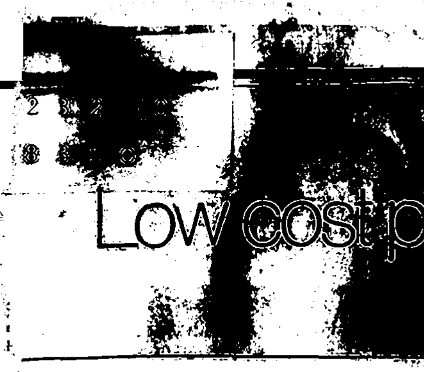

Low cost pumps for the Third World

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INTRODUCTION

THIS ARTICLE is confined to two principal types of mechanical pump; the positive displacement, reciprocating pump and the rotating impeller pump.

The reciprocating pump is known to have been in use in Roman times and although its origin is obscure, it is sometimes attributed to Ctesibius, about 275 BC[1]. For many centuries reciprocating pumps were usually operated by hand and sometimes by wind or animal power. When thermal power came into use in the 18th century its first application was to pumping, but still to reciprocating pumps, although now very much larger than hand operated pumps. The rotating, impeller type of pump followed the progressive development of rotating mechanical prime movers. The connection of a rotating prime mover to a rotating pump with or without speed ratios was simpler and more efficient than transmissions for reciprocating movements.

The basic need to lift water is no different in the Third World from the First or Second Worlds. There are, however, differences in the nature of the demands to be satisfied, in operating conditions and above all in the resources available for providing power and meeting costs. This does not imply that there is no demand in developing countries for plant and machinery just as complex and sophisticated as in the Western World. There is a need, but it is generally limited to a few enterprises such as major water supply undertakings for urban communities, or large scale irrigation projects for plantation agriculture. In most developing countries the majority of the population is still in the low-income bracket, living in a rural environment with scarce technical, physical and financial resources and their demands are for simple, robust, low-cost water supply machinery and equipment which is easily maintained from locally available resources and can be operated by semi-skilled or unskilled people.

TABLE 1: Domestic Water Use in Developing Countries

Type of Supply	Litres per Person per Day
Collection from wells, streams or other natural sources	1.5–25
Public standpipe	10–50
Household with single tap	15–90
Multiple tap household	30–300

Water Needs

Although the climates in developing countries are generally much hotter than in the Western World and one might therefore expect water needs to be correspondingly greater, these needs are usually much lower, because 80 or 90 per cent of the population live under rural conditions. **Tables 1** and **2** illustrate this.

TABLE 2: Domestic Water Use in Britain

Type of Supply	Litres per Person per Day
Rural areas	150
Urban areas – all properties	183
Urban areas – high standard housing	230

There are, however, high standard housing areas in all developing countries, where domestic consumption is much greater than in Britain and may amount to 300–400 litres per person per day, but these are not typical of the Third World as a whole.

Referring to **Table 1** it will be seen that there is a correlation between the availability of water in the household and the quantity used. If water has to be carried 1 000 metres or more and uphill, the daily per capita consumption is usually 15–20 litres. In Bangladesh, which is flat and has abundant supplies of shallow groundwater, the daily consumption in rural areas is 45 litres per head.[4]

In regions where animals are a significant feature of the agricultural economy, the water needs of livestock may take precedence over the needs for human domestic requirements. As with human beings, consumption rates are very variable and depend upon climate and location, but **Table 3** will serve as a guide to rates of consumption by animals in warm climates.

TABLE 3: Livestock Water Requirements in Warmer Climates

Type of Supply	Litres per Head per Day
Cattle	20–60
Horses, mules, donkeys	20–45
Sheep, goats	1–7.5

In arid and semi-arid regions where water is used for irrigated agriculture, the agricultural requirements generally dominate the use and allocation of water resources, because they are so much greater. For example, to raise a crop on a hectare of land in a growing season of six months would require from 15 000–18 000 m^3 of water, which would be enough to provide a domestic water supply for a rural population of between 1 000 and 2 000 people for the same period.

Pumping Requirements for Rural Communities

In urban and high standard housing areas consumers can usually afford to pay whatever is needed to ensure their water supplies. Installations are planned and designed for maximum convenience and efficiency and investment and operating costs can be recovered through a water tariff system. In rural areas the financial considerations are a very severe constraint and technical simplicity and low cost are essential.

As with any other water supply system, water may be obtained from surface sources or from groundwater. In low-economy rural situations, surface water sources are less expensive to develop and maintain, although they may involve health hazards because satisfactory treatment systems are too costly or too difficult to manage under rural condi-

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tions. Groundwater sources generally have an advantage in that they require little or no treatment, but raising deep groundwater can be expensive; they may have to be used where no other sources exist. Many examples of the use of deep groundwater for rural water supplies can be found throughout the Sahel belt of Africa and these supplies need to be heavily subsidized by governments.

In considering pumps for the Third World the following essential requirements need to be met:

Equipment must be durable and hard-wearing.
The system must be socially acceptable.
It must be cheap to operate.
It must be easy to maintain.
It must have a reliable back-up and repair service.
Capital cost must be low.

Generally speaking, a soundly engineered machine will give long and useful service when used for the purpose and functions for which it is designed, and will fail quickly under abuse. Pumps are no exception to this pattern.

Hand Pumps

The type of hand pump manufactured in Europe and the United States to designs which were evolved at the end of the last century and in the early years of the present one, is a good example of a piece of equipment designed for one set of conditions and failing under different conditions. Those who were first involved in exporting hand pumps from the industrial countries did not fully appreciate the difference in operating conditions between a one-family installation in a temperature climate, working for less than an hour a day and a village pump in the tropics which is used continuously for six or seven hours each day.

A first requirement therefore, for hand pumps in the Third World, is that they must be durable and hard-wearing and it is surprising how little attention, with one or two notable exceptions, has been given to this by pump manufacturers. The exceptions are two or three products with pump stands and fittings so massive that they are virtually unbreakable. Unfortunately, these are now also so costly to manufacture that they tend to be too expensive for rural development programmes.

The question of social acceptability is a matter of importance to rural communities, which tend to be conservative and find it difficult to accommodate to change unless there are very obvious benefits. In most rural communities the women are the traditional collectors of water, so that if a new pump can be operated by the women, its introduction presents no serious problem. However, there have been cases in some parts of West Africa where the introduction of a hand pump has created problems. This has occurred in societies where, although women are the traditional collectors of water, machinery must be operated by men. The hand pump therefore presented a serious dilemma, the resolution of which in some cases was the destruction of the pump and the return to the traditional method of collecting water from a polluted surface source.

As the hand pump is a do-it-yourself piece of equipment, it costs nothing to run and as long as its working parts are sound, it is almost maintenance-free. But all pumps need some maintenance and this can produce severe problems in remote areas where suitable equipment is not readily available. In most developing countries where hand pumps are installed, a surprisingly large proportion of pumps are out of order at any one time. In India, some years ago, this reached alarming proportions. It has been reported quite recently that in the Chittagong Hill area of Bangladesh, 60 per cent of all the deep well hand pumps are out of order at any one time, mainly awaiting maintenance crews to install simple spares such as cup seals.[5]

Low cost is another essential requirement for hand pumps, for two reasons. Firstly, since one pump can only serve a small number of people, large numbers of pumps are required in any community development programme. Secondly, because rural communities are not wealthy, water supply developments normally have to be subsidized.

Choice of Hand Pump

Until comparatively recently there was little guidance available on the suitability of various types of hand pump which were being manufactured in different parts of the world; at the same time there was a growing concern over the failure of hand pumps. The first organization to give serious attention to this matter was USAID who in 1966 commissioned the Battelle Columbus Laboratories to develop a reliable hand pump for developing countries. This led to the evolution of the Battelle pump, which was then field-tested in different parts of the world.

In 1976, when the writer was seconded to the Ethiopian Water Development Authority under ODA technical assistance, he was called upon to advise on the choice of a suitable hand pump for use in Ethiopia. As little information was available on the comparative performance of manufactured hand pumps, he submitted a proposal to ODA for a testing programme in which a number of different types of hand pump would be installed in rural community areas and their operating performance monitored. This proposal was not accepted, but about a year later ODA commissioned the Consumers' Association to carry out a similar programme, on a selection of hand pumps, at their testing laboratory in the UK.[6] The valuable work which had been started for ODA has since been expanded for the World Bank under the Rural Water Supply Hand Pumps Project, testing two more batches of hand pumps from different parts of the world.[7]

Table 4 summarizes some basic information on the wide range of hand pumps which is available. Much of the information on this table has been obtained from the reports on the various hand pump testing programmes, together with additional information supplied by manufacturers about their own products. This table does not attempt to draw comparisons, beyond giving an idea of the enormous range in the cost of hand pumps which apparently fulfil much the same functions. In fact, the very wide variations of cost are related firstly to the country of origin and secondly to the durability of the equipment.

As none of the currently available hand pumps meets all the requirements for a rapidly expanded programme for water supplies in the Third World, which is the main objective of the present Water Decade, a World Bank/United Nations panel is encouraging manufacturers of hand pumps throughout the world to make fundamental changes to their existing designs, in order to produce the VLOM (village level operation and maintenance) pump. If village level maintenance could be achieved, this would largely eliminate the very high cost of routine maintenance and repairs. It has been said that the prize for the successful development for such a pump design could be a market for as many as 20 million such pumps by the end of the century.[8]

Output of Hand Pumps

The output of a hand pump depends primarily on the power capacity of its human operator. It is generally accepted that the average adult human being can develop between 60 and 75 watts, working continuously for a prolonged period. For short bursts of energy the power developed may be ten times as much as this, but when it is remembered that it is mainly women and children who fetch water in the Third World, an average figure of 60 watts is probably rather more than actual performance. It should then be remembered that hand

TABLE 4: SOME DATA ON HAND PUMPS

Brand or Manufacturer	Model	Country of Origin	Weight of Pump-stand and Cylinder kg	Ex-Factory Unit Cost £	Notes
I. SHALLOW WELL – FREE DISCHARGE					
UNICEF	New No 6	Bangladesh	31	13	1
UNICEF	Bandung	Indonesia	26	35	1
IDRC Ethiopia	Type BP	Ethiopia	11	49	1
Blair	90 mm	Zimbabwe	?	85	2
Bumi	–	Zimbabwe	72	138	3
II. DEEP WELL – FREE DISCHARGE					
AID/Battelle	–	Indonesia	45	78	1
Dempster	23F (CS)	USA	?	92	4
India	Mk II	India	?	105	4
Consallen	LD4	UK	?	116	3
Vammalan Konepaja Oy	Nita AF-76	Finland	34	214	1
Kangaroo	M1	Holland	?	217	3
GSW (Beatty)	1205	Canada	?	263	4
Kangaroo	M2	Holland	?	289	3
Monarch	P3	Canada	?	403	4
Atlas Copco	Kenya	Kenya	74	433	1
Abi	Type M	Ivory Coast	?	577	4
Briau SA	Nepta	France	57	589	1
Vereinigte Edel-Stahlwerke	A18	Austria	105	832	1
III. DEEP WELL – DELIVERY LIFT					
Sea Commercial Co	Jetmatic	Philippines	19	25	1
Kawamoto	Dragon No 2(D)	Japan	24	119	1
Saha Kolkarn	Korat 608A-1	Thailand	53	191	1
Robbins & Myers	Moyno IV 2.6	USA	64	415	1
Mono	ES 30	UK	?	597	4
Climax	–	UK	?	1177	4
Godwin	W1H51	UK	?	1394	4
Duba Tropic	Type II	Belgium	?	1542	3
IV. DIAPHRAGM TYPE					
Patay	DD 120 B	UK	15	86	3
Petropump	Type 95	Sweden	?	357	4
Vergnet	Hydropompe Type 4C2	France	?	536	4

NOTES:
1. Data from UNDP/Global Interregional Project GLO 79/010, Report No 1 March 1982, published by the World Bank, with costs adjusted to October 1982.
2. Information from 'A Simple Low-Cost Water Pump for Shallow Wells' by Peter Morgan, Appropriate Technology, Vol 3, No 3, December 1981.
3. Costs obtained from recent quotations, adjusted if necessary to October 1982.
4. Data from Consumers Association (UK) Report of October 1980, with costs adjusted from 1977 to October 1982.

pumps are not always highly efficient, either mechanically or hydraulically and their overall efficiency may be only 50–60 per cent. The human being is therefore not a very powerful source of energy and if labour has to be hired for pumping, human energy can be very much more expensive than other forms.

Animal Power

In Egypt, in a number of countries in the Middle East and in the Indian subcontinent, draught animals are used for raising water. The power output of an animal is usually taken as about 600 watts per thousand kg of its weight. A heavy horse or bullock weighing about 1 000 kg therefore produces ten times as much power as a human being. Animal power is usually associated with machines such as water wheels, which can be operated by an animal moving slowly and continuously on a circular track. This source of power is not easily adapted to reciprocating pumps or to modern high speed rotating impeller pumps.

Engine-Driven Pumps

Modern engine-driven pumps are usually rotating machines of one kind or another, driven by combustion engines or electric motors. They are made in all sizes and to almost any desired specification in terms of discharge and pumping head. They are generally reliable, durable, efficient and economical to run. They are found all over the world, including all developing countries, wherever mechanical power can be used.

In view of their excellent performance when properly looked after and maintained, one may wonder why we consider any other than engine-driven pumps. There are several reasons. In the first place, machinery which gives trouble-free service in industrialized societies, where repair and maintenance services are readily available in the event of breakdowns, does not always perform quite so well in the Third World. The rigours of tropical weather, dust, ingenious but often untrained and illiterate operators and the absence of satisfactory repair and maintenance facilities all ensure a shortened working life for all but the toughest of machinery, so that any advantages which may be gained from relatively cheap running costs are quickly offset by the heavy expense of premature replacement.

A second reason for not being able to use mechanically driven pumping machinery is the difficulty of organizing a water supply scheme, sharing the capital cost, managing the implementation of the scheme and administering its operation, in a rural community. All these tasks present formidable problems and it may well be more feasible to install a hand-operated system which each consumer works.

A third reason for not always being able to use mechanically-driven pumps is financial. For 260 million people in the least developed countries in the world, even the cost of operating and maintaining a small engine-driven pumping installation is beyond their means.

Water and Wind Energy

In recent years there has been great interest in returning to some of the more direct forms of natural energy. Where water is flowing in rivers and streams, the water itself can be used to raise water. The traditional water wheel, which is still used in the Far East, is an example of this. There is current research in developing run-of-river power and some interesting trials with a prototype system are being carried out under the auspices of the Intermediate Technology Development Group on the River Nile at Juba.

The hydraulic ram, which was popular in Europe and the United States 40 or 50 years ago, is still a useful and effective water lifting machine in hilly country with fairly plentiful supplies of flowing water.

Before the era of cheap oil fuels and the widespread use of the combustion engine, wind-pumps were a common feature in rural areas all over the world. Today there is active interest in returning to the use of wind energy as a source of power and many countries, including Britain, have wind energy research and development programmes. In some respects wind pumps are very appropriate for the Third World, because running costs are almost nil and there are many situations, particularly in coastal areas and on islands, where the wind blows for most of the time.

The capital cost of a wind-pump installation is generally rather greater than that of a combustion engine or electrically driven installation of equivalent capacity, but when total costs are compared, taking into account running costs and the shorter working life of mechanical power units, the wind-pump is the more economical.

There are sometimes misconceptions about the power capacity of a wind-machine. Some years ago, quite a large wind-pump with a 20 ft diameter wind wheel was constructed at a borehole water point in Ethiopia, to replace a 30 hp diesel-electric pumping installation serving about 5 000 people. Under the prevailing wind conditions, which had not adequately been investigated, the wind-machine produced an average of about 7 hp and the water supply was very much worse than it had been under the diesel-electric power. This innovation resulted in very severe complaints from the local community.

Another point to be considered with wind-pumps for domestic water supplies is the need to provide adequate storage for periods when there is no wind; the cost of providing this storage may be high if several days of storage are needed.

A hazard which wind-machines face rather more in the tropics than in temperate climates is the more frequent incidence of the extreme winds of tropical storms and tornadoes. Most wind-machines which are available commercially are provided with automatic safeguards which turn the vanes out of the wind as it produces overload conditions, but this may not be sufficient to protect the structure in very high winds.

Solar Energy

For many decades attempts have been made in various ways to harness solar energy, but it is only recently, with the development of the photo-voltaic cell, that solar energy for pumping water has become a practical proposition.

The main advantage of solar energy for pumping in the tropics is that it is the only energy resource that is readily available where it is needed and in the case of pumping for irrigation, the available energy is greatest during the times of day when it is most needed. The main disadvantage at the present time is that it is a technology which is still under research and development and the hardware for even small units, up to 500 watts capacity, is very expensive and may be in the region of £10 per watt.

In 1979 the World Bank engaged consultants (Sir William Halcrow and Partners in association with the Intermediate Technology Development Group) to evaluate the use of solar energy for small-scale irrigation pumping systems. Twelve solar pumping systems were monitored in three countries (Mali, the Philippines and the Sudan) together with laboratory tests on equipment. of the 12 systems tested, 11 were photo-voltaic (PV). In the PV system, silicon solar cells, usually 100 mm in diameter, are connected in groups known as modules, several modules being mounted in a panel called an array. The modules may be connected in series or parallel according to the load requirements. For small-scale pumping, the power collected is usually used to drive a small centrifugal pump.

This research programme has already led to the conclusion that solar pumping systems are feasible for small-scale irrigation.[9] The consultants have subsequently extended their studies to cover rural water supplies, as well as irrigation and the requirements which need to be satisfied to make these systems cost-effective. Their report to the World Bank on these studies was due in January 1983. Small solar pumps are currently being used successfully by Oxfam for pumping water from shallow wells to supply refugee settlements in North West Somalia and these are generally reported to be giving trouble-free performance.

Although solar pumping systems consist of highly sophisticated technology, the equipment produced for practical use is robust. The systems require little operational attendance beyond keeping the arrays clean and the pumps free from sediment. On the other hand, if there is an electrical failure, it would be quite beyond the means of local resources in most developing countries to trace and cure the fault; servicing and repairs could be very costly indeed.

CONCLUSION

All over the world there is a lively interest in developing and improving pumping systems to meet the needs of the many millions of people in rural and semi-urban communities in developing countries. In many cases conventional mechanically-powered pumps are the right solution, provided that adequate servicing and back up facilities are readily available. In many other cases with the rise of oil prices, mechanical pumps are not feasible and current research and development programmes are being directed towards finding solutions using other, not quite so conventional, energy sources such as the wind and the sun.

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