Designing the “B” type Zimbabwe Bush Pump

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Introduction

The Bush Pump has been used as the National Standard Hand Pump in Zimbabwe since 1933, when it was first designed by Tommy Murgatroyd in Plumtree in 1933. In those early years it was known as the Murgatroyd Pump.

I never had the pleasure of meeting Tommy Murgatroyd, but it was clear that in designing his masterpiece he had simplicity of design and robustness as key features. I suspect that he, like me, made a habit of looking through scrap heaps and figuring out what would be made with the bits and pieces he found.

Some of Murgatroyds pumps are still working, or at least they still were a few years ago when I had the pleasure of seeing some of his original units at work in Plumtree. I suspect they are still working almost 80 years after they were installed. Of course during a period of many decades, the “down the hole” components, that is the pipes rods, cylinders and foot valves would have been changed many times. These “down the hole” component, I suspect, were originally derived from old windmill pumps used in Southern Africa. They are robust. The brass cylinders were quite long at 600mm (some were longer) and had a three inch (75mm) internal diameter. The type of foot valve varied, but the heavy duty unit with wings on the main valve, causing it to rotate and even the wear of the rubber seat, was by far the best and is still retained as the standard.

Murgatroyd used a hard wood bearing, usually made of teak in his design and also a strong pump stand, in this case made of six inch (150mm) steel borehole casing. The teak block was cut and drilled and then boiled in old engine oil. To link the teak bearing, which also operated as a lever, to the uppermost rod, he used a shackle arrangement, also passing through a hard wood guide. The handle consisted of a length of 2 inch (50mm) steel pipe – the same as the pipes which descend into the borehole (or well). These pipes are called the “rising main.” The pump stand was concreted into the ground at an appropriate distance from the borehole. The concrete block was massive and held firm. It was virtually immovable. Perhaps why so many of his pumps can still be seen to this day.

The main steel head bolt supporting and pivoting the wooden block was mounted on a large U shaped bracket bolted to the head of the pump stand.

In those early years the pump was bolted together, in a blacksmithing era. There were no welded components. Bolts that came loose were tightened from time to time. I am
not sure how many pumps of this type were built. It may have been hundreds, many placed in remote settings. They used to clank away for years without the need for repair. In those far away days, perhaps the demands were less and as in so many remote areas of the country cattle watering was as important as a domestic supply. This is still true today. Allan Wright, a former District Commissioner in the Nuanetsi Administrative Area, the largest in the country, wrote in his classic book “Valley of the Iron Woods,” that he used to offer up a prayer every time he approached the site of one of Mugatroyds pumps – it always seemed to be working! The Murgatroyd Pump was such a marvel – I want to place a few photos of it here.

Water points were simply called Boreholes – often in the remotest areas

The pump stand was high and made of steel boreholes casing. The bearing and lever made from a block of teak, a hardwood which can be cut and drilled. Mopane wood is harder but wears out tools that try to cut or drill it.
The surroundings were not always hygienic, but the pump usually worked. Note the shackle arrangement Murgatroyds used. And also the number of missing bolts. But it still pumped water. The link between the wooden block and the rod had quite a few components.

HYBRIDS

As time passed, hybrids began to appear with features which heralded the introduction of Cecil Andersons design, like the “link arms”
Cecil Anderson’s Bush Pump

Cecil Anderson retained the wooden block, steel handle, and pump stand using steel borehole casing. He used link arms and a sliding tube arrangement to link the block with the rod and large U bolts to attach the pump head to the borehole casing.

Cecil Anderson’s Bush Pump

Sometime in the 1960’s Cecil Anderson, an engineer with the Department of Water, restyled Murgatroyd’s pump so that it could be removed from the borehole site and taken to a district workshop for repair. He cleverly used large U bolts attached to welded plates on the pump stand which would attach it strongly to the section of steel borehole casing rising above ground level. By this time the concept of welding had been introduced. Pumps were welded together and built mainly by the Department of Water itself. Anderson also used a different method of linking the wooden block to the upper rod with two link arms and a sliding sleeve arrangement. He retained the use of the steel borehole casing as the pump stand and the length of 50mm pipe as the handle.

The two main head bolts in Andersons pump were used to squeeze a length of one inch steel pipe (outer diameter 34mm) at the head of the pump stand between two rising steel plates welded to the head of the pump stand. The steel pipe formed the working surface against which the wooden block rotated. Wooden blocks were boiled in oil to act as a lubricator and preservative.
It was this pump which Zimbabwe inherited at Independence in 1980. At that time a few thousand pumps were already operating in the rural areas of Zimbabwe, maintained by the ADF (African Development Fund), which became the DDF (District Development Fund). Pumps were maintained by pump mechanics operating at district level using district based workshops.

This was the Bush Pump which Zimbabwe inherited in 1980. Andersons excellent idea of bolting the pump head to the borehole casing is clearly shown.

For routine maintenance the piston seal was the fastest wearing part, requiring the lifting of pipes and replacement of seals on the piston within the cylinder. More substantial repairs were carried out by removing the pump and doing repair work at the district workshop.

After 1980, with the flood of donor funds and many expatriate engineers, many foreign visitors saw the pump as antiquated and best placed inside a museum. Zimbabweans thought differently. Various attempts were made to replace the old Bush Pump by the expatriates. But the Government of Zimbabwe, for which I then worked, was determined to retain their old masterpiece, antiquated as it might have looked to those who viewed it for the first time. Several attempts were made to modify or change the Anderson model both by the NGO’s and even by the government itself. By the mid 1980’s there were about 8 different types of so called Bush Pump being built at factories and Government and NGO workshops all using different parts. This was an undesirable situation. The Technical Sub-committee of the National Action Committee, to which I belonged at the time, made a decision to put an end to the multiplicity of Bush Pump designs and restyle a new single standard. I was assigned this task in 1987.
Restyling again

I had always been inspired by the fact that the Bush Pump was born in Africa to serve Africa. It had been designed by those who had the “feel” for the conditions under which it was expected to operate.

In the third major restyling of the pump head (after Murgatroyd and Anderson) I had to consider the great merits of earlier models. They included a pump stand that was robust, using a hard wood block as a bearing and lever, and a steel pipe as the pump handle. Also Anderson’s creation of large U bolts which secured the pump to the borehole casing. In addition retaining a pump head open to the atmosphere to avoid sweating of steel components, and where pivot pin tightening was easy. The bits that made up the working parts could be easily seen.

But several refinements and improvements were also necessary. One of these was to make the pump more compact and portable whilst retaining strength. As it turned out, I restyled the pump head (with wooden block removed) so it would fit into the back of my VW Golf.

A major challenge was to keep the pump mechanics simple, reducing the number of wearing parts, reducing friction and also overcoming some shortcomings of earlier pumps. These included a tendency for pivot pins to become loose leading to wear on the supporting steel plates. A method was required to keep the main pivot pins tight even with the vibrations and knocks it had to endure. Also a method of reducing the “end knock” when the pump rod reached the end of its stroke. A rubber buffer was required. The link between the wooden block and the rod had to be simplified.

Over two sleepless nights in early March 1987, I came up with a possible solution – to use a floating washer system through which the rod could pass, even it was moving horizontally as well as vertically. I calculated that for the full 230mm stroke, the rod itself moved only a small distance forward and backwards, and also in this case, slightly from side to side as well. The pump handle does not move up and down strictly vertically it actually tries to move in a shallow arc! This is because people stand by the side of the handle whilst pumping. Using this system the rod could be connected directly to a U bracket slung from the forward hole drilled in the wooden block. Almost a direct link – no shackles, no link arms or sleeve pipes. It had to be tried!

Using careful geometry these rod movements were possible within the 50mm pipe used for the rising main. The wearing parts became the floating washers which were cheap and easy to replace. Two washers were used, within and on top of a floating washer
housing. The upper one to support the rubber buffer and U bracket and the long “string” of pumps rods. Also an inner floating washer to act as an extra hygienic seal to stop objects being thrown down the rising main. Evidence over the last 20 + years reveals that floating washers wear slowly, but are easy to replace.

The wooden block of all Bush Pumps, has 4 drilled holes drilled in it, not two. The first prototype I built had a block with only the necessary two working holes. However I decided to retain the original design of having four holes drilled, as for the extra 25% of wood used in extending the block length, the life of the block itself could be doubled by using the second set of holes when the first set were worn out. As it turns out, the wooden bearing last for many years, even with a single set of holes. This was a bit of over-engineering I chose to retain.

I was also concerned with the use of clamped 25mm steel pipes as working surfaces for the main bearings in Andersons pump, as these come under immense strain, can come loose and cause wear. Sometimes the wood would expand, pinching the pipe, so the working surfaces became steel on steel. It was clear that something new was required to ensure that the wood against steel bearing was maintained at all times and also the wear on the side arm plates by the main pivot pins was reduced.

From the start I chose to use a solid bar of 35mm bright mild steel for the new pivot pins. These pivot pins were fitted with squared heads recessed and welded to them. In both front and rear pivot pins the movement of the squared head was reduced by the using a pivot pin head securing plate on both the pump stand and also the U bracket supporting the rods. At first the securing plate was welded to the underside of the bolt head position on both the main pump stand and also the U bracket. However in the trials it was found that wear took place on the U bracket above the bolt and not beneath it. Wear on the U bracket hole tended to enlarge the hole upwards. Wear on the pump stand side arms tended to enlarge the hole downwards. Consequently the securing plates were welded below the bolt head on the pump stand and above the bolt head on the U bracket. In addition the thickness of the steel plate, both on U bracket and pump stand on the threaded end of the pivot pin was doubled. These were designed to reduce wear on the pump frame and U bracket. These designs have been retained.

In addition, to reduce the chance of pivot pin loosening bolt loosening and causing wear, strong 5mm thick spring washers were used under the nut. A corresponding large spanner was designed specifically for bolt tightening. Keeping bolts tight is very important. Loose bolts cause wear on permanent parts of the pump stand.
Development of first prototype of the “B” type Bush Pump

I assembled the first prototype “B” type in my garden in Marlborough, Harare, in early March 1987, with the pieces, some salvaged from other pumps, loosely placed and tacked together. This prototype was then taken to the Eastlea workshops of the Department of Water Development to be welded together properly so it could be placed on trials in Epworth.

Backyard Development

By 1987 many versions of the Bush Pump were being built. On the left photo on the right (in red and blue) the “A” type, a shorter version of Andersons model which retained link arms and a sliding tube. Just behind it the first prototype “B” type.

Early March 1987. Working out the geometry! The first prototype was partly held together with clamps and built up from parts from other pumps. The first floating washer housing was sealed but very soon made so it could be dismantled.
Endurance Trials of the “B” type Bush Pump

The first prototype “B” type was then placed on endurance trials in an extra heavy duty setting in the Epworth peri-urban settlement near Harare. It seemed to work well and UNICEF (Thank you David Williams) funded the production of 10 extra pumps made by Lane Engineering. In a collaborative exercise between my team at the Blair Research Laboratory, the Department of Water Development, DDF and UNICEF, we placed in these extra 10 pumps in rural settings to test for their effectiveness. Later the same year further pumps were ordered from V&W Engineering, who have since made over 20,000 more “B” type Bush Pumps.

The very first “B” type being tested in Epworth in March 1987. The “B” type was also tested in several rural locations in collaborative work with the DDF and Unicef.

The pump tests were severe. Some worked for over 20 hours a day in the heavily used settings at Epworth and others placed on very deep (100m) boreholes in Lower Gweru. A few Bush Pumps are expected to function at great depth – I presume the height of the Victoria Falls at 110m sets an upper limit!! Most are used on wells and boreholes between 30m and 40m deep. But the pump functions just fine on shallow wells too.

I was particularly anxious to find weakness in the pump stand when under great stress. These weaknesses were found. In Epworth cracks appeared on two heavily used pumps on the steel channel at the point just above the rising main support plate. Before that
time the side arms welded to sides of the steel the steel channel (used to make the main pump stand), extended only about 100mm below the top of the channel. The weakness revealed, the two side arms were extended beyond the point where the weakness appears, an improvement which appears to have been successful.

Endurance trials of the “B” type in Epworth

Further trials in the rural areas during the two years of testing

With my loyal and talented assistant Ephraim Chimbunde in one rural test site.
With my friend and colleague David Williams, at the time WASH officer with UNICEF and the DDF staff. Ten pumps, made by Lane Engineering were fitted in the rural areas with DDF support during this era of testing.

Working with the DDF on pump trials.
Some trials were undertaken in remote areas.

People found the new pump easier to operate.

Endurance trials on very deep boreholes in Lower Gweru.
Results from endurance trials

As described earlier, the heavy duty trials revealed where the wear on bolt holes in the main pump frame and U bracket took place. Design changes were made to ensure the best possible performance of the pump. These also included a dip plug, introduced to allow water levels to be monitored in wells and boreholes whilst the pump was fitted.

“B” type pumps tested on very deep boreholes also revealed where improvements could be made. On very deep set pumps (fitted with extended steel handles often filled with concrete to counterbalance the weight of the rods), the pump stand with 12mm thick side arms tended to twist. So for use in extra deep settings the side arms were thus increased in thickness to 16mm and the bright mild steel pivot pins adjusted accordingly.

To overcome the hygienic aspects of the pump, I chose to fit an apron around the base plate support plate holding up the “rising main”. The plate and its surrounding apron fitted around and over the top of the borehole casing. This refinement also had the advantage that even if the large U bolts attaching the pump to the casing were loose or even removed the pump would stay in place. In fact, on this model just about all the bolts can be removed, one by one, and the pump can still be made to work. Skat’s Pump Specialist Karl Erpf and I once on a tour of pump inspections once saw a pump being worked vigorously with the 2 main pivot pins missing. Lengths of steel rod (nSimbe’s) had been put in place. Obviously a temporary measure, but proving perhaps, that the head could be made to work – no matter what had happened to it.

In 1989, after two years of rather vigorous testing and following a report of its progress during its evolution, the Government of Zimbabwe accepted the “B” type Bush Pump as the new National Standard. The first official drawings of the “B” type pump head were produced on 26th May 1989 by the Ministry of Energy and Water Resources and Development. These drawings were computerized in 1996 by Santana Design Studio, Harare. The computerized drawings were later adopted and redrawn by Karl Erpf of the Swiss Centre for Development Cooperation in Technology and Management (The SKAT Foundation), when the pump became a Public Domain Hand Pump in 1999. SKAT’s new drawings became the International Specifications for the Zimbabwe Bush Pump. These drawings have been refined and updated again for use in Zimbabwe by The Standards Association of Zimbabwe. The “B” type Bush Pump has been retained as the National Standard Hand Pump since that time.
Movements of the wooden block and rod during pumping

During the normal operation of the pump, an effective stroke of about 230mm can be maintained whilst confining the rod within the internal diameter of a 50mm NB galvanized pipe. In fact if the uppermost pipe is 50mm, all lower pipes can be 40mm using a 50mm to 40mm heavy duty reducing socket to connect uppermost pipe to the rest of the pipes below.
The wooden block, which is made of teak, is attached to the pump stand and rotates around a large bolt called a pivot pin held tight with a lock washer. The rods which connect to the piston within the cylinder, far below, move up and down within a series of steel pipes (known as the “rising main”). The uppermost rod passes through a floating washer housing, where a set of 2 moving washers accommodate for the horizontal movements of the rod within the pipe. The uppermost rod is connected to the pump head through a “U bracket”. The U bracket is attached to another pivot pin which passes through a forward hole in the wooden block. The wooden block has 2 sets of holes, a method derived from earlier Bush Pumps. When the first set of holes wears out, the second set can be put into use. The wooden bearing has a very long life. The aim of the “B” type was to simplify the design, reducing the number of working and wearing parts as well as to reduce the risk of bolt loosening, reducing friction and also to make the pump head more compact and easier to transport whilst retaining strength.
General photos of the pump head components

The lower part of the pump stand showing the base plate support plate (apron plate) and apron and the two large 16mm U bolts which secure the pump stand to the borehole casing. On the left the upper part of the pump stand and the U bracket in position.

The water discharge unit in position. The steel pipes of the rising main are connected to this through a heavy duty socket. The water discharge unit uses a “floating washer system” to accommodate the movements of the rods as they travel up and down during the pump stroke. A rubber buffer cushions the end of the down stroke. The floating washer system uses an inner and outer floating washer. The inner washer helps reduce foreign objects passing down into the rising main from above. The outer floating washer acts as a base for the rubber buffer to rest on.

The inner floating washer in place. A spacer ring separates the upper and lower plates of the floating washer system. On the right the upper plate has been secured in position and the outer floating washer and rubber buffer fitted.
“Down the hole” developments

During the era of testing and beyond I worked with Mr Erwin von Elling, the owner of V&W Engineering on “down the hole components” and particularly with “open top cylinders.” The standard Bush Pump uses a 50mm rising main and 75mm cylinder necessitating the lifting of pipes and rods to gain access to the two leather seals on the piston. In line with other international developments, research was also undertaken with “open top cylinders” where the cylinder (and piston) diameter was less than the diameter of the rising main. 50mm, 63.5mm and 75mm open top cylinders were formed by swaging the malleable brass into new shapes which would allow open top cylinders to be made. The 50mm version could operate with cleaned 50mm pipes, but the 63.5mm version required 65mm NB (nominal bore) pipes which were heavy and costly. The same has been found for the India Mk III.

Being accustomed to the generous water output of the 75mm cylinder, most users disliked the 50mm version, with the 63.5mm version being acceptable as an alternative. The cost and weight of 65mm steel pipe limits its use at most depths used by the Bush Pump, although at shallower depths, perhaps up to 20m it may be useful. Mr von Elling also designed a unique series of hook and eye rods, using a very hard steel coating and malleable interior core of mild steel for the hooks and eyes, much like the Japanese sword. This system worked well.

The common trend however has been to standardize on the use of a 75mm cylinder in combination with 50mm pipes. However, I believe that work should continue on the open top cylinder design as this makes routine maintenance of “down the hole” components (particularly seal replacement) much easier.

“Open top” cylinders designed for use with the Bush Pump – 50mm, 63.5mm and 75mm. The 63.5mm version shows the most promise
Research and Development

A great deal of R&D has taken place over the years since the “B” type went into action. Most of this has concentrated on “down the hole” development, particularly with alternative materials for rising mains and rods. High density polyethylene and even high impact PVC have been tried as alternatives for the rising main. PVC and even stainless steel wire have been tried as rod materials. But we keep coming back to the old well tried and tested galvanised steel pipes and mild steel rods. I think stainless steel rods would be a good idea, but there is no current production in Zimbabwe. And perhaps, for the future, some new ultra high strength modern plastic/carbon fibre material could be tested for the rising mains. It has to be tough, to hold up the weight of water and also, because boreholes are not always drilled vertically, causing wear of rod on pipe going around a curve. It’s challenging!
Ease of maintenance for schools and elsewhere

Some years ago we tried the open top cylinder version on moderately shallow boreholes to see whether school pupils with support from enthusiastic teachers could cope with replacing seals in the piston. There was some success. This avenue of work deserves to be revisited. Not only for schools, but also institutions and even on a broader scale. The “open top” cylinder version shows the best way forward.

School pupils with the support of enthusiastic teachers can perform routine maintenance

Mass Production

Pumps must be made properly according to local and international specifications. The use of jigs to maintain consistency is important.
International and local Specifications

24 years on...the challenge goes on.

Technology alone counts for much if reliability is to be achieved, and that was the primary aim of all this work. A good pump which delivers water to the people it serves, reliably.

Over twenty years, very few refinements have been found necessary with the “B” type Bush Pump head. An interesting modification was the introduction of a “course sieve” with 8mm holes within the output pipe. This resulted from the realization that it was possible to push stones down the rising main with a stick passed horizontally through the discharge pipe. Although uncommon, this weakness has been now been corrected.

Although International and National Specifications are available, several manufacturers still fabricate pumps which do not adhere to the specifications and the GOZ has embarked on a program of correcting this problem. Pumps which are not manufactured correctly or are not installed correctly, do not function properly and may give poor service to the communities they are expected to serve. The use of substandard leather seals in the piston, for instance, which may be slightly lower in cost, but drastically reduce the working life of the unit, lead unnecessarily to increased “down time” and maintenance costs. High quality seals are essential if maintenance costs are to be kept as low as possible and a reliable service maintained for longer.
Maintenance systems
Hand pumps like all machines require reliable maintenance systems to back them up. Cars, bicycles and anything mechanical must rely on a maintenance system. And this applies to hand pumps too. A number of pump maintenance systems have been tried in Zimbabwe. The district based “Pump Mechanic” and his team, the “three tier” pump maintenance system and “Pump Minders” supported by community and working under the District Development Fund. Much greater attention should be given to workable maintenance systems, not only in Zimbabwe, but elsewhere in Africa, to ensure the pumps work well and for longer periods. The system working under the DDF where “Pump Minders” are employed, supported by the community, appeared to have promise. This system surely requires rejuvenation and the GOZ is planning a revitalized “Pump Minder” training program which also incorporates training for all Bush Pump installers like borehole drillers and technicians working for Government and NGO’s.

Historical perspectives
To many of my colleagues and certain for me personally, the historical side of the Zimbabwe Bush Pump has great importance. There is an element of local pride within any country of the world for local enterprise. And Zimbabwe has made its contributions to the world of water. I personally admire those who have believed in this local achievement and not abandoned local initiatives to keep local innovation alive. This long history of the Bush Pump, starting eighty years ago, is something to be proud of and something to continue to uphold. In more modern times, it is a wonderful piece of African history.

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