A VLOM Handpump for 80 Metres

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Abstract

VLOM handpump technology for borehole depths of 45 metres and greater remains a problem in the industry. Most currently available handpumps on the market for these depths are complicated or heavy, requiring specialist tools or knowledge, or lifting gear, to maintain. Lightweight options tend not to be robust enough to withstand the loads at these depths, and so are unreliable, or are prohibitively expensive.

This paper presents a new VLOM handpump arrangement comprised of components from the Afridev and India MkII handpumps and incorporating the Bottom Support System. The resulting ("Oxfam") pump has been successfully installed in Ethiopia to 70 metres and operated continuously for 6 months without problems.

Introduction

It is well accepted that handpumps designed for use in remote locations in developing countries should satisfy the VLOM (Village Level Operation and Maintenance) criteria if the pump is to be sustainable. In general terms the sustainability of a pump depends on (a) ease of use and maintenance, (b) durability (including corrosion resistance) and (c) the cost and availability of spare parts. However, at present there are no clear guidelines which quantify these factors, so there tends to be debate amongst pump designers, manufacturers and users as to how 'VLOM' certain pumps are.

The two former factors (the 'technical' aspects) tend to be less critical for shallow (less than 30 metres) installations. The loads on the pump are low, allowing the use of lightweight and corrosion resistant plastics such as uPVC and HDPE, and mechanisms can be kept simple and relatively inexpensive.

In deeper installations, however, the technical challenges are generally greater. As the loads on the pump increase, the use of stronger, heavier, (and more expensive) materials becomes necessary. This in turn often leads to the need for heavy lifting gear (tripods, chain blocks, pulleys etc) for maintenance, as well as more complicated mechanisms in the pump design. Capital costs, and cost of spare parts all increase, adversely affecting sustainability.

At present there are several alternative VLOM pumps for shallow installations, however there are very few available for installations deeper than 45 metres. The added difficulty of spare parts distribution and government restrictions on allowable pump types also means that introducing new pumps on to the market is very difficult. This paper presents a new pump arrangement which addresses most or all of these difficulties.

Background

In 1995 Community Aid Abroad Oxfam Australia began working with an Ethiopian partner organisation, OSHO (Oromo Self Help Organisation) on a small drilling program near the Zewai and Dugda Lakes, in Central-Southern Ethiopia. The program aimed to drill 24 boreholes between 30 metres and 80 metres deep and install handpumps to give communities access to potable water.

Both OSHO and the beneficiary communities were adamant that the pumps used in the project be corrosion resistant and VLOM. For the shallower boreholes (up to about 45 metres) the Afridev pump was selected as it was in widespread use in Ethiopia, and is considered to be a VLOM pump. For deeper installations however there were no handpumps available which fitted these criteria and were still within the project budget.

The pump finally chosen for the deeper installations was a hybrid pump comprised of components from the India MkII, the Afridev and incorporating the bottom support system.

This arrangement is known as the Oxfam Pump.

Oxfam Pump Arrangement

The Oxfam Pump is a hybrid of components of existing pumps that were proven, readily available and inexpensive. The Afridev[1] Pump and risers with the strengthened plunger valve (adopted from the UNICEF 50OTC cylinder arrangement) met the OSHO requirements for a non-corrosive, readily maintained unit, and the India MkII pedestal and pump rods were designed for and were in wide use to 100 metres. The bottom support system allowed the Afridev PVC riser pipes to be used to 80 metres by eliminating riser tension and stretch (see below).

The arrangement evolved to a certain extent out of circumstances, rather than being a purpose designed pump. It is therefore considered a foundation from which the arrangement can further evolve rather than being a finished design.

Table 1 outlines the components in the pump, their origin and the reasons why they are used.

Table 1 – Outline of Oxfam Pump Components

Component	**Origin**	**Reasons for inclusion**
Pedestal Assembly	India Type	• The bearings are fully sealed ball bearings, strong enough to withstand the loads imposed in boreholes of up to 100m deep. • The mechanical advantage is 7:1 compared to 5:1 with the Afridev • The handle has the capability of having counterweights, which facilitates pumping at great depths • The connection to the rods is suitable for 12mm rods (see below) • It has the possibility of incorporating a pressure adaptor which allows for pressure pumping to a header tank or through a pipe system to an irrigation system (when sufficient water is available)
Plunger Rods	India Type	• Rod diameter 12mm (c/f 10mm Afridev rods), therefore stronger and less stretch (but greater effort required to operate due to heavier rods). • Screwed together arrangement stronger than Afridev hook and eye arrangement
Plunger Valve	India Type	• The brass plunger valve is UNICEF design and is much more robust than the standard Afridev type. • The rubber seal is much stronger than the U-seal of the Afridev, necessary for greater depths.
Footvalve	Afridev	• Proven and adequately robust for up to 80 metres. • Unlike India MkII design, allows for removal of foot and plunger valves without removing entire rising main column.
Cylinder	Afridev	• Compatible with footvalve and riser pipes. • Adequate strength
Rising Main	Afridev	• UPVC therefore light and corrosion resistant • In common use in many countries • Less expensive than GWI pipe.
Couplers	Under development	Standard Afridev method of joining riser pipes employed, however work is continuing on this aspect of the pump.
Support Pipe	New Component	Designed to suit. Again, work is continuing on this component (see below)

[1] It is assumed that the reader is reasonably familiar with plunger/footvalve type handpumps including the Afridev and India MkII handpumps.

Bottom Support System (BSS)

The concept behind the BSS is simple. Instead of hanging the (PVC) rising main column from the pump pedestal arrangement, the column sits on the base of the borehole. There are a number of advantages in this, as outlined below:

Loading

PVC is significantly stronger in compression than in tension (Perry, 1963). In a top hung PVC column the entire weight of the water, as well as the self weight of the pipe, is carried by the pipe. For example, at 70m the load in a top hung Afridev riser pipe is approximately 2.6 kN (160kg of water plus 100kg self weight) with the pump at rest; during pumping a water hammer effect is added each time the plunger valve opens which can be equal in magnitude to the static water load acting on the footvalve (Low, 1938), in this example around 1.4 kN. This gives a potential intermittent load of around 4.0 kN.

In general these columns are constructed by solvent cementing the riser pipe lengths together in the field, and so every joint becomes a potential point of weakness. In addition, boreholes are seldom straight and the snaking action during pumping can cause stress concentrations leading to failure, particularly at joints near the pump cylinder.

When the column is supported from the bottom of the borehole, the entire column is loaded in compression. Any tensile loads (caused, for example, by irregularities in the borehole) are thus compensated by the normal loading regime, rather than exacerbating it. In addition, the weight of the water is not carried by the rising main pipe, but is transferred to the borehole casing and the ground through the footvalve and bottom support pipe, so the rising main pipe merely carries its self weight.

Pipe Stretch

Being an elastic material, PVC stretches when loaded. The magnitude of stretch in a PVC pipe full of water varies directly with the static head. For example, a 70m Afridev riser pipe full of water will stretch by about 40mm. As mentioned above, the water hammer effect can almost double the stress, causing the stretch to increase by the same proportion.

The cyclical loading of a plunger/footvalve type pump means that the load is alternately taken by the footvalve and the plunger valve. When lifting water the plunger valve, and thus plunger rod column, takes the all the water load whilst just after TDC the water load plus any water hammer impinges on the footvalve. Thus, during normal operation of a top hung PVC rising main pump, the rising main is stretching and contracting like an elastic band. As well as the fatigue implications, this has the effect of reducing the efficiency of the pump.

With the BSS, however, as the load is taken alternately by the plunger rod column and the bottom support pipe (through the footvalve), the riser pipe column never carries the main loads, and so stretch is eliminated.

Results So Far

To date ten Oxfam pumps have been installed in boreholes ranging in depth from 30m to 70m. These installations are in Oromia, South-West Ethiopia, however in June 2000 five more will be installed in Laos, and further installations are planned in Mozambique in late 2000.

In general no major problems have been identified, however a number of issues have arisen as a result of the BSS. The following is a summary of these issues, and brief descriptions of how they have been addressed:

1. Strength of the Bottom of the Borehole (bottom conditions)

As the bottom of the borehole may have to support up to 4 kN, the strength of the borehole is a critical issue. In existing boreholes, if drilling records are available then these can be examined to see what sort of material the borehole ends in, otherwise an investigation is required to ensure the borehole base is strong enough to withstand these loads.

If the borehole base is weak, then it should be reinforced with concrete. The proposed method of doing this is dropping a dry-mix of concrete in a jute or hessian bag into the borehole, tamping it down and allowing it to cure in the water.

2. Silting

If fine silt is present in the borehole, then this can settle around the base of the bottom support pipe. In these circumstances the action of pumping can cause this silt to consolidate around the support pipe making removal of the support pipe (and thus rising main column) extremely difficult. The proposed method of overcoming this problem is to have a separate support pedestal (GWI or thick walled PVC) permanently placed at the bottom of the borehole onto which the bottom support pipe sits. This will allow easy removal of the pump for maintenance or inspection.

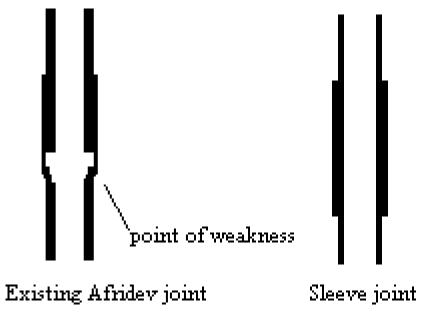
3. Length of the Bottom Support Pipe

In boreholes where the bottom of the borehole is much deeper than the cylinder position, the problem of excessively long bottom support pipes is overcome by the use of the support pedestal mentioned above. The length of this pedestal is tailored to the borehole, allowing the bottom support pipe attached to the pump to be uniform in all installations.

4. Transfer of Loads in Joints

The traditional Afridev rising main joint is a simple male-female solvent cemented joint. These joints (usually field made) rely on the shear strength of the solvent cemented joint to transfer loads from one pipe length to the next. A point of weakness is also formed at the shoulder of the female flared end (see figure 1). It has been noted that, particularly close to the cylinder (ie the deeper joints), that these joints are subject to failure. It is therefore proposed that, at least in joints below 45 - 50m (to be specified), this jointing method should be replaced by joints which allow direct transfer of the loads from pipe length to pipe length. Straight sleeve joints or (preferably) screwed joints achieve this; the latter also enabling the dismantling and removal of the column without necessitating cutting.

Figure 1. Typical Afridev type riser pipe joint.



5. Riser Pipe Installation

PVC solvent cemented joints do not reach full strength for about 24 hours. The accepted method for installing the Afridev rising main, however, is to support the column by holding the most recently attached pipe, with the rest of the column hanging below. This means that the joints are loaded almost as soon as they are made, and usually well before they have reached full strength. In shallow installations this is not generally a problem, however for deeper installations these joints can become significantly weakened, or even fail due to this early loading regime.

The installation method recommended with the Oxfam Pump (also applicable to other pump types) is to support the rising main column during installation from the bottom using the safety rope. Rope guide plates have been developed for this purpose (see figure 2).

Figure 2. Rope Guide Plates for Installation, Viewed from above riser pipe column

Conclusions & Further Work

The Oxfam Pump represents an alternative VLOM pump for boreholes in the range 45m to 80m. It has the advantage that it is comprised of components from pumps already in existence, so very little additional tooling by manufacturers or new types of spare parts are required. At the time of writing, ten units had been installed up to depths of 70 metres with no significant problems identified. By the time of publication, a further 10 to 20 units should have been installed.

The pump is still very much under development, and so suggestions for improvements and new test sites are very welcome.

Acknowledgments

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