.g. finger traps) when pump is being abused. 6 - Some safety hazards possible if pump is used carelessly. 4 - Possible safety hazards to operator or bystander under normal conditions of use. 2 - Safety hazards present. Care needed to avoid injury. 1 or less - Pump could be dangerous to use. Care needed to avoid major injury.

APPENDIX IV

COMPARATIVE TESTING

It is important that any organisation carrying out comparative laboratory tests of handpumps should be qualified to do so. It is felt that the following are requirements if pumps are to be tested successfully.

(a) A wide knowledge of prevailing customs and cultural and socio-logical backgrounds in developing countries.

(b) Experience of comparative testing generally; and the proven ability to interpret the results in the light of the type of usage or environment prevailing so that realistic conclusions may be drawn.

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

The principles of comparative testing should also be thoroughly understood. Several booklets (1 have been written on this subject and the main items 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, but the principle should be followed as far as possible.

(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.

JUNE 1978 A.9925

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 1 2 3 4 5 Much too low	
Q2	How comfortable was the handle to hold in use?	Not at all comfortable 1 2 3 4 5 Very comfortable	
Q3	How much effort was required to work the pump?	A lot of effort 1 2 3 4 5 Very little effort	
Q4	Overall, how easy was the water pump to operate? (Please explain rating in the comments column)	Not at all easy 1 2 3 4 5 Very easy	

PROPOSAL DOCUMENTS SECTION

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WORKING MEETING ON HANDPUMP SELECTION AND TESTING

Harpenden , Hertfordshire , U.K ,
29 May - 1 June 1979

C. Proposal Documents

P.D. 1. Laboratory and Field Testing - World Bank/UNDP Global Project Proposal

P.D. 2. Field Testing Country Project: India

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P.D. - 2

WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
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HANDPUMP FIELD TESTING PROJECT

PROPOSAL

India

PROTOCOL FOR COMPARATIVE FIELD TESTING OF MODIFIED HAND PUMP (SINGUR)

1. Title of the Project :

Study of Hand Pump (Shallow tube well) for WHO/UNICEF Assisted Projects and Other Rural Water Supply Phase II : Comparative field testing of Modified pump (Singur) : CWS 008

2. Objectives :

The purpose of field testing is to test a newly designed or improved pump design on criteria relating to use the pump will have and the way the pump will be treated in a real life situation. These criteria may have to do with environmental factors and/or human factors that cannot readily be reproduced in a laboratory or otherwise simulated. In the case of the present modified hand pump (Singur) the pump has already undergone a laboratory testing at CMERI. But certain human and environmental factors could not be simulated in the laboratory testing (vide Para 2, page 26). Hence, it is proposed to carry out a systematic field testing of the modified design at Singur Field Centre, in an actual use position. Since the modified design is considered to be an improvement over the existing locally available pumps, it is also proposed to carry out a comparative field testing with the best locally available pump No. 6, and also Bangladesh Pump No. 6 (if made available either free or at cost) which is understood to have not yet undergone an extensive field testing.

3. Proposed activity :

Twenty samples of modified Hand Pump (Singur) with twenty each of best commercial pump and Bangladesh Pump No. 6, will be installed in the villages, covering roughly a population of about

6,000 (at a rate of 100 users per pump). The test area will be carefully chosen to provide identical criteria both with respect to socio - economic and socio - technical situations. A control area of about the same size which is identical physically, culturally and socio - economically will be chosen where same number of test samples will be installed. While in the test area, detailed instructions and maintenance help will be available as a part of exisitng routine maintenance programme. In this way it is possible to evaluate to what extent the extra-care bestowed on users in the test area has been the influencing factor in the success of the new design. All pumps will be installed under standard conditions, (height of handle, pedestal height, etc.) so that excessive stooping or reaching is avoided and people of all ages, handicapped people and the children are able to pump with ease. Pump performance of each test sample will be measured at regular intervals by skilled field engineers and data collected on pre-written proforma, for a period of 18 - 24 months.

All pumps will be maintained with proper lubrication of bearings, pins, etc. All broken down parts will be replaced expeditiously so that the pumps are restored to service with minimum loss of time. Adequate spares of all the models will be held in stock for this purpose and a record of replacements maintained;

Ergometric and anthrometric measurements of the dimensions, motion and work of the users will be carried out to determine the average characterisitcs of the users population. These observations and measurements will be made without prior announcement to eliminate HAWTHORNE effect.

Socio-cultural observations will be carried out with the assistance of Health Education Specialists of the Institute by informal discussions with individual families and in groups. It is not proposed to use any filling up of proforma for this purpose.

In the control area, attempt will be made, to carry out maintenance of test pumps by village volunteers who can be given an initial training in renewal of parts of the pump.

All data collected will be evaluated statistically. Assistance of the Statistical Section of the Institute will be taken in choosing both operation and control population, in the preparation of the proforma, and finally in the evaluation of results.

4. Details of budgetary components :

	1979 mm	1979 $	1980 mm	1980 $
1. Additional staff support :				
i. Field Engineer (1)	12	1075	12	1075
ii. Field Investigators (3)	36	1800	36	1800
iii. Secretarial charges (2)	24	1200	24	1200
2. Materials :				
a. Cost of fabricating 40 nos. modified hand pump (Singur)		825		
b. Cost of purchasing 40 nos. best available market pumps		530		
c. Cost of purchasing (if free supply is not provided from UNICEF/Bangladesh), Bangladesh Pump no. 6		670		
3. Purchase of spares and tools and lubricants to suffice for 24 months		200		400
4. T.A./D.A. and contingent expenditure		300		300
5. Preparation of report (supplying 100 copies to WHO)				325
Total :		$ 6600		$ 5100

5. Justification for Research grant :

The WHO/UNICEF initiated a study at the Institute, to field test the commercially available handpumps to identify the defects and make recommendations for improving the quality of these pumps.

When this work was completed and a report submitted, they further desired that the Institute should design a modified pump to overcome the defects in the commercially available pumps, fabricate a few prototypes according to modified design and test it in the laboratory. This work was also carried out and a report on the design, fabrication and laboratory testing was completed and submitted to WHO. Under the present proposal, it is intended to carry out a comparative field testing of the modified hand pump with the best locally available pump and the new Bangladesh hand pump No. 6, of which assistance of WHO is sought for by way of Research grant. Such a request is fully justified as the field testing of the new design will complete the study initiated by WHO in all its aspects.

All India Institute of
Hygiene & Public Health,
110 Chittaranjan Avenue
Calcutta 700073
The 6th December, 1978

(S. Subba Rao)
Professor of Sanitary
Engineering
Project Co-ordinator

BACKGROUND DOCUMENTATION SECTION

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E. Background Documentation Section

South East Asia

B.P. 1. Evaluation of Simpel and Inexpensive Pumps for Community Water Supply Systems.

Bangladesh

B.P. 2. Repairs and Maintenance of Tubewells

B.P. 3. Report on the Final Evaluation of the Pilot Project for Maintenance of Handpump Tubewells with People's Participation

B.P. 4. Bangladesh Rural Water Supply Programme

India

B.P. 5. Study of Handpump (Shallow Tubewell)

B.P. 6. Testing of Bengalore Pump
PP. 33-36 Report SEA/ENV.San/168
WHO-SEARO March 1976.

B.P. 7. Development of India Mark II Pump

B.P. 8. KSC ST Project Handpump Evaluation and Testing

B.P. 9. Draft India Standard Specification for Deepwell Handpump

Indonesia

B.P. 10. Handpump Testing Project

B.P. 11. Rural Water Supply Systems in Indonesia

Thailand

B.P. 12. Handpump Evaluation and Testing

B.P. 13. Development of Handpump for Rural Thailand

Malawi

B.P. 14. Wells Programme Annual Report, December 1977

B.P. 15. Field Survey of Handpumps

B.P. 16. Improvement and Testing of Shallow Well Pump

Ghana

B.P. 17. Field Testing Evaluation Programme

Costa Rica; Nicaragua

B.P. 18. Field Testing of Hand-operated Water Pumps.

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EVALUATION OF SIMPLE AND INEXPENSIVE PUMPS FOR COMMUNITY WATER SUPPLY SYSTEMS

PROGRESS REPORT

EVALUATION OF SIMPLE AND INEXPENSIVE PUMPS FOR COMMUNITY WATER SUPPLY SYSTEMS

Submitted to

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Chief, Community Water Supply and Sanitation
Division of Environmental Health
World Health Organization

by

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Bangkok, Thailand

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

Main Characteristics \ Pump type	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.

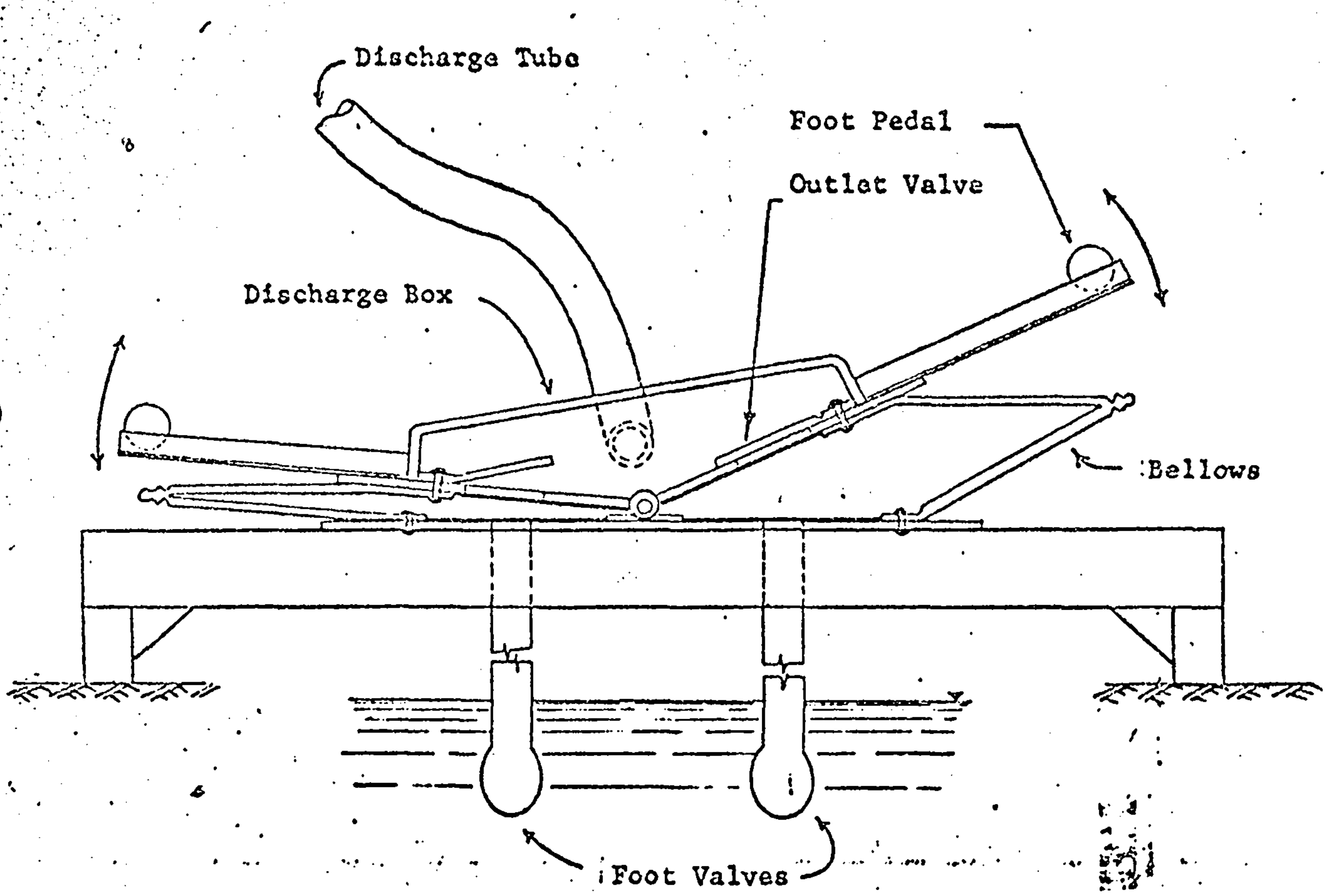

Fig. 1 - Manually Operated Foot Pump for Rural Community Water Supply

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.

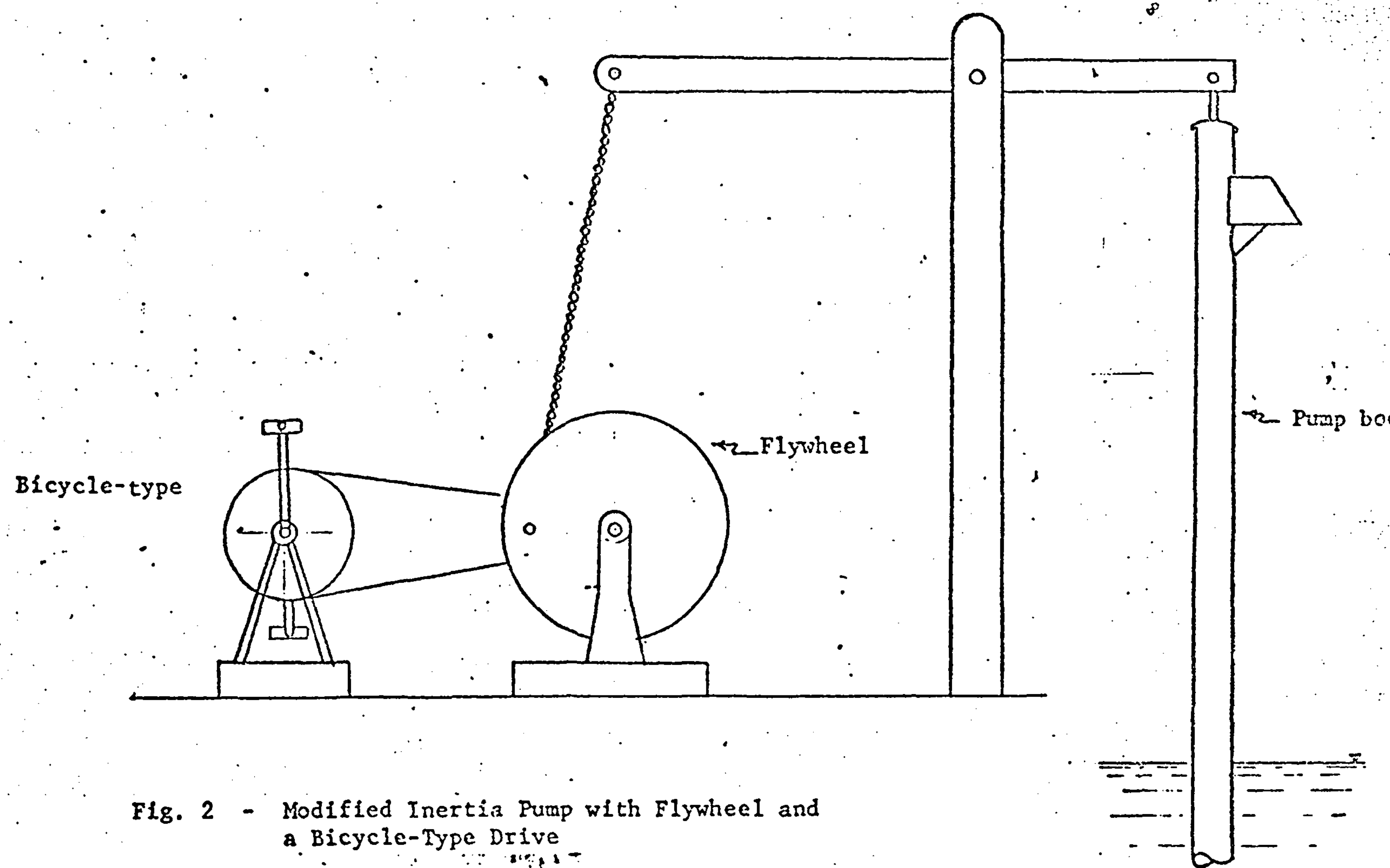

Fig. 2 - Modified Inertia Pump with Flywheel and a Bicycle-Type Drive

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B.P. - 2

WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

REPAIRS AND MAINTENANCE OF TUBEWELLS

30. India Mark-II pump: The India mark II pump is a deep tubewell hand pump evolved by UNICEF, India and the AFARM Group of Voluntary agencies in Maharashtra from the "Sholapur" design of the AFARM Group 36/. This pump uses welded steel fabrication, roller bearings, sealed lubrication and has a single pivot action connecting the handle to the pump rod through a short length of motor cycle chain. All moving parts are enclosed in a steel housing. The pump has a pedestal design to be grouted into the concrete platform, completely independent of the casing for support. This pedestal has an inside diameter of 6 inches and fits over the standard 4-inch and 5-inch casing used in the UNICEF-assisted Rural Water Supply Programme in India, forming a complete seal to any surface pollution. The three-piece assembly India Mark II Pump Head Pump (pedestal-water tank-head) is presently under mass production at Richardson and Cruddas, Madras (a Government of India Undertaking) and costs about US$128 per assembly. A limited assessment of the pump indicated that 80 per cent of conversion heads still were operating at the end of a 12-month trial period. Figure 6 shows details of India Mark II hand pump.

31. Bangladesh New No. 6 Hand Pump: The Bangladesh New No.6 hand pump 37/ was developed by UNICEF Bangladesh and the Department of Public Health Engineering (DPHE), Bangladesh, with over 300 000 planned for installation by 1979. The new pump represents a cross between the Battelle pump and the old Maya No. 6 pump. The new name is part of the effort to insure local acceptance. (No. 6 designates a 3-1/2 inch cylinder diameter, about 90 mm).

The major improvements on the traditional No. 6 are:

1) Increased bearing surfaces on cast iron moving parts and pivot pins.

2) Use of round, smooth mild steel pins held by cotter pins, rather than nuts and bolts at pivot points.

3) A piston rod with reinforced bearing areas and jam nut at plunger end.

4) Polyvinyl chloride (PVC) cup seal or bucket instead of leather bucket.

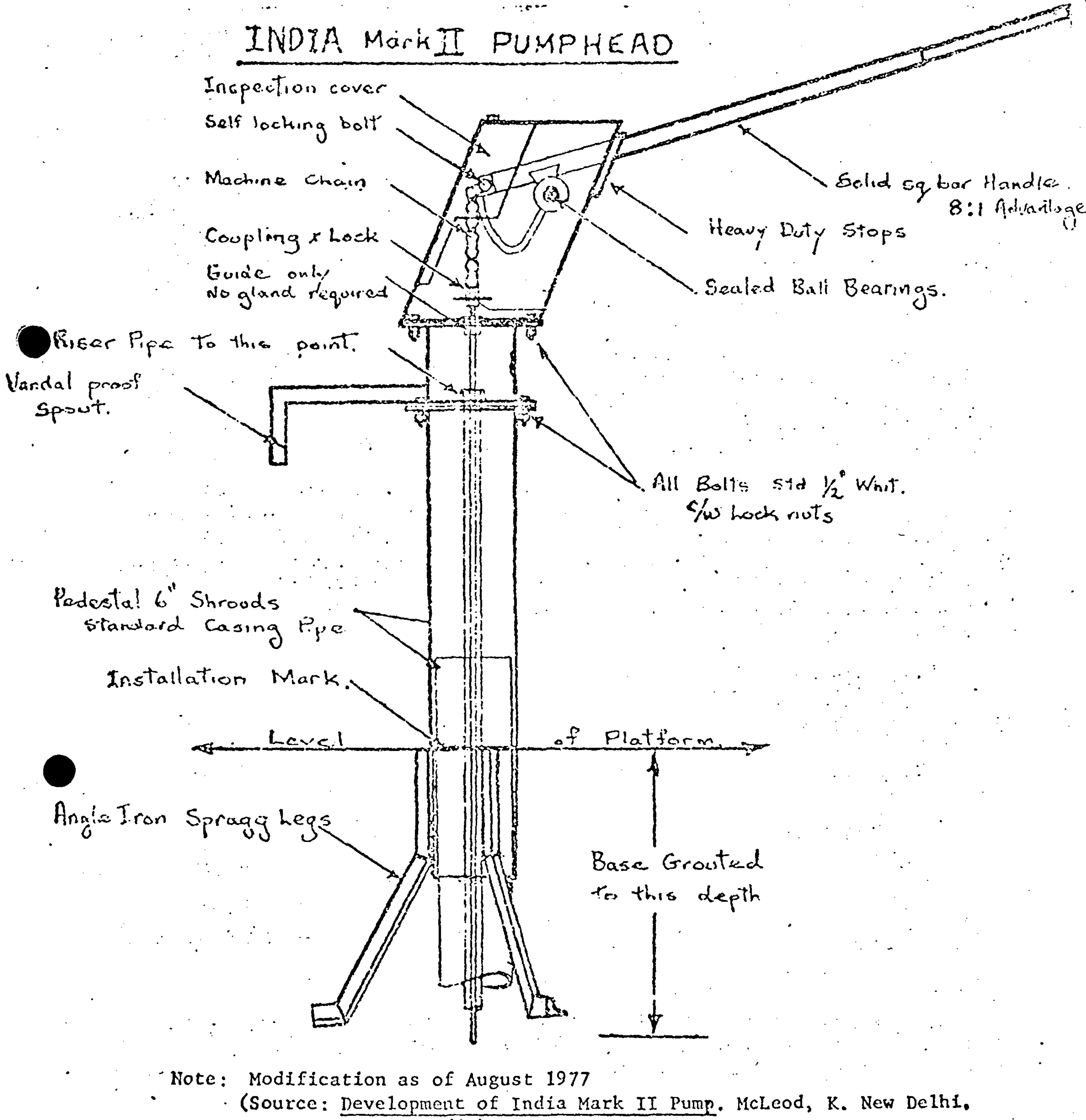
5) More stable configuration of four nuts and bolts located at "heel" and "toe" points of headcover (2, 4, 8 and 10 O'clock positions relative to the fulcrum at 6 o'clock), rather than the three points on the old design.

6) Standardized size (2-1/2 inch x 1/2 inch) for all nuts and bolts instead of three or four sizes on previous pumps. Lock washers have been added to nuts and bolts (approximately 65 mm x 13 mm).

7) A stronger handle with higher mechanical advantage and an 8-inch (20 cm) stroke length. The cross section of thehandle was changed from an "I" to a "T".

The design of the pump was strongly influenced by the severe shortage of pig iron and the casting technology available in Bangladesh. For example the "New No. 6" is about 20 lb. (9 kg) or 15 per cent lighter than the Battelle shallow well pump configuration. This savings was achieved partly through redesign of the base plate of the pump stand for Bangladesh standard installation (threaded connexions to well casing), and foregoing pump stand interchangeability with deep well pumps.

Figure 6



Note: Modification as of August 1977
(Source: Development of India Mark II Pump, McLeod, K. New Delhi, UNICEF India)

The polyvinyl chloride (PVC) cup seals used in Bangladesh have been found to have 2-3 times longer lifespan and greater uniformity than the traditional leather buckets available. In Bangladesh, they are less expensive than leather cups (PVC about $0.12 each, leather about $0.25 each). Because cup seal wear was the leading reason for pump shutdown (estimated at 25 to 30 per cent at one time), the PVC cups have made a major contribution to improved maintenance. Over time the water-lubricated PVC cups may be honing (making smoother) the iron cylinder walls. Figure 7 shows the Bangladesh New No. 6 handpump.

32. Hydraulic Ram (Hydram): A hydraulic ram (hydram) is a simple pump developed about 200 years ago, which uses the energy from flowing water in a pipe to force a small portion of the water to a height higher than the source. There needs, however, to be sufficient flow in the stream or other source of water and the necessary slope in the ground to generate the required energy for raising the water to the required elevation. The hydraulic ram requires absolutely no fuel or electricity, only water pressure.

WHO SEARO in its Regional publications Series No. 2[38/] included installation details and components of hydraulic rams. Silver [39/] prepared a useful guide on hydraulic rams and suggested that anyone with a minimal amount of mechanical aptitude can survey, design, and build a hydraulic ram from locally available parts, and do any necessary maintenance.

Silver[39/] observed that in the mountainous regions of Nepal, and other areas of similar topography, there are many thousands of places where, if a hydram were installed, much time spent hauling water could be used for other purposes. Because this simple pump works 24 hours per day, for many years (many working installations are over 50 years old) and requires little attention, it is suitable for areas where people have little technical expertise.

Figure 8 shows a hydraulic ram built from local materials. The cost [C/] of several hydrams made from locally available parts in Nepal was gathered by Silver and shown below:

Pump Size (Drive pipe)	Labour	Materials (In Nepalese Rupees)	Total
1.5" (38 mm)	50/-	220/-	270/-
2" (51 mm)	66/-	254/-	320/-
2.5" (63 mm)	70/-*	437/-	507/-
4" (102mm)	113/-*	1055/-	1168/-

[C] Notes:

1. The above costs do not include the gate valve on the drive pipe and on the delivery pipe. The equipment used was: a lathe, a grinding wheel, a drill press, welding equipment, and assorted metal working hand tools.

2. One US $ = 12.45 Nepalese Rupees

*The 2.5" and 4" pump built here used commercially available vertical delivery valve which made the total cost more expensive than a pump with a "homemade" delivery valve, but not by any means better or more efficient.

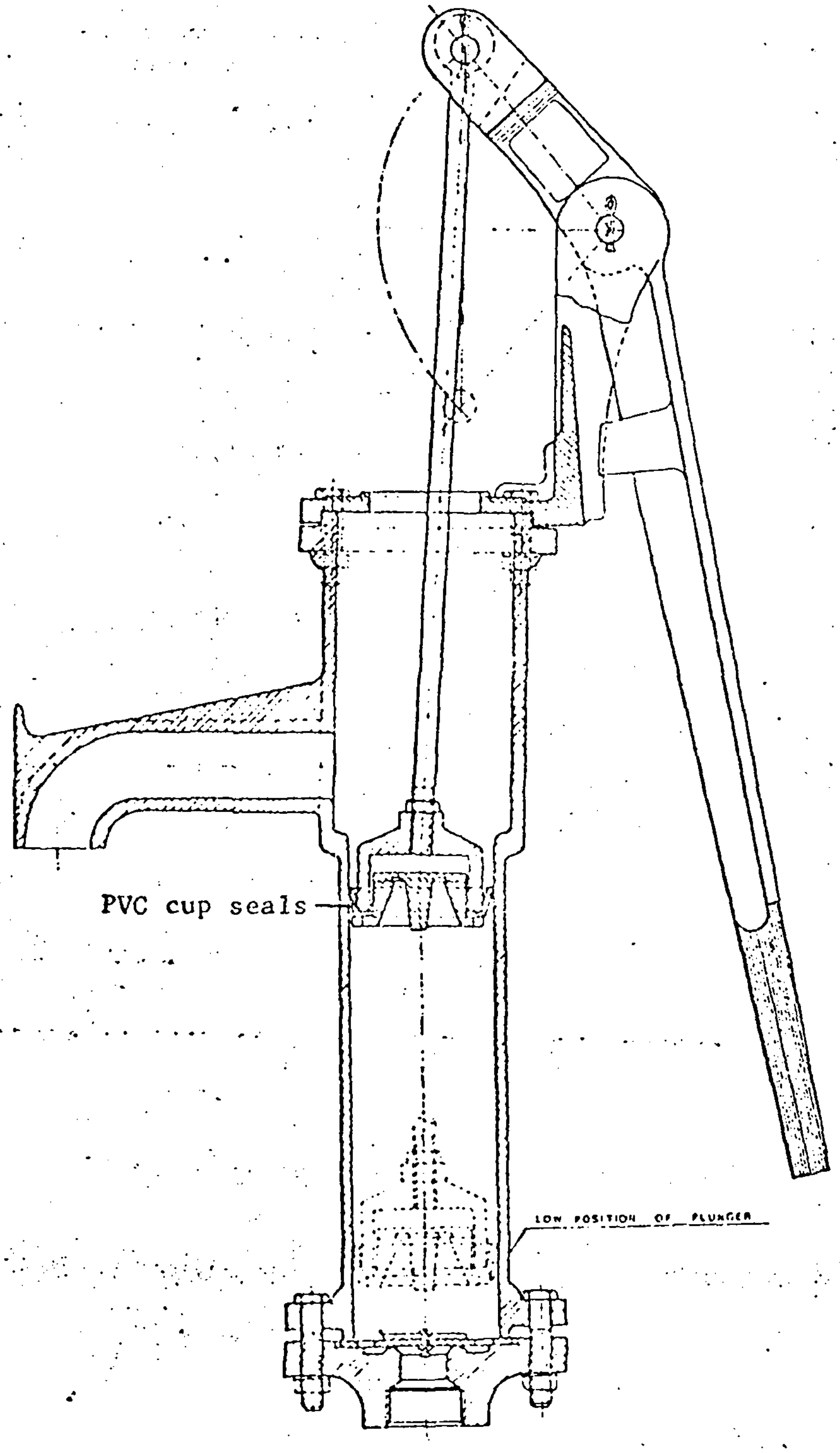


Figure 7 - Bangladesh - New No. 6 Hand Pump

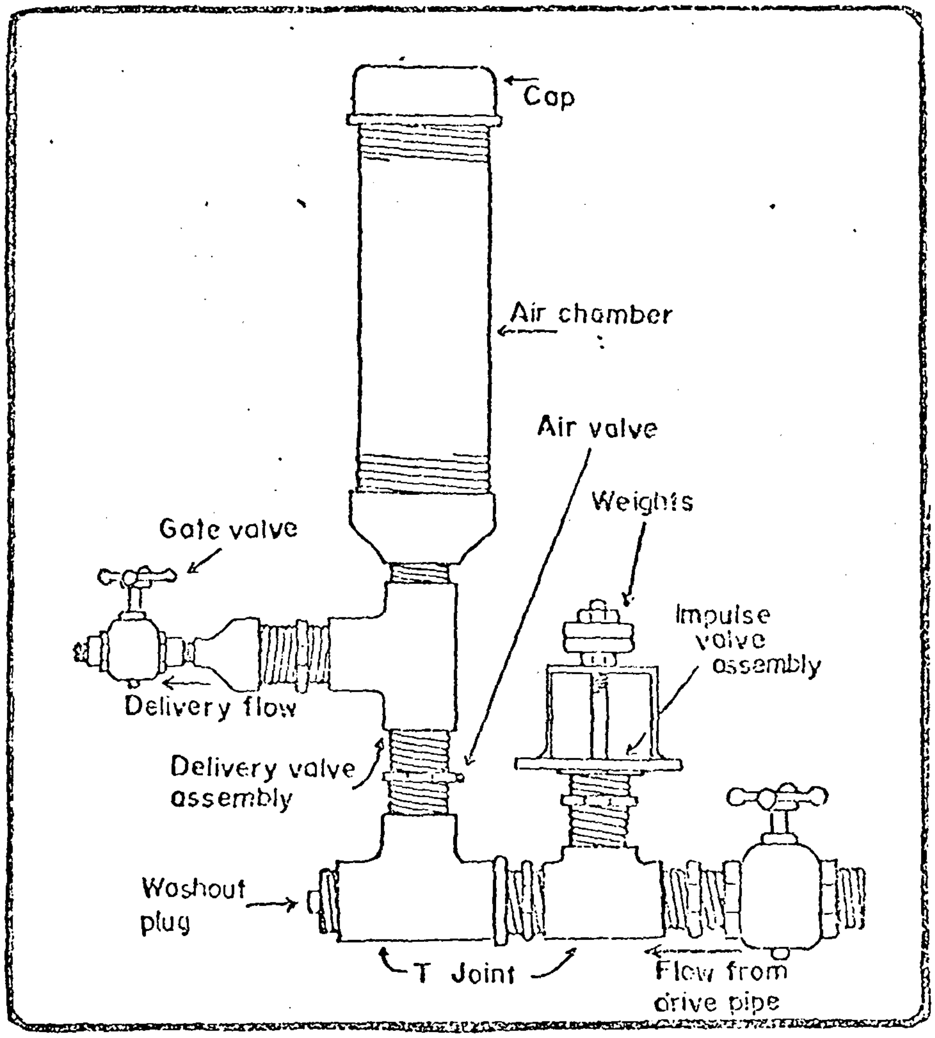


Figure 8: A Hydraulic Ram Built from Local Materials in Nepal

(Source: Use of Hydraulic Rams in Nepal. A Guide to Manufacturing and Installation. Silver, N. Kathmandu, UNICEF Nepal. 1977).

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B.P. - 3

WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden , Hertfordshire , U.K ,
29 May - 1 June 1979

REPORT ON THE FINAL EVALUATION OF THE PILOT PROJECT FOR MAINTENANCE OF HANDPUMP TUBEWELLS WITH PEOPLE'S PARTICIPATION

REPAIRS AND MAINTENANCE OF HANDPUMP TUBEWELLS BANGLADESH

1. INTRODUCTION

The Directorate of Public Health Engineering (DPHE) is essentially entrusted with the job of promoting Environmental Sanitation through the supply of safe drinking water in both urban and rural areas. When a water supply scheme is completed it needs operation and maintenance. In the case of urban piped water supply systems, operation and maintenance, after completion of works by the DPHE, are normally entrusted to the Pourashavas. But in the case of rural water supply systems (rural hand tubewells) the operation in effect is carried out by the individual user. The department need only maintain them.

Proper maintenance in fact is vital for any water supply system and particularly so for the rural hand tubewells as the health of about 200 people is dependent on every single hand tubewell and thus the vast majority of population of the country as there are already over 300,000 wells. Hence DPHE has taken up the task of maintaining them also besides sinking. If DPHE fails to maintain hand tubewells properly, soon the tubewells will be out of order and people will be deprived of safe drinking water and in effect the existence of DPHE will be meaningless. So, the maintenance and repair of rural hand tubewells is a sacred duty of DPHE.

2. MAINTENANCE

Literally, maintenance means to nurse, to develop, to upkeep, etc., and technically it means to keep an installation in true working condition. In general, the term maintenance of hand tubewells means to keep the pump in good working order, to keep the strainer clean and to keep the platform in good condition.

3. <u>REPAIR</u>

Repair of a hand tubewell means generally the repair of hand pump. The handpump consists of many movable parts of various materials assembles together. The hand pump consists of the following parts: (Figure 1) - Barrel, Base, Head Cover, Piston Rod, Plunger, Handle, Bucket, Seat Valve, Valve Weight, Nuts and Bolts, etc.

It is just common sense to understand that the component parts of any machine go out of order due to wear and tear from long use, sometimes due to mishandling and occasionally due to unusual break-down and needs fresh spare parts to bring the machine into commission. In the case of the hand pump of a tubewell, there is no exception to it. But the salient point is, are DPHE wells brought into commission in the quickest time as they would demand?

The most vulnerable parts of a hand pump to wear and tear are the bucket and seat valve, because they are made of either leather or PVC. Other parts being of cast iron or midl steel last longer. A PVC bucket may last between 6 months to one year whereas a leather bucket lasts between 15 days to 3 months. This is our latest finding. Also PVC bucket is much cheaper than leather bucket. Seat valve is made of leather and may last between 6 months to 1 year. DPHE is now using PVC bucket extensively. PVC seat valves have not yet proved successful.

Tools and plant required for repair of hand pump, as shown in figure 2 are: Uria wrench, Pipe wrench, Sly wrench, Screwdriver, Hack-saw blade, Hack-saw frame, Pipe cutter, Chain pipe tong, Die etc. Use of each of the above tools would be demonstrated to you in the field after the class hour.

4. MANAGEMENT OF MAINTENANCE AND REPAIR

Today DPHE has got 300,000 rural hand tubewells spread over an area of 55,200 sq. miles. Each tubewell needs care and attention of a responsible person who can repair it.

In the management set up, last tier consists of the mechanics who are the directly responsible persons for repairing of wells by going from village to village like a postman. Four mechanics in each Thana have been placed for this. They have been posted in Unions. For supervision and control over the activities of mechanics two Sub-Assistant Engineers and one Assistant Engineer have been posted in the Sub-Division headquarters. This means that these three persons, are to manage and control about 26 mechanics spread anywhere in 876 sq. miles of a Sub-division boundary. This is in addition to their other jobs of execution of rural hand tubewells spread over the same area. If the mechanics do not move and work with dedication, it is extremely difficult for Asstt. Engineers and Sub-Assistant Engineers to keep watch over their movements. It requires initiative, intelligence and tact on the part of the Assistant Engineers to monitor their movements. The Assistant Engineers can utilize the offices of Union Parishads as information media. The Chairman of each Union Parishad has been given authority to look after the activities of the mechanics. Assistant Engineers should impress upon the Chairman the necessity of their giving authentic reports against the inefficient and defaulting mechanics. For this, the Assistant Engineers should see the Chairman in their places at least one a year. Unless people are taken into confidence and told about our purpose, the maintenance programme would be a failure.

It should be remembered that for every well that is out of order, about 200 people will suffer for want of safe drinking water. And if an epidemic of diseases like, Cholera, Typhoid or Dysentery breaks out, lots of people fall sick from waterborne diseases and many may die.

5. INVENTORY:

It requires strict control over the inventory of materials both in stock as well as issued and used by the mecahnics. The proof of use of a component part is the production of a damaged part to be taken back to store stock by the mechanics. If that is not done then what else is the proof of utilization? For this, the Assistant Engineers should make random checks in the field with the copies of the previous month's progress reports of mechanics.

6. CONSTRAINTS:

The mechanics have got no permanent address or a place of residence in the Union where they can be called up.

If DPHE had Thana offices with stores under some supervising staff, service and inspection could be quicker and thorough.

However, till such a position is reached the DPHE Engineers will have to work much harder and make up for the constraints.

7. CONCLUSION:

The ultimate goal of the DPHE is to eradicate water-borne diseases and thus improve environmental sanitation of the entire country. This is really a humanitarian job and hard too, because it is difficult to induce people to adopt health habits and even if attempted it will take a long time. The best way is, therefore, to give health education to school children. They may also be taught about the simple mechanism of a hand pump and how to repair it. Then they will find interest at least to check if the mechanics have actually repaired wells. Also they can diagnose the defect and inform the authority through suitable information media.

COMPLETE HAND PUMP No. 6

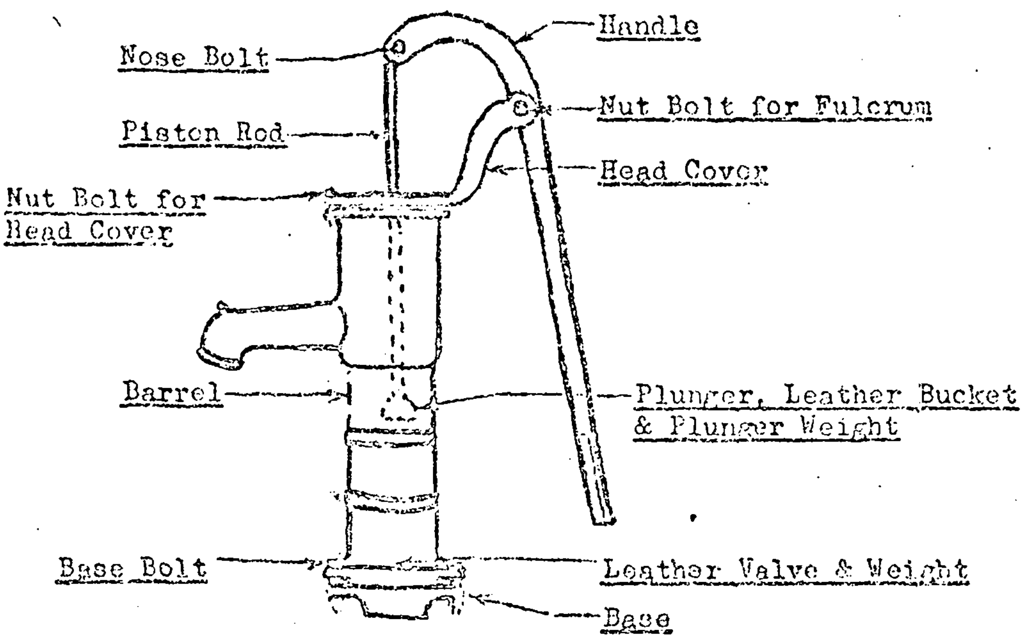

FIGURE - 1

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WORKING MEETING ON HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

BANGLADESH RURAL WATER SUPPLY PROGRAMME

largest (shallow well) handpump installation programme in the world.

30.8.96

HEFFINCK

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 villages/, 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 theneselves.

?. 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 Period (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 to 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. 15.51	
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	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	

who international reference centre for community water supply

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B.P - 5

WORKING MEETING ON HANDPUMP SELECTION AND TESTING

Harpenden , Hertfordshire , U.K ,
29 May - 1 June 1979

REPORT ON

STUDY OF HAND PUMP (SHALLOW TUBE WELL)

FOR WHO/UNICEF ASSISTED PROJECTS

AND OTHER RURAL WATER SUPPLIES

REPORT
ON
STUDY OF HAND PUMP (SHALLOW TUBE WELL) FOR WHO/UNICEF ASSISTED PROJECTS AND OTHER RURAL WATER SUPPLIES

PHASE II

DESIGN, FABRICATION AND TESTING OF MODIFIED HAND PUMP (SINGUR)

Part 1 : Report on Laboratory Testing

UNDER

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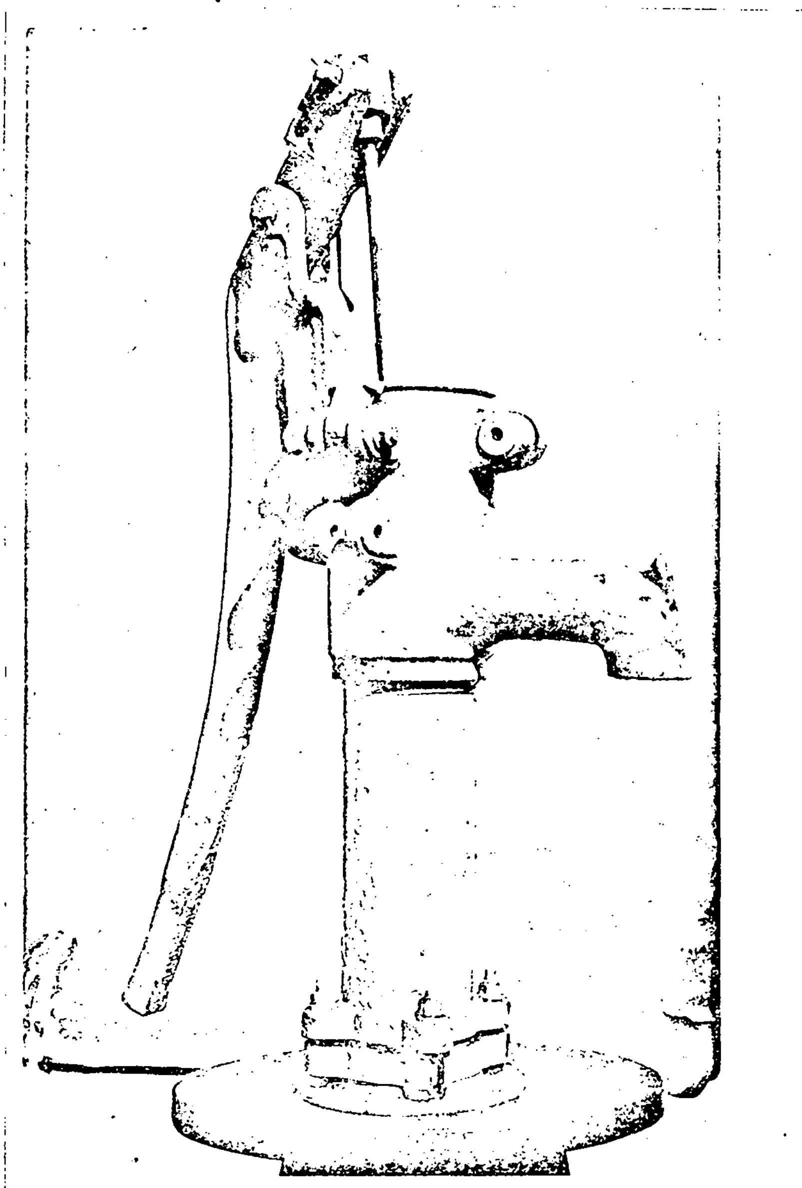


A. Introduction :

WHO/UNICEF sponsored a research project in 1969, at the All India Institute of Hygiene and Public Health, on "Study of hand pumps (shallow well type) for rural water supplies" under Prof. N. Majumder, the then Professor of Sanitary Engineering as the Principal Officer-in-Charge of the study. The object of the study was to identify the defeciencies in the present makes of pumps (locally made) through scientifically carried out observations and then to evolve suitable specifications and drawings for a standard pump that would overcome these deficiencies. Eventually such a pump will be manufactured and tested on its proven value. Perhaps, these specifications would also be adopted as national standards. The first phase of the study, viz., identification of deficiencies in the existing pumps in order to develop a new design was carried out under the able guidance of Prof. N. Majumder, who was designated as the Project Coordinator. This study was initiated towards the end of 1969 and was completed by the end of March 1973. A final report on this part of the study was prepared by Prof. N. Majumder and submitted to W.H.O.[1]

Consequent on the transfer of Prof. N. Majumder in April 1973, W.H.O. desired that the project be continued at the All India Institute of Hygiene and Public Health, and designated Prof. S. Subba Rao, Professor of

Sanitary Engineering as the Project Coordinator for this study.

B. Findings of the first phase of the study :

Main deficiencies identified in the first phase of the study as already reported by Prof. N. Majumder[1] are as under :

(1) The high phosphorous content (0.5 to 0.58%) of grey iron used in the making of these pumps makes the pump brittle and hard, leading to breakage of head and handle and more wear and tear of the moving parts as the cylinder's inner surface cannot be machined smoothly. Hence, the grade of cast iron used, should not contain phosphorous more than 0.15 to 0.20% to reduce hardness and also allow better machining, thus improving the smoothness and waviness of the cylinder inner face.

(2) The commercial pumps do not have a truely cylindrical pump body as indicated by the laboratory tests on ovality and waviness of the surface. Although it has not much effect on leather buckets which swells and conforms to the actual surface when wet, but it may affect the performance of cups which are made of non-swelling material like plastic, neoprene, etc.

(3) The plunger used are of poor casting, projecting rough edges and blow holes. The machining and threading allowance in casting is much less than required and hence full depth of threading cannot be cut,

providing cutting of threads only upto 40% of full depth resulting in breaking away of threads easily, thus requiring replacement of entire plunger assembly more frequently. The surface finish of poppet (plunger valve) valve and its seat is also very poor leading to poor matching area. This will lead to more slippage.

(4) The quality of leather used in leather cups widely vary. Many are poorly tanned or even untanned resulting in quick crumbling of leather and twisting requiring replacement.

(5) The leather used in flapper valve is also poorly tanned and repeated wetting and drying make it loose its elastic property and cracks at the contact point of the weight leather. The valve thereafter does not function properly resulting in leakage, requiring frequent replacements. Another defect is the improper machining of the flapper-valve seat on the base of pump when it is fitted. This leads to air leakage.

(6) The bolts and nuts used are not to any standard dimensions and threading. The tolerance available between the bolts and the hole for inserting them in the base as well as cylinder bottom is 1.58 mm (1/16") which should not exceed 0.794 mm (1/32"). Same is true in respect of pump heads for the 12.7 mm (1/2") bolts. The increased tolerance results in undesirable play and minimizes rigidity.

(7) Handle and head : The forked end of the handle for accommodating the piston rod has rather a much larger gap 12.70 mm (1/2") than needed. This also results in too much lateral play which accelerates wear and tear of eye of the plunger rod resulting in shearing off of the eye. This should be reduced to 1.58 mm (1/16"). At the hinged point where the level arm (handle) is fixed to the pump head and the piston rod, 12.70 mm (3/8") B.S.W. bolt has been used and the tolerance is about 0.4 mm (1/64"). Replacing the bolts by M.S. pin and reducing tolerance between 0.005 mm to 0.0076 mm (0.002" - 0.003") will improve performance by reducing wear and tear and breakages. Such tolerance is responsible for side play of the handle leading to cuts in the metal of the head and enlarging width of slot for the plunger rod.

(8) The machining of the seat of the flapper-valve and the cylinder bottom is not done properly causing air leakage resulting in breakage of vacuum. This should be done more carefully and to correct diameter and depth so that the valve fits correctly and there is no leakage of air from outside when the cylinder is fastened with the base with bolts and nuts.

(9) The quality of threading of piston rod and plunger is extremely poor. As stated earlier due to insufficient material in casting of plunger and defects in rounding of the ends of piston rod made from flats

threads could be cut to only 40% of the full depth to be engaged. Heating to forge the flat end to round shape makes it loose its M.S. properties to some extent and as such threads break away quickly. This can be solved by using 12.7 mm (1/2") round rods instead of flats for plunger rods.

C. Second phase of the study :

Prof. S. Subba Rao, Professor of Sanitary Engineering took charge of the study in December 1973 and the work was resumed from January 1974. From the report of Prof. N. Majumder it was clear that one of the main findings is the poor grade of cast iron containing excessive phosphorous content, which causes brittleness and also does not lend itself for smooth machining of the cylinder inner surface. This results in faster wear and tear of the leather buckets, greater mechanical strain on all moving parts, such as, piston rod, plunger, bolts and nuts, and handle resulting in increased wear and tear and breakages. Hence, in order to improve this condition, basically better grade cast-iron with low phosphorous content was necessary for casting pump-body. Since, it would be more costly and also may not be available for small enterprenuers who are the majority pump manufacturers in the country, it was thought expedient to try some sort of a liner, such as, plastic, hylum, etc. A market survey revealed HDP, uPVC were more readily available than hylum and other materials. Hence, even before a new design was made to overcome all other defects, reported in the earlier findings, it was decided to incorporate a lining to the existing pumps with some modifications and given an initial field trial.

4. Initial field trial with liners :

Five raw castings of commercially made pumps were obtained and fabricated in a local workshop with unplasticised and high density polythene cylinders lining. Three of the pump cylinders were lined with uPVC liner of 90 mm OD (4 kg/cm^2) wall thickness 2.1 to 2.6 mm. Two of these pumps were fitted with polythene buckets (cups) and third with a leather bucket of 3¼" (73 mm). The other two pump cylinders were lined with HDP liners of 90 mm OD 4 kg/cm^2 and wall thickness 4.4 to 5.1 m. These two were provided with polythene buckets of 3¼" (73 mm). All these pumps were installed in the rural area on selected tube wells with identical use positions and observed for performance for a period of 10 months. The trial observations showed that unplasticised PVC cylinder liner provided a smoother and better surface than HDP liner. People found it easier to pump and used more number of strokes per minute than the one without a liner and thus could fetch more water for the same time and energy spent. Being satisfied that unplasticised PVC liner could provide a smoother surface and thus obviate the need for using better grade cast-iron and smooth machining of cylinder surface, a new design and drawings were prepared, incorporating several changes to overcome the deficiencies identified in the existing pumps as per the findings in the first phase of the study programme. Details of improvements made in the design are discussed below.

1. Material for pump : Grey cast iron as per I.S. specification 210 (62) grade 15, is proposed for casting pump cylinder, barrel with spout, cap, plunger poppet, plunge yoke, plunger follower, base, fulcrum fork bar, handle, and flapper valve weight. Steel as per I.S. 1570. C-20 grade is proposed for manufacturing flange-plate, piston rod, piston rod end, hexagonal bolts and nuts, punched washers, cottor-pins, and cylindrical pins. Two alternate types of cylinder liners are used in the design i.e. (i) unplasticised PVC (uPVC) (90 mm, 4 kg) class PVC 2112, conforming to IS 4985-1968, (ii) hylum (manufactured by Bakalite Bylum Ltd., F-105).

The cup (bucket) and flapper valve are proposed to be of polythene.

2. Pump body (cylinder and barrel with spout) (Part No.9 &16) : The pump body in the new design is divided into two seperate parts, viz., cylinder and barrel with spout, to be coupled together by means of a

threaded joint. This design seperating cylinder portion from the rest, lends itself for better machining of the cylinder inner face for smooth finish. However, with the provision of liner (PVC or Hylum), there is no need for smooth finishing of cylinder inner face. Only one single cut machining should be sufficient for easy insertion and withdrawal of liner. The design of cylinder provides for a recession in thickness (leaving an offset at top). The slight offset at the upper end (above the stroke length) holds the liner tightly preventing its movement vertically as well as circumferentially. The tolerance between the internal diameter of cylinder-bore and the outer diameter of the liner is kept just sufficient for easy insertion and withdrawal of liner by manual operation.

3. Fulcrum and fulcrum bar : In the new design the fulcrum is shifted from the pump cap to pump barrel. The reason for this change (although results in slight increase in weight) is our experience in the field with the commercially available pumps in which fulcrum is cast integral with pump cap. Because of the lever action, the nuts (as there are no check nuts provided) and bolts holding the pump cap to the pump barrel get slackened. Once the nuts are slackened, the wear and tear of bolts and slipping of bolts and nuts results. When the cap gets loosened from its seating, it causes zig-zag movement of

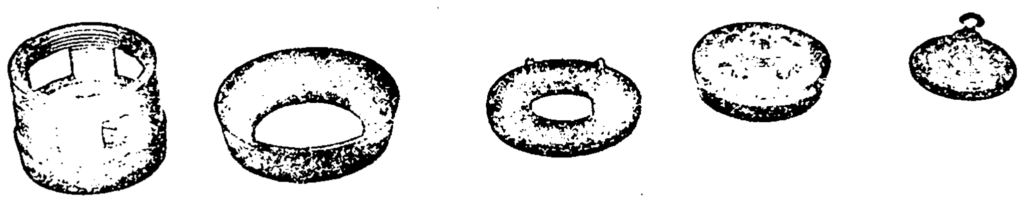
the piston-rod resulting in greater and uneven wear of the bucket. Both these effects increase maintenance attendance and cost of maintenance. The present arrangement of locating fulcrum on the pump barrel obviates this problem and also reduces the need for a heavy cap. Hence, the thickness of cap is advantageously reduced to 7 mm.

4. Fulcrum fork bar : (Part No. 23) : Made of grey cast-iron has one end forged for fixing handle. The other end is fixed to barrel by means of steel cylindrical pins, or by bolts and nuts. The clearance in the forked end between the handle and the fork is kept at 1.58 mm (1/16") to prevent lateral play of the handle. The hole in the tonngues of the fork to house the cylindrical pin is kept 16 + 0.018 mm diameter for a perfect fit not allowing any lateral play and is placed perfectly horizontal.

5. Handle (Part No. 26) : The design of the handle is slightly modified to suit the change in fulcrum position. The shape is so adjusted to provide for the full stroke length without causing inconvenience to users of all height and age with a mechanical advantage of 4.3. The forked end of the handle houses the square head of the piston rod and the clearance is kept to a minimum. Lateral play is completely eliminated by this design. Major length of the handle is kept 'T' section 30 x 6 m at the thinnest portion except for forged upper end.

The bottom end is rounded for good and smooth grip for the users. After the field testing, it will be considered whether the section could be reduced or holes punched so as to reduce its weight. The handle is jointed to piston rod end and the forged end of the fulcrum bar by means of bright steel pins and cotter pins in perfectly machined housings. Bushings are not proposed. In case excessive wear and tear is noticed in the field testing the holes will be provided with brass bushings.

6. Piston rod (Part No. 24) and Piston rod end (Part No. 27) : In the commercial pumps, the piston rod consisted of a flat, rounded at one end for threading to connect to plunger assembly and the other end of the flat widened and a hole punched to form an eye to connect to forked end of the handle. Heating to form the above ends would make it loose its mild steel property. The eye would widen leading to lateral play and ultimate shear. The threads would wear away quickly. Average replacement required for piston rod made of flats as observed was quite high (20 - 27 per 100 tube wells per year). Hence in the new design the flat is replaced by a 12 mm mild steel round which overcomes these defects. Also threads could be cut to full depth in rounds as against only 40% depth in case of flats. The top of piston rod end is provided with a seperate square head of 30 mm side, reduced to a 22 mm diameter round. The round portion is bored



and threaded to connect the piston rod. This design completely eliminates the large tolerance (12.7 mm or more) that existed between the piston rod eye and the forked end of the handle in the old design which would lead to lateral play accentuating for the wear and tear of the holes and of all parts connected with it. Similarly, replacement of eye by a square head connected by mild steel pin and cotter pin also eliminates the wear of eye and ultimate shear of the eye.

7. Plunger assembly (Part Nos. 10, 12, 14 & 15) : In the new design, plunger assembly consists of four parts instead of three in the old design. These are - (1) plunger yoke, (2) plunger follower, (3) plunger poppet and (4) flange plate. The whole design is made more sturdy to overcome inadequate sections for full depth thread cutting both on the yoke and the follower. Secondly, unlike in the old design, a flange plate is provided to hold the cup (bucket) by means of 4 numbers of non-ferrous galvanised iron screws. This arrangement would eliminate need for unscrewing yoke and follower every time a cup or bucket has to be inserted or removed and the rusted threads would give way necessitating the replacement of either of the two or both yoke and follower. (See drawings). The design of poppet valve is also improved. A void space is provided in the poppet which could be filled up

with heavy metal like lead to increase its buyont weight in water when lifted from its seating so that it quickly returns to its seat reducing slippage of water and increasing efficiency of pump. Besides mating surfaces both on the valve seat and the poppet have been perfectly machined for a 100% mating area. The threads on piston rod and on the plunger yoke and follower are cut to full depth for a perfect jointing.

8. <u>Hinge points</u> : The two hinge points, viz., connecting handle to fulcrum fork bar and to pump rod are essentially made of mild steel pins. The other hinge points could be of either mild steel pins or nuts and bolts of good quality with H7 tolerance, with punched washers.

9. <u>Cup seal (bucket) (Part No. 11)</u> : In the old design, the cup is made of leather. The leather used are not of any standard quality and even untanned leather have been used, resulting in high wear and tear and frequent replacement. In the new design where a plastic or hylum cylinder liner is used, polythene cup has been used. The quality of polythene used for cup and that used for flapper valve is shown in Table - 1.

Table - 1 : Quality of polythene used for cup and flapper

Sample	Hardness in Shore A (Ave. of 5 tests).	Tensile strength (Ave. of two tests)	% elongation (gauge length = 20 mm)
Polythene for cup (bucket)	88 Shore 'A'	1.34 kg/mm^2	185%
Polythene for flap valve	80 Shore 'A'	1.01 kg/mm^2	270%

(As per Test Report from CMERI)

Since PVC hylum liner is used, there is no need to use a material like leather which when wet can swell and stretch to conform to the ovality or waviness of the surface of the cylinder (Author's opinion). Hence, a polythene cup, which has no swelling property has enough flexibility and pliability to conform to the liner surface, which is smooth with a waviness well within the desirable limit of 2-3 microns (8-12 micro inch). Hence, polythene cups with an outside diameter less by 0.2 mm than that of liner's inside diameter, areused in both the liners, i.e. PVC and hylum. The water pressure on the cup during the pumping stroke will bend the lip outwards and ensure perimeter contact with the liner wall. A few cups of neoprene were tested and found to be too soft to be used in this type of pump in the present design of plunger assembly. The cost of neoprene cups is also high as compared to polythene or leather. Reinforce neoprene is not available in India.

10. Flapper valve (Part No. 3) : The main defects noticed in the flapper valve used in commercial pumps are : the poor quality of leather, poor tanning and by repeated cyclic wetting and drying condition, the valve looses its elastic property and cracks at the contact point of the weight-leather. The valve thereafter does not function properly resulting in leakage requiring very frequent replacements as reported in the first phase of this study. Replacing leather by polythene showed better performance and no cracking. Hence, a flapper valve made of polythene with a flap-valve weight fixed with bolt and nut is provided. The seating of flapper on the pump base is perfectly machined for 100% mating surface. It is also proposed to provide a plastic bushing to obviate the need for a perfectly smooth finish to valve seat. Ball-valve-design was considered not suitable for shallow well type pumps.

11. Cylinder liner (Part No. 7) : Unplasticised PVC pipe manufactured by Chemplast Ltd., according to I.S.S. 4985/1968 belonging to class PVC 2112 is used as a liner. The classification is according to ASTM for PVC belonging to type 2, Grade I with hydrostatic design stress of about 1250 psi (see Manufacturer's catalogue). The PVC liner used is ± 90 mm O.D. with a tolerance of ± 0.3 mm on the O.D. (average thickness of wall ± 0.5 mm) as per manufacturer's catalogue. The pump cylinder is

cast to provide just sufficient tolerance (about 0.5 mm to 1.0 mm) for easy push and pull of the liner. The cylinder inner face is to give a rough single cut machining to prevent any damage to the liner exterior wall during insertion or extraction. It has been observed in the initial trial conducted, that PVC liner could be pulled out easily after one year's of use, as the PVC has no swelling property under wet condition. Therefore the liner could be replaced easily, if and when required.

Alternately, hylum (cotton fabric impregnated with an epoxy resin), cylinder liner was also considered. Messrs. Bakalite Hylam Ltd., could not supply hylum pipe of the required diameter. Hence a solid bar of required O.D. (90 mm) was obtained from them and was bored on a lathe in a local workshop to the required I.D. Since Messrs. Bakalite & Co., delayed supplies, C.M.E.R.I. were reluctant to carry out the test with hylum lining. However, on insistence, they carried out testing on hylum liner for a period of 250 hours only. The hylum used is according to manufacturers trade No. F 105. The inside finish we could get in the local workshop was less than 250 micro inches.

11. <u>Base (Part No. 1)</u> : Basically there is no change in the design of pump base plate. The tolerance available between the bolts and the hole for inserting them which was 1.58 mm (1/16") in the old design, has

been reduced to 0.794 mm (1/32"). The machining of the seat of valve is done perfectly to the correct diameter and depth so that the flapper valve fits correctly and there is no leakage of air from outside. The cylinder liner is slightly projecting so as to ensure pressing over the flapper perimeter when cylinder is joined by bolts and nuts to the base and thus is held tight between the base and the offset at top of cylinder to prevent any lateral or rotating movement when the plunger moves in it. Standard hexagonal bolts and nuts (mild steel) with washers are used for jointing cylinder to base. The flapper mating area on the seat is perfectly machined. Also, provision is made for inserting a plastic or brass bush which is optional. Standard threads are cut in the central hole for a perfect jointing of $1\frac{1}{2}$" diameter galvanised iron suction pipe. 4 numbers 11 mm (3/8") diameter holes are provided on the rim for fixing base to foundation bolts and nuts.

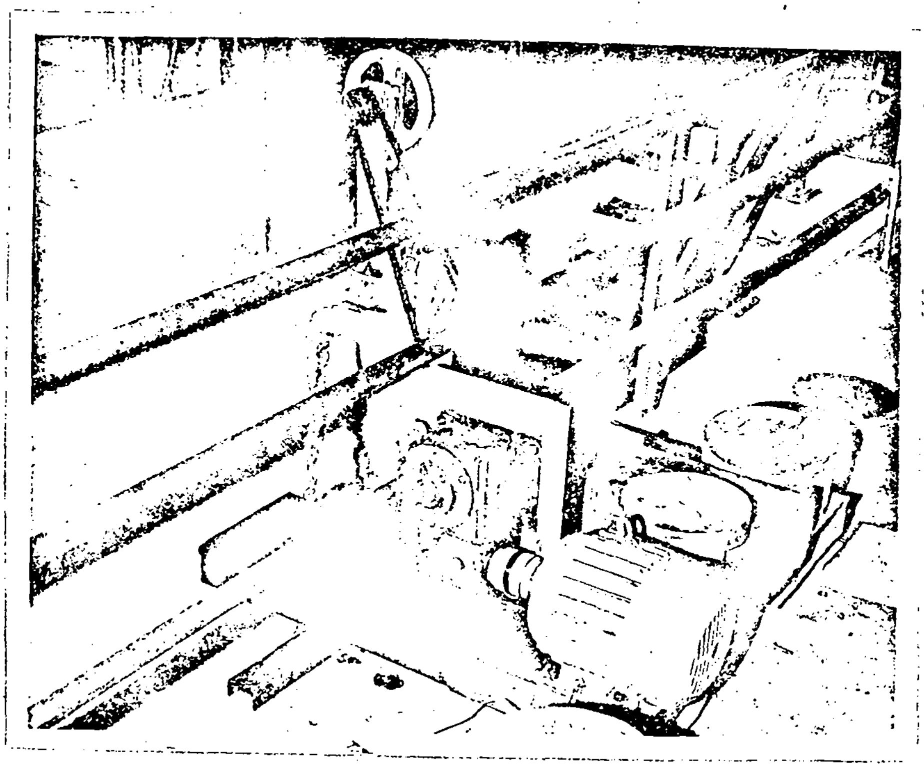
D. Manufacture of prototypes and testing :

An agreement was entered into with the Central Mechanical Engineering Research Institute, Durgapur, for manufacturing prototype pumps as per our design and for laboratory testing of the pumps. The detailed drawings as per design were prepared at the All India Institute of Hygiene and Public Health and handed over to C.M.E.R.I. for preparing assembly drawings from the original design drawings. Accordingly, four prototype pumps were cast and fabricated in C.M.E.R.I. workshop. Two of the prototypes were provided with PVC liners and the other two with hylum liners. One prototype pump with PVC liner and another prototype pump with hylum liner were tested on a simulated test rig in the laboratory.

<u>See Figure 1</u> - <u>Schematic view of the hand pump test set up (C.M.E.R.I. drawing)</u>

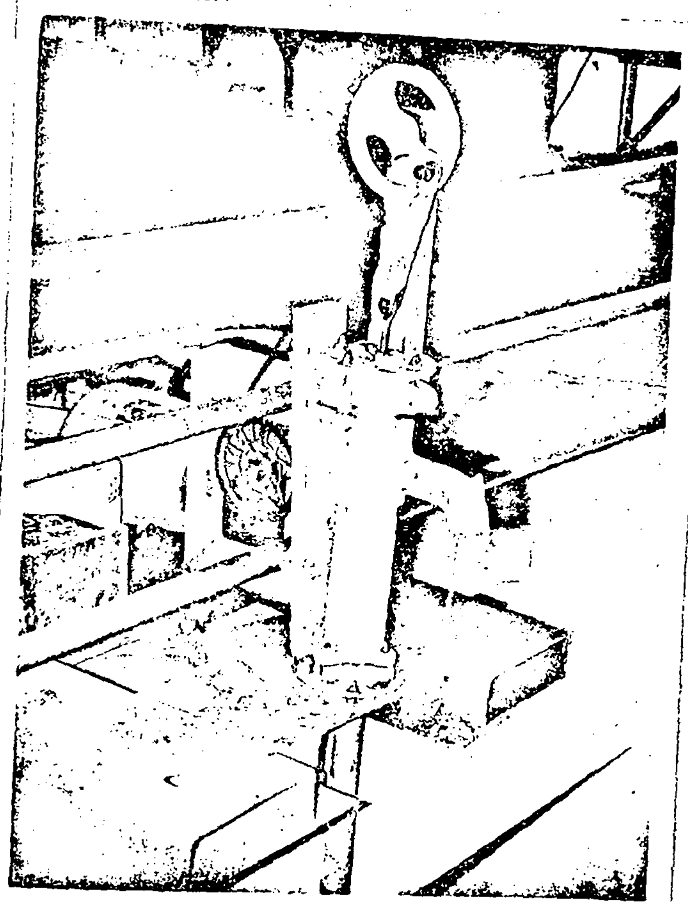
Figure 1 shows the set up of the test rig as designed by C.M.E.R.I. Although we very much desired that the pump handle should be included and the reciprocating motion of the handle be also simulated in the design of the test rig, the C.M.E.R.I. regretted their inability to do so. The rig as simulated, consisted of a motor (5 H.P. 2850 r.p.m.) coupled with a reduction gear box (1 : 500) and consequently to a chain and sprocket drive to obtain the desired pump speed of 15 r.p.m. as shown in Photographs 1 and 2.

Photograph 1



Photograph 1 : View of the drive unit assembly from right side.

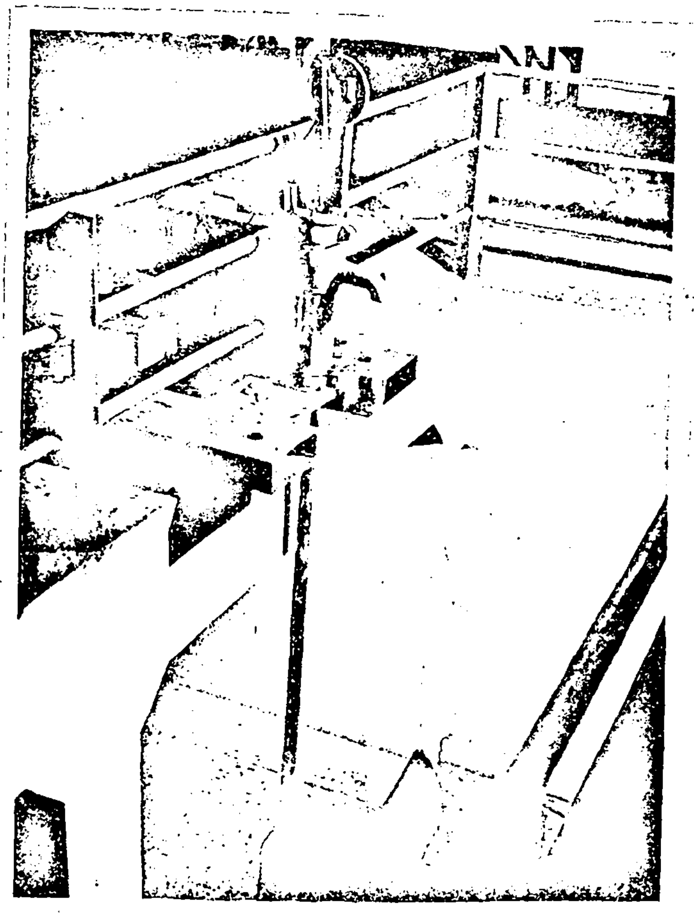
Photograph 2



Photograph 2 : View of the drive unit assembly from left side.

In this set up the stroke length available was 170 mm as against the actual stroke length of 178 mm (7"). The pump was operated at about 4 metres suction and the discharge water recirculated through ground storage tank as seen in Photograph 3.

Photograph 3



Photograph 3 : View of the complete test rig set up showing suction lift and storage tank.

Test was conducted for a continuous period of 800 hours in case of pump with PVC liner and 250 hours in case of pump with hylum liner. Both were fitted with polythene cup (bucket). Discharge from the pump was measured periodically during the test and recorded. The discharge during the test period varied from 860 c.c. to 670 c.c. per stroke in the case of PVC liner pump and was constant at 800 c.c. per stroke in case of hylum lined pump. The discharge is fairly good and is somewhat equal to manual pumping rate.

Test results :

Within the stroke length of 170 mm two positions at a distance of 50 mm one from top and other from bottom were chosen for measurement of initial and subsequent diameter at the end of the test.

1. PVC lining : The measurements as taken at different points around the periphery are shown in Table - 2. Table - 3 shows the surface finish of the lining along the length at ten different points. The average wear at level 1 from top was 0.233 mm and that at level II from bottom was 0.200 mm which amounts to 0.273% and 0.235% at levels I and II, respectively.

Table - 2 : Measurement of inside diameter of the PVC liner (I.S. 4985-1968)

Orientation of the line of measurement.	I.D. before testing (mm)	I.D. after testing (800 hours)		Remarks
		Level I 50 mm from top	Level II 50 mm from bottom	
$0^o - 180^o$	85.116	85.356	85.306	Diameters have been measured at different angular positions on a particular horizontal plane.
$45^o - 225^o$	85.236	85.456	85.356	
$90^o - 270^o$	84.746	84.936	84.936	
$135^o - 315^o$	84.556	84.836	84.856	
Average diameter	84.913	85.146	85.112	Wear at Level I = 0.233 mm Wear at Level II= 0.200 mm

Table - 3 : Surface finish of PVC lining

Sl.No.	1	2	3	4	5	6	7	8	9	10	Average
Surface finish (μ inch)	23	20	26	28	26	24	25	26	24	17	23.9 u inch = 0.6 micron

2. Hylum lining :

The results of test on hylum lining are presented in Table - 4 below.

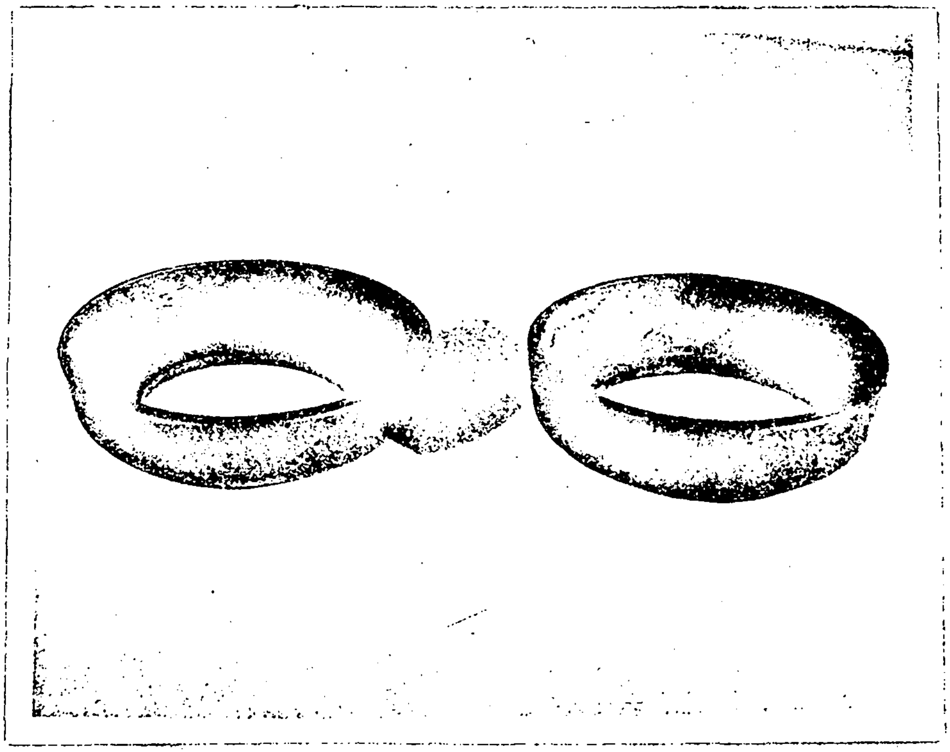
Table - 4 : Measurement of inside diameter of the hylum liner

Orientation of the line of measurement.	I.D. before testing (mm)	I.D. after testing (for 250 hours) Level I (50 mm from top)	Level II (50 mm from bottom)	Remarks
$0^\circ - 180^\circ$	85.08	85.28	85.25	Diameters have been measured at different angular position on a particular horizontal plane
$45^\circ - 225^\circ$	85.22	85.33	85.32	
$90^\circ - 270^\circ$	85.13	85.20	85.19	
$135^\circ - 315^\circ$	85.00	85.15	85.22	
Average diameter. (mm)	85.107	85.240	85.245	Wear at Level I=0.133 mm at Level II=0.138 mm

The wear of hylum lining was 0.133 mm at Level I and 0.138 mm at Level II and hence the change in diameter was 0.156% and 0.162% at Levels I and II, respectively.

Both the bucket and flapper remained in good condition in both the tests. There was no visible wear and there was no need to measure the wear. The photograph No. 4 shows the condition of bucket before and after the test which shows absolutely intact condition after use.

Photograph 4



Photograph 4 : Polythene buckets - unused (left) and used for 800 hours (right).

E. Discussions :

1. The wear of PVC liner used in the improved pump design, was only 0.200 to 0.233 mm after 800 hours testing, which is contrary to reported wear of 3 mm (⅛") in one month in Bettelle pump study which is much more than our present finding. Even the period of test was also much less in case of Battelle pump study. The contradictory results may be due to different classes of PVC used in the two studies. In this study PVC class 2112 is used, whereas in the Battelle pump study at Bangladesh, PVC 1120 is reported to have been used, which perhaps is of a different quality.

2. The wear of hylum lining was, on an average, 0.135 mm about 0.16% of diameter in a test period of 250 hours as against an average of 0.254% in PVC liner in a test period of 800 hours. Apparently it looks as though the wear in hylum liner is more than in PVC liner, it is not correct to draw any conclusion when the test periods are not equal. However, the observed wear in hylum liner is somewhat higher than the reported wear of hylum liner in Bangalore deep well pump cylinder study where a cylinder wear of 0.001 inch (0.0254 mm) is reported in a 1000 hours' test, at 40 - 48 strokes per minute with a stroke length of 4.5 inches. The hylum used in Bangalore pump was hylum TF 2211 whereas the cylinder used in this study was HF 105. Perhaps, the quality of the two are different. Hence, the results showed that both

types of liners are suited for the purpose and have an added advantage of being easily replaced by a new one by the maintenance staff.

3. The polythene cups (buckets) could replace the leather cups for better performance and less replacement. The finding in this study is again is contradictory to what has been reported in literature that PVC cups cannot be used with PVC cylinders. However, the material used in this study is not PVC but polythene.

4. Unlike in the case of leather, there was no fatigue and cracking of the polythene flapper and as such it is felt that this material could replace leather in flapper valve. Thus the need for developing a better type of foot-valve like ball-valve, butter fly flapper, etc. is felt unnecessary in order to keep down cost of pump manufacture. However, this has to be further confirmed in field test, where the valve will be subject to wet and dry conditions, mildew, etc. Reinforced neoprene is not available in the country. This, however, could be tried in case the polythene flapper does not give satisfactory performance in the field trial.

5. The poppet valve (T) of the new sturdy design has given excellent performance in the laboratory testing as can be seen from the more or less constant pumping rates. The pumping rate was 860 - 870 c.c. per stroke in case of PVC liner testing, as against a theoretical

discharge of 993 c.c. Hence, the slippage was 12.96% (should not exceed 15% preferably 5%) which remained constant throughout the test. Similarly, in the case of hylum lining, the slippage was more but was constant throughout the test. On further field testing for slippage, the need for improving poppet valve will be examined. If the closing time has to be reduced we will increase the weight of poppet by filling the hole with lead or other heavy metal or if the mating area is not perfect the same will be improved and modified, if required.

6. Since pump handle was not simulated in laboratory testing the performance of pin joints, piston rod head, in the new design, could not be evaluated in the laboratory testing. Hence, it is essential to carry out field testing for a critical evaluation of these vulnerable parts of the pump.

F. Weight of pump and manufacturing cost :

The average weight of the prototype pump is about 30 kg. This could, however, be reduced to 25 kg by reducing cylinder thickness, weight of handle, etc. A decision to this effect could be taken only after field testing.

The cost of prototype as worked out by CMERI is Rs. 85/= per pump which in regular production schedule should come down to Rs. 65/= or less. The current average market price of commercially available pumps is about the same.

Conclusion :

In conclusion, the new modified design which we would like to designate as "Modified Hand Pump (Singur)" has given a satisfactory performance in the laboratory testing. However, field testing is absolutely essential for a more critical evaluation to confirm the findings in the laboratory. It is proposed to take up field testing at an early date.

ACKNOWLEDGMENT

The authors wish to express their sincere gratitude to WHO/UNICEF and the Government of India for providing the opportunity to continue the study and develop a modified design for Hand Pump (shallow well type) which is of vital importance to developing countries and particularly to India. They wish to thank Prof. A.K.Banerjee and Dr. N. Deodhar, the past and present Director of the All India Institute of Hygiene and Public Health, Calcutta, for their support to this continued study. They are also indebted to staff of Sanitary Engineering Section of the Institute and Rural Health Unit & Training Centre, Singur, for assisting them in the conduct of the study.

Their thanks are specially due to Director, Central Mechanical Engineering Research Institute, Durgapur, and his Scientists who collaborated in the fabrication and field testing of the modified design, but for whose wholehearted support the work could not have been completed.

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WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

TESTING OF BENGALORE PUMP

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.

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B.P - 7

WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

DEVELOPMENT INDIA MARK II PUMP: INDIA

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 the village hand pump, in 1974, when surveys and feedback information indicated, that the locally produced and imported reciprocating handpumps were unsuitable for the conditions found in the average village application.

For the sale 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 disaster, 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 beneficiairies, and drawing water from a static water level (SWL) of 150 feet (Our average installation serves 500 beneficiairies and SWL would be approximately 60/70 feet).

2. The Pump Head, complete with 100 feet of rising main, B class 1½" BSP - connecting rod ½" and 2½" ID cylinder to cost less than U.S. $ 200. (Appreciate that the programme call 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 feet, 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.

6. The above ground mechanism, the pump head, must ensure hygienic standards; its 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 a 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 a "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 exisitng 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 to two months, the conversion head, proved to be far more durable, as 80 % were still operating without failure, at the end of 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).

Costing

Hand Pump complete with 100 feet rising main, connecting rods and cylinder	US $ 182,-
Pump Head only (Head - Water tank - spragged pedestal)	US $ 63,-
Rising Main 1¼ BSP. B class GI Pipe to 100 feet (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 1976. 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 thousans people. The cylinder is at 150 feet 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 lowe 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 up to 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 of the handle is still to be standard, designed by Sholapur, and utilises SFK 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 quire 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 district 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 and Development Organization (MERADO), Madras, endeavoured to expand the concept, we eventually withdrew our support when we realized 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 finalise 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 first 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 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 beneficiairies 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 1½" 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 on-y upgrading 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 1½" Bright Round Bar, with a coupling welded to one end and threaded to 50 mm depth. Providing the threads (std ½" BSW) are to recognizable 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 plus one year 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 feet 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 1977, initially converting existing installations to the new 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.

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.

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B.P. - 8

WORKING MEETING ON HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

KSC ST PROJECT HANDPUMP EVALUATION AND TESTING

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) By increasing the coefficient of friction between mating threads: 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 machinery 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.

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B.P. - 9

WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

DRAFT INDIAN STANDARD SPECIFICATIONS

FOR DEEPWELL HANDPUMP

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.

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WORKING MEETING ON HANDPUMP SELECTION AND TESTING

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HANDPUMP TESTING PROJECT

WORLD HEALTH ORGANIZATION
INO - BSM - 001
National Rural Community Water
Supply and Sanitation.

Jakarta, Indonesia

R E P O R T

ON TESTING OF THE THREE WATER HAND PUMP PROTOTYPES

by

Stan Szabo
WHO Sanitarian

Origin of hand pumps : INDIA, "Jalna Sholapur", (deep well)
THAILAND, "Khorat", (deep well)
BANGLADESH, Conventional, (shallow well).

I. INTRODUCTION :

Provision and coverage of the entire population with safe potable drinking water (INPRES - President Instructions) particularly in rural Indonesia has received high priority during the Second National Five Year Plan / PELITA II.

A ground water is readily available in aboundance in rural areas, the cheapest mean of providing safe water is hand pump, but at the reduced cost (low production cost) preferably manufactured locally. In the rural areas only such handpump is accessable to the rural low income community.

As installation of the handpumps in Indonesia, at present, is on large scale (15.000 - 20.000 anually), the Government has strong feeling and determination that the type of handpump with adequate quantity of spare parts for rural areas has to be standardized. This is possible only through the tests of the various prototypes of the hand pumps.

UNICEF has provided 6 handpumps for test in order to find out if relevant for local manufacturing.

II. OBJECTIVES :

1. The pumps after installation had to be tested at least during the 4 - 5 months period.

2. Tests of the pumps (users shall operate them normally) had to produce informations about durability (breakdowns), output of the water after certain period of performance (one year), and the cost for maintenance.

3. If found relevant the pumps might be manufactured locally in order to supply population with pumps at a reasonable price, of easier purchase and availability of spare parts under the hand.

III. PRELIMINARY OPERATION :

1/ At the central level of the Directorate of the Health Services office, the group of the officials took the responsibility for the establishment of the administrative and technical procedures in order to assure satisfactory testing process.

WHO Sanitarian was responsible for the technical and practical implementation of the tests respectively in Jakarta and Bandung area.

2/ Required preliminary work were :

2.1. Selection of the testing place. It had to be similar or typical rural Indonesian area.

2.2. Contact with the local authorities, give explanation and assure cooperation and acceptance.

2.3. Contact with further local/village authorities ("Lurah-the chief of the field community) in order to assure the full cooperation and participation of the community.

2.4. Designate one field worker for testing and submit him under two days short course in order to familiarize him with the test itself and particularly compilation of the testing forms.

2.5. Preparation of the forms: "Work bench inspection" (the form provides information on technical and physical condition of the pumps before installation); The form for field test (a) and (b) - (see annexes please); and the form for the breakdowns as well.

2.6. Having data of the places for the construction and installation (several visits were paid to the villages) calculation of the transportation of materials was necessary and essential because if out of the road on muddy terrain the cost is obviously higher.

In order hands, standard design for the technical improvement of the water source had to be unified for both places in order to avoid an extra expence for drilling or unnecessary additional construction.

Above minimal criteria are essential and as assertained were sufficient for the normal conduction of the tests.

IV. MAINTENANCE :

It was suggested that one sanitation worker designated by the DHS in both cases (Jakarta and Bandung), were sanitarians, should be responsible for the supervision of the works and installation and afterward for the test and finally for maintenance of the pump.

His job description :

a/ Supervise the works of the skilled workers in improvement of the water source and installation of the handpumps.

b/ Conduction and recording of the entire test.

c/ Weekly inspection of the pump, lubrication as needed (oil and grease) and repair if necessary, tight the nuts and bolts with appropriate keys. During this particular activity, the sanitarian was instructed to be accompanied with one or more villagers in order to teach them practically the maintenance of the handpump.

d/ Keep the handpump clean and its surroundings and finally report every other irregularity to the health section.

V. TESTING :

Six prototypes of the handpumps were received from UNICEF in Jakarta, namely: Indian "Jalna Sholapur", Thailand "Khorat" (both deep well handpumps) and Bangladesh conventional shallow well handpumps.

Selected places for testing :

1) Jakarta Kampong (marginal village of the capital 15 km. dist.) namely PONDOK LABU - Kali Jati RT-006/02 **

2) Bandung, two Kampongs in marginal zones of the town, namely Lingkungan Pasteur RT-007 and RT-003 Ciumbuleiut respectively.

** RT = The lowest social and administrative form in rural Indonesia, i.e. group of 20 - 30 families named "Rukun Tetangga".

- The owners of the wells have had agreed that the testing handpump installed on their well should serve to the community (not exceeding 200 persons).

- Improvement of the well had to be done by the skilled operator and paid by the DHS Jakarta and Bandung respectively.

- Responsible official for supervision and maintenance should have free access at any time.

- The handpumps after the testing period shall remain onward in permanent use of the community without any compensation.

Test :

JAKARTA test had initiated in June 1977 through October 1977 i.e. during the dry season, and two "counts of users" were repeted until March 1978. As Jakarta Kampongs are closer and supervision of installations and test was assured, the test procedure passed without any problem. (Bangladesh handpump test was interrupted for two days due to the head cover supporting fork destruction, but this was, as informed by the community, atributed to the someone's vandalism).

BANDUNG test has initiated in September 1977 and programme until March 1978 - during the wet season ***. The test has been interrupted several times due to the different inconveniences and technical problems.

Affirming that installations of 3 handpumps in Jakarta were under the close supervision and apparently better skilled technicians and at present in good working conditions, the Bandung area where technical works of installation were less supervised, the technical problems had a significant impact on the testing procedures. It is important to appreaciate that what has happened during the installation of the handpumps.

India "Sholapur" showed good normal works but with the weak output of water. Two weeks later the rubber ball valve had to be replaced; (it was difficult to find the motive why the rubber ball valve in the contact with the water was so quickly consumed?). Locally made ball valves were replaced two times. However, the pump is now in operation. The test has been postponed, and the DHS in BAndung would make an attempt in order to provide few original valves.

*** : Monsoon weather-rains - period: from September to February/March.

Thailand "Khorat", hand pump in Jakarta testing area is considered as easy stroking, robust and with an economical output of water suitable hand-pump, (these characteristics are convenient particularly in the areas were ground water during the dry season is scarce and demand for the water very high i.e. the number of strokes considerably increased), unfortunately, in Bandung area the PVC cylinder was badly damaged due to the inappropriate sinchronization between the stroking handle, lengt of the plunger rod and cylinder pumping works?. The lower cap with the valve was forcibly separated and from the bottom of the well recuperated. Suggested device for the reactivation of the hand pump was accepted, locally manufactured and installed in order to put it in the public service again. The test has been suspended for five months. However, new brass cylinder were provided by the UNICEF. One has been promptly installed in December 1977. The test has been reassumed in February 1978;

Bangladesh conventional hand pump, was installed on the shallow well on August 1977. The pump drive was removed and the bolt on the leather valve was replaced with new one and put in the public service again. Unfortunately, the well runned out of water for three months. The test started in November and interrupted again the for the period of three weeks due to shortage of water. The test reassumed again in January 1978.

As stated in Bandung DHS the handpump testing will continue and will be monitored very closely over the next testing period, until June 1978.

Requirements :

Wells : - Deep well
- Shallow well
- Dug well

Water level : - Minimum depth = 7 m (for deep well hand pumps)
- Quantity of the water $\pm$ 3 m^3
- Clean and improved environment of the well done by the community or owner.

(Note: Average depth of the wells in rural area not exceedes more than 18 - 20 m).

Manpower : Experienced worker in plumbing and in masonry was hired and figured as contractor.

Community: Test and installation of the handpumps was very appreciated by the community and all possible cooperation was received.

VI. EVALUATION :

It has been observed that Jakarta handpump prototypes, during the pre-test period and during the test itself and during the Post test period, were performing in'a good efficiency each on it's own property.

Latest performance after one year of operation:	- Bangladesh	: 56 sec./15 lit./strokes 12.
	- India	: 1 min,35 sec./15 lit./strokes 34.
	- Thailand	: 1 min,23 sec./15 lit./strokes 41.

Factor to be taken consideration :

1). Installation of the handpumps should be done by the skilled worker with appripriate tools.

2). SUpervision of the works should be established in order to avoid unnecessary serious damages.

3). Failure in the installation should be communicated immediately to the health sanitation section.

4). Any justified or unjustified interruption of the test should be promptly communicated to DHS.

5). All motion parts of the handpump(handle, pins,rod ...) should be lubricated weekly.

6). Handpump should be watched and cleaned (periodical painting with protective paint saves the handpumps).

VII. CONCLUSION :

It is premature at this stage to comment mass local production of any of these handpumps under the testing programme, but desireability for local manufacturing exist due to the known opportunities as lower cost of production, sawings on transport, availability of locally produced spare parts etc. It would have enormous effect on the cost if the consideration is taken that present INPRES programme requires thousands of handpumps to be installed throughout the country.

However, among others, more of these types of handpumps shall be imported for further tests and analysis in different geological, hydrogeological and climatic circumstances through the 1978/79 year.

Jakarta, April 1978.

Following a field study on locations of deep well handpumps "Dempster" in East Java, Central Java, Yogyakarta, West Java and D.K.I. Jakarta, the team has come to the following conclusions:

1. Efficiency of "Dempster" pumps

a. The efficiency of the "Dempster" is good. It can draw water from dug wells and piping wells to a maximum head of 30 meters.

b. It can supply a relatively large quantity of water, between 9 and 20 liters per minute, at 30 to 40 strokes per minute.

c. Operation presents no problems. Elementary school pupils and housewives can easily operate this deep well handpump.

d. It has a long life span, provided that maintenance is good. Several pumps have been working since 1970.

e. Replacement of damaged parts (usually worn out cup seals) usually takes about 30 minutes when performed by 3 persons.

2. Damage

a. The most common sources of trouble, according to the field study, are worn out sup seal, loose rod, worn out handle, and stuck plunger.

b. The causes are generally bad installation, careless and rough handling, bad maintenance, lack of equipment and parts, and failure to check the pump regularly after installation.

c. Sometimes the pump was found to be not in a vertical position, so that operation was heavy, and the effect little water and abnormal wear of the cup seal. Other defects occasionally encountered were:

- the pump's rod connections were not fastened tight enough, so that they got loose;
- same for the rod holder;
- the foot valve was not separated from the plunger at the installation, so that the plunger got loose;
- rod length does not correspond with well depth, the rod has to be shortened and the new connection is made with a different standard worm. The result is a loose under section of the rod;
- the pump was installed when the ground water level was high. In the dry season the cylinder is too high to reach water;
- in clay soils the strainer can become blocked. In these circumstances wells with double casing are necessary;
- in one case a pump was installed at a positive well, which gave some water of its own accord. Here, a shallow well pump would have been better, and cheaper.

d. Operation

In several places the pump has to serve more than 500 people. It is worked day and night, and is therefore often damaged, as are the pumps installed in front of schools and in other public places, where children often play with them.

e. Maintenance

Common sources of trouble are the following:

- people foget to oil or grease pins, so that they quickly wear out. The pump becomes unstable and noisy. The pins have to be replaced more often than ought to be the case.

- worn cup seals are not replaced in time, so that the pump stands idle. Sometimes spares are not available, sometimes they are not of the same type or quality as the original. In one case the spare cup seal was so bad that it expanded with use, and caused the entire system to get stuck.
- In another instance, the bolts of the cup handle were slack, causing unnecessary friction and quick wear.

Suggestions

1. Make maintenance and installation workers attend intensive training courses.
2. Make complete equipment for installation and maintenance available.
3. Have available sufficient spare parts of the same quality as the originals, especially leather cup seals.
4. Prepare an operation and maintenance instruction manual in the Indonesian language for each type of pump.
5. The present standard rod length of 6 meters is too long. We think rods should be supplied in units of 3 meters.
6. Better supervision during installation is necessary, so that no mistakes are made.
7. The pump has to be checked regularly, e.g. once a month, so that any defects are discovered in time.
8. Ground water levels should be studied before installation to precent unpleasant surprises in the dry season.
9. If the ground water level is high, this type of pump is not necessary. It should not be installed in places where a simpler type would also do.

10. The local community should be given every information on the correct use of the pump. They should appreciate how important and profitable it is for their daily lives. Only then can they be expected to take the care necessary for continued good working order of the pump.
11. The number fo people served by one pump should preferably not exceed 100.

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WORKING MEETING ON HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

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

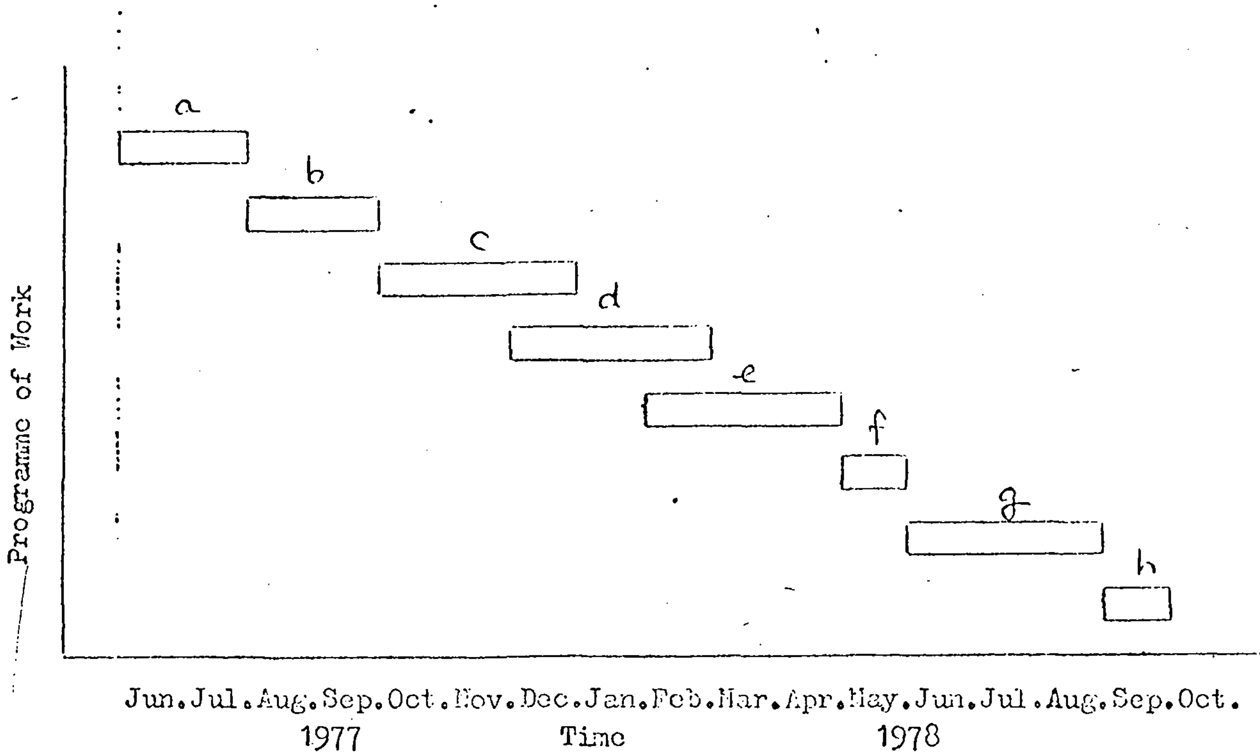
e) Improvement of handpump design based on the above data.

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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WORKING MEETING
ON
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29 May - 1 June 1979

DEVELOPMENT OF HANDPUMPS FOR RURAL THAILAND

Development of Handpump for Rural Thailand

by

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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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B.P. - 14

WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

WELLS PROGRAMME ANNUAL REPORT

DECEMBER 1977

who international reference centre for community water supply

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B.P. - 15

WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

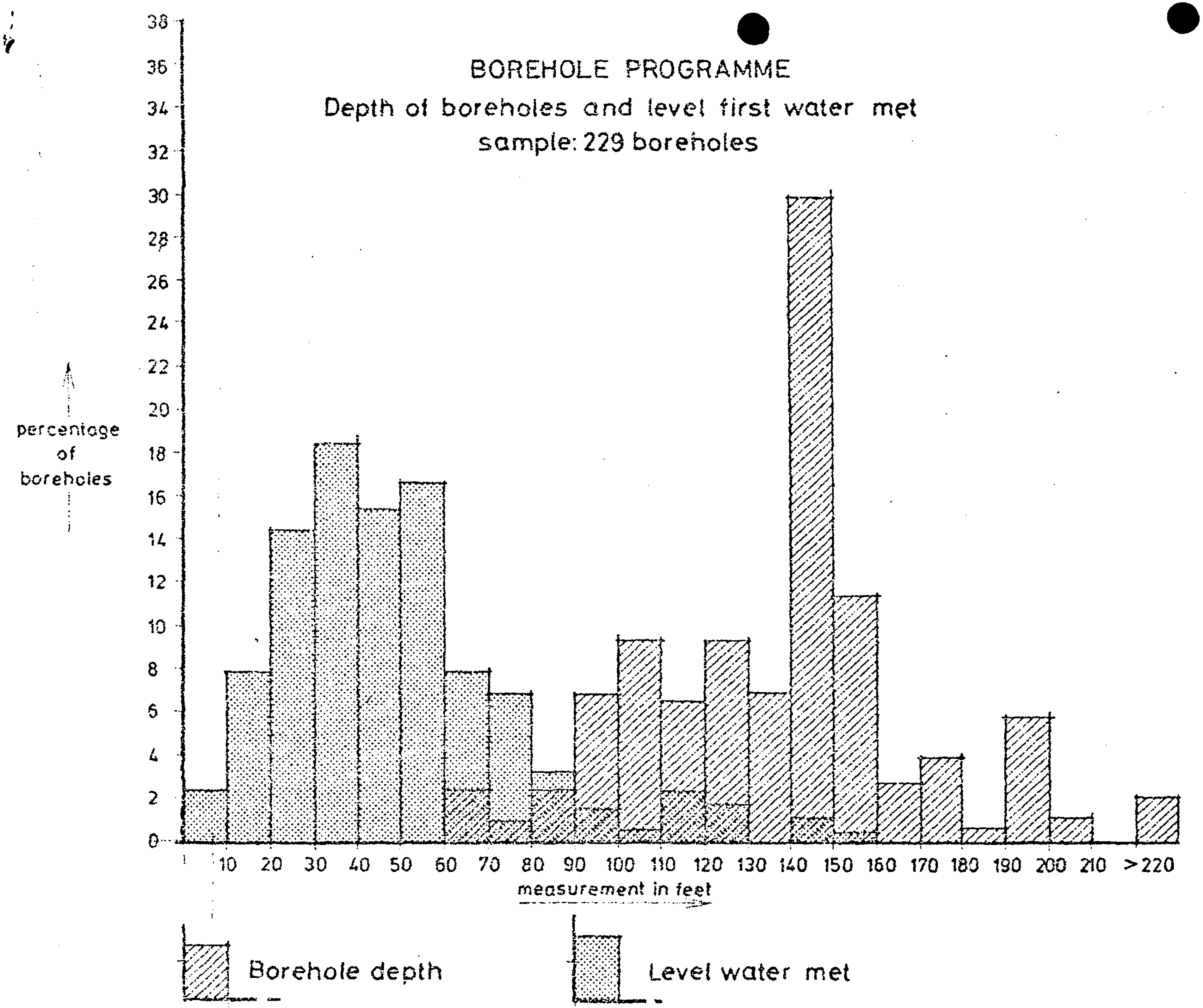
Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

FIELD SURVEY OF HANDPUMPS

SURVEY OF BOREHOLES IN CHIRADZULU DISTRICT

Borehole number	Location	year drilled	Pump type	Donor	flow in L/min.	distance to latrine	condition of apron	drainage	result of water test	use of b/hole	Remarks
PM 81	Makanani	1976	B & C	EZE	–	300 m	fair	poor	satisfactory	little	water rusty
FP 61	Masanjala Sch.	196..	Climax	?	9	20 m	poor	poor	satisfactory	well	internal leakage
FC 64	Chilala	1972	Climax	DCA	13	300 m	fair	fair	satisfactory	fair	
RM 6	Ng'ombe	1975	Climax	EZE	13	80 m	poor	poor	satisfactory	well	
FP 59	Bandawe Sch.	1974	Climax	EZE	none	50 m	good	good	–	–	out of act.
PM 219	Milepa H/C	1976	Climax	ICCO	14	40 m	poor	poor	suspicious	well	pumps also in over head tank
D 120	Masauli	1969	Climax	EZE	9	100 m	fair	fair	satisfactory	well	
FP 58	Mauwa court	1975	Climax	EZE	5	60 m	fair	good	satisfactory	fair	water rusty internal leakage
Q 308	Ndunde H/C	1968	Climax	BfdW	14	60 m	fair	poor	contaminated	well	pipe to tank blocked
FC 63A	Masala	1972	Climax	DCA	8	80 m	fair	poor	satisfactory	fair	
X 161	P. Ind. Mission	1971	Climax	?	9	50 m	poor	poor	suspicious	well	
DM 35	Mphaso	1976	B & C	ICCO	11	50 m	good	fair	contaminated	fair	
DM 36	Mtupanyama	1976	B & C	ICCO	9	40 m	good	fair	suspicious	little	salty rusty water
Y 196	Mtupanyama	1971	Climax	DCA	10	50 m	poor	poor	contaminated	fair	
DM 33	Nsoni School	1976	Irriga	ICCO	4	20 m	fair	poor	contaminated	fair	rusty water
RM 17	Majiguta	1975	Climax	EZE	1	30 m	fair	poor	satisfactory	well	rusty water
RM 7	Kholomani	1975	Uganda	EZE	27	30 m	fair	poor	suspicious	little	well nearby
FC 62	Misomali	1971	Climax	EZE	6	120 m	fair	fair	satisfactory	fair	water rusty
DM 34	Chimwawa Court	1976	B & C	ICCO	6	120 m	poor	fair	contaminated	fair	taste not liked pump handle brok.

Borehole number	Location	year drilled	pump type	Donor	flow in L/min	distance to latrine	condition of apron	drainage	result of water test	use of b/hore	Remarks
FC 61	Ndala	1971	Climax	EZE	8	50 m	good	good	suspicious	well	milky water in rainy season
FC 60	Kanje Mkt.	1972	Climax	DCA	12	80 m	good	good	satisfactory	well	
RB 160	Malabvi School	1973	Climax	EZE	12	70 m	good	fair	satisfactory	well	
PM 82	Mombezi Mkt.	1975	B & C	ICCO	8	50 m	poor	fair	badly contaminated	well	pump worn out
FC 65	Manawa	1971	Climax	EZE	9	150 m	poor	poor	satisfactory	well	
R 70	Kachingwe	1969	Bush	EZE	13	60 m	fair	poor	contaminated	well	
PM 430	Nyungwi Sch.	1976	B & C	ICCO	7	70 m	excellent	good	suspicious	well	down stream of school
PM 76	Namiwawa	1975	B & C	ICCO	–	50 m	fair	very poor	badly contaminated	little	rusty water
Q 261	Namadzi	1968	B & C	BfdW	9	50 m	poor	poor	badly contaminated	fair	internal leakage
PM 423	Mbulumbuzi	1976	B & C	ICCO	8	70 m	fair	poor	badly contaminated	well	down stream of school



BOREHOLE PROGRAMME
Depth of boreholes and level first water met
sample: 229 boreholes
percentage of boreholes
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 >220
measurement in feet
Borehole depth
Level water met

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WORKING MEETING ON HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

IMPROVEMENT AND TESTING OF SHALLOW WELL PUMP

ENGINEERING DEPARTMENT

SHALLOW WELL PUMP IMPROVEMENT RESEARCH PROJECT

REPORT ON STAGE I OF PROJECT

WKK

APRIL 1978

C O N T E N T S

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 Mambuma 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).

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 (0.016m^3) 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.

(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[le] 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 implemen[ted] at the time of the survey. An assessment of the vibration of the footvalve is as follows:-

Excessive vibration	:	13
Average vibration	:	30

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 ½ 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 $\frac{1}{5}$ 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).

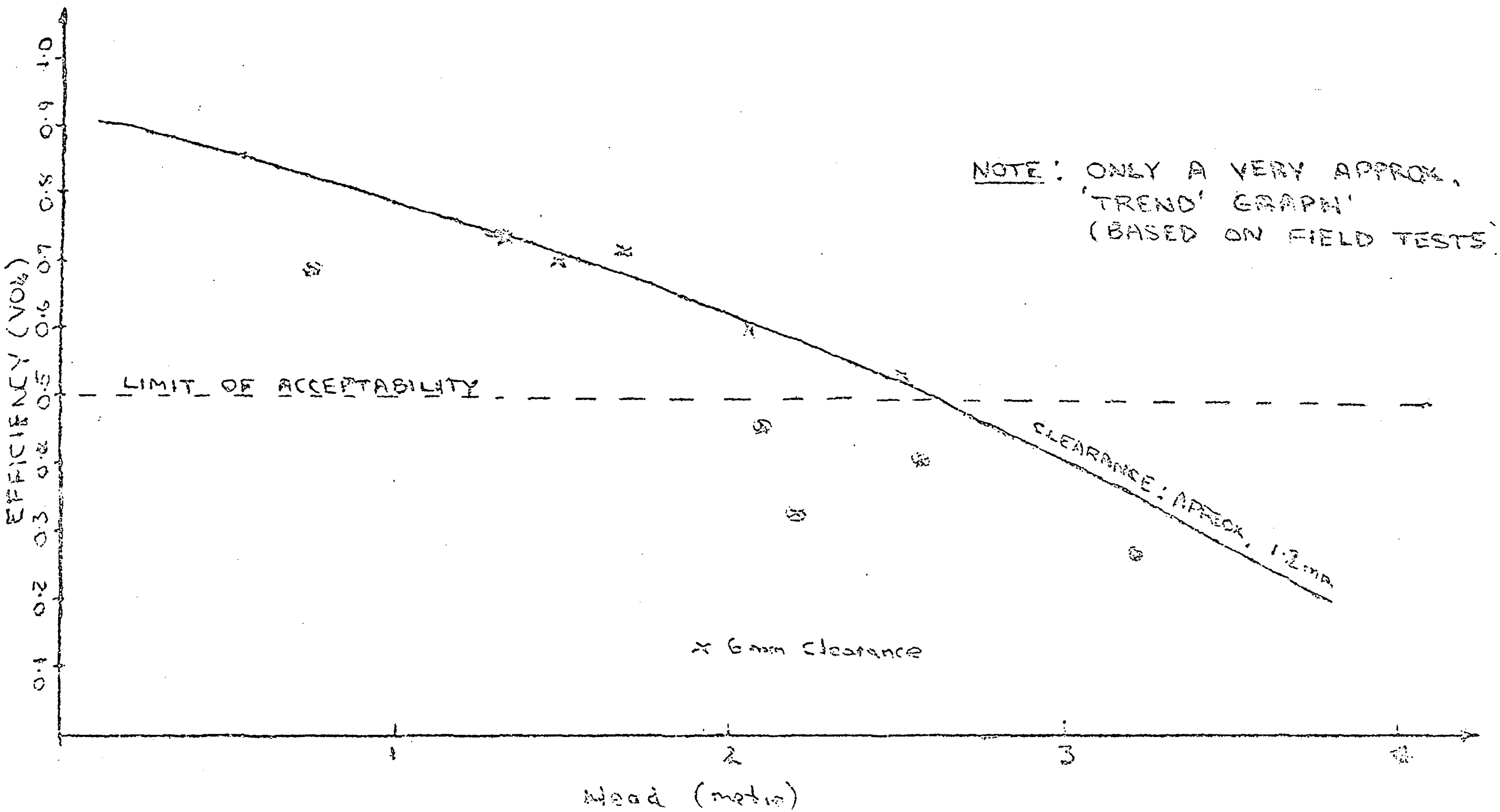
(5) Assessment of Final Design(s):

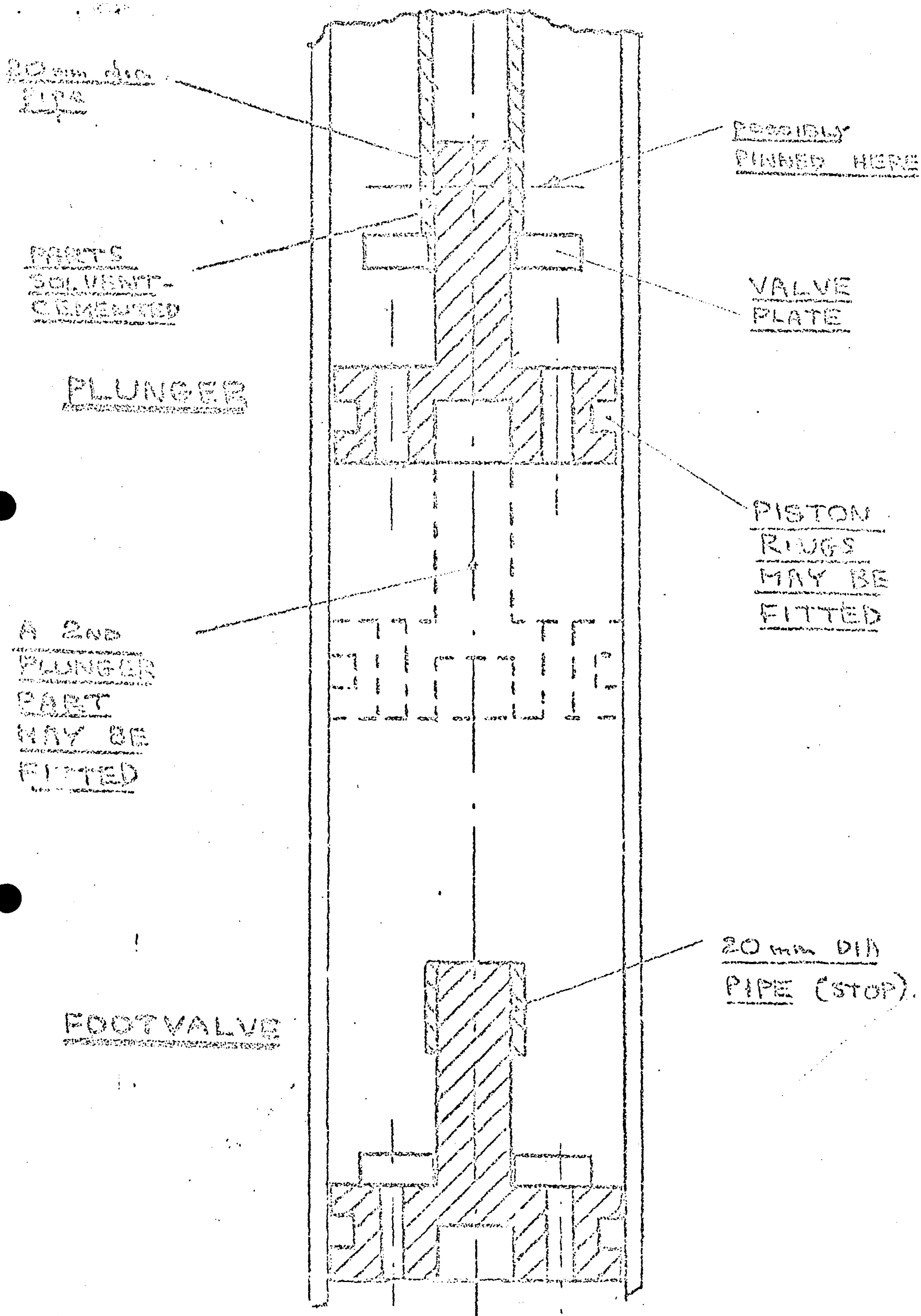
The measurements taken during the proposed work programme of laboratory tests will include wear and tear data and the maintenance requirements of the pump. The designs under test will take due consideration of the objectives of pump maintenance at the village level and the possible local manufacture of some components. After laboratory assessment one or two pump designs will be selected for field installation and evaluation.

WKK/HLC

7th April 1978

FIG 1. GENERAL TREND: VOL. 3 vs. HEAD



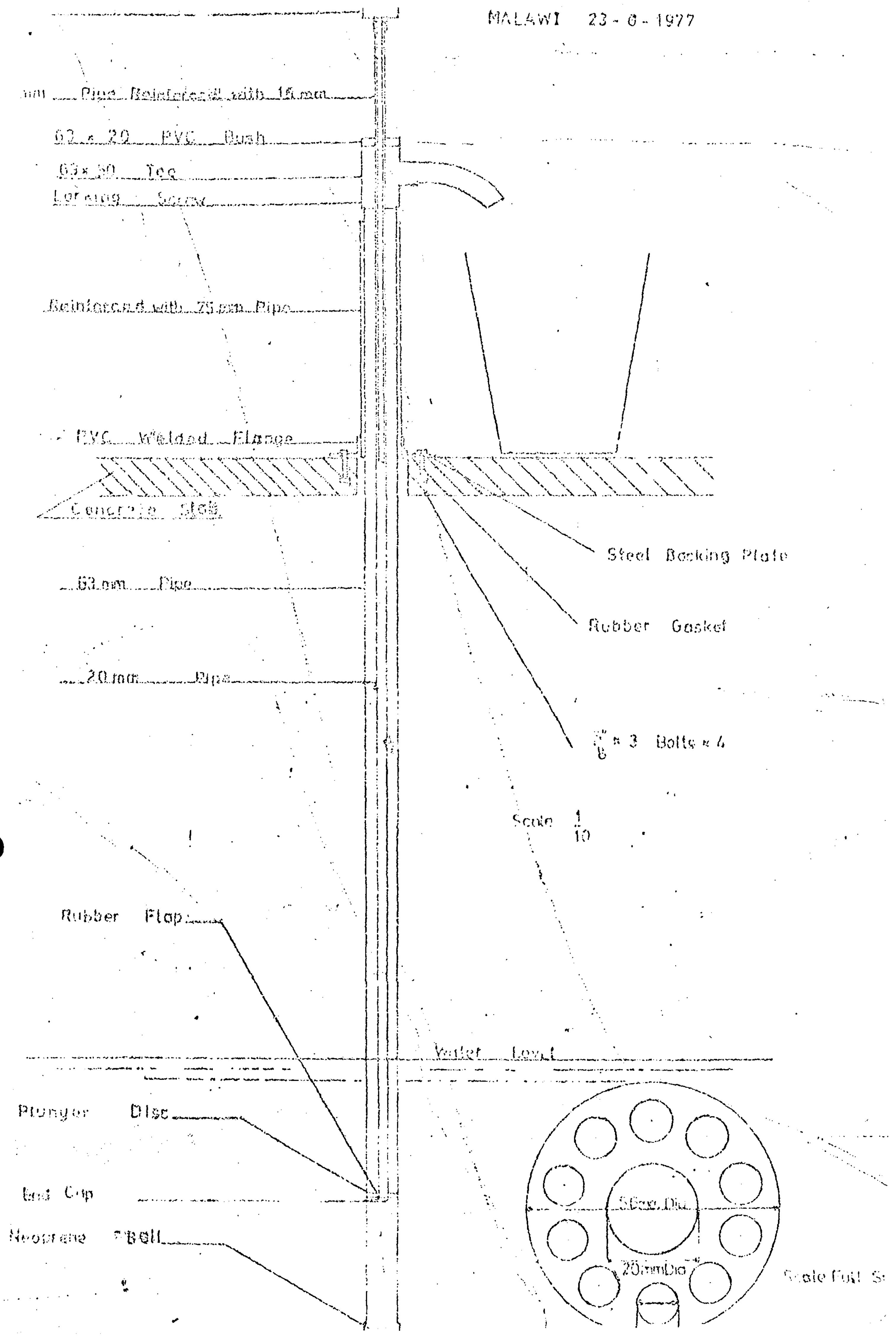


MODIFIED 'WATERLOO' PUMP

LOCATION OF WELLS

LOCATION	WELL NUMBER	INSTALLATION DATE
Mtsiro	51	
Katontha	16	
Kazulambonda	22	
Nthondo	27	
Mvitungwi	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
Mawinda (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	

MALAWI 23-8-1977

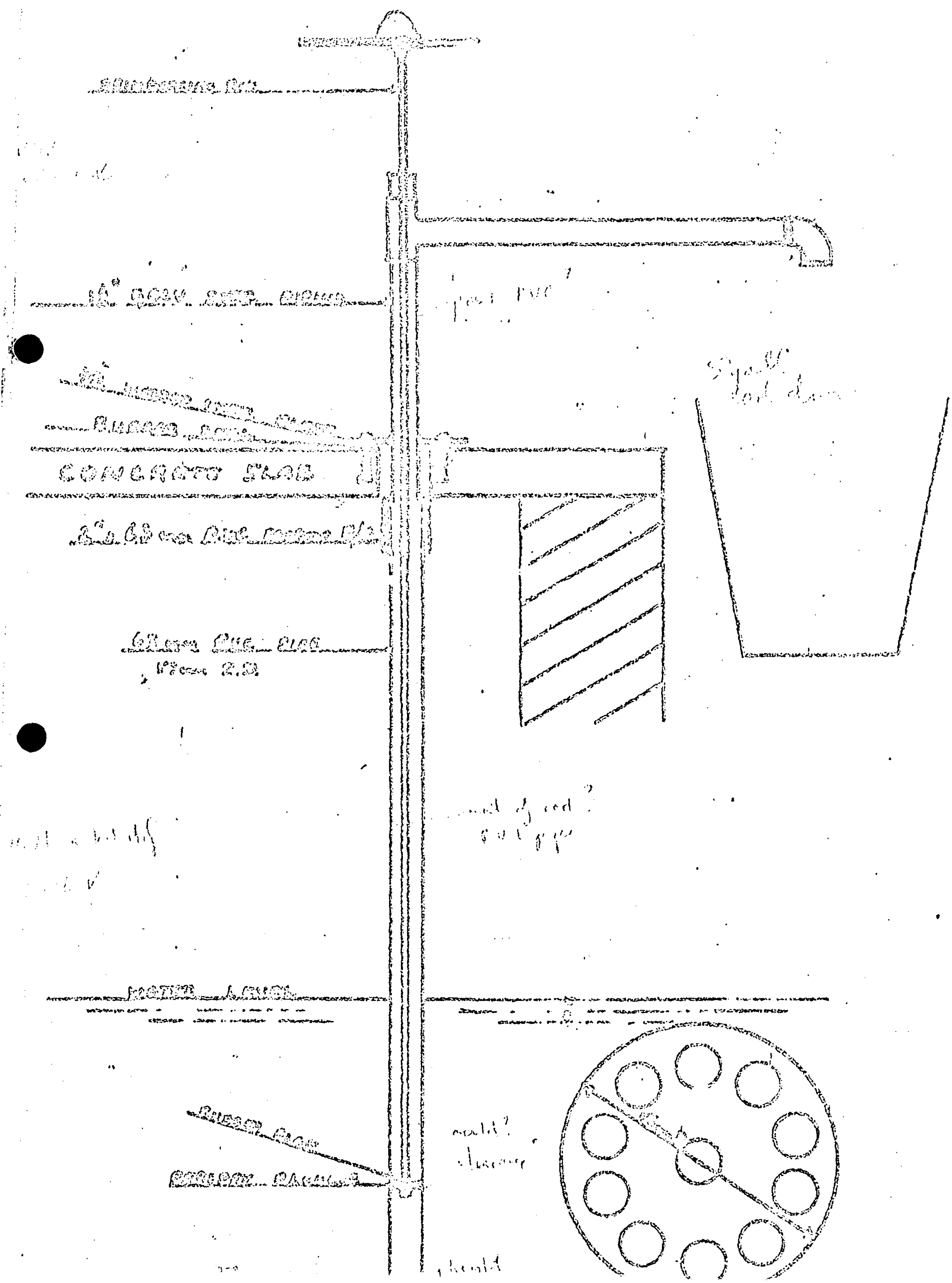


SHALLOW WELL P.V.C. HAND PUMP

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



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.

who international reference centre for community water supply

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B.P. - 17

WORKING MEETING ON HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

FIELD TEST EVALUATION PROGRAMME

DETAILS OF TEST PROCEDURES AND HAND PUMP SELECTION PROCESS

1: BACKGROUND ASSOCIATED WITH COMMENCEMENT OF TEST PROGRAM

The Ghana Upper Region (CIDA) Water Supply Project was launched in November 1973. Equipment assembly and training commenced with the first test hole in June 1974. Actual construction of rural ground water well supplies commenced after the rainy season in November 1974. By August 1976, a total of 1168 rural hand pump wells had been completed.

Because it was recognized at the outset that a durable hand pump would be required to meet the conditions, the experience of international organizations was solicited prior to the selection of a Project pump, an evaluation of Canadian hand pumps was carried out, a 4-month field test program conducted, and shop testing established which subjected the Canadian pumps to 2,000,000 cycles of operation. Having proceeded with what was thought to be reasonable caution, the Ghana Water and Sewerage Corporation selected the Beatty hand pump, manufactured by GSW Ltd., Canada.

Installation of the first order of 500 Beatty hand pumps commenced in June 1975. By the time a need had developed to place a second order of hand pumps in October 1975, a number of deficiencies had been identified on the initial supply of Beatty pumps.

The initial shortcomings of the first hand pumps were largely overcome through design changes incorporated in the subsequent order of 800 Beatty hand pumps which were delivered to the site in March 1976.

Throughout 1976, steps were taken to further upgrade the 1300 Beatty hand pumps which have been used on the Project thus far. The Supplier of these pumps, GSW Ltd., provided a substantial number of improvements and replacement parts under warranty. Complete rehabilitation of these pumps is scheduled for completion by the end of 1977.

In spite of the improvements which have been made and the fact that the present operating performance of the Beatty pumps is proving considerably better than experienced at the outset of the Project, there is no doubt but what a higher caliber of hand pump is desirable to meet the operating conditions of the Upper Region. It became patently clear in late 1975 that the only means of selecting a type of pump which would meet the conditions was through a field test evaluation program of hand pumps available on the world market. Consequently, the Upper Region hand pump test program was launched.

2. DURATION OF HAND PUMP TEST PROGRAM AND BASIS FOR ACCEPTING PUMPS TO BE TESTED

In December 1975 it was decided that there was a need to carry out a hand pump field test evaluation program to establish the type of pump which would give the most satisfactory performance under the operating conditions of the Upper Region of Ghana.

By the time a consensus was reached as to the scope of the test program and a preliminary screening of a number of pumps completed, plus arranging with manufacturers to provide some test models, it was February 1976 before the first test hand pumps were installed in the program. Since that time, 50 hand pumps of 15 different manufacturers from 10 countries have been incorporated into the evaluation program. Several new makes were introduced to the test program in December 1976 and January 1977. In response to special requests, a few more were added during the past six months. For instance, GSW Ltd. developed a Beatty prototype to be tested which has just arrived on site and has not yet been placed into service.

In order to obtain sufficient data to establish the relative performance of the various test pumps, it was decided to continue the evaluation program to the end of June 1977. This was to have been followed by the enclosed formal report which would outline the test results in detail, including a recommendation for a hand pump to be purchased for Phase 2 of the Project. A decision has also been made to continue the test program until the end of 1979.

It should be pointed out that consideration was given to a large number of pumps which were never included in the test program because of obvious design deficiencies, poor experience elsewhere, or because their design configuration and quality of manufacture was similar to those already being tested. For instance, testing of such pumps as the Beyer, Pompes Briau, and Bodin were rejected. As was the "Afro pump" made in Kenya. Most of these were rejected from further consideration because they were similar to and had no apparent design advantage over pumps which were already on test.

On the other hand, several varieties of the basic Beatty pump were tested in an effort to find replacement parts which would facilitate realizing the maximum useful life from the units already purchased.

As a matter of interest, the Inter-African Committee for Hydraulic Studies (CIEH) in Upper Volta has been conducting a test program on a number of pumps including the "ABI" from Ivory Coast and the "Vergnet" from France. Because of this, two of the Upper Volta test pumps have been monitored throughout the past year as an extension of the Ghana program. Experience of others under similar circumstances over a longer period of time was considered advantageous in the selection of the Project hand pump. The Committee's experience was used as a basis for rejecting some pumps and introducing others to the test program.

It is also of interest to note that the test program has been carried out at a minimum of cost because many of the suppliers provided the pumps free of charge. The Consultant further minimized the costs by having its site personnel monitor the hand pump test program as an additional work load over and above their regular duties.

3. INSTALLATION AND MONITORING PROCEDURES

All test pumps were located in the general vicinity of Bolgatanga, with the farthest being approximately 20 miles from the Town. Sites were selected on the basis of their year-round accessibility, areas of relatively heavy utilization, and with minimum differences possible in usage and static lift conditions.

Prior to installation, the test pumps were inspected and preserviced. Some of the pumps were installed as complete units, whereas others made use of the downpipes and cylinders purchased with the Beatty Project pumps. A number of the initial test pumps were slightly modified to facilitate use of available below grade components such as drop pipes and sucker rods. Each pump was clearly identified with a permanent well head number so that accurate records could be maintained regarding test performance. All potential wear points were carefully measured with a Vernier caliper so that subsequent wear through use could be clearly established through time.

After a hand pump went into the test program, it was inspected visually every ten days to observe its operating condition. In order to establish the relative use of each hand pump in the evaluation of performance, a manual count was periodically carried out at each test pump to determine the number and size of containers being filled and the resultant water pumped within a specified time period. For the majority of pumps, these utilization counts were conducted on a day long basis every two months. A control group was recorded monthly and occasionally weekly to gain an insight into the actual operating conditions of the hand pumps. An attempt was made to install mechanical counters to further validate the relative pump utilization and to make an assessment of actual handle movements in the pumping process. These proved vulnerable to damage and tampering and so visual counts were relied upon. A number of meters were also tried so that an accurate recording could be made of the water being pumped.

Eventually a successful meter was installed below grade on one of the pumps which served as a basis for correlating the manual counts. By use of a torque wrench device, the relative ease by which the user could operate each pump was also measured. In addition the number of cycles (handle strokes) and time required to pump a gallon of water was determined for the various pumps on test.

Until the end of 1976, each test pump was dismantled at three month intervals so that the amount of wear could be accurately measured and recorded. After a detailed inspection, the pumps were reassembled, lubricated, and placed back into service.

During the first half of 1977, the three month inspection and lubrications were discontinued. The reason being to subject the test pumps to very severe conditions during the forthcoming dry season and thereby accelerating the test results regarding wear conditions. This was also a means of establishing whether or not the various pumps on test were capable of operating continuously for six months without preventive maintenance. It could be argued that since maintenance should be provided under actual use conditions some of the pumps might have performed better if 3 month servicing had been provided. However, the main interest was to accelerate the wear and ascertain what period of time the various pumps could operate without receiving maintenance attention.

The test pumps were spot painted so that they could easily be identified by the regular GWSC maintenance crews. Instructions were issued to all relevant personnel that they were not to carry out any repairs or maintenance on the test pumps. All servicing and repairs were done under the direct supervision of the Consultant's officer in charge of the test pump program. When a breakdown occurred, the circumstances were recorded. Repairs were made and the pump placed back into service as soon as practicable. Care was taken not to replace parts which were merely worn. Complete failure of a pump component must occur prior to a replacement being made. Again under normal maintenance circumstances, a worn part would have been replaced with a new one. But the exercise at hand was to establish the life span of these weak pump components. Each well has its own record file. Care was taken to ensure that an accurate and up-to-date record was kept of every happening in connection with each pump. Photographs were taken to supplement the written record regarding wear and failures of pump components. Every effort was made to establish an objective record of the comparative performance of the various pumping units.

At the same time as the Upper Region test program is being carried out, the Consultant and GWSC have investigated actual field experience gained in the use of various types of hand pumps elsewhere, particularly in the nearby West African Countries.

Attached to this Report are samples of the monitoring which was carried out and the test pump data sheets which are on file.

Prior to preparation of this Report, all test pumps were dismantled, inspected and measured for wear. They were then lubricated and placed back into service for continued testing.

4. DISCUSSION OF CONSIDERATIONS ASSOCIATED WITH HAND PUMP SELECTION

The criteria which has been adopted for the selection of a hand pump to meet the needs of the Upper Region (CIDA) Water Supply Project involves the following considerations:

a) Relative Pump Performance During Field Test Program.

b) Comparative Capital Cost of Hand Pumps.

c) Range of Maintenance Costs for Various Hand Pumps.

d) Life Span and Replacement Cost of Component Parts of Each Pump.

e) Long Term Total Cost of Alternative Pump Selections.

f) The Economics of Purchasing High Priced Pumps.

g) Design Improvements and User Acceptance.
   - i) general;
   - ii) well head sanitation;
   - iii) ease of maintenance;
   - iv) ease of operation and user acceptance.

h) Adaptability of Selected Pump for Other Parts of Ghana.

i) Pump Supplier Capability and Reliability.

j) Potential Local Manufacture of Pumps.

k) Suitability of Selected Pumps for Village Maintenance.

l) Implications of Hand Pump Standardization.

In addition to the foregoing, a number of other factors were brought into the consideration, such as number of parts per pump, delivery period for supply, depth to which pumps can operate, and the probability of failure in the event that inadequate maintenance is provided in the long term.

a) Relative Pump Performance During Field Test Program

The field test data forms the basis for all further considerations. Unless there are unusual extenuating circumstances, only those pumps which performed well during the test have been included in the select group of pumps to be evaluated in detail. Under conditions whereby there was a pump which has considerable promise and performed well in the field tests except for one or two minor defects, this pump was included in the select group on the premise that the weaknesses would be overcome through design changes. Some pumps have been excluded from a detailed analysis because they failed completely during the test program and had to be taken out of service. The UST pump has been included in the select group because it is manufactured in Ghana.

b) Comparative Capital Costs of Hand Pumps

As a prerequisite for recommending a hand pump for the Project, competitive quotations were solicited from the suppliers of the pumps in the test program. The actual prices received are included in this document. Figure 1 in Section 12 illustrates the range of capital costs for the various pumps on test.

The objective consists of having firm contract supply prices for all the pumps prior to making a recommendation. Potential suppliers have provided quotations which are valid until at least October 1977, so that GWSC can give ample consideration to the recommendations and authorize purchases which are based on firm prices without having to go back to the suppliers on a negotiation basis after they know they have been selected. This will hold true even if GWSC decides to select some pump other than that recommended. If the decision process is prolonged and an order cannot be placed by October 1977, at least a reasonable basis will have been established for negotiating a supply price for the unit which is to be purchased for the completion of the Upper Region Project.

In addition to the basic cost of a new pumping unit, firm quotations have also been obtained for spare parts. There appears to be a considerable spread in the cost of spare parts from the various manufacturers. Over the long term, this could be an important maintenance cost consideration. This too was taken into account in the hand pump selection.

c) <u>Range of Maintenance Costs for Various Hand Pumps</u>

Regardless of the hand pump selected, some maintenance costs will be involved in keeping each pump in satisfactory operating condition. Every pump has wearing components which periodically must be replaced. Vandalism and accidents result in the need to replace a few damaged units from time to time. The objective of course is to select a pump which has the promise of requiring the least amount of maintenance. This in turn should result in a hand pump which provides the best service performance and at the same time is the most economical to maintain. Providing the capital cost of the pump is reasonable, the most economical pump selection should result.

The difficulty of course is to establish the relative level of long term maintenance required for the various pumps within the select group. 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.

The evaluation of maintenance costs is complex, as further detailed in the following pages regarding "Life Span and Replacement Costs of Alternative Pumps". And many value judgments are involved. Fortunately the field test program which has been carried out helped to establish the relative performance of component parts and result in more meaningful value judgments than if no test data were available. The following Section 7 on "Methodology of Hand Pump Selection" and the data displayed in Figure 2 of Section 12 provides more detail on the considerations involved.

d) Life Span and Replacement Costs of Component Parts of Each Pump

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 be of much value in the selection of the best pump for the Upper Region Project.

Each hand pump has a number of components, several of which 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. So when we speak of the life of a pump, we are not referring only to the most rugged and longest lasting component, we are really assessing the multitude of components as a whole to establish the economic usefulness 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 an approach has little merit in evaluating the relative life span of alternative pumps unless the cumulative cost of parts replacement is taken into account. What is required is a separate evaluation of the probable useful life of each component part over a span of 20 to 30 years. Within a 20-year 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 may be replaced only once, whereas it may be necessary to replace others several times within a 20-year period. The cumulative cost and present value of such replacement parts for one pump compared to those of another provides a reasonable means for establishing the relative usefulness or economic life span of the alternative pump choices.

It is evident that 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, the exercise is largely guesswork.

However, the type of detailed information which has been collected as part of the Upper Region field test program makes such an evaluation reasonably valid. In many cases, the finite life span of a component part cannot be determined within the time limits of a test program, but its performance relative to the other pumps in the test is usually measurable. In this way, the value judgments become meaningful.

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 which are most vulnerable to wear and damage. The cost of spare parts to replace the worn out components also play an important role in the 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.

In order to determine the probable range of spare parts requirements and overall maintenance costs of several pumps on test, the detailed calculations of Section 11 illustrate the range of probable life span of the component part for a select group of pumps. In other words, an estimate was made of the shortest useful life a component part might have. At the same time another estimate was made of the longest life span of this same part. Using these two extremes a "most likely" life span was selected. The total cost implications of purchase price plus maintenance of the various pump models was then established using the "most likely" figures. In addition, however, the sensitivity of the individual value judgments of "shortest" and "longest" were assessed in order to evaluate the validity of the conclusions. The results of this procedure are displayed graphically in the Figures of Section 12.

The foregoing discussion on life span and replacement costs of hand pumps illustrates the factors involved and the detail upon which the Consultant has based the recommendation for a Project hand pump.

e) Long Term Total Cost of Alternative Pump Selections

In selecting the most economical hand pump to suit the prevailing conditions, it is the long term total cost involved which is of concern. A low cost pump with a high maintenance, or a high cost pump with low maintenance, may not be as economical as a median cost pump with average maintenance. It is the combination of initial pump cost with the projected maintenance which has to be compared for a number of test pumps which shows promise of providing the desired level of operating performance.

Figure 3 of Section 12 illustrates the comparative total cost of alternative pumps over a 20-year time frame. The total cost includes initial pump price, annual maintenance including vehicle use and operating spares and parts replacements. Associated workshop and administrative charges are also part of the total cost displayed.

f) The Economics of Purchasing High Priced Pumps

It has often been assumed that the purchase of high priced pumps will automatically reduce maintenance costs. Whereas a high quality pump is no doubt desirable, the most costly units are not necessarily the most economical, nor the most preferable.

One aspect which is frequently overlooked is that regardless of the type of hand pump selected, some basic form of maintenance organization is required. Therefore a high priced pump does not totally eliminate the need for maintenance.

Another aspect is that high priced units usually have high priced spare parts. Even costly hand pumps require some replacement spare parts, and although they may not have to be replaced often, the cost is high when it does happen. Therefore over a twenty year span the parts for such a pump may be considerably more costly than for other pumps, even though fewer are required.

Some exceptionally high priced pumps on the market are also very bulky and heavy. This could necessitate special equipment for installation and maintenance purposes, which in turn increases the maintenance costs. Also, some high priced pumps have not shown a marked improvement in performance over lower priced units. This is illustrated on attached Figure 7 of Section 12, whereby the overall total maintenance costs of some high priced pumps is likely to be similar to lower cost models for the variety of reasons outlined in the foregoing discussion. A high cost pump is not necessarily the solution to the hand pump problem of the Upper Region.

The capital cost is only one of the factors involved in making a pump selection. If a higher cost pump results in lower maintenance or substantially improved performance and reliability, the additional cost can usually be justified. However, it is normally desirable to have the lowest cost pump available which will satisfactorily do the job. Any additional price paid for a pump must be justified through lower maintenance costs and better performance. These do not automatically come with pumps which are higher priced.

g) Design Improvements and User Acceptance

i) General

Most of the standard pumping units provided by the various manufacturers contain some design inadequacies. The Consultant is not merely selecting a standard design offered by the manufacturers, but instead will upgrade the selected pump to meet the standards established for the Project.

The approach being used in making a hand pump selection is to assess the test program data in concert with the various considerations discussed in this document. At the same time as a recommendation is made in connection with the selected test pump, there may be a requirement for a proposal to be presented regarding design changes to this chosen pump. The recommended improvements would be intended to overcome any weakness uncovered during the test, plus improve the selected model with regard to such aspects as well head sanitation, ease of maintenance, ease of operation, and user acceptance.

ii) Well Head Sanitation

A review of many hand pumps on the world market reveal that only limited attention has been paid to sanitary considerations in the design of some units. In our opinion, several promising pumps in the test program need design improvements to reduce the possibility of well contamination.

The approach which has been used in the recommendation of a hand pump for continuation of the Upper Region Project consists of selecting a pump on the basis of the test results and related considerations, and at the same time proposing design modification to improve the sanitary aspects of the recommended units wherever necessary.

iii) Ease of Maintenance

A few pumps on test hold the promise of performing satisfactorily on a long term basis, but are designed in such a way that it is difficult to install and maintain them. The approach adopted is that the short-comings of the select group of pumps are identified, and if one of this type is chosen, design improvements would form an integral part of the recommendation pertaining to purchasing these pumps. It is unrealistic to accept the standard manufactured unit when a few modifications could result in maintenance efficiencies and cost reductions.

iv) Ease of Operation and User Acceptance

Some of the units on test are easy to operate and others are more difficult. A few designs are awkward for children to use. Under deep static lift conditions, some of the units would require a lot of energy to pump the water. In some cases, two children are needed to operate the pumps.

It has been interesting to observe the preferences of the Villagers in connection with the test pumps. Certain models are preferred over others for a variety of reasons.

Value judgments on such aspects as these have been taken into account in the selection of the recommended hand pump.

h) Adaptability of Selected Pump for Other Parts of Ghana

The hand pump evaluation program was established to satisfy a need pertaining to a Project in the Upper Region. In spite of this, the conclusions of the test program will be of considerable value for hand pump considerations in other parts of Ghana. Therefore a pump selection for the Upper Region should take into consideration the adaptability of this pump to the southern regions.

In some instances, the conditions to which the above-grade components of the pump are subjected could be the same throughout the Country. In others, the additional pumping load of deep well service conditions would require a significantly stronger above-grade configuration. The below-grade portion of the pumping units are likely to vary as well. Therefore, in selecting a hand pump for the Upper Region, consideration has also been given to the suitability of the various pumps to the possibility of deeper boreholes and different ground water conditions elsewhere in the Country.

i) Pump Supplier Capability and Reliability

The focus to date of the pump test evaluation program has been to select a hand pump which can satisfy the operating conditions. In the final analysis, however, the capability and reliability of the supplier to provide an acceptable service over the long term could be more important than the differences between pump performances. In other words, 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 his product. In addition, the prospective suppliers must be willing to modify the design of its pump to overcome weakness identified in the test. If only a "standard" manufactured unit is for sale, then the Consultant is not prepared to recommend such a supplier.

From the test results, it is evident that there are several pumps which have proved acceptable from a field test performance point of view. Within this select group of pumps there are some differences regarding supplier capability and reliability. Therefore, the final recommendation has taken this aspect into consideration.

j) Potential Local Manufacture of Pumps

From an overall development point of view, Ghana may wish to set up a manufacturing plant to produce its own requirements for hand pumps. This could take the form of constructing facilities to mass produce those pumps which are already being built in Ghana on a research basis. Or an arrangement could be made to have one of the pumps, which would presently have to be imported, manufactured in Ghana. A third arrangement might consist of importing specific components and carrying out the assembly and manufacture of the remaining parts in Ghana.

The economic considerations which would form part of determining the viability of such a venture would be the potential long range market for hand pumps in Ghana, the export possibilities, the availability of raw materials, alternative management arrangements, and an assessment of associated articles which might be manufactured in the same plant to further enhance the stability of the endeavour.

Because of the projected pump installation schedules for the Upper Region (CIDA) Water Supply Project, the time required to establish a manufacturing facility becomes an important consideration.

Pumps of a particular design might more readily be manufactured locally than those of a different configuration or principle of operation.

Although a detailed study of the matter is beyond the scope of the test pump program, considerations pertaining to the feasibility of local manufacture have been taken into account in the selection of a Project hand pump.

k) Suitability of Selected Pump for Village Maintenance

One of the foremost considerations involved in a pump selection is the maintenance cost implications. Through time, maintenance costs are likely to be an ever increasing item. Therefore an effort needs to be made to continuously seek ways of reducing the maintenance costs wherever possible.

The two obvious ways of reducing future maintenance is to install a high quality, low maintenance pump. And at the same time work towards developing the capability of the villagers to the point whereby they are able to service and maintain the pumps for all but the most difficult aspects of pump repair or replacement. The aim then is to select a high quality, low maintenance pump which also holds the promise of eventually being maintained primarily at the village level.

Even though the villagers may not be in a position to provide pump maintenance at the present time, consideration should be given to this possible eventuality. For every level of repair that can be done by village people, a service trip for a maintenance vehicle is eliminated and a saving achieved. Through time, it is conceivable that in at least some districts educational programs could result in maintenance savings through villages taking over the responsibility of regular servicing and minor repairs.

Some of the pumps on test lend themselves more readily to the concept of eventual village maintenance than others. This too forms part of the considerations pertaining to the selection of a hand pump.

1.) Implications of Hand Pump Standardization

The Hand Pump Field Test Evaluation Program which has been conducted is for the purpose of determining which hand pump best suits Ghanaian circumstances. Presumably there could be one pump which comes closer to meeting Ghana's requirements than any other under test. In which case a recommendation could be made to select a single model.

Although the test program is being carried out to find a solution to the hand pump considerations of the Upper Region, it is conceivable that the recommended pump could be adopted by GWSC for the entire Country. For reasons of standardization, such a decision could be viewed as the most logical course of action to take.

Standardization is generally accepted as an economical and practical objective for a water supply corporation. However, one must be conscious of the degree of standardization proposed and the possible implications involved. For instance, if Ghana decided to utilize only one type of hand pump for the entire Country, to the exclusion of all others, the successful pump supplier would in effect have a monopoly. Through time, the Corporation could be subjected to poor service from the lone supplier, and/or unrealistically high pump prices due to the absence of competition. Both of which are highly undesirable. For these reasons, having at least two acceptable hand pumps (which might be needed in any case because of the type of service involved) is normally considered desirable.

As far as the Upper Region is concerned, it is quite conceivable that the GWSC will adopt a single pump model for the ongoing drilling program. The monopolistic implications are of less concern when only one pump model is designated for a particular region because a different pump could be selected for the other regions. In this way a degree of competitiveness is maintained among the pump suppliers on a countrywide basis.

It is undesirable to have several makes of pumps scattered all over a region. From a maintenance and spares inventory point of view, one type of pump per region is preferred. Therefore the objective should be one of standardization within a region to the maximum degree possible. However, this is likely to be difficult to accomplish.

At the present time, there are several types of pumps in the Upper Region. Arrangements could be made to transfer most of the non-standard models to other areas. However, the hundreds of Beatty pumps in place have several years useful life and are likely to remain in operation for some time. Consequently any new pump which may be selected from within the test group and introduced into the field would constitute a digression from standardization. Another factor which makes standardization difficult to achieve is the way in which development of Ghanaian rural water supplies is likely to occur in the foreseeable future. Through bi-lateral aid arrangements, conditions could emerge which necessitate the introduction of non-standard pumping units. This is not likely to be a factor in the Upper Region because of the proposed completeness of the present program. On a National basis, it does suggest that the utilization of only one pump model throughout the Country is likely to be impracticable.

The limits of standardization are also a function of scale as well as geographical deployment. Once there are 1000 pumps of one make in a region, the introduction of 500 to 1000 pumps of a different design is of sufficient scale to facilitate their inclusion in the maintenance program with only a limited reduction in efficiency. There should be no hesitation of introducing a second hand pump model to the Upper Region just because 1200 Beatty pumps are already in operation.

With the objective of achieving an acceptable level of maintenance efficiency, it is suggested that standardization in the Upper Region be approached on a district basis. This would facilitate two and possibly three makes of pumps in the Upper Region for the next few years.

Hand pumps can be relocated with relative ease. Therefore the deployment of pumps could be such that if only a few pumps of a particular make are to be left in operation in the Upper Region, they could all be located in one District. Any new pumps which may be introduced as a result of the test program could be concentrated in another part of the Region. Through time, the situation could develop where only two types of pumps remained and eventually through replacement of obsolete units, only one pump model might be used throughout the Upper Region if it were considered advantageous to do so several years hence because of maintenance efficiencies. From a cost standpoint, a review of the maintenance savings possible through relocation of all Beatty pumps in two or three districts, reveals that the benefits are insignificant for most pumps on test.

It is therefore evident that the hand pump which is to be recommended for continuation of the Upper Region Project need not, and possibly should not, be considered as the one and only pump to be used throughout Ghana on a long term basis. At the same time, because of the ease with which district standardization could be accomplished, future procurement of pumps need not be biased toward the models which presently are in operation in the field. These conditions provide sufficient flexibility to facilitate the selection of a pump which shows the greatest promise of best meeting the projected needs of the Upper Region without being prejudiced by the pumps which are presently being used throughout the Region or proposed elsewhere in the Country.

5. DESCRIPTION OF EXISTING MAINTENANCE ORGANIZATION

An important aspect of selecting a Project hand pump from within the test models is the long term cost involved in maintaining and servicing the alternative designs. Consequently, to fully assess the basis upon which the enclosed recommendation has been made, it is necessary to have an appreciation of the existing and anticipated maintenance organizations. The following is a description of the present maintenance program and the basis for projecting future maintenance costs.

The establishment of a maintenance organization to look after the newly installed water supplies was an integral part of the Upper Region (CIDA) Water Supply Project. Basically, the existing maintenance division within the regional waterworks operation was expanded to cope with the increased workload. This involved the recruitment of additional staff, changes in responsibilities, improvement of existing district workshops, and the construction of new workshops in some areas. All personnel involved in the maintenance organization are on permanent staff, and report through the long established GWSC regular channels to the Regional Manager. The Project has provided a few Consultant personnel to assist with the formulation, design, and implementation of the additional maintenance responsibilities.

From the outset, the components of the maintenance program were selected on the basis of servicing the Beatty pump which was selected for the initial 1200 Project wells. The system was designed to also service existing Godwin and various other hand pump models scattered throughout the Region. All mechanized wells were included in the responsibilities of the maintenance personnel. Because of poor access to the pumps occasioned by the limited road network, and due to the ever increasing cost of petrol, it was decided to utilize Honda 90 motorcycles for routine inspections of the hand pumps. These motorcycles were intended for the purpose of oiling the pumps, providing preventive maintenance as well as making minor repairs, and reporting pump failures. The inspector's site visit was also considered to be a first step in communicating with the Villagers and educating them regarding pump usage, water conservation, well head sanitation, and maximizing the health benefits of the newly established potable water supplies. Regular inspections on a 2-3 month basis were considered necessary at the outset and 8 motorcycles were purchased for the inspection of 1200 wells, based at the 5 district workshops throughout the Region.

Specially equipped, one ton GMC service trucks were selected to carry out major repairs on the hand pumps and to provide maintenance to existing mechanized wells. These units do not make routine inspections, but respond only to reports from the inspectors or the Villagers of hand pump failures. It should be appreciated that although the inspectors can make minor repairs, they are not capable of carrying heavy replacement parts on a motorcycle. Therefore trucks are essential for major repairs and for such continuing maintenance service as pulling the pump out of the well for replacement of cylinder leathers (which have a service life of 1-3 years dependent upon use). It was decided that 8 service trucks would be distributed among the 5 district workshops.

Selection of numbers of motorcycles and service trucks was based on the approach of introducing the minimum equipment considered necessary to satisfactorily do the task. Experience has shown that the size of fleet adopted to initiate the program is appropriate for the conditions encountered.

Because the Project has been extended, the number of hand pump well supplies to be maintained in the Upper Region will reach 2500 by 1980. An expansion of the maintenance organization will be required to cope with the increased demands. It has been decided that a superior design to the Beatty pump, in spite of the numerous Project improvements, will be provided for the remaining wells. The expansion and type of long range maintenance program will be influenced significantly by the type of pump selected and whether or not it will become economically advisable to replace the Beatty pumps within the next 5-10 years. Once a hand pump is selected for Phase 2 of the Project from within the test group, the design of the revised maintenance program will be finalized and implemented. Since the test program will be continued until the end of 1979 and because there is reason to believe the Beatty pumps will perform satisfactorily into the 1980's, it is anticipated that any major replacement of Beattys is not likely to commence for at least another five years. It is conceivable that a pump other than that selected for Phase 2 of the Project might be chosen to replace the Beattys on an attrition basis.

It should be kept in mind that the projected life span of a motorcycle is 1-3 years, and a service truck 3-6 years. Since these vehicles need to be replaced through time, there will be opportunities to increase or reduce the numbers involved, as well as change the type of vehicle, depending upon prevailing conditions.

In selecting a hand pump for completion of the Project, the cost of the various alternative maintenance programs associated with the different groups of pumps is primarily based on expansion of the existing maintenance organization. For a few pumps, however, significant changes in the maintenance structure through time is envisaged. In other words, the economic analysis is based on as practicable assessment as possible as to what must be done at present combined with what might be feasible in the future.

It should be realized that regardless of the hand pump selected, some form of central maintenance organization must be provided. To assume that a pump can be acquired which will require no maintenance is unrealistic. Minimization of the level of maintenance required is all that can be expected.

6. ACCEPTABLE PERIOD FOR PUMPS TO BE OUT OF SERVICE

With the objective to provide a reliable water supply, it is desirable to have the pumps working on a continuous basis without any interruption in service. This, of course, is impossible. As with any mechanical device, hand pump failures are going to occur, regardless of the efficiency of the maintenance program.

Occasionally, some of the pumps will be put out of operation through vandalism and accidents. But most of them will fail through wear and metal fatigue. A fatigue failure cannot always be detected by a visual inspection, particularly those aspects which are below grade and down the well. Although the goal consists of minimizing such failures, pump breakdowns are inevitable.

For the foreseeable future, under Ghanaian conditions, the shortest time period between a breakdown and when the pump can be repaired and placed back in service again is between 3-5 days. A practicable work objective would be to endeavour to have all breakdowns repaired and service restored within one week of when the failure occurs.

The reason for a downtime period of one week is related to the circumstances of the Area. For instance, the motorcycle inspector attached to the maintenance organization will not be able to repair all the breakdowns, but will report failures to the service truck crews. If a pump went out of service just before an inspector arrived and a service truck was available the very next day, the downtime could be as small as 2-3 days. However, this will not be the normal case. The service trucks have to attend to mechanized wells as well as hand pumps, and also have downtime of their own. In addition, there could be a backlog of service calls to make on previously reported pump failures. Normally, a reported breakdown of hand pumps will have to be scheduled into the work program of the service vehicles. Therefore, a response time for pump repair is likely to be at least 3-4 days after a failure is reported.

Although the service truck response time is critical to minimizing the time a pump is out of service, the report of a failure is likely to be the main determining factor. Rarely will a motorcycle inspector arrive on the day of the breakdown. It is both unnecessary and impracticable to inspect each pump more often than every two to three months if a reliable pump is utilized. From a continuing maintenance cost point of view, a pump that needs to be inspected and maintained no more than once every 3-6 months is highly desirable. Therefore, most of the reporting of failures is likely to be done at the discretion of the village users. Even if the inspections were increased to every month, or every two weeks, a pump might be out of service several days before it is reported.

Reporting a pump out of service by the Villagers will normally be dependent upon how critical the breakdown is to the water consumer, using his value judgment of course. In some cases, a second well is available within acceptable walking distance. Under these circumstances, the Villagers may wait until a motorcycle inspector makes his rounds or a village representative makes a trip to the district reporting centers. Although the additional walking distance to the alternative well is an inconvenience and involves labour which might be directed to more beneficial purposes, a potable water supply is still available to the public and the duration of pump outages could be considered as non-critical to the users.

In many cases, an alternative well water supply is not available within reasonable walking distance. Again, the reporting time period will depend upon the judgment of the Villagers. For approximately six months of the year, surface water is available in streams, ponds, and the thousands of traditional hand dug wells. Under present conditions, a village is likely to respond to a pump breakdown in the rainy season by merely reverting back to its traditional source of surface water and hand dug wells. The fact that this water may be contaminated appears to be of secondary importance to them. Consequently, a pump breakdown is likely to be reported by an inspector or when it is convenient for one of the Villagers to travel to the district centers, there being no other means of communication available to them. With the village educational programs which are being launched as an integral part of the Upper Region Water Supply Project, there is reason to believe that through time the Villagers will place increased importance upon drinking the potable well water supply in preference to surface water in ditches which is frequently polluted. As a result, the reporting response of villagers to a pump failure should eventually approach the dry season conditions on a year-round basis.

Another factor which will influence a village decision to report a pump failure during the rainy season is related to road access difficulties. Although the motorcycle inspectors can traverse most of the country throughout the year, service trucks face two constraints during the rainy season. Firstly, there is a reluctance on the part of the truck operators to cross fields of planted crops in an area where self-sufficiency of food is difficult to achieve. At the same time, the Villager knows the value of his crop in terms of his survival and would generally prefer the pump out of service rather than have his crops damaged. Secondly, since access consists of crossing fields, following tracks or foot paths, the trucks begin to bog down as the rainy season progresses. In August, September and October, many pumps cannot be reached by truck because of the lack of a suitable road and because the stream beds can no longer be crossed. Because of this wet season truck access constraint, the Villagers are being encouraged to build suitable access roads with their own resources wherever practicable. On the other hand, during the dry season a truck can traverse practically every part of the Upper Region to answer a service call.

The dry season, particularly the hot months of February to May, are the most critical to the Villagers as far as a reliable water supply is concerned. During this period the streams are dry, most of the small surface reservoirs have run out of water, and the ground water table has dropped below the bottoms of traditional hand dug wells which vary from 15 to 30 feet in depth. The hand pump performance now becomes of primary importance to the user. Experience over the past two years has established that this is the period of maximum pump use and is the time when pump failures are reported most quickly.

Under dry season conditions, the Villagers will dispatch a special messenger on foot or bicycle to the district center, or the word is passed on through the communication links facilitated by the market days which move from village to village. Of course those wells closest to the district centers could be reported in one or two days, but the majority will take three or four days. Some even take a week.

From the foregoing it is evident that the minimum average time that the hand pumps of the Upper Region are likely to be out of service upon pump failure is likely to be in the order of one week. It is also patently clear that in many cases a downtime of two weeks cannot be avoided until such time as changes can be made in the local conditions.

The maintenance organization is therefore formulated on the basis of ensuring that the service trucks respond as quickly as possible to a reported pump failure. And the motorcycle inspections are scheduled to provide the type of preventive maintenance which is required for the specific type of pump in use, with the objective of minimizing the frequency of pump failures.

7. METHODOLOGY OF HAND PUMP SELECTION

Some aspects of the following discussions of methodology of hand pump selection have already been covered in detail in the Section 4 considerations. In these instances only a summary statement has been made under the follow section of the Report and are included for reasons of continuity and completeness. If further information is desired, the reader should refer back to Section 4.

a) Assessment of Test Results

The field test records were assessed as to number of breakdowns on each pump, type of failure, and degree of measured wear of moving parts.

b) Pump Usage and Static Lift Conditions

Relative usage of the various pumps was analyzed as well as the relative static lift conditions.

c) Purchase Price of Pumps

The capital cost for each type of pump was established on the basis of competitive tenders from the various pump suppliers. (Once a pump is selected for the Project, an order can be placed with the successful supplier at the fixed tender price established in this document.)

d) Purchase Price of Pump Spare Parts

Parts components for each pump were identified and their respective costs established based on tendered prices from suppliers.

e) Long Term Cost of Spare Parts Replacement

The 10 and 20 year accumulated cost of replacement spares for each type of pump on test was arrived at by using tendered spares prices in conjunction with the projected life span of each pump part. Spare parts replacement was considered over a 30 year period and the average annual cost of spares calculated. Present value calculations were also conducted. For total cost calculations, spare parts costs were based on projected 1980 costs.

f) Determination of Useful Life of Pump Parts

Life span projection for each component part of every pump on test was based on the collective value judgment of eight persons involved with the Project. On an individual basis, value judgments were solicited for each and every part of each type of pump on test. The participants were requested to estimate the probable maximum, minimum, and "most likely" years of service each part would provide under Ghana conditions.

The results were assessed and an average taken of the various estimates for each of the three ranges of estimates. These average life spans for pump parts were then ranked and compared in detail against the other pumps in the test. (For example, the range of life of a wooden pump handle was assessed against the projected life span of a pump having a steel handle to ensure that proper relative values had been used.)

Because of the number of credible value judgments involved, and the detailed analysis of the results, certainly the range of life span for each part (shortest life to the maximum possible) is likely to prove valid. The economic comparison of the various pumps is based primarily on the "most likely" useful life of each pump part which lies within the extremes of the shortest and longest probable life span of the part in question. Through time, the actual useful life of a particular pump part might prove to be longer or shorter than that employed in this economic evaluation. However, the figures used are considered to be as reasonable under the circumstances and certainly within the margin of error associated with other factors involved in the overall economic comparison of hand pumps on test. The sensitivity of the results were tested by also carrying out a full economical analysis of the "shortest" and "longest" life span of pump parts.

g) Additional Considerations for Pump Comparisons

Other aspects of each pump which were taken into the consideration associated with ranking the units included:

- Number of parts per pump.
- Spare parts and capital cost as a percentage of total long term cost of each pump.
- Pump delivery period and supplier reliability.
- Depth to which the pumps can operate, and suitability for use elsewhere in Ghana.
- Number of pump cycles and time to pump a gallon of water.
- User acceptance and ease of pumping.
- Feasibility of Ghana manufacture.
- Ease of maintenance for GWSC service crews.
- Suitability for maintenance at the Village level.

h) Determination of Maintenance Organization for Different Pumps

Having assessed the relative merits of the various pumps, an evaluation was carried out to determine the type and extent of maintenance organization which would be required for each pump. Actually, the pumps were grouped into several categories for the purpose of determining the fleet of maintenance vehicles and manpower required to provide the level of service desired. The approach used in establishing the cost of the alternative maintenance arrangements (primarily the number of service trucks, inspectional motorcycles, and related workshop activity and staff), was to assume that GWSC would actually select a specific pump on test and then conceive a maintenance system which would be required to ensure an acceptable level of performance for that pump. An alternative complement of maintenance equipment was then conceived on the assumption of the GWSC selecting one of the other pumps on test, and so on.

The same methodology developed for the determination of life spans for spare parts was adopted for the establishment of the number of trucks and motorcycles required for each maintenance district for the alternative maintenance systems assumed. For instance, the range of number of motorcycles required for a particular district was established by rationalizing the minimum and maximum number which would be required under varying assumptions of travel time, downtime of vehicles, terrain, spacial separation of wells and access conditions. From within this range, a "most likely" number of vehicles was then selected for the various pump types. An economic analysis for each pump was then based on the "most likely" case for comparative purposes with other pumps in the system.

It should be appreciated that during the past two years a considerable amount of data has been assembled with regard to the type of maintenance required and the level of service which can reasonably be achieved.

For instance, we know the average number of wells per day a motorcycle inspector can visit and effect minor maintenance repairs on a district basis. We also know the number of hand pumps per day the service vehicles can reasonably be expected to visit and make above and below grade repairs. The percentage of pumps broken down and needing a service truck for repairs in relation to the number inspected on a daily motorcycle inspection is also known. Actual representative downtime of motorcycles and trucks has been established. The percentage of time the service truck spends on hand pump repairs versus mechanized wells is known on a district basis. Annual mileage per vehicle and operating costs have been ascertained. As illustrated by the appended document on annual spare parts requirements for the existing 1200 Beatty pumps, considerable knowledge is available of the frequency and type of pump failure which can be expected.

Because there are 1200 Beatty pumps already in the maintenance system throughout the five districts of the Upper Region, and since a newly established maintenance organization is in place utilizing 5 district workshops, 8 specially equipped service trucks, and 8 Honda motorcycles, this was used as the starting point for the formulation of alternative maintenance arrangements for the various pumps on test. The combination of motorcycles for inspection and minor repairs, followed up by a specially equipped service truck to make major repairs on pumps which have been reported by the inspectors or the villagers to be broken down, has been adopted as a basis for most of the pumps on test. Because of the limited road system and distances to be travelled, the motorcycle is obviously the most practical and economical means of traversing the trails and footpaths to inspect the pumps. During the rainy season, a truck cannot reach some of the well sites. And during the growing season, it is not reasonable to damage the crops by crossing the fields with a truck unless a pump is broken down. However, trucks are essential to remove the existing Beatty pumps from the well in the event of a major repair being needed. It is also needed for most of the pumps on test. To summarize, the basic concept is to utilize an inspectional service to provide the appropriate level of maintenance required for a mechanical device such as a hand pump, and reserve the trucks to service only reported breakdowns. This is not only economical, but is the most practical arrangement because of road access difficulties. At least for the next five years, the motorcycle inspection concept will reduce the number of pump failures and minimize the length of time a pump is out of service. Also, such inspections provide a communication link with the Villagers which holds the promise of facilitating an educational program for the people in the use of the pump, conservation of water, sanitation around the well head, and derivation of the maximum health benefits from these newly established ground water supplies. In addition, it provides one means of working towards the long term objective of gradually increasing the capability of the Villagers to assist with the maintenance of their water supply and thereby reduce the long term maintenance costs.

Starting with the existing 1200 Beatty pump and the known conditions, alternative maintenance vehicle fleets were developed on the basis of how much better the performance of a particular test pump might be than the Beatty pumps. This was projected to the 1980 case when there will be 2500 hand pumps throughout the Upper Region, plus a significant number of mechanized pumps. Consideration was given to completely replacing the Beatty pumps through time, as well as the 1980 case of having two principal types of pumps in the Upper Region. (These two will consist of the existing Beatty pumps plus the installation of the new design to be selected subsequent to the evaluation of the recommendations of this Report.)

For some of the pumps on test, a maintenance organization was considered which eliminated the motorcycle inspections through time. Either the projected performance of the pump was considered to be such that frequent maintenance would not be required and/or the Villagers could eventually provide the preventive maintenance needed. In these cases, the service trucks would be used to repair a pump only after the Villagers reported it out of service.

It should be mentioned that some of the maintenance schemes considered utilized heavy, expensively equipped trucks because of the facilities required to remove some of the heavier pumps on test. Others would only need smaller units with less special equipment. Some could suffice with a simple pick-up truck.

i) Varying Costs of Maintenance Schemes

Each maintenance organization was costed, for both capital and operating expenses (recurrent costs). These costs were then combined with that related to the pump purchase price and projected spare parts to arrive at the accumulated 10 and 20 year costs for each pump. An economic comparison was then made of the various pumps. Maintenance costs and spare parts replacement were based on projected 1980 levels of activity and costs. Section 11 provides the economic considerations for a select group of pumps and Section 12 outlines the economic comparison of various pumps on test.

j) Considerations Associated with Limited Sample Size

One of the limitations of the hand pump test program is the small sample size involved. Generally, only 2 or 3 pumps of each type have been incorporated into the test. Although it was not practicable to do so, a much larger number of each kind of pump would have constituted a better research program.

To compensate for this limitation, Project personnel travelled outside Ghana to gain additional operating experience for all those pumps on test which appeared, by virtue of their construction and test performance, to be among the group of pumps from which a selection would likely be made. The Mono pump was assessed in Nigeria, the Vergnet and ABI pumps in Upper Volta and Ivory Coast, the Uganda pump in Kenya, and the Sholapur pump in India.

As a matter of interest, manufacturers' premises were inspected for the majority of pumps on test to assess their capability to meet Project needs.

k) Summary of Key Aspects Involved in Pump Selection

Having completed the foregoing exercise, a recommended pump was selected using the following criteria:

- Test performance of pump.
- Long term cost of pump.
- Suitability of pump to eventually being partially maintained at the village level as a means of minimizing the long term maintenance costs.
- Consideration of numerous miscellaneous aspects as previously outlined, including reliability of supply and the feasibility of manufacturing the alternative pumps in Ghana.

8. LIST OF HAND PUMPS IN TEST EVALUATION PROGRAM

A - LEVER OPERATED RECIPROCATING HAND PUMPS

B - WHEEL OPERATED RECIPROCATING HAND PUMPS

C - CRANK OPERATED HELICAL ROTOR HAND PUMPS

D - FOOT OPERATED HYDRAULIC PISTON PUMP

a) <u>General Description of Test Pumps</u>

With 50 hand pumps on test, representing 15 different manufacturers, from 10 countries, it is difficult to gain an appreciation of the scope and detail of the test program without going into the matter in some detail.

To provide an insight into the test program, the following section has been included which summarizes the main identifying features and differences associated with the various pumps on test. Also, pictures are provided in Section 10 of this Report to show the alternative configurations involved.

In an attempt to illustrate the major operational differences of the various units, the test pumps have been divided into the following four classifications:

A. Lever Operated Reciprocating Plunger Hand Pumps

B. Wheel Operated Reciprocating Plunger Hand Pumps

C. Crank Operated Helical Rotor Hand Pumps

D. Foot Operated Hydraulic Piston Pump

In the following section, the test pumps have been organized in alphabetical order. The well head number is the principal identifying feature for record purposes.

It should be realized that many of the pumps on test have similar plunger operated, below grade components. Since most of the initial operational difficulties occurred above grade, a standard GSW Ltd. Beatty pump rod, drop pipe and cylinder was used on a number of different test pumps during the early part of the testing program. Unless specifically mentioned otherwise in the following description of test pumps, the below grade portion can be assumed to be the standard GSW Ltd. component. A number of the test pumps have different below grade components by virtue of their design. And others have been included to compare the relative performance of a GSW Ltd. design to similar products available from other suppliers. For instance, a separate exercise was carried out to determine the relative merits of the below grade portion of a Beatty pump versus that of a Monarch pump, both of Canadian design.

b) Summary of Pump Classifications and Number on Test

CLASS A - Lever Operated Reciprocating Plunger Hand Pumps		Country	Number of Pumps on Test
. ABI Type "M"	- (ball bearings at fulcrum)	Ivory Coast	
. African	- (ball bearings and cable)(metal frame)	Ghana	
	- (wood frame)	Ghana	
. Beatty	- (from first order of 500 units)	Canada	
	- (from second order of 800 units)	Canada	
	- (bronze oilite bushing) (2" cylinder)	Canada	
	- (nylon teflon bushings)	Canada	
	- (nyletron bushings)	Canada	
	- (bronze oilite bushings)	Canada	
. Consallen LD4	- (ball bearings)	U.K.	
. Dempster 23F	- (steel pin in nylon bushings)	U.S.A.	
. Godwin "HLD"	- (handle type)	U.K.	
. Monarch P-2	- (GWSC 1973 purchase modified by project)	Canada	
P-3A	- (steel pin in cast iron)	Canada	
P-3B	- (bronze oilite bushings)	Canada	
P-3C	- (ball bearings)	Canada	
. Nigerian Battelle	- (mild steel in cast)	Nigeria	
. Sholapur Hand Pump #002		India	
. "Uganda" East African	- (wood frame)	Kenya	
. "UST" Ghana (Kumasi)		Ghana	
. Vogel	- (mild steel in cast)	Germany	

CLASS B - Wheel Operated Reciprocating Plunger			
. Godwin 'W1H'	- (common Ghanaian model)	U.K.	

CLASS C - Crank Operated Helical Rotor Hand Pumps			
. Mono Lift	- (rotary)	U.K.	
. Moyno 1V4	- (rotary)	Canada	

CLASS D - Foot Operated Hydraulic Piston Pump			
. Hydro-Pompe "Vergnet"	- (hydraulic foot pump)	France	

CLASS A - LEVER OPERATED RECIPROCATING PLUNGER HAND PUMPS

Well Number	Model and Manufacturer	Identifying Features	Date of Installation
452 E-4	ABI Type "M" Abidjan Ind. (Ivory Coast)	(ball bearings at fulcrum) - Pivot point at rod connector steel on steel - fabrication - steel and cast iron - rubber guides in drop pipe control pump rod movement - drop pipe 1.35" galvanized - pump rod .5" galvanized - cylinder 2" x 12" brass	Jan. 26/77
455 H-43	ABI Type "M" Abidjan Ind. (Ivory Coast)	(ball bearings at fulcrum) - same as #452 E-4	Jan. 27/77
456 E-3	AFRICAN Pleuger (Ghana	(ball bearings and cable) - pivot points consist of ball bearings at fulcrum and a cable over horsehead guide at rod connector - fabrication - steel - standard Beatty drop pipe @ 1½" - cylinder 2" PVC with synthetic cup leather (does not fit into a 4" standard project casing) - pump rods 5/8" steel	Nov. 9/76
455 H-19	AFRICAN Pleuger (Ghana)	(wood frame) - similar to 456 E-3 with wood frame and horsehead instead of steel	Mar. 18/77

CLASS A - (cont'd)

Well Number	Model and Manufacturer	Identifying Features	Date of Installat
455 D-3	BEATTY #1205 (GSW Ltd., Canada)	(from first order of 500 units) - pivot points consist of cast iron on steel (a pin with no bearing or bushings) - fabrication - steel and cast iron - vertical travel of pump rod maintained by two guides through a crosshead with babbit bushings - Beatty cylinder 3" x 10" brass - Beatty drop pipe 1½" galvanized - pump rod 7/16" galvanized	Sept. 29/
455 A-1	BEATTY #1205 (mod.) GSW Ltd. (Canada)	(from second order of 800 units) - similar to #455 D-3 with project requested modifications on the following: handle socket (oil wicks), base, pipe flange, cap guide and pivot pins	Mar. 10/7
455 F-19	BEATTY #1205 (mod.) GSW Ltd. (Canada)	(from second order of 800 units) - same as #455 A-1	May 18/76
455 H-1	BEATTY #1205 (mod.) GSW Ltd. (Canada)	(from second order of 800 units) - same as #455 A-1	Feb. 25/7
455 H-27	BEATTY #1205 (mod.) GSW Ltd. (Canada)	(from second order of 800 units) - same as #455 A-1	May 28/76
455 G-10	BEATTY #1205 (mod.) GSW Ltd. (Canada)	(bronze oilite bushings) (2 in. cylinder) - remainder similar to 455 A-1	Feb. 7/77

CLASS A - (cont'd)

Well Number	Model and Manufacturer	Identifying Features	Date of Installation
455 G-11	BEATTY #1205 (mod.) GSW Ltd. (Canada)	(bronze oilite bushings) (2 in. cylinder) - remainder similar to 455 A-1	Feb. 7/77
455 F-6	BEATTY #1205 (mod.) GSW Ltd. (Canada)	(bronze oilite bushings) (2 in. cylinder) - remainder similar to 455 A-1	Feb. 8/77
453 B-8	BEATTY #1205 (test mod.) GSW Ltd. (Canada)	(nylon-teflon bushings) - handle stop modified to allow additional clearance for fulcrum - remainder similar to 455 A-1	May 27/7
455 I-2	BEATTY #1205 (test mod.) GSW Ltd. (Canada)	(nylon-teflon bushings) - same as #453 B-8	May 26/76
453 C-9	BEATTY #1205 (test mod.) GSW Ltd. (Canada)	(nyletron bushings) - remainder similar to #453 B-8	May 27/76
453 C-15	BEATTY #1205 (test mod.) GSW Ltd. (Canada)	(nyletron bushings) - same as #453 C-9	May 26/76
453 B-1	BEATTY #1205 (test mod.) GSW Ltd. (Canada)	(bronze oilite bushings) - remainder similar to #453 B-8	May 26/76
453 C-11	BEATTY #1205 (test mod.) GSW Ltd. (Canada)	(bronze oilite bushings) - same as #453 B-1	May 27/76
455 I-1	BEATTY #1205 (test mod.) GSW Ltd. (Canada)	(bronze oilite bushings) - remainder similar to #455 A-1	Aug. 5/76

Well Number	Model and Manufacturer	Identifying Features	Date of Installat[ion]
455 H-42	CONSALLEN LD4 Consallen Structures Ltd. (U.K.)	(ball bearings) - pivot points have expanding assembly to keep bearing tight - fabrication - steel - cylinder 2" stainless steel with neoprene seal - Beatty drop pipe 1½" and 7/16" pump rod	May 19/77
455 H-44	CONSALLEN LD4 Consallen Structures Ltd. (U.K.)	(ball bearings) - remainder same as #455 H-42	May 25/77
455 F-3	DEMPSTER 23F (Ex) Dempster Industries (USA)	(steel pin in nylon bushing) - pivot points have nylon lining - fabrication - cast iron - vertical travel of pump rod guided by one brass bushing - above ground supplied only - below ground standard Beatty	Feb. 29/7
455 F-7	DEMPSTER 23F (Ex) Dempster Industries (USA)	- same as #455 F-3	Feb. 29/7
455 F-10	DEMPSTER 23F (Ex) Dempster Industries (USA)	- same as #455 F-3)	Feb. 29/7
455 F-15	GODWIN 'HLD' H.J. Godwin Ltd. (U.K.)	(handle type) - pivot points have steel on steel with oilholes (no bearings) - fabrication - steel and cast iron - vertical travel of pump rod maintained by one brass bushing - above ground supplied only - below ground standard Beatty	June 18/

CLASS A (cont'd)

Well Number	Model and Manufacturer	Identifying Features	Date of Installation
455 G-1	MONARCH P-2 (mod.) Monarch Industries Ltd. (Canada)	(GWSC 1973 Purchase Modified by Project) - pivot points have a bronze bushing at fulcrum and a sealed ball bearing at rod connector - fabrication - cast iron - vertical travel of pump rod not maintained, consequently sideways movement occurs during each stroke - above ground available only - below ground standard Beatty	July 13/76
455 C-16	MONARCH Test P-3A Monarch Industries Ltd. (Canada)	(steel pin in cast iron) - fabrication - cast iron and wood handle - vertical travel of pump rod maintained by two brass bushings - above ground supplied only - below ground standard Beatty	June 4/76
455 C-1	MONARCH Test P-3B Monarch Industries Ltd. (Canada)	(bronze oilite bushings) - remainder similar to #455 C-16	Oct. 8/76
455 H-13	MONARCH Test P-3C Monarch Industries Ltd. (Canada)	(ball bearings) - remainder similar to #455 C-16	May 28/76
455 H-15	MONARCH P-3C Monarch Industries Ltd. (Canada)	(ball bearings) - same as #455 H-13	May 29/76

CLASS A (cont'd)

Well Number	Model and Manufacturer	Identifying Features	Date of Installat
455 D-5	NIGERIAN BATTELLE Nigerian Industriés (Nigeria)	(mild steel in cast) - pivot points consist of mild steel on cast iron (no bearings) - fabrication - cast iron - vertical travel of pump rod maintained by two cast iron borings - cylinder - 3" PVC (does not fit into a 4" standard project well casing) - drop pipe - 1" PVC	Nov. 8/76
455 I-9	NIGERIAN BATTELLE Nigerian Industries (Nigeria)	(mild steel in cast) - similar to #455 D-5 with larger bell on pump base - below ground standard Beatty	Sept. 7/7
455 C-25	SHOLAPUR HAND PUMP #002 Sholapur Well Service (India)	- pivot points consist of ball bearings at fulcrum and roller chain over a guide at rod connector - fabrication - steel - above ground supplied only - below ground standard Beatty	Sept. 30/
455 F-30	SHOLAPUR HAND PUMP #002 Sholapur Well Service (India)	- same as #455 C-25	Oct. 11/7
455 G-6	"UGANDA" EAST AFRICAN Craelius-Terra Test Ltd. (Kenya)	(wood frame) - pivot points consist of steel on steel with oil holes at main locations (no bearings) - fabrication - wood and steel - vertical travel of pump rod maintained by guide pipes - above ground supplied only - below ground standard Beatty	July 23/7

CLASS B - WHEEL OPERATED RECIPROCATING PLUNGER HAND PUMPS

Well Number	Model and Manufacturer	Identifying Features	Date of Installat
453 B-17	GODWIN 'W1H' H. J. Godwin Ltd. (U.K.)	(common Ghanaian model) - pivot points consist of an enclosed crank case with oil lubrication, gear reduction, roller bearing mounted crankshaft - fabrication - cast iron and steel - vertical travel guided by a roller type lubricated crosshead - drop pipe 4" galvanized - cylinder 3-3/4" brass - extractable - pump rods - pine wood	Included test May (Pump ori ally put service (
455 F-16	GODWIN 'W1H' H. J. Godwin Ltd. (U.K.)	(common Ghanaiar model) - same as #453 B-17 with cylinder - 2-3/4" brass extractable - drop pipe 3" galvanized - pump rods - pine wood	In service in 1956. On test May 1976.
455 F-29	GODWIN 'W1H' H. J. Godwin Ltd. (U.K.)	(common Ghanaian model) - same as #453 B-17 with cylinder - 2¼" brass - extractable - drop.pipe - 2½" galvanized - pump rods - pine wood	Oct. 26/76

CLASS C - CRANK OPERATED HELICAL ROTOR HAND PUMPS

Well Number	Model and Manufacturer	Identifying Features	Date of Installation
455 G-12	MONO LIFT Mono Pumps Engineering Ltd. (U.K.)	(rotary) - gear box, oil lubricated enclosed with ball bearings on driveshaft and oilite bushings on crankshaft - fabrication - cast iron - steel rotor - single thread helical rotor in double thread rubber stator with no need for valves - drop pipe 1½" galvanized - driveshaft ½" galvanized with rubber stabilizers	Dec. 8/77
455 H-41	MONO LIFT Mono Pumps Engineering Ltd. (U.K.)	(rotary) - same as #455 G-12	Dec. 7/77
455 G-9	MOYNO 1V4 The Robbins & Myers Co. of Canada	(rotary) - gear box, grease lubricated enclosed with ball bearings on crankshaft and driveshaft - fabrication - cast iron and steel - steel rotor - single thread helical rotor in double thread rubber stator with no need for valves - drop pipe 1½" galvanized - drive shaft ½" galvanized with rubber stabilizers	Nov. 23/76
455 I-16	MOYNO 1V4 The Robbins & Myers Co. of Canada	(rotary) - same as #455 G-9	Nov. 24/76

CLASS D - FOOT OPERATED HYDRAULIC PISTON PUMP

Well Number	Model and Manufacturer	Identifying Features	Date of Installa
452 F-12	HYDRO-POMPE "VERGNET" Mengin (France)	(hydraulic foot pump) - a piston operated hydraulic pump with only a foot pedal and fountain above grade - an expandable rubber tube inside a stainless steel cylinder, all submerged below water level - no bearings or pivot points	Apr. 22/
455 H-39	HYDRO-POMPE "VERGNET" Mengin (France)	(hydraulic foot pump) - same as #452 F-12	Dec. 14/

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. - 18

WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

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

Bimonthly Inspection Report of Water Pumps

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

____

____

____

____

____

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 1

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!

ASP

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 8, 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 8, 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 [illegible] 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.

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 ($ft-lb_f$)	Theoretical Work ($ft-lb_f$)	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 is 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.

HANDPUMP TESTING PROJECTS DOCUMENTATION SECTION

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

WORKING MEETING ON HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

F. Handpump Testing Projects Documentation Section

C.A. Harpenden Rise Laboratory

T.P. 1. Testing of Hand/Foot Operated Water Pumps for Use in Developing Countries.

C.A. Harpenden Rise Laboratory

T.P. 2. Testing of IDRC Prototype Pumps.

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T.P. - 1

WORKING MEETING
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TESTING OF HAND/FOOT OPERATED WATER PUMPS FOR USE IN DEVELOPING COUNTRIES

2. CONSTRUCTION

The plunger construction represents a departure from the more conventional practice of using a flexible material, usually leather, as a seal. Instead diagonally split polyethylene rings, cut from a tube of slightly larger outside diameter than the inside diameter of the cylinder, are used to give a rigid seal. They function in a manner similar to that of piston rings on an internal combustion engine. The plunger itself is made of UPVC, (machined in the case of the pumps tested here, but designed to be moulded in large scale production) and consists of two parts. The lower half has the grooves to locate the sealing rings while a brass shaft through the centre of both halves holds the assembly together. Eight holes are drilled, on identical pitch circles, through the two halves of the plunger. These must be carefully aligned on assembly, otherwise water will not flow freely through the plunger. (It would be better if there were some form of location). A plate valve covering the holes on the upper half is used to ensure unidirectional flow. The plate can be made from varying materials, but on the pumps tested was made of plastic (probably nylon) on a plunger designed to work in deep wells, and of rubber on a plunger working in medium depth wells. Figures 1-3 show photographs of the plunger assembly.

The footvalve assembly is made in a similar way to the plunger, i.e. from UPVC, with a rubber plate valve. To the central bolt is attached a steel eye which can be used for lifting the valve from the well. A fairly thin leather washer is used to seal the valve inside the ABS cylinder/well casing and this is secured by a circular steel plate. Photographs are given in Figures 4 and 5.

Two variants of the plunger were tested. The first (H/H), designed for deep wells (> 40 m), has two rings, one narrow and one wide, with holes drilled through from the top of the plunger to the underside of the wider ring. This enables the water pressure to force the ring outwards against the cylinder bore and increase the effectiveness of the seal. The second version of the plunger (L/H) does not use any system for increasing the seal pressure, but has two narrow rings in the place of one wide one. It is designed for shallower wells (around 25 metres).

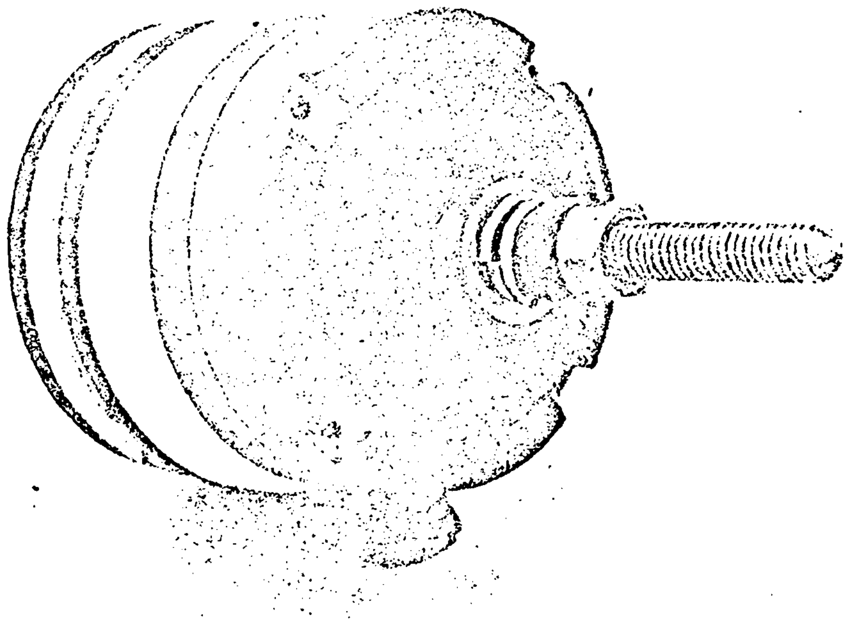


FIGURE 1 L/H PLUNGER

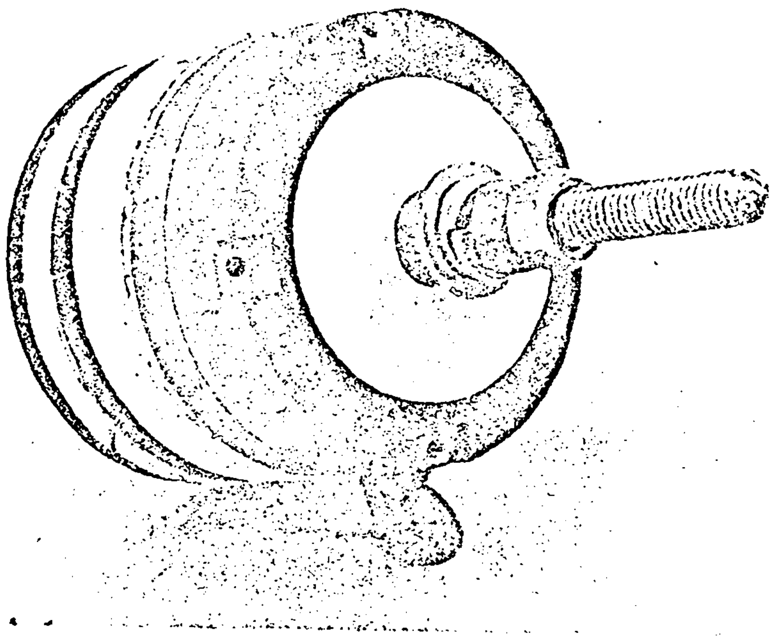


FIGURE 2 H/H PLUNGER

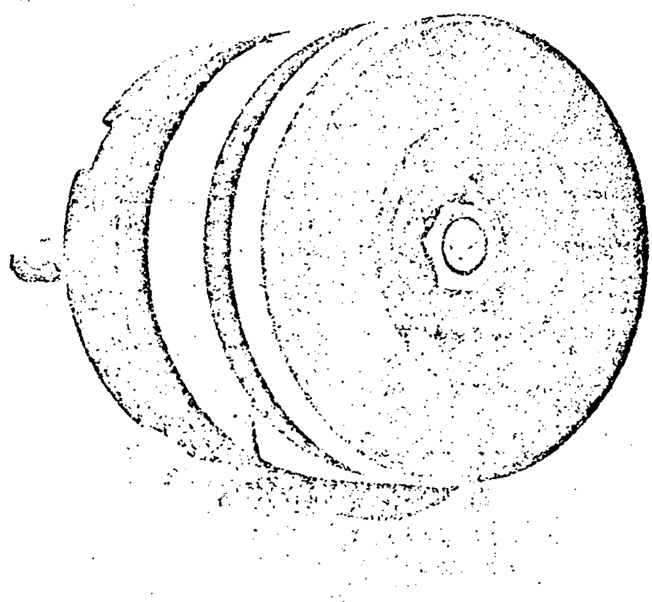


FIGURE 3 - UNDERSIDE VIEW OF H/H PLUNGER

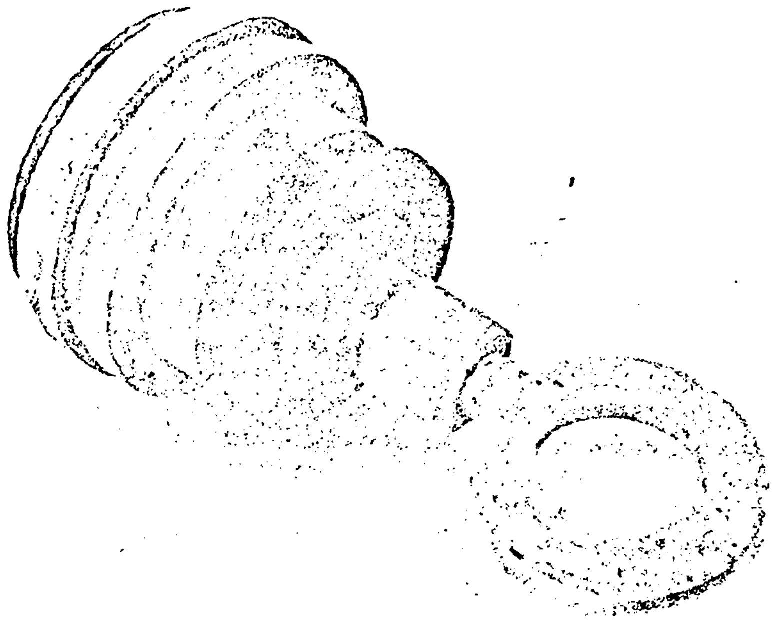


FIGURE 4 FOOTVALVE (TOP VIEW)

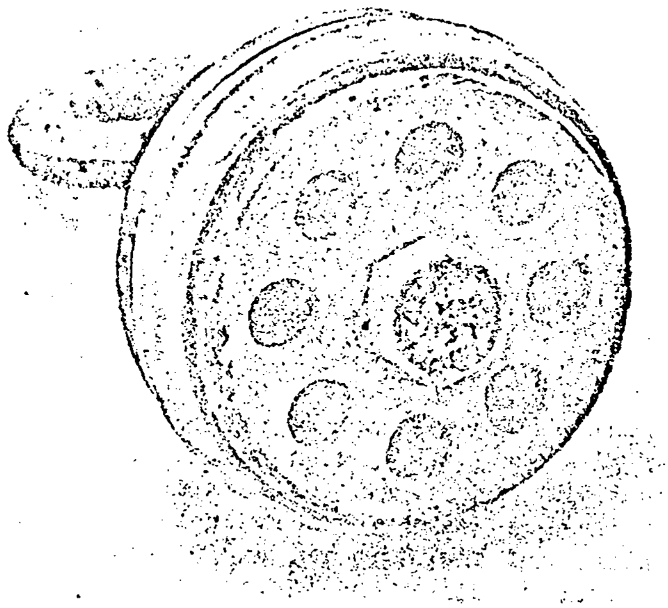


FIGURE 5 VIEW FROM UNDERSIDE

3. DESIGN ASSESSMENT AND COMMENTS

Assessing the design of a pump requires both knowledge of conditions prevailing in an LDC and considerable multi-disciplinary skills. The comments made are the considered opinions of the authors, supported by appropriate expert advice.

When the Laboratory was originally commissioned to test the pumps we were told that a polyethylene ring seal was used because such a material is cheap and commonly available in LDC's. PVC pipe was also used originally because it was cheap but, due to the variations in the circularity, the diameter and the bore smoothness of the commercially available PVC pipe, the more expensive ABS pipe was chosen instead.

With a smooth bore pipe, which does not vary significantly in diameter, as the cylinder and when pumping water which can be guaranteed free from all solid impurities, this design should perform satisfactorily. We feel, however, that when a pump is designed for manufacture and use in an LDC, it should be able to accommodate considerable tolerances without deterioration in performance. With the variation in bore that is possible in plastic pipe, a flexible seal would be much more appropriate. Generally the bore of extruded plastic pipe is smooth, but it can sometimes have slight waviness and ovality which can be accommodated by a flexible seal but not with a hard seal. We consider that the use of such a flexible seal, preferably made from a synthetic elastomer (which is more resistant to solid impurities in the water than leather) could reduce costs, while allowing manufacture in an LDC. It would also enable wider tolerances in dimensional specifications.

The use of a rubber plate valve is probably adequate in medium depth wells but we found that, after being immersed for a time in water, the rubber tended to become rather concave. Particularly when pumping from low heads, this could result in loss of all the water from the drop pipe. A rigid plate valve, such as that fitted on the high head version of the pump is better, provided the flatness of the plunger top can be maintained when it is moulded in high volume production. Alternatively, a different type of elastomer, which is unaffected by prolonged immersion and banging against its stop, could be used or a rigidly-backed rubber disc or a stop equal in diameter to the rubber disc.

A further disadvantage of using hard seals is the necessity to use holes drilled through from the top of the plunger to the inside of the top ring, when pumping from deeper wells (>40 m). This method is used to increase the pressure of the seal against the wall of the tube. Such holes have to be positioned accurately, and require rather sophisticated moulding techniques. If such a procedure is used in an LDC, steps would have to be taken to ensure that the quality control of the process is adequate.

The use of polyethylene rings can also cause problems due to the known tendency of plastics to creep and relax internal stresses. It is highly probable that the hoop stress will relax considerably once the pump is installed. In fact, on the endurance tests on the pumps, this relaxation had taken place and the ring gap had almost completely closed after 1000 hours, thus reducing the force with which the ring is held in contact with the cylinder wall.

3. DESIGN ASSESSMENT AND COMMENTS (cont)

We also feel that the cross-sectional area of the holes through the plunger is too small. Calculations indicated a maximum pressure drop of 1 psi across the plunger at a speed of 20 strokes/minute. This is acceptable as the flow is laminar. At higher speeds, however, the flow becomes turbulent, and the pressure drop increases to around 8 psi at 60 strokes/minute, which is unacceptable (see force/displacement graphs Figs 21 to 26). As the pressure drop is proportional to the fourth power of the hole radius, it can be seen that even a small increase in radius can make a considerable difference.

From the corrosion viewpoint, the use of plastics has considerably reduced the potential problems. The use of zinc-plated steel nuts with brass studs and fittings is not recommended, however, as this combination forms a bimetallic corrosion couple which results in rapid corrosion of the plated steel. If brass is used for maximum corrosion resistance, then all metal fittings should be of compatible materials. For hard waters which are scale-forming, zinc-plated steel components could be used, or even mild steel. Particular attention should be given to connections to the pump rod. Galvanised rod, or wooden rod with a galvanised connection, should not be used in contact with copper alloys of any kind. Connections between wooden pump rod sections may be galvanized however, since they are not in contact with other metals.

The quality of the plastic pipe used as the well casing/cylinder should also be carefully considered because the mechanical properties of plastics are very different from metals. In particular the creep and fatigue properties are much more important considerations than with most of the metals used in pump construction. Especially in the case of the wall thickness of the pipe, it is much better to err on the safe side, perhaps by including a length of thicker wall pipe in the well casing for use as the cylinder. (One of the cylinders split open during the endurance test - see Section 6)

The footvalve seems to have fewer problems, the two main ones being common to the plunger viz, the bimetallic corrosion couple of zinc and brass, and the distortion of a rubber plate valve. Our other main concern was in replacing the foot valve in the well after it had been extracted. In our experience it tended to tilt sideways and jam in the well casing/cylinder. The easiest method of relocating it was to push it down with a tube of slightly smaller diameter than that of the well casing. This method could take rather a long time in deeper wells however. Perhaps it would be better if a short length of PVC tube, the outside diameter of which is very slightly less that the internal diameter of the cylinder, were fitted to the top of the foot valve. The plunger could then be used to push the footvalve back down the pipe by locating on the top of the PVC tube.

1. INTRODUCTION

This interim report gives the results of tests performed to date on two prototype pumping cylinders supplied by the International Development and Research Centre of Ottawa, Canada. All performance tests and the first stage of the endurance tests have been completed thus far.

The pumps are developments, based on theoretical considerations and previous tests performed in America, in an attempt to find suitable pumping equipment for manual use in less developed countries. In many LDC's there are problems with the supply of certain raw materials (eg cast iron), whilst some other materials are very expensive (eg brass). These pumping cylinders are therefore designed to -

(a) Use as far as possible, inexpensive materials which are available in an LDC, the quality of which can be maintained adequately.

(b) Facilitate the construction of reliable pumps which are cheap and easy to maintain when necessary, often at the village level.

(c) Eliminate corrosion problems where possible by using polymeric materials.

A particular feature of the pump design is that it does not need a separate well casing, drop pipe and cylinder. Instead, a single ABS pipe is used as both the cylinder drop pipe and the well casing. With this arrangement the plunger and the footvalve can easily be removed for repair if necessary. If the wear on the "cylinder" should become excessive, the pump rod length can simply be altered so that the plunger acts inside a new length of pipe.

Such a concept has attractive features. This report examines the pump both critically and constructively and gives the results of tests to determine its performance and likely reliability under varying conditions. The next section describes the pump construction and its mode of operation.

TABLE 2

MARKET INTELLIGENCE INFORMATION

MANUFACTURER	BRAND	MODEL	CYLINDER SIZES	TYPE OF PUMP	STATED MAXI-MUM LIFT
Abidjan-Industrie Boite Postale 343 Abidjan, Ivory Coast	AB1	Type M	60 mm 70 mm 80 mm	d/w: lift: h/o	Not stated 30 m 12 m
Atlas Copco Terratest Ltd. Cearn Chambers Government Road PO Box 40090 Nairobi, Kenya	Kenya Hand Pump	Shallow Deep	Not known 46 mm 57 mm 70 mm 100 mm	s/w: suction: h/o d/w: lift: h/o	60 m 50 m 25 m 15 m
Baker-Monitor Division 133 Enterprise Street Evansville Wisconsin. 53536 USA	Monitor Monitor Monitor Monitor Monitor Monitor	11 HA 11 HB 23 HD 11 HD 12 HD 10 CP	- - - - - -	d/w lift: h/o d/w lift: h/o d/w lift: h/o d/w lift: h/o d/w lift: h/o s/w: h/o	-
Balaji Industrial and Agricultural Castings 4-3-140 Hill Street Ghasmandi, P.B. No 1634, Secunderabad 3, INDIA	Manufacturer of several standard (eg UNICEF) designs, most marketed under the "Balaji" brand name				
Barnaby Climax Ltd. White Ladies Close Little London Worcester WR1 1PZ England	Climax	N/S	2¼ in) 2¾ in) 3½ in) 4 in) 2½ in 3 in 3½ in 4 in	d/w: extract-able valve pump h/o d/w: none extractable valve pump: h/o	(130 ft (100 ft (75 ft (60 ft 100 ft 80 ft 60 ft 50 ft

TABLE 2 (Cont)

MARKET INTELLIGENCE INFORMATION

MANUFACTURER	BRAND	MODEL	CYLINDER SIZES	TYPE OF PUMP	STATED MAXI-MUM LIFT
A. Bodin 37150 Bléré France	Celtic	CL 0	90 mm 80 mm	d/w: lift: h/o *	7 m 11 m
	Celtic	CL 10	100 mm 90 mm 80 mm	d/w: lift: h/o *	7 m 14 m 15 m
	Solo	SL 2	90 mm 80 mm 70 mm 60 mm 50 mm	d/w: lift: h/o *	13 m 18 m 26 m 30 m 40 m
				* All can be used as s/w with cylinder in pump stand	
Briau SA. B.P. 43 (37009) Tours Cedex France	Omega	30 60		d/w: hydraulic lift: h/o	(30 m (60 m
	Nepta		40 mm 50 mm 60 mm 80 mm 100 mm 140 mm	d/w: Cable lift: h/o	100 m 65 m 45 m 25 m 16 m 9 m
		Nepta F	40 mm 50 mm 60 mm 80 mm 90 mm 100 mm 140 mm	d/w: cable lift without exhaust pipe: h/o	100 m 65 m 45 m 25 m 20 m 16 m 9 m
		Royale	100 mm 90 mm 80 mm 70 mm 60 mm 50 mm		10 m 12 m 16 m 20 m 28 m 40 m
		Dauphine	100 mm 90 mm 80 mm		10 m 13 m 16 m

TABLE 2 (Cont)

MARKET INTELLIGENCE INFORMATION

MANUFACTURER	BRAND	MODEL	CYLINDER SIZES	TYPE OF PUMP	STATED MAXIMUM LIFT
Columbiana Pump Div. of Reliance Electric Co. Columbiana, Ohio 44408 USA	Columbiana	Fig. 80	2½ in 3 in	d/w: lift: h/o	75 ft
		Fig. 121	2½ in 3 in	d/w: lift: h/o	75 ft
		Fig. 19-2	3 in	s/w: suction: h/o	25 ft
		Fig. 20-2	3 in	s/w: suction: h/o	25 ft
		Fig. 21-2	3 in	s/w: suction: h/o	25 ft
		Fig. 126	2½ in 3 in	d/w: lift: h/o	75 ft
Complejo Metalurgico Especializado S.A. Apartado No 3854 Managua D.N. Nicaragua	AID/ Battelle	Deepwell version	3 in	d/w: lift: h/o	-
		Shallow well version	3 in	s/w: lift: h/o	
Consallen Structures Ltd 291 High Street Epping, Essex		LD 4 5 6 7	50 mm 63 mm 75 mm 88 mm	d/w: lift: h/o	60 m 45 m 30 m 15 m
Dempster Industries Inc. Beatrice Nebraska	Dempster	33 F (EX) CS	2 in 2¼ in 2½ in 3 in 3½ in 4 in	d/w: lift: h/o (could be used as force pump)	
Duba Nieuwstraat 31 B-9200 Wetteren Belgium	Tropic	Type 111	50 mm 60 mm 70 mm 80 mm	d/w: lift: h/o	100 m 70 m 50 m 40 m
English Drilling Equipment Co Ltd. Lindley Moor Road Huddersfield HD3 3RW	None	None	2¼ in 2¾ in 3¼ in 3¾ in	d/w: lift: h/o	585 ft 390 ft 280 ft 210 ft

TABLE 2 (Cont)

MARKET INTELLIGENCE INFORMATION

MANUFACTURER	BRAND	MODEL	CYLINDER SIZES	TYPE OF PUMP	STATED MAXIMUM LIFT	
Ernst Vogel A-2000 Stockerau PO Box 42 Austria	Vogel	7S) 7) 7W)	76 mm	d/w: lift: h/o	7.5 m	
		7St) 7T)	76 mm	s/w: suction: h/o	16 m	
					1 man	2 men
H.J. Godwin Ltd. Quenington Cirencester, Glos. GL7 5BX	Godwin	X1 X2 X3 X4	2¼ in) 2¾ in) 3¼ in) 3¾ in)	d/w: lift: h/o: extractable cylinder	100 ft 75 ft 60 ft 50 ft	175 ft 130 ft 110 ft 80 ft
		X5N X6N X7N X8N	2½ in) 3 in) 3½ in) 4 in)	d/w non-extractable cylinder lift: h/o	100 ft 70 ft 50 ft 40 ft	175 ft 130 ft 90 ft 70 ft
	Godwin	WIH 51 WIH 52 WIH 53 WIH 54	2¼ in) 2¾ in) 3¼ in) 3¾ in)	d/w: lift: h/o extractable cylinder	200 ft 140 ft 100 ft 75 ft	350 ft 250 ft 175 ft 130 ft
		WIH 55N WIH 56N WIH 57N WIH 58N	2½ in) 3 in) 3½ in) 4 in)	d/w: lift: h/o non-extractable cylinder	160 ft 120 ft 85 ft 65 ft	280 ft 210 ft 150 ft 110 ft
	Godwin	HLD 2¼ HLD 2¾ HLD 3¼ HLD 3¾	2¼ in) 2¾ in) 3¼ in) 3¾ in)	d/w: lift: h/o extractable cylinder		
		HLD 2 HLD 2½ HLD 3 HLD 3½	2 in) 2½ in) 3 in) 3½ in)	d/w: lift: h/o non-extractable cylinder		
	Godwin	HLS 2½ HLS 3½	2½ in 3½ in	s/w: suction: h/o		
G.S.W. Ltd. Pump Division Hill Street Fergus, Ontario Canada NIM 2xI	GSW (Beatty)	1205	Not known at present	d/w: lift: h/o		

TABLE 2 (Cont)

MARKET INTELLIGENCE INFORMATION

MANUFACTURER	BRAND	MODEL	CYLINDER SIZES	TYPE OF PUMP	STATED MAXIMUM LIFT
Kawamoto Pump Manufacturing Co. Ltd. No 11-39, 4 Chome Ohsu, Naka-KU Nagoya, Japan	Dragon Dragon	2 (c) 2 (d)	64 mm 64 mm	d/w: lift: h/o s/w: suction: h/o	20 m 9 m
Kumar Industries P.O Edathara Via Palghat Kevala State India	Service Bharat Bharat Bharat Kacrale Kacrale	3 4 5 6 2 3	76 mm 76 mm 82 mm 89 mm 64 mm 76 mm	s/w: suction: h/o	
Kitrick Management Co 4039 Creek Road Cincinnati, Ohio 45241 USA	Gem IXL E.2.			s/w: chain pump: h/o s/w: steel chain pump: h/o s/w: bucket pump: h/o	
Lee Howl and Co Ltd Alexandra Road Typton, West Midlands DY4 8TA	None	4 5 51 262	80 mm 80 mm 80 mm 80 mm	s/w: suction: h/o s/w: suction: h/o s/w: suction: h/o s/w: suction: h/o	
Lifetime Products Corporation P.O. Box No 102 Industrial Area Jodhpur, India	Life-time	AH1 AH4 ?	63.5 mm 76.2 mm	d/w: lift: h/o d/w: lift: h/o	200 ft 125 ft 200 ft
Mengin Zone Industrielle d'Amilly BP163 45203 Monfargis France	Vergnet	4C2 4A	30 mm 40 mm	d/w hydraulic, lift: f/o d/w: hydraulic lift: f/o	200 ft 80 ft

TABLE 2 (Cont)

MARKET INTELLIGENCE INFORMATION

MANUFACTURER	BRAND	MODEL	CYLINDER SIZES	TYPE OF PUMP	STATED MAXIMUM LIFT
Monarch Industries Ltd 889 Erin Street Winnipeg, Canada	Monarch	P3 2 series 2D6	Not known 3½ in 3½ in	d/w: lift: h/o d/w: lift: h/o d/w: lift: h/o	
Vammalan konepaja OY 38200 Vammala Finalnd	Nira			d/w: lift: h/o	
Mono Pumps (Engineering) Ltd. Mono House Seckforde St. Clerkenwell Green London EC1R OHE	Mono lift	W ES30		d/w: lift: h/o	
Petro Pump Carl Westmans (Vag 5) S-13300 Saltsjöbaden Sweden	Petro	95 48		d/w: diaphragm h/o d/w: diaphragm h/o	50 m
Pumpen fabrik-Beyer Niels-Bohr-Ring 12a 2400 Lübeck 1 W. Germany	Beyer	153 82 151 152	3 in 3¼ in 3 in 3½ in	s/w: suction: h/o	
		153s 82s 151s 152s	3 in 3¼ in 3 in 3½ in	s/w: suction: h/o	
		2 3 4 5	3 in 3½ in 4 in 4½ in	s/w: suction: h/o	
		G250	2½ in 2¾ in 3 in 3¼ in 3½ in	d/w: lift: h/o	
		H52	2½ in 2¾ in 3 in 3¼ in 3½ in	d/w: lift: h/o	
		D47	2½ in 2¾ in 3 3¼ 3½ in	d/w: lift: h/o	

TABLE 2 (Cont)

MARKET INTELLIGENCE INFORMATION

MANUFACTURER	BRAND	MODEL	CYLINDER SIZES	TYPE OF PUMP	STATED MAXIMUM LIFT
Sea Commercial Co. Inc. P.O Box 1489 Manila Philipines	Seacom Seacom	mini Jet-matic Jet-matic		s/w: suction: h/o s/w / d/w: suction lift: h/o	28 ft 66 ft
Sholapur Well Service 560/59, South Sadar Bazar Civil Lines Solapur 413 003 INDIA	Sholapur	002/2		d/w: lift: h/o	
Pijpers International Water Supply Engineering PO Box 138 Nijkerk Holland	Kangaroo	N/S	50 mm) 75 mm) 100 mm)	d/w: lift: spring f/o	20 m 10 m 6 m
Robbins and Myers Springfield, Ohio 45501 USA	Moyno	1V2.6 2V2.6	- -	d/w: lift: h/o d/w: lift: h/o	45 m 90 m

Abbreviations:

d/w: deep well

s/w: shallow well

h/o: hand-operated

f/o: foot-operated

N.B. we have not differentiated between force pumps and lift pumps, as most pumps which are nominally lift pumps can be easily modified to operate as force pumps

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

WORKING MEETING ON HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

TESTING OF IDRC PROTOTYPE PUMPS

SUMMARY

This interim report details the results of comparative tests which have so far been carried out on the first six of twelve brands of handpump, suitable for rural water supply in developing countries. A full analysis of results has not yet been performed. For the purposes of the tests, the pumps were coded by the letters A-M (The brands are given in Table 1). Below is a brief summary of the results.

CODE A

A fairly new hand-operated pump, using a diaphragmatic hose as the pumping element and a single ¾"in. drop pipe both to operate the pump (using reciprocating motion) and to deliver the water. The pumping mechanism seems capable of development into a cheap, reliable pump of adequate performance and user acceptance. The pump tested however has several design and manufacturing problems which need to be ironed out. In particular -

(1) The well is not adequately sealed against contamination - the pump is clamped to the protruding well casing - a design for which such a seal would be very difficult to provide.

(2) The pump is designed for use in wells drilled into hard rock. Although the pump can be made to grip in a well casing, the size is not compatible with that required for the pump stand.

(3) Two manufacturing faults, which could easily be rectified and yet which have serious consequences, have been discovered. Firstly a hardening thread sealant has been used on the pumping element; this has a tendency to break off and jam the discharge valve. Secondly, incorrect thread cutting on the anchor locking wedge caused a thread to strip and the pump to fail during the endurance test.

The forces required to operate the pump are fairly high, and yet up to depths of around 25m, the pump is not difficult to use.

The pump's resistance to pilferage and vandalism is poor.

CODE B

Another new design, a foot-operated pump using a hydraulically operated diaphragmatic hose. The pump is very easy to maintain. We feel, however, that its comparatively unusual operating system could baffle many people in developing countries and, unless suitable precautions were taken, could result in a neglect of maintenance in some cases. It is fairly easy to use, has a fairly good performance and so far has had no problems with reliability. We think the pedal rod guide and seals may need occasional replacement - a very easy task however. A good stock of spares would have to be kept since many of them would be difficult to make in LDC.

Our main criticism is that water from the hydraulic circuit gradually leaks out during pumping and the pedal height drops. This must occasionally be rectified by lifting the foot pedal manually (once or twice/minute) to reprime the hydraulic circuit. A problem which the pump would be better without.

CODE C

A well established design of hand-operated pump using a conventional pump cylinder, which is likely to be very good as a family pump but is unlikely to stand up to the intensive use demanded by a village pump. In the endurance test, the stuffing box nut was found to wear fairly quickly, resulting eventually in breakage of the pump rod. The pinned handle bearings were also beginning to wear significantly. The performance was good and the pump was easy to use. It was not particularly robust however and was prone to vandalism and pilferage.

CODE D

A rotary "progressive cavity" pump operated, one or two-handed, by twin handles, the movement of which is converted to rotary shaft motion by bevel gears. The pump has been reliable on the endurance tests so far and seems to require very little maintenance. We have two main criticisms however.

(1) The gearbox is very prone to oil leakage, both from the handle bearing and, after some time, from the shaft seal. This could eventually empty the gearbox of oil and also could contaminate the water if it seeped i the gland packing.

(2) The performance of the pump is poor and, as a result, the pump was not popular with the users. See section 9.5 of this report for a full discussion.

The pump is very robust and is likely to stand up to considerable abuse.

CODE E

A robust and sturdy hand-operated pump, very generously engineered, but with many external fastenings which could render it liable to vandalism. It has a conventional pump cylinder and is driven by a handle on a heavy (nearly 100 kg) counter-balanced flywheel. The flywheel has two opposing effects. It makes the pump very smooth and easy to operate, even on deep wells, (this pump was the most popular with our users) but it could also be a possible safety hazard. It can continue to rotate for several revolutions after the user has stopped turning the handle, especially if a fast pumping speed has been used, and the handle could easily injure any young child who stepped in the way.

To date, the pump has given no problems on the endurance tests, and its construction suggests that it should be very reliable. Cylinder inspection is likely to be the only significant maintenance required.

Two points require further consideration however.

(1) The design of the base could be improved, to resist well contamination by surface water.

(2) The leathers supplied by the manufacturer with the pump, and also a second set of leathers bought later, were too thick. As a result, the plunger jammed in the cylinder after the pump had been installed. At present we recommend that any leathers supplied with this pump be carefully measured before installation and, if necessary, an alternative source of supply should be used.

CODE F

A robust, generously engineered, hand-operated pump which uses a conventional pump cylinder and is driven by a handwheel geared down so that about 4 revolutions give one pumping cycle. The pump was rather slow to operate and was not popular with users, for this reason, and also, probably, because its uneven pumping movement was very disconcerting in use.

To date there have been no problems in the endurance tests and the pump seems likely to prove reliable. Its resistance to pilferage is not good. We also think the base design could be improved, particularly to increase the resistance to contamination by surface water.

INTRODUCTION

Hand pumps have been available for many years. Indeed, in the Western world they were common 100 years ago but in modern times the availability of piped water supplies has relegated the hand pump, as a source of drinking water, to a comparatively unimportant position. There has been increasing interest, however, in the use of hand pumps to provide safe drinking water in developing countries. This has been especially true during the last 10-15 years and is expected to become more marked during the coming World Water Decade (the 1980's).

Where there is suitable ground water, the use of a hand pump is generally the cheapest means of providing a potable water supply. The use of such pumps in developing countries however has produced many problems as well as solving some. Many, perhaps the majority, of these problems have their roots either in the sociological and cultural attitudes of the pump users or in the organisation (or lack of it) of the hand pump installation and maintenance programme. One major problem, however, is the unreliability of many of the pumps which have been installed and the havoc wrought with the water supply consequent upon it. This unreliability may result from several sources :

(1) The intensive use of a pump in a village water supply scheme which may require it to be in operation for perhaps 12 hours of the day, when it was designed for only occasional use - e.g. on a farm.

(2) The use of cheap and unreliable pumps in an effort to provide water to the greatest number of people within the scope of a limited budget.

(3) The choice of a poor pump simply due to the lack of suitable, unbiased and reliable test data on the pumps available.

(4) Lack of sufficient knowledge of pumps to foresee those peculiar features which could clash with the cultural behaviour of the pump users.

To the authors' knowledge there has been no wide scale, fully comparative testing of hand pumps under controlled laboratory conditions. The British Ministry of Overseas Development was particularly concerned about this and in July 1977 signed a contract with Harpenden Rise Laboratories, Harpenden, UK, a laboratory specializing in the comparative testing of consumer products, for the testing of 12 brands of hand/foot-operated pumps for use in developing countries. The tests envisaged were fairly long term, each pump being endurance tested for 200 days as well as having extensive performance and user tests and engineering evaluations. The tests were designed to run in two stages with 6 pumps being tested in each stage and were limited to deep well lift pumps.

This report is the first progress report and gives the results of all tests, except that of endurance, on the first batch of six pumps.

2. CHOICE OF PUMPS

Before any testing could commence it was necessary to select 12 pumps from all over the world as being typical of those used in village water supply schemes. A complete world market survey was performed. Letters were sent to around 100 manufacturers asking for details of the pumps they made, including spares and prices, their manufacturing capacity, the countries in which their pumps were normally sold, and their approximate market share if known. From the replies received a selection of deep well pumps was made based generally on the following criteria.

(a) As many different types of pump as possible should be included in the tests, i.e.

Flywheel-operated

Foot-operated

Normal hand-operated with reciprocating motion

with as many different pumping methods as possible, e.g.

Hydraulically-operated pumps

Spring-operated pumps

Diaphragm pumps

Simple lift pumps

(b) The pumps should include some old, well-established designs as well as some of the more modern, innovative designs.

(c) Pumps should be included which have been, or are at present being tested in field trials known to the authors.

A list of the pumps selected is given in Table 1 together with a brief description of the features for which each was chosen. Table 2 shows a summary of all pumps made by manufacturers who answered our letters. The final choice was difficult and several pumps had to be left out which had interesting and novel features which could have made them perform well in some situations.

Two samples of each pump were ordered together with any spares which it was thought might become necessary. Where several sizes of cylinder were available, a size generally between 55 and 67mm diameter was selected, except where the pump design criteria made a different size a better choice. The aim was to choose, where possible, pump combinations which could be used at depths of around 20-40m. In some cases, where no pumping depths were quoted by the manufacturer, choice was difficult.

MISCELLANEOUS

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

WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

G. Miscellaneous

M.P. 1. Directory of Handpump Manufacturers

M.P. 2. Rate of Wear of PVC Pump Cylinders (Laboratory Testing)

M.P. 3. Comparative Testing of Consumer Products
ISO Guide 12.

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

M.P. - 1

WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

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
("M 1400", "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 Manual
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, Vanlenzuelc
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
Parecia 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 45211

("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

M.P. - 2.

WORKING MEETING ON HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

RATE OF WEAR OF PVC PUMP CYLINDERS

(LABORATORY TESTING)

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
("M 1400", "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 Andrê 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

M.P. - 3

WORKING MEETING
ON
HANDPUMP SELECTION AND TESTING

Harpenden, Hertfordshire, U.K,
29 May - 1 June 1979

COMPARATIVE TESTING OF CONSUMER PRODUCTS

ISO GUIDE 12-1977 (E)

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.

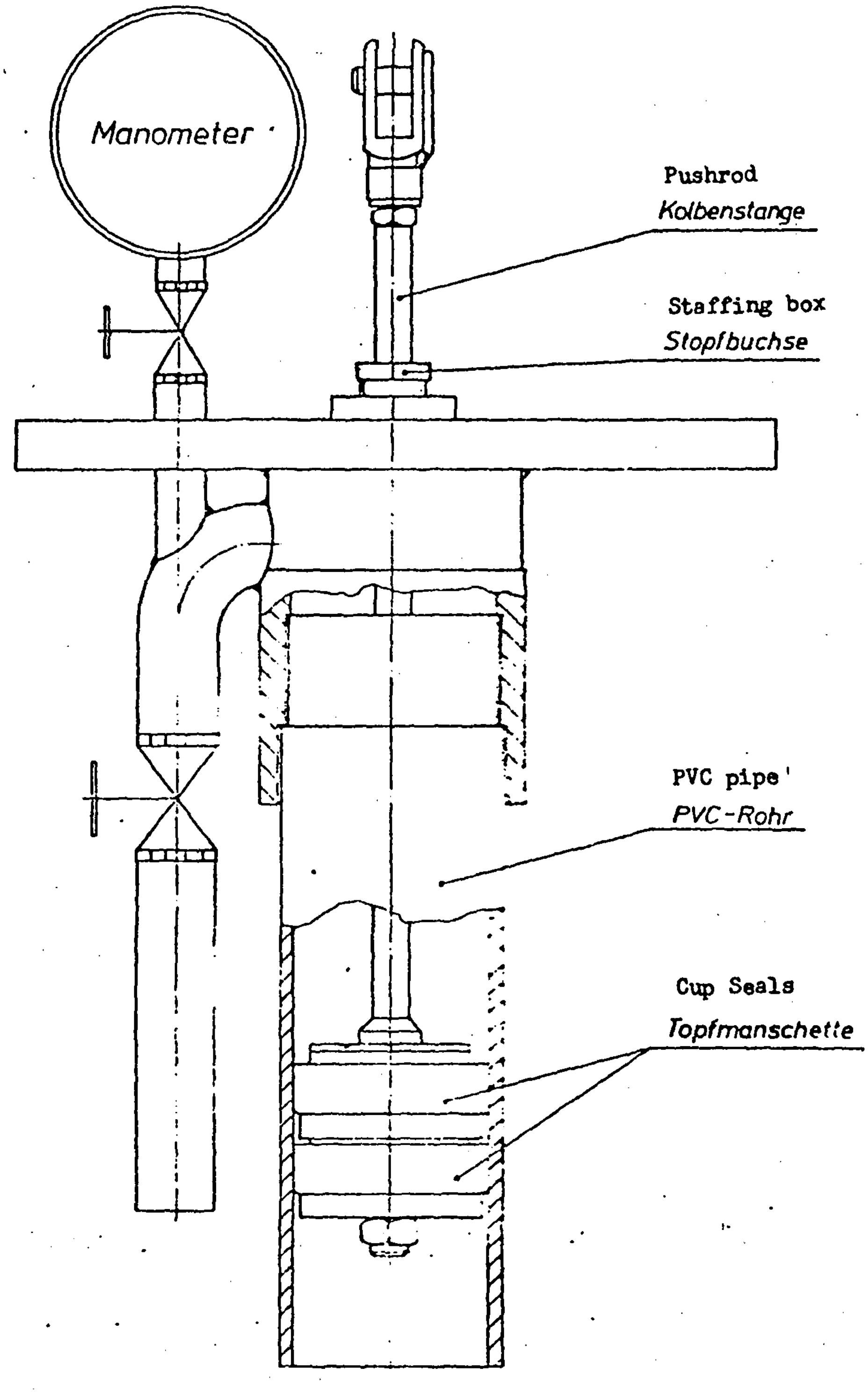
When the piston ascends water is lifted from the tank and pushed through the discharge pipe in which the gate valve is located. The gate valve is adjusted to provide an impedence to the egress of the water, thereby creating a pressure which is measured by the manometer. The water is then recirculated 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.

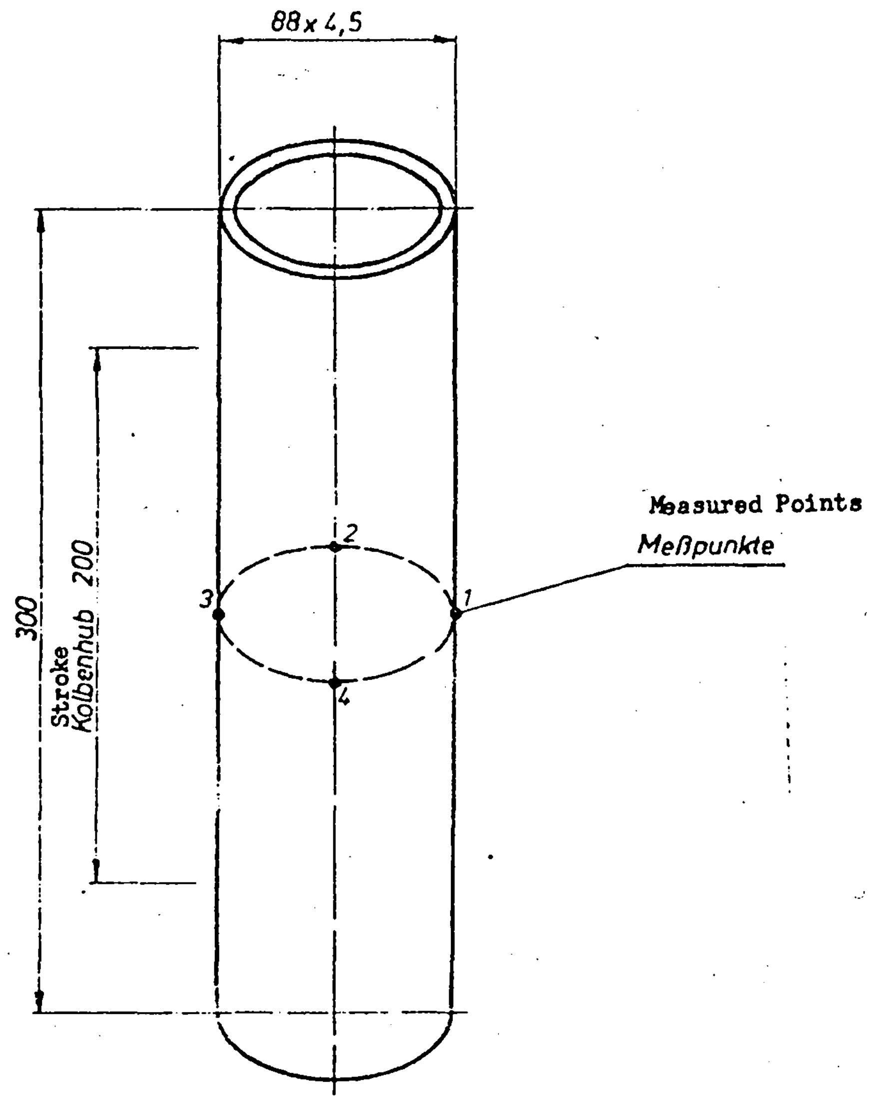


Test Stand for Rate-of-Wear Experiment

Prüfstand für Verschleißprüfung

gez.: 10. 2.76 Klass

PREUSSAG AG
Kunststoffe u. Armaturen
Werk Siederdorf



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