REPORT

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The Development of a Treadle Pump

Lessons from the South African Experience

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1. INTRODUCTION

The use of treadle pumps for irrigation in developing countries in Africa and Asia has greatly improved the potential for many smallholder farmers. However, it **was** initially felt that the treadle pump would have a limited market in South Africa. This was **due** to the vast differences found in South Africa in both the willingness to grow produce and the limited access to water resources, especially ground water. This theory **was** discarded after more in-depth research showed that treadle pumps could be used to transfer water from both open water sources and water captured from rainwater harvesting. Research also showed that the treadle pumps could greatly assist the rural poor of South Africa in terms of food security and poverty alleviation. This resulted in the development of a project **to** introduce treadle pumps into South Africa.

The first two years of work was aimed at understanding the treadle pumps as much as possible. This involved importing a number of available units from developing countries in Africa **and** Asia and testing them to determine their suitability in South African conditions. These tests showed the need to redesign the pump according to South African circumstances. Most of the countries where **successful** introduction has taken place have a much wider availability of water. The water is usually very close to the point of use and the distribution of that water is the limiting factor. Due to the shallow water table, the **pumps** are merely used to access the ground water, and redistribute **it** around the fields. South Africa does not have a shallow water table. Open water sources are far more abundant here. However, many sources are incised in deep valleys or are some distance from **the** desired point of application and are therefore difficult to access. The heads and distances required for pumping are therefore much greater in South Africa.

South Africa **does,** however, have a more convenient access to materials than other developing countries. This makes it possible to manufacture a pump out of standard, ready-made fittings, largely eliminating the problem of quality control that other countries face and allowing for rural based manufacture, Labour costs in South Africa are higher than other developing countries, and many of the steel pumps would **be** more expensive if manufactured and **sold** here. South Africa also has a well-established hardware trade and better roads, allowing for easier promotion, distribution and after sales service.

Initial redesign took place towards the end of the second year **of** the project. The objective therefore of the third year was to develop this **pump** into a final prototype stage. This report **presents** the outcomes **of** this third year of the **study.** Results of the initial research can be found in Kedge, 2001. The report contains four sections. Chapter two is **the** technical work that took place to further develop the pump. Chapter three is an overview of the field evaluations that involved farmers evaluating the pumps in practical conditions. Chapter four presents the results of the rural manufacturing research. Lastly, the Appendix presents the raw data. Each chapter contains a discussion and conclusion section.

2. Pump Development and Laboratory work

2.1 Introduction

A prototype treadle pump was designed at the end of 2001. The year 2002 saw this pump undergoing many changes as a result of laboratory and field testing. The process was slow, as it is with any new product. Problems would arise and be solved only to develop into new problems. The difficulty lay in the constant requirement for a low-cost product that still maintained a suitable quality. Anyone could design an ideal treadle pump if the end price is not a consideration. However, this would eliminate the exact end-user target market that the treadle pump technology is attempting to assist, the rural poor. The aim therefore became to settle for a product that was “good enough”. Factors had to be constantly weighed up against each other and often ideal solutions had to be sacrificed for low-cost solutions. The intention was also to keep the design simple allowing for rural based manufacturing.

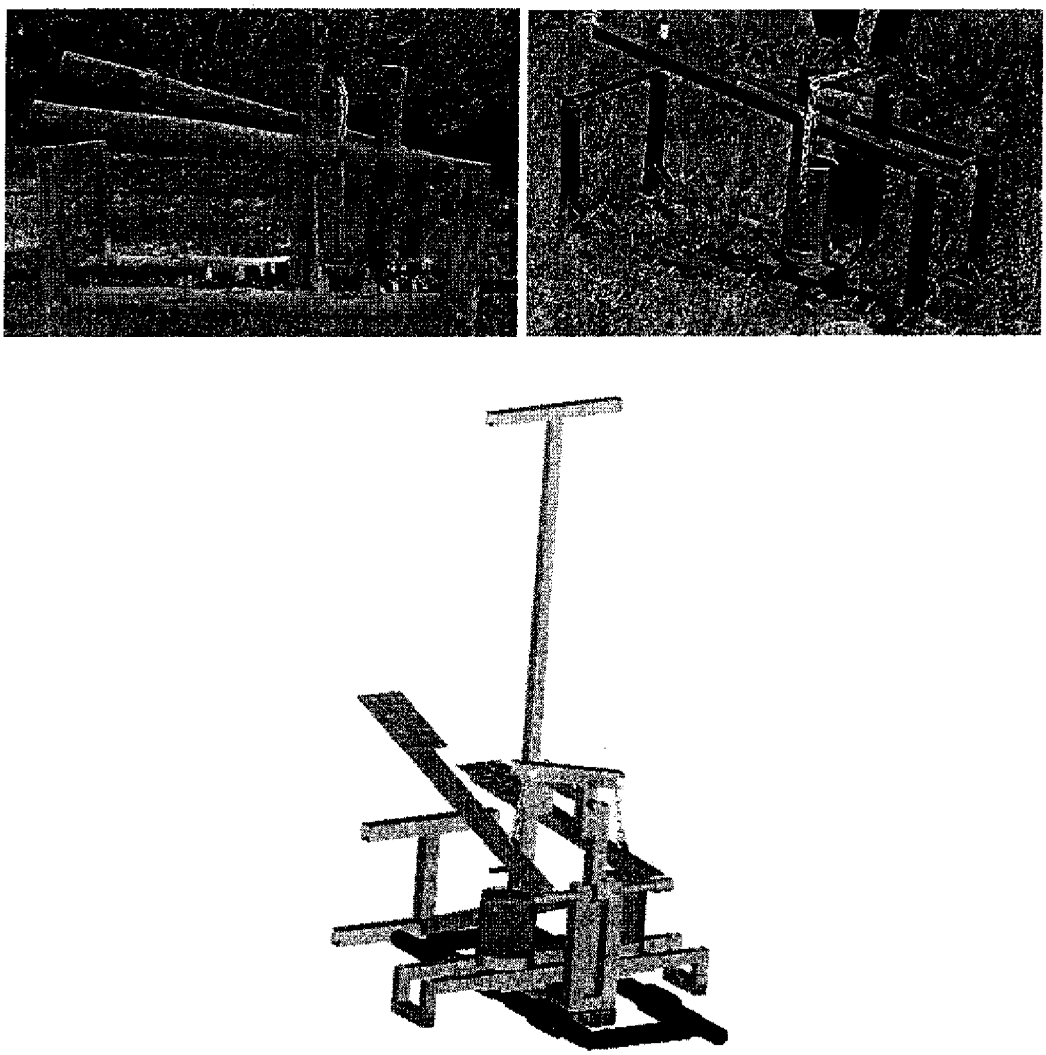


Figure 1. Three stages of the treadle pump development.

It was felt that the initial design should centre around similar models that were introduced elsewhere, however, keeping in mind that additional pumps would be required to solve the majority of people's needs in South Africa. A high pressure pump for use in water supply and a high flow suction pump were also considered but were put on standby after it was found that too much time was being spent on those rather than completing the original model. It should also be mentioned here that while suction pumps can also give problems, they are generally a lot more forgiving than pressure pumps due to their operation. Therefore many things that might not provide serious problems with suction pumps require detailed development with a pressure pump. This chapter will present the design work that was carried out on the treadle pump. It will highlight the main challenges that arose and will present the results of laboratory tests carried out on the pumps.

2.2 Pump Components

The most challenging aspect of designing the treadte pump was keeping it in an affordable price bracket. Each component had to be carefully considered in order to keep costs down, but still maintain quality. The intention was to use standard parts so that quality control would be kept to a minimum, in order to allow for local artisans to assemble the pumps, thereby keeping the back up service closer to the end user. All the pumps that were imported had been welded and required jigs for manufacture. South Africa could use standard parts due to their availability.

The initial pump designed and built in South Africa was based on galvanized fittings. Brass non-return valves obtainable at most cooperatives and irrigation stores were used. The frame was made of steel. While the pump operated well, it was decided that the valves and galvanized fittings were too expensive, and a cheaper solution was sought.

The basic pump then developed has PVC cylinders and contains valves, which are fabricated from standard nylon reducers and rubber balls, T-pieces and elbows. The second pump consisted of the same pump section that is in place today, however, differed in the frame. A wooden frame made out of easily obtainable gum poles was thought to be cheaper, and more accessible for most rural people. However, the frame was large and bulky, and while it could still be an option for some people, it was decided to refine the frame and return to steel.

Each component required close development to acquire an effectively operating pump. In order to keep costs down it was decided that "good enough" would suffice rather than "perfection". The following section presents the various components of a treadle pump. Experience gained is divided into:

- the lessons learnt from testing the imported pumps;
- the lessons learnt through the development and testing work that has been done on the South African design;
- problems faced and solved.

2.2.1 Valves

The most significant result that came from testing the friction through the valves of the imported pumps was the importance of valve design on friction losses through the pump. A pump with small holes produced a friction loss through the valves of about ten times greater than all the other pumps. This is a result of the smaller diameter holes through which the water must pass. The rubber flap valves of the other pressure pumps did not cause significant friction, however, they did not seal properly resulting in water from the outlet pipe flowing out of the cylinders when pumping stopped. It was therefore highlighted that the water requires sufficient space to pass through the valve, and that the valve must seal properly for a more efficient pump. All the pumps tested had valves that were part of the entire pump frame, and therefore required a fairly complex construction to fit them. This arrangement results in difficulties of accessing and replacing the rubber flaps on some of the pumps, as well as presents complications in manufacture, therefore increasing the need for quality control.

In order to decrease the costs of the brass non-return valves used in the initial South African design, an attempt was made to use rubber flaps in conjunction with nylon reducers to make a valve. However, the rubber was difficult to attach and another solution was required. It was then decided to contrive a ball valve. A rubber ball, widely used as kids' play balls, of similar size to the outlet of the nylon reducer was found. It was necessary to prevent the ball from blocking off the outlet side of the valve, and a piece of wire was used. When tested, these valves produced very little friction as a result of the ball being free to move back and forth in the reducer, without needing to be forced open. This differs from the rubber flap valves of the imported pumps in that the flaps' natural position is closed, and they open as a result of the pumping stroke. The balls naturally float, opening the valve, and close as a result of the pumping stroke.

This does, however, present a problem when priming the pump. The balls do not move when pumping begins if there is no water in the pump, as air will not cause them to move. It is therefore vital to pour water into the pump before pumping begins. This problem could be solved by mounting the suction side valves vertically. However, this would increase the height that the operator is above the ground. It would also be possible if a spring or a seat was attached inside the fitting, forcing the ball to close naturally. This would, however, complicate manufacture slightly, and add additional friction to open the valve.

When the pump was tested against a high pressure tank, in order to see what pressure could be reached, a surprising result was that the ball valves were the first to give way, at 17 metres pressure head. Various tests showed that both pressure and suction side valves were forced into their fittings at this head, due to the direct head of the water on the pressure side, and the combination of the force of the operator pumping and the suction force on the suction side. This was overcome by sourcing slightly larger balls. Various balls, including marbles and squash balls, were tested by exposing them to sudden high heads, thereby simulating the treadling action. Tests showed, however, that the rubber balls sealed the best. Initially it was thought that the smaller balls could be used in a smaller sized fitting, but this did not work as they did not seal properly and vibrated against their seat when pumping began due to the force on the ball being exerted from all directions. As the balls only gave way at 17 m pressure head it was decided that they would be fine to use, with the limiting head of the pump set at 15 m. This proved not to work in practice, as the same result of the balls being pushed into their fittings occurred in the field due to the high friction in the 20 mm delivery pipe that was being used.

2.2.2 Cylinder-Piston Combination

The cylinder and piston mechanism is the heart of the pump and if not sized and fitted correctly would result in very poor operation of the pump, if any at all. This lesson was learnt from some of the imported pumps, where it was found that the piston cups were incorrectly sized and therefore did not seal against the cylinder walls, preventing a vacuum from being created. In one case, manufacturers imported rubber piston cups, and were totally dependant on the exact sire of the cups in the shipment that arrived. They then had to adjust the sire of the cylinders to accommodate the cups that were obtained, and this resulted again in poor quality pumps. This combination is particularly important for the pressure pump, as the water on top of the cylinders of the suction pumps provides a seal anyway, and the pump can therefore still operate.

It appears that the shorter the piston stroke, the easier it is to maintain the seal of the pistons. This is because the treadles move in an arc, and it is therefore necessary to create an additional pivot point in order for the piston rods to still move vertically. Obviously, the shorter the piston stroke the less the treadtes move, the less the arc, and therefore less non-vertical movement occurs. One pump has a simple yet ingenious way of accounting for this arc movement. This involves a chain that rests on a rocker, which is set up so that the chain can only pull the rods vertically. However, this system lends itself to this pump, a completely steel unit, which requires precise welding. The pump also has larger diameter cylinders than the majority of pumps, allowing for a shorter stroke.

Other pumps overcome this movement by cutting a slot in the treadles, which allows the piston rod to move in the slot, therefore still rising vertically. It was this simple mechanism that was adopted in the South African design, as it proved the least expensive and again "good enough" solution. However, it was still necessary to limit the piston stroke, in order for the rods to have as minimum movement as possible.

The cylinders of the majority of the imported pumps are manufactured from rolled steel, which is welded in place. This again presents problems in quality control because if this seam is not smooth, the piston cups could be damaged or would wear quicker. The South African pump's cylinders are made from 110 mm, class 12, PVC pipe. This is readily available in South Africa, and overcomes the problem of rust and the welded seam. 110 mrn was chosen as'this size end cap is the easiest and cheapest to obtain. The end caps are attached to the cylinders using a strong PVC weld glue. They are then screwed into the pump section using a male threaded tank connector, which screws into a female T-piece.

4" leather cups were initially used for the pistons because they had the tightest fit inside the cylinders. These leather cups are also a standard part available in South Africa and are used an windmills, Initially, 110 mm, class 9 PVC pipe was used because the piston cups fitted in easily when dry. However, when they were wet they became softer and increased the clearance between the cylinder walls. Class 12 pipe, with a slightly smaller inside diameter was then used and required the cups to be soaked and then formed inside the cylinders before they could be used. The leather cups caused endless problems in the field where operators did not keep them moist. This resulted in the cups drying out and shrinking and therefore not operating correctly. This prompted the change from leather to rubber piston cups. Unfortunately the rubber cups are not a standard part, however, no other solution could be found. Dunlop Rubber Company developed a mould based on the Enterprise Works pumps' rubber cups. The initial cups that were obtained had a very tight fit with the cylinders, and therefore resulted in a high friction. Rubber grease was then put on the cups, which improved things greatly. However, it was felt that having to use rubber grease in the field would be a weakness in the pump and Dunlop was again approached to redesign the mould. The second batch of rubber cups was based on cups obtained with **the** ApproTEC MoneyMaker Plus pump. These included more of a taper with the effect of decreasing the contact surface between the piston cups and cylinder walls. This new design reduced the friction greatly and the rubber grease was no longer required.

The piston rods are made from gate hangers, again standard parts, and the piston cups are secured to the **rods** with steel discs and nuts. This allows for easy replacement once worn.

2.2.3 Treadles

The treadles serve two functions in a treadle pump. They provide a place for the operator to stand, and they link the frame to the pump mechanism. The majority of the imported pumps use wooden treadles, however, due to the lack of availability and the higher cost of suitable wood the South African unit makes use of steel treadles. The positioning of the treadles **is** very important in order to provide comfort for the operator and to therefore gain a greater ergonomic efficiency. The laboratory tests highlighted this, **as** well **as** the need for comfortable foot rests. **A** stroke length of **about** 180 mm at the foot rests, the height of an average step, proved the most comfortable. This has to be balanced with the positioning of the pivot point, the length of the treadle and the desired piston stroke length **in** order to obtain the greatest mechanical advantage. The end positioning of the treadles of one of the tested pumps, was lower than the pivot point, and this angle resulted in pain in the front of the ankles of the operator.

The South African pump has a treadle length of 700 mm. This was chosen in order to keep the pump compact. This length can comfortably reach 12 metres delivery head.

2.2.4 Frame

The skeleton or frame of the treadle pump has **very little** influence on the actual operation of the pump. for this reason the frame can virtually be made out of any available materials, **as** was shown with the initial gum pole frame. However, in order to make the pump more compact, allowing for the possibility of "kit" distribution, a smaller steel frame was designed and built. This frame is held together by a combination of welding and bolts, and can **be** dismantled for easier distribution. The welding required for the frame is not complicated, **and** does not require the use of jigs.

The shape of the frame does, however, affect the stability of the pump. It is thought that *two* sorts of frames will ultimately be used. The first will consist of the current steel frame, which is small and compact enough to carry home and store after use. However, this frame **is** not very stable when placed on uneven ground, especially when the ground becomes wet, which inevitably happens around the pump. Therefore, it would require a level surface, either a concrete **slab,** concrete blocks placed in the ground or flat wooden planks. The second frame would consist of a more permanent set **up** for users who do not require the pump to be transported, either home or around the field. This frame could **be** made from concrete, and would require **an** actual pump installation. This innovation will likely develop once local people begin manufacturing and using the pumps, and therefore producing the frame as to their needs.

The frame underwent many changes throughout the test period due to results from the field evaluations and the durability testing of the pump. The initial frame contained just the necessary parts and was adjusted for strengthening as time went by. The following figure shows the changes that were made.

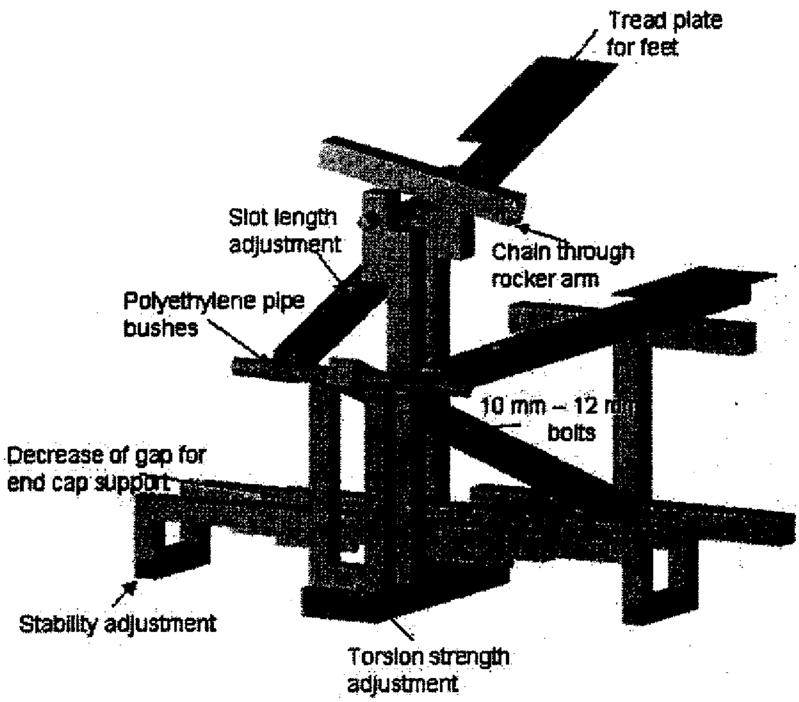


Figure **2.** Adjustments to the design made through the year.

2.3 Performance Testing

The pump initially underwent performance testing in the laboratory in order to determine the flow rates at various suction and pressure head combinations. The following table presents the results obtained from these tests. These performance tests were all carried out with the leather piston cups instead of the rubber. It is believed that better values would be obtained with rubber, however this still needs to be done.

Table 1. Results from the performance tests.

Suction height (m)	Delivery height (m)	Flow rate (l/s)	Flow rate (m^3 / h)
1	2	0.55	1.98
1	4	0.55	1.98
1	7	0.5	1.8
2	2	0.37	1.33
2	7	0.42	1.51
3	2	0.48	1.73
3	7	0.43	1.55
4	2	0.47	1.69
4	7	0.34	1.22
5	2	0.46	1.66
5	7	0.26	0.94
6	7	0.18	0.65

The pump was then also linked up to a pressure tank at zero suction head in order to determine the maximum pressure head that could be reached. The fairly averaged size operator started straining at about 30 m pressure and the frame also started twisting quite a bit. However, it proved that a pressure head limit of about 12 m could be reached without any problems.

2.4 Durability Testing

The objective of the durability test phase of the pumps was not to determine the absolute life of the pump, as too many factors would influence this in the field, but rather to determine the relative life of the individual components against each other. The "weak links" in the design were sought. The test rig, designed and constructed by Anthony Amankrah of Fort Cox College of Agriculture and Forestry, mechanically simulates the manual foot operation of treadling at an optimum cadence of 60 strokes per minute (30 strokes per minute per cylinder). The rig replicates the alternate up and down push on the treadles from the connecting pump rod ends of a crank assembly of two Climax F104 single wheel hand pumps. The shafts from the two crank mechanisms supported in flange bearings are connected to a rigid coupling and each shaft is keyed at 180 degrees out of phase to each other. A 2.2 kW helical gear motor with output speed of 60rpm drives a chain transmission, which operates the foot-treadling simulator. The pressure head was set at about 5 m throughout the tests and the suction head was zero.

This test phase took place after the initial batch of rubber cups was received from Dunlop. As mentioned earlier these cups provided a high friction with the cylinders. They were then greased with motor grease in order to overcome this friction. Four pumps were tested on the test rig and each lasted about 24 hours before two of them broke at the position marked on the below diagram, and the other two's piston cups loosened on the piston rods. The grease appeared to wear away over this period and the pistons were very difficult to remove from the cylinders. Having discussed this later with the Dunlop representative, it was mentioned that motor grease in fact causes rubber to swell, hence the seizing of the pumps. Special rubber grease was then tried. The first pump lasted about 72 hours and then broke in the same place as before. The section that broke was then replaced with a stronger, 32 x 32 x 2 mm square tube. The pump then lasted about 106 hours and again broke in the same place.

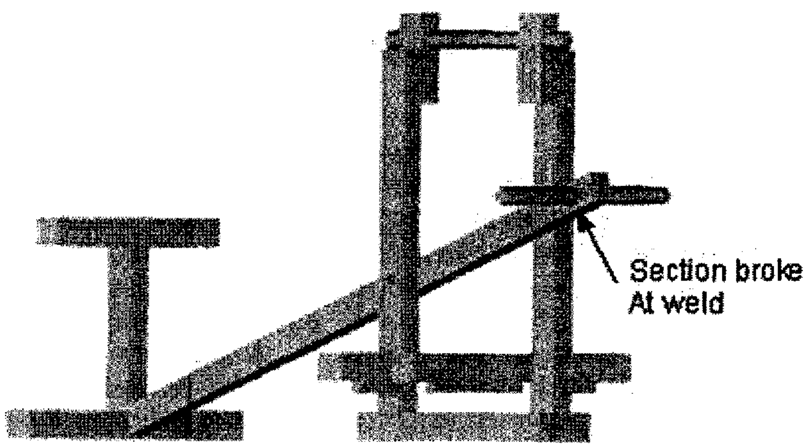


Figure 3. The point where the pumps broke on the test rig.

The next pump tested **had** the torsion **strength** adjustment that **can be** seen in figure 2. It also had the **new** rubber cups received **from Dunlop.** It **lasted 480** hours. **The frame still had** not broken after **this time, and the test was stopped as** a result of a **tiny** crack that occurred in one of the PVC end caps. It was then decided to rest the end caps on thin rubber strips, rather than **directly on** the steel in order to reduce **the** chance of cracking.

2.5 Single Cylinder Hand pump

Figure 4 presents a diagram of the single cylinder hand pump and **the** parts required for **its** assembly. The **pump** was developed towards the end **of the** year. It is based on the design **of the ApproTEC** single **cylinder** hand pump, however, again **use** is made **of** standard parts. The pump still requires testing to determine both head and flow rate values. Due to its low cost and light weight, this hand pump **could** greatly assist in the water supply sector.

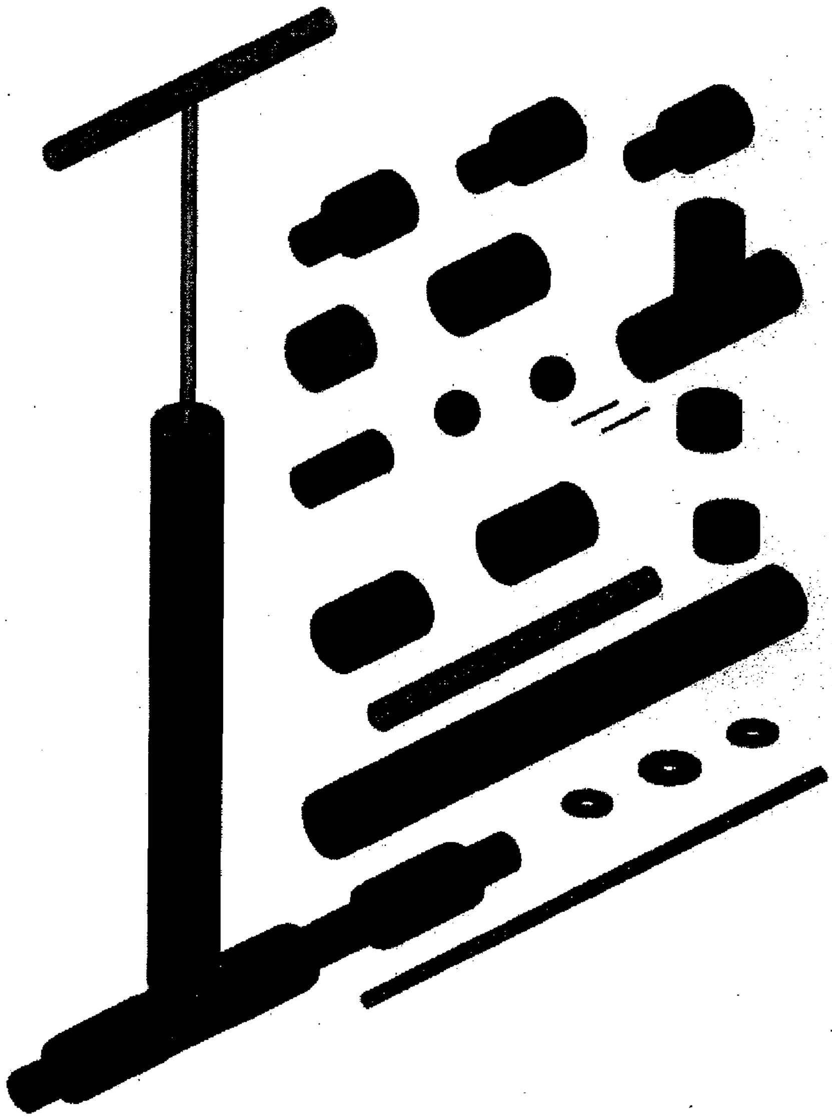


Figure 4. The single cylinder kit hand pump.

3. Field Evaluations

3.1 Introduction

The main aim of the field evaluations that took place during the year 2002 was to evaluate the new treadle pump design whilst being used in practical situations. The pump required testing by farmers in order to view technical problems that might arise while being used in the field. A secondary objective was *to* view the applications of the pumps, how people would use them and if the design was suited to the requirements of the end user. Eleven sites were used in order to carry out these evaluations. This chapter presents a summary of the results obtained from the field evaluations. A more detailed look at the particular sites can be found in Appendix B in terms of lessons learnt, feed back gained and both successful and unsuccessful experiences. Figure 5 presents a map of South Africa showing the position of the sites.

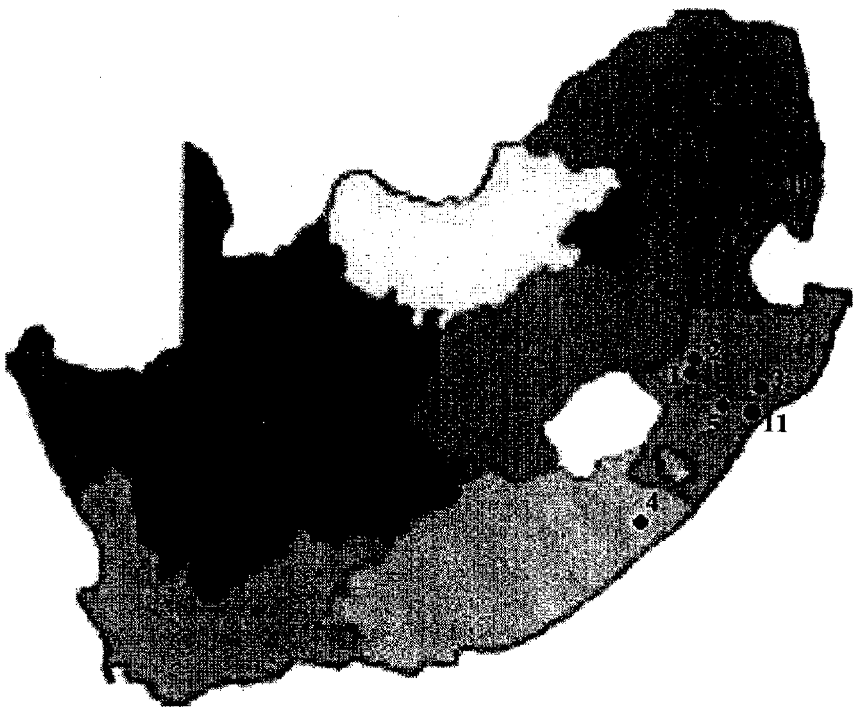


Figure 5. The sites used for the field evaluations of the treadle pumps.

3.2 Background

The intention behind the site selection for the field evaluation phase was to select sites that could be monitored by people working with the farmers and dealing with them daily. A few sites were also chosen as a result of interest showed by people working with communities. In hind site, it would have been better to select all the sites according to the interest shown by those involved, rather *than* asking extension *officers* to monitor something that they did ask for in the first place.

The pump installation phase took time, as each site required a pre visit in order to determine its suitability and the quantities of piping required. The monitoring phase also took up a lot of time and each site was visited as often as was practically possible.

3.3 Discussion and Conclusions

There is a mixed feeling about the success of the field evaluations that took place in 2002. It is believed that the site selection was not done suitably. Of the 11 pumps that went out, five were used often by farmers, five were not and the remaining pump at site 4 is unclear to the extent of its use. It is interesting to note here that four of the five pumps that were not used were situated in Department of Agriculture assisted gardens, where the extension officers involved stated that they did not feel that the gardens would still operate without their input and assistance. It might therefore not be a reflection on the pumps that they were not used, but rather the people involved.

The most successful site was the garden situated at the homestead near Bureford. This was an ideal situation where water was available near the house, and the pump assisted the farmers to expand their garden. Other successful sites were Inanda and the other Bureford site, where the farmers left the pumps in the gardens and therefore did not have to set it up and prime it everyday. On more than one occasion farmers mentioned that it was an effort to carry the pump and set it up at the garden everyday. This highlights a difference in South Africa where water is not readily available and therefore gardening is carried out in community gardens nearby water sources. Groups of women use these gardens to grow vegetables during the dry season, when they cannot grow them at their homesteads. They do not, however, all irrigate at the same time but rather when it suits each individual. Sharing a pump therefore becomes difficult in this situation. The farmers at the Riverside garden overcame this by taking advantage of their children on a Saturday morning by pumping all the drums full, which were then used throughout the week.

Technical problems did arise throughout the evaluations, and suitable adjustments were incorporated into the design. Changing from leather to rubber piston cups was a major adjustment that took place as a result of the fieldwork. The farmers were not able to keep the leather permanently wet, and it was therefore decided to make this modification. It is still unclear whether the frame should be small and compact for easier transport, or whether a permanent installation would be better. It is believed that there will be a need for both types, depending on the specific site.

None of the sites used the pump for anything else but irrigation. The applications usually involved filling up drums situated in the gardens. A few sites irrigated using a hosepipe and the Hazyview site filled drums for drip irrigation. The field evaluations did focus more on the technical aspects of the product, as that was the main objective. It is felt now that the design is finished, the applications side can be looked at in more depth. This will prompt redesign according to the needs of the people. This might include a high-pressure pump for water supply if the theory is correct that this is the priority for rural people.

In conclusion, it is recommended that the site selection for future introduction work be carefully carried out. This initial phase can determine the success or failure of the product. Sites where people are motivated and hard working, and are carrying out irrigation should be used. Sites where water is situated nearby a homestead are ideal, as would be the case where people are practicing rainwater harvesting.

3. Rural Manufacturing Research

3.1 Introduction

The initial intention when designing the kit treadle pump was to obtain a simple product that could be manufactured in rural areas. This would create a huge advantage when it came to future dissemination, as it would put the end user in close contact with the manufacturer. It would also cut out a number of role-players in-between that would potentially increase the cost of the pumps. It would create a new product for many manufacturers who are currently all manufacturing the same products, namely burglar guards, fences and gates. Rural manufacturing would also give the end users much more direct contact with the manufacturers which could then assist in providing spares and maintenance for the pumps. However, a number of disadvantages also follow this theory of rural manufacture, the most significant being the requirement for quality control. In order to keep this to a minimum it was decided that rural manufacturers would be supplied with kits containing all the required materials to manufacture the pumps. This would eliminate the possibility of incorrectly sized components or poor quality steel being purchased and used.

In order to test the practicality of rural manufacture, which would be the first of its kind in the treadle pump sector, a small workshop was held with a group of selected manufacturers. This chapter presents the outcome of this workshop and reports on the pumps that were made by these manufacturers. It also contains a copy of the manual that would be received by future manufacturers along with the kits, if this direction is to be followed.

3.2 Aims and Background

It was initially unclear as to the types of manufacturing skills in the rural areas, as well as the level of machinery that can be found there. The aim of this phase of the research was to hold a workshop in order to train a few selected rural welders to manufacture the treadle pumps, as well as to learn more about their skills and their ability to make a satisfactory, quality product. Five participants were randomly selected by merely observing their signs outside their welding stores and stopping to talk and demonstrate the pump. The following table presents the details on the participants.

NAME	AREA	CONTACT	EXPERIENCE
Shadrack Mariri	Jane Furse	072477 1979 013 265 1397	2 years
Elmun Nkosi	Riverside	0132989822	2 years
William Masernola	Lokgau	0825204482	6 years
Fannie Masha	Strydkraal	0721597716 0723457771	22 years
John Soki	Glen Cowial		1 year

The training workshop was held at the premises of Norman Mariri's welding shop in Jane Furse on the 21 November, 2002. It was a practical training session in which a pump was manufactured using the step-by-step guide. The participants were then each issued with a box kit containing all the components and materials to manufacture a pump. They also each received a manual, a copy of which can be found at the back of this report. The participants were then given a week to manufacture their own pump. These pumps were collected the following week and brought back to the Institute for inspection and durability testing. A payment of R200 for labour costs was made to each participant.

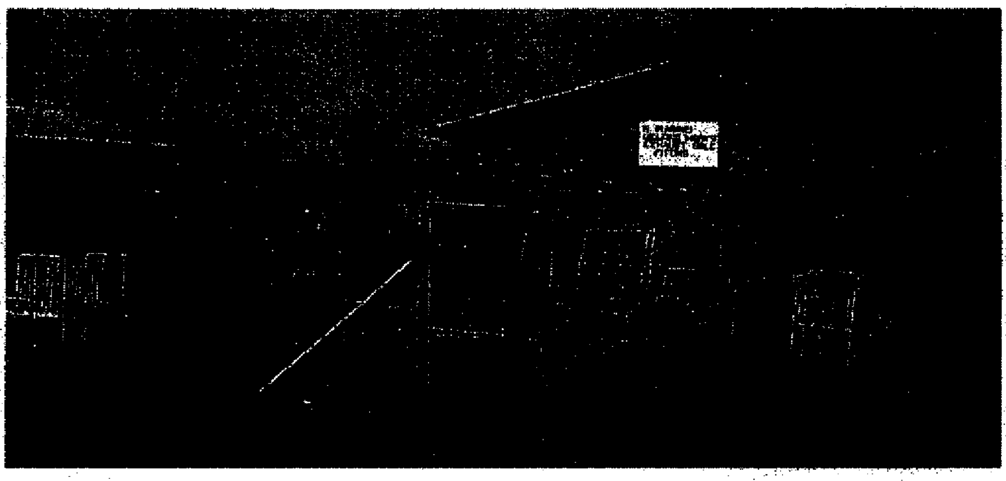


Figure 6. The welding shop where the workshop was held.

3.3 The Workshop

The training workshop began with a short discussion on the plan for the day. Details of each participant were obtained and the manuals were handed out. The PVC end caps were first glued onto the cylinders as the glue needed to dry while the pump was being made. The group then moved into the workshop to begin the training. The first step was to make the frame. All the components required to make the frame were taken out of the box and shown to the participants. The steel had already been cut to size and all the 20 mm holes and the slots in the treadles had already been drilled. This was because it was unclear before as to the extent of the machinery that would be available during the workshop.

The pieces that required drilling (42.5 mm holes) were then set aside. Mariri's welding shop had a drill press. It did not look as though it had been used before. The holes were then drilled, however this took a very long time. Perhaps the drill bits were blunt, or the drill was not strong enough. It showed that they would definitely not have been able to drill the 20 mm holes. This drilling and preparation phase took about an hour. The 8 mm holes were not drilled as they were not crucial to the pump's frame.

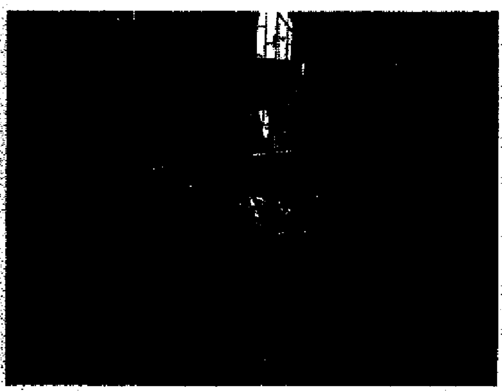


Figure 7. Drilling the holes.

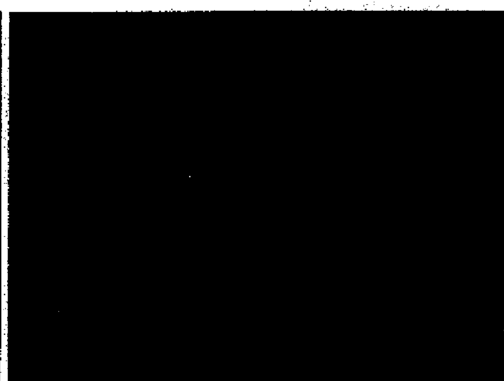


Figure 8. Lining up the frame.

The steps were then followed to manufacture the frame, The attendants appeared quite competent in their welding skills. The frame took about an hour to weld together. *There* was no workbench to work on so it was done on the floor. **A** sample pump was set up for the participants to view.

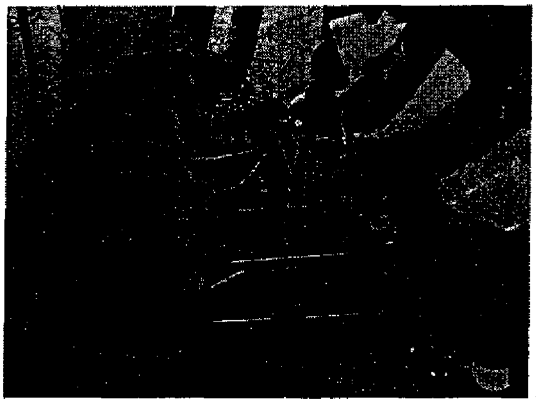


Figure 9. Final touches on the frame.

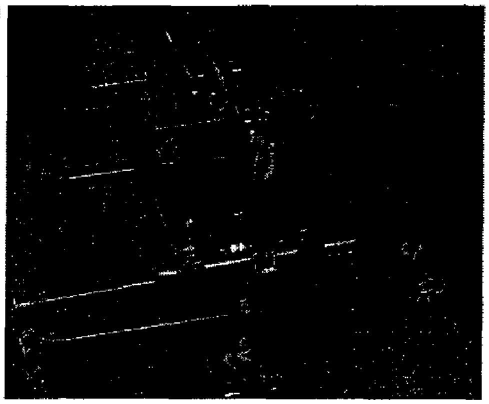


Figure 10. The completed frame.

The frame was set aside once it was completed in order to begin with the pump section. Again each component was taken out of the box and shown to the participants. The steps of the manual were followed. Care was taken to explain the importance of placing the **balls** in the correct place for the valves, **and** of tightening the clamps. The pump section also took about an hour to **assemble** and was then placed on the frame. The pistons **were** not made either in the workshop **or** individually **by** the attendants **as** the rubber cups were not yet ready at the time of the workshop.

Figure 11. Assembling the pump section.

Figure **12.** The participants and completed pump.

Two additional attendants from the next-door welding shop also took part in the training session **as** they were interested, however, **were** not given kits to build. The workshop was finished at about 12 pm after which Norman provided lunch for the participants. Discussions were held about the pump and the **kits** were handed over. It was decided after much debate that the trainee pump would be left at Norman's shop ***if*** any of the attendants wanted to use it as **an** example. It was also decided that a week would be sufficient time for them to complete their pumps.

The attendants all expressed their thanks for the training opportunity. Norman in particular stated that he was very glad for this technology, as they had virtually saturated the market with gates and burglar guards. He was very keen to get the final product and begin manufacturing and marketing the pumps.

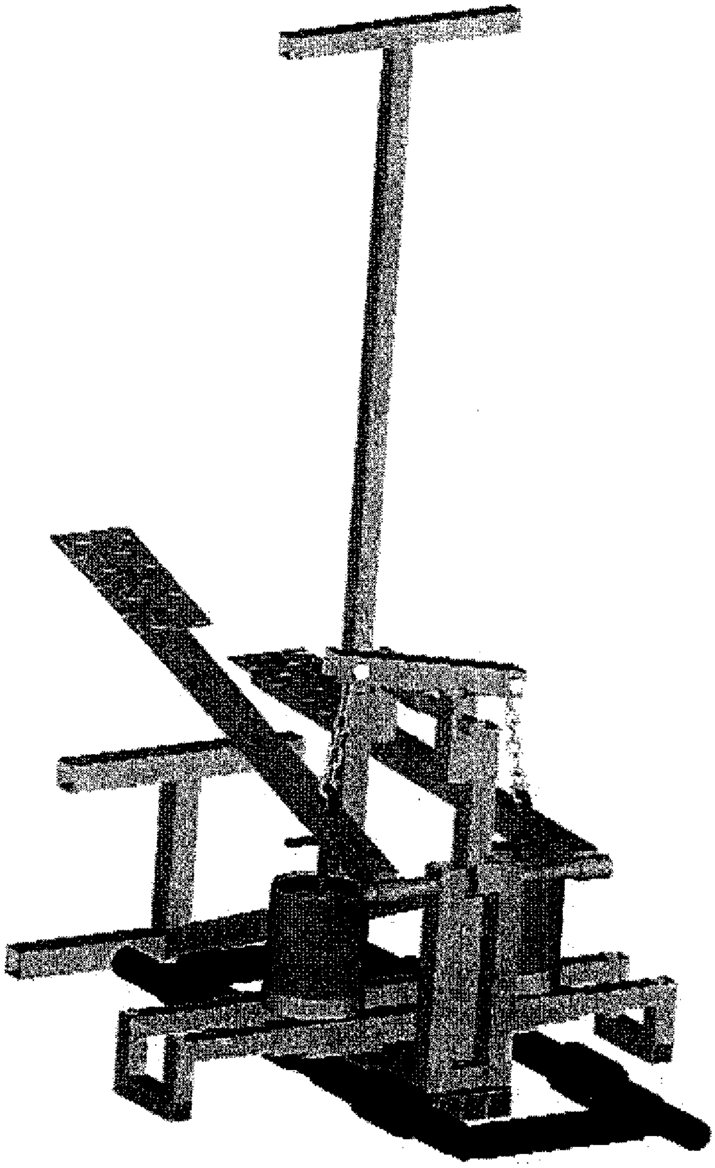
3.4 The Five Manufactured Pumps

The initial intention to allow one week for the pumps to be manufactured had to be changed after Nkosi and Soki had no power and could therefore not weld. The pumps were then fetched on the 4 December. Masemola phoned to say that he had finished with his pump within three days of the workshop. Masha did not finish his pump within the specified time as he had an order for toilets for a school that were required urgently before the hdidays were over. While Mariri stated on the phone that he had finished with his pump, it was not yet complete when we went to fetch it. It was not manufactured by his brother who had attended the course, but rather an employee from the workshop. Overall the pumps were made very well. A more in depth summary of each one can be seen in Appendix C. Nkosi and Soki built their pumps together as Soki did not have the correct equipment. All the manufacturers stated that they found the manual easy to follow.

5.3 Appendix C

5.3.1. Manufacturers Manual

A GUIDE TO MANUFACTURING THE KIT TREADLE PUMP



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This report has been written for individuals or organisations interested in manufacturing the kit treadle pump. The wording and layout has been kept simple so as to be understood by all manufacturers.

1. TABLE OF CONTENTS

2. INTRODUCTION

A treadle pump is a manual water pump designed for use by small-scale farmers. Treadle pumps are cheap to purchase and have very low running costs. They are also easy to maintain. The kit treadle pump designed by the Agricultural Research Council's Institute for Agricultural Engineering (ARC-IAE) is made from standard parts, which allows for easy assembly with very few tools. A list of the required tools is presented in the appendix. This report is a step-by-step guide to manufacturing the kit treadle pump. It is important that the steps are followed carefully to ensure a good quality product. The report is divided into three main sections, namely the frame; pump section and then final assembly. Each section begins with a materials list required *to* complete the section.

3. FRAME

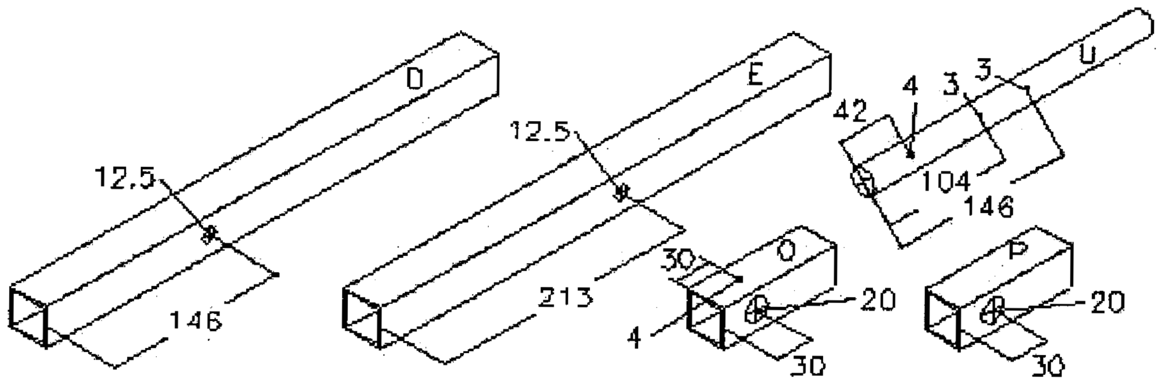
3.4 MATERIAL REQUIREMENTS:

Dimension (mm)	Description	Quantity	Length (mm)	Code
32 x 32 x 2	Mild steel square tube	3	700	A, B, C
32 x 32 x 2	Mild steel square tube	5	400	D, E, F, G, H
32 x 32 x 2	Mild steel square tube	3	300	I, K, L
32 x 32 x 2	Mild steel square tube	1	250	J
32 x 32 x 2	Mild steel square tube	2	80	O, P
32 x 32 x 2	Mild steel square tube	2	260	W
		TOTAL	5930	
25 x 25 x 1.6	Mild steel square tube	1	800	Q
25 x 25 x 1.6	Mild steel square tube	2	300	M, R
25 x 25 x 1.6	Mild steel square tube	4	200	a, b, c, d
25 x 25 x 1.6	Mild steel square tube	1	180	N
25 x 25 x1.6	Mild steel square tube	2	127	e, f
25 x 25 x1.6	Mild steel square tube	4	68	g, h, i, j
25 x 25 x1.6	Mild steel square tube	1	45	Z
		TOTAL	2951	
12 x 12	Mild steel square bar	4	100	S
20	Mild steel bright steel	1	220	U, T
20	Mild steel bright steel	1	280	
27 x 3	Mild steel hollow tube	3	40	V
6	Mild steel round bar	4	30	X
3	Mild steel tread plate	2	100 x 200	Y
20, class 3	Polyethylene pipe	3	80	
M12	Galvanised bolt	2	90	
M12	Galvanised nuts	4		
M12	Galvanised washers	4		
M8	Galvanised bolt	1	30	
M8	Galvanised nut	1		
	Primer			
	Paint			

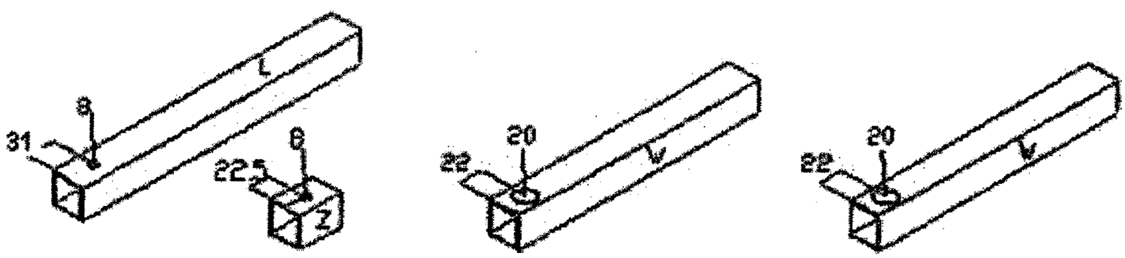
3.2 PREPARATION: DRILL AND CUT

DRILL:

1 x 400 mm: O 12,5 mm hole, 146 mm from end. (D)
1 x 400 mm: O 12,5 mm hole, 213 mm from end. (E)
***2* x** 80 mm: O 20.5 mm hole, 30 mm from end. **(O,**P)
1 x 80 mm: O **4** mm hole, 30 mm from end. **(O)**
1 x **220** mm bright steel: *O* 4 mm, 42 mm from end. **(U)**
1 x **220** mm **bright steel:** O 3 mm, 104 mm and 146 mm from **end.** (U)



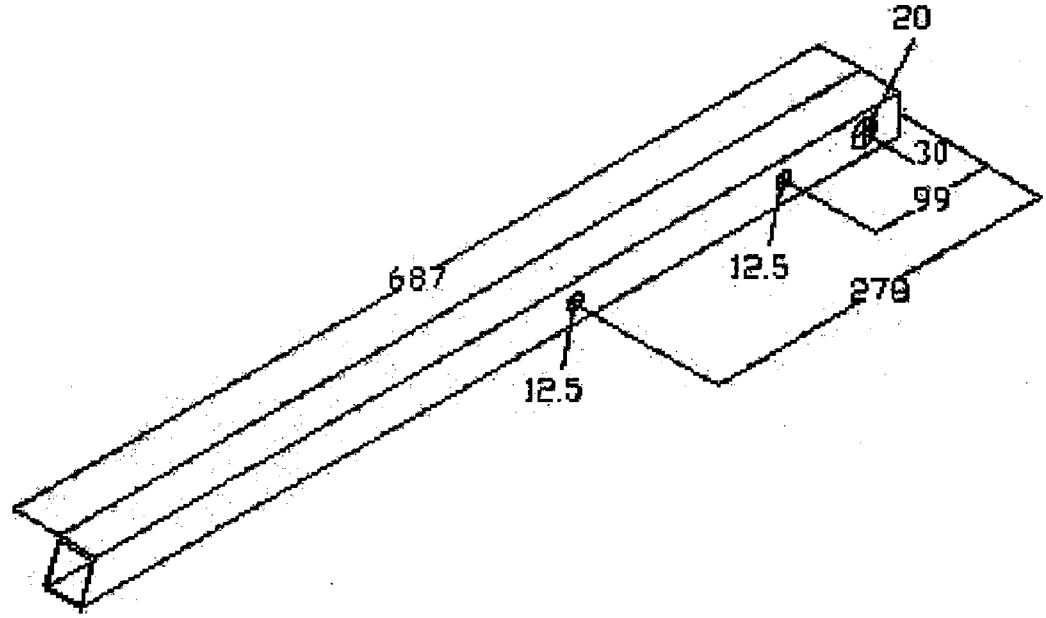
1 x 300 mm: *O* ***8.5*** mm hole, 31 mm from end. (L)
1 x 45 mm **(25x 25):** *O* **8.5**mm hole in centre. **(Z)**
2 x 260 mm: *O* 20.5 mm hole 22 mm from end. (W)



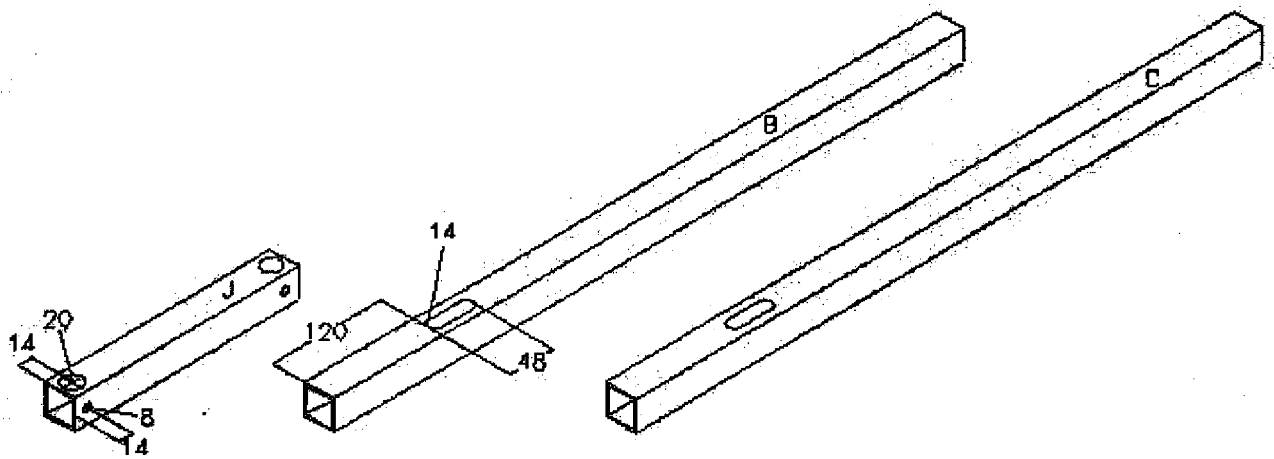
CUT AND DRILL:

Angle the 700 mm piece (A) such that the one side measures 687 mm and the other measures *700* mm.

Drill two *O* 12.5 mm holes 99 mm and *278* mm from the non-slanted end. Drill one *Θ* 20.5 mm hole 30 mm from the non-slanted end.

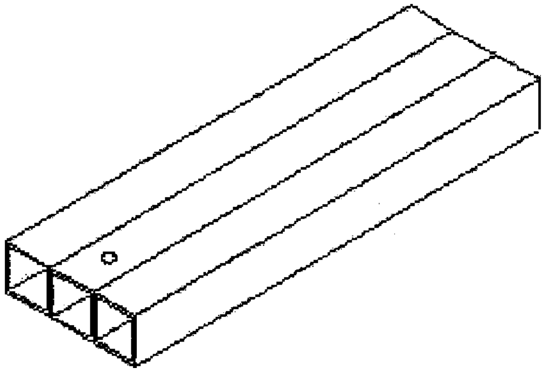


Drill two *Θ 8.5* mm (right through) and two *O* 20.5mm holes (not right through) in the 250 mm piece (J), 14 mm from each end as shown. Cut a 14 mm wide slot of length 48 mm in each of the remaining 700 mm (B & C) pieces from 120 mm from one end.

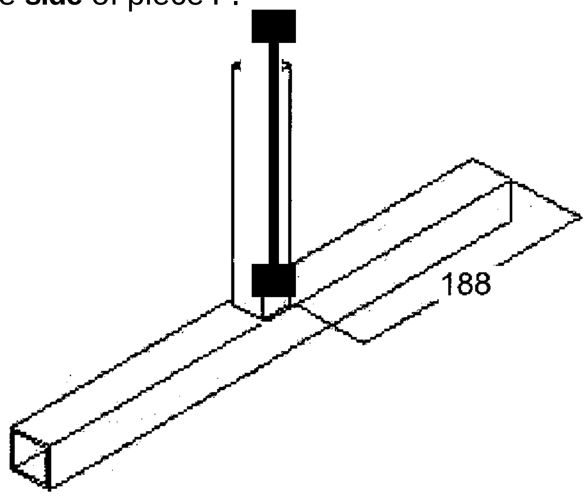


3.3 WELD:

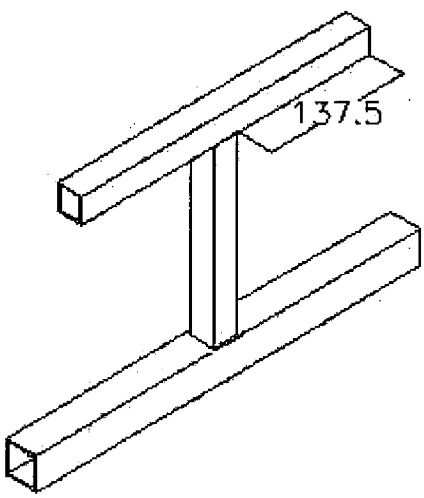
3.3.1 Weld three *300* mm (I, K, & L) pieces together, the piece with the **O** 8.5 mm hole **in** the centre.



3.3.2 Weld the 180 mm (N) piece vertically to **a** 400 **mm** (F) piece as shown. Piece N **should be** flush **with** one **side** of piece F.

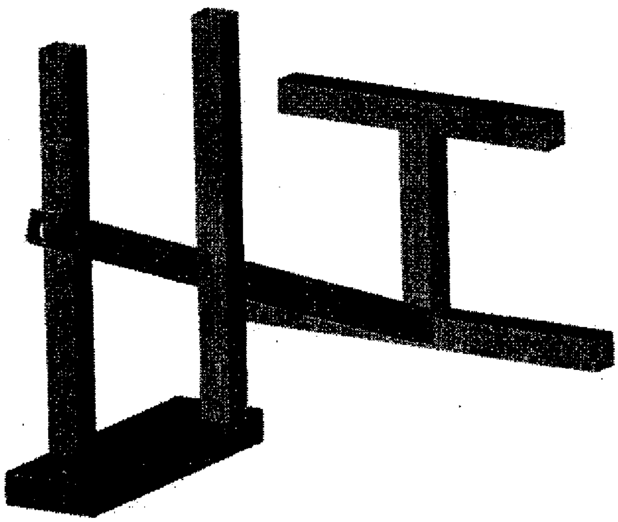


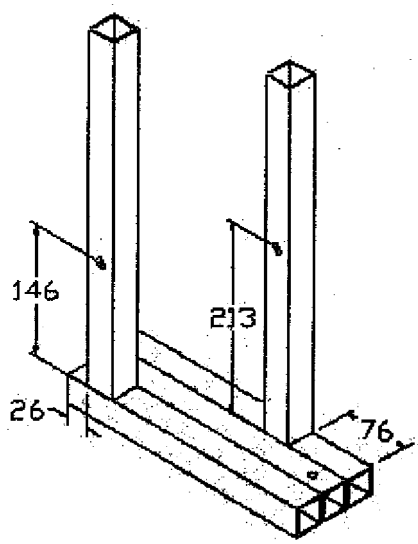
3.3.3 Weld the 300 mm piece **(M)** horizontally to the **180** mm piece **as** shown.



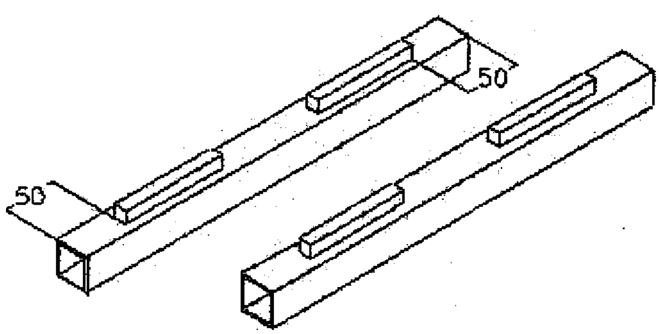
3.3.4 Weld piece A to the section from the previous step (clause 3.3.3). Note the 5 mm gap on the drawing.
Hint: Use a piece of 5 mm flat bar to level the 5 mm gap.

3.3.5 Line up pieces D and E with the piece from the previous step (clause 3.3.4) using the M12 bolts. Square them and weld them to the piece from the first step (clause 3.3.1) as shown, 26 mm from one end and 76 mm from the other.

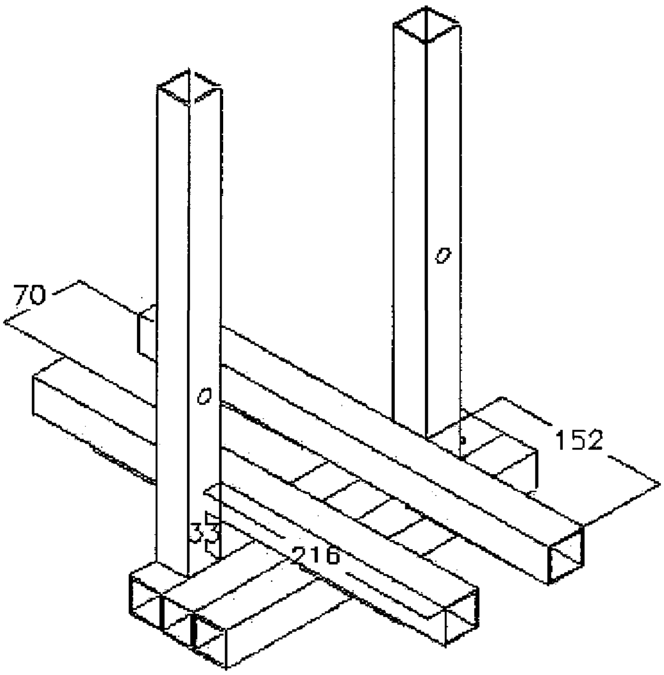




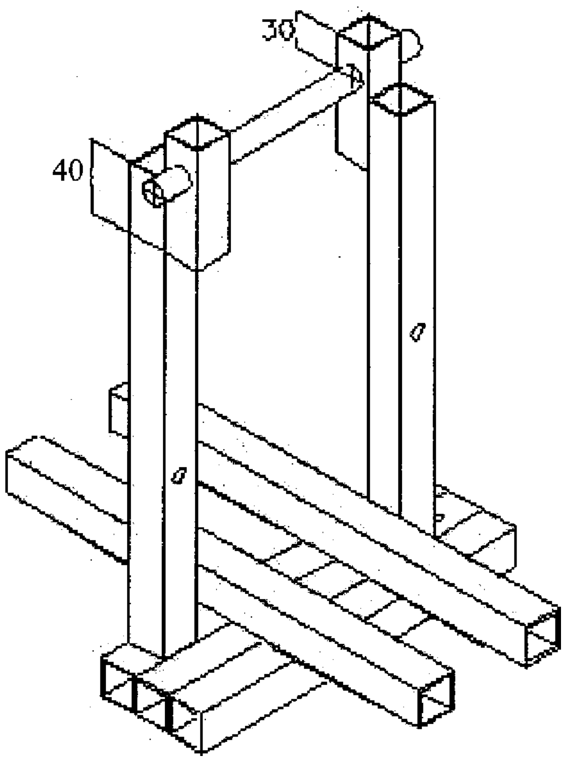
3.3.6 Weld *the* 12 x 12 square bar (S) onto the remaining two 400 mm pieces (G & H) as shown.



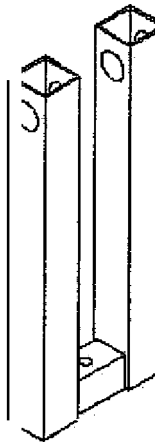
3.3.7 Weld the pieces from the previous step (clause 3.3.6) onto the main section from clause 3.3.5 as shown. The pieces should **be** levelled such that the bottom of pieces *G* and **H** are ***33*** mm above the top of piece **L.**



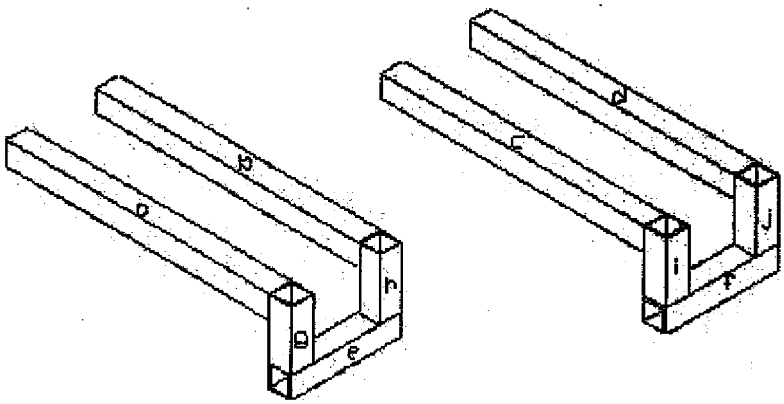
3.3.8 Line **up** the two 100 mm pieces (**O**& P) with **the O** 20 mm bright steel shaft (**U**) as shown. Weld the two 80 mm pieces *to* attach.



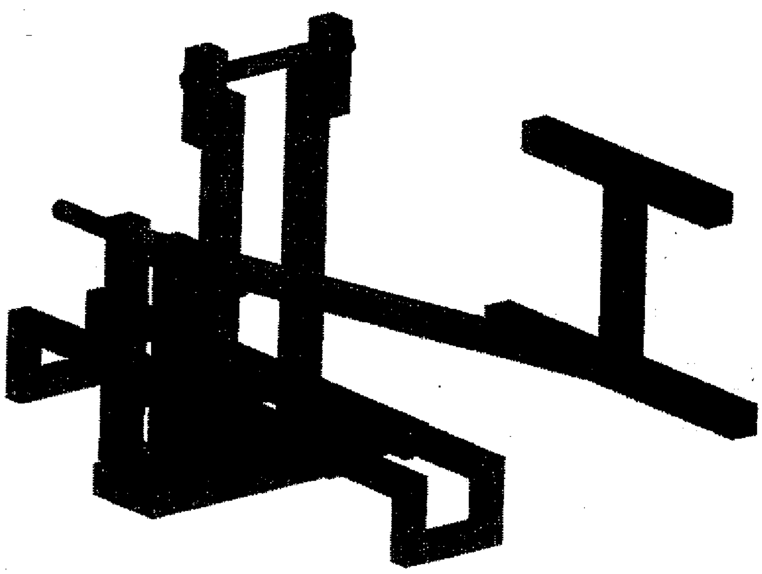
3.3.9 Weld parts **W and** ***Z*** **together as shown below.**



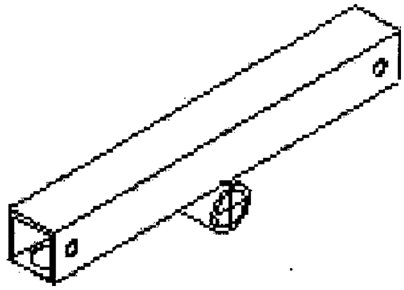
3.3.10 Weld parts a, b, g, h and e and **parts c, d, i, j** and **f together as shown below.**



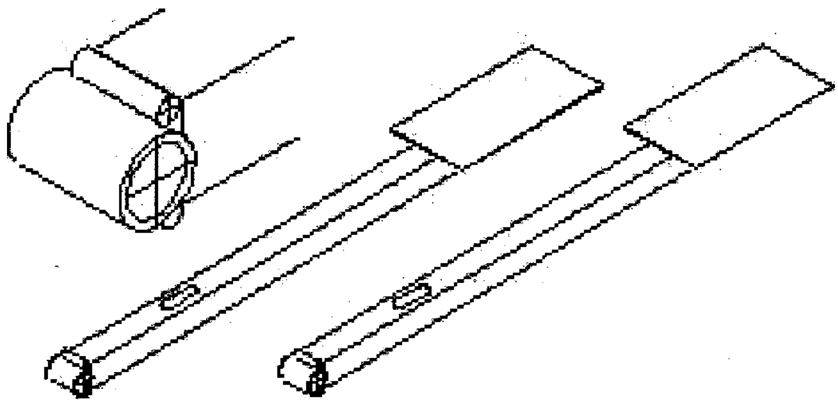
3.3.11 Attach the piece **from step 9** to **the rest of** *the* frame **using the M8 (30 mm) bolt through piece** L. **Place the 300 mm shaft** (T) **through the** *O* **20 mm holes in the piece from clause 3.3.9 and piece A and** secure **with 6 spot welds. Assemble the** frame **again as shown below.** The **pieces from clause 3.3.10 slide into parts G and H to make the frame** more **stable.**



3.3.12 Weld one of the pieces of the 27 x 2 hollow tube onto the centre of the 250 mm piece **(J)** on the same side as the two 20 mm holes.

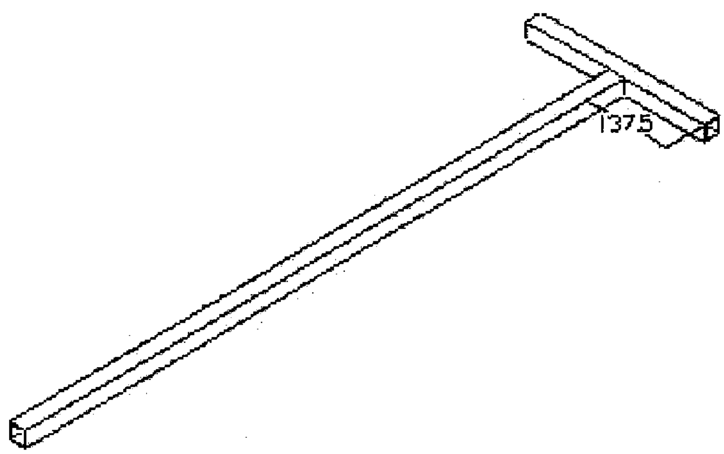


3.3.13 Weld the other **two** pieces of hollow tube onto th 700 mm square tube pieces (B & C) and strengthen with the O *6* mm round bar as shown. Weld the treadle plate onto the other side of the pieces.



3.3.14 Complete the three bushes of clauses 3.3.12 and 3.3.13 by placing the O 20 mm polyethylene pipe inside the 27 x 2 mm hollow tube. Lubricate the pipe first with oil to make it easier to slide inside the tube and then hit the pipe inside with a hammer. **Cut** off the **excess** pieces of polyethylene **pipe** that protrude.

3.3.15 Weld piece Q to the centre of piece R as shown to make a handle.

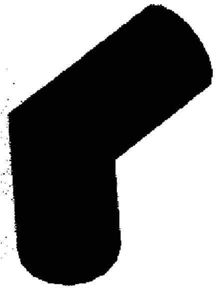


3.3.16 Paint the steel sections of the frame using a primer.

4.1 MATERIAL REQUIREMENTS:

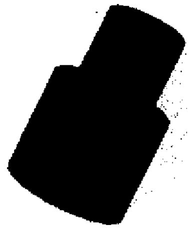
Dimension	Description	Quantity	Length
M12	Gate Hanger	2	300 mm
M12	Nuts	8	
12	Round bar	2	30 mm
32	Clamps	20	
50	Clamps	8	
32	Polyethylene pipe	Class 3	1,1 m
50	Polyethylene pipe	Class 3	0,5 m
	PVC weld	1 tin	

Ø 32 mm nylon fittings

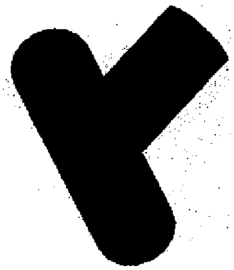


2 x elbows

2 x female T-pieces

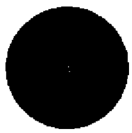


8 x *O 50* – *O* 32 reducers

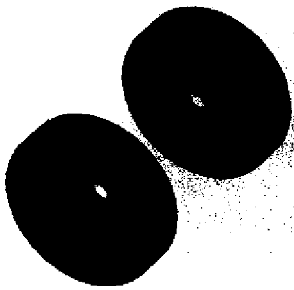


2 *x* T-pieces

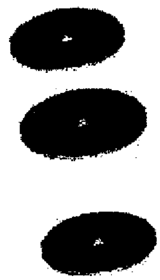
4 x *55* mm *O* 3mm wire



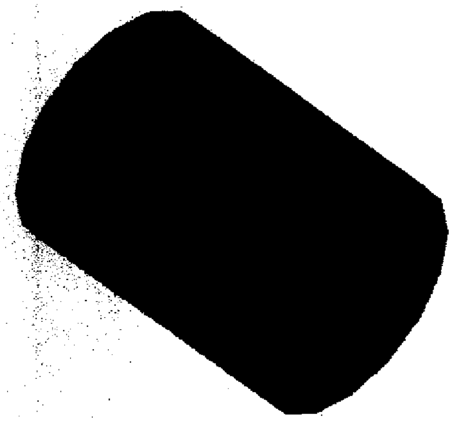
4 x *O 36* mm rubber balls



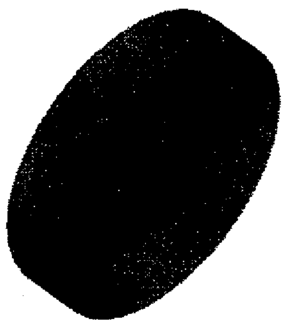
4 x rubber cups



4 x *O* 87 mm steel discs
2 x *O* 98 mm steel discs



Class 12 PVC pipe

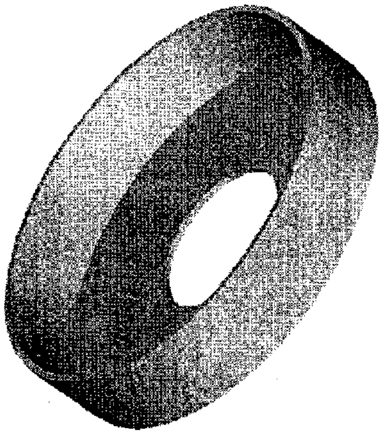


2 x *O* 110 mm PVC end caps

2 x Ø 32 mm tank connectors

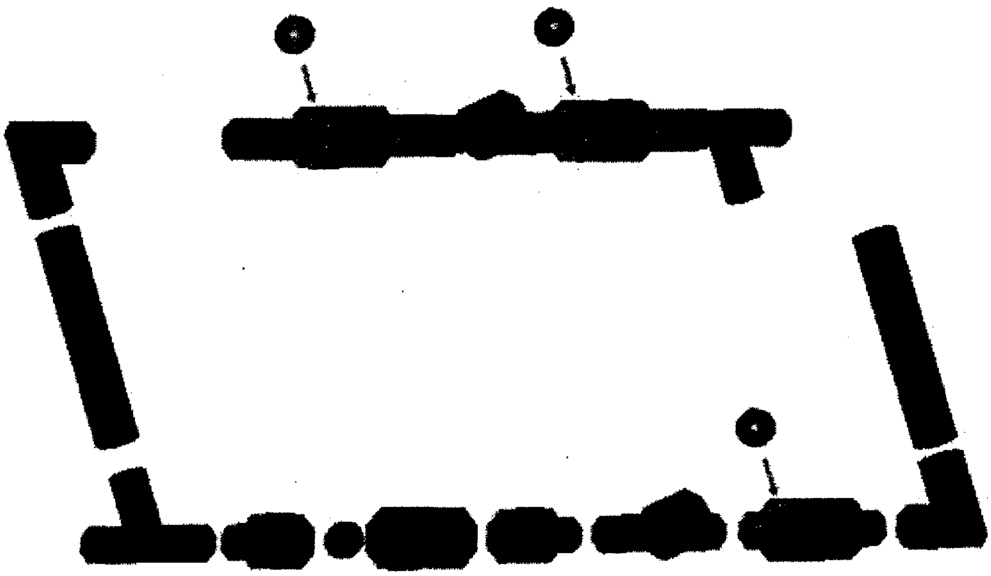
4.2 ASSEMBLY

4.2.1 Cut a hole of Ø **41** mm in the two PVC **end** caps.

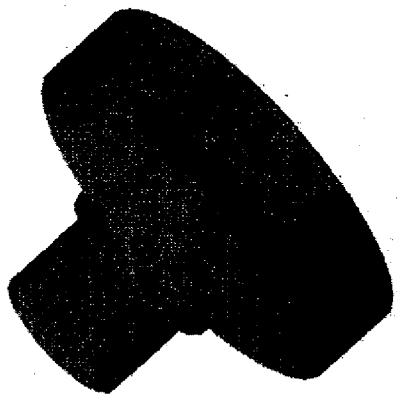


4.2.2 Drill two, Ø 3 mm **holes** in four of the nylon reducers, about **4** mm in from the edge. Place the **ball** inside the fitting and then the wire through the holes to secure in place.

4.2.3 Assemble the nylon fittings with polyethylene pipe as shown below. Secure tightly with the clamps. It **is** very.important that the balls are **positioned** as shown.

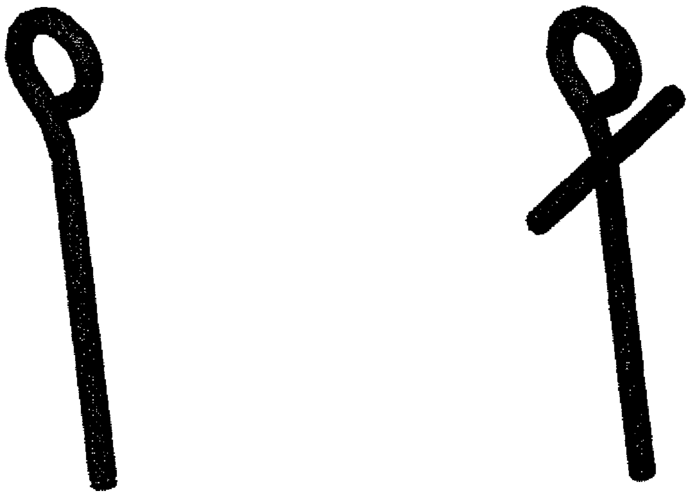


4.2.4 Place the tank connectors through the holes in the PVC end caps and tighten with a pipe wrench.

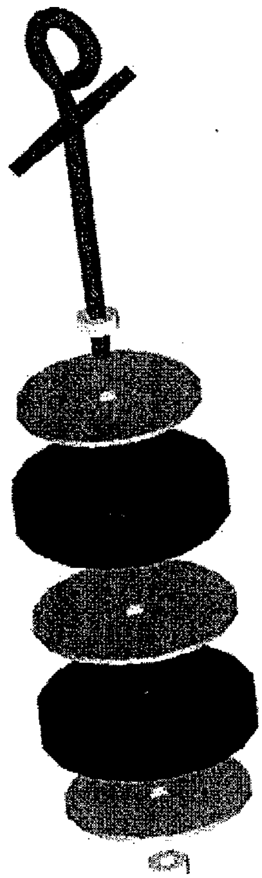


4.2.5 Use PVC **weld glue (high pressure) to secure the end caps to the PVC pipe. The surfaces should be roughened with sand paper first. The glue should be left for 24 hours** to **set.**

4.2.6 Cut the gate hangers to a total length of 150 mm. Weld the **Ø 12** mm round bar to the gate hanger a distance of 50 mm from the top **as** shown below.



4.2.7 Make two pistons **by** placing the steel discs and the rubber **piston** cups onto the gate hangers and securing with nuts as shown in the diagram below. The *O* 98 mm **disc** goes *between **the*** **rubber cups** with the O 87 mm discs inside each rubber.



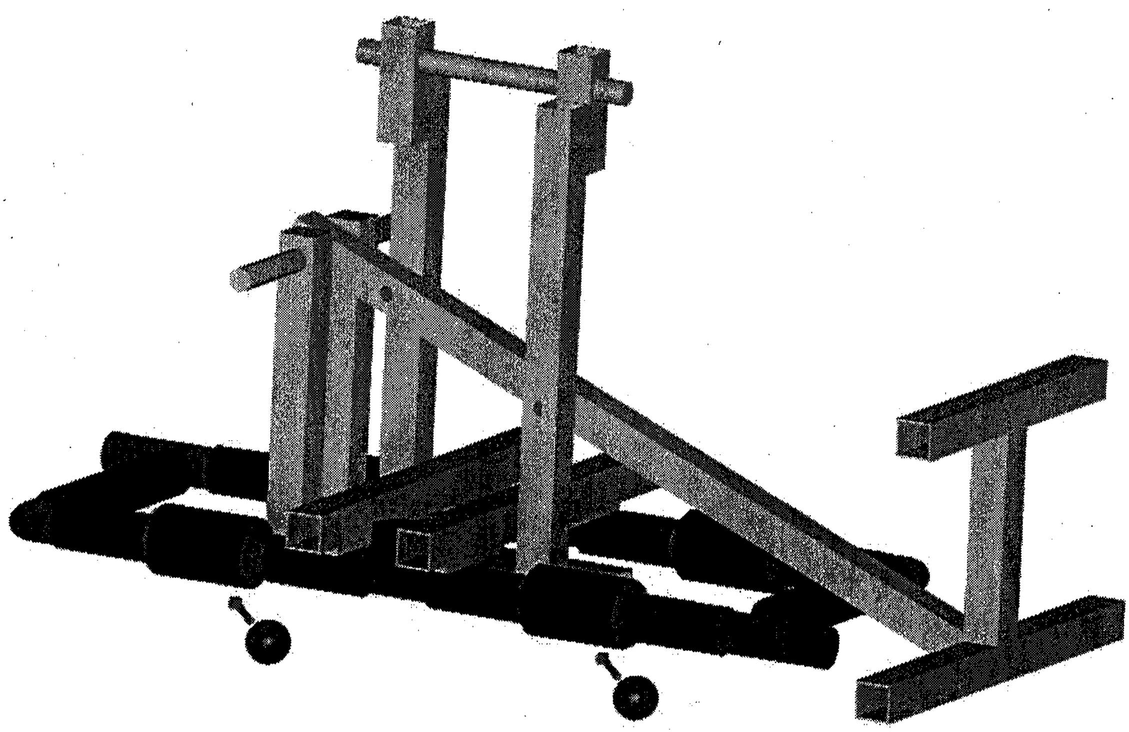
5. FINAL ASSEMBLY

5.1 MATERIAL REQUIREMENTS:

Dimension	Description	Quantity	Length
2	Split pins	2	50 mm
M4	Bolt	1	50 mm
M4	Nut	1	
M8	Bolt	2	50 mm
M8	Nuts	4	
	Chain		
	D Shackles	2	
	Thread tape		

5.2 ASSEMBLY

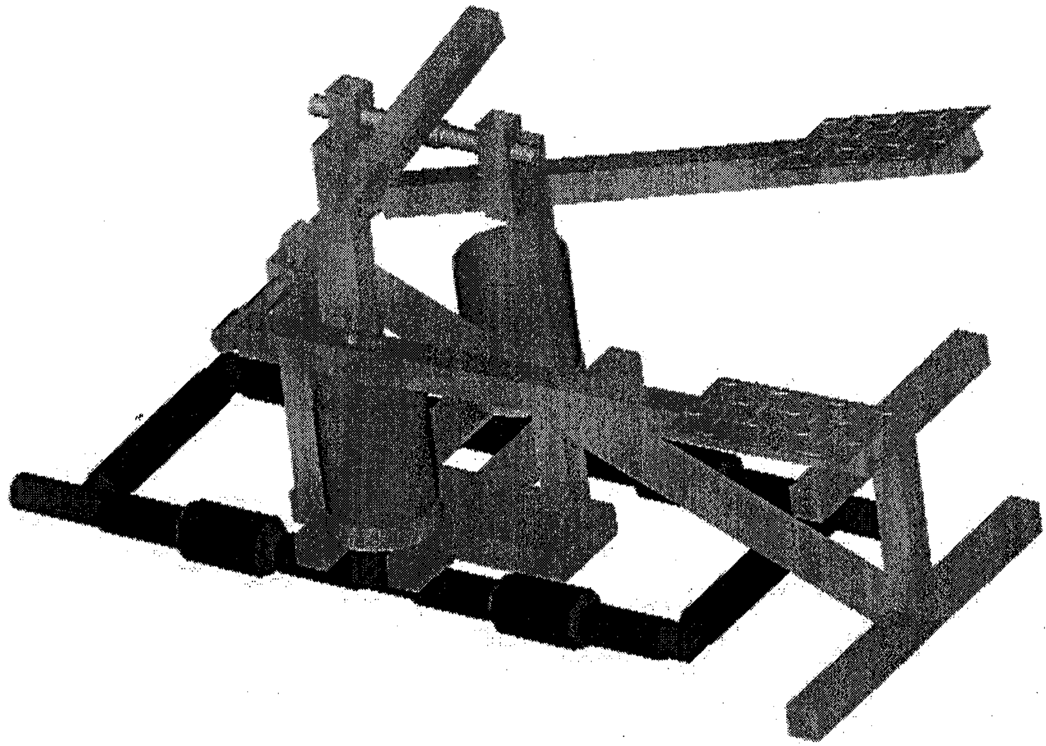
5.2.1 Place the pump section onto the frame such that the balls are all closest to the back section of the frame (the I piece). The female T-pieces should sit in between parts G and H of the frame, in the centre.



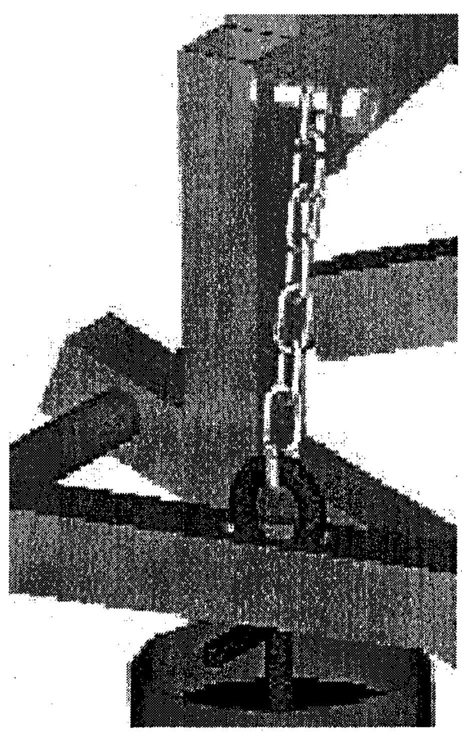
5.2.2 Place thread tape around the thread of the tank connectors and then screw the tank connectors tightly into the female T-pieces so that the end caps of the cylinders rest on parts G and H of the frame.

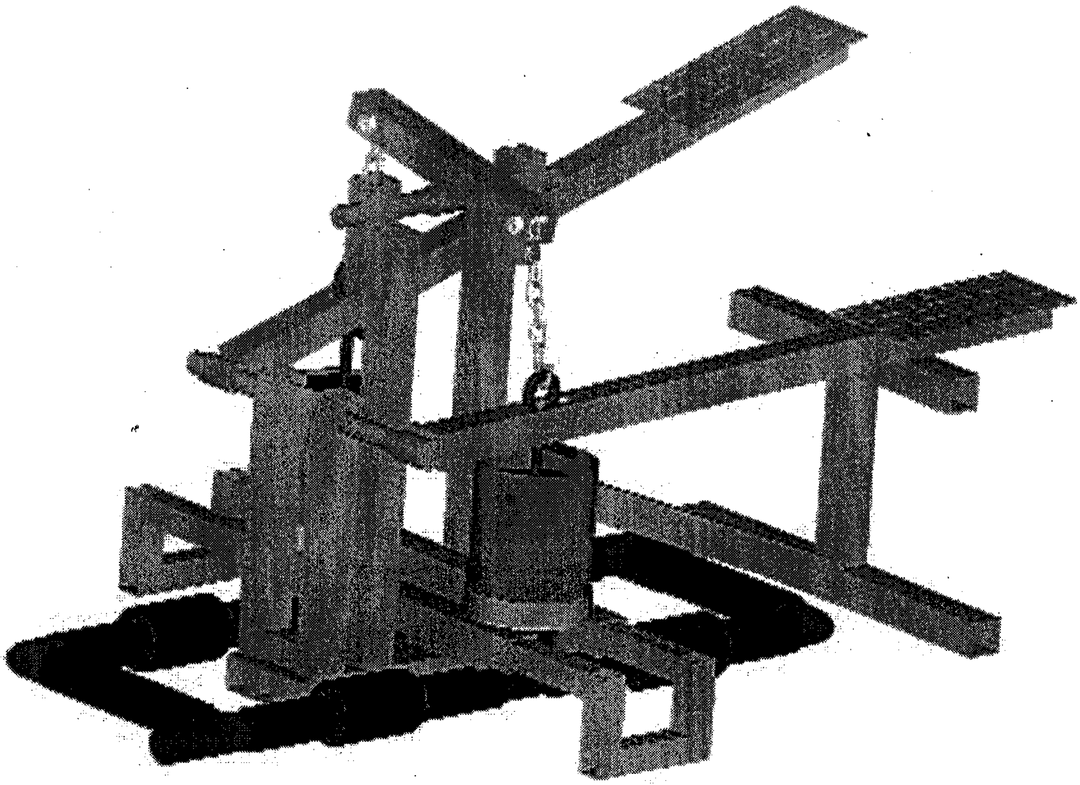
5.2.3 Place the bush of the rocker arm (M) through the shaft (U) and secure on either side with a split pin.

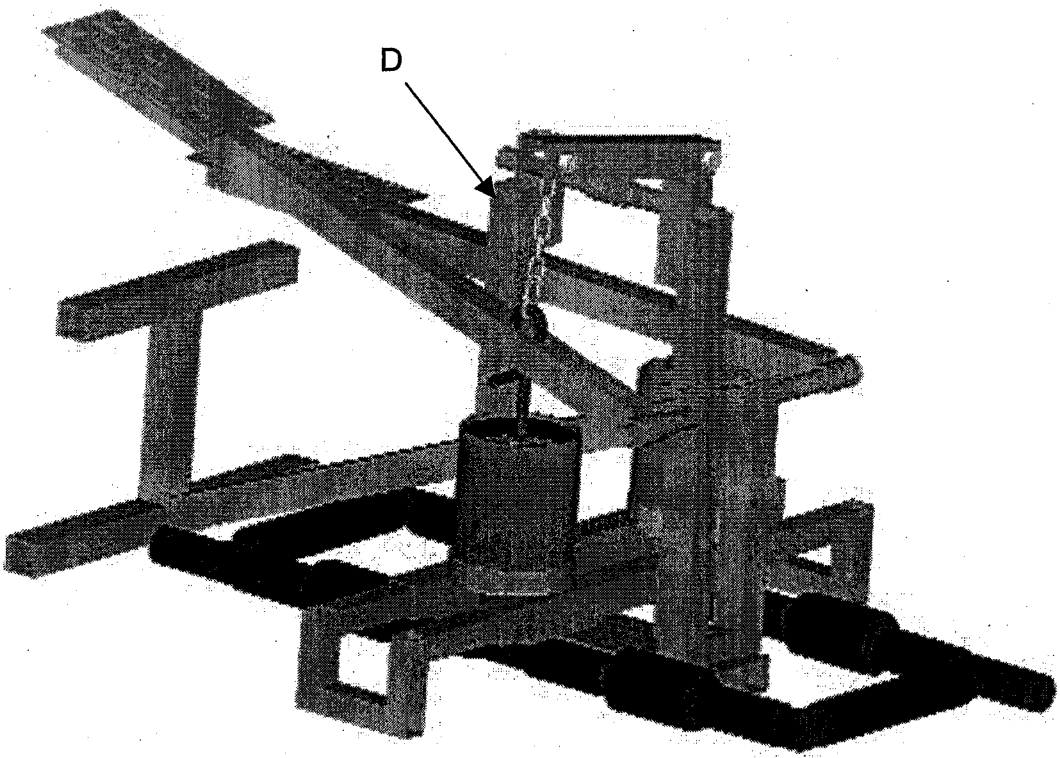
5.2.4 Place the bushes of the treadles (B & C) through the shaft T so that the slots are directly above the cylinders.



5.2.5 Place the pistons into the cylinders so that the top of the gate hanger goes through the slot in the treadles. Attach the chain to the eyebolts with the shackles. Attach the other end of the chain to the rocker arm by placing the last link through the O 20 mm hole and securing with the M8 (50 mm) bolts.







5.2.6 Place the handle into the upright piece D.

6. APPENDIX

TOOLS REQUIRED

Manufacturers have two options when building the kit treadle pump. They can either purchase their own materials, in which case they would be required to cut them to size and drill all the holes. They can also purchase a kit form of the pump, where by all the materials required to build the pumps are placed in a box. The steel has already been cut to size, and the machine work for the more complicated sections has already been completed. The following table presents the tools required to manufacture the pumps for the two different options.

DESCRIPTION	SIZE	REQUIRED FOR	KIT	OWN MATERIALS
Cut off machine		Cutting steel		*
Bench Grinder		Neaten up edges		*
Drill press		Drilling holes		*
Tape measure		Measuring holes	*	*
Drill bits	∅ 12.5	D, E, A	*	*
	∅ 4	U	*	*
	∅ 3	U, valves	*	*
	∅ 20.5	O, P, A, W, J		*
	∅ 8.5	L, Z, J	*	*
Milling machine	∅ 14	Slots		*
Welding machine		Welding frame	*	*
Welding helmet		Welding	*	*
Square		Frame	*	*
Spanners	19 mm	M12 bolts	*	*
	15 mm	M8 bolts	*	*
	7 mm	Clamps	*	*
	8 mm	Clamps	*	*
Angle Grinder		Cut Tread plate Neaten up welding	*	*
Hole saw		End cap hole		*
Hand drill		Hold hole saw		*
Pliers		Cut wire		*
Hacksaw		Cut pipe, eyebolts	*	*
Rubber mallet		Insert fittings	*	*
Flat screw driver		Clamps	*	*
Pipe wrench		Tank connectors	*	*
Bolt cutter		Chain		*
Bench vice		Pistons	*	*
Compressor		Spray painting	*	*
Spray gun		Spray painting	*	*