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HANDPUMPS for COMMUNITY WATER SUPPLY

Report of the Research and Development Coordination Meeting

and an

Agenda for Action

Harpenden, United Kingdom
April 1987

Sponsored by: **The UNDP/World Bank Rural Water Supply Handpumps Project**

In cooperation with: **The Overseas Development Administration, UK**

Organized by: **The Consumer Research Laboratory, UK**

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DEDICATION

This report is dedicated to Claude Girardet who died in June, in memory of his enthusiasm and commitment to our work together in handpump development.

Claude spent most of his working life with Dupont in Geneva and was an extremely experienced plastics engineer. He first became involved in handpump research and development in April 1985, when a group from the Handpumps Project and SKAT visited Dupont to elicit their advice on the role engineering plastics could play in handpump design. Claude showed an interest in the issue far beyond the call of duty, and was instrumental in setting up a collaborative effort whereby the Handpumps Project team in Nairobi received regular and invaluable advice from Dupont, through SKAT. Claude visited Nairobi in March 1986 to participate in a handpump design meeting, and again his personal commitment to devoting his expertise to the benefit of poor people in developing countries was clear. He was directly involved in the design, testing and prototype production of bearings and valves for the Afridev, and the success of this development work was greatly aided by his contribution. Claude agreed to attend this meeting, to share with the participants his knowledge of plastics and his belief in the role they can play in solving many of the outstanding problems of handpump design.

Our work will be more difficult without Claude.

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PREFACE

Only one-half of the world's population has adequate access to potable water supplies today. Those who lack this basic service are predominantly members of the poorest sector of the populations of developing countries. Governments of developing countries are often confronted with the dual responsibility of initiating new water supply programs while lacking sufficient funds to maintain current systems. Because of the financial constraints faced by these countries, low-cost, community-based systems are perhaps the only feasible option to meet the needs of their low-income populations and thereby reach the goals of the International Drinking Water Supply and Sanitation Decade (IDWSSD).

Wells equipped with handpumps already serve perhaps 500 million people, and there is little doubt that they are an important water supply option for low-income rural communities without access to the resources and skills necessary to run more complex water supply systems. When organizational, financial and physical (water and energy) constraints are taken into account, wells equipped with handpumps are a sound technology choice for a large segment of the more than 1,500 million persons in need of water supplies in rural areas of low-income countries.

The work on low-cost water supply systems carried out at the beginning of the Decade focused primarily on technology problems -- the handpumps themselves. During the course of the Decade, however, the focus has expanded to include other critical elements of the community water supply system, such as community participation, well construction and maintenance, and training. It has become evident that these elements are interdependent, with both hardware and software components contributing to the success or failure of the community water supply system. Handpump technology remains the core issue, however, as no system can succeed if the technology fails. Despite the progress which has been made, further work is needed on the designs of several types of handpumps based on VLOM (Village-Level Operation and Management of Maintenance) technology.

The principal purpose of the meeting which is the basis of this paper was to define a handpump research and development program which would address the key research issues still to be resolved, optimize the use of resources (skills, facilities and funds) and explore additional sources of funding. It is hoped that this report will stimulate further, coordinated investment in handpump research. As can be seen in the summary table on page 7, no sources of funding have been identified for the portfolio of research topics. Funding is especially crucial at this point in the Water Decade, as the work to be undertaken not only addresses those pumps now in the design and development stage, but the replacement parts for the millions of pumps which now serve as the only adequate water source for many parts of the world.

The meeting participants would like to express appreciation to the Consumer Research Laboratory (CRL) at Harpenden (formerly the Consumers' Association Testing and Research Laboratories) without whom the meeting would not have been possible. CRL was responsible for the preparation, organization and reporting for the meeting and therefore played a major role in its success.

1. INTRODUCTION

In April 1987, a group of twenty people involved in handpump research and development met for four days of intensive discussions at the Glen Eagle Hotel, Harpenden, England. Everyone in the group had current interests in handpump research and development, whether as representatives of funding agencies, as Regional Project Officers of the UNDP/World Bank Handpumps Project, as technologists working in research institutions, or as consultants with special interests in the subject. The group was joined by members of staff from the Consumer Research Laboratory (CRL) at Harpenden (previously known as CATR), and representatives of the Crown Agents, European Vinyls, and DuPont, Switzerland.

The principal purpose of the meeting was to coordinate future handpump research and development. To this end, the meeting set out to define a handpump research and development program which would address the key research issues, optimize the use of resources (skills, facilities and funds) and explore additional sources of funding.

This report draws together discussions, both of working groups and of plenary sessions, covering a wide range of research and development topics. The meeting concluded that the most pressing hardware problems, affecting almost every country, centered on the rising main, handle bearings, piston seals, corrosion in the below-ground assembly and the development of direct action pumps.

The meeting was constantly reminded by several participants of the importance of software issues, including matters such as community participation and training. Although there was much interest in holding discussions on these issues, neither the original mandate nor time allowed for this discussion, and it was concluded that the meeting should retain its hardware focus.

The most important priority for future handpump research and development was thought to be the further development of plastic rising mains. Comprehensive research and development program proposals are set out in the Plan of Action (page 7).

2. OBJECTIVES OF THE MEETING

It was agreed that the following objectives would be the fundamental reference points for all subsequent discussions at the meeting.

A. Review activities, progress and constraints in handpump research and development.

B. Identify major research and development issues.

C. Plan the most effective use of available technical and financial resources.

D. Prepare a plan of action for future research and development.

3. BRIEF REVIEW OF EXISTING RESEARCH AND DEVELOPMENT PROGRAMS

United Kingdom

ODA (the Overseas Development Administration) continues to support research and development in rural water supply in developing countries, in cooperation with the UNDP/World Bank Handpumps Project.

Handpump testing at the Consumer Research Laboratory has now been under way for about eight years, and manufacturers continue to submit handpumps for laboratory testing. The new handpump testing tower in Harpenden is in full operation, and a number of boreholes have also been provided on the Harpenden site. Current research and development work include: further testing of polymer bearing systems; an empirical study of the forces acting in rising mains, leading to a series of comparative endurance tests; and testing of alternative materials for lightweight pump rods for direct action pumps. Planned projects include the investigation of seal-less pistons and fluidic diodes.

Federal Republic of Germany

The Federal Republic of Germany continues to support handpump research and development. Topics of particular interest are the development of corrosion-resistant systems for use in aggressive groundwaters of West Africa. Software development, including topics such as training programs, design and quality control standards, community participation, information exchange, etc., is actively encouraged. The importance of the VLOM concept is recognised, as is the need for further field testing of handpumps.

Switzerland

SKAT (the Swiss Center for Appropriate Technology) is committed to the transfer of technology to developing countries, and is collaborating with the UNDP/World Bank Handpump Project, with financing from the Swiss Development Corporation. SKAT's focus is on providing assistance in the local manufacture of handpumps and current work includes the development and manufacture of plastic below-ground components and polymer bearings, which have been incorporated in the Afridev handpump, in cooperation with Dupont and Optimold in Switzerland and the Handpumps Project Team in East Africa. Other interests of SKAT include its work on stresses in rising mains, seal-less pistons and fluidic diodes.

Netherlands

Interaction Design has begun a project, with funding from the Netherlands Government and in cooperation with handpump manufacturers Volanta and Van Reekum and consultants DHV, to examine the dynamic behavior of rising mains at depths greater than 15 meters. Their test facilities include a 100m borehole.

IRC (the International Reference Center in the Hague) is involved in the generation, collection and transfer of information in specific problem areas, including maintenance, the role of women, community participation, and community financing.

Sweden

Lund University of Technology has been studying piston, valve and seal design, and has investigated the use of a reinforced rubber belt to replace the chain in the India Mark II. Good results have been obtained with rubber ball valves; experience with leather cup seals has been generally good but variable. Cross-linked polyethylene shows promise as a cylinder lining material. This work is being financed by SIDA (the Swedish International Development Agency) and is now being undertaken for the Handpumps Project.

Canada

IDRC (the International Development Research Center) has encouraged the development of modular handpump designs with the potential for local manufacture. The Center supports research based in a number of developing countries, and has actively promoted the development of low-lift PVC handpumps. The Center has close ties with the University of Malysia's Mechanical Engineering Department, which is undertaking significant handpump research and development.

East Africa

The Afridev handpump is the product of several years of development work by a group in East Africa collaborating with government and donor agencies and supported by a number of organizations in Europe. The pump is a "repository" for design solutions identified for many of the general problems of handpump design, including bearings, rods, rising mains and cylinder valves. Attention is now focused on solving outstanding problems of corrosion, particularly in the bearing housings, improvements to the molded piston/footvalve design and to the internal finish of the stainless steel cylinder liner, and in devising an easily-separated rod connector suitable for volume production.

Although it is still undergoing field trials, the Afridev pump has demonstrated that village-level maintenance of deep-well handpumps is a realistic objective, and that an effective and reliable deep-well VLOM handpump can be manufactured in a developing country. A crucial element of the Afridev design is the relatively small cylinder diameter combined with a lever arm offering a modest mechanical advantage but a relatively long pump rod stroke.

In Ethiopia, further development of the innovative Ethiopia BP50 pump has been hampered by difficulties in obtaining needed raw materials, particularly uPVC pipe of adequate quality. Pumps are currently made with steel pipes and rods, and a conventional cast piston. The Ethiopian Government remains committed to local manufacture, user maintenance and an integrated approach to the problems of water supply. Corrosion is a serious problem.

India and South Asia

The India Mark II continues to build on its considerable success over the last ten years. More than one million handpumps are installed today, and UNICEF, the Handpumps Project and others are investigating possible design changes which will result in significant improvements to the pump. Current interest centers on extractable cylinders, on improvements to the handle bearing arrangement and on other modifications which will make the pump more suitable for village-level maintenance. Research into the suitability of uPVC pipes as deep-well rising mains continues to be of interest.

For low and intermediate lifts, the Tara pump has demonstrated the potential for a simple, locally-made direct action pump. However, the Tara was designed specifically for the conditions of Bangladesh (50 - 75 users per pump), and it may need some modification for use elsewhere. Attention is focused on developing a modular direct action design, incorporating the best features of the Tara pump, which can then be adapted to fit the manufacturing facilities and conditions of use found in other countries.

West Africa

Corrosion of the below-ground parts of handpumps has been identified as the most serious cause of handpump breakdown in West Africa (and is a major problem worldwide), and local research has concentrated on the relationship between water quality and pump reliability. Data from a large number of handpumps in the region confirm that pump rod breakages -- usually resulting from corrosion -- are responsible for 60 percent of failures. Plastic rising mains, which are inherently corrosion resistant, are therefore of particular interest, and progress has been made on designing a locally-made PVC rising main connector.

The Vergnet handpump has been widely adopted in Francophone West Africa and is an innovative design that lends itself to village-level maintenance. A major problem with the pump that requires urgent resolution is the relative rapid failure and high cost of the hydraulic diaphragm.

4. KEY QUESTIONS FOR HANDPUMP RESEARCH AND DEVELOPMENT

The meeting recognised that the successful implementation of rural water supply projects in developing countries depends on careful consideration of both "hardware" and "software" issues. However, the meeting had been called specifically to address the issues of handpump research, design, development and manufacture. This agenda was adhered to.

Four key questions need to be asked when defining handpump research and development needs. These questions relate to:

Maintenance
Performance and Reliability
Manufacture
Finance.

Maintenance: who will maintain the pump and what tools and skills are available?

In the great majority of applications, the responsibility for maintenance will fall on the users of the pump -- the villagers themselves. It is therefore unrealistic to design for more than a minimum of tools and more than the most basic mechanical skills.

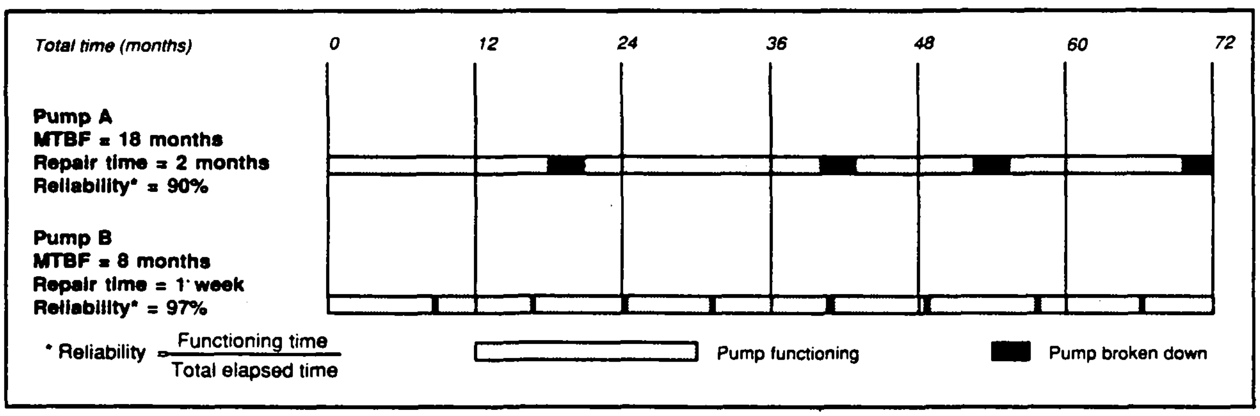
Maintenance is partly a hardware issue, in that the pump must be designed and constructed in an appropriate way, and partly a software issue, in that local communities need to acquire the institutional ability to manage handpump maintenance. However, community management -- Village-Level Operation and Management of Maintenance (VLOM) -- is being shown to be more than a hypothesis: it is a realistic objective. Research and development work must concentrate on handpump designs which can be successfully maintained at the village level, and in essence this means the simpler, the better.

Performance and Reliability: what level of pump performance is required in terms of reliability, discharge rate, and user acceptability?

Reliability is the cornerstone of successful handpump performance. Generally, a pump which provides a sufficient discharge rate to meet the community's needs and produces water of good quality will be acceptable to users. But whatever the pump's discharge rate, and however easy it is to use, it cannot serve its purpose if it is out of action too frequently or for long periods due to breakdown or wear.

The most important facet of reliability is *availability*. In classical reliability engineering, *reliability* is expressed as the mean time between failures (MTBF). This is not the most appropriate measure of reliability for a handpump. The success of a handpump is better measured in terms of *availability*, which is the proportion of time for which the pump remains in working order. This shift of emphasis is most important, because it means that a pump which breaks down relatively frequently but is quick and easy to repair works better than a pump which seldom breaks down, but then may take a long time to be put back in working order.

In this illustration (taken from *Community Water Supply: the Handpump Option*), pump A might be considered the more reliable in the sense of maximizing the MTBF, as it breaks down relatively infrequently. However a mobile maintenance team is required to repair the pump, and so it tends to be out of action for some time. The MTBF approach does not take account of "down time" while the pump is awaiting repair.



Definitions of Reliability

By contrast, pump B offers greater availability than pump A. Although it breaks down more often, Pump B is easily and quickly repaired by the users. It is therefore more appropriate to the needs of the community.

Whatever the method of measurement of reliability, however, the significance of cost must not be overlooked. This has two facets. Firstly, for successful village-level maintenance, the villagers must be able to afford to replace broken and worn out parts. Secondly, if the cost of boreholes and pumps are low, then more pumps can be provided; each pump would serve a smaller community, and therefore a less robust pump could provide the users the same reliability, as it would be used fewer hours per day.

It has been suggested that relatively, though not excessively, frequent breakdowns might contribute positively to village level maintenance. For example, if the pump requires attention every three months, there is an opportunity to refresh and extend the required skills. Regular preventative maintenance will have the same effect. In contrast, memories may fade if the pump only requires attention every two years or so.

Ideally, the life of the pump should equal that of the borehole. A realistic objective is for all the non-wearing parts to have a 10-year life.

Manufacture: where will the pumps be made and who will make them?

Local manufacture of handpumps in countries of use will play a major part in ensuring that programs can be sustained, as spare parts will be readily available.

Handpump designs must therefore take local manufacturing facilities into account, and should be adaptable to local raw material supplies, available skills and production technologies. Handpump manufacture will help to promote and sustain industrial development. The best assurance of a continuing supply of spare parts at the right price is that they are produced locally without donor assistance. Nevertheless, and particularly in the short term, it may be appropriate to obtain some finished components from external sources if the means of manufacture do not exist locally.

Rigorous quality control and quality assurance procedures will be essential to ensure that handpumps are fit for their purpose, wherever they are made. However, it is recognised that such procedures tend to be less well established in developing countries, and that establishing such procedures is an area in which external assistance is likely to be appropriate.

Provided that the design is appropriate, many developing countries already possess manufacturing facilities which could cope with handpump production. The promotion of local manufacture will not exclude established handpump makers in the industrial world, who have a good product at the right price. The domestic market in some countries may not sustain local handpump manufacture; alternatively, in other countries, local industry may not be able to meet demand. In addition, there is considerable scope for established manufacturers to collaborate with local industry through joint ventures.

Finance: who will pay the capital costs and the maintenance costs?

There is no universal answer to the first part of the question: who will pay the capital costs? However, experience suggests that donor agencies are prepared to fund, in part at least, and governments are willing and able to subsidize the capital costs of many of the rural water supply schemes. However, neither governments nor donors are able to accept the inherently more open-ended, longer-term commitment needed to support a maintenance structure.

There is little doubt that the financial burden of handpump maintenance will fall on the user community, if the scheme is to be sustained in the long term. In principle, this is good, as community participation in maintenance costs will help to generate a sense of ownership and responsibility. But it is essential that the design of the pump ensures that spare parts are affordable and available and that the necessary skills are within the community's reach.

In the longer term, the objective should be for the user community to be able to afford both to buy and maintain its pump.

Considering these issues, the meeting concluded that handpump research and development should concentrate on conventional, lever-arm, reciprocating piston pumps for intermediate and high lifts and direct action pumps for low lifts. The inherent ease of below-ground maintenance of Vergnet-type pumps justifies further development of the diaphragm, but the conventional reciprocating piston pump seems to offer the best chance of achieving a robust and reliable product, made in a developing country, capable of being maintained by villagers, at a reasonable cost. This conventional concept should not and does not preclude use of modern materials and manufacturing techniques, or the encouragement of joint ventures with manufacturers in the industrial world.

Pumps using other principles may offer some specific advantages over the conventional approach, but have not been shown to present a more promising package overall.

The progress of research and development should be through an integrated program of testing in the laboratory and in the field.

5. PLAN OF ACTION FOR FUTURE RESEARCH AND DEVELOPMENT

To formulate this plan, subjects for future research and development have been grouped into topics such as plastic rising mains, polymer bearings and laboratory procedures for handpump testing. Within each topic, a program for research and development is outlined, with indications of the degrees of priority assigned to each element of the program. It is important to note that degrees of priority A-C are relative: all topics need to be addressed soon, however items of priority A are urgent.

The elements of the programs in the Plan of Action are described in broad terms: detailed terms of reference will be required for each element to enable costs to be estimated. Also, sources of funding must be identified.

A summary of the Plan of Action is presented in Table I.

TABLE 1: PLAN OF ACTION

TOPIC	COMPONENT	PRIORITY	TIME SCALE	FUNDING SOURCE
5.1 Plastic rising mains (p8)	5.10 Design guidelines and quality control procedures for plastic rising main systems.	A	1.5 years	to be identified
	5.11 Design, manufacture and test prototype plastic rising main systems.	A		
5.2 Polymer bearings (p10)	5.20 Complete work on polymer bearings.	A	2 years	to be identified
	5.21 Improve bearings for India Mark II.	A		
	5.22 Investigate other types of polymer bearings.	B		
5.3 Cylinders, pistons, footvalves, and seals. (p12)	5.30 Complete molded piston and footvalve design.	A	2 years	to be identified
	5.31 Investigate seals, cylinders and valves.	A		
	5.32 Improve design of elastic pumping elements.	A		
	5.33 Investigate seal-less pistons.	B		
5.4 Direct action pumps. (p14)	5.40 Resolve outstanding design issues for direct action pumps for community use.	A	1.5 years	to be identified
	5.41 Design new footvalve for Tara.	B		
5.5 Corrosion (p16)	5.50 Develop corrosivity index.	B	2 years	to be identified
	5.51 Investigate corrosion resistent materials and cathodic protection.	B		
5.6 Laboratory procedures for handpump testing. (p18)	5.60 Develop improved procedures for laboratory testing.	C	1 year	to be identified
5.7 Pumpstands. (p20)	5.70 Formulate handpump standards, especially mounting standards.	A	1 year	to be identified
	5.71 Review and analyse basic handpump design factors.	B		
5.8 Pump rods. (p22)	5.80 Develop easy connect couplings.	A	1 year	to be identified

5.1 PLASTIC RISING MAINS

Objective: To develop a reliable plastic rising main for deep-well handpumps.

The rising main is the single greatest outstanding problem in handpump design. Widely-used galvanized mild steel rising mains are strong and reasonably priced; however, they are rapidly damaged by corrosive groundwater and they are very heavy in the diameters needed for extractable cylinder elements. The use of stainless steel overcomes the problem of corrosion but introduces extremely high, generally non-affordable costs. Plastic pipe, particularly uPVC, is widely available, relatively cheap and corrosion-resistant. However, there are many unanswered questions about the use of uPVC rising mains and many failures have been reported.

Relatively little is known about the static and dynamic stresses in handpump rising mains, especially those made from plastics such as uPVC. It is therefore not possible to have full confidence in large-scale application of plastic rising main systems, and further analysis and testing of rising main components including pipes, connectors, support systems and centralizers is needed. However, the inherent advantages of low cost, light weight and corrosion resistance together with successful field tests make plastic rising mains very attractive for handpumps.

uPVC is the major plastics material used for pipes, because it is relatively stiff, strong and cheap. However, it has an acknowledged sensitivity to notch failure. uPVC is widely available and extensively used for water supply and in many other applications, but existing systems of pipe and couplings have been designed primarily to resist internal pressure. The handpump application is unique because the pipe is called upon to withstand substantial axial stresses. Manufacturers of uPVC plastic have a thorough understanding of the properties of the material, but the handpump application is unfamiliar.

There is evidence that uPVC pipes from different sources, although ostensibly made to similar standards, can vary widely. In pipe manufacture, the molecular weight of the feedstock, the composition of stabilizers, the proportion of filler and the melt temperature must be carefully controlled to achieve pipe of consistent high quality.

At present, the only off-the-shelf coupling systems suitable for uPVC rising mains are solvent-cemented couplings. These have clear disadvantages for ease of extracting the rising main. Threaded couplings are available but are unreliable under stress.

5.1 PLASTIC RISING MAINS

COMPONENT	ACTIVITY	PRIORITY
5.10 Design guidelines and quality control procedures for plastic rising main systems.	Identify sources of expertise in the plastics industry, including plastics manufacturers, and prepare a compendium of resource persons and institutions.	A
	Collect plastic pipe samples from a wide range of developing countries and analyze their physical properties and composition. Prepare a summary report.	A
	Develop a mathematical model of rising main behavior, and prepare a technical report that sets out the operating conditions including stresses, strains and deflections of the rising main.	A
	Develop design guidelines for plastic rising main assemblies, including suggested dimensional and material specifications.	A
	Develop quality standards and quality control procedures, including simple tests for uPVC pipes manufactured in developing countries.	A
5.11 Design, manufacture and test prototype plastic rising main systems.	Collaborate with manufacturers to produce improved rising main systems, including plastic pipe, support mechanisms, pipe connectors and centralizers.	A
	Test prototype hardware in the laboratory and in the field.	A

Current R&D activities: In-well testing and mathematical modeling of plastic rising main systems by Consumers Research Laboratory (UK) and Interaction Design (Netherlands). Work by various manufacturers including Wavin, Vammala, Mono, Pumpenboese, Preussag, Insto and SWN.

Current funding sources: ODA, DGIS, and UNDP/World Bank (INT/81/026)

Related topics: 5.4 Direct action pumps
5.5 Corrosion

5.2 POLYMER BEARINGS

Objective: To improve the polymer bearing system incorporated in the Afridev, to design similar bearing systems for wider application in other pumps including the India Mark II, and to investigate other polymeric and elastomeric bearing systems.

The polyacetal/polyamide bearings developed in East Africa and currently used in the Afridev have demonstrated the potential contribution of polymer bearings to village-level maintenance. However, the working life of polymer bearings in the field varies widely from pump to pump, which is not easy to explain. Rapid wear of the locating lugs has been a problem which should not prove difficult to overcome, but corrosion of the bearing housings, dust and water ingress and high pumpstand temperatures may all play a part in determining the rate of wear of the sliding surfaces.

Ball races in the India Mark II have a working life of about two years; a set costs about $8.00, but the handle often has to be replaced also when the bearings wear out. Ball races contribute to making the pump more difficult to manufacture, since close tolerances and high standards of quality control are necessary. They are difficult to fit, remove and replace, making them ill-suited to village-level maintenance. They can be irreparably damaged by shock forces and are susceptible to contamination by dust and water.

Some experiments have been carried out with non-sliding elastomeric bearings; the results were inconclusive but not discouraging. The new Atlas Copco handpump, currently on test at the Consumer Research Laboratory, incorporates such a bearing. The advantage of elastomeric bearings is that sliding contact, and the wear that results from it, are eliminated. The number and variety of synthetic elastomers available has been increasing in recent years.

Experiments with proprietary systems using relatively thin layers of bearing materials such as PTFE have been unsuccessful, indicating that bearings of this type are unlikely to be suitable for handpumps. Wooden bearings have been successful in some designs, however. Although unlikely to provide a design solution for wide-ranging applications, they may have a place in specific projects where other bearing systems are unavailable or inappropriate.

5.2 POLYMER BEARINGS

COMPONENT	ACTIVITY	PRIORITY
5.20 Complete work on polymer bearings.	Monitor current field testing of polyacetal/polyamide bearings in Afridev; investigate methods of corrosion protection for bearing housing.	A
	Assess wear characteristics of polyacetal/polyamide bearings at elevated temperatures under controlled laboratory conditions and compare with field test results.	A
5.21 Improve bearings for India Mark II.	Devise alternative means of housing existing India Mark II ball races, including possible use of tolerance rings, resilient liners and split bearing housings. Design and manufacture prototypes and test them in the field.	A
	Design polymer bearings for the India Mark II pump suitable for fitting to existing pumps, in lieu of ball races, and for fitting to an appropriately modified India Mark II pumpstand.	A
5.22 Investigate other types of polymer bearings.	Investigate other polymer materials for use as handpump bearings; consult expert sources; design, manufacture and test prototype bearings.	B
	Investigate elastomeric materials for use as compliant, non-sliding bearings; consult expert sources; design and manufacture prototypes for evaluation.	B
	Test prototype bearing systems in the laboratory and in the field.	B

Current R&D activities: Lab testing of polyacetal/polyamide bearings by CRL. Work by various manufacturers such as Atlas Copco.

Current funding sources: ODA and UNDP/World Bank (INT/81/026)

Related topics:
5.5 Corrosion
5.7 Pumpstands

5.3 CYLINDERS, PISTONS, FOOTVALVES AND SEALS

Objective: To develop integrated designs for pistons, footvalves and seals which are easy to manufacture and to maintain; to investigate alternatives to conventional sliding piston seals.

The traditional handpump piston is cast in gunmetal, machined and fitted with one or two leather cup seals. Foundry facilities are not available in many developing countries. Machining brings a requirement for careful quality control to ensure adequate performance and interchangeability of spare parts. Leather cup seals are intrinsically variable and wear rapidly when there is sand in the water. Seal failures are responsible for 37 percent of all breakdowns of India Mark II pumps -- more than any other single factor.

Engineering plastics, processed by injection molding, have been shown to have potential for pistons and footvalves even in deep-well handpumps. Injection-molded plastics find a ready market in developing countries, and potentially suitable manufacturing facilities are therefore becoming more widely established. Provided that the design is appropriate, molded plastic pistons and footvalves can be cheaper, more consistent and easier to fit than their traditional counterparts, and are corrosion resistant.

At their best, leather cup seals can perform well, but quality control is difficult, and the material is inherently variable. Synthetic seals are widely used in other fields of engineering, and there is evidence that they are less susceptible than leather to sand abrasion.

There has been a good deal of recent discussion about the significance of valve behavior in overall pump performance. Specifically, it has been said that late closure of the piston valve will generate high shock loads in the below-ground assembly, contributing to premature failure of the pump rods or rising main.

The Volanta and UPM pumps do not use flexible piston seals. In the Volanta, the seal is achieved by making a long stainless steel piston a close fit in a glass-fibre-reinforced plastic cylinder. In the Pompe UPM, rigid molded plastic pistons are fitted at each pump rod connection. Both these pumps retain conventional piston valves, however. There is a need for further research into 'dynamic' sealing techniques, either retaining the conventional valve or going one stage further to eliminate not only the flexible sliding seal but also the valve itself, making a 'diodic' piston. Such designs are likely to be especially applicable to direct action pumps, where piston speeds are greater and there is direct 'feedback' between the piston and the pump user.

5.3 CYLINDERS, PISTONS, FOOTVALVES AND SEALS

COMPONENT	ACTIVITY	PRIORITY
5.30 Complete molded piston and footvalve design.	Investigate alternative materials and methods of assembly of molded pistons and footvalves; investigate potential application to other pumps including the Mark II and direct action pumps.	A
	Identify sources of supply of SS tube for plastic cylinder liner; investigate required standard of internal finish and finishing techniques.	A
5.31 Investigate seals, cylinders and valves.	Further investigate seal and cylinder types, comparing cup seals, U-seals in leather, rubber, polyurethane, etc., cross-referencing seal type with cylinder material and surface finish.	A
	Investigate valve behavior and its effect on the pump system, and produce design guidelines for valve type, size, lift and timing.	A/B
5.32 Improve design of elastic pumping elements	Investigate design and manufacture of elastic pumping elements, as used in the Vergnet, to lower cost and improve reliability. Field test prototypes.	A
5.33 Investigate seal-less pistons.	Review existing seal-less pistons in handpumps and other engineering fields; lab and field test prototypes.	B
	Review existing 'diode' pistons in other fields of engineering; design and manufacture prototypes; assess in laboratory and field tests.	B
	Review, assess and further develop methods of protecting the cylinder against sand contamination.	C

Current R&D activities: Lund University is working on seal design and the University of Malaysia on valve hydraulics.

Current funding sources: SIDA (Sweden), IDRC (Canada), UNDP/World Bank

Related topics: 5.4 Direct action pumps

5.4 DIRECT ACTION PUMPS

Objective: To develop better designs for direct action pumps.

Direct action pumps have the potential to provide an appropriate means of community water supply from relatively shallow lifts of up to 15 meters. Because they are inherently simple, they should be cheap, easy to manufacture and especially suitable for village-level maintenance. The Tara pump has been successful for extended family use in Bangladesh -- its country of origin -- but has proved to be insufficiently strong for community use in Africa.

Direct action pumps depend on lightweight, high-displacement pump rods to distribute the operating effort between the upstroke and downstroke, to make the pump easy for people to use. In practice, this means a sealed, tubular pump rod, lighter than water and of a diameter which is about 80 per cent that of the rising main. Plastics, which are light in weight, corrosion resistant and widely available as extruded pipes, are an attractive choice for this application. However, lack of stiffness on the downstroke tends to produce buckling and wear between the pump rod and the inside of the rising main.

Because piston speeds are inherently high in direct action pumps, the level of performance required of the piston seal is less than that for a lever-arm pump. However, wear at the guide bush can be high.

5.4 DIRECT ACTION PUMPS

COMPONENT	ACTIVITY	PRIORITY
5.40 Resolve outstanding design issues for direct action pumps for community use.	Adapt molded polymer pistons and footvalves to a direct action derivative.	A
	Review results of current work on lightweight pump rods and produce design guidelines for pump rods for direct action pumps.	A/B
	Investigate pumpstand guide bush and T-handle designs of existing pumps; develop improved bush/handle designs; assess in laboratory and field test.	B
	Investigate methods of pump rod connection and centralizing; develop improved connector and centralizer designs; assess in laboratory and field tests.	B
5.41 Design new footvalve for Tara.	Develop an easy-to-extract footvalve for the Tara pump.	B

Current R&D activities: Work on lightweight pump rods by CRL and various manufacturers, particularly Wavin and Vammala; large scale testing of the Tara production design.

Current funding source:

Related topics:
5.3 Cylinders, pistons, footvalves and seals
5.8 Pump rods

5.5 CORROSION

Objective: To identify practical methods to measure the corrosion potential of groundwater and match material selection.

Corrosion of the below-ground parts of the pump is the single greatest cause of failure of handpumps in many areas. However, more work is needed to understand the relative contributions of the various factors of water quality to corrosion of the pump. An "index of corrosivity," allied to simple on-the-spot measuring techniques, is required. The resulting value of the index for a particular application would determine which materials could and could not be used.

In aggressive waters, galvanizing has proved to be an inadequate means of protection for steel pipes. Protection of the outer surface is particularly important, and there may be scope for alternatives to galvanizing, such as electroplating, plastics and rubber coatings.

Cathodic protection -- providing sacrificial material to act as the focus for corrosion and thereby protect the primary components -- is widely used to combat corrosion in other fields such as marine engineering.

Hybrid solutions are already in use experimentally in West Africa. Corrosion-resistant pipes of plastic or stainless steel are used for that part of the rising main immersed below the water level, with galvanized steel for the remainder.

5.5 CORROSION

COMPONENT	ACTIVITY	PRIORITY
5.50 Develop practical corrosivity index.	Review chemical processes causing corrosion and select simple on-the-spot techniques for measuring the important determinants of corrosion.	B
	Devise an index of corrosivity, relating index values to the selection of materials for handpumps.	B
5.51 Investigate effectiveness of corrosion resistent materials and cathodic protection.	Review current experiments with hybrid GI/stainless and GI/plastic rising mains.	B
	Investigate alternatives to galvanizing for steel pipes, including electroplating and coating with plastics or rubber; assess potential solutions in the field.	B
	Investigate use of cathodic protection for handpumps and test in the field.	C

Current R&D activities: Extensive field research in West Africa.

Current funding source: GTZ/KfW, SDC, UNDP/World Bank (INT/81/026)

Related topics:
5.1 Plastic rising mains
5.2 Polymer bearings
5.7 Pumpstands

5.6 LABORATORY PROCEDURES FOR HANDPUMP TESTING

Objective: To improve the established procedures for handpump testing in the Laboratory.

Handpump testing at the Consumer Research Laboratory has now been under way for about eight years. The original test program was based on the best advice available in 1978, and much has been learned at CRL and other labs since then. The test procedures have been updated in the interim, but against the background of maintaining comparability with earlier tests.

There is a case for changing some of the procedures to reflect current knowledge of the conditions of service of handpumps, and to acknowledge maintenance as the predominant factor in successful handpump operation. In particular:

- A smooth, uniform mode of operation in the endurance test reflects neither the short, sharp actions typical of many users, nor the lateral forces that people tend to apply.

- Testing at 45 meters depth does not reflect that most handpumps are called upon to work from considerably shallower depths.

- Testing at 15 meters depth for both deep-well and direct action pumps would provide a direct comparison.

- The endurance test, based on the number of hours of operation, does not reflect different amounts of work carried out in that time by pumps with different rates of output.

5.6 LABORATORY PROCEDURES FOR HANDPUMP TESTING

COMPONENT	ACTIVITY	PRIORITY
5.60 Develop improved procedures for laboratory testing.	Devise and assess potential improvements to the present procedures for performance and endurance testing of handpumps, e.g. operation at shorter, faster strokes and work concentrated at shallow depths.	C
	Devise better methods of assessment of maintenance and manufacturing requirements.	C

Current R&D activities: The following organizations are currently undertaking lab testing of handpumps, including intensive component testing and system endurance testing: CRL, University of Malaysia, CAAMS (two labs in China), Lund University of Technology, and Interaction Design. Most manufacturers also have test facilities.

Current funding source: GTZ, UNDP/World Bank (INT/81/026)

5.7 PUMPSTANDS

Objective: To develop design and manufacturing standards for pumpstands to ensure satisfactory performance and ease of maintenance, and to encourage interchangeability.

There are many different styles of pumpstands in current use, few of which are interchangeable. The scope of differences in methods of mounting, materials and processes used in manufacture, handle height and movement, operating force, spout configuration, etc., is very broad.

Some design differences -- such as the method of mounting at the wellhead -- could be readily overcome by specifying global standards. Others -- such as handle type and movement -- are more deeply-rooted in the overall design of pumps, and require research and development to establish optimum configurations.

5.7 PUMPSTANDS

COMPONENT	ACTIVITY	PRIORITY
5.70 Formulate handpump standards, especially mounting standards.	Formulate standards for pumphead and pumpstand mountings to promote interchangeability.	A
	Review the potential application of ISO standards for handpump materials, dimensions, manufacturing processes and quality control procedures.	C
5.71 Review and analyze basic handpump design factors.	Analyze pump system geometry to evaluate the concept of uniform cylinder size and variable mechanical advantage.	B
	Investigate ergonomic aspects of pumpstand design, including operating force versus pump discharge, T-bar versus straight handle, rotary versus lever arm, height and configuration of spout.	B

Current R&D activities: None known.

Current funding source:

Related topics:
5.2 Polymer bearings
5.4 Direct action pumps
5.5 Corrosion

5.8 PUMP RODS

Objective: To develop designs for pump rods with couplings which are easy to assemble and dismantle, ideally without tools, and which can be manufactured economically in developing countries.

Pump rod couplings which are easy to assemble and dismantle make a very important contribution to ease of below-ground maintenance. The ideal design would need no tools, would have no loose parts which might fall into the well, would incorporate a pump rod centralizer and could be manufactured at a reasonable cost in a developing country.

To date, this has proved to be a very difficult design brief, but the experience with experimental hook-and-eye joints in the Afridev pump has demonstrated their superiority to conventional threaded joints for ease of maintenance. However, the hook-and-eye design proved to be unsuitable for volume production. Hook-and-eye joints in the Volanta have also been unsuccessful at depths beyond 30 meters.

5.8 PUMP RODS

COMPONENT	ACTIVITY	PRIORITY
5.80 Develop easy connect couplings.	Review ongoing assessment of forces in below-ground assemblies to establish design requirements for pump rods and couplings.	A
	Devise schemes for pump rods with easy connect/easy disconnect couplings; manufacture prototypes for laboratory and field testing.	A
	Prepare design and manufacturing standards.	C

Current R&D activities: CRL work on high displacement rods. Manufacturers also involved in various aspects of rod design.

Current funding source:

Related topics: 5.1 Plastic rising mains
5.4 Direct action pumps

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