PROGRESS REPORT

EVALUATION OF SIMPLE AND INEXPENSIVE PUMPS FOR COMMUNITY WATER SUPPLY SYSTEMS

Submitted to

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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 d sign, 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.

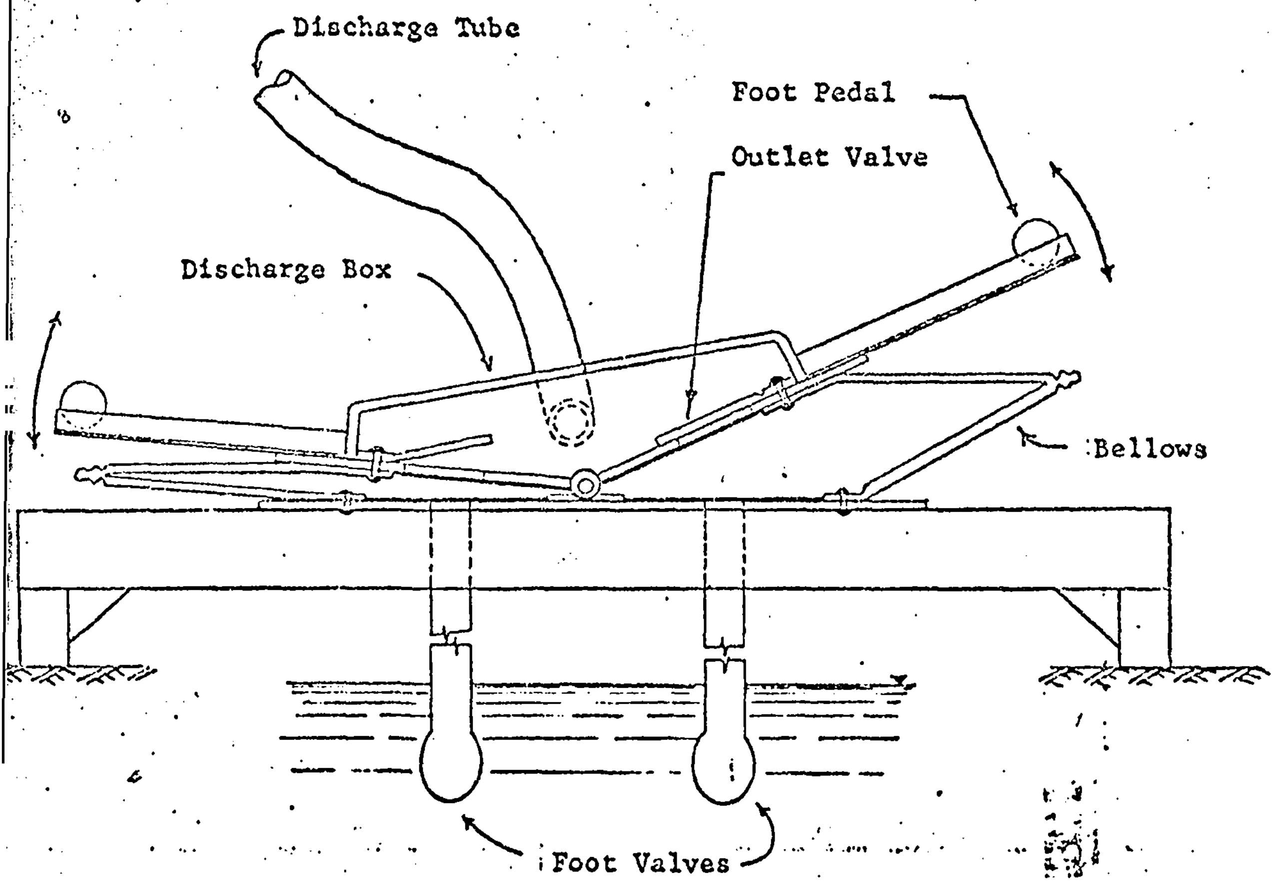

Fig. 1 - Manually Operated Foot Pump for Rural Community Water Supply

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.

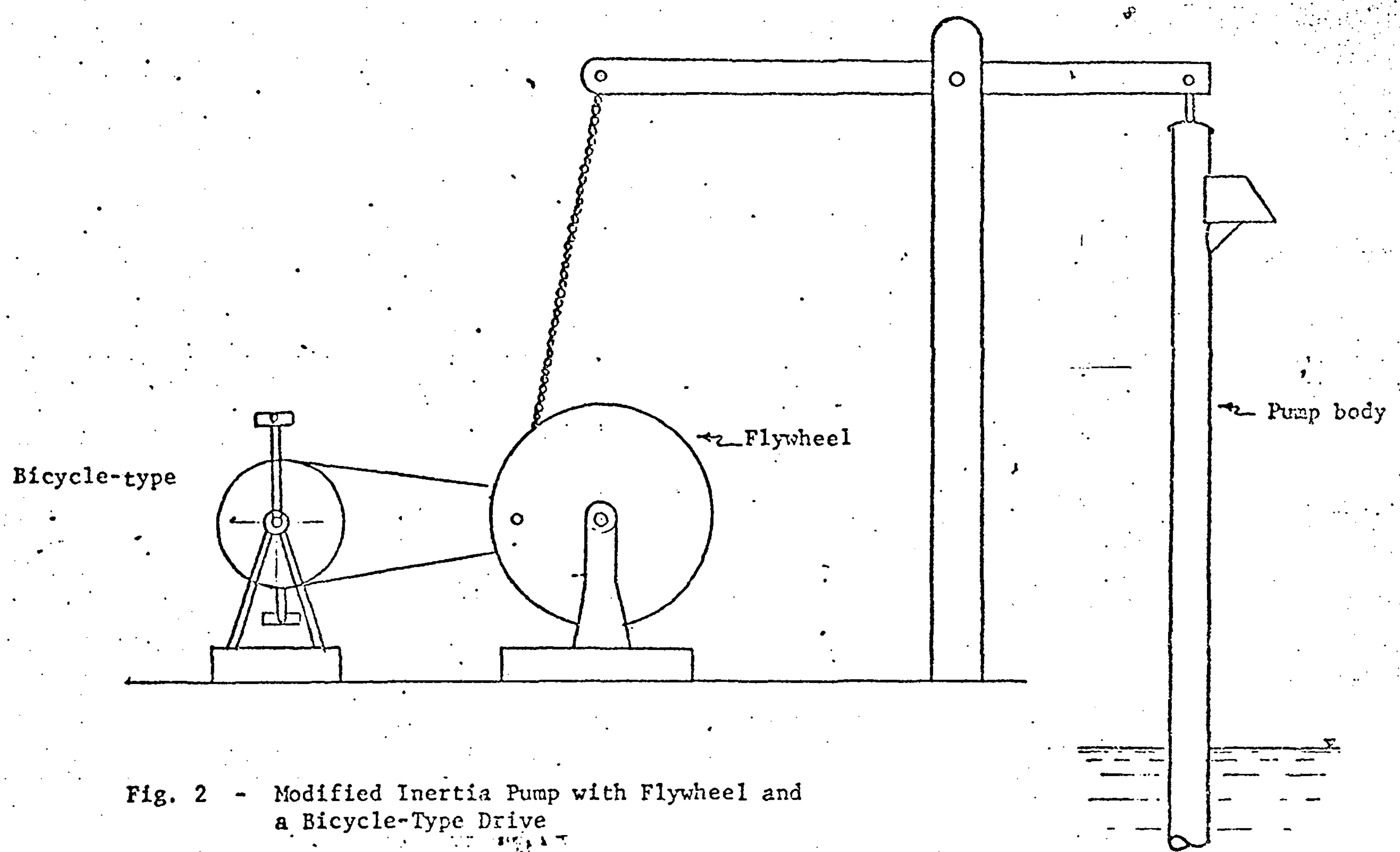

Fig. 2 - Modified Inertia Pump with Flywheel and a Bicycle-Type Drive

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