The Zimbabwe Bush Pump
Recent research into technical methods of reducing down time, using standard down-the-hole equipment
Introduction

The history and development of the Zimbabwe Bush Pump is well recorded in numerous documents (see aquamor.info). It has been the Standard National Hand Pump option for the country since 1933 and has passed through a number of technical developments since that time.

Currently over half the estimated 50 000+ Bush Pumps placed in the rural areas within Zimbabwe are out of action. This is a combination of technical, economic and other problems faced by the country at this time. This report attempts to make suggestion which address the technical problems. Most of these technical problems are found in “down-the-hole” equipment of the pump. Standard down-the-hole equipment includes 50mm GI pipe as the rising main, a 600mm long 75mm brass cylinder with matching piston equipped with two leather seals, a heavy duty brass foot valve and mild steel 16mm pump rods.

Various other options are on trial including 63.5mm and 50mm open top cylinder models which can use either GI or high quality thick walled PVC pipe. This equipment, following international trends, allows the piston and its seals to be removed through the rising main and thus makes seal replacement much simpler since there is no need to lift the rising main to gain access to the seals, which is the current method.

This report discusses small modifications of current standard down-the-hole equipment, namely 50mm GI rising main, 75mm cylinder and heavy duty foot valve and 16mm steel pump rods. Minor refinements are made to the design or method of installation which have the potential to overcome many of the “down-the-hole” problems. The use of GI pipe has been retained partly because there is no other rising main option available which can cope with the wide range of depths which the Bush Pump operates in (3m to 100m). It is known that aggressive ground water occurs in some parts of Zimbabwe, and this can cause problems with corrosion in both the rising main and rods. But overall the problem of corrosion is not so large as to require a major shift away from the standard equipment.

Types of pump breakdowns which cause prolonged down time in the Bush Pump

Any method which can improve on problems encountered with down-the-hole equipment will clearly reduce down-time (when the pump does not deliver water) and thus increase the delivery of water to the users. This also reduces the high cost repairs and maintenance. By far the greatest number of breakdowns occur due to failure of “down-the-hole” components. According to Pump Minders interviewed by the writer in 1998 (Aquamor 1998) the main reasons for pump breakdown are as follows in this order of magnitude:

1. Worn piston seals.
2. Leaky GI pipes.
3. Leaky foot valves.
4. Silt and stones
5. Rods breaking under strain.
6. Threads breaking on pipe.
7. Loosened bolts on the Pump head

It is now important to examine each of these potential problems in detail and make suggestions for improving the situation and by doing so, reducing down time. This report confines itself to the standard configuration of the Bush Pump with 50mm NB GI rising mains, a 75mm brass cylinder and heavy duty foot valve and 16mm mild steel rods. The discussion of alternative methods using open top cylinders, has been described in other report, and is a continuing line of research.
The piston and wear of piston seals.

The piston seals are the fastest wearing part of any Bush Pump. They are also the least expensive and one of the most important parts of the pump, especially when it comes to maintenance issues. The quality of the leather seals varies considerably as delivered from the pump makers. Some seals are of good quality and can last for some years. Other seals are of such poor quality that they can break down within weeks. SEAL QUALITY is of paramount importance, especially with the non-extractable piston used in the standard “down-the-hole” equipment used with the Bush Pump. It is vital that high quality seals are used throughout, even if this component must be imported from a reliable manufacturer of high quality components.

It is known however that seal life is not only influenced by seal quality, but also by amount of usage, water quality (especially physical), smoothness of cylinder walls, depth of pumping etc. In terms of physical quality, the quality of the borehole and casing unit is also important as it has an influence on sediments in the water which will cause premature wear on the seal. In Zimbabwe, two leather seals are used on the piston to fit within the 75mm cylinder. This has been standard equipment for over 85 year. Generally leather seals which are harder tend to retain their properties longer than soft leather seals which can become distorted and change their configuration during use. The best leather is found in certain parts of the cows hide and treatment with certain oils such as Neatsfoot oil is important.

An example of a standard piston and leather seals used on the Bush Pump

Piston design

The piston design used in Zimbabwe probably originates from work carried out by the American firm Myers, who built excellent hand pumps in the early part of the 20th Century. It is interesting to note that their brass pistons were fitted with a range of leather pistons seals from one seal to four seals.

The piston and seals of pumps made by Myers
Copies of illustrations showing 1 – 3 seals from the Myers 1940 pump catalogue
A question of great importance is why Myers chose to fabricate pistons which could accept a range of between one and four piston seals. It is possible, although to the writer's knowledge, not yet proven by experiment, that a combination of 4 seals will operate for longer in a known environment than 3 seals, and 3 seals with operate for longer than 2 seals and 2 seals will operate for longer than a single seal. It is possible that the leading (uppermost seal) takes the greatest strain on the upstroke, with lower seals taking less strain. If this is the case – a question must be asked - is there a case for remodeling the existing 2 seal piston to a 3 or 4 seal piston, thus theoretically extending the life of the seals in combination? Recent contact with another American supplier, revealed that pistons with more seals are used mainly on deeper installations since a combination of more seals is better able to deal with the increased pressure at greater depth. If this is the case, then it is possible that an increase in the number of seals may also prolong the working life of the piston seals, as a combined unit. Prototypes of the Zimbabwean piston have been made which use 3 seals in combination.

The standard 75mm diameter Bush Pump piston has been slightly modified so it will accept 3 seals. These photos show a prototype. The lower brass section of the piston around which the seals and spacer rings are mounted is extended so an extra spacer ring and seal can be added.

Note also that Myers introduced a phosphor bronze spring to effect a quick return of the piston poppet valve. This has never been used on Bush Pump pistons or on Bush Pump heavy duty foot valves. But in current trials the phosphor bronze return spring has been used effectively on the foot valve, reducing the potential for leaks, as a better seal is made when the spring is fitted. Where pumps use smaller diameter cylinders (e.g. 50mm) the efficiency of the valves becomes more important, as the slip of water backwards, as the poppet closes reduces the final water output.

**Leather seals**

Standard 75mm diameter leather seals vary greatly in quality. Poor seals become soft quickly and can become misshapen on the piston and lose their properties (worn leathers on left of each photo). Well-chosen quality leather seals can last for much longer periods. The frequency of replacing worn seals increases the cost of maintenance and reduces the effect provision of water to the intended users.
Nitrile rubber seals

Nitrile rubber seals have been used on experimental 50mm and 63.5mm pistons in Zimbabwe, but not on 75mm pistons (75mm high quality nitrile rubber seals may not be commercially available). The results so far have been variable - nitrile rubber seals also vary in quality depending on the supplier. Quality 63.5mm nitrile rubber seals working within a stainless steel cylinder with highly polished internal walls were tested in Zimbabwe years ago with up to 5 – 6 years working life.

Rod to Piston connection

This is also an important connection – between 16mm rod and the piston and its seals. The photos below show this joint on a piston with 3 seals.

The rod to piston joint. The piston with 3 seals has been chosen here. In these photos a specific length of 16mm threaded rod is threaded and bonded into the piston cage. A lock nut (or rod connector) is bonded tight to the thread against the piston head. The bonding secures the thread and also prevents water invasion of the thread. The protruding male thread, cut to the appropriate length, is screwed into the female thread of the socket located at the lower end of the lowest rod. Marine Silicon Sealant is applied to the thread and the socket and the nut are tightened securely together. The sealant bonds the joint and does not allow water to enter the threading within the joint.
Problems with galvanised iron pipes used in the rising main.

50mm (2 inch) galvanised iron rising main pipes have been used on the Bush Pump since 1933. Trials with PVC, high impact PVC and high density polyethylene have also been tested in the past but with limited success. Currently trials are being repeated with thick walled high quality PVC pipes using a 50mm open top cylinder which may be serviceable down to 30 – 40m. This work shows promise. The Afridev hand pump also uses a PVC rising main, and later models of the India Mk series also use PVC. The existing depth range for galvanized pipes for the Bush pump lies within the range of 3m to 100m. No other type of well proven rising main material can cope with this full range. The main advantage of galvanized pipes lies in their strength being serviceable for the full range of requirements for the Bush Pump fleet. However they are heavy, expensive and subject to corrosion, especially in those areas where ground water is known to be aggressive. Nevertheless they have been maintained as the standard for nearly 85 years.

In terms of corrosion of the pipe, this is most apparent on those threaded parts which are exposed to water, where the galvanizing has been removed. Rust at the joints can lead to wear and leakage. Also repeated dismantling and rejoining lengths of steel pipe can further damage the pipe joints. Pipes which are poorly manufactured and have inferior welding along the seam can also fail prematurely in more aggressive water. Pipes with thinner walls will also have a reduced life span. Pipe threads should enter the connector completely leaving little of no thread exposed to the water.

A GI pipe showing corrosion of both pipe and threads.

There is also internal pipe corrosion on the entire surface of the inner pipe. This will reduce the wall thickness and strength of the pipe over time and also reveal any weak points in the long welding strip along each pipe. Pipes with thinner walls are clearly less durable. The Bush Pump specification clearly indicates a precise minimum wall thickness for the pipes. A minimum requirement for wall thickness is 3.2mm. The quality of the galvanizing can also play an important role in determining the life of the GI pipe. Currently new pipes used in the Zimbabwe program are imported from South Africa, which has its own set of standards and specifications.

Another factor is that rust can fall off the side walls of the pipe and descend into the valve gear of the piston or foot valve. This is most serious if the particles lodge between the foot valve poppet and the rubber poppet seal, which may cause leakage, which is most undesirable. Excess use of pipe sealant can also affect the efficiency of the foot valve poppet. Sealant can fall down the rising main during installation without due care. Foot valve protection is discussed later.

The most commonly used sealant for the pipe joints (if sealants are used at all) is known as “plumber’s paste.” This helps to make a more secure seal and reduces wear on the threads compared to a situation where no sealant is used. Sealants for GI pipe thread make dismantling easier with less damage being inflicted to the threads, which are generally the most vulnerable part of the rising main. Sometimes pipes are put together with cross threaded joints which leads to damage of the threads. In more recent experimental work the “plumber’s paste” sealant has been replaced by Marine Silicon Sealant. This makes an excellent seal and can waterproof threads very effectively, offering significant advantages to the most vulnerable part of the GI pipes. Marine Silicon Sealant is also used in the revised method of joining the robust 16mm pump rods (see later).
Threads breaking on GI pipe.

This can be due to abuse, to poor installation methods, corrosion and also to the pipe having to find its way through curved boreholes. These put considerable strain on the pipes and their threaded joints. Also where the pipes descend into wider diameter wells, the pipes may sway within the well chamber. Where the pipe has been removed and replaced several times the thread may have been weakened by general wear and tear on the threads. Every time the pipe is unscrewed there will be some wear at this point. The eventual breakdown will occur. Plumbers paste or sealant should always be used. Curved boreholes are not popular with hand pumps. But sadly they are not uncommon. On a curved borehole the chances of wear and breakage of the pipes and rods are considerably increased. And the pump is harder to use. Once again the weakest point will be the thread on the joint and this has been discussed above. Pipe threads should not be exposed to water, but should be held within the pipe socket. In this position, they can be protected by a good sealant such as Marine Silicon Sealant.

Leaky foot valves.

The Bush Pump uses a well-established heavy duty foot valve which can cope with considerable pressure over the full range of the Bush Pump depth requirements. However it must be manufactured strictly according to specifications, with a durable rubber insert as the poppet seat – which should remain serviceable for several years. High quality recommended foot valves should always be used. They should be inspected, cleaned and tested before use. Two types of HD foot valves have been manufactured – one with male and one with female threads through which the valve is attached to the cylinder (see references). It should be noted that in the standard 75mm cylinder configuration, the lower end cap of the cylinder also incorporates a check valve, which acts as a back up to the main foot valve.

Leakage is one of the potential problems encountered with the foot valve. If the foot valve leaks, extra work is required to gain water at the surface which causes more wear on both pump and user. For this reason the foot valve must be carefully fabricated and inspected after manufacture.

In more recent work, the problem of leakage can be improved or overcome by the addition of stainless steel screens bonded both above and below the poppet valve and also the incorporation of a phosphor bronze return spring as used in the early Myer pumps. Current experiments reveal that such a combination can greatly improve the efficiency of the foot valve. The spring also hastens the return of the poppet to its setting position and this reduces water slip. The spring also induces an improved water tight seal between poppet and seat.
The experimental heavy duty foot valve used on the Bush Pump in parts showing the phosphor bronze spring and stainless steel screens.

Pump rod corrosion and breakage

The 16mm rods are very rugged and have been retained in the current specifications. 12mm GI rods have also been tested but are weak by comparison and have been rejected. 12mm stainless steel rods have also been tested, but the samples tested had a tendency to bend when not extracted carefully. Also the thread length on these stainless steel threads was shorter than the current 16mm rods. It is true that if the rods are not adjusted carefully to the correct operational length, then an end knock will occur either at the lower or the upper end of the stroke. That is why careful installation, following the well laid out instructions is essential.

For decades the method of connected the 16mm rods has remained unchanged. However it has been clear that a change of method is required. Currently each rod is threaded at each end and two rods are connected through a steel socket or pipe connector. The joints are tightened with lock nuts. Maximum strength is attained when the thread length within the connector is the same for each rod. But this may not be the case. Also, as with the threaded pipe joints, the rod threads can be exposed to water, thus encouraging rusting and weakening threads at the most vulnerable point, especially if the water is corrosive. In practice the lock nuts can become either welded with rust to the rod or in some cases loose due in part to corrosion, which can further compromise the strength of the joint.

Corrosion of the rod can pass down inside the rod connector
This method of rod jointing has been revised in experimental pumps and tested in corrosive water for more than 2 years, and reveals that rusting of the threads and weakening of the rod joint can be considerably reduced. The photos below show the new method of joining rods. There are no lock nuts and once again Marine Silicon Sealant has been used to both protect the threads and also secure the joint – reducing the chance of unthreading. Such rod jointing deserves to be tested on a wider scale.

The method of joining rods without lock nuts and exposed threading. The threads are coated with marine silicon sealant and the two sockets tightened together. Water cannot enter the threads. This method has been on trial for 2 years in aggressive water and shows promise. A further improvement would be to use stainless steel connectors, also with Marine Silicon Sealant.
Rods breaking under strain.

This can happen when the rod is not adjusted to the correct length (either too long or too short) and an "end knock" occurs when the piston comes into contact with the upper or lower end of the cylinder. This leads to strain on the weakest point which is usually the threaded link between rod and piston.

**Silt and stones falling down the rising main**

Silt and small stones falling into working parts can jam the valves of the piston or foot valve or lead to tightness of the seals in the cylinder. The silt and other debris may have fallen through the rising main following the previous installation. When pipes are laid on the ground prior to installation, silt and sand can penetrate the ends as they lie on the ground. If the pipes are not thoroughly cleaned before installation the silt, sand and small stone chips can fall down the rising main and lead to problems. Cleanliness of all working parts is vital if the pump is to work at its best.

The original specifications of the Bush Pump did not account for the possibility of mischievous persons, (mostly children) pushing items such as stones and small coins down through the Bush Pump outlet pipe with a stick and waiting for the splash. This possibility has now been rectified by a revision of the design in which a course screen is placed within the outlet pipe to reduce or eliminate this possibility.

The course screen fitted to the water discharge pipe

**The pump head**

Of all the problems linked to maintenance, the pump head itself has the fewest maintenance requirements if properly made in the factory, correctly installed and cared for in the field. The “B” type pump head was designed to reduce the number of wearing parts, compared to earlier models and also reduce wear of the parts. But like all machines it performs best when built and installed correctly.

The two main head bolts (pivot pins) which pass through the wooden (teak) block, which acts as a lever and bearing, are made with 35mm solid steel bar with large spring washers and heavy duty nuts to hold the head bolts tight, thus reducing the chance of loosening. With the frequent vibration these bolts can endure, they may become loosened and require tightening. A special spanner has been designed to do this job and should be delivered with every pump as standard. All pump caretakers should have such a spanner.

Since the wooden bearings can last for many years, replacement is rarely necessary. Smaller nuts and bolts can also come loose and require tightening. The pump has been designed in such a way that many of the smaller bolts can become loose or even go missing and the pump head can still be made to function with local ingenuity. As with all machines that vibrate, bolt tightening is important. The pump design necessitates that the geometry of the pump is carefully followed during the manufacturing stage and according to the specifications. Manufacturers should use special jigs that ensure that the geometry is correct, so the rod descends down through the correct point within the water discharge unit (see various descriptions elsewhere on Aquamor.info).
Conclusions

It is hoped that this experimental work will be replicated by the DDF of the GOZ in a small number of test sites to establish whether the changes described have merit, especially in heavy duty sites and also sites with more aggressive water. In this case the overall aim is to improve the performance of the pump as a complete unit and thus reduce down time and provide a better service for the users. It is also hoped that when these improvements are made, they will also reduce the overall costs of maintenance, partly because seals may last longer and require changing less often and also the operating life of the pipes and rods will be lengthened thus requiring replacement less often.

Information revealed in this brief report has been obtained during the writers own experiments and also by interviews made with DDF staff over the years. Specifically a report written in 1998 where pumps minders were interviewed provided much information (see below). Sadly, many early DDF reports, which provide much more detail have been lost. But without intricate detail it is clear where the main technical problems lie. And as this report shows, there are ways to overcome several of these problems. Eventually the outcome of research can only be tested and proven by rigorous testing in field conditions.

Acknowledgements

I wish to thank many colleagues, current and former, working in several government ministries, notably the District Development Fund (DDF), Ministry of Environment Water and Climate, Ministry of Health and Child Care, International Organisations, NGO’s and manufacturers, who have played their part, over the years, in keeping our Zimbabwe Bush Pump alive. This report reveals that even after nearly 85 years, the Bush Pump is still evolving. The work describes in this report was performed privately by the writer, in support of Zimbabwe’s Rural Water Supply Program.

Peter Morgan
March 2017

References

Aquamor.info A series of manuals describing the Zimbabwe Bush Pump, its history, design, specifications, inspection and installation.