DTU

Ram pump programme

Computerised ram pump calculators
A short user guide

TECHNICAL
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RELEASE

DTU Ram Pump Programme

Computerised calculator programmes

These programmes are supplied as "Freeware", which means that the DTU reserves no copyright. You can copy and distribute the programmes as much as you like — as long as you do not charge any money for doing so. Please do not change the programme code in any way.

Although every effort has been made to ensure that this software performs correctly and that its documentation is accurate, the DTU accepts no liability whatsoever for errors contained herein or incidental consequences resulting from the use of this material. Disks are checked for viruses before leaving the DTU, but no guarantee of non-infection can be made after the first use.

Microsoft Windows is a trademark of Microsoft Corp®.

Hardware requirements

The minimum hardware requirement for these programmes is an IBM compatible PC with an 8088 processor. If you have the minimum requirement, only the DOS programme DOSPUMP will run. Although all three programmes should work on an IBM compatible machine with an 80286 processor running Windows 3, we recommend that the Windows programmes are used on an IBM compatible machine with at least an 80386 SX processor and four megabytes of RAM that is using Microsoft Windows 3.1 (or later versions).

Contents

1. Calculator Installation

There are three programmes on the 720k 3.5" disk inside the cover of this book. Two of them must be installed on a hard disk and run under Microsoft Windows®. The third programme runs under DOS and can be run from the floppy disk drive or installed onto a hard disk.

The two Windows programmes are:

WINPUMP
PUMPDATA

The DOS programme is:

DOSPUMP

You will not need to use both the Windows and the DOS programmes because they do the same thing. If you have a version of Microsoft Windows® on your computer, do not bother to install DOSPUMP as well as the other programmes.

1.1 Installing the Windows ram pump programmes

To install the ram pump programmes that run under Microsoft Windows® insert the disk in the floppy disk drive, then type the letter identifying the drive, followed by a colon (:).

For example:

A:

Then press the [Return] key.

The [Return] key is also called the [Enter] key and often has an arrow on it, like this ↵.

Type **PWIN** followed by the letter identifying the hard disk drive being used, a colon (:) and a backslash (\), and the directory name **DTUPROGS**, which is where the programmes will be installed.

For example:

PWIN C:\DTUPROGS

Then press the [Return] key.

When the programmes have been installed, a message appears advising you that installation is complete and telling you to press any key to continue.

Press the space bar.

The Windows programmes have now been copied to your hard disk, but Microsoft Windows® does not know this. The next stage of installation tells Microsoft Windows® that they are there and installs them as Icons at the Microsoft Windows® Programme Manager screen.

To do this, type the letter identifying the hard disk drive where the programmes have been copied, followed by a colon (:).

For example:

C:

Then press the [Return] key.

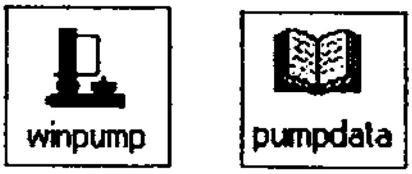
Type **CD\DTUPROGS** and press [Return] to change to that directory on your PC.

Type **SETUP** and press the [Return] key.

Microsoft Windows® starts and the DTU programme installation window appears. The DTU programme installation window has two buttons:- OK and EXIT.

Use the mouse to click on the OK button to start the installation.

The programmes are installed in a few seconds with progress being shown in the bar above the control buttons. A programme group called DTU programmes is created under Microsoft Windows' Programme Manager, and the DTU Windows programmes are installed there with these icons.



1.1.1 To run the Windows DTU calculator programmes — WINPUMP and PUMPDATA

Start Microsoft Windows® and click the mouse on the icon for the programme that you want. Click twice quickly (using the left mouse button) to run the chosen programme.

1.2 Installing the DOS DTU ram pump calculator programme — DOSPUMP

To install the ram pump calculator that runs under DOS, insert the disk in the floppy disk drive, then type the letter identifying the drive, followed by a colon (:).

For example:

A:

Then press the [Return] key.

Type **PDOS C:\DTUPROGS**

When the programmes have been installed, a message appears advising you that installation is complete and telling you to press any key to continue.

Press the space bar.

If you do not have a hard disk, the programme can be run from the floppy disk.

1.2.1 To run the DOS DTU calculator programme — DOSPUMP

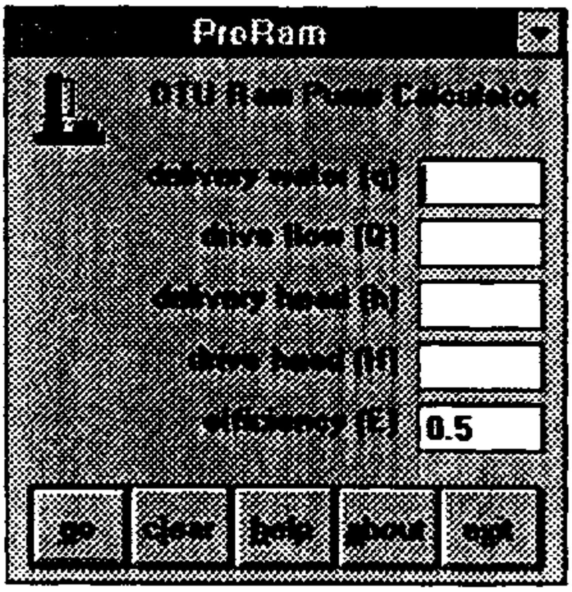
There are two ways to run this programme — from the hard disk or the floppy disk.

Running from the <u>hard disk</u>	Running from the <u>floppy disk</u>
Type the letter identifying the hard disk drive where the programmes have been copied, followed by a colon (:).	Put the floppy disk into the drive, then type the letter identifying the floppy disk drive, followed by a colon (:).
For example:	For example:
C:	A:
Then press the [Return] key.	Then press the [Return] key.
Type **CD\DTUPROGS** and press [Return] to change to that directory on your PC.	Type **DOSPUMP** and press [Return] to start the programme.
Type **DOSPUMP** and press [Return] to start the programme.	

2. Using the DTU programme WINPUMP

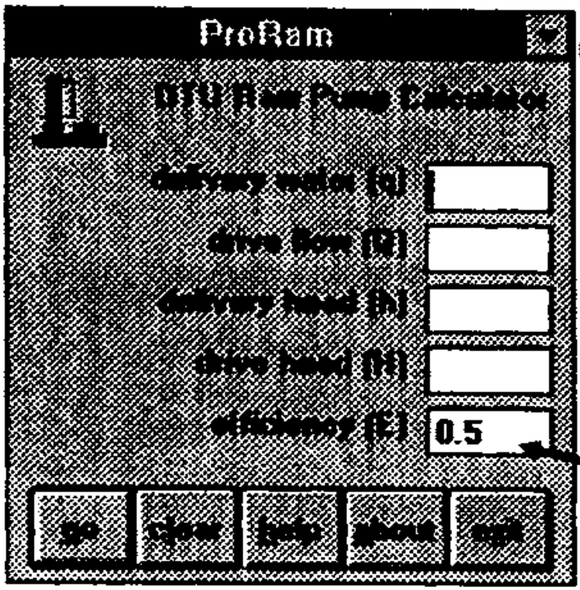
When you click on WINPUMP the ProRam window opens. This window is used to enter variables to work out the equation: $E\ (Eta) = \frac{q\ h}{Q\ H}$.

This is the ProRam window:



efficiency (E) 0.5

Winpump is used by filling in any four of the variables for a ram pump system, (Q,q,H,h, and E) and clicking on the GO button. The missing variable is then provided for you.



Use this button to "minimise Winpump, but leave it running in the background behind other programmes.

When you have made an entry in one box, press the Tab key to move to the next box (or use the mouse to click on it.

You can change the value given for "efficiency" if you know that your pump has a higher or lower value. The value is expressed as a fraction of 1, so a 75% pump efficiency would be typed in as 0.75.

The buttons each have one letter underlined. Each button makes something happen, and it can be made to do this by either typing the underlined letter, or clicking on it with the mouse.

If you are using more than one pump, always remember to divide the drive flow between them before calculating.

When you have made one calculation and wish to make another, click on the "clear" button. All the values will disappear, except for 0.5, which is the default pump efficiency.

If you want to know the pump efficiency of an existing system, delete the entry for efficiency and fill in the other variables, then click on the GO button.

To leave WINPUMP, click on the "exit" button, of type the letter X.

WINPUMP's usefulness is limited, but it can be very handy for making quick calculations of the effect of changing parts of a system's design. For example, you can quickly find out what difference it would make to the delivery flow if you added a metre to the drive head or reduced the drive flow.

An example is when a system design is actually going to deliver more water than is needed and by varying the entries for drive head and delivery head we can see whether we could save money on the drive pipe, or deliver to a point high enough above the originally planned delivery tank for the excess to be usefully gravity fed to a garden plot.

DOS users will find that the DOSPUMP programme is a very similar calculator to WINPUMP. It looks different because it runs under DOS, but it does the same things.

3 Using the DTU programme PUMPDATA

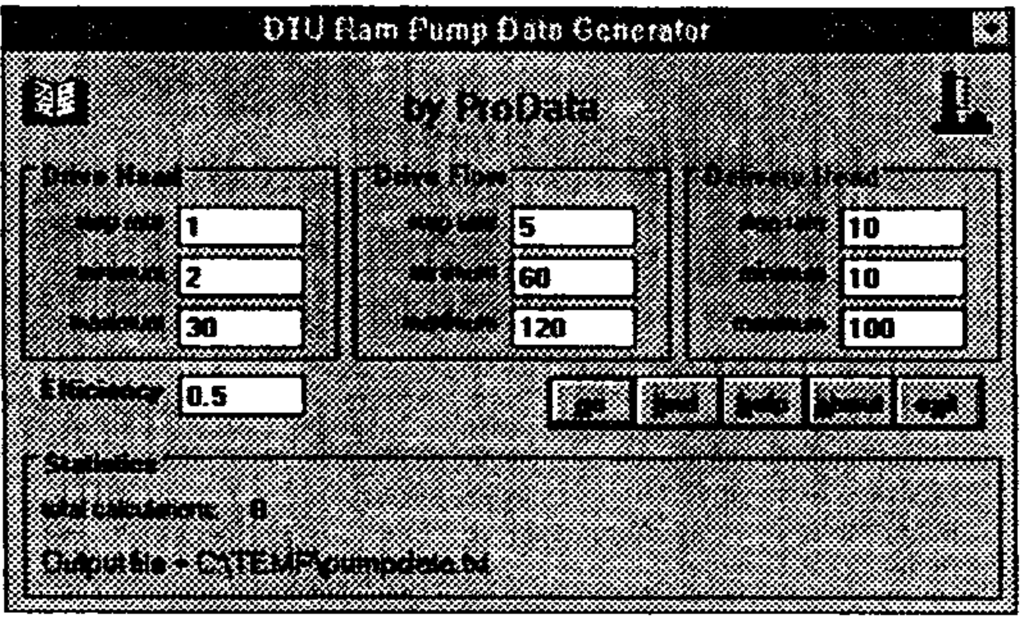
When you click on PUMPDATA the DTU Ram Pump Data Generator window opens. This window is used to enter variables to work out the equation

$$q = \frac{\eta Q H}{q h}$$

for a wide range of conditions. All possible answers within the ranges given are calculated. The range of results can then be sorted and printed.

This is the DTU Ram Pump Data Generator window:

A range of values for the Drive Head (H), Drive Flow (Q) and Delivery Head (h) are calculated for a particular pump efficiency. If you know the efficiency of the pump in use, begin by changing the efficiency value (which is given as 0.5 or 50% by default).



Drive Head
step rate 1
minimum 2
maximum 30

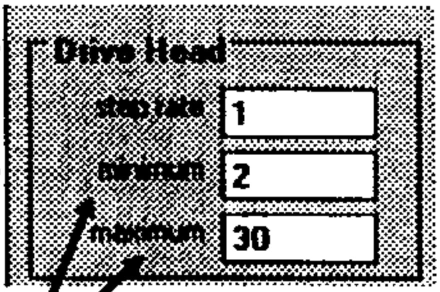
Drive Flow
step rate 5
minimum 60
maximum 120

Delivery Head
step rate 10
minimum 10
maximum 100

Efficiency 0.5

Statistics
total calculations: 0
Output file = C:\TEMP\pumpdata.txt

When the efficiency has been set, the "Drive Head" figures are entered (in Metres).



Drive Head
step rate 1
minimum 2
maximum 30

The "step rate" is the amount by which the value is advanced for each set of recalculations. For example, with a step rate of 1, the Drive Head will be calculated for every value between the minumum of 2 and the maximum of 30 (whole numbers only). If the step rate is changed to five, the minimum number will be advanced in fives to the maximum.

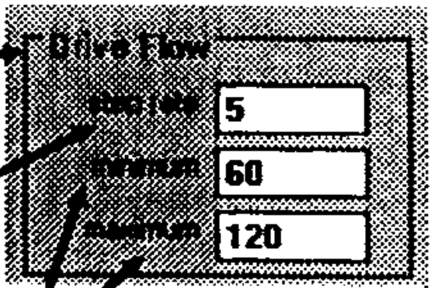
Change the step rate to a bigger figure to reduce the number of calculations carried out if your computer is very slow.

Change the minimum and maximum Drive Head to those available at the site being calculated.

When the "Drive Head" range has been set, the "Drive flow" figures are entered (in litres per minute).

The "step rate" is the amount by which the value is advanced for each set of recalculations. For example, with a step rate of 5 as shown, the Drive flow will be calculated in fives from the minumum of 60 to the maximum of 120 litres per minute. If the step rate is changed to 10, the number will advance in tens from the minimum to the maximum.

Change the step rate to a bigger figure to reduce the number of calculations carried out.



Drive Flow

step rate 5

minimum 60

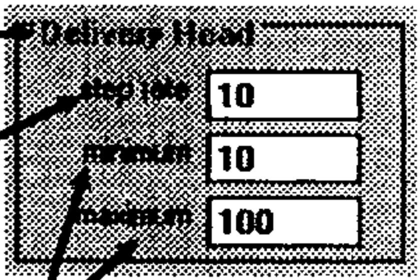
maximum 120

Change the minimum and maximum Drive flow to those available at the site being calculated. If a single flow is known, type that flow into both the minimum and the maximum boxes.

When the "Drive flow" range has been set, the "Delivery Head" figures are entered (in metres).

The "step rate" is the amount by which the value is advanced for each set of recalculations. For example, with a step rate of 10 as shown, the Delivery Head will be calculated in tens from the minumum of 10 to the maximum of 100 metres. If the step rate is changed to 20, the number will advance in twenties from the minimum to the maximum.

Change the step rate to a bigger figure to reduce the number of calculations carried out.



Delivery Head

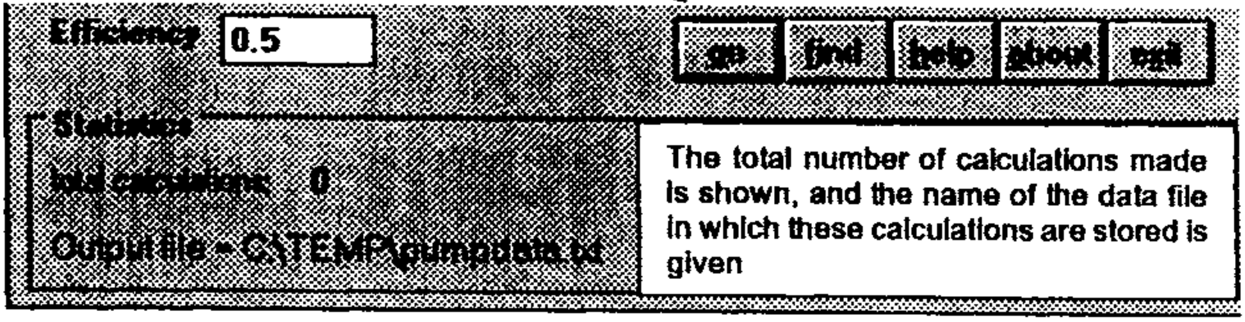
step rate 10

minimum 10

maximum 100

Change the minimum and maximum Delivery Head to those available at the site being calculated.

After setting the Step rates and the maximum and minimum entries for Drive Head (H), Drive Flow (Q) and Delivery Head (h) at a site, click on the "go" button to start making calculations.



Efficiency 0.5

Statistics

total calculations 0

Output file = C:\TEMP\pumpdata.txt

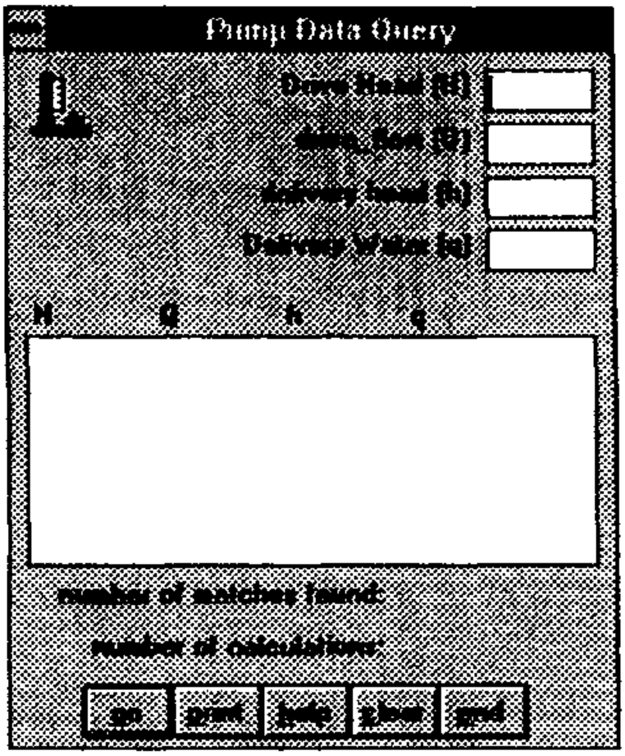
The total number of calculations made is shown, and the name of the data file in which these calculations are stored is given

3.1 Looking at the results

When the calculations have been made, they are saved in the file called "pumpdata.txt" on your hard disk. You can look at this using a wordprocessor or other programme if you want to. To look at the calculations in this programme, and to select restricted ranges to look at, click on the "FIND" button to open the PUMP DATA QUERY window.

Asking the calculator a question

A Query is simply a question. You can ask to see the data for a restricted set of variables, or for all. To see all, just click on the GO button without putting anything in the boxes.



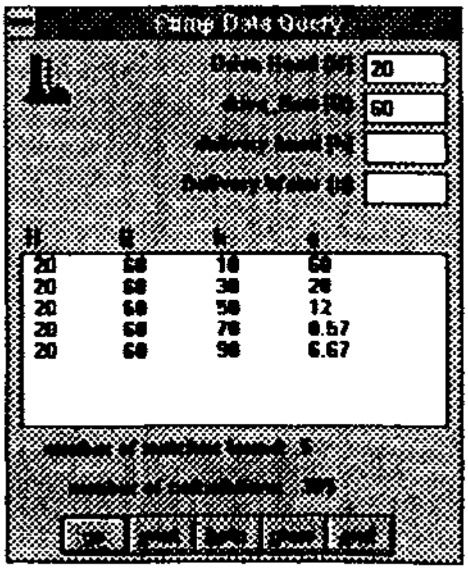
To see a restricted part of the calculations you have just made at the DTU Ram Pump Data Generator window, make at least one entry in the boxes alongside Drive Head, Drive Flow, Delivery Head and Delivery Flow.

For example, if you wanted to see how much drive flow would be needed at a site with a known drive head, delivery head and required delivery flow, type the known values in the boxes and click on the GO button.

EXAMPLE

In this example, a drive head of 20 metres was possible but the drive flow was restricted to 60 litres per minute. We wanted to know how much water could be pumped to a range of heights. The step rate for the delivery head had been given as 20 metres at the DTU Ram Pump Data Generator window, so only five calculations for delivery head were made for its range of between 10 and 100 metres.

Notice how it is possible to generate silly answers if you are not careful. The first calculation in the list shows a Drive Head of 20 metres and a Delivery Head of only 10 metres — gravity feed!



Drive Head (H): 20
drive flow (Q): 60

```
H     Q     h     q
20    60    10    60
20    60    30    20
20    60    50    12
20    60    70    8.57
20    60    90    6.67
```

number of matches found: 5

Printing the result

To print the information you have found, simply click on the PRINT button. Make sure that your printer is attached and turned on, with paper in it before trying to print anything.

It can be useful to print a range of calculations for a particular site before visiting it. For example, you might know that the site must deliver 10 litres a minute before the client will be interested, you might also know the efficiency of the pump to be installed, and the fact that there is plenty of drive water (120 litres a minute or more). You may also know that the delivery head is at least 50 metres. If you then find all possible combinations of drive Head and Delivery Heads of 50 metres or more that give a delivery flow of 10 litres a minute or more, this would be useful to have with you when assessing a site.

Asking another question

If you want to find the answer to another question, click on the CLEAR button to clear your first question and its answers from the window. Then type in the relevant values for your new question and click the mouse on the GO button.

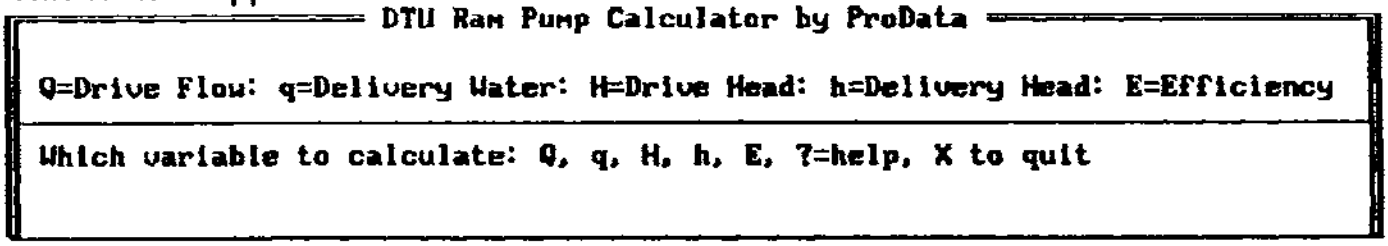
Leaving the PUMPDATA programme

When you have finished making your calculations, click the mouse on the END button to close the DTU PUMPDATA programme.

4 Using the DTU programme DOSPUMP

Refer to section 1.2.1 To run the DOS DTU calculator programme - DOSPUMP to start the programme from your hard disk or from the floppy disk provided.

This is what appears on the DOSPUMP main screen.



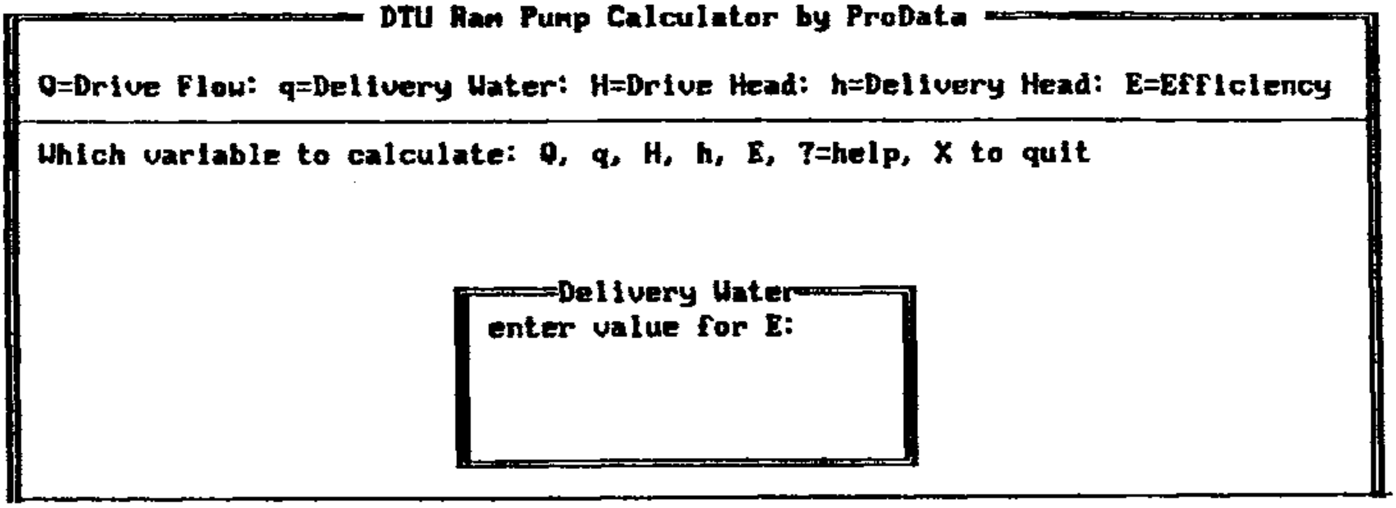
```
                 DTU Ram Pump Calculator by ProData

Q=Drive Flow: q=Delivery Water: H=Drive Head: h=Delivery Head: E=Efficiency

Which variable to calculate: Q, q, H, h, E, ?=help, X to quit
```

Type which one of the five variables, Q, q, H, h, and E you want to calculate.

☛ *Be careful to type "Q", "H" and "E" as upper case letters and "q" and "h" as lower case letters.*

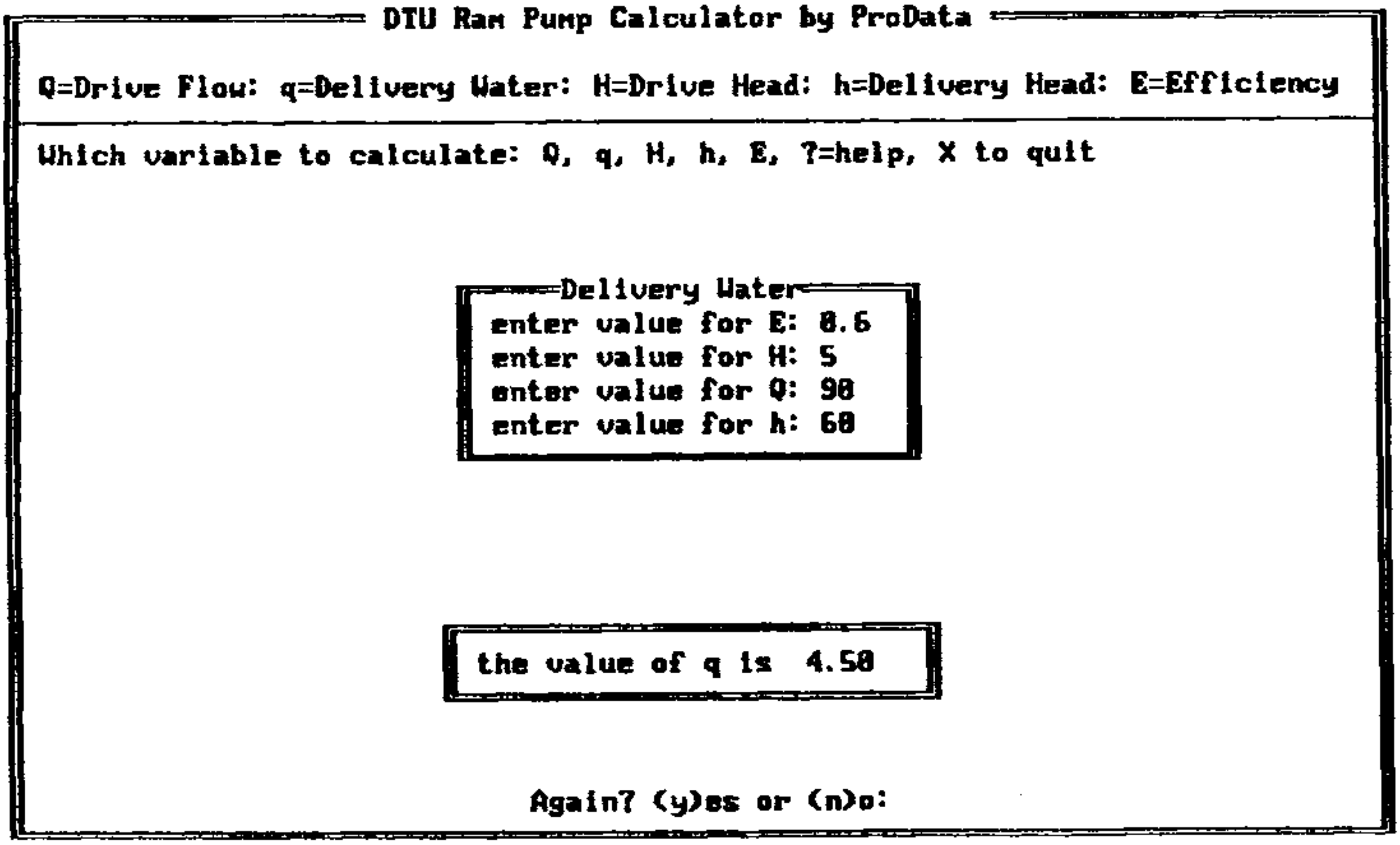
WINPUMP users will find that the DOSPUMP programme is a very similar calculator. Because it runs under DOS its appearance is different, but it does the same things as WINPUMP.

Whichever variable you select, a window will open asking you to enter a value for the other variables, one at a time. For example, if you type "q", the window shown below opens prompting you to give a value for E (the pump efficiency).



```
DTU Ram Pump Calculator by ProData

Q=Drive Flow: q=Delivery Water: H=Drive Head: h=Delivery Head: E=Efficiency

Which variable to calculate: Q, q, H, h, E, ?=help, X to quit

Delivery Water
enter value for E:
```

You are asked for each of the other four variables in turn, and when you have entered them (press [Return] after each entry), the programme displays the missing value lower on the screen. An example is shown below.



```
DTU Ram Pump Calculator by ProData

Q=Drive Flow: q=Delivery Water: H=Drive Head: h=Delivery Head: E=Efficiency

Which variable to calculate: Q, q, H, h, E, ?=help, X to quit

Delivery Water
enter value for E: 0.6
enter value for H: 5
enter value for Q: 90
enter value for h: 60

the value of q is  4.50

Again? (y)es or (n)o:
```

When you have entered all the variables, a window at the bottom of the screen a message prompts:

"Again? (y)es or (n)o:"

Type the letter Y to clear the screen and calculate a result for another set of variables.

Type the letter N to close DOSPUMP.

DTU

Ram Pump Programme

AN INTRODUCTION TO HYDRAULIC RAM PUMPS
(and the DTU range)

TECHNICAL
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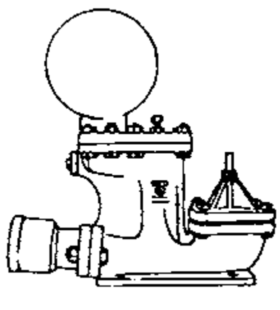
An introduction to hydraulic ram pumps

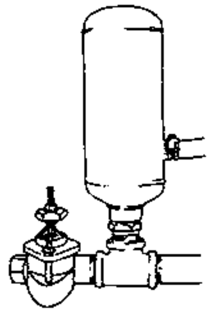
This Technical Release explains briefly what ram pumps are, how they work, and how you might select them. It finishes with a catalogue of the current DTU designs of pump for local manufacture in developing countries.

Contents

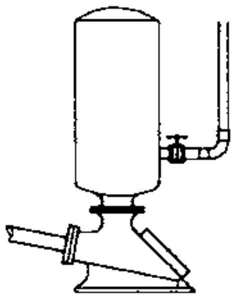
A much fuller description of how to design and install ram pumps systems can be found in the book *Ram pumps and the design of ram pump systems*, DTU, UK 1995, which is available from the DTU at the address on the back cover of this Technical Release. A list of Working Papers and other Technical Releases, several of which refer to ram pumps, can also be found on the back cover of this Technical Release.



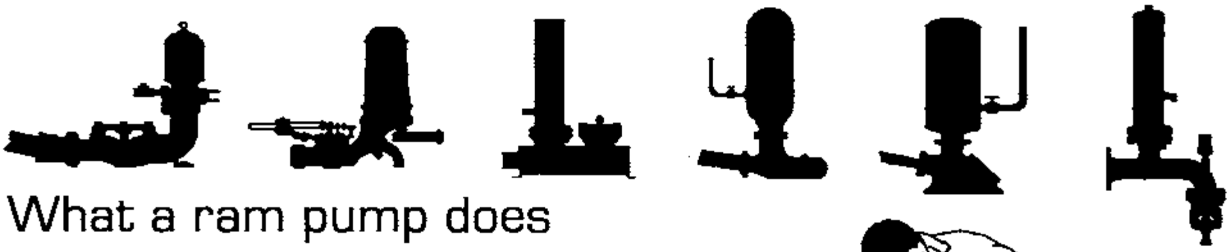
AN EASTON RAM PUMP
UK



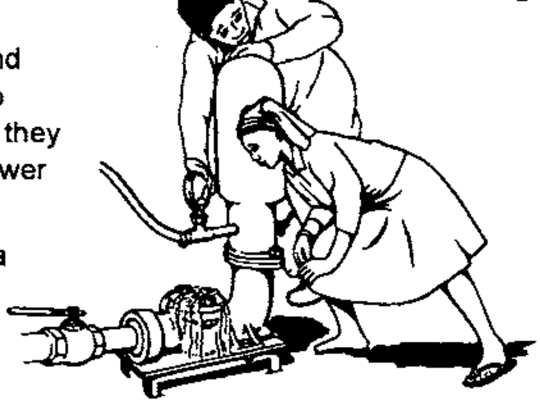
A GAVIOTAS RAM PUMP
Columbia



A "PREMIER" RAM PUMP
India



What a ram pump does

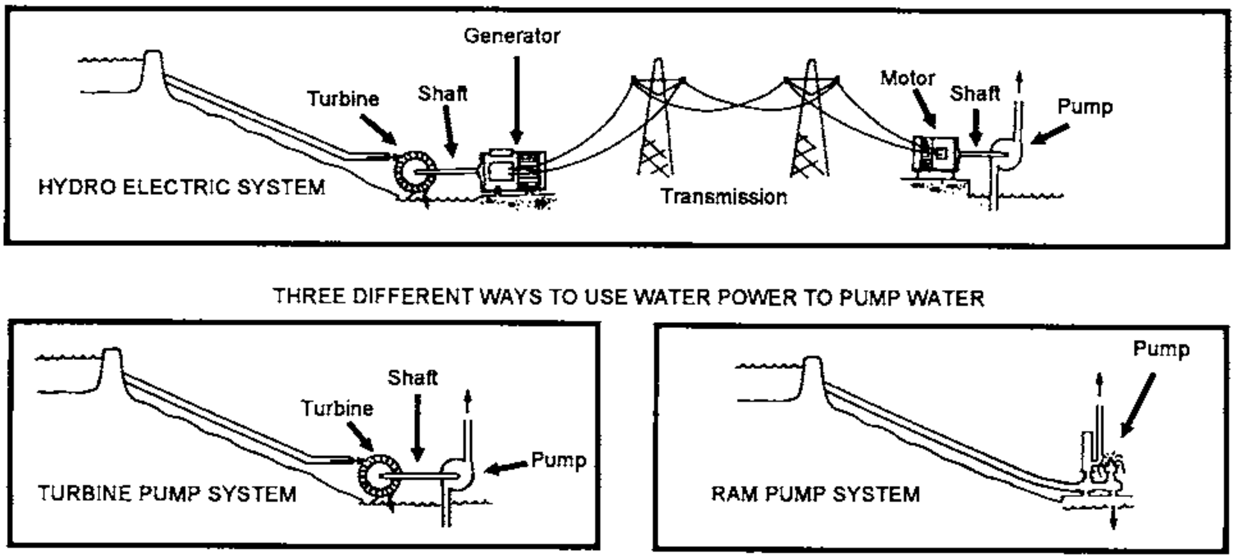


Some ram pumps are made from many parts and look very complicated. Others look too simple to work. Whether they look simple or complicated, they all work in the same way and they all get the power to run in the same way.

Many people are surprised when they first see a ram pump working. They think that it is driven by a hidden motor, or by magic. They watch it pumping and are amazed.

Every kind of pump needs a source of power. They can be powered by people or animals, the wind, falling water, electricity , or fuels such as diesel and petrol. The source of power is often separate from the actual water pump and the two can be joined together by, for example, a shaft. The ram pump uses the power of falling water and there is no separate motor or mechanism that turns the pump. This is why a well designed ram pump can look much simpler than some other pumps. It *is* a very simple machine, although the reasons for it working well are not simple at all.

The drawing below may help you to understand how much simpler a ram pump system is than other ways of using water power to pump water.

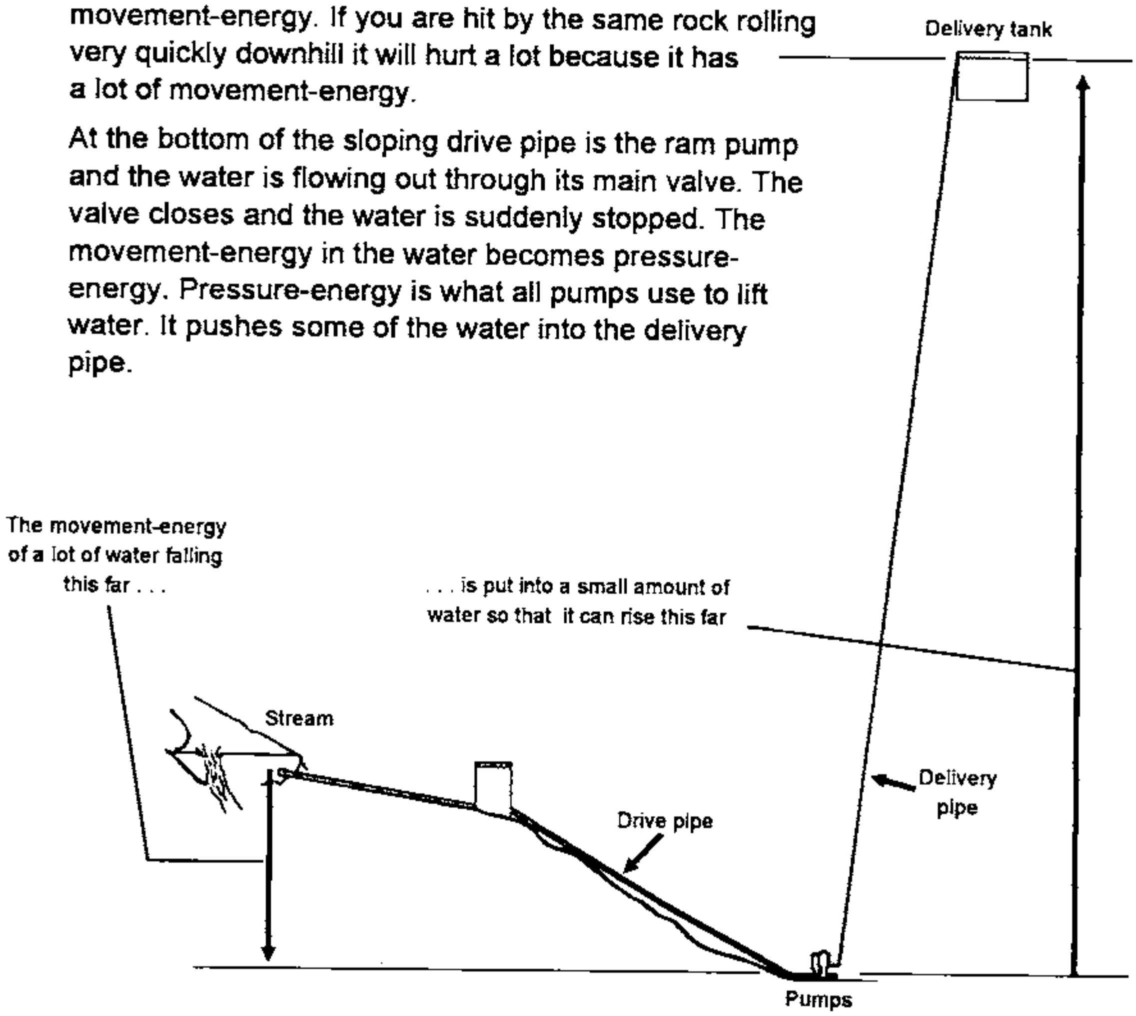


THREE DIFFERENT WAYS TO USE WATER POWER TO PUMP WATER

As far as we know, the ram pump was first discovered or invented 200 years ago. Since then it has been rediscovered many times.

Water is diverted from a spring or river and flows down a sloping drive pipe, gathering speed like a rock rolling downhill. As the water gathers speed it gathers energy. The faster it goes the more movement-energy it has. If you are hit by a small rock rolling slowly downhill it will stop without hurting you very much because it does not have much movement-energy. If you are hit by the same rock rolling very quickly downhill it will hurt a lot because it has a lot of movement-energy.

At the bottom of the sloping drive pipe is the ram pump and the water is flowing out through its main valve. The valve closes and the water is suddenly stopped. The movement-energy in the water becomes pressure-energy. Pressure-energy is what all pumps use to lift water. It pushes some of the water into the delivery pipe.



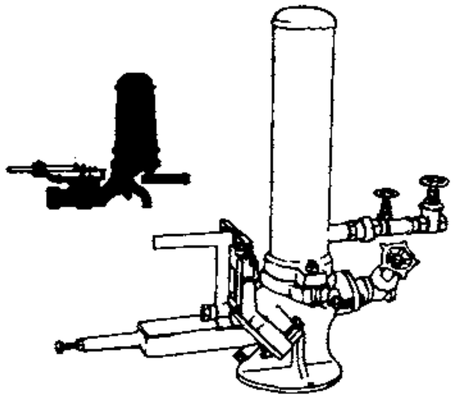
SKETCH OF A RAM PUMP SYSTEM

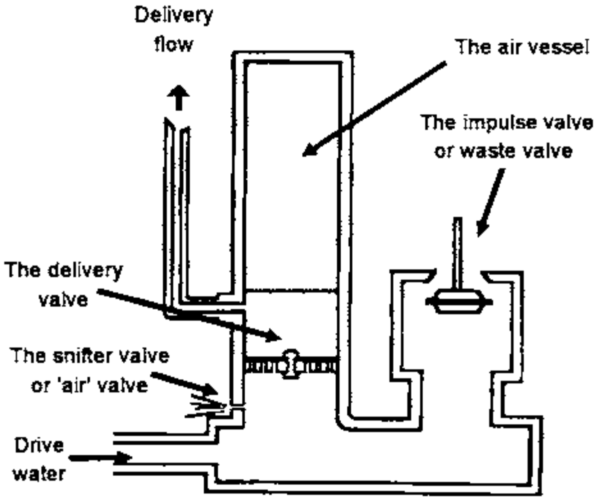
The movement-energy of all the water falling down the drive pipe is put into a small part of that water. The small part of water then has enough pressure energy in it to be 'delivered' to the place where it is needed.

All ram pumps need a lot of water falling down a pipe to provide the energy they use, and they only pump a small amount of the water. This is why they can only be used in places where there is more water than you need to pump. Usually, each pump will pump about 5 to 10% of its drive water. The rest goes back into the stream for other people to use.

The parts of a ram pump

Ram pumps come in many different shapes and sizes but they all have the same basic parts. They all have two main valves, which are an impulse valve and a delivery valve. They also have an air vessel of some kind.



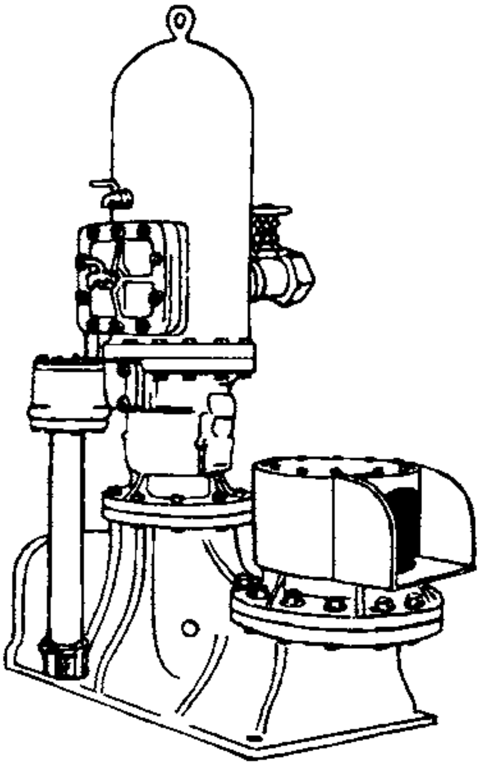


A DRAWING OF A RAM PUMP CUT IN HALF

Most pumps have an air vessel that is slowly filled with air by the snifter valve when the pump is started. The air acts as a shock absorber, absorbing the high pressure surges of the pump. A few modern pumps have an air vessel that is closed by a rubber diaphragm, like the Platypus pump shown on page 12. The pump operator pressurises the air vessel by pumping in air in the same way as you would pump up an inner-tube for a tyre. The diaphragm takes away the need for a snifter valve.

Some ram pumps have the air vessel and the impulse valve the other way around from the pump in the drawing so that the drive water reaches the impulse valve first. Some big ram pumps have more than one impulse valve working together to get the same effect.

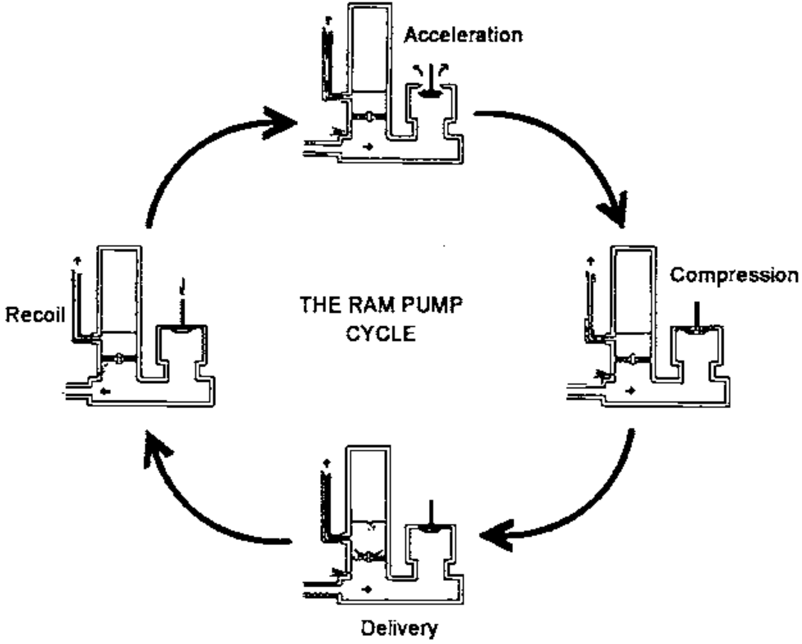
A few pump makers build ram pumps that keep the water that is pumped separate from the drive water. This allows you to pump clean water from a nearby spring while using the power of dirty water from a river or stream. These are sometimes called 'compound' rams. The pumps are more complicated and expensive than ordinary ram pumps, so they are not covered in this Technical Release.



A LARGE GREEN AND CARTER 'COMPOUND' RAM PUMP

The ram pump cycle

Ram pumps have a pumping cycle. The last part of each cycle is the first part of the next, so the pump keeps on working.

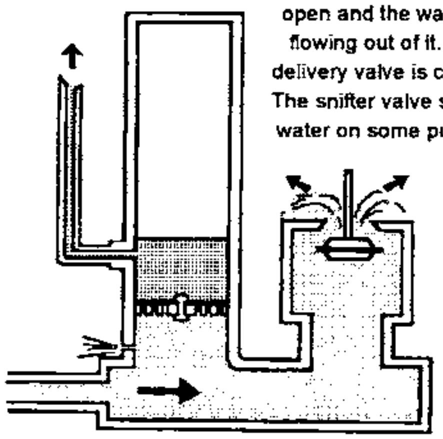


Each cycle happens very quickly, often about once a second. This means that there is no time to see what is happening. The time each stage takes is usually measured in 'milliseconds', which are thousandths of a second. A mosquito flaps its wings about 1000 times a second, so a millisecond is roughly the time it takes for a mosquito to flap its wings once.

It is easiest to explain how the ram pump cycle works by dividing it into four stages called ***Acceleration, Compression, Delivery*** and ***Recoil.***

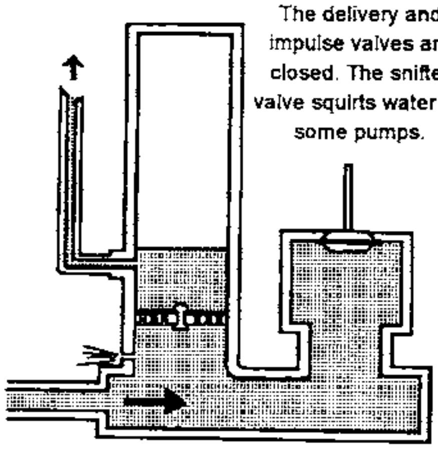
In the explanation that follows the pump is cycling 60 times a minute, or once a second. The time that each stage takes is given in flaps of a mosquito's wings. Because the cycle takes one second, there are a total of 1000 flaps of the mosquito's wing.

Acceleration (about 900 flaps of a mosquito's wing)
When the impulse valve on the pump is open, water flows down the drive pipe and comes out through the open valve. The water flowing past the open valve drags past it, trying to close it. The flow down the drive pipe and out through the impulse valve gets faster and faster. As it gets faster, it drags harder on the valve until it is strong enough to drag it closed.



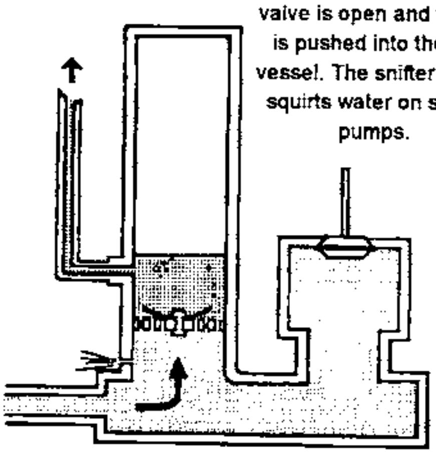
ACCELERATION

Compression (1 or 2 flaps of a mosquito's wing)
When the impulse valve shuts, the water flowing down the drive pipe cannot come out through it. At the moment the valve closes, the water is travelling very fast and suddenly it has nowhere to go. As it got faster, it gathered movement-energy like the rock rolling down a hill. The movement-energy changes to pressure-energy as it compresses the water in the body of pump. It is as if each small part of the water is bumping into the one ahead as they rush to come down the pipe and escape. As a result there is a sudden rise in pressure that is sometimes called "water-hammer". The pressure rises to a level much higher than the pressure in the pump's air vessel.


The delivery and impulse valves are closed. The snifter valve squirts water on some pumps.

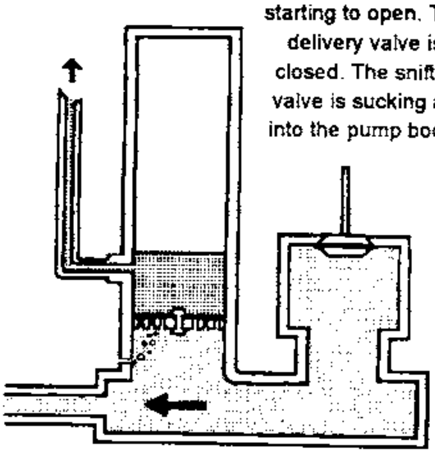
COMPRESSION

Delivery (about 50 flaps of a mosquito's wing)
Because the pressure rises higher than the pressure in the air vessel, the delivery valve is pushed open and water flows through it. The pressure in the pump body drops quickly to equal the pressure in the air vessel. The water coming down the drive pipe slows down and the pressure in the pump body drops. As soon as the pressure falls enough to be lower than the pressure in the pump's air vessel, the delivery valve closes. The delivery valve is a one-way valve, which stops water flowing back from the air vessel into the pump.


The impulse valve is closed. The delivery valve is open and water is pushed into the air vessel. The snifter valve squirts water on some pumps.

DELIVERY

Recoil (about 50 flaps of a mosquito's wing)
When the delivery valve closes, there is still some pressure in the pump body and drive pipe. The valves in the pump are closed, so the only direction in which the water can move is back the way it came. The water coming down the drive pipe has stopped, so the pressure-energy can be released by moving back up the drive pipe. The water in the pump body bounces back a little way up the drive pipe. This bouncing back makes the pressure in the pump body fall low enough for the impulse valve to reopen. On some pumps the impulse valve includes a spring to help it reopen, on some they reopen because of their own weight. The low pressure in the pump body means that a small amount of air is sucked through the snifter valve. The air waits under the delivery valve until the next cycle when it will get pushed into the pump's air vessel. This makes sure that the air vessel always stays full of air.


The impulse valve is starting to open. The delivery valve is closed. The snifter valve is sucking air into the pump body.

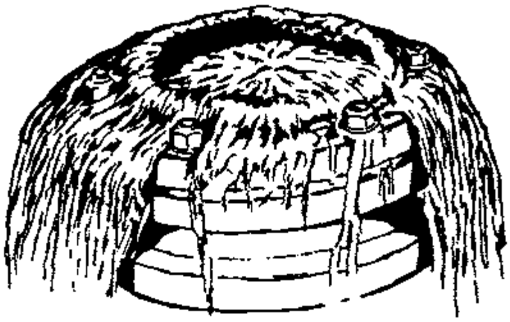
RECOIL

Very quickly, the pressure left in the pump body is released by bouncing back up the drive pipe. When the bouncing back is complete, water begins to flow down the drive pipe again. This is where the cycle started, and the water **Accelerates** down the drive pipe through the open impulse valve.

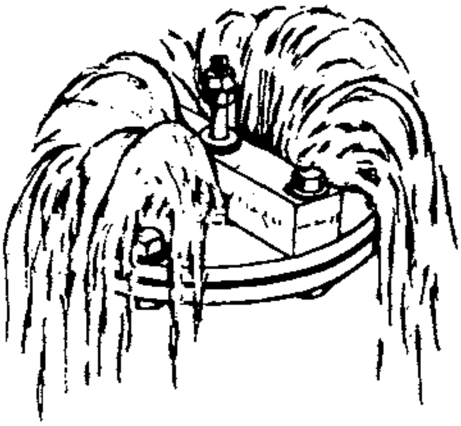
During each pumping cycle only a small amount of water is pumped. Most of the movement-energy harvested from a large amount of water is transferred into a small amount of water. The high pressure in the pump body pushes water through the delivery valve and into the air vessel. It provides the power to push the small amount of water much farther uphill than the big amount of water fell downhill.

Throughout each pumping cycle the pressure in the pump's air vessel is steadily forcing water up the delivery pipe. The air vessel smoothes the pulses of water coming through the delivery valve into a steady flow up the pipe to the delivery tank.

While a ram pump is working, water flows out of the impulse valve and splashes onto the floor of the pump house. This happens during the 'acceleration' phase of each cycle. It is the splashing water and the noise of the "water hammer" that people notice when they see a working ram pump. The water splashing out is often called 'waste' water. Although 'waste' water is not delivered by the ram pump, it is the movement-energy harvested from this water that pumps the water that is delivered. A better name for 'waste' water would be 'used' water. The noise varies from pump to pump. Pumps with impulse valves that have no moving metal parts are the quietest, but they can still disturb people who live nearby. This is because of the water hammer "drumming" in the drive pipe.



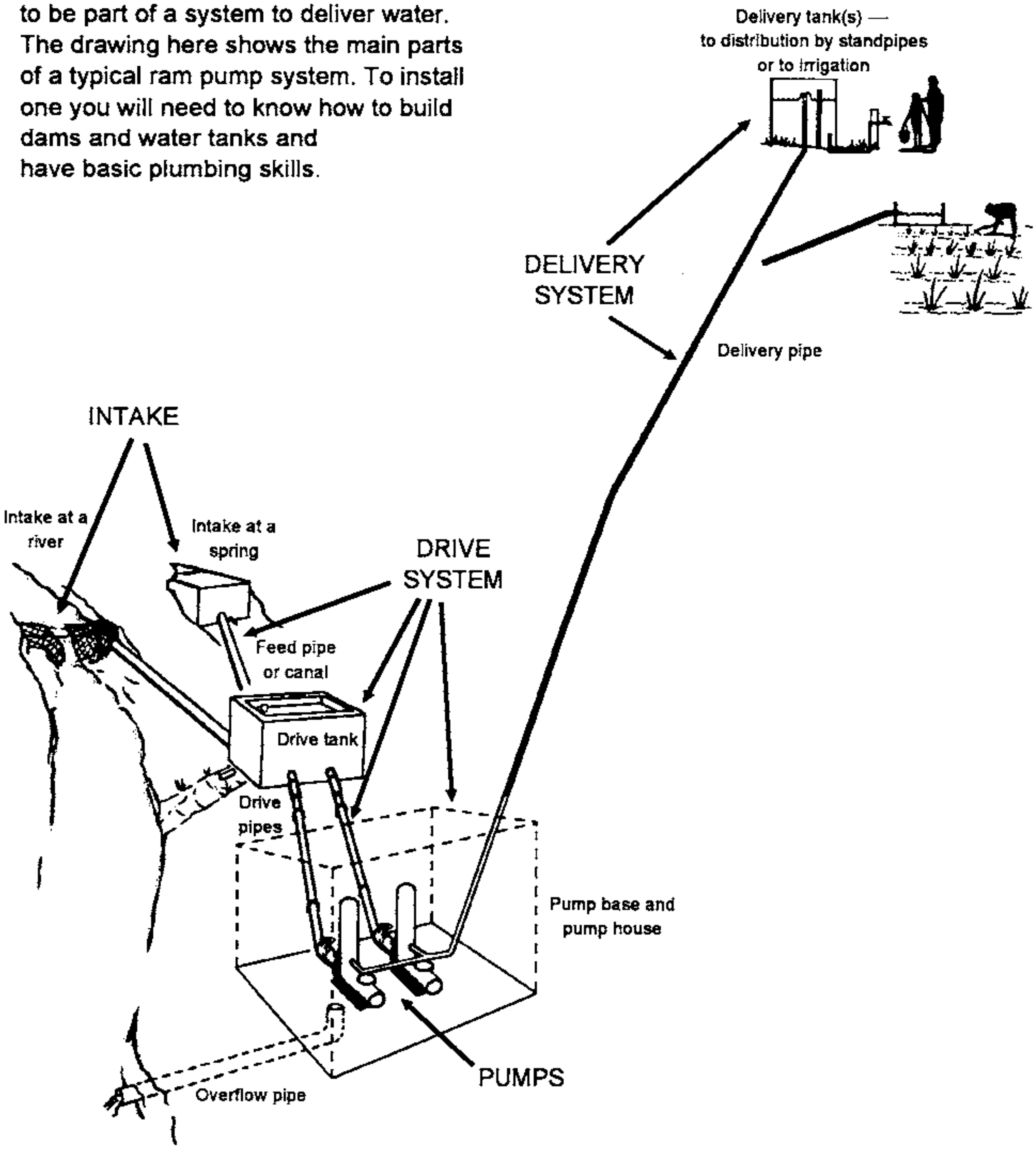
THE IMPULSE VALVE OF A BLAKES RAM PUMP
This has no moving metal parts. It pulses gently and is fairly quiet



THE IMPULSE VALVE OF A DTU M8 RAM PUMP
This splashes and is noisy.

The parts of a ram pump system

A ram pump does not work alone. It has to be part of a system to deliver water. The drawing here shows the main parts of a typical ram pump system. To install one you will need to know how to build dams and water tanks and have basic plumbing skills.



THE MAIN PARTS OF A RAM PUMP SYSTEM

As you can see, ram pump systems can have more parts than some other water pumping systems. This means that they may be more expensive to install. The main advantages of using ram pumps are that they can often be maintained by the users and cost little to maintain and nothing to run.

When to use ram pumps

Ram pumps can only be used where water flows downhill and where there is much more water flowing than you want to pump. They are usually used to lift water from springs or streams in hilly areas. Sometimes they are used for irrigation, but more often they are used for community water supplies.

There is a limit to how high a ram pump can lift. This varies from pump design to pump design. Some pump makers make unrealistic claims for their pumps. Generally, ram pumps with up to 4" drive pipes can deliver a useful amount of water to heights of up to 100 meters. Some pumps cannot pump this high, so check a pump's instructions before choosing which pump to use.

In most cases it is important that the pumps work all year round. They cannot do this if the springs or streams from which they get their water run dry or get very low in the dry season.

A ram pump system is very cheap to run but it does need care and maintenance. The people using the system must be committed to its maintenance and understand how to do it.

The water supplied by any water system to a community must be distributed in a way that meets the people's needs and is seen to be fair. The people must be involved in planning the system, especially the way the water is distributed. They must also be prepared and able to pay for occasional replacement parts.

So, ram pump systems can be useful when there are the following things.

- A flow of water that is dropping quite quickly. It does not have to be flowing steeply in the stream or river. The system designer can usually make the water do that.
- A source of water that has a much bigger flow than you want to pump.
- A source of water that does not get very low or dry up at some times of year. This applies especially to irrigation systems because the time they are needed is usually the time when the water is lowest.
- A place for the pumps that is not more than 100 meters below the place where the water must be delivered.
- A willingness for system care and maintenance to be provided by the community that uses the water.
- A community involved in planning and paying for the system.

If a site meets these conditions, it is probably worth carrying out a site design survey. A design survey will give a good idea of the amount of water that can be delivered and how much a system will cost.

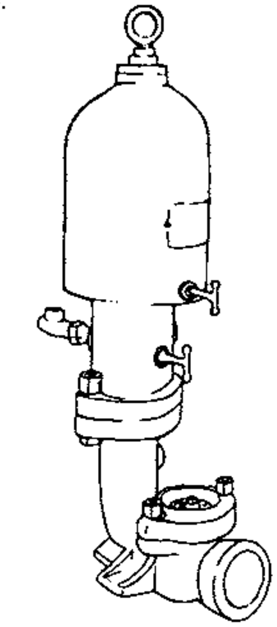
When you are installing a community supply, remember that many sources of water are not safe to drink. Springs are usually safe but water from streams and rivers is usually not safe to drink. The water must be filtered or boiled before you use it. Slow sand-filters that clean the water can add quite a lot to the cost of a system.

Choosing which ram pump to use

Ram pumps have been made for general sale for well over a hundred years. Many of the early designs were much stronger than they needed to be. Some were also more complicated than they needed to be. A few of the pumps made early in this century are still being used around the world. Many pumps made fifty years ago are still working even though the makers may have stopped selling them a long time ago.

Some of the traditional ram pump makers are still in business at the time this is written. The most famous is perhaps John Blake in the UK. The basic design of their pumps has been so successful that it has been copied by a number of makers from China to Africa.

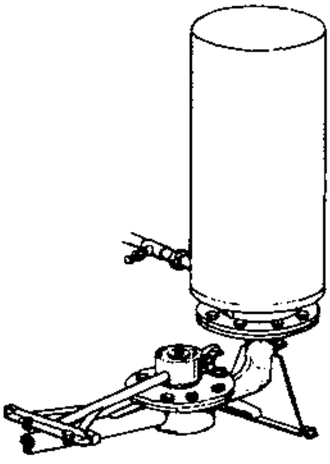
Buying ram pumps from traditional makers can be very expensive if they have to be imported. Although some run for years without needing spare parts, others need them frequently. It can be expensive and difficult to get the spare parts and advice you will need. The only way to avoid the spare parts problem is to buy pumps that are made locally or arrange to have your own pumps made. You are probably reading the Technical Release to help solve the problem of lack of advice.



A SMALL 'JOHN BLAKE' RAM PUMP, UK

Recently, a number of small engineering firms have started to make ram pumps to meet local demand. Be warned that some of these businesses do not understand ram pumps very well and their pumps can be poorly designed and made. Try to see an example of the pump installed and working before buying one.

If you want to make your own ram pumps, several designs are freely available from European organisations. The DTU believes that its own range of designs are the easiest to make in small workshops and give the best performance.



A 'DCS' RAM PUMP
Nepal

Ram pumps vary a great deal in size, but a single ram pump does not normally pump a lot of water. If a lot of water is needed, two or three pumps are usually installed and they are all left working constantly. For example, if a single pump delivered 5 liters of water a minute to a tank, it would deliver 7,200 liters of water each day. If three pumps were side by side in the system, they could deliver together 21,600 liters of water each day.

Some pump makers produce a range of pump sizes so that you can choose from it a single pump that will deliver enough water for your needs. If you know that the pumps are very reliable and easy to tune, it can be sensible to just use a single pump. If you are buying pumps that are locally made and do not have a well known reputation, it is better to buy two smaller pumps than one big one. Then, when a pump needs to be maintained or repaired, the other pump will keep working and some water will be delivered.

Buying a pump

Which pumps you buy will depend on which pumps you can get.
You will need to find out these things from the maker's instructions:

- The size of the pump's drive pipe. This is the pipe's internal diameter (ID).

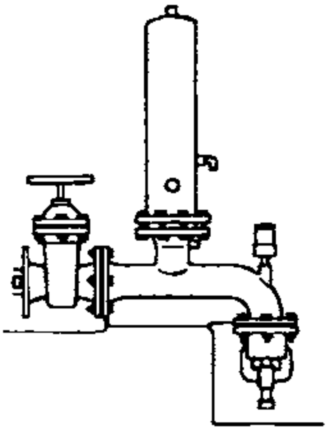
  ☛ *If you choose a pump with a drive pipe bigger than 4" you should get the manufacturers to help design the system.*

- The pump's maximum and minimum drive flow. This is the most drive water it can use, and the least drive water it can use.
- The pump's maximum "feed" or "drive" head. This is the highest feed head that it can use.
- The pump's maximum delivery head. This is the highest that it can pump to.

The instructions also tell you the pump efficiency. It is always useful to know a pump's efficiency but unfortunately pump maker's claims about efficiency are not often reliable.

Imported pumps

If you can afford to buy imported and well known pumps, that may be the best choice. They often cost five to ten times as much as a locally made copy, and between ten and twenty times as much as a pump you make yourself. There are so many ram pumps available for import that it is not possible to assess them here, but most well known names give good and reliable service. Remember that all pumps will need spare parts eventually, and some imported spares are very expensive. If you are installing a system for someone else, remember to make sure that *they* will be able to get the spares when they need them. There are many ram pumps around the world that no longer work because the people who installed them have left the area. After some time the pumps needed parts and the users had no idea how to get them.

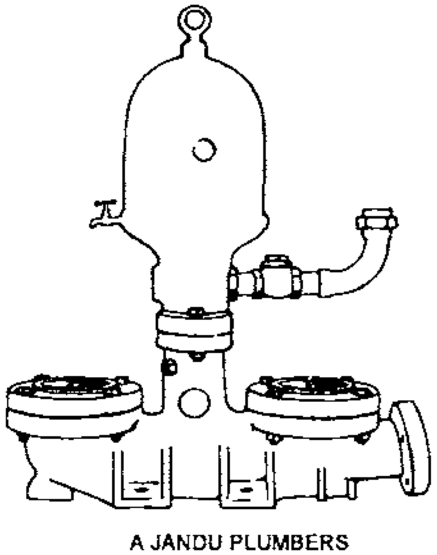


A PFISTER AND LLANGHAUS RAM PUMP, Switzerland

Locally made pumps

There are advantages if you buy from a maker that can be contacted easily when spare parts are needed. Try to make sure that the maker has been in business for some time so that they are still likely to be in business when the spares are needed. Locally made copies of pumps may need a spare part much more frequently, but if the spares are cheap and easy to get, that is not usually a problem. Check any pump that is locally designed very carefully.

The drawing on the right is of a pump made by Jandu plumbers in Tanzania. It is based on a heavy cast-iron John Blake design. Notice that it has two impulse valves so that it can use more drive water and harvest more energy to pump the delivered water.



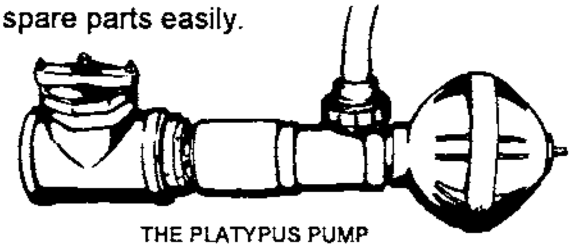
A JANDU PLUMBERS TWIN-IMPULSE RAM PUMP Tanzania

What to look for in a pump

With any make of pump, the first thing to check is that the makers give the pump's operating ranges. Do not buy pumps that do not include some instructions that tell you the operating ranges. Even if the pump is good, you will not know how to design the system properly and it may let you down.

- Look at the whole pump. If it looks very complicated with lots of small parts, it is probably more likely to break down.
- Check that the pump is well made. Inspect any welds carefully to see if they are fairly regular and not lumpy.
- Look at the hole or holes around the impulse valve where the water comes out. The combined area of those holes should be at least as big as the hole inside the drive pipe. If it is not, the drive pipe is bigger than it need be and the pump is badly designed. Some pumps with a body that is screwed together from pipe fittings have this problem. Surprisingly, some of the best known pumps also have it. If it is the only thing wrong with a pump it can be ignored.
- Look for any parts that look as if they may bend or break easily and avoid these designs if you can. Pay special attention to the impulse valve arrangement, which has to open and close millions of times a year.
- Check that the impulse valve moves up and down freely and appears to seal. If it has a spring or lever arrangement, make sure it is protected against rust.
- Check that the air vessel is made from thick steel. Usually 3mm is thick enough. If possible, check that the air vessel has been painted or galvanised inside and out.
- Avoid pumps that have already started to rust. They may be old stock, or carelessly made. If the nuts and bolts are rusty it may make the pump hard to maintain. When a pump is being used, the water will wear paint away from some parts very quickly. Those parts will not rust much because the moving water will keep them clean.
- Check that the pump includes a way to attach it firmly to a base or cradle. Pumps made from cast iron often have feet with holes for bolts. Pumps made using pipe fittings may use "U" bolts.
- Look at any rubber parts carefully. If the rubber is starting to perish the pump may be old stock and the rubbers will need to be replaced soon.
- Check that the pump has a snifter valve. It may be a small hole or a valve and is usually in the body of the pump just below the delivery valve. Very rarely the air vessel is made with a diaphragm inside like the Platypus pump shown below. These can be pumped up like a car tyre and do not need a snifter valve. All other pumps must have one. If they do not they can be dangerous.
- Make sure that you can buy spare parts easily.

The Platypus pump has an inflatable air vessel and is designed to run completely under water.



THE PLATYPUS PUMP
Australia

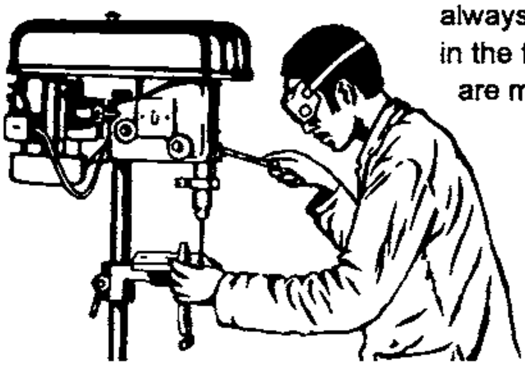
Using an old ram pump

If you have found an old pump that you want to use, contact the makers before deciding to do so. If the makers do not make the pumps any more, you may not be able to get spare parts. Also, you may not be able to find out the operating ranges of the pump.

Engineers may be confident that they can make any part that needs to be replaced. Be warned that the rubber parts on European ram pumps are nearly always made from a very special compound and the pump will not work reliably with anything less.

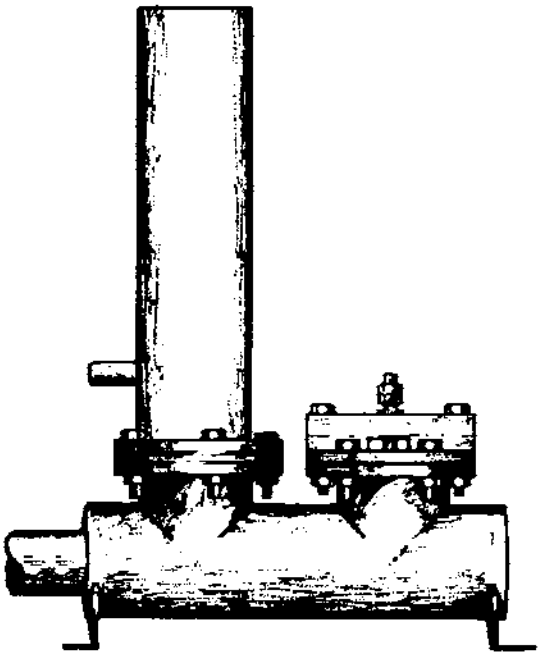
Making a ram pump in a small workshop

There are two big advantages in making the pumps or having them made in a local workshop. The first is that spare parts are easily made and so always available. The second is that the pumps cost so little in the first place. In the case of the DTU designs, the pumps are made from materials that are cheap and easy to get, so the spare parts are also cheap.



There are also disadvantages in making the pumps or having them made in a local workshop. The workshop must have a skilled metalworker to make the pumps or they will almost certainly be unreliable. Also, using cheap and available materials means that some small parts wear out and need to be replaced quite often.

The DTU S2 pump shown in this drawing is built from steel pipe and plate that is widely available around the world. This pump has a high efficiency. It can be made in a small workshop that has welding facilities, a gas cutting torch and a pillar drill.



THE DTU S2 RAM PUMP

The DTU range of ram pumps

Since 1988 the Development Technology Unit has been developing designs for ram pumps. These have been intended to enable small industries in developing countries to manufacture reliable pumps using commonly available materials. The pumps are much cheaper than imported ones but their lives are shorter. Indeed, it is assumed that they will need and get some maintenance over their working lives. Parts most likely to wear out have been made easy to copy and replace.

Three pumps are described briefly here. All are latest versions of pumps used in Africa and Asia for some years. Two are of steel (for respectively 1" and 2" galvanised iron drive pipes) and one is of plastic the P90 (for use with 90mm plastic pressure pipe) The P90 could be made entirely with hand tools. The S1 and S2 require simple power tools (welder, pillar drill) and the skills to go with them. Whilst a lathe or gas cutter are also required to make the steel pumps, the operations involving these machines are so few and simple that they could be sub-contracted to an urban machine shop at little expense.

TABLE OF PUMP CHARACTERISTICS

	S1	S2	P90
Material (mainly piping)	Steel	Steel	PVC or ABS
Drive flow range (in liters per minute)	20 — 60	40 — 120	100 — 360
Drive pipe size (high drive flows)	1"	2"	90mm
Drive pipe size (low drive flows)	¾"	1½	90mm
Maximum delivery head in meters	80	100	20
Maximum drive head in meters	15	15	3
Typical delivery flow in liters per minute	½ — 10	1 — 20	3 — 40
Typical life (assuming minor repairs)	5 years	5 years	2 years

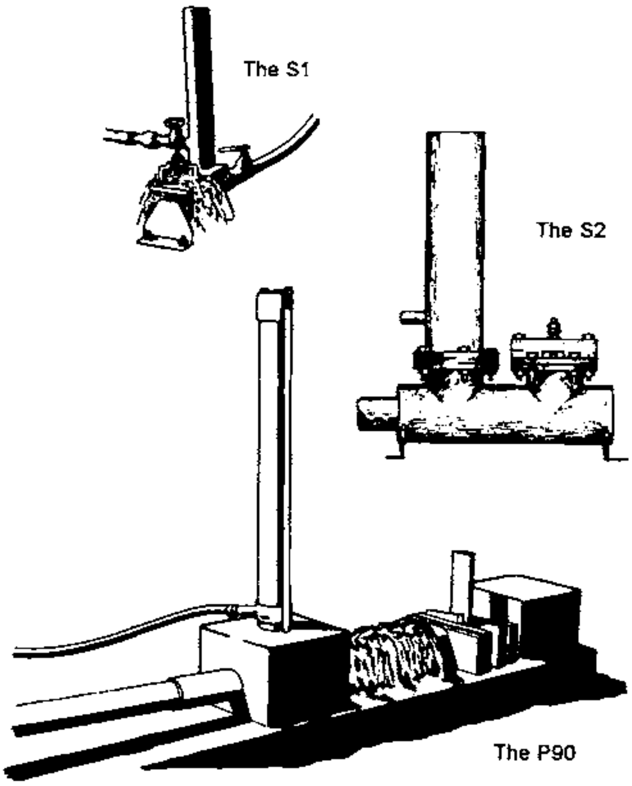
Note that if two pumps are used in parallel, the drive flow and delivery flow of the system will be doubled

S1 pump. This small pump is normally used to supply drinking water to a house or small group of houses. The drive flow is usually taken from a spring.

S2 pump (formerly M8). This medium size pump can be used for water supply to a village or institution, or to irrigate gardens or to water cattle. Its drive flow is usually taken from a large spring or a small stream.

P90 pump. This large pump is mainly used for irrigation, drawing its drive water from a (diverted) stream or drop-structure in a canal.

For full details of each pump see other DTU Technical Releases:
TR 11: The DTU S1 ram pump
TR 12: The DTU P90 ram pump
TR 14: The DTU S2 ram pump.


The S1

The S2

The P90

DTU

Ram Pump Programme

HOW RAM PUMPS WORK

TECHNICAL
15
RELEASE

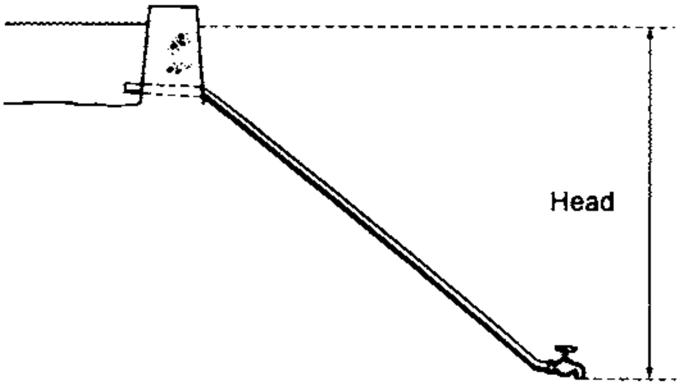
How ram pumps work

This Technical Release explains what is happening inside working ram pumps. It shows how changes in the design of a ram pump system can change its performance. It will be useful to anyone who is designing ram pump systems and to anyone who is tuning ram pumps to give the best performance.

This section begins with a few examples of simple systems and introduces the words that are used later. It also shows the way that the water flowing through pipes can be shown on a graph. Even if you are already understand terms such as *terminal velocity* in pipes, you should read all of this part so that you know the way that we are using the words.

Falling water

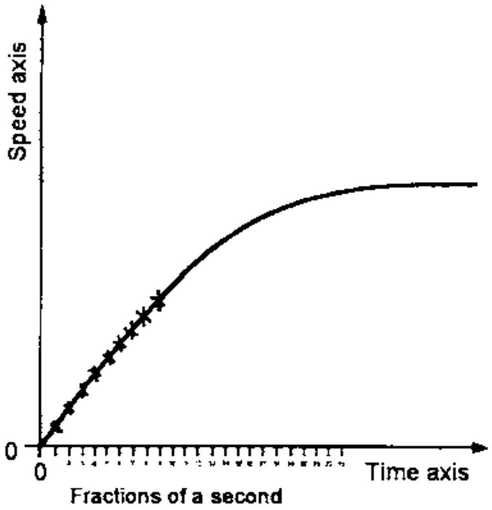
Head



In the drawing here there is a reservoir of water behind a dam. A small pipe passes through the bottom of the dam and runs down the hill. At the end of the pipe there is a tap which is closed. The height from the water level in the reservoir to the tap is called the *head.*

When the tap is opened, water starts to flow down the pipe and out through it. It flows slowly at first, but speeds up very quickly. After a short time the water reaches its maximum speed and the flow becomes steady. If the tap is left open, water will of course continue to flow steadily down the pipe from the reservoir and out through the open tap.

A graph can be drawn to show how the water coming out through the tap gets faster at first, and then flows at its maximum rate. The graph alongside shows what happens. Imagine that a stop-watch was started as soon as the tap was opened and the speed of the water in the pipe was measured every hundredth of a second. The graph has the speed of the water flowing through the pipe marked on the side axis. The time that has passed is marked along the bottom axis.

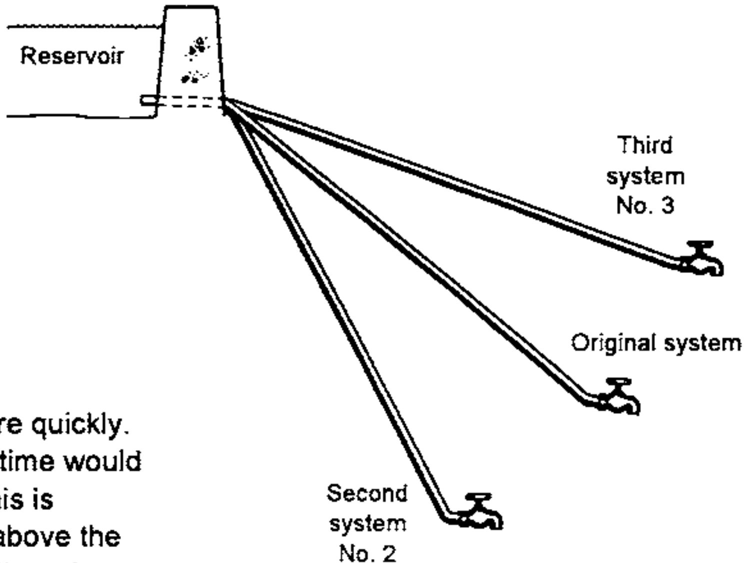


Before the tap was opened and the stop watch was started, there was no water coming through the tap. That is why the graph starts when the "Time" is zero and the "Speed" of the water in the pipe is also zero.

At first the line on the graph goes up very quickly. As the water flows it rubs against the sides of the pipe. This rubbing is usually called *friction*. As the water gets faster, the friction becomes bigger and stops the speed of the water from increasing as quickly. This is shown on the graph by the curve of the line getting flatter and flatter. After a while, the water is flowing as fast as it can and the line on the graph is flat. This shows that the water is continuing to flow out of the tap at the same speed.

A larger head

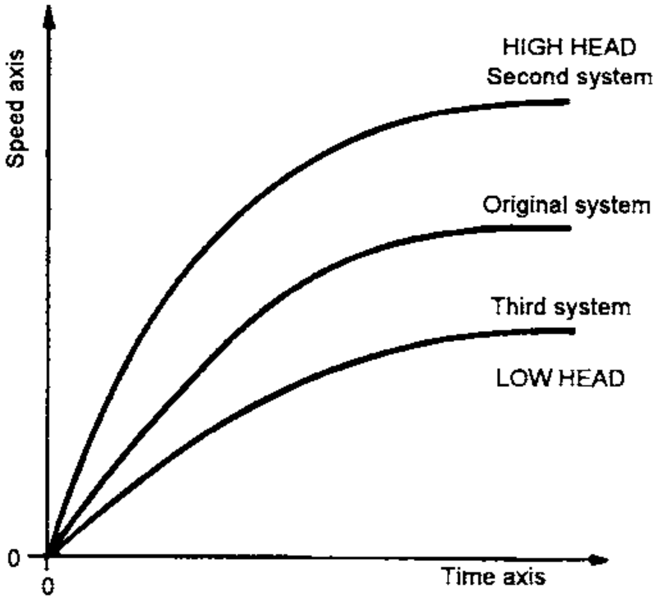
In this drawing there is a water supply with a reservoir and three pipes and taps. The pipes are labeled as the original, second and third systems. In the second system it is further downhill to the tap (the *head* is bigger than in the original system). When the tap on No.2 is opened, the water will flow down the pipe and out through the tap more quickly. The line showing speed against time would rise more steeply on a graph. This is because the reservoir is higher above the tap than it was on System 1, so there is more pressure pushing the water down the pipe and out through it.



As the water gets faster the friction between it and the wall of the pipe gets greater. The curve of the line on the graph begins to flatten out. When the water is flowing as fast as it can, the line on the graph is flat. Because the *head* in the second system is greater than the *head* in the first, the water flows faster in the second. This is shown on the graph at the top of the next page.

A smaller head

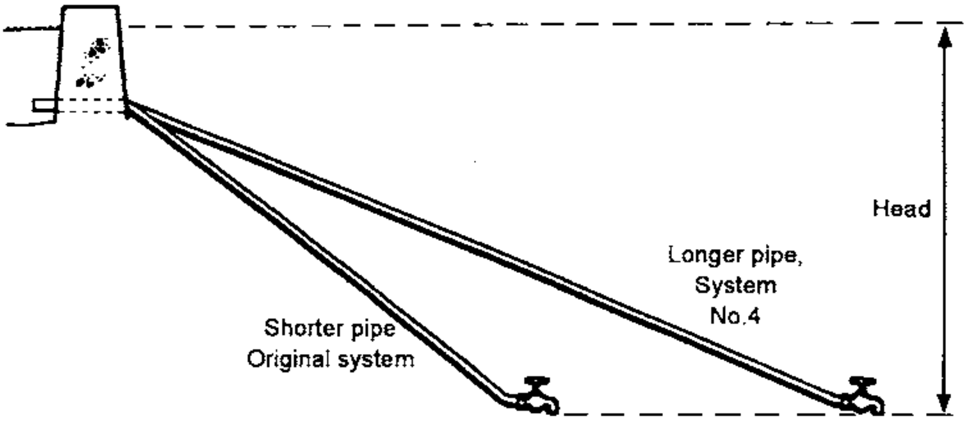
For the third system, the drop from the reservoir to the tap (the *head*) is much less than in the original system. When a graph of System number 3 is drawn, the line on the graph showing speed against time does not rise as sharply and flattens out at a lower speed. This is because there is less pressure pushing the water down the pipe and out through the tap. The speed of the water when it reaches a steady flow is the slowest of the three examples.

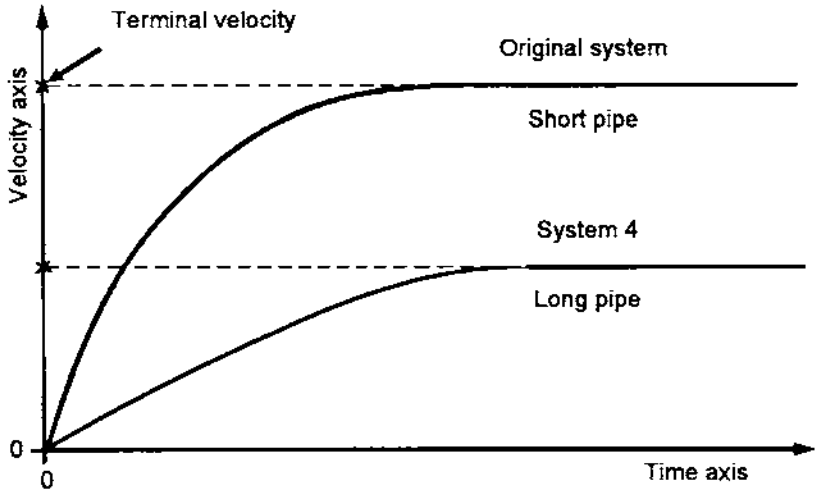


Acceleration

The rate of increase in speed is called the *acceleration*. When the tap is first opened, the speed of the water increases very quickly, so the *acceleration* is very high. As the water flows more quickly there is more friction and the line on the graph flattens out. This shows that the water is still accelerating but that the rate of acceleration is becoming lower. When the water is flowing as fast as it can, there is no more acceleration and the line on the graph is flat. This maximum speed is called the *terminal velocity*. In this case, the word *"terminal"* is used to mean *"as much as possible"*. *"Velocity"* is really just another name for *"speed"*. *"Terminal velocity"* just means *"top speed"*.

In the drawing below another pipe is installed from the reservoir. The new pipe is called System number 4. The pipe is the same diameter as the first one, but it is much longer. The height from the reservoir to the tap (the *head*) is the same. When the tap of this new system is opened, the water accelerates down the pipe and out through the tap. Because the water has to flow through a longer pipe there is more friction to slow it down, so its *terminal velocity* is not as fast.



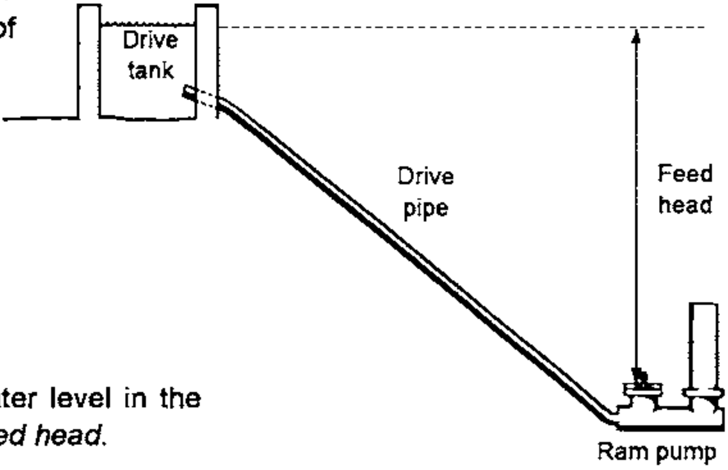


On the graph of this example above, the original system is also shown. The line on the graph flattens out at a lower speed and in a longer time.

If any one of the pipes in these systems was replaced by a pipe with a bigger internal diameter, the graph would change. This is true even if the bigger pipe were the same length and ran along the same route. When the acceleration of the water was measured again, you would find that the water reached a faster *terminal velocity.* This is because the larger pipe would have less friction. In a bigger pipe, there is more room for the water to pass through without touching the sides.

How ram pumps use the water

In the drawings of Systems 1 to 4 there was a reservoir at the top of a pipe with a tap at the bottom. From now on the reservoir is replaced by a tank and the tap on the end of the pipe is replaced by a ram pump.

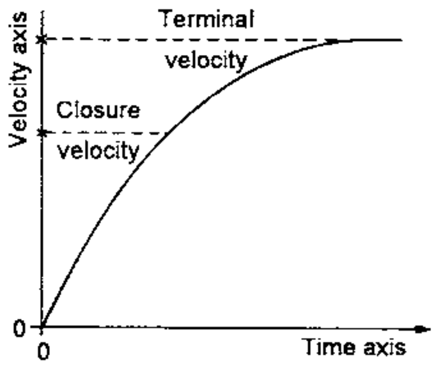


Feed head
The drop in height from the water level in the tank to the pump is called the *feed head.*

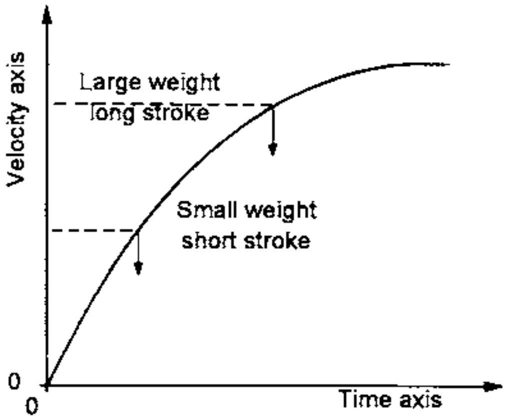
Closure velocity
When the ram pump is not working and the impulse valve is closed, there is no water coming through it. When the impulse valve is pushed down, water begins to come out through the open valve, getting faster as it accelerates down the pipe. The force of the water flowing around the impulse valve tries to lift it closed but the weight of the valve keeps it open. The force of the water trying to close the valve gets bigger and bigger.

When the force trying to close the valve becomes bigger than the weight, the valve starts to move upwards. All impulse valves will close when the drive water reaches the right velocity. What that velocity is will depend on how the impulse valve on the particular pump is tuned. The water accelerates down the pipe and out through the impulse valve until it reaches the *closure velocity* and the valve closes.

A graph can be used to show the increasing velocity in the system just as it was for the examples with the tap. If the impulse valve was held open and water allowed to flow out for a long time the graph would show it reaching a *terminal velocity* just as before. The shape of the line on this graph would depend on the feed head, the pipe diameter, the pipe length and the amount of friction through the pump. If the pump was operating normally, the impulse valve would close when the velocity reached the *closure velocity*. This point can be marked on the graph.

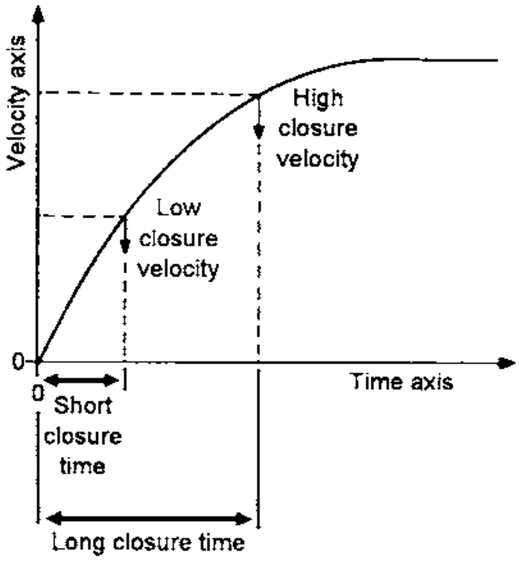


At any ram pump site the settings of the impulse valve (the stroke length and the valve weight) will decide how big the *closure velocity* is. A valve with a small weight and a short stroke has a low closure velocity. It will close when the water reaches only a low velocity. A valve with a large weight and a long stroke will need a much higher velocity to make the valve close. The *closure velocity* of the pump can be changed by making adjustments to the impulse valve — in other words, by *tuning* the pump.



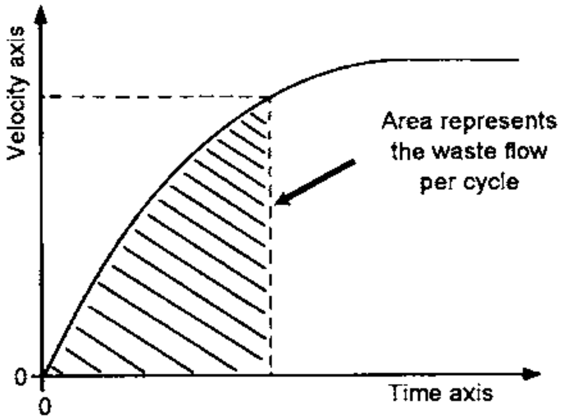
The time it takes for the water to reach the *closure velocity* can be worked out using the same graph. This is done by drawing a straight line across from the Velocity (Speed) axis at the *closure velocity* until it reaches the line on the graph. Another line is drawn from this point straight down to the bottom of the graph where it hits the Time axis. The scale on the Time axis can then be read to find out how long it takes to reach *closure velocity*.

You can see that if the pump has a high *closure velocity*, it will take a long time for the valve to close. If the stroke of the impulse valve was reduced, the velocity needed to close the valve would also be reduced and the time it would take to reach the new *closure velocity* would be less. So, reducing the length of the impulse valve stroke on a pump will make it work faster.



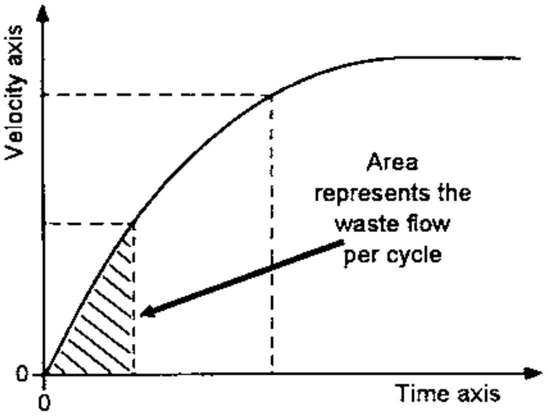
Closure velocity and waste flow

When a pump has a high *closure velocity* a lot of water will flow through the impulse valve before it shuts. This water is often called the *waste flow* for one cycle and can be represented by the area under the graph that has been shaded.



Area represents the waste flow per cycle

By shortening the length of the impulse valve stroke, the pump can be made to work faster and the *closure velocity* will be lower. The area representing the *waste flow* on the graph will be smaller, showing that the amount of water flowing through the pump (the *waste flow*) has gone down.

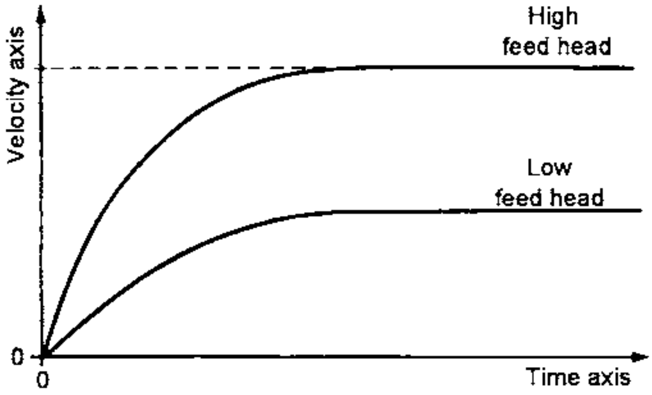


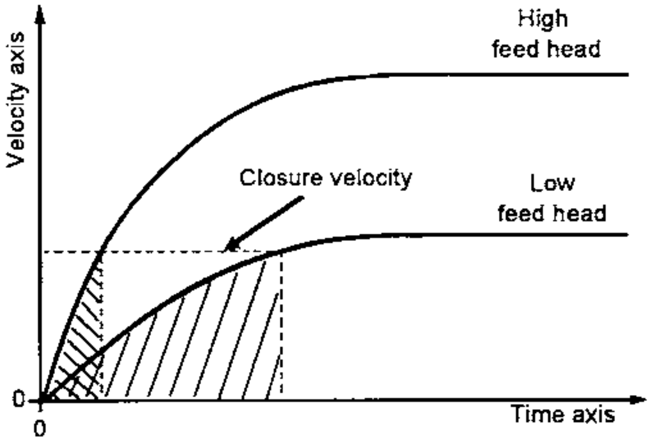
Area represents the waste flow per cycle

Closure velocity and feed head

You saw earlier with the reservoir, pipe and tap that when the head from the reservoir to the tap was increased, the acceleration was faster and the line on the graph rose more steeply. If the *feed head* of the ram pump system is increased, the line on the graph also rises more steeply.

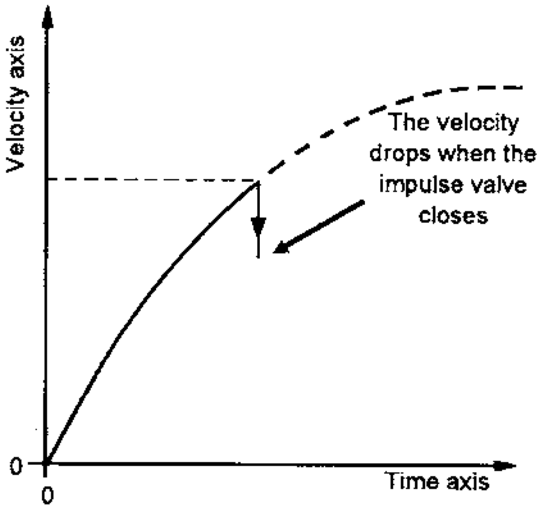
If the same ram pump system was given a different feed head, the *closure velocity* for the system would stay the same as long as the same pump was used and its tuning was not changed. The area under the line on the graph for the system with the higher feed head would be much less, showing that the waste flow was smaller. It would also take less time to reach the *closure velocity*, so the pump would work faster.





Water delivered from a ram pump

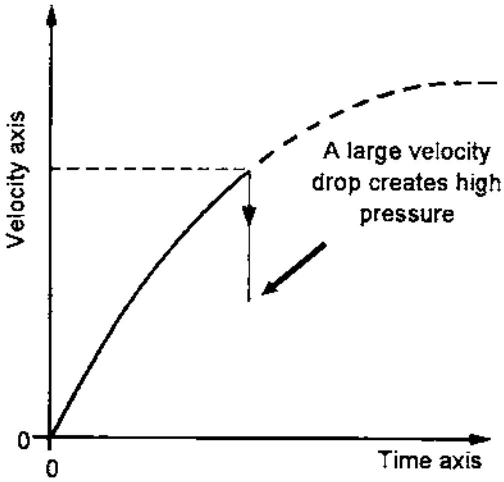
When the impulse valve on a ram pump closes, the water flowing down the drive pipe and through the pump has nowhere to go. The velocity of the water drops very quickly. As the velocity of the water drops, the energy of the moving water is turned into pressure energy. The more the velocity of the water drops the more the water pressure inside the pump rises.



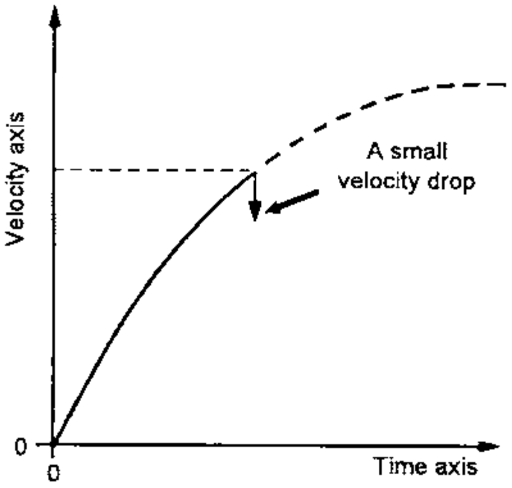
Delivery head

The velocity of the water continues to fall until the pressure in the ram pump is higher than the pressure in the air vessel. The pressure in the air vessel will depend on the height from the pump to the top of the delivery pipe. The height from the pump to the top of the delivery pipe is called the *delivery head.*

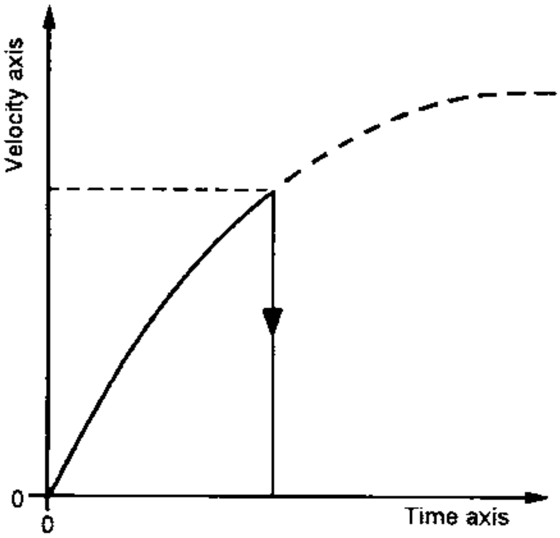
When the *delivery head* is high, there has to be a big drop in the velocity before the pressure in the pump is bigger than the pressure in the air vessel.



When the *delivery head* is small, the velocity only has to drop a small amount before the pressure in the pump is higher than the pressure in the air vessel.

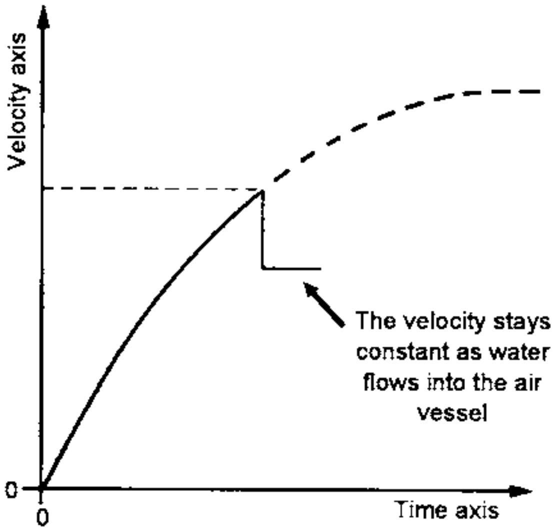


If the delivery head is very high, the closure velocity may be too small. When it is too small, there is not enough velocity to turn into pressure energy when the impulse valve closes. The pressure in the pump rises, but not enough to reach the delivery pressure. The water loses all of its velocity but the delivery valve does not open. The impulse valve may then open again and water flow through, allowing the velocity of the water to increase until the impulse valve closes again. When this happens a pump can work with the impulse valve opening and closing but without the delivery valve opening, so no water is pumped.



Delivery pressure

When the pressure in the pump is greater than the pressure in the air vessel, the delivery valve opens. Water flows through the delivery valve and into the air vessel. The water has lost velocity and gained pressure. It flows at the lower velocity into the air vessel. Water will continue to flow through the delivery valve at this velocity for a certain period of time. The amount of time will depend on the time it takes for a shock wave to travel up the water in the drive pipe to the drive tank and back down to the pump again.



This is more fully explained in the box on the next page. It is not necessary to understand all the details so you can miss out the box if it seems too complicated. All you need to know is that the water flows through the delivery valve at the reduced velocity for a certain period of time. The length of time will depend on the length of the drive pipe. If the drive pipe is short the period of time will be short. If it is long then the period of time that the water flows through the delivery valve will be longer. Remember that the pump is likely to be cycling every second or so, so the periods of time are all only fractions of a second.

More advanced explanation

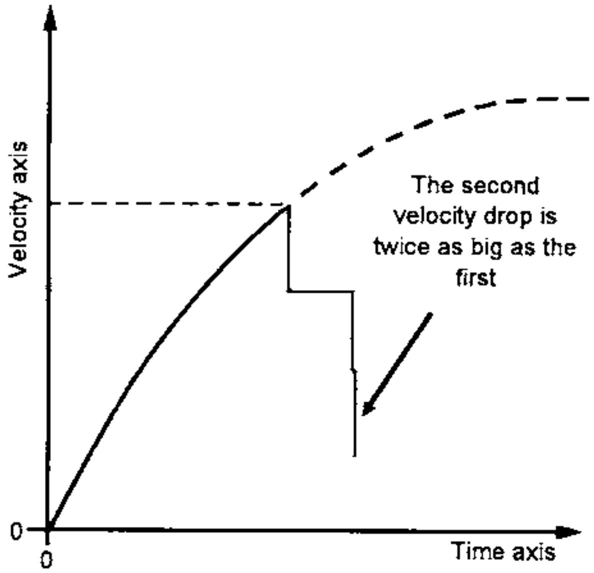
When the impulse valve closes, the water moving inside the pump suddenly slows down. When the first bit of water starts to slow down, its pressure rises. The water behind it also slows down and its pressure also starts to rise. Pressure rises along the drive pipe as all the water slows down and its pressure rises.

Try to imagine a line between the water in the pipe that has slowed down and the water that is still moving at full speed. This imaginary line travels very quickly from the impulse valve up the drive pipe to the drive tank. On one side of the line the water has slowed down and the pressure has risen. On the other side the water is still moving at closure velocity. This imaginary line is at the front of a "shock wave". The drop in velocity of the water across this shock wave is the same as the drop in velocity needed to open the delivery valve.

The shock wave travels at very high speed (usually over 1000 meters per second) up the drive pipe until it reaches the drive tank. The drive tank acts a bit like a mirror that turns things around and reflects them back. It is a low pressure shock wave which travels back down the drive pipe towards the pump.

The time taken for the shock wave to travel from the pump to the drive tank and back again will depend on the length of the drive pipe and the speed of the shock wave. The pressure in the pump, and the velocity of the water flowing through the delivery valve will remain constant until the shock wave has gone up the drive pipe, been reflected and come back down to the pump. The graph below shows that the velocity of water in the pump stays constant for a set period of time. The time will depend on how long it takes the shock wave to go up and down the drive pipe.

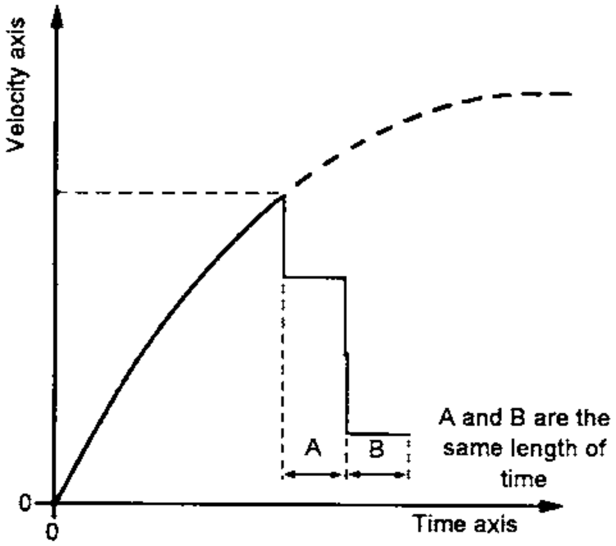
When the shock wave in the drive pipe has returned to the pump, the velocity of the water drops again. This keeps the pressure in the pump high enough to push water through the delivery valve into the air vessel. The second velocity drop is twice as much as it was the first time.



More advanced explanation

When the reflected shock wave reaches the pump the velocity there drops due to the lower velocity of the water *behind* the shock wave. It immediately drops again to recreate the pressure needed to keep the delivery valve open. Both of these drops in velocity are the same size as the first velocity drop when the impulse valve closed.

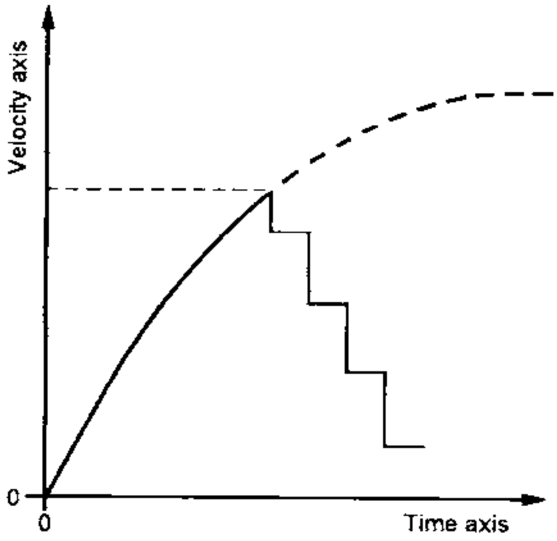
Water continues to flow through the delivery valve at the reduced velocity. It flows for the same amount of time as before, while the second shock wave travels up to the drive tank and back again.



More advanced explanation

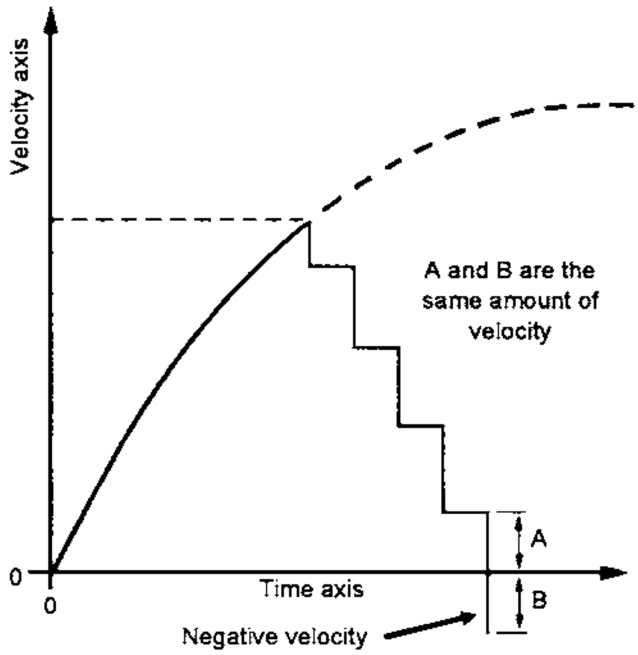
The second part of the second drop in velocity produces another increase in pressure that keeps the pressure in the pump greater than the pressure in the air vessel. Water flows through the delivery valve at the lower velocity. The increase in pressure starts another shock wave that travels up the drive pipe. The second shock wave is also reflected by the drive tank and another low pressure shock wave travels back down to the pump. Water continues to flow from the pump into the air vessel until the reflected shock wave reaches the pump.

Each time a shock wave comes back to the pump, the water's velocity drops again and a new shock wave travels up the drive pipe. Water continues to flow into the air vessel at the reduced velocity. The velocity in the pump continues to step down in this way until there is not enough velocity left to make another full step.



Recoil

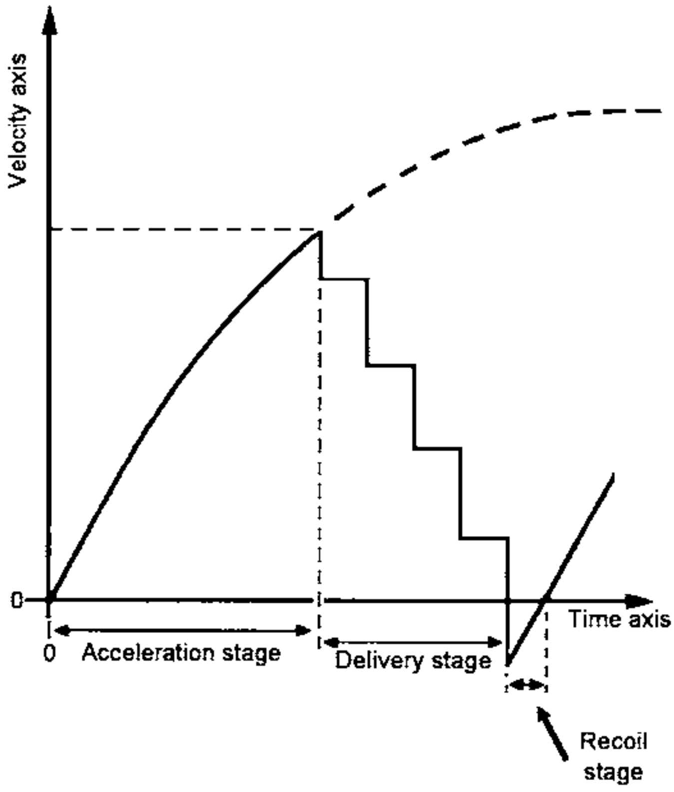
When there is not enough velocity left to make one complete step the pressure can no longer stay high enough to keep the delivery valve open, so it shuts. The water in the system is still moving with a low velocity down the drive pipe. The impulse and delivery valves are both closed so the water has nowhere to go. The water bounces back up the drive pipe towards the drive tank. The water is like a spring that is pushed against a wall so that it compresses and then is suddenly let go. It opens up and flies away from the wall.



As the water moves away from the pump it has a negative velocity, so the line on the graph goes under the base (under 0 on the Velocity axis). The negative velocity will be the same size as the positive velocity that was left when the delivery valve closed. When the water has a negative velocity it moves away from the pump towards the drive tank.

The negative velocity is shown where the line on the graph goes below 0 on the Velocity scale. The water flowing back up the drive pipe slows down and stops, then the line on the graph crosses back over the Time axis. After that, the impulse valve has reopened and the water begins to accelerate down the drive pipe. The line on the graph rises in the same way as before. The section of the graph below the line is called the "recoil" stage of the pump's cycle.

When the delivery valve closes and the water in the pump *recoils* back up the drive pipe, it is actually flowing away from the pump. This leaves a low pressure or vacuum in the pump. The low pressure lets the impulse valve drop open with its own weight.

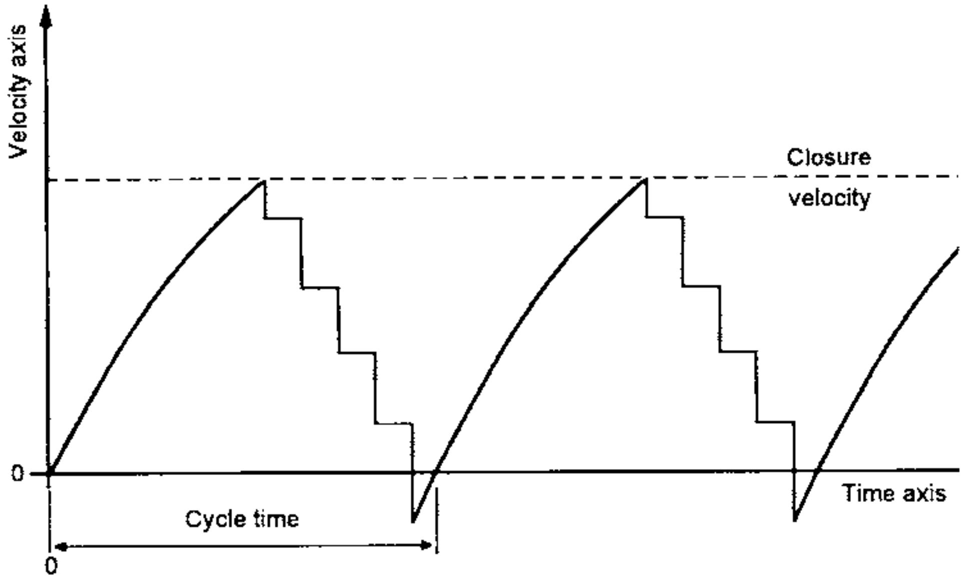


When the water has stopped recoiling, it starts to flow down the drive pipe and out through the open impulse valve again. It accelerates down the drive pipe and through the open valve as it did at the start of the pumping cycle.

The pump cycle

To make the operation of the pump easier to understand the pump cycle can be divided into three stages. They are called the *acceleration, delivery and recoil* stages. There is a very short pressurisation stage as well, but that can be ignored. The graph at the bottom of the previous page shows how these stages refer to different parts of the cycle.

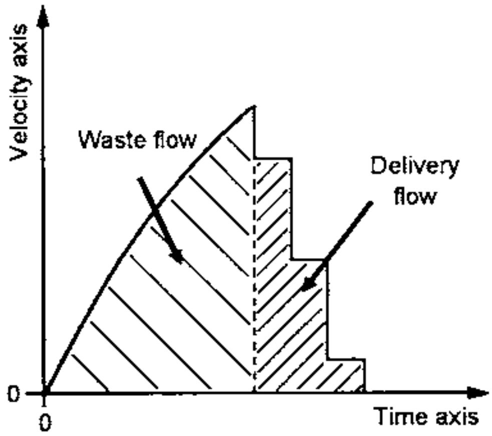
As the pump continues to operate, the same cycle is repeated. The water accelerates down the drive pipe and out through the impulse valve until the velocity of the water reaches closure velocity. Then the stages of delivery and recoil occur before the cycle starts again. The graph can be used to see the time taken for each cycle and work out how fast the pump is operating.



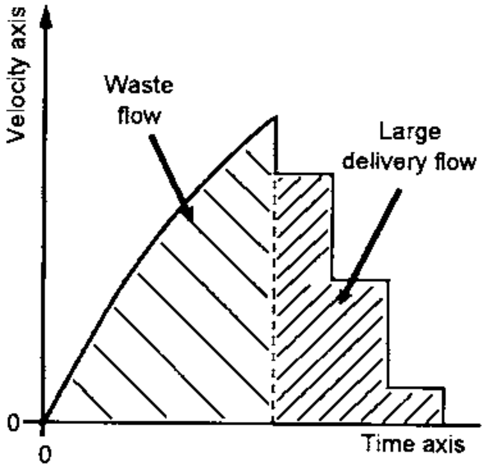
The impulse valve closes and the pump beats every time the line on the graph reaches closure velocity. For a pump working at 60 cycles a minute, the "cycle time" would be 1 second.

Delivery flow

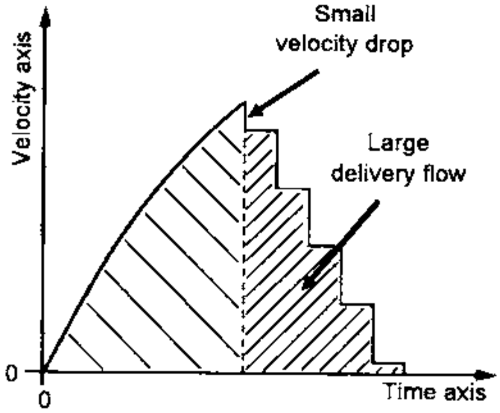
You saw on page 6 how the amount of waste flow could be represented by shading the area under the line on the graph. In the same way, the amount of water flowing from the pump into the air vessel can be represented by the area under the graph during the delivery stage. This is called the *delivery flow* per cycle.



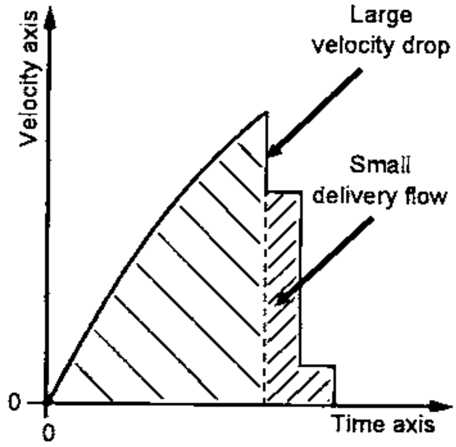
When the area under the falling part of the graph is large it means that there is a large *delivery flow*. Two things increase this area. One is increasing its height. The other is increasing its width either by having more steps or by having longer steps.



Systems with a low delivery head will only need a small drop in velocity to deliver water. The delivery stage will have many small drops in velocity before all the velocity is used up. The large area under the line on the graph shows that a large amount of water will be pumped with each cycle.



If the delivery head of the same system was increased, the acceleration of the water and the closure velocity would be the same but the drop in velocity required to reach the delivery head would be much higher. The graph shows that there would be a few large drops in velocity during the delivery stage of the cycle. The area under the graph during the delivery stage would be much smaller, showing that the flow through the delivery valve was small. Much less water would be pumped with each cycle.

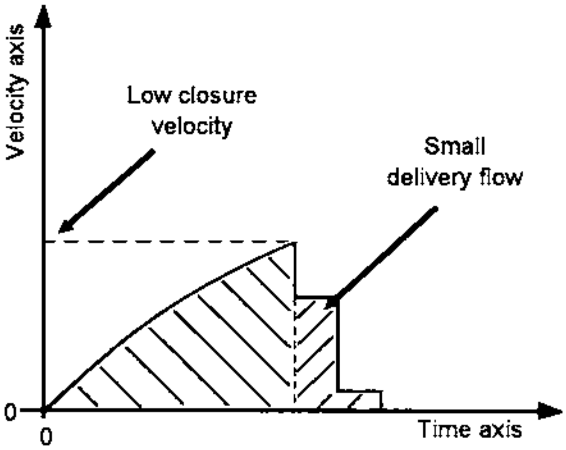


More advanced explanation

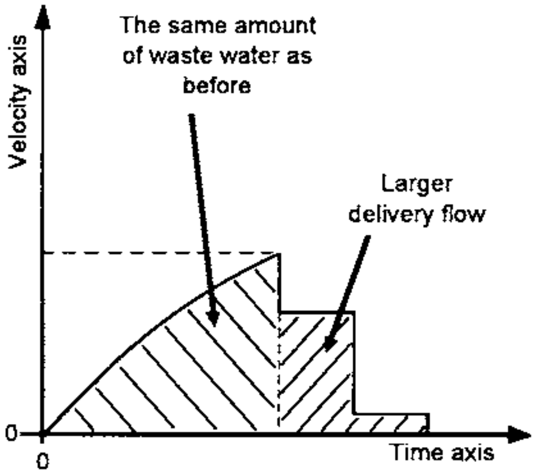
Because the drive pipe is the same length in both of the systems just described, the time taken for a shock wave to travel from the pump to the drive tank and back again would be the same. So the flat sections of the graphs, showing when the water is flowing at a steady velocity through the delivery valve, would each last the same length of time. The delivery stage of the pump cycle in a system with a low delivery head would be longer than it would be in the same system with a higher delivery head. The acceleration time would be the same in both cases and the time for the recoil stage would be very small. When the delivery head is increased, the length of the delivery stage is reduced and the pump operates faster.

Getting the best delivery flow

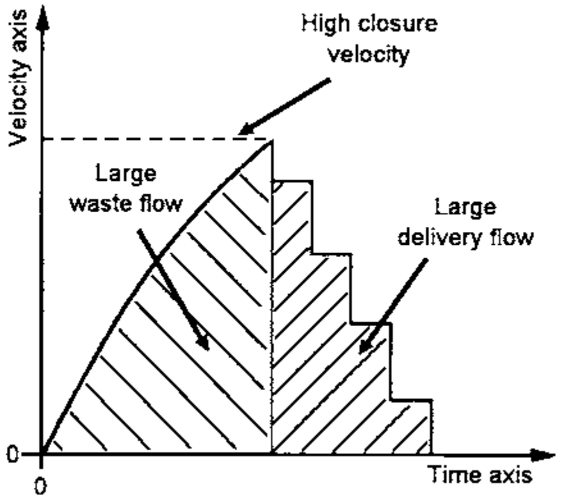
This is explained using an example. Suppose you are asked to design a ram pump site on a stream where the flow of water in the dry season is quite small. There is an obvious ram pump site but it only has a small drop, so the feed head would also be small. If a pump was installed there, the acceleration of the water would be quite low and so the graph would not rise very steeply. The impulse valve of the pump could be adjusted to use all the water available in the stream. With a low feed head, the acceleration and closure velocity would also be low. The pump would not deliver much water.



The owner of the site says that he needs more delivered water than the proposed site would give, so you have to look more carefully at the site design. Suppose that you find that you can double the feed head without too much trouble. Normally the drive pipe length will also double. By keeping the closure velocity the same, the feed flow will hardly change. The delivery head would be increased by an amount equal to the extra feed head, but this has little effect on the flows. Although the drops in velocity would be about the same as before, the steps are twice as wide and much more water would be delivered.



If the same site has plenty of water available in the rainy season, you could recommend changing the tuning of the impulse valve when the stream is full so that the closure velocity was increased. The valve would then take longer to close and much more water would flow through it. The delivery head would be the same as before so the drops in velocity would be the same size. Because the closure velocity would be higher there would be more drops in velocity during the delivery stage and more water would be pumped.



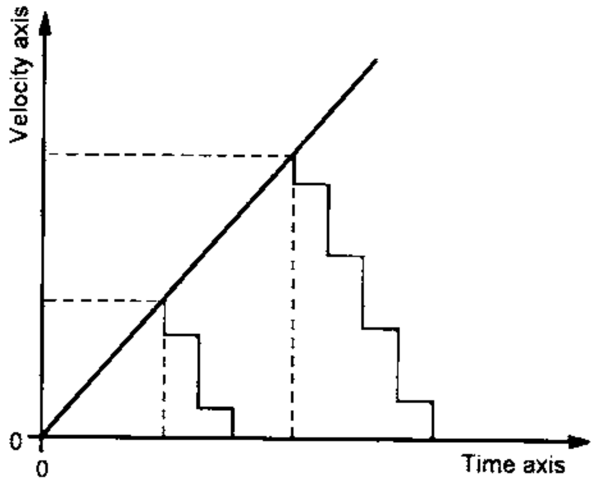
More advanced explanation

As the closure velocity is increased (by changing the settings of the impulse valve) three things happen:

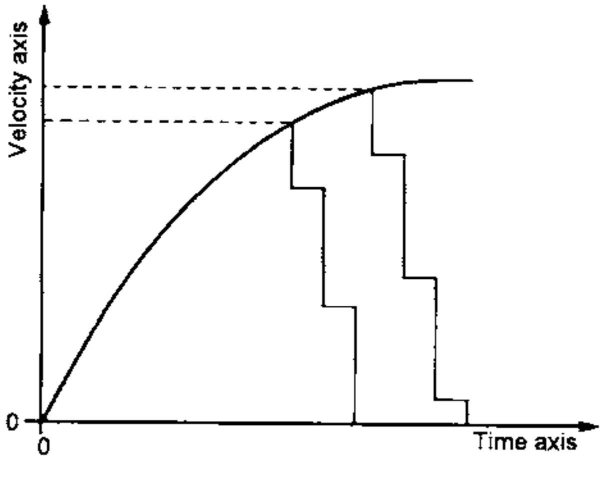
- the drive flow per cycle increases a lot
- the delivery flow per cycle increases a lot
- the pump works a little more slowly (fewer cycles per minute)

The overall effect is to increase both the delivery flow per minute and the drive flow per minute.

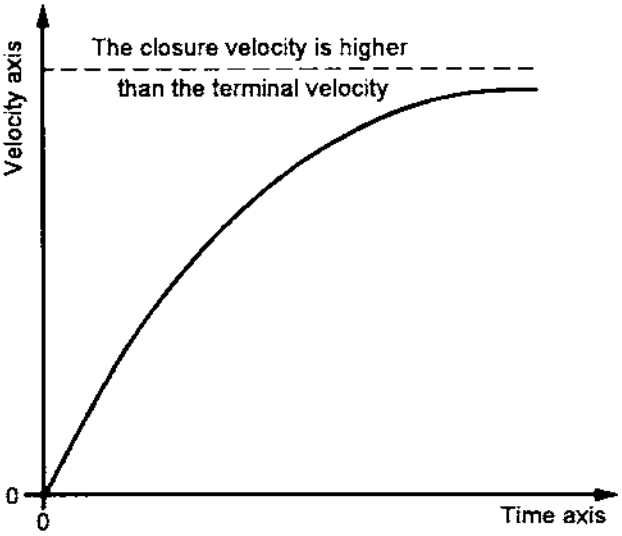
When the closure velocity is in the steep section of the line on the graph, increasing the closure velocity will increase the delivery flow per cycle and the total water delivered by the pump.



If the impulse valve was tuned so that the stroke was very long or the weight very heavy, the closure velocity would be in the flatter section of the line on the graph. The drive flow through the pump would increase a lot but the delivery flow would change very little. The time taken for each cycle would also increase so that there would be fewer cycles per minute. The pump would become less efficient and would actually pump less water per minute.



Increasing the weight and stroke of the impulse valve too much would stop the valve from closing at all. This is because the valve cannot close when the velocity needed to close it is more than the terminal velocity of the water through the pipe.



The following DTU Technical Releases give further information about ram pumps.

TR 11: The DTU S1 ram pump

TR 12: The DTU P90 ram pump

TR 14: The DTU S2 ram pump

TR 16: An introduction to hydraulic ram pumps (and the DTU range)

DTU

Ram Pump Programme

TECHNICAL
14
RELEASE

DTU S2 PUMP

DTU TECHNICAL RELEASE NO.14 : THE DTU S2 PUMP

INTRODUCTION

This Technical Note is in four parts.

The first part (1 page) is a 'Stop Press' UPDATE containing amendments (dated November 1998) to the original which was written in 1995.

The second part (4 pages) is a summary of the pump's design and performance, suitable for copying, laminating and posting in the pump house.

The third part (20 pages numbered 1-20) is a detailed description of how to use the drawings to make an S2 pump. It should be read in conjunction with the amendments mentioned above.

The fourth part is a set of 16 drawings, of which Nos. 11a, 13, 14 and 14a have been added as amendments and offer alternatives to earlier drawings.

The 'Status' of this pump is that several dozen have been made, mostly in Africa, but that none has been run continuously for years on end. The pump is not a 'very-long-life' design although, in normal applications and incorporating the amendments in the UPDATE, continuous use should require only occasional replacement of worn parts. The Drawings deliberately do not precisely define the materials to be used, because the design is supposed to be somewhat adaptable to what is available. If all the metal parts are of mild steel, corrosion will cause some problems - especially affecting nuts and bolts and the impulse valve stem. If possible these parts should be made of stainless steel.

It is not the intention of the Development Technology Unit to undertake further development of this pump. However the Unit's Director would be happy to receive any comments from the field about its performance or any suggestions for further 'UPDATES'.

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TR14 UPDATE - November 1998

Since this Technical Release was written in 1995, based mainly on field experience in Zimbabwe and Zaire, the DTU has obtained further experience with this S2 model of ram pump. The following modifications derive in particular from observations during extended testing in Staffordshire, England during Summer 1998. The modifications are expressed as variants on the production procedure of the (original) pages that follow. Extra drawings have been added (Dwgs. 11A, 13, 14 and 14A).

1) [*Problem of steel washer cutting into delivery valve rubber disc*]
   Refer to page 14 - Making the S2 pump delivery valve.

Fit a rubber washer, made from the same material as the valve disc and of the same diameter as the steel washer, between the steel washer and delivery valve disc.

2) [*Wear and tilting wobble of impulse valve stem*]

Refer to page 12 - Making the S2 pump impulse valve - and to old Drgs Nos.9, 11a & 12 and new Drawing No.11a.

Fit a second (upper) stage to the impulse valve guide. This requires that a longer valve stem and longer guide bolts are made/used than those shown in drawing number 12. The plain section of the valve stem is 50 mm longer (i.e. 100 mm overall length), the bolt shank is 50 mm longer (i.e. 130 mm long).

If a *new* two stage guide is to be used then the assembly should be welded together *before* the holes are drilled. However if the second stage of the guide is fitted *as an addition to/modification of* an existing impulse valve, then (to ensure correct location and operation of the valve itself) any welding should only be undertaken *after* the impulse valve is fully assembled and bolted to the pump body, as detailed on pages 17 to 18.

3) [*Problem of delivery valve gasket blowing out midway between the clamping bolts*]

Refer to old Drawing No.3 & new Drawing No.13

New gasket size, internal diameter = 95 mm, outside diameter = 165 mm. Using the internal diameter of the gasket shown in Dwg.13, which is a little smaller than that of the flange in Drg. 3, ensures that it protrudes slightly inside the flange. This wider gasket is primarily required between the air vessel and delivery valve plate, but can also be used between delivery plate and pump body and in the impulse valve.

4) [*Problem of rusting bolts*]

Thoroughly grease all bolts prior to assembly and use nuts or washer/nut combinations that extend to the end of the bolt threads, leaving almost no thread exposed. Of course if stainless steel bolts and nuts are available and affordable, they should be used in preference to plain steel.

5) [*Problems in aligning pump with drive pipe*]

If possible, the drive pipe, pump and cradle should be assembled in situ within the shuttering for the concrete base *prior* to any concrete being poured

6) [*Problems with marking out delivery valve plate for drilling*]

Refer to old Dwg. Nos. 5, 6 & 7 and new Drgs. Nos. 14 & 14a.

An alternative layout of holes in the delivery valve plate is to have them in parallel staggered rows as shown in Drawing number 14. The delivery valve rubber disc now flexes as a butterfly's wings and has to be retained by a bar or rod held in position by two bolts (rather than the original single central bolt) - see Drawing 14A. Slightly inferior pump output may be experienced (due to more back-leakage before the delivery valve recloses) but this layout is easier to mark out and make, so there is less chance of having too thin a wall between adjacent holes. As before, care should be taken to not so tighten the bar-retaining bolts that the valve rubber disc no longer lies flat on the valve plate. The nuts on these bolts should if possible be self-locking or held on with a locking compound such as 'Locktight'. The alternative of using a second locknut on each bolt is not so good.

7) [*Problems with silting up of intake pool*]

Ram pumps driven by water drawn from immediately below springs, or from large reservoirs, have little problem with silting. Pumps drawing water from behind small dams (e.g. 400mm high) on streams may experience major silt problems, with the 'pool' silting up by as much as 300mm after a single storm. Drawing all drive water through silt will almost certainly overload the silt-settling capacity of the drive tank. There is no easy way of automatically keeping such a pool silt-free and such locations are therefore not suitable for ram pumps unless someone is on site to apply frequent manual desilting procedures to both pool and drive tank.

DTU S2

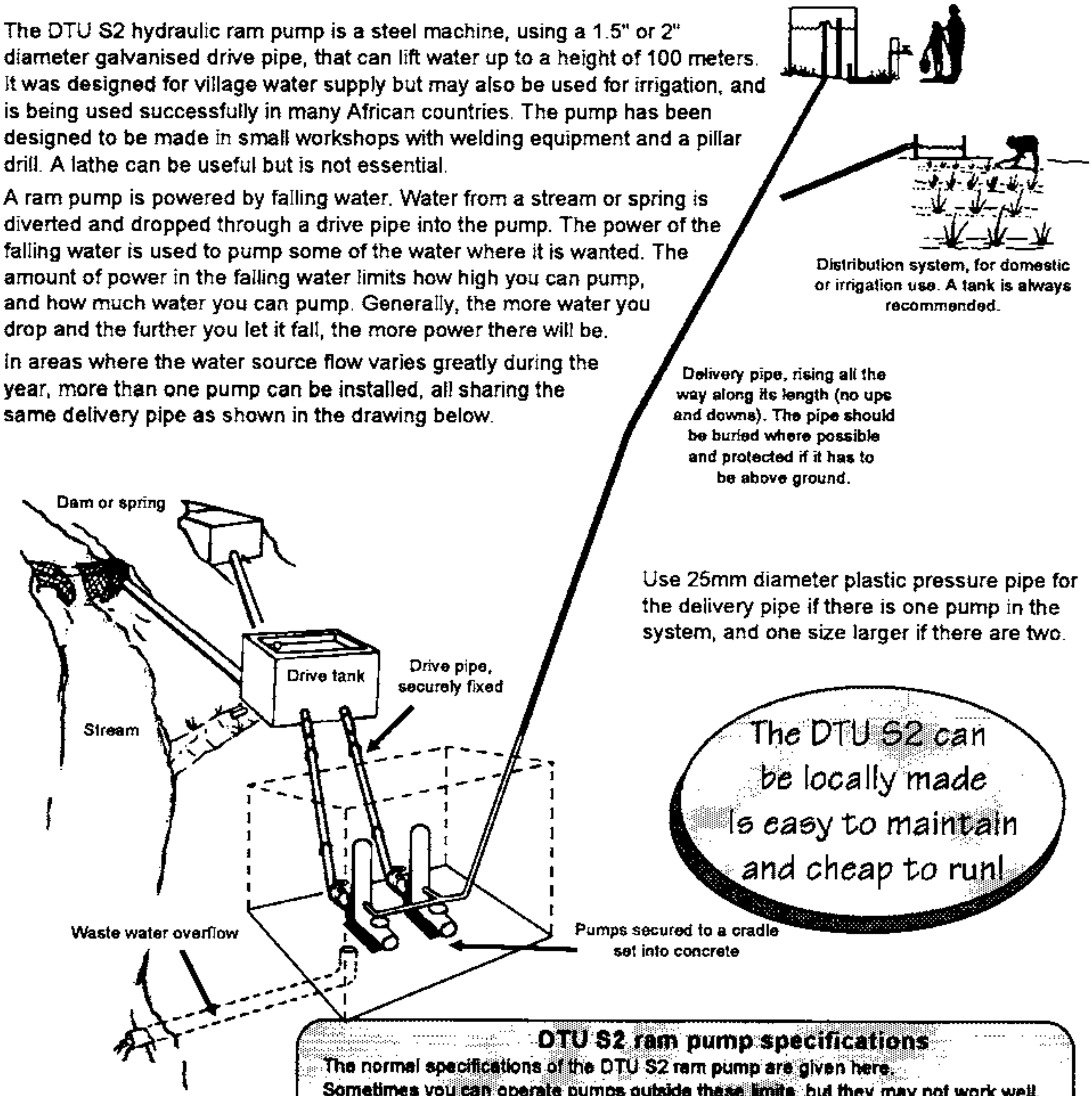
hydraulic ram pump

The name "S2" stands for a Steel pump with a drive pipe up to 2" in diameter.
The S2 replaces the DTU M8 pump

The DTU S2 hydraulic ram pump is a steel machine, using a 1.5" or 2" diameter galvanised drive pipe, that can lift water up to a height of 100 meters. It was designed for village water supply but may also be used for irrigation, and is being used successfully in many African countries. The pump has been designed to be made in small workshops with welding equipment and a pillar drill. A lathe can be useful but is not essential.

A ram pump is powered by falling water. Water from a stream or spring is diverted and dropped through a drive pipe into the pump. The power of the falling water is used to pump some of the water where it is wanted. The amount of power in the falling water limits how high you can pump, and how much water you can pump. Generally, the more water you drop and the further you let it fall, the more power there will be.

In areas where the water source flow varies greatly during the year, more than one pump can be installed, all sharing the same delivery pipe as shown in the drawing below.



Use 25mm diameter plastic pressure pipe for the delivery pipe if there is one pump in the system, and one size larger if there are two.

The DTU S2 can
be locally made
is easy to maintain
and cheap to run!

DTU S2 ram pump specifications

The normal specifications of the DTU S2 ram pump are given here.
Sometimes you can operate pumps outside these limits, but they may not work well.

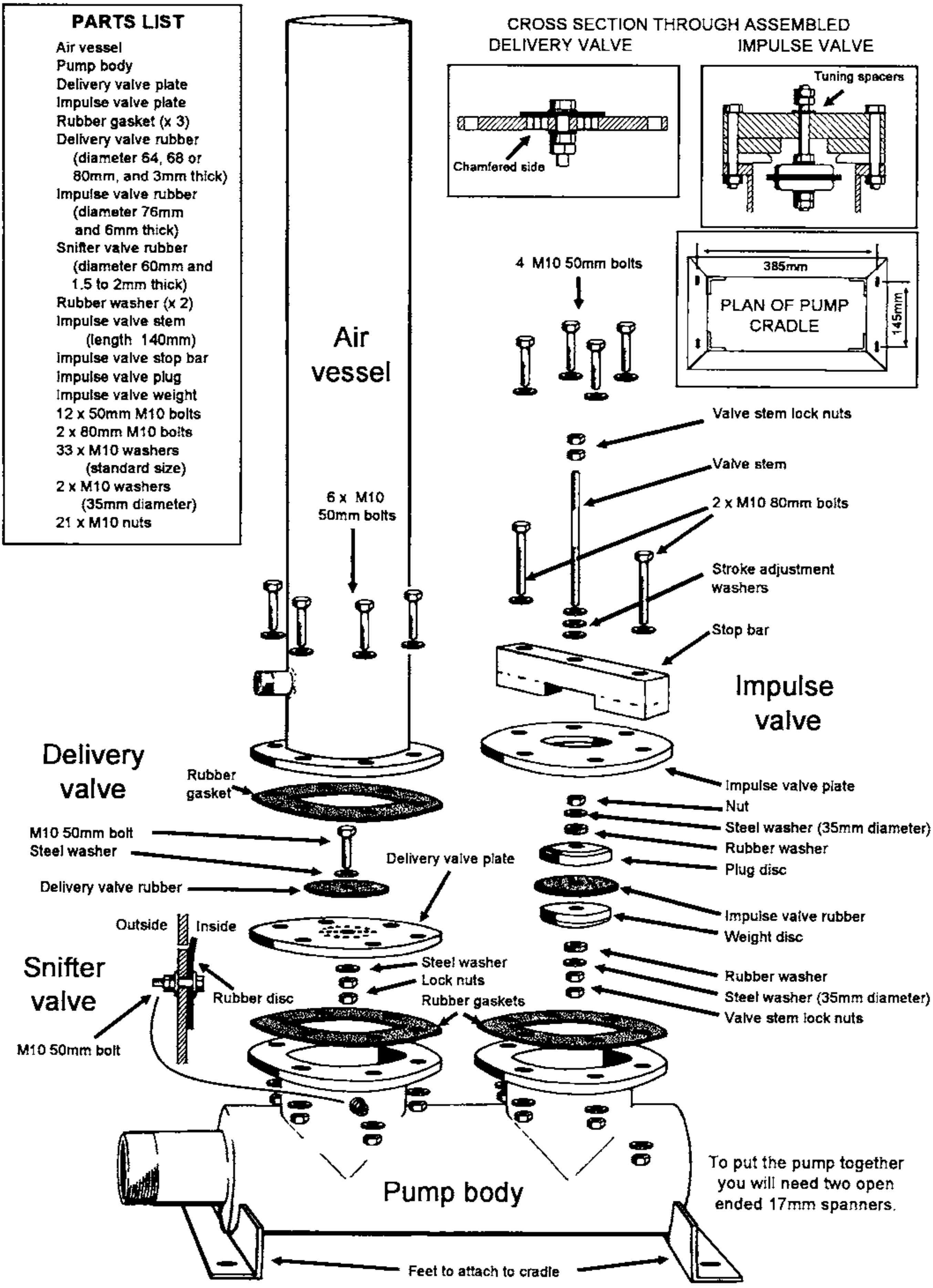
drive head range — 2 to 15 meters
drive flow range — 40 to 120 liters a minute
drive pipe material — Galvanised iron
drive pipe diameter — 1.5" for flows from 40 to 60 liters a minute
drive pipe diameter — 2" for flows from 60 to 120 liters a minue
delivery head range — up to 100 meters
typical delivery range — 1 to 25 liters a minute
delivery pipe diameter — 25mm

DTU S2 PUMP: USER INSTRUCTIONS

AN EXPLODED VIEW OF THE DTU S2 PUMP

PARTS LIST

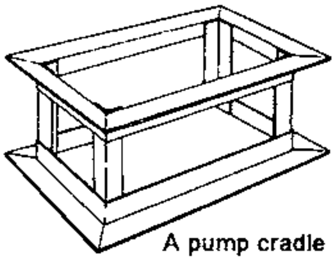
- Air vessel
- Pump body
- Delivery valve plate
- Impulse valve plate
- Rubber gasket (x 3)
- Delivery valve rubber
  (diameter 64, 68 or 80mm, and 3mm thick)
- Impulse valve rubber
  (diameter 76mm and 6mm thick)
- Snifter valve rubber
  (diameter 60mm and 1.5 to 2mm thick)
- Rubber washer (x 2)
- Impulse valve stem
  (length 140mm)
- Impulse valve stop bar
- Impulse valve plug
- Impulse valve weight
- 12 x 50mm M10 bolts
- 2 x 80mm M10 bolts
- 33 x M10 washers
  (standard size)
- 2 x M10 washers
  (35mm diameter)
- 21 x M10 nuts



To put the pump together you will need two open ended 17mm spanners.

Installation notes

The DTU S2 pump should be installed in a properly designed system. To prevent vibration causing breakages, it should be firmly bolted to a steel frame (called a pump cradle) that is half buried in a concrete base. The cradle is usually made from 40 x 40mm angle iron and will vary in size depending on the number of pumps installed. Hole locations for just one pump are shown on the previous page.
All pipes in the system should be supported firmly, and buried where possible. The drive and delivery tanks should be constructed on good foundations by experienced tradesmen. Pipe joints to the drive tank should allow the pipes to move slightly without damaging the tank walls or leaking badly.


A pump cradle

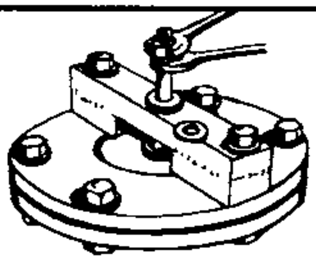
Starting and stopping the ram pump

Although ram pumps often start very easily, they can be awkward the first time they are run.
To start the pump:

1. Make sure that any valve fitted on the delivery pipe is open and then open the drive pipe valve. Water will flow out of the open impulse valve until it suddenly shuts. If it reopens automatically, the pump should continue to run on its own. If it does not, you must prime the delivery system as described in Step 2 alongside.
2. Push down on the top of the impulse valve stem with your foot to reopen it (wear strong boots). Again, water will flow out of the open impulse valve until it suddenly shuts, then push down immediately to re-open the valve. Keep helping the valve to re- open until it will do so by itself.

To stop the pump, hold the impulse valve stem up to close it or shut the valve at the bottom of the drive pipe.

Tuning for best performance



The DTU S2 can be tuned to adjust performance. This is done by changing the up and down movement of the impulse valve, which is usually set to around 15mm. Tuning is usually done to achieve either the maximum delivery flow or the most efficient use of the drive water available.

Maximum delivery

When there is plenty of drive water available, the pump can be tuned to deliver as much water as possible. To do this, remove all washers from the impulse valve stem so that the valve has as much up and down movement as possible (about 20mm).

WARNING: - this also puts the pump parts under greater stress and makes them wear more quickly.

Low drive flow

If the pump uses more water than is available it will soon stop. If this happens it must be tuned to use less. The impulse valve should be tuned down to use 90-95% of the water available from the source. To tune the pump down, add washers onto the impulse valve stem so that the valve has less up and down movement. The shorter the stroke, the smaller the amount of drive flow needed, and the less water is delivered. The minimum stroke length is around 10mm.

Routine maintenance

While the pump is running normally, a visit should be made once a week to check that bolts are tight and that there are no leaks. Once a month an inspection of the whole system should be carried out. It is also recommended that a log book is kept to record the checks and repairs that have been made.

Monthly maintenance check list (without stopping the pump):

1. Inspect all the joints to check for leaks.
2. Check if there is sufficient air in the air vessel. This can be done by listening carefully to the pump. If there is insufficient air in the air vessel, the pump will be much louder than usual. This means that the snifter valve is probably blocked and will need to be cleared. If a bleed screw is fitted, when opening it, air or a small amount of water followed by a rush of air means the air level is OK. If only water emerges, then again the snifter valve will have to be checked for blockage.
3. Clean any filters installed in the system.
4. Remove excess silt or debree from tanks or from behind the intake dam or weir if necessary.
5. Walk along all pipes looking for damage. Also, inspect the tanks for leaks, particularly at pipe joints.

Pump repair

If the pump stops or it delivers less water than usual, it may require adjustment or repair.

Look at the pump and if there is no obvious fault start it again if you can. Watch the pump and listen for irregular pumping or unusual noises. A worn impulse valve, for example, is usually obvious because water squirts through when the valve is closed. Some parts of your ram pump may need occasional replacement. the frequency of this will depend on how hard the pump is working and on the cleanliness of the drive water.

Tools you will need:

2 x 17mm ring/open end spanners to disassemble and assemble the pump
2 x Adjustable wrenches - to loosen a union joint on the delivery pipe (if fitted)

Taking the pump apart

Depending on the fault it may be necessary to disassemble the impulse valve and/or the air vessel. Before attempting to take apart the pump:

1. Make sure that the drive pipe valve is closed and the impulse valve is open. This will allow you to work on the impulse valve ONLY.
2. Depressurise the air vessel.

   WARNING - Before attempting to remove the air vessel, always release the pressure in it slowly. An ideal system will have a gate valve or one-way valve and a union fitted between the air vessel and the bottom of the delivery pipe and the optional bleed screw fitted to the air vessel. With the pump stopped, close the gate valve in the delivery pipe to stop it draining back. If a one-way valve is fitted it will close automatically. Then loosen the bleed screw to release the pressure in the air vessel. If none of the above are fitted, the only other way to release the pressure in the air vessel is to loosen each of the air vessel flange bolts one turn at a time until the water and air escapes through the join at the flange. You will certainly get wet this way.

Checks

1. Check the delivery valve rubber for wear and blockage of the valve holes. Check that the lock nuts on the valve bolt are tight.
2. Check that the snifter valve is in good condition.
3. Remove the impulse valve and check the impulse valve rubber and the rubber washers for wear. Check that the nuts on the valve stem are tight and check for excessive wear of the stem. Replace parts if necessary.
4. Check the pump body is firmly bolted down, then reassemble the pump, ensuring that all bolts are greased.

Putting the pump back together

Assembly of the pump is shown in the exploded view drawing, but the following important points need to be kept in mind:

1. Assembling the delivery valve

   Put together the delivery valve plate, the rubber and the bolt. Make sure the side of the plate with the chamfered holes is on the opposite side to the rubber, and that the rubber is on top.

   Screw on the first nut until it is finger tight and then undo it by one turn. Care must be taken not to overtighten the bolt and nuts as this will affect the performance of the valve. Next, screw on the other nut and tighten it up against the first. Use the spanners to tighten them firmly together. This will lock them together, and also allow a small up-and-down movement of the bolt and rubber.
2. Assembling the snifter valve

   Put the 'shaped' bolt and washer together, feed the bolt through the valve rubber, then push this through the pump body. Make sure that the shaped curve of the bolt head and washer align with the curvature of the body.

   Screw on the first nut until it is only finger tight. If the nut is on too tight the rubber will curl away from the pump body and will need to be slackened off slightly. Then screw on the second nut and tighten the two nuts firmly together using the spanners. Then check that the rubber has not distorted. If it has, slacken the nuts half a turn and tighten the outer one again.
3. Assembling the air vessel/delivery valve/rubber gaskets

   Align the delivery valve, air vessel, pump body and rubber gasket mounting holes and feed through the bolts. Make sure the delivery valve is the correct way up (the valve rubber facing upwards) and then tighten the nuts by hand. Use the spanners to tighten each nut and bolt a little at a time, working around the flange. This will draw the assembly together evenly.
4. Assembling the impulse valve

   The first parts to assemble are the valve stem, discs and rubbers. Screw on a nut to the longer threaded end of the stem up to the end of the thread. Push a steel washer on up to the nut, then add a rubber washer. Follow this with the valve plug disc, with the chamfered side towards the nut. Slide the valve rubber up against this, then the weight disk with the chamfered side facing away from the rubber. Follow this with another rubber washer and a steel washer. Screw a nut up them until it is finger tight. Thread on another nut and use the spanners to tighten the nuts together. This part of the assembly is sometimes known as the valve plug.

   Hold the impulse valve plate and the valve plug together, with the chamfered side of the plate opposite to the side against which the valve rubber presses. Slide the stop bar onto the top of the stem and thread a nut loosely on the stem.

   Align the valve assembly, pump body and rubber gasket and feed through the flange bolts. The two longer bolts feed through the cross-bar as well.

   Thread on the six nuts by hand, then use the spanners to tighten the four shorter bolts that hold down the valve plate. Again care must be taken to ensure that these nuts are tightened evenly. The next step is to make sure the closed valve plug is centred in the valve plate hole before tightening down the two remaining nuts that secure the stop bar. To check the alignment, open and close the valve manually turning the valve plug to make sure it does not catch on the hole in the valve plate.

Now you only need to set the stroke length of the valve for the pump to be ready for use.

Spare parts to keep on the site

- impulse, delivery and snifter valve rubbers
- an impulse valve stem
- a few spare M10 nuts, bolts and washers

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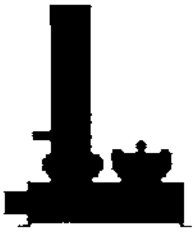
Making a DTU S2 ram pump



When you have decided to make a pump, the first thing you must do is make photocopies of the DTU S2 ram pump design drawings in Technical Release number 14b. The copies can be used in the workshop and it will not matter if they get dirty or are damaged. Some of the drawings can also be used as templates.

It will be useful to have the copies of the design drawings beside you as you work through this Technical Release. The pump's normal operating ranges are on the first drawing.

The manufacture process is presented under the following headings.

- **The parts of the pump**
  This introduces the main parts of the DTU S2 pump.

- **Tools required**
  The DTU S2 pump was designed to be made in small workshops with limited tools. This section describes the tools recommended. We have assumed that you are a workshop technician who already knows how to use the tools.

- **Guides and Templates**
  Simple guides and templates are useful, so we have included descriptions of guides and templates, and suggest ways of making them.

- **Materials needed to make a DTU S2 ram pump**
  A "shopping list" of the materials that you will need is given on page 6. This can be photocopied and taken with you when you buy materials.

- **A step by step guide to manufacture**
  The process of manufacture is described in detail under this heading. It begins with making the pump body and air vessel, and goes on to cover the valves and the pump cradle.

- **Assembly and testing**
  Putting the valves together properly is very important, so the process of assembly is described. The description includes some suggested ways of checking that they work properly.

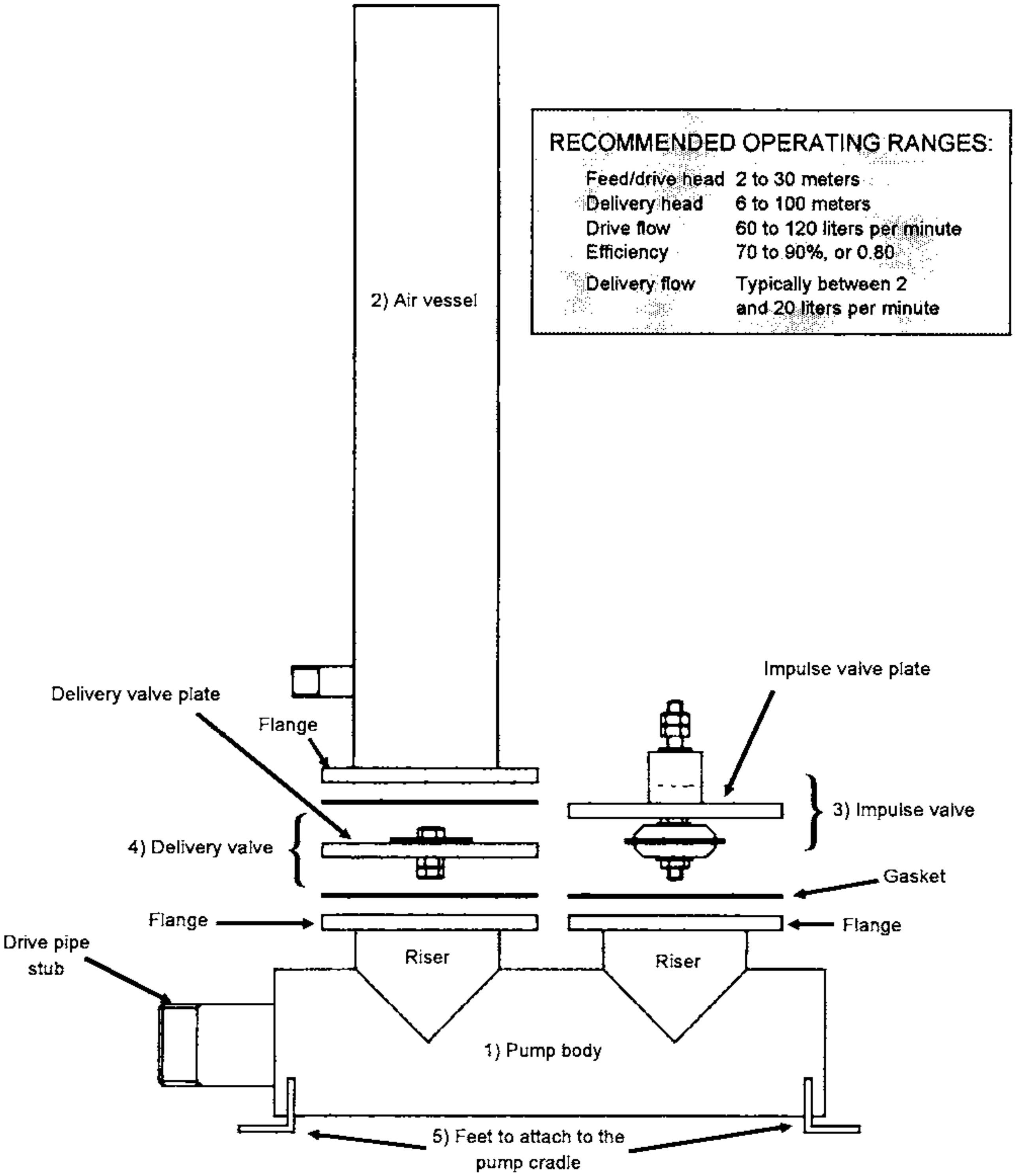
- **Spare parts**
  This explains which spare parts to supply with a pump. It points out which parts you should expect to wear out or fail.

- **Optional addition**
  The addition of a "bleed" screw in the air vessel can make it easier to find out what is wrong with a pump when it does not perform properly. It can also make the pump easier to maintain. The "bleed" screw is described under this heading.

The parts of the pump

The picture here shows the main parts of a DTU S2 ram pump. There are five, apart from the risers and flanges. The pump's recommended operating ranges are given in the box.

1 The pump body
2 The air vessel
3 The impulse valve
4 The delivery valve
5 Feet to attach the pump to the cradle.



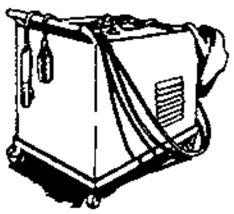
RECOMMENDED OPERATING RANGES:

Feed/drive head	2 to 30 meters
Delivery head	6 to 100 meters
Drive flow	60 to 120 liters per minute
Efficiency	70 to 90%, or 0.80
Delivery flow	Typically between 2 and 20 liters per minute

Tools required

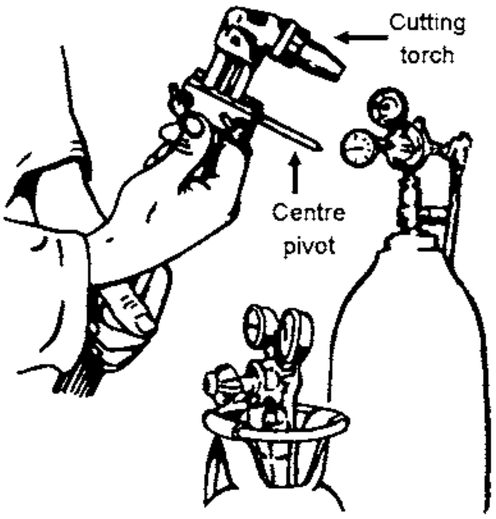
DTU S2 ram pumps can be made in a workshop with welding facilities, a drill, a hacksaw and files. It is hard work making them with as few tools as this. It is also hard to make the pumps to a high enough standard. Cutting and filing the parts by hand will take a very long time and it may not be possible to make the parts accurately. Do not plan to make more than one pump unless you have access to some other power tools.

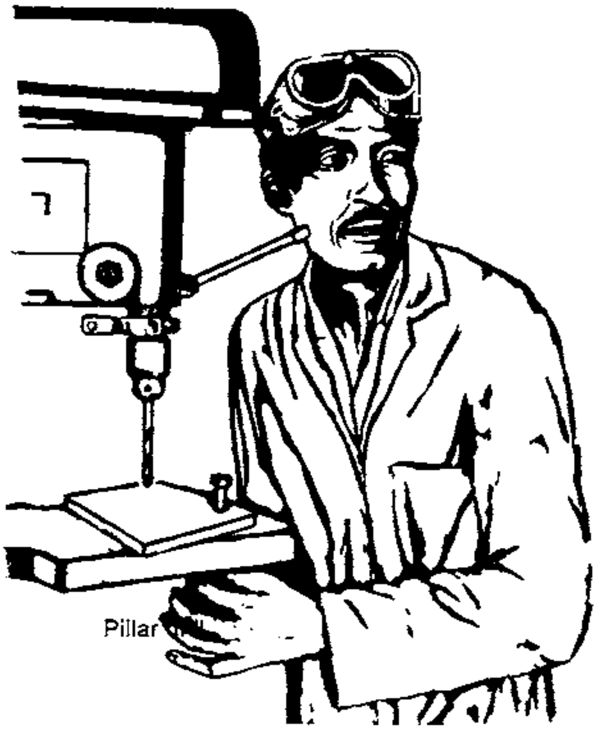
Most small workshops do not have a lathe, but many do have a gas cutting torch. Many also have a bench-grinder and a hand-held angle grinder. The step-by-step manufacturing guide that follows assumes that the pump is being made using a gas cutting torch, an arc-welder, a pillar-drill and grinding machines. Some parts of this guide will be useful to people who are making the pumps using other tools. A lathe can be useful for making parts of the impulse valve when one is available.

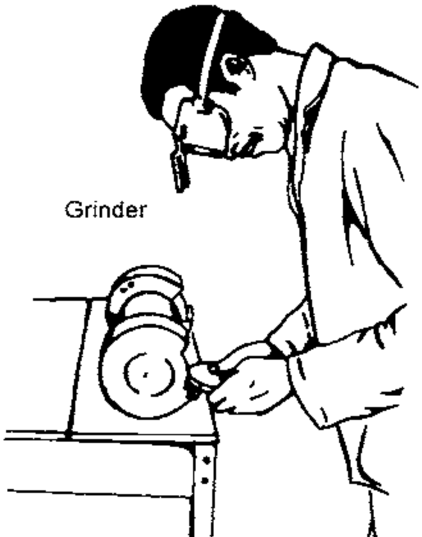


Arc welder

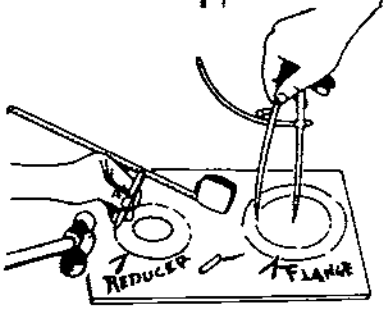
To cut circles accurately with a cutting torch, a centre pivot can be bought or made. The one shown here was made in the workshop where it is used.







You will also need chalk, a scriber, a measuring tape, dividers, a centre punch, files, a 10mm hole punch, an M10 tap and die, drill bits, two 17mm spanners, goggles, gloves, PTFE tape, a setsquare, a feeler-gauge and a hammer.

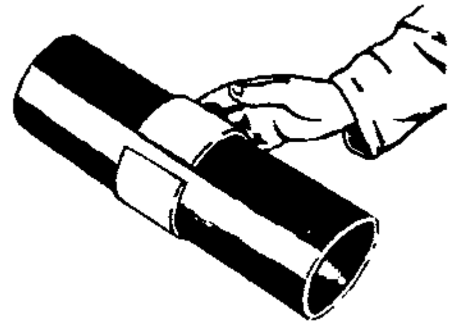


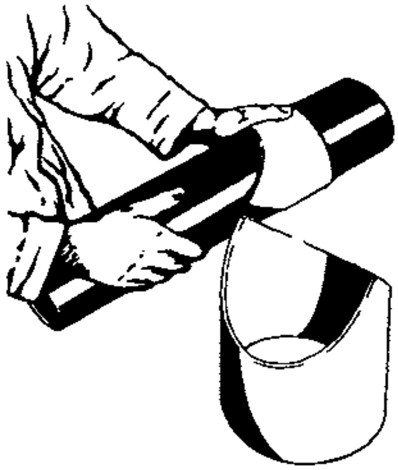
Guides and templates

When you are planning to make a number of pumps, it is worth making a few guides or templates or guides to help when marking up, cutting and drilling.

Guides for marking out the pump body

Use a short piece of PVC pipe of the same size as the pipe to be marked. Cut the PVC pipe along its length and push it over the steel pipe. Hold it in place and use it as a guide to score a line around the pipe.





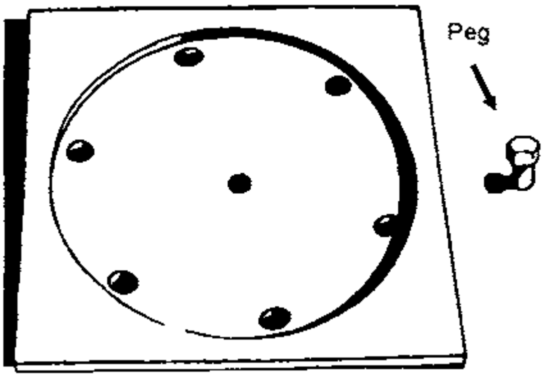
A "V" notch template like the one shown on the left can be made using thin plate (1mm) or PVC pipe. This is a guide for marking up the notches cut into the pump body and for the risers that fit into the notches.

When you have scored the line in the right place you can make it easier to see by rubbing chalk over it. Scored lines can be very hard to see through the protective goggles used when cutting. Use a centre punch to mark dots along the scored line. Use the punch about every 5mm.

It is very important to mark up clearly. If you do not, you may not cut a straight line with the torch and so you may have to start again.

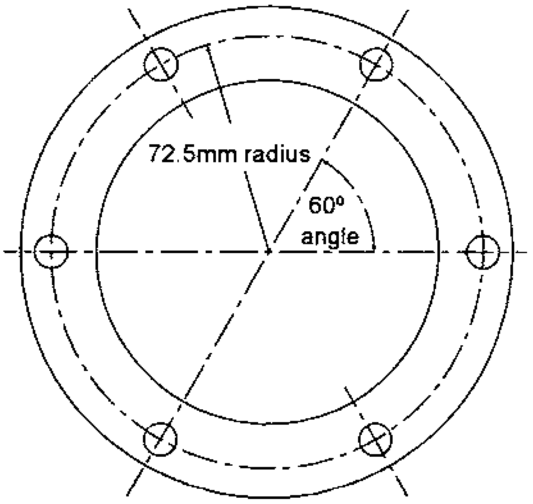
Flange and valve plate template

Design drawings number 3, 5, 6, 7, and 10 can be copied and used as templates. If you want to make a lot of pumps it is probably worth making a a steel template for the flanges. If you do not have access to a lathe, consider having the template made for you in another workshop.

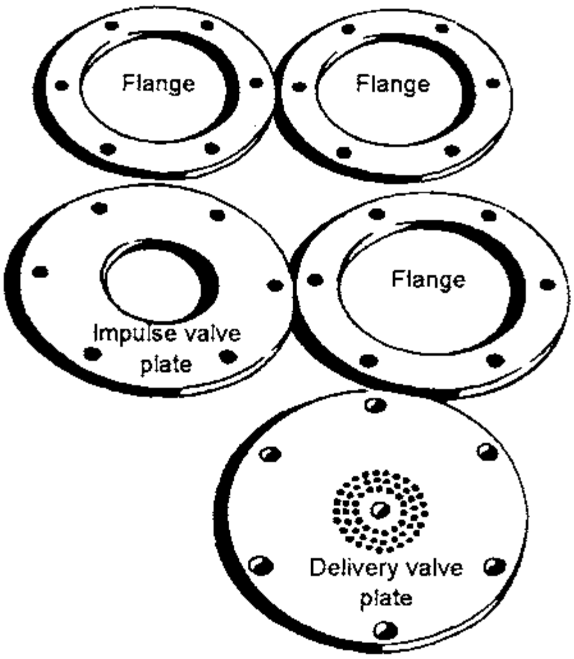


The template can be recessed with a lathe so that the flange drops into it when it is the right size. The example shown is recessed and has a ring of large holes around the outside. The example shown also provides a pattern for the bolt holes on the flanges and both valve plates.

When the first hole in the outer ring has been drilled a "peg" made by cutting a bolt is put into the hole to prevent the disc turning inside the template.



A simple template like this can be made using thin plate



You must drill the flange holes equally spaced and at the correct radius. If you do not, the flanges may not bolt together, or may only bolt together one way around.

Some people simplify the making of flanges by stacking them and drilling them together. Although this will always mean that the holes line up, it can mean that only the holes that were underneath each other when they were drilled line up. When the pump is put together is it important that the holes align whatever way around the parts are turned. Either take great care marking up each flange and be sure that the centre-punch marks are perfectly positioned before drilling, or use a template.

Materials needed to make a DTU S2 ram pump

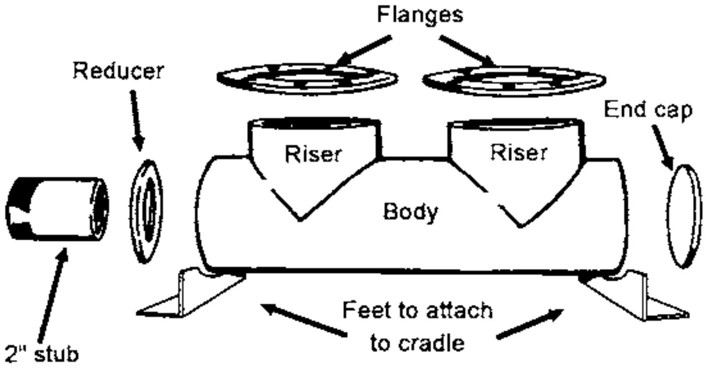
STEEL	Size	No. of	Length/area	Notes	✔
STEEL PIPE	4" (105mm internal diameter)	1	1350mm	The outside diameter of 4" pipe is 115mm. The wall thickness should be 5mm.	
STEEL PLATE	10 or 12mm	1	330 x 500mm	Do not use plate less than 10mm thick.	
STEEL BAR	25 x 25mm	1	165mm	If this is hard to find, make some by welding together a stack of thinner 25mm wide bars.	
STEEL BAR	25 x 15mm	1	165mm		
STAINLESS OR MILD STEEL ROD	10mm	1	280mm	If this is not available, mild steel reinforcing bar will do. This includes enough to make a spare impulse valve stem to supply with the pump.	
RUBBER	Size	No. of	Area	Notes	
GASKET RUBBER (inner tube)	Car or small truck	1	825 x 170mm	Make sure that it has not perished. This includes enough to make two spare flange gaskets to supply with the pump.	
IMPULSE VALVE RUBBER	6mm	1	152 x76mm	Offcuts of conveyor belt and shoe sole material have been used in the past . This includes enough to supply a spare of each with the pump.	
DELIVERY VALVE RUBBER	3mm	1	160 x 80mm		
NUTS & BOLTS	Size	No. of	Length	Notes	
BOLTS	M10	1	30mm	These must be stainless steel or galvanised. The 4 x 40mm bolts, nuts and washers to hold the pump to the cradle are included. Extra nuts and washers are needed for the valve stem and are included in the totals. The totals also include a few spares that you should supply with the pump.	
BOLTS	M10	10	40mm		
BOLTS	M10	8	50mm		
BOLTS	M10	3	80mm		
NUTS	M10	28			
WASHERS	M10	40			
CONSUMABLES				Notes	
WELDING RODS	The amount you use will vary according to your skills.			Select rods to give good penetration on the 5mm walls of steel pipe and on 10mm steel plate.	
GAS				For the cutting torch.	
PRIMER (PAINT)				Either have the parts of the pump galvanised or paint it. In most cases it is easiest to paint it	
ENAMEL PAINT					
THINNERS					

✎ Photocopy this table and tick off the materials as you get them so that you know you have everything you need before you start.

A step by step guide to manufacture

Before starting, decide which delivery valve template you will use. This will depend on the delivery head at the site where the pump is to be installed. If you do not know where the pump will be installed, use drawing number 5, which is the standard design.

Cutting the pump parts



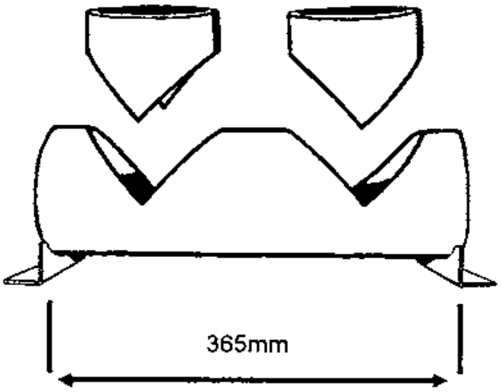
All the cutting for this pump can be done with a cutting torch. To save grinding and to minimise scrap, the metal cut from the centre of the flanges is used as the ends of the pump body. The ends are called the "Reducer" and the "End cap". The pump body is made from steel pipe with an internal diameter of 105mm (4" pipe).
The length shown on the S2 design drawings is 365mm.

The discs of steel that fall out when the flanges are cut will fit inside the pump body, but are not big enough to cover the ends. So the ends are welded about 5mm inside the body. This should leave enough overlap to weld neatly to.

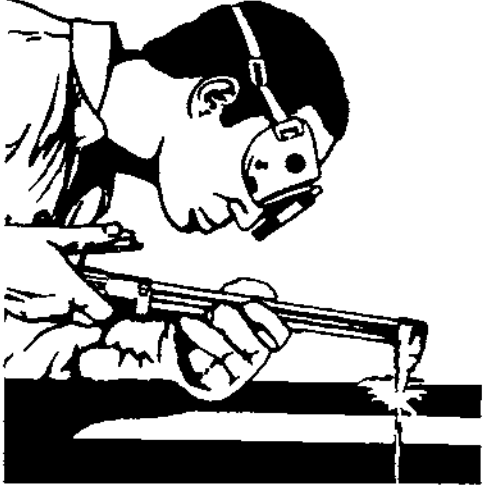
The feet are cut from 40 x 40mm angle iron. A curve that fits the pump body is cut out of one side of the angle iron.

The body is cut from a length of pipe by using the PVC pattern to score a line around the pipe. Mark it with chalk if it does not show up clearly, then go over the line with a centre punch to make sure it can be seen when cutting.

Skilled use of the cutting torch can result in the cut parts falling apart with clean edges. Even then, they will probably need to be tided up a little with a file or a grindwheel.



It is necessary to have a clean cutting nozzle on the torch, and to set the gas pressures appropriately.



If the pipe being used is galvanised, it can help to grind away the galvanise from the area to be cut. It is not worth using galvanised pipe for the pump body unless it is easy to get because a lot of the galvanised protection burns away by the time the pump is finished.

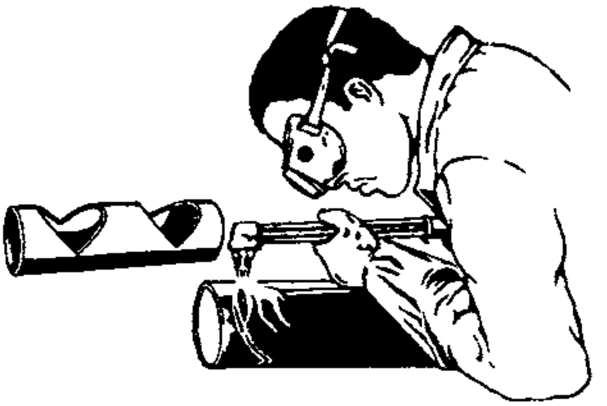
☠ *The fumes given off by burning Zinc galvanising are poisonous and should not be breathed.*

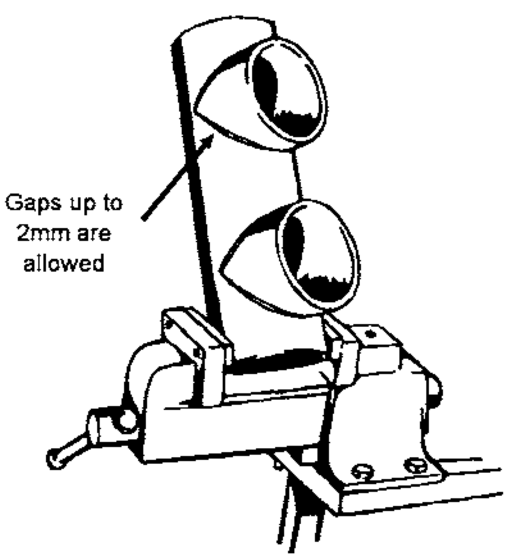
Cutting the S2 pump risers

The risers are made from the same pipe as the pump body. They are welded into "V" notches cut into the pump body. Both the risers and the notches can be marked up using the "V" notch pattern or template. At its shortest point, each riser should be no less than 30mm high. At its longest point it should be 87.5mm high.

Remember to go over the scored lines with a centre punch to make them easier to see.

Use an angle grinder or a bench-grinder to clean up the cuts so that the parts fit together properly. A gap of up to 2mm can be filled with weld.

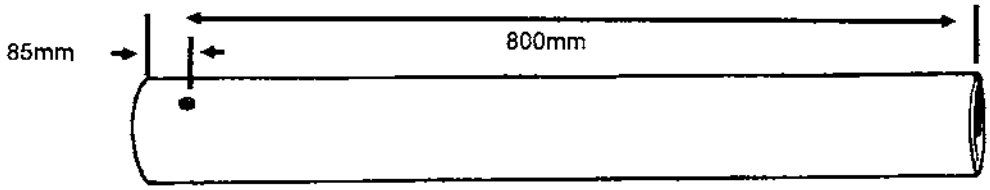




Place the risers in the pump body and grind them to fit. It can be useful to mark the risers and the notches, then grind each riser to fit a particular notch.

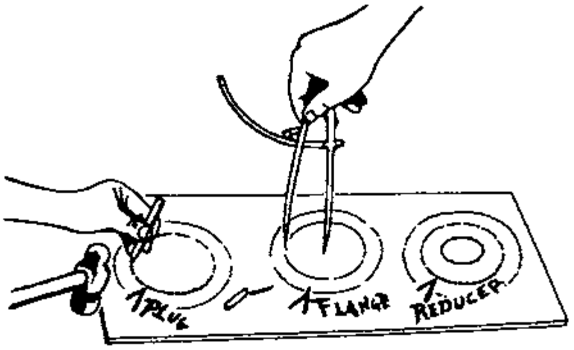
Cutting the S2 air vessel body

The air vessel body is cut from the same 105mm (4") pipe as the pump body. The length should be 800mm. This size will always be big enough, so do not change it. A ¾" hole should be cut (or drilled) with its centre 85mm from one end of the pipe. This is where the delivery pipe stub is attached.

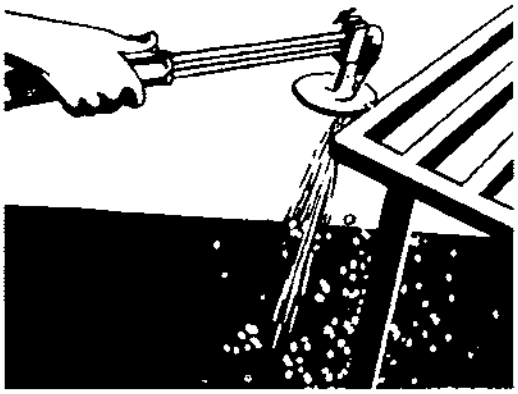


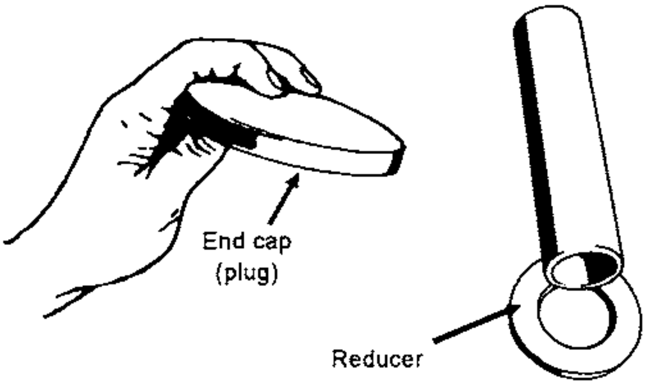
Cutting the S2 pump flanges and plates

The S2 pump body has two flanges and two pump body ends. The ends are called the "End cap" and the "Reducer". The "End cap" is the inner circle cut from a flange. The "Reducer" is the inner circle cut from a flange with another hole cut in the middle of it. The "Reducer" reduces the pipe size from the 4" pump body to the 2" drive pipe, so the inside hole is cut to take a stub of 2" pipe. The S2 air vessel has one flange and one end cap.



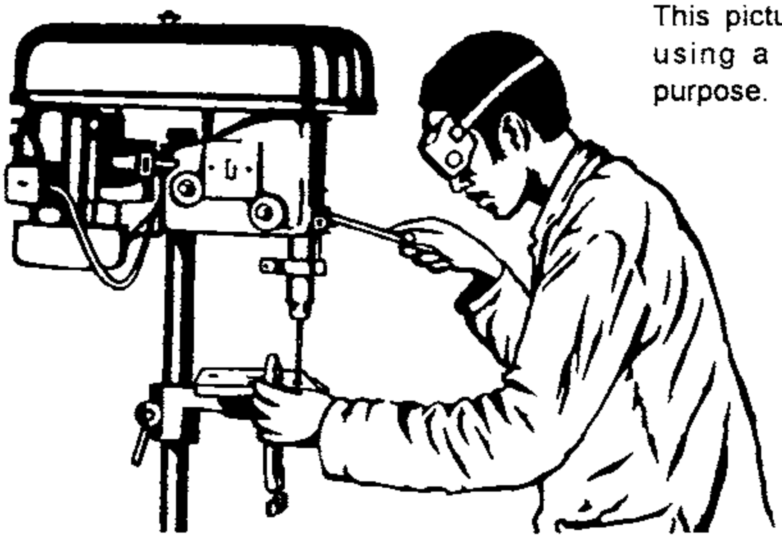
Mark up the flanges carefully, and cut the outer circle first. It can be useful to tack-weld the edge of the first circle to the workbench to make it easy to cut the second circle.





Drilling the flanges and valve plates

It is wise to make a template before drilling the flanges. Use a photocopy of design drawing number 3 as a template. Put it over the disc to be drilled, then use a centre punch to mark the hole centres through the paper template. To make the template last longer, glue it to thin cardboard before you use it.



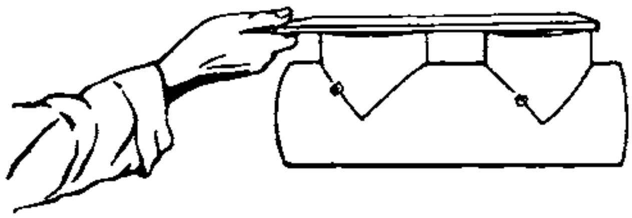
This picture shows a flange being drilled using a steel template made for the purpose.

☛ *Notice that the holes are drilled before the flanges are welded to the pump body.*

Welding the S2 pump body

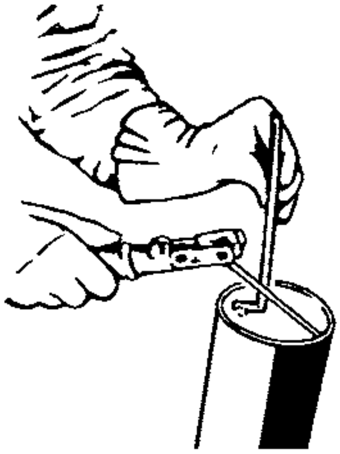
When the parts of the pump body and air vessel have all been cut they must be welded together. The following pictures show a suggested order in which to weld the parts. This order can be changed to suit the person doing the welding. It is important that the welder be skilled because the welds must be strong and not leak under pressure.

[1] Tack-weld the risers onto the body, making sure that their tops are level.

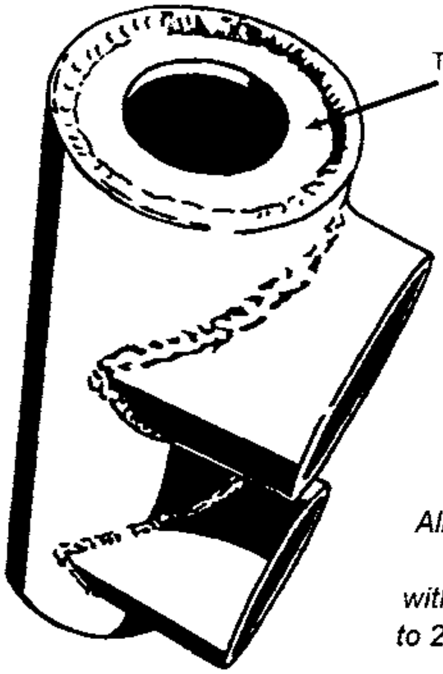


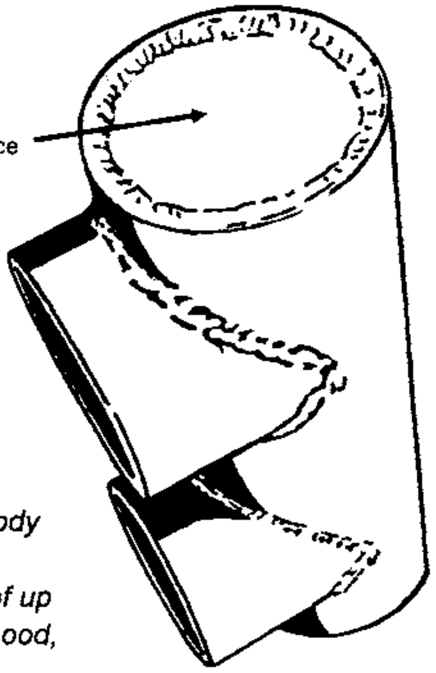
[2] Weld the risers all the way around on the outside of the body.

[3] Weld the end cap and the reducer 5mm inside the ends of the pump body.



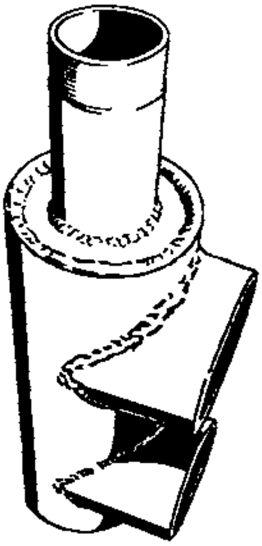
If the ends are a loose fit, tack a rod to them and hold them in place while tack-welding them. Then weld all the way around.



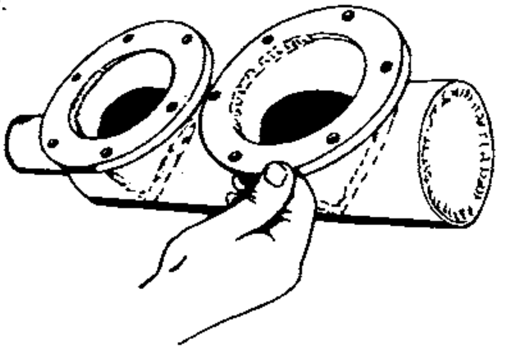


All welds on the pump body must be capable of withstanding a pressure of up to 25 bar. Be sure to get good, even penetration.

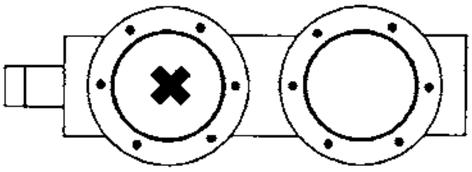
[4] Weld the stub of the 2" drive pipe into the hole in the reducer. Cut a thread on one end of the stub before cutting it from a length of pipe.



[5] Tack-weld the flanges onto the risers and make sure that the flanges are level, then weld all the way around.

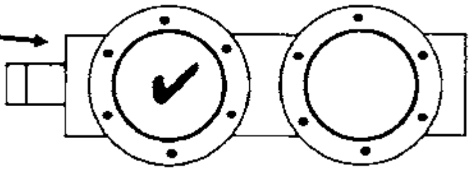


Make sure that the flange holes are not in line with the pump body.

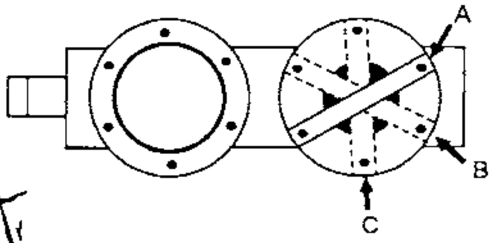


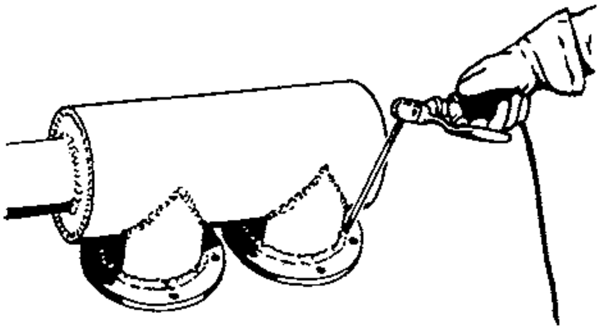
Flange hole alignment

They should be offset like this.

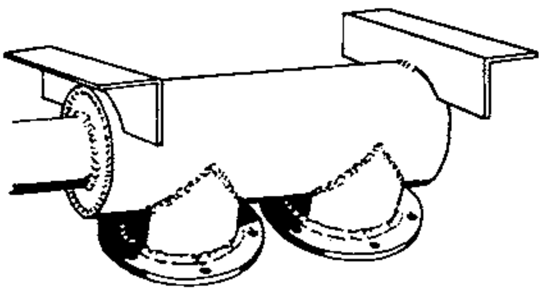


The impulse valve stop bar can later be bolted to the flange in any of the three possible positions, A, B, or C.





[6] Turn the pump body over and weld around the flanges on the other side.



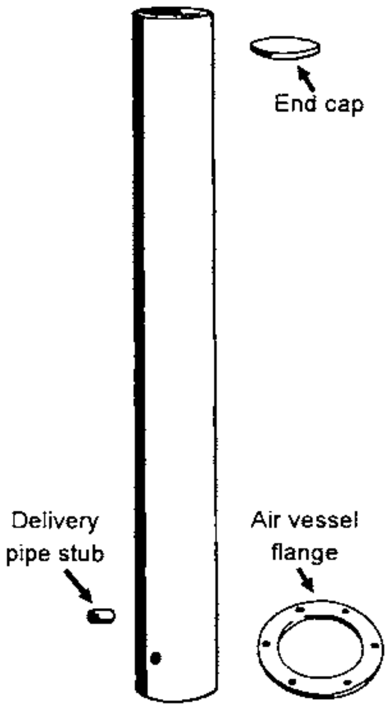
[7] Tack-weld the angle iron feet to the bottom of the pump body, 5mm in from each end. Make sure that they are both level, then weld them on both sides.

Welding the S2 pump air vessel

8 Weld the air vessel End cap in place, 5mm below the top of the air vessel.

9 Weld the air vessel flange in place, being sure to get it level. Weld it inside and outside.

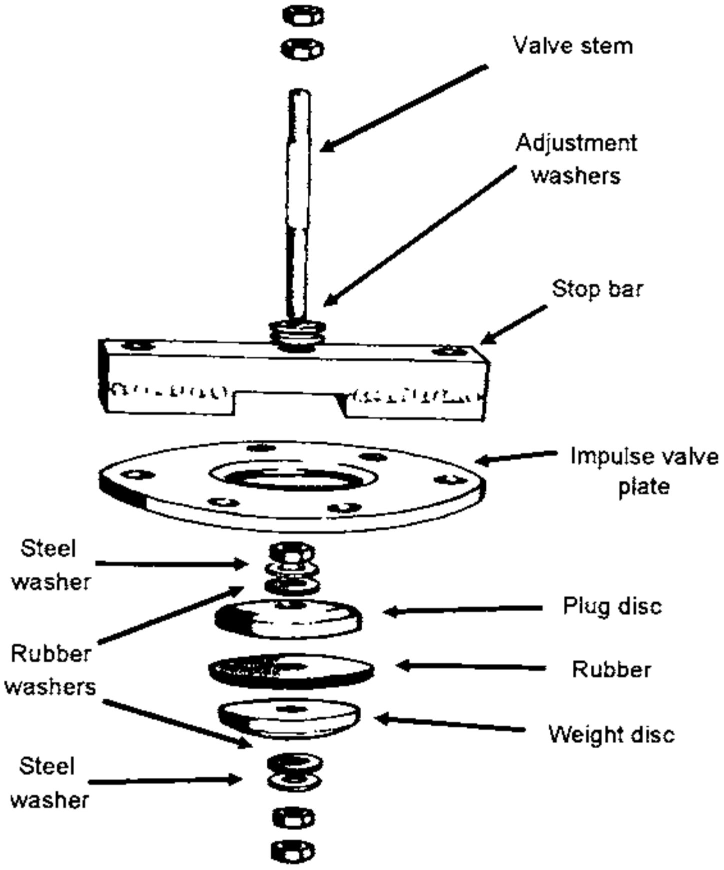
10 Weld the delivery pipe stub into the hole in the air vessel. Cut a thread onto the stub before you cut it from the end of a length of pipe.

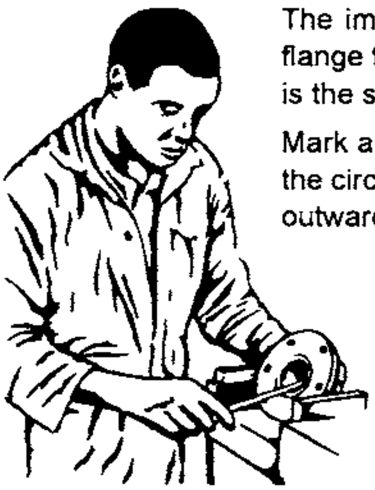


Making the S2 pump impulse valve

The valves are the most important parts of these pumps. They must be made accurately or the pump will not be as efficient as it should be and may be unreliable. If they are made carelessly, the pump may not work at all.

The valve stem rises and falls as the pump works. When it falls it pushes the plug down to allow water to flow through the central hole in the impulse valve plate. When it rises it pulls the plug up to almost block the hole, and the rubber makes a final seal.

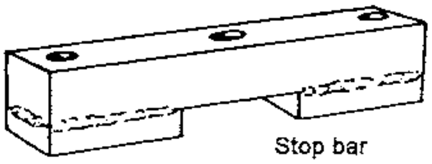




The impulse valve plate is a disc of 10 or 12mm steel plate. Use the flange template to drill holes around the outside. The outside of the disc is the same size as a flange (165mm diameter).

Mark a circle with a radius of 33mm from the centre of the disc and cut the circle out. Use a file to chamfer one side of that hole so that it slopes outward at 45°. The chamfer should be 5mm deep.

The stop bar is a 165mm length of 25mm square steel, with two 58.5mm lengths of 15 x 25mm bar welded to it. The bar is drilled to fit on top of the impulse valve plate.



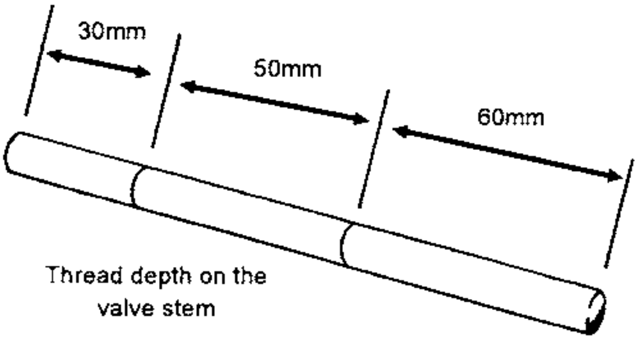
Stop bar

It is important that the holes are drilled upright through the bar, so use a pillar drill when you can.

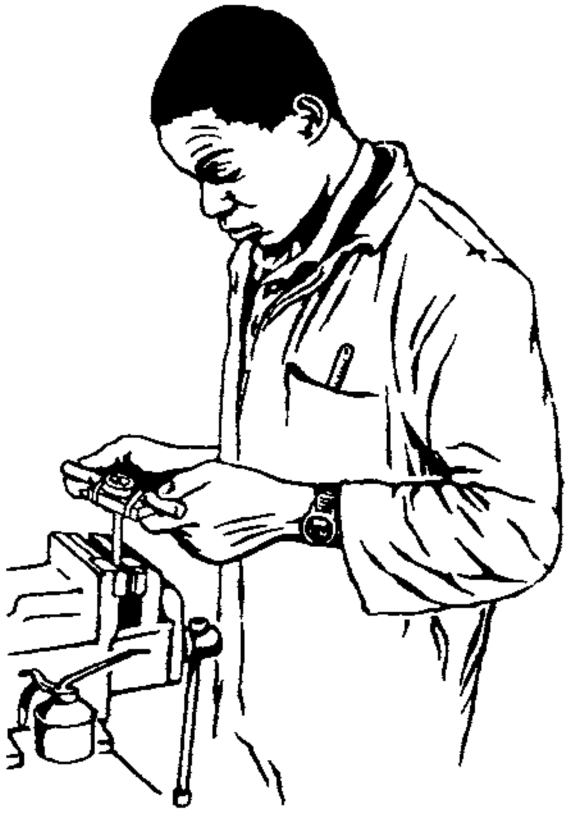
Lathe alternative

Drill the holes in the stop bar and cut the threads on the valve stem with a lathe when you can.

People prefer their pumps to look good, so it is often worth grinding away any excess weld on the stop bar using a grindwheel. In the drawing alongside, a hand-held grinder is held in a vice to make a temporary bench-grinder. If you do this, make sure that the grinder is held firmly.

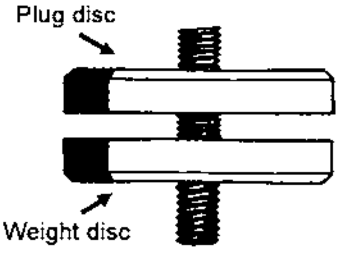


Thread depth on the valve stem



The valve stem is 140mm of 10mm stainless or mild steel bar. If plain bar is not available, reinforcing bar can be used, but it may not last as long. The bar must be straight. A slightly bent bar may break quickly when the pump is being used.

The stem must be threaded at each end. The depth of the thread is greater at the bottom than the top.



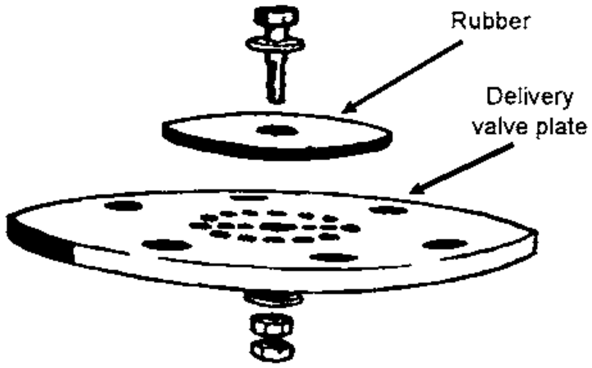
The impulse valve plug and weight discs are identical. When they are put onto the valve stem, the second is put on upside down.

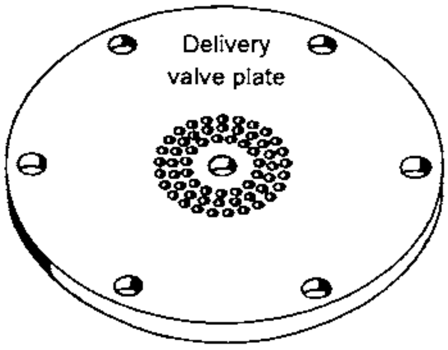
Cut two 60mm disks from the same 10 or 12mm steel plate that you used for the Impulse valve plate, then drill a hole of 11mm diameter in the centre of each. It is important that the holes are straight.

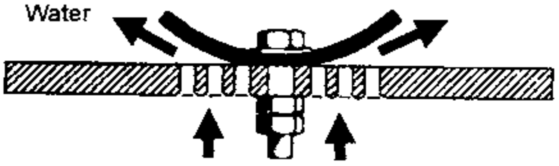
One edge of each valve disc must be chamfered with a 45° angle. The chamfer should only be 3mm deep, leaving 7mm of the edge straight.

Making the S2 pump delivery valve

This is a simple flap valve. The delivery valve rubber is pushed up when the pump reaches delivery pressure, and flaps closed when the pressure drops. When the rubber is bent up, water flows through the small holes into the air vessel and into the delivery pipe.

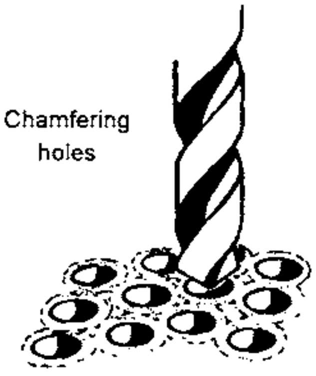






CROSS-SECTION THROUGH A DELIVERY VALVE WITH THE RUBBER OPEN

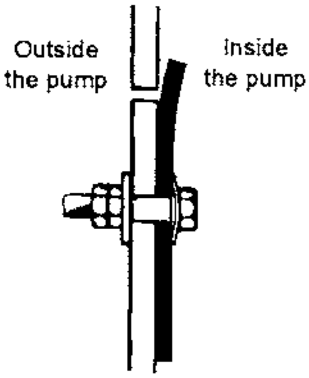
The delivery valve plate is cut from the same 10 or 12mm plate used for the flanges. You should have already chosen which of the design drawings numbers 5, 6 and 7 to use as a template. Punch through the template to mark out the holes. The central rings of holes allow water to pass through when the valve is open. To increase the flow through these holes, chamfer them using a larger drill bit (6 - 8mm) on one side of the valve plate.

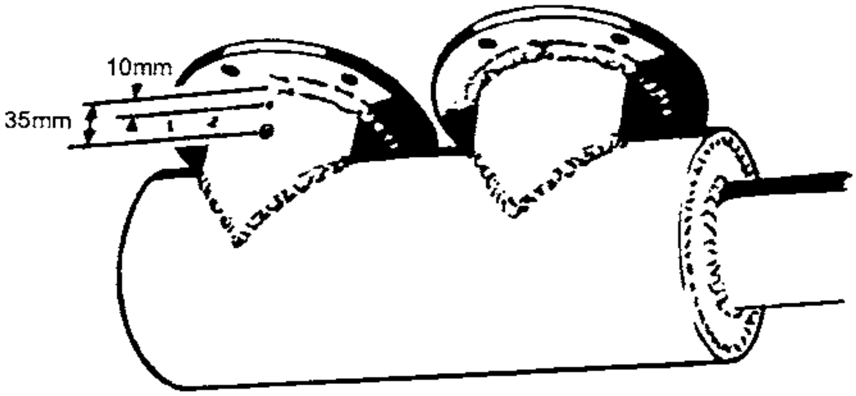


The chamfered side must be underneath when the valve is put together.

Making the S2 pump snifter valve

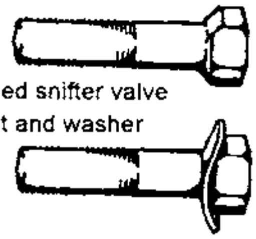
The snifter valve is a small flap valve in the riser furthest away from the drive pipe stub. When the pump is running, it allows a little air into the pump body. The air is pumped through the delivery valve with the water and keeps the level of air in the air vessel constant.





Drill a 1 or 2mm diameter hole in the riser 10mm below the bottom of the flange, (or 20mm below the top of the flange, which is the same thing). Drill a 10mm diameter hole 25mm below the first hole. The 1 or 2mm hole is the hole that air will come through.

The rubber flap inside the pump body must sit flat against the side of the riser. Because the riser is curved, you must file away parts of the bolt head and bend a washer as shown in the drawing. Then, when the bolt is tightened, the rubber flap will be able to sit flat. Be careful not to tighten the bolt enough to distort the rubber. Usually it is enough to tighten the nut with your fingers, then lock another against it using spanners.



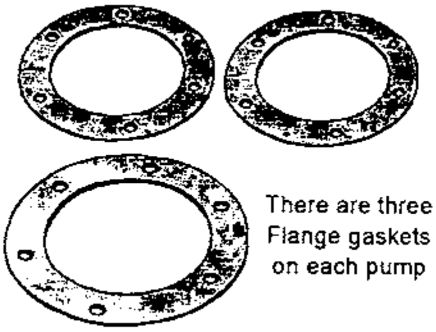
Shaped snifter valve bolt and washer

It is very important for the air in the air vessel to remain at a constant level, so it is essential that the snifter valve is fitted and working properly. If it does not work properly, the pump will be less efficient, and may even be damaged.

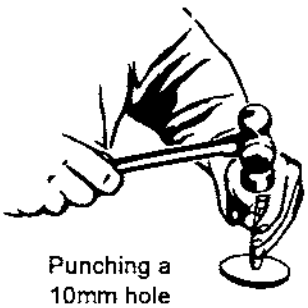
Rubber parts

You will need valve rubber and flange gasket rubber to complete an S2 pump.

Flange gaskets are usually made using old inner tube rubber. Make sure that it is not so old that it has started to perish, and try to select an area where it is more or less the same thickness. On some tubes, especially those made for big wheels, the rubber can be twice as thick in some places as others. Using the flange template as a guide, cut the big circles using a sharp knife. The bolt holes should be punched out using a 10mm hole punch. This leaves clean holes on which the threads of the bolts do not catch.



There are three Flange gaskets on each pump



Punching a 10mm hole

Delivery valve rubber

Impulse valve rubber

Inner tube rubber can also be used for the snifter valve rubber disc.

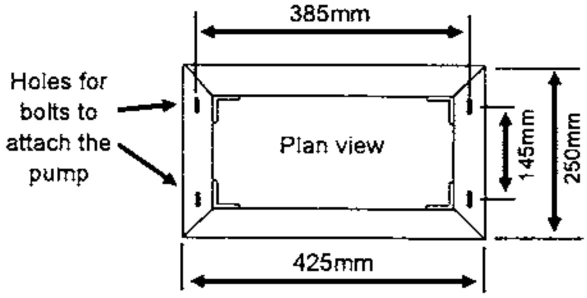
The large impulse valve rubber must be stiff but the delivery valve rubber has to bend easily. The impulse valve rubber should be about 6mm thick. Thicker rubber will probably be all right, but do not use thinner rubber. The delivery valve rubber should be about 3mm thick. Delivery valve rubber can also be used for the small impulse valve rubber washers above and below the impulse valve discs. We have used rubber made for shoe repairs and offcuts of conveyor belt when we cannot buy rubber sheet easily.

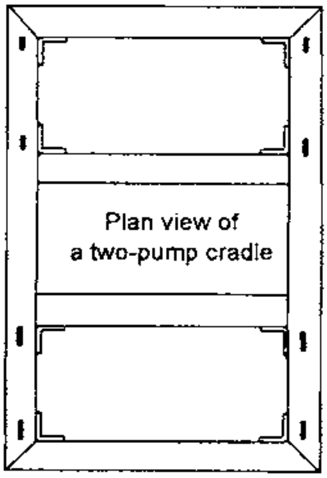
The pump cradle

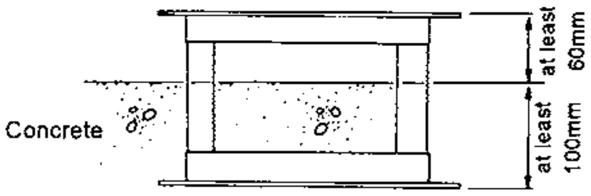
You should not make and sell a pump without including a pump cradle. If a ram pump is not securely fixed during use, it will break, and may break the connecting pipework too.

It is important that you use steel strong enough to hold the pump firmly, and that the cradle is buried in a strong concrete base. The pump tries to vibrate when operating and will soon shake itself loose from an insecure base.

Use 40mm angle-iron, about 5mm thick, to make the cradle. It can be extended to support two pumps when needed.







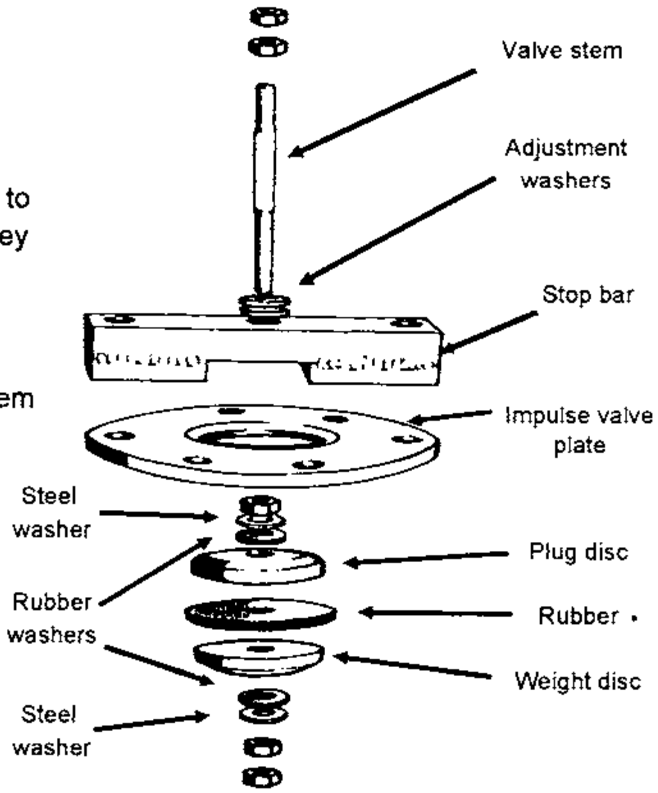
SECTION THROUGH A CRADLE INSTALLED ON A CONCRETE BASE

The pump is attached to the cradle by the angle iron feet that you have welded to the bottom of the body. Notice that the holes are slotted so that the pump can be moved from side to side slightly to allow for small mistakes in drive pipe alignment. The cradle must stand up from the concrete far enough to make it easy to reach the fixing nuts.

Assembly and testing

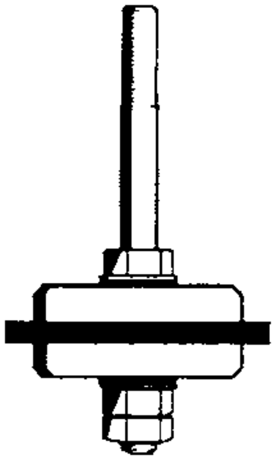
Putting the pump together properly is very important. The process of assembling the valves is described here, including some simple ways of testing them. Paint all the metal parts you have made before you assemble them for the final time. You may like to assemble them loosely before painting to check that everything is OK. To make the pump last longer, it should be painted inside and out with a metal primer, then a good enamel paint.

Assembling the impulse valve



The impulse valve design drawings, numbers 9, 19, 11 and 12, are also templates. Start by holding each part against the drawing of it on the template to check that the dimensions are right. If they are not right, either adjust them or make them again.

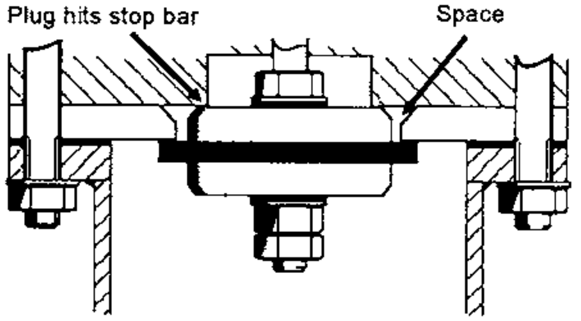
When the parts are all the right size, thread a nut onto the end of the valve stem that has a longer thread. This will be the bottom of the valve stem. Screw the nut to the end of the thread and use a spanner to lock it there. Then push a steel washer and a rubber washer up to the nut. Put the plug disk onto the stem, with the chamfered edge towards the nut and washers already there. Then push the impulse valve rubber over the stem up to the plug disc. Put the weight disc over the stem with the chamfered edge facing away from the valve rubber. Then push a rubber washer and a steel washer up to the weight disc. Thread on a nut up to the washer. Thread it on finger tight. If you use a spanner, do not tighten it so that it squashes the rubber washers. Hold the nut with a spanner and use another spanner to lock a second nut against it. The valve stem should look like the one in the drawing below.

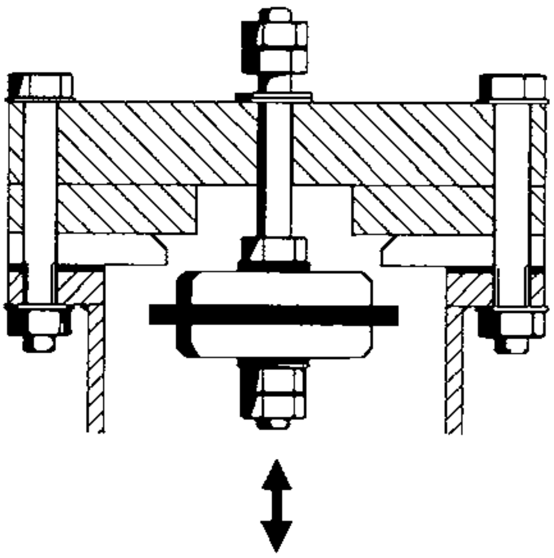


Push the stem up through the impulse valve plate and through the stop bar. Drop two washers over it and thread on two nuts. Lock them lightly against each other. They should be adjusted when the pump is installed, so do not over-tighten them.

When the valve has been assembled, bolt it to the pump with a rubber gasket between the impulse valve plate and the flange on the pump. The impulse valve goes on the riser furthest away from the drive pipe stub. Tighten all the bolts on the flange except the two holding the stop bar in place. Put nuts on these but leave them finger tight.

Check that the impulse valve can move freely up and down without the plug disc catching on the sides of the hole in the Impulse valve plate. If it does catch, push the stop bar away from the side that catches. The stop bar has a small amount of movement between the bar and the threads of the bolts holding it.

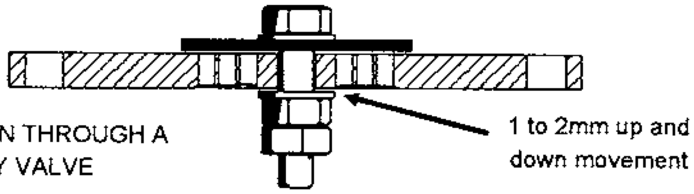




There should be a space all the way around between the side of the plug disc and the Impulse valve plate. If the pump has been made exactly to the measurements, the space will be 3mm. If it is less than 1mm, you should take the valve apart and check the parts against the templates. If the plug disc is too large you may be able to make it smaller. If the hole in it is not in the centre, you will probably have to make another. If the hole in the impulse valve plate is too small or not round, you may be able to file it out. Do not file it so that the hole is bigger than 66mm as shown in design drawing number 10. The plug disk must also hit the stop bar all the way around. Turn the plug disk to make sure that this is so.

Assembling the delivery valve

The delivery valve must be assembled so that the nuts are tight on the bolt, but the bolt has some up and down movement. This is shown on the drawing below. When the bolt head is pressed down against the washer and rubber on top of the delivery valve plate, there should be a gap on the underside of 1 to 2mm between the plate and the washer.

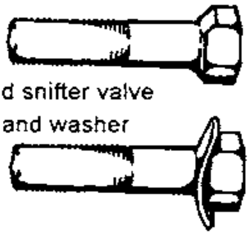


CROSS SECTION THROUGH A
DELIVERY VALVE

To assemble the valve put a washer over a 40mm M10 bolt and push it through the delivery valve rubber. Make sure that the rubber moves freely on the bolt. It the hole in the centre was cut out with a hole punch, it should move freely up and down. If the rubber distorts when it is pushed over the bolt, you must make the hole in the middle bigger. This can sometimes be done with a round file or a stick with emery paper wrapped around it.

Check that there are no rough edges on the holes in the delivery valve plate then push the bolt through it. The chamfer on the delivery valve holes should be on the underside of the plate, away from the bolt head. Push on a washer and thread on a nut, leaving 1 to 2mm up and down movement in the bolt. Use a feeler-gauge if you have one, or do up the nut with your fingers until it starts to get tight, then unscrew it one full turn. Use spanners to lock a second nut against the first, then check that there is still enough up and down movement. It should be at least 1mm and not more than 2mm.

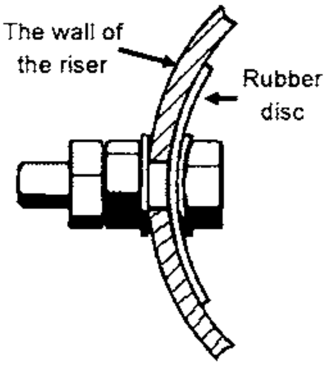
Assembling the snifter valve



Shaped snifter valve bolt and washer

The snifter valve rubber must sit flat against the inside curve of the riser below the delivery valve. To make this happen you must shape a nut and washer as shown on page 15.

Make sure that there are no rough edges on the inside of the two holes you have drilled through the riser on the pump body. Even a small burr can stop the valve working properly. Also make sure that the holes have not been blocked by paint.



CROSS SECTION of the snifter valve assembly from above

To assemble the valve, push the rubber over the bolt up against the shaped washer. Make sure that the rubber moves freely on the bolt. It the hole in the centre was cut out with a hole punch, it should move freely up and down. If the rubber distorts when it is pushed over the bolt, you must make the hole in the middle bigger. Then push the bolt through the riser on the pump body. Make sure that the rubber disc covers the small snifting hole in the riser. Be sure to use a disc of rubber rather than a smaller flap. If the disc turns it will still cover the snifting hole.

Push a washer over the thread outside the pump body and thread a nut onto it. Holding the head inside the pump, tighten the nut half a turn with spanner. Check that the rubber disc has not distorted. If it has, slacken the nut off until the rubber disc sits flat against the riser. When the disk sits flat and there is no play in the nut and bolt, use spanners to lock a second nut against the first.

Spare parts

It is important that you make the pump parts carefully to match the dimensions given on the design drawings. Then, if a part needs to be replaced, it can be made from the drawings and taken to the pump. If the parts are made carelessly, the pump may have to be brought to the workshop so that you can make a part that fits.

The DTU S2 ram pump costs much less than any commercial pump we have seen. It is made using materials and tools that are widely available. The disadvantage of this is that some parts will wear out or fail more quickly than they do on expensive pumps. The parts that have failed in the past are the rubber discs and the valve stem. You should make spares of these and supply them with the pump. A valve stem made from stainless steel usually lasts a lot longer than a stem made from mild steel. After the pump has been taken apart a few times it may also need a new flange gasket. The head or the thread on a bolt or nut may also get damaged, so the pump should be supplied with a few extra nuts, bolts and washers of the right size.

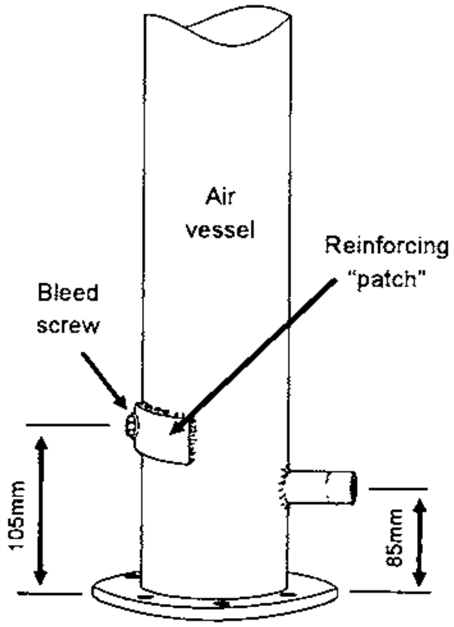
Provide these spares with each pump:

- a spare impulse valve stem;
- spare impulse and delivery valve rubbers;
- 2 spare flange gaskets.
- 1 spare 40mm M10 nut and bolt;
- 1 spare 80mm M10 nut and bolt;
- 2 spare 50mm M10 nuts and bolts;
- 4 spare M10 nuts and 6 spare washers.

If the impulse valve discs are not made carefully with their holes in the centre, the valve plug disk may not turn freely in the hole in the valve plate. It may not strike the stop bar on both sides all the time when the valve plug is turned through 360°. This may also happen if the hole in the middle of the stop bar is not drilled absolutely vertically through it. If you find these faults, you must make the parts again.

Optional addition

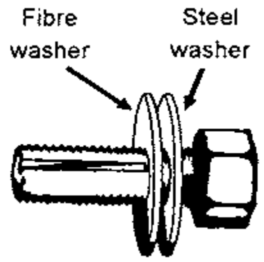
The addition of a "bleed" screw in the air vessel can make it easier to find out what is wrong with a pump when it does not perform properly. It can also make the pump easier to maintain.



Many commercially available pumps have a bleed screw on the air vessel. The screw is opened to check that there is enough air in the air vessel, and to let out the water when there is too much. It is also a useful way of letting the pressure out of the air vessel when you want to take it apart for maintenance.

The bleed screw should be position just above the delivery pipe stub on the other side of the air vessel.

The pressure in the air vessel can get very high, so the bleed screw and its thread must be made carefully to prevent it leaking. To make the thread longer and more secure, a "patch" cut from the same 4" pipe as the air vessel should be welded over the area first. Then you drill a hole through the patch and the wall of the air vessel. Cut a thread in the hole so that an M10 bolt will screw into it.



The thread on the bolt used should be 30mm long. Holding the head of the bolt in a vice, use a hacksaw to cut a shallow slot along the threads. Do not cut more than 1mm deeper than the bottom of the thread. When the hacksaw blade hits the bolt head, stop. The bolt should look like the one in the drawing alongside. You will need to use a steel and a fibre washer under the bolt head to make a good seal.

To bleed air or water from the air vessel, simply undo the bolt a few turns until air starts to hiss out, or water to spray out.

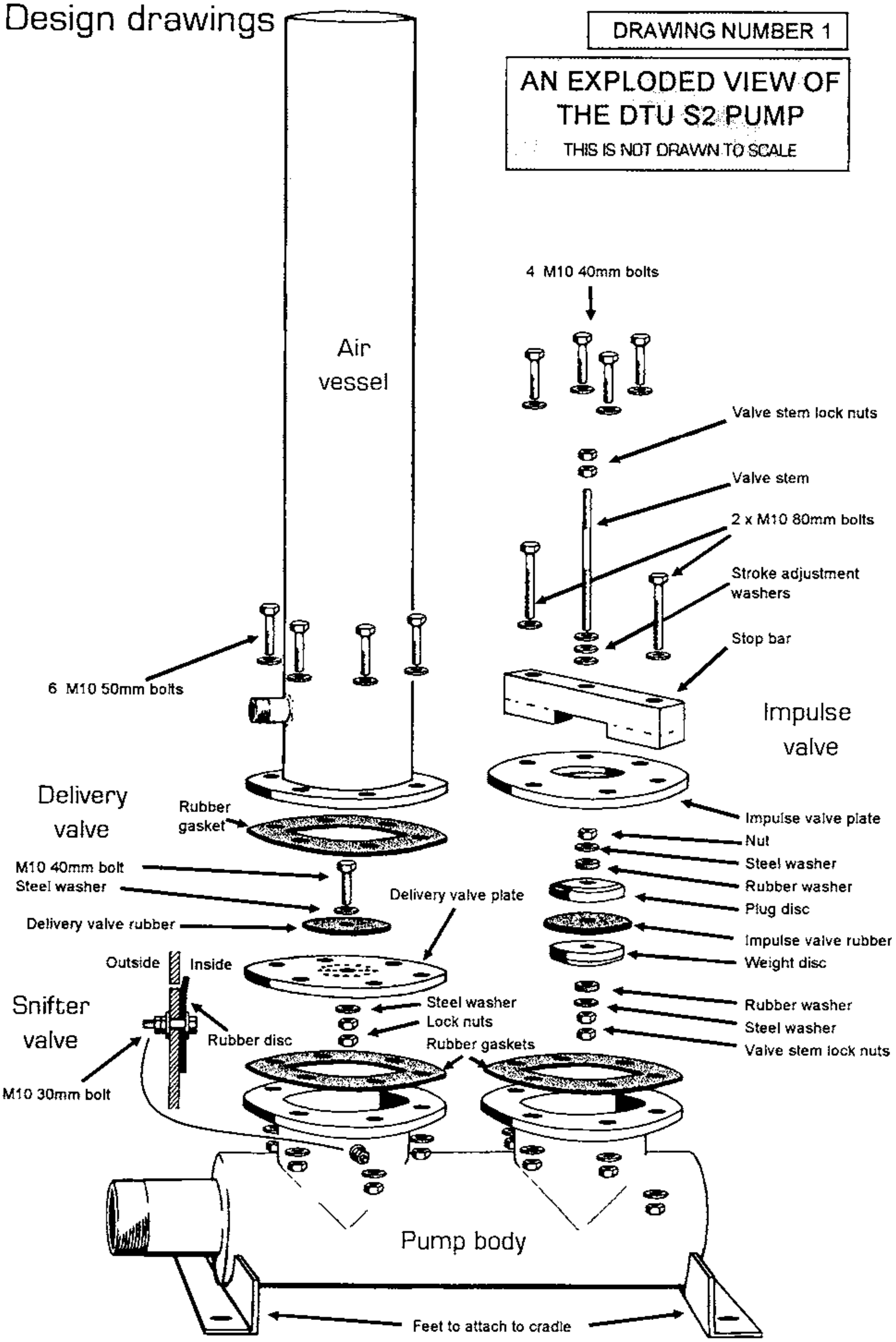
DRAWINGS

DTU S2 pump
Design drawings

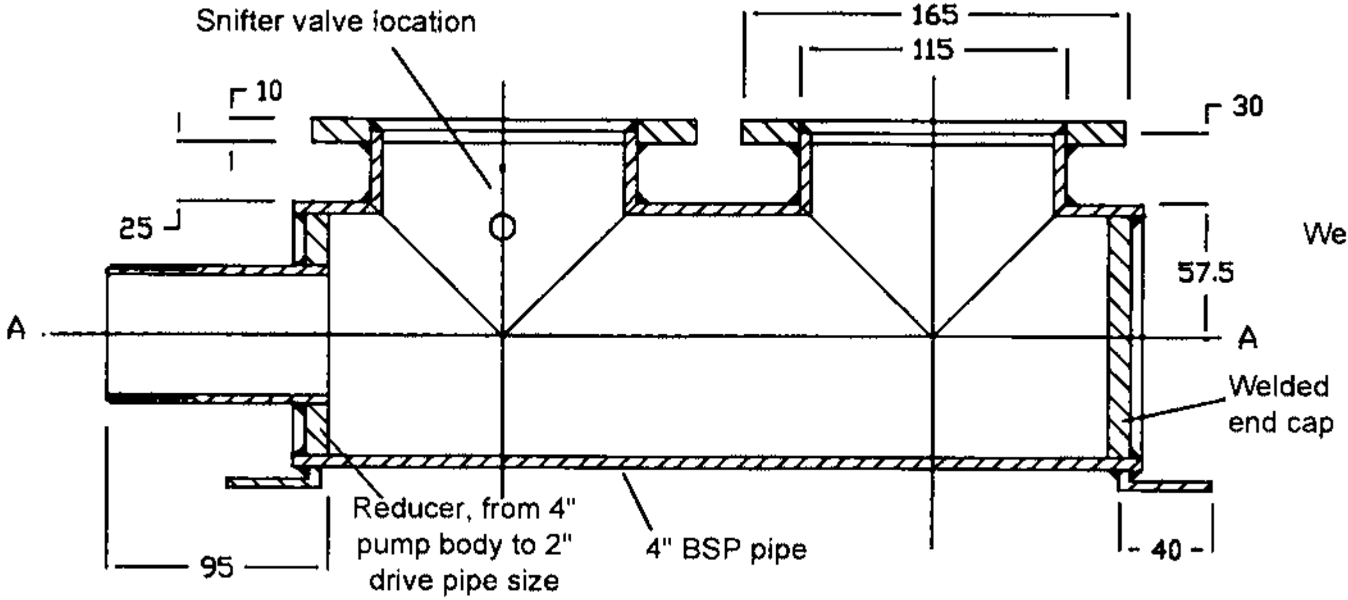
DRAWING NUMBER 1

AN EXPLODED VIEW OF THE DTU S2 PUMP

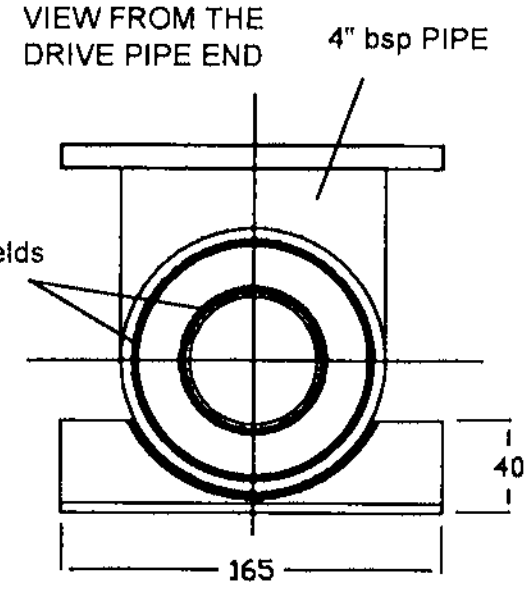
THIS IS NOT DRAWN TO SCALE



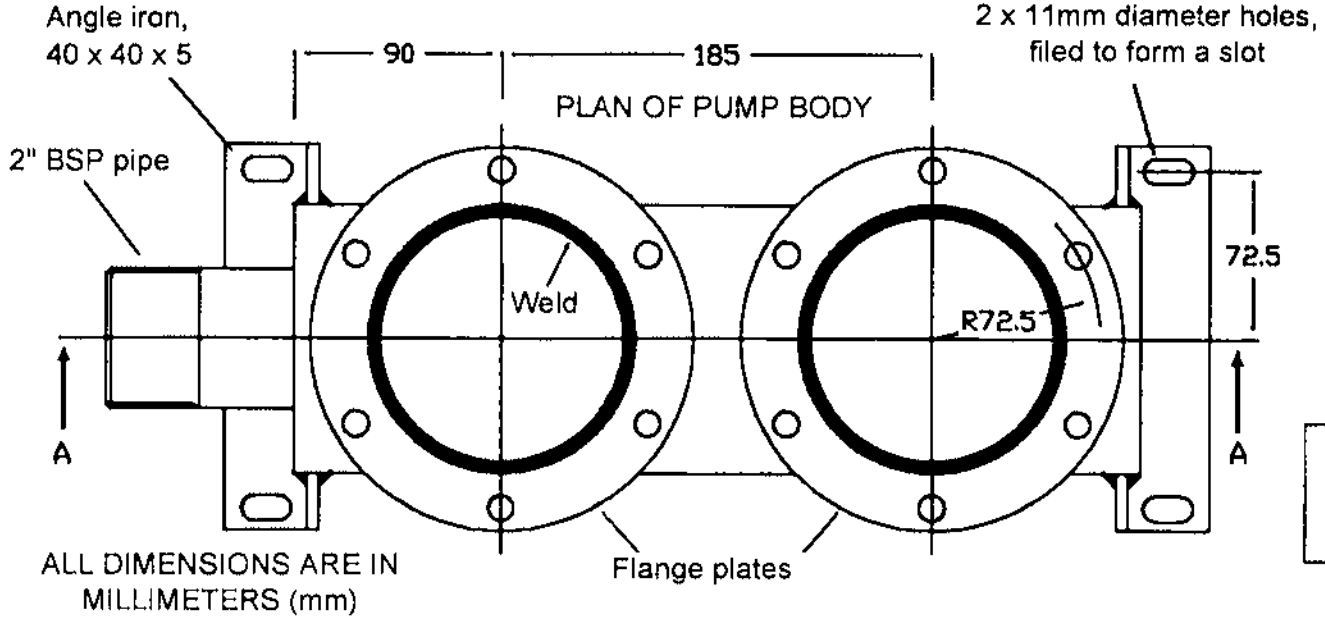
CROSS SECTION THROUGH THE MIDDLE OF THE PUMP BODY
that is from A to A on the plan drawing below



VIEW FROM THE DRIVE PIPE END



PLAN OF PUMP BODY



ALL DIMENSIONS ARE IN MILLIMETERS (mm)

MATERIALS

PIPE: the pipe used is mild steel with a 4" (115mm) outside diameter and an inside diameter of 105mm.

PLATE: the plate is mild steel either 10 or 12mm thick.

ANGLE IRON: use 40 x 40mm angle iron, about 5mm thick. Use bigger angle iron if this size is hard to get.

ALL THE JOINTS SHOULD BE WELDED

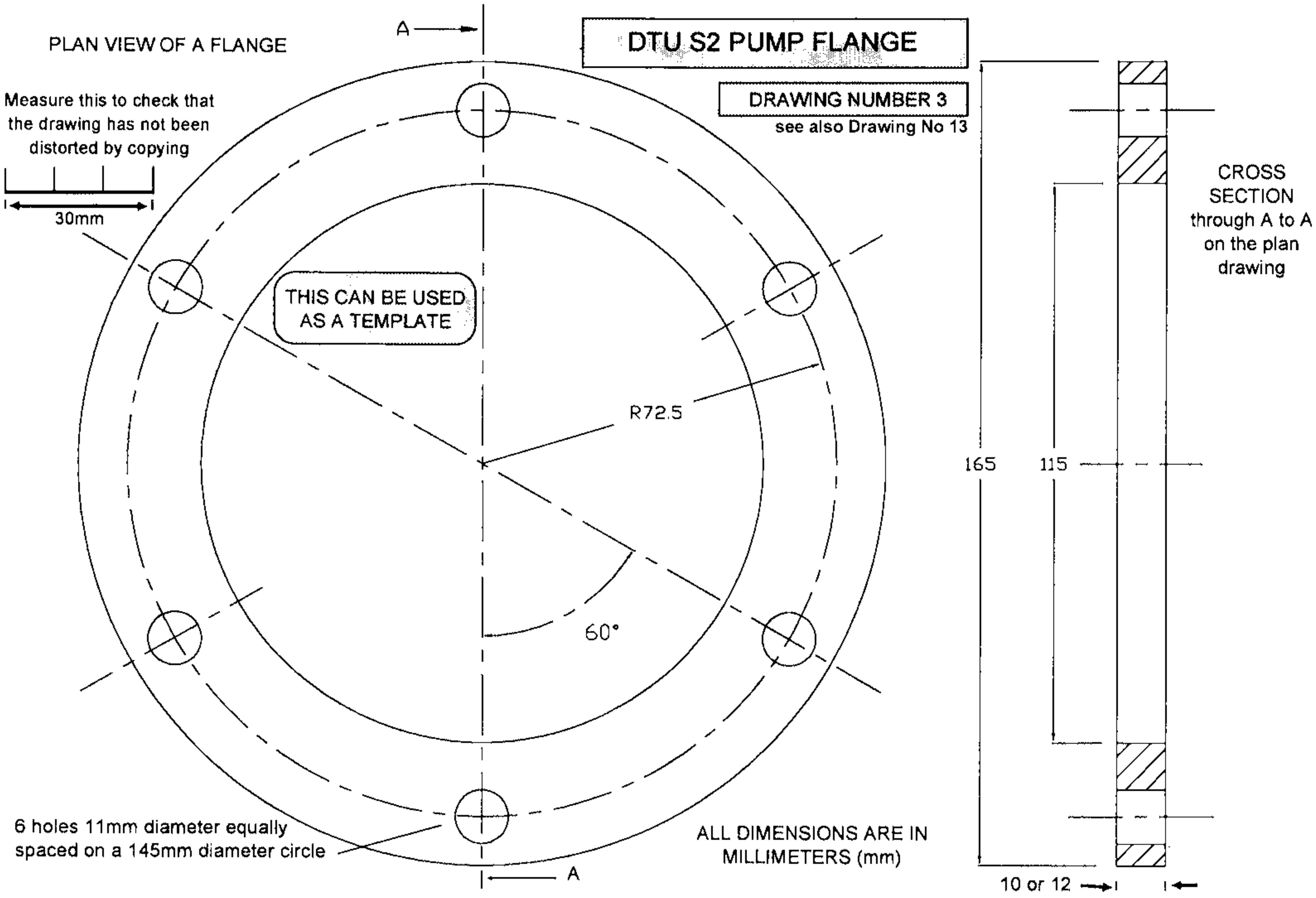
DRAWING NUMBER 2

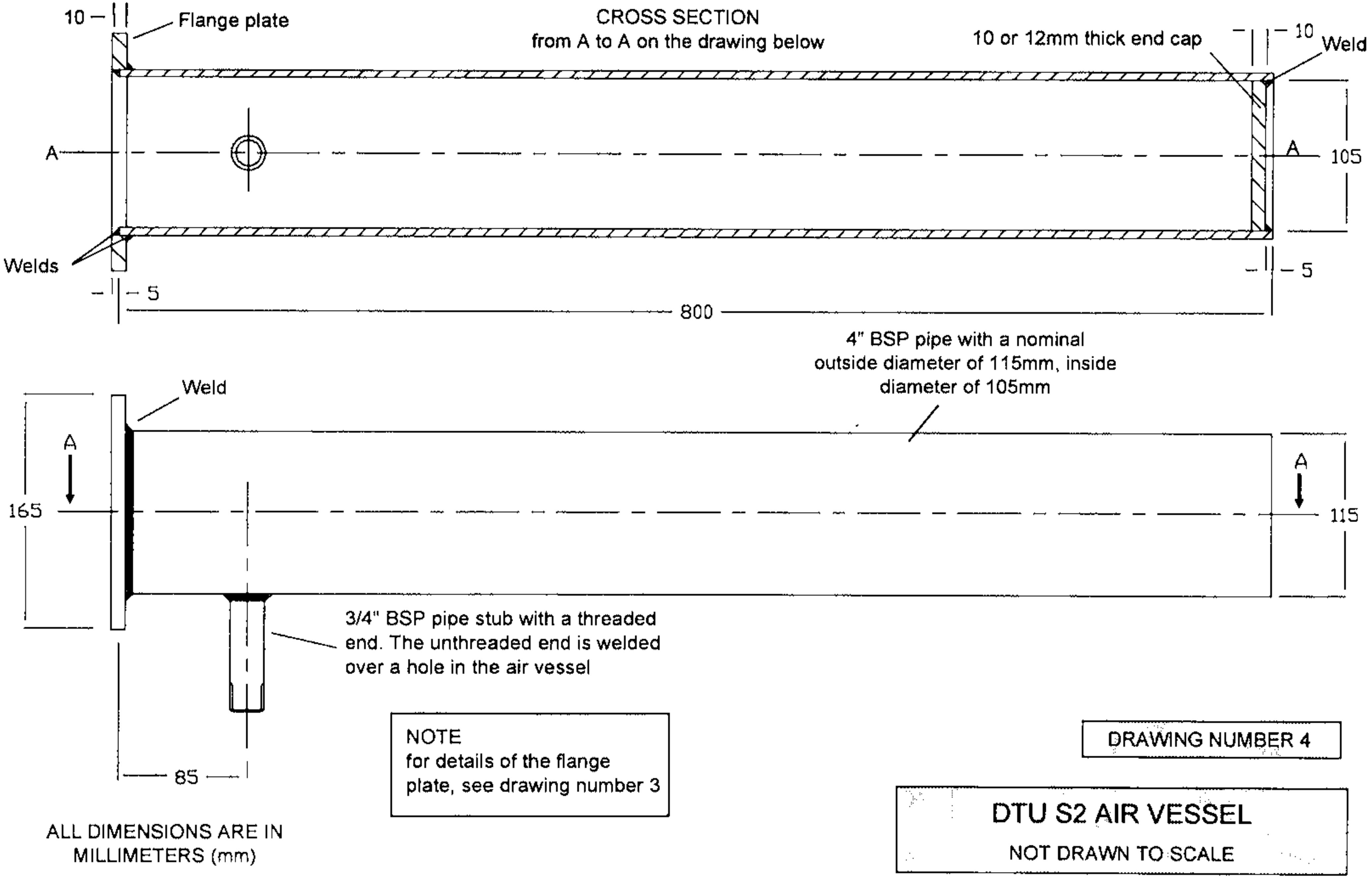
DTU S2 pump body

NOT DRAWN TO SCALE

DTU S2 PUMP FLANGE

DRAWING NUMBER 3
see also Drawing No 13





NOTE
for details of the flange plate, see drawing number 3

ALL DIMENSIONS ARE IN MILLIMETERS (mm)

DRAWING NUMBER 4

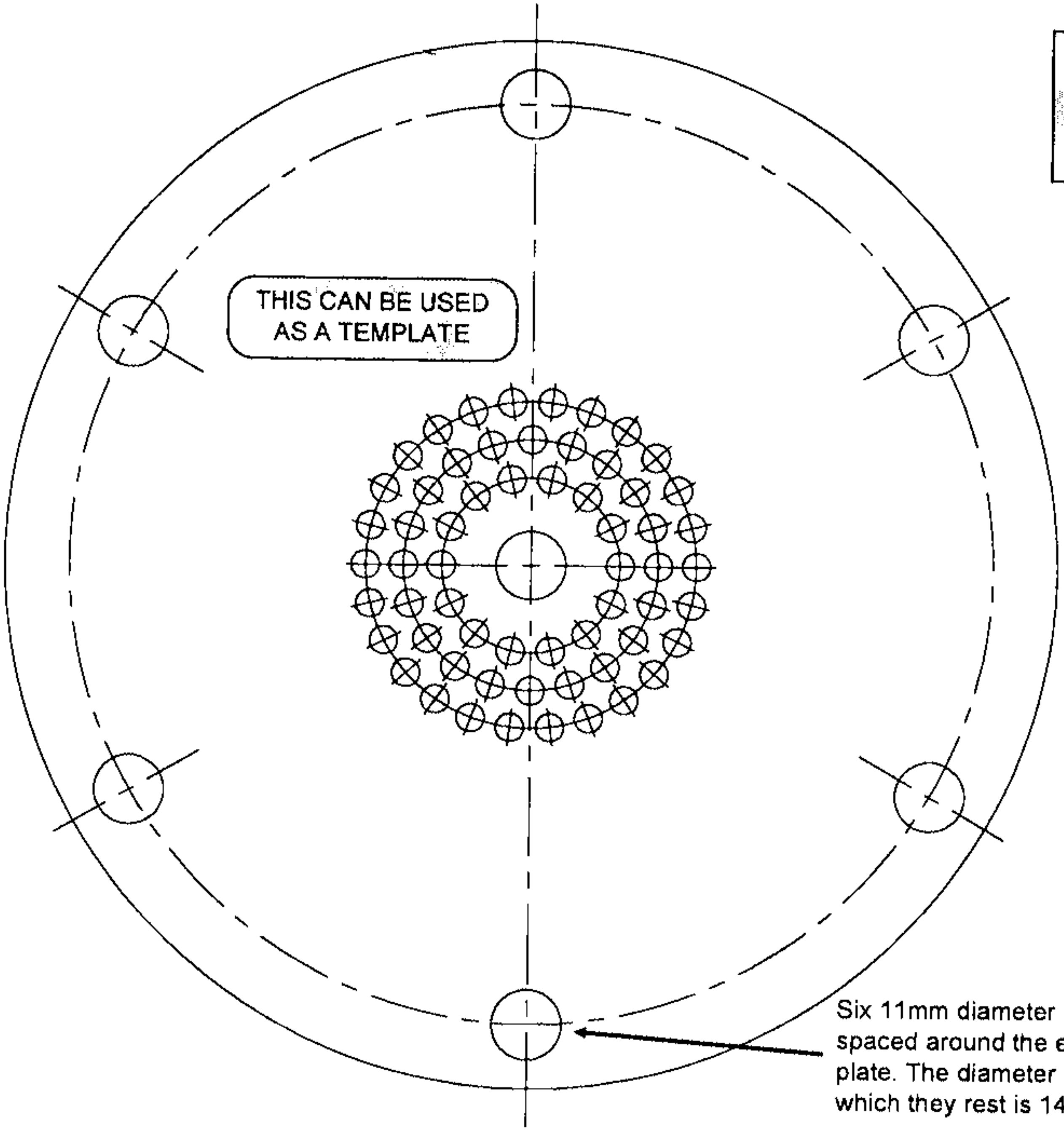
DTU S2 AIR VESSEL

NOT DRAWN TO SCALE

DELIVERY VALVE PLATE 1

Suitable for delivery heads over 75 meters
DRAWN TO SCALE: 1:1

DRAWING NUMBER 5



Six 11mm diameter holes are equally spaced around the edge of the valve plate. The diameter of the circle on which they rest is 145mm.

NOTES

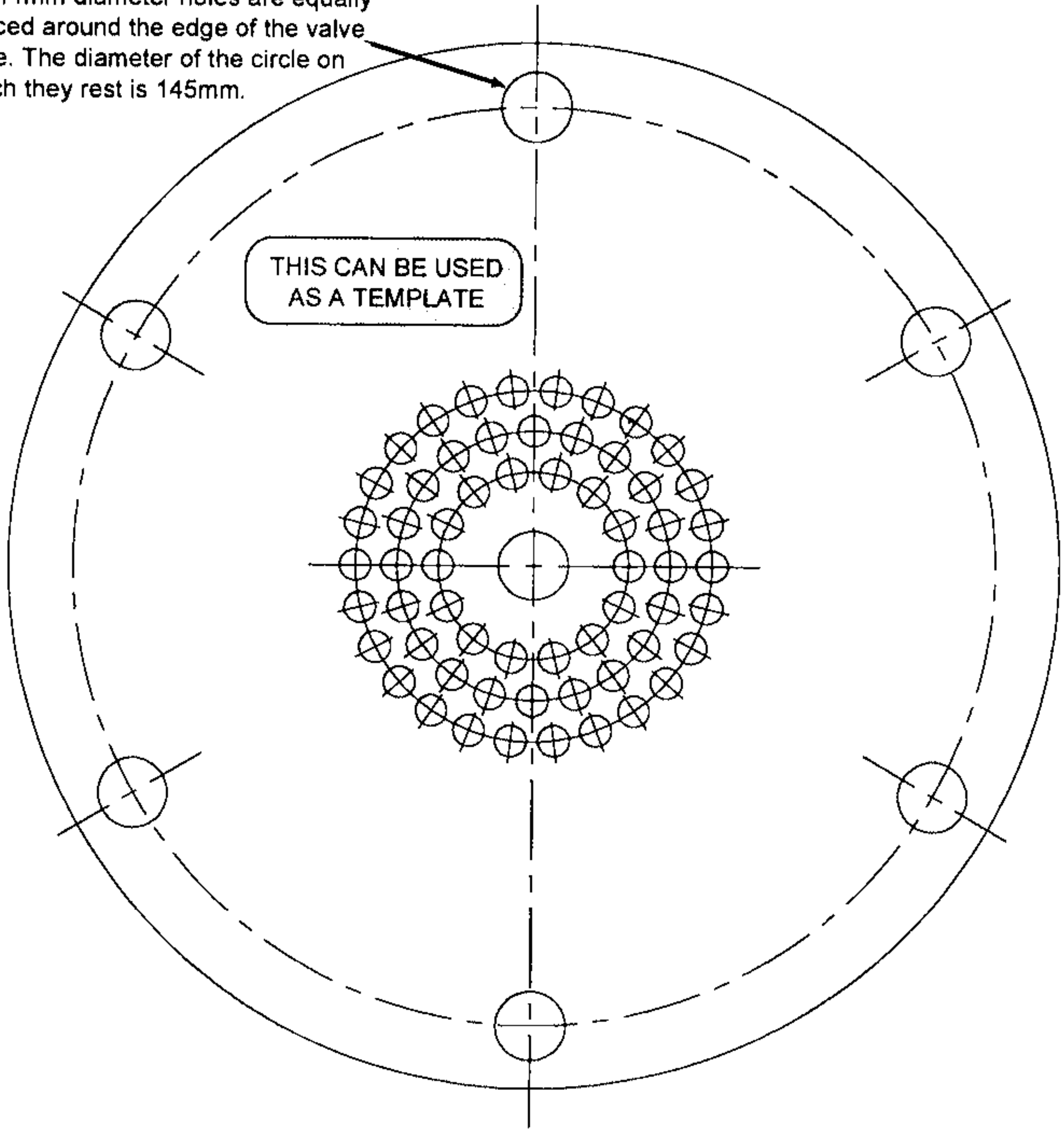
The centre hole is 10.5mm in diameter.

The rings of holes are 4.5mm in diameter. They are equally spaced on circles drawn from the centre with a radius of 14, 20 and 26mm. All these holes must be deburred and chamfered on one side. The chamfered side will be the underside of the delivery valve.

The valve rubber diameter is 64mm and it should be at least 3mm thick.

The plate should be 165mm in diameter and 10 or 12mm thick.

Measure this to check that the drawing has not been distorted by copying


Six 11mm diameter holes are equally spaced around the edge of the valve plate. The diameter of the circle on which they rest is 145mm.

THIS CAN BE USED AS A TEMPLATE

Measure this to check that the drawing has not been distorted by copying

NOTES

The centre hole is 10.5mm in diameter.

The rings of holes are 5mm in diameter. They are equally spaced on circles drawn from the centre with a radius of 15, 21.5 and 28mm. All these holes must be deburred and chamfered on one side. The chamfered side will be the underside of the delivery valve.

The valve rubber diameter is 68mm and it should be at least 3mm thick.

The plate should be 165mm in diameter and 10 or 12mm thick.

DRAWING NUMBER 6

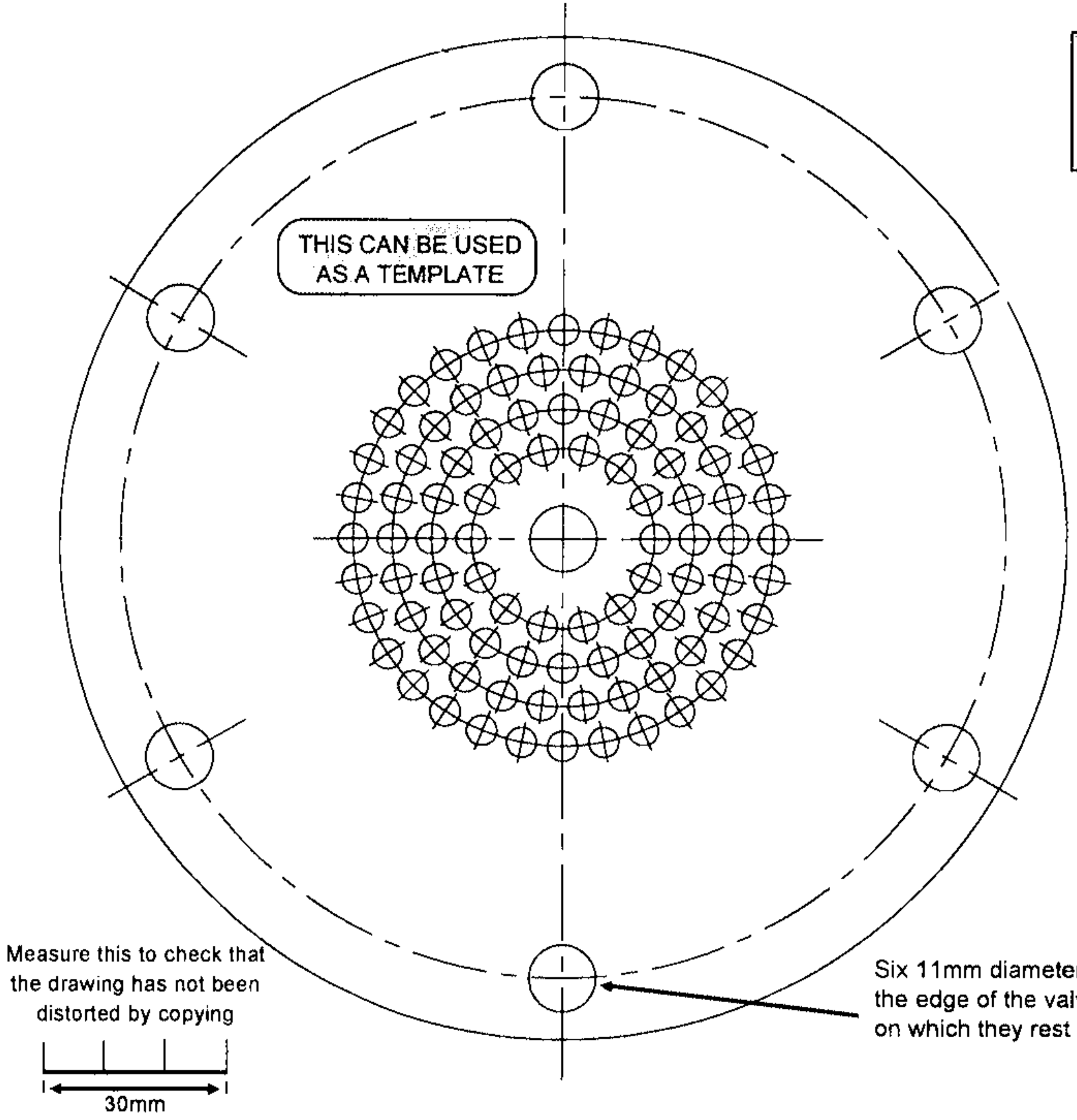
DELIVERY VALVE PLATE 2

Suitable for delivery heads of 35 to 75 meters
DRAWN TO SCALE: 1:1

DELIVERY VALVE PLATE 3

Suitable for delivery heads up tp 35 meters
DRAWN TO SCALE: 1:1

DRAWING NUMBER 7



THIS CAN BE USED AS A TEMPLATE

Measure this to check that the drawing has not been distorted by copying

Six 11mm diameter holes are equally spaced around the edge of the valve plate. The diameter of the circle on which they rest is 145mm.

NOTES

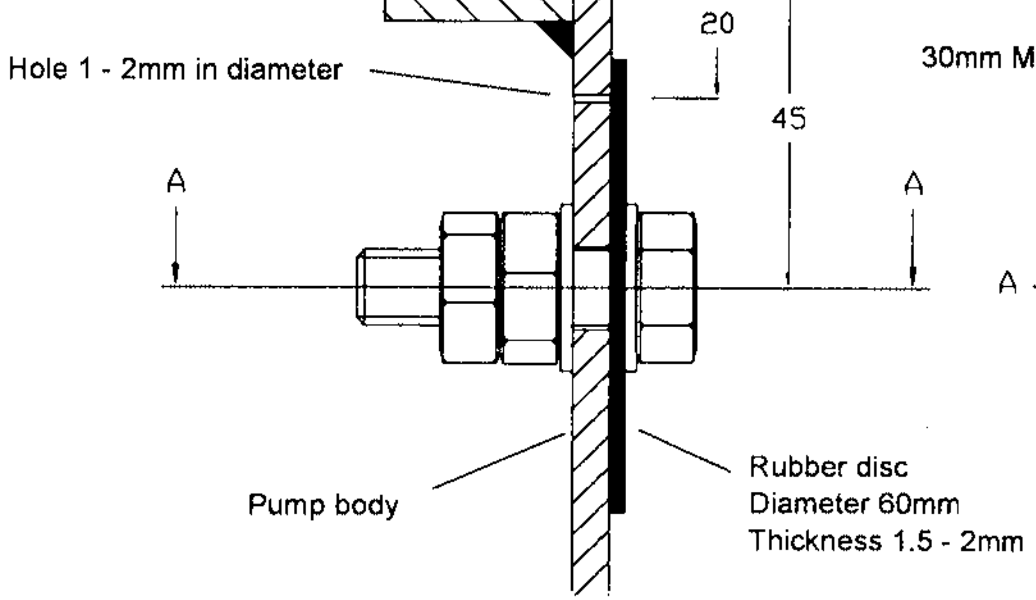
The centre hole is 10.5mm in diameter.

The rings of holes are 5mm in diameter. They are equally spaced on circles drawn from the centre with a radius of 15, 21.5, 28 and 34.5mm. All these holes must be deburred and chamfered on one side. The chamfered side will be the underside of the delivery valve.

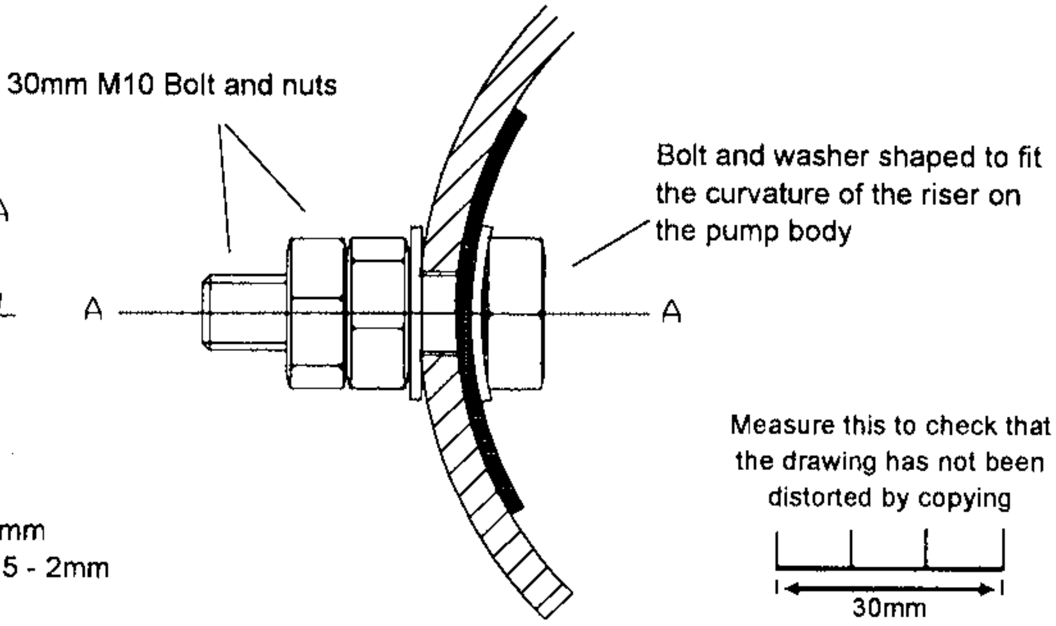
The valve rubber diameter is 80mm and it should be at least 3mm thick.

The plate should be 165mm in diameter and 10 or 12mm thick.

CROSS SECTION
THROUGH THE
SNIFTER VALVE
ASSEMBLY

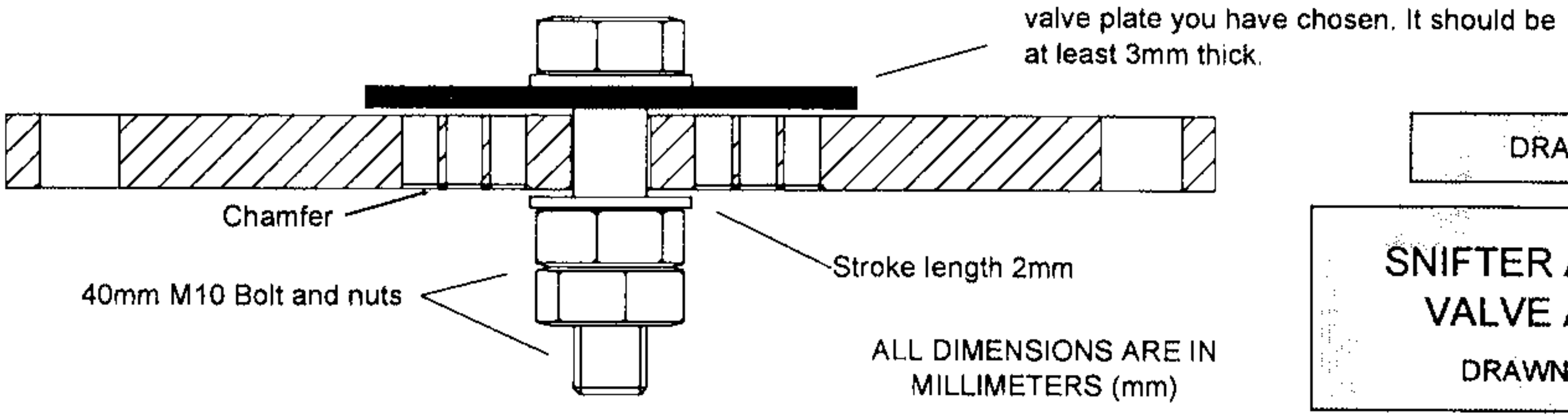


PLAN VIEW CROSS SECTION
that is from A to A on the assembly drawing



Measure this to check that
the drawing has not been
distorted by copying

CROSS SECTION THROUGH THE DELIVERY
VALVE ASSEMBLY



ALL DIMENSIONS ARE IN
MILLIMETERS (mm)

DRAWING NUMBER 8

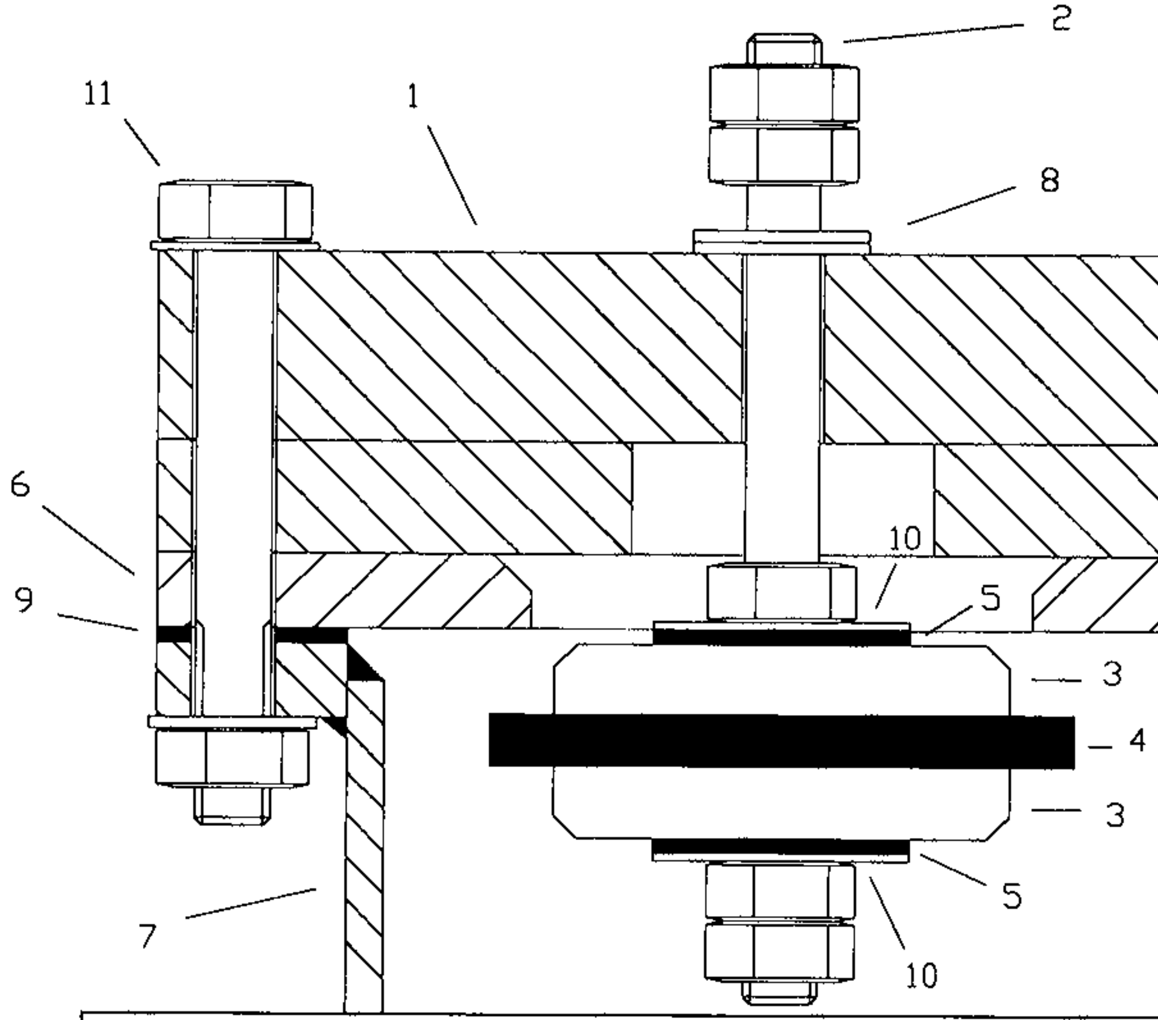
SNIFTER AND DELIVERY VALVE ASSEMBLIES

DRAWN TO SCALE: 1:1

IMPULSE VALVE ASSEMBLY

DRAWN TO SCALE: 1:1

DRAWING NUMBER 9



PARTS LIST

1 - Stop bar

2 - Valve stem

3 - Valve disc (x2)

4 - Rubber disc

5 - Rubber washer (x2)

6 - Valve plate

7 - Pump body

8 - Stroke adjustment washers

9 - Rubber gasket

10 - Large steel washers, about 35mm in diameter (x2)

11 - M10 Bolts, nuts and washers

BOLTS
M10 x 80mm (x2)
M10 x 40mm (x4)

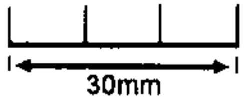
NOTES

The rubber disc (4) is 76mm in diameter and 6mm thick. Do not use a larger disc.

The rubber washers (5) are made to the same diameter as the steel washers (10) and can be 1.5 to 3mm thick.

The rubber gasket (9) can be 1.5 to 3mm thick and is cut to match the pump body flange. Drawing number 3 can be used as a template.

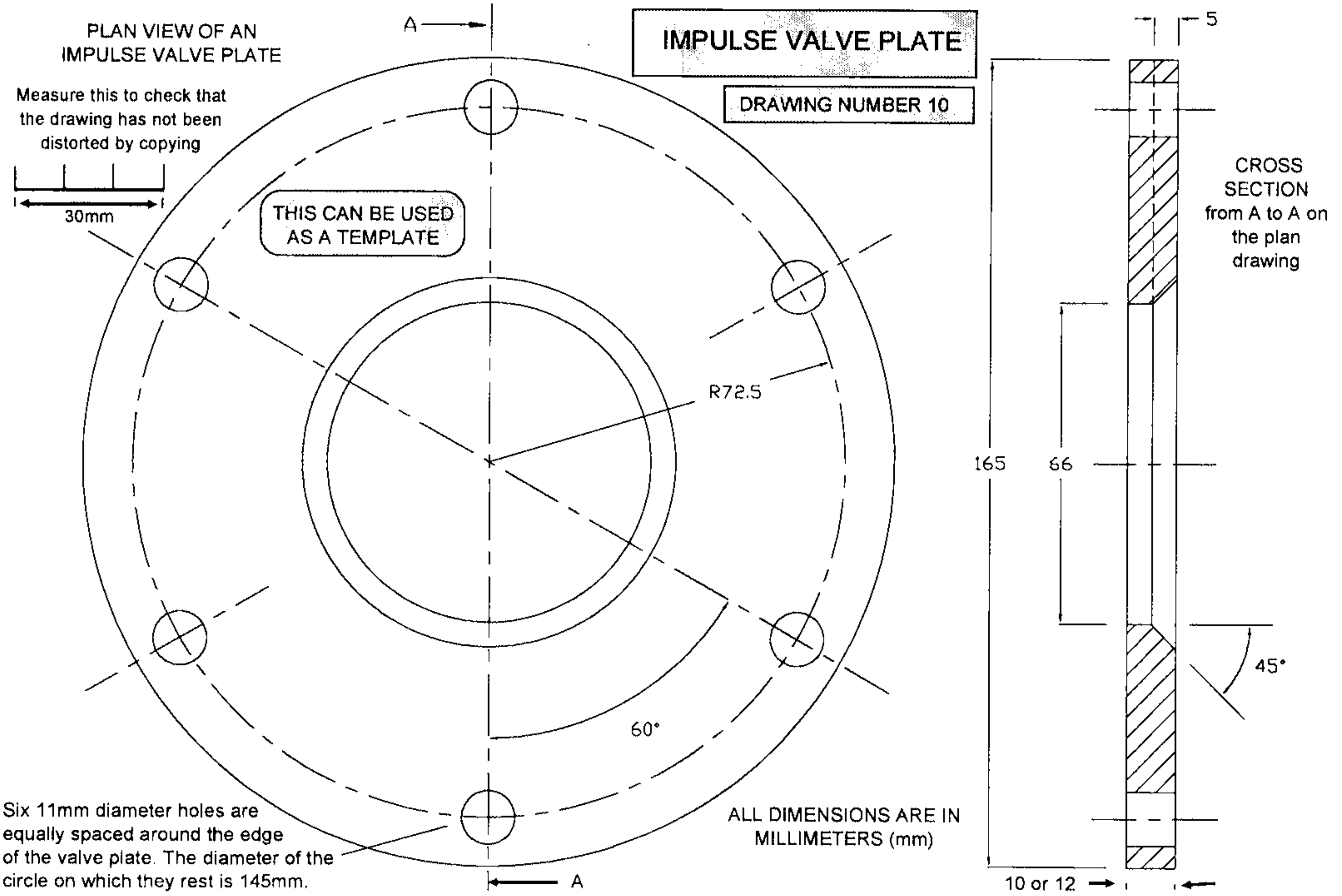
Measure this to check that the drawing has not been distorted by copying



ALL DIMENSIONS ARE IN MILLIMETERS (mm)

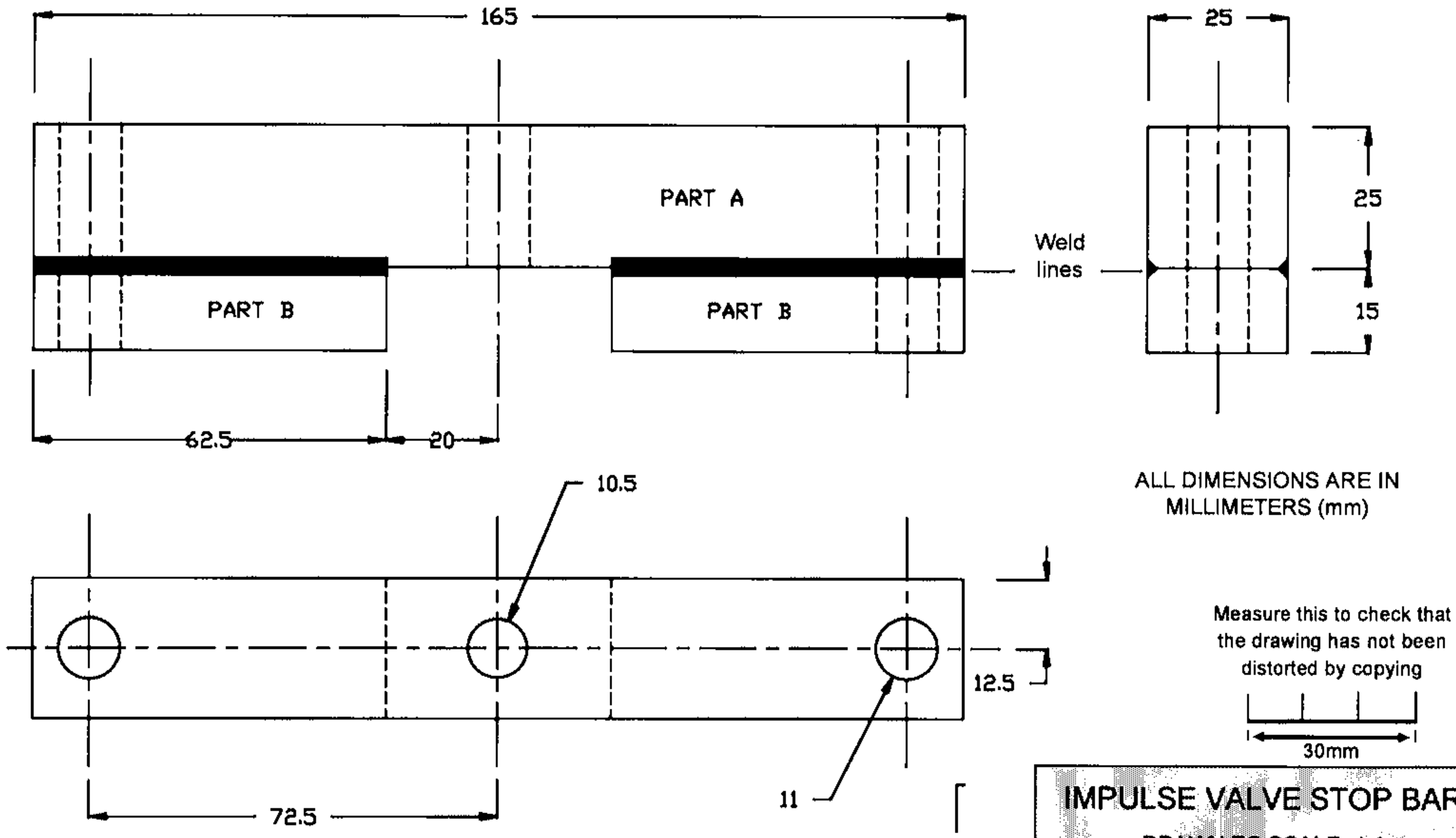
IMPULSE VALVE PLATE

DRAWING NUMBER 10



Six 11mm diameter holes are equally spaced around the edge of the valve plate. The diameter of the circle on which they rest is 145mm.

ALL DIMENSIONS ARE IN MILLIMETERS (mm)



ALL DIMENSIONS ARE IN
MILLIMETERS (mm)

Measure this to check that
the drawing has not been
distorted by copying

NOTES

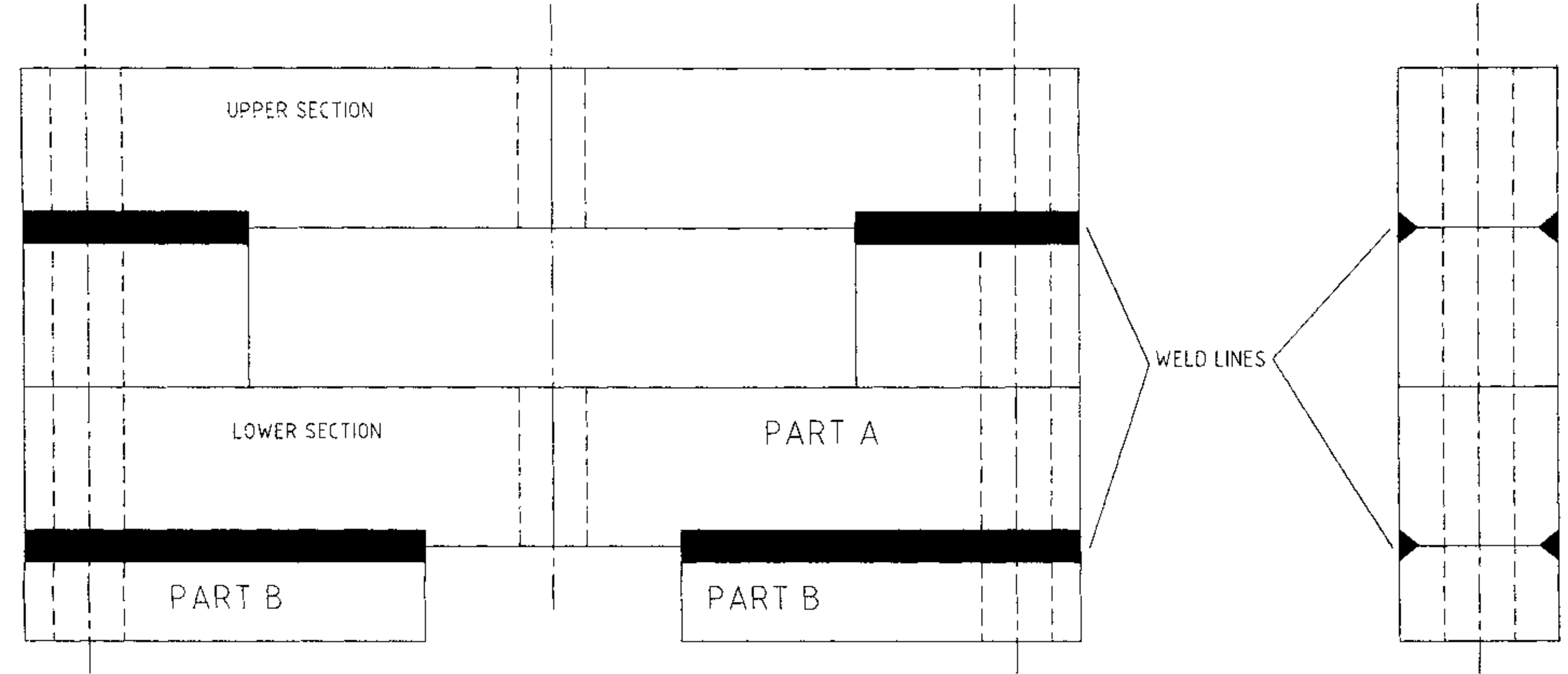
If you cannot get the right size of bar, the height of Part B must be a minimum of 15mm. Part A should be 25mm high, but sizes down to 20mm can be used. The width of Parts A and B should be 25mm but a width down to 20mm can be used.

Make the bar from mild steel. Only use stainless if it is available and you have the tools.

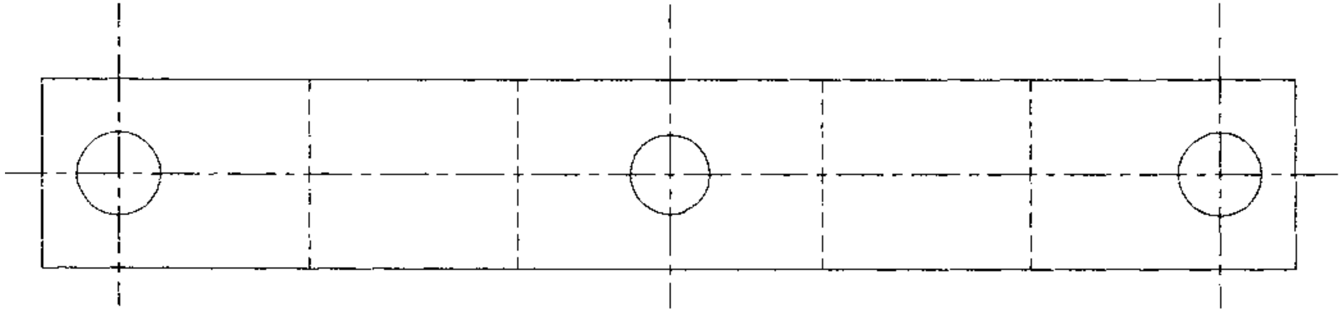
IMPULSE VALVE STOP BAR

DRAWN TO SCALE: 1:1

DRAWING NUMBER 11



Lower section as per
drawing No. 11
Upper from 25 x 25 mm
and drilled to match lower
assembly



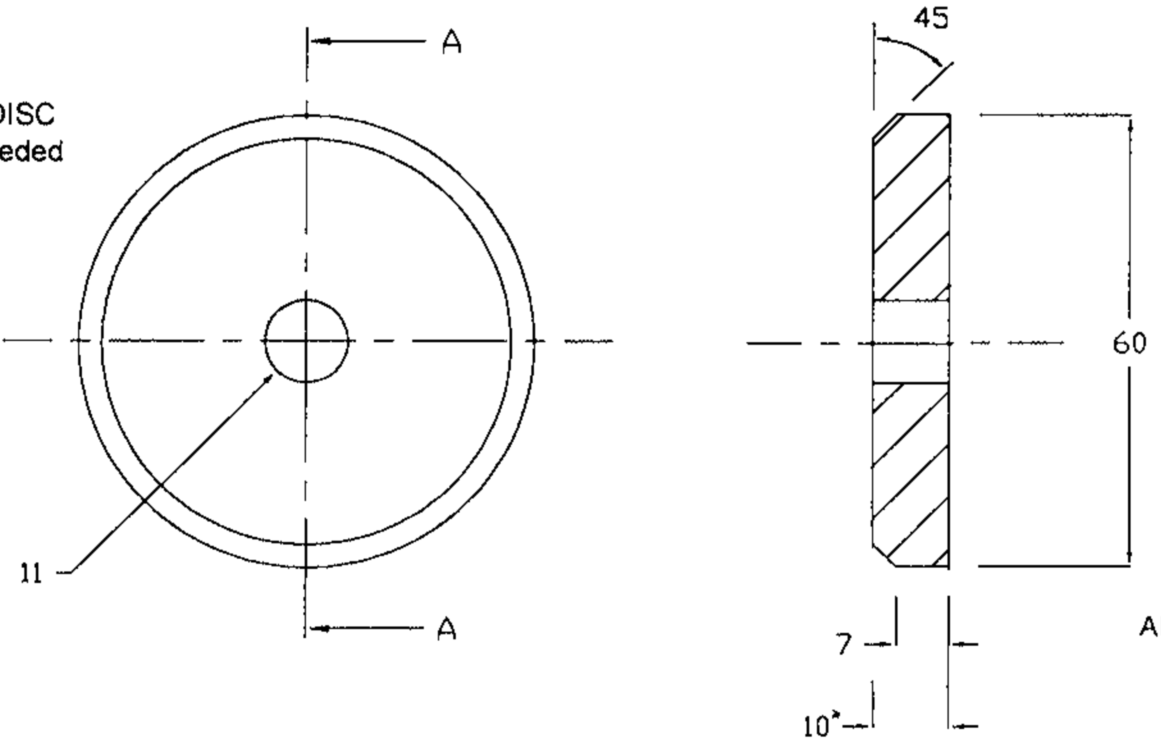
Outer Holes 11.0 mm dia. Middle Hole 10.5 mm dia.

TWO STAGE IMPULSE
VALVE STOP BAR/GUIDE

DRAWING NUMBER 11a
DRAWN TO SCALE 1:1

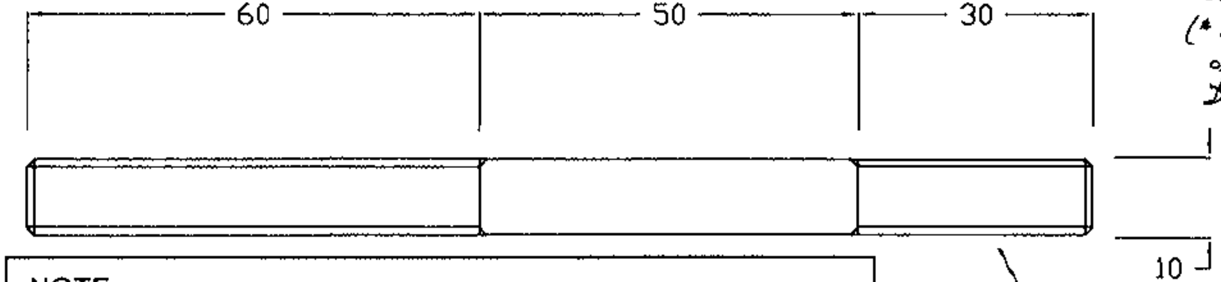
PLAN OF AN
IMPULSE VALVE DISC
Two of these are needed
for each valve

CROSS SECTION
From A to A on the
Plan drawing



ALL DIMENSIONS ARE IN
MILLIMETERS (mm)

IMPULSE VALVE STEM

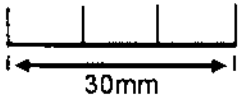


NOTE

The valve stem is made using either 10mm diameter steel bar or 10mm diameter reinforcing bar. Use stainless if you can.

The thread is hand turned using an M10 x 1.5 die.

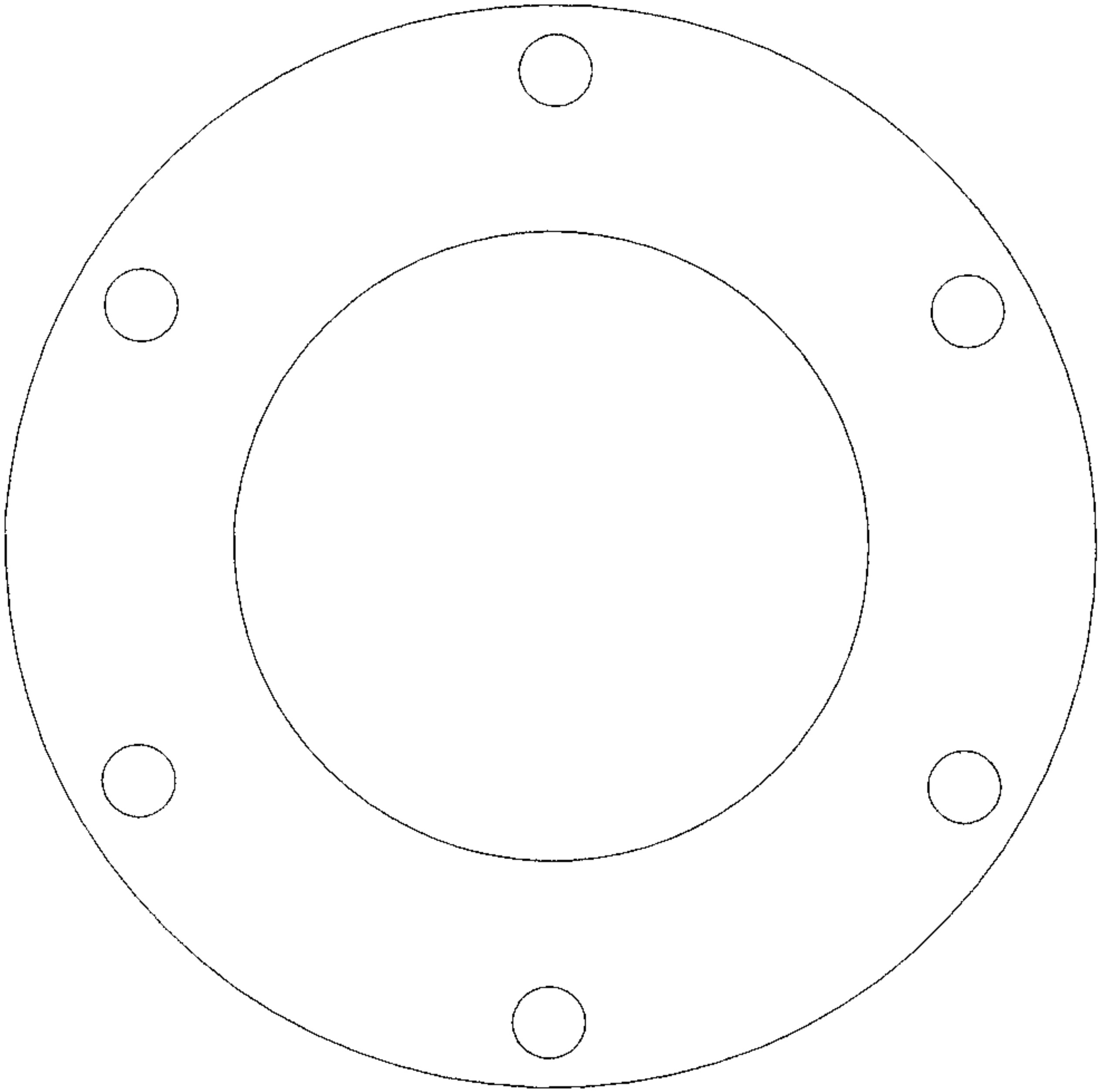
Measure this to check that
the drawing has not been
distorted by copying



DTU S2 IMPULSE VALVE DISCS AND STEM

DRAWN TO SCALE: 1:1

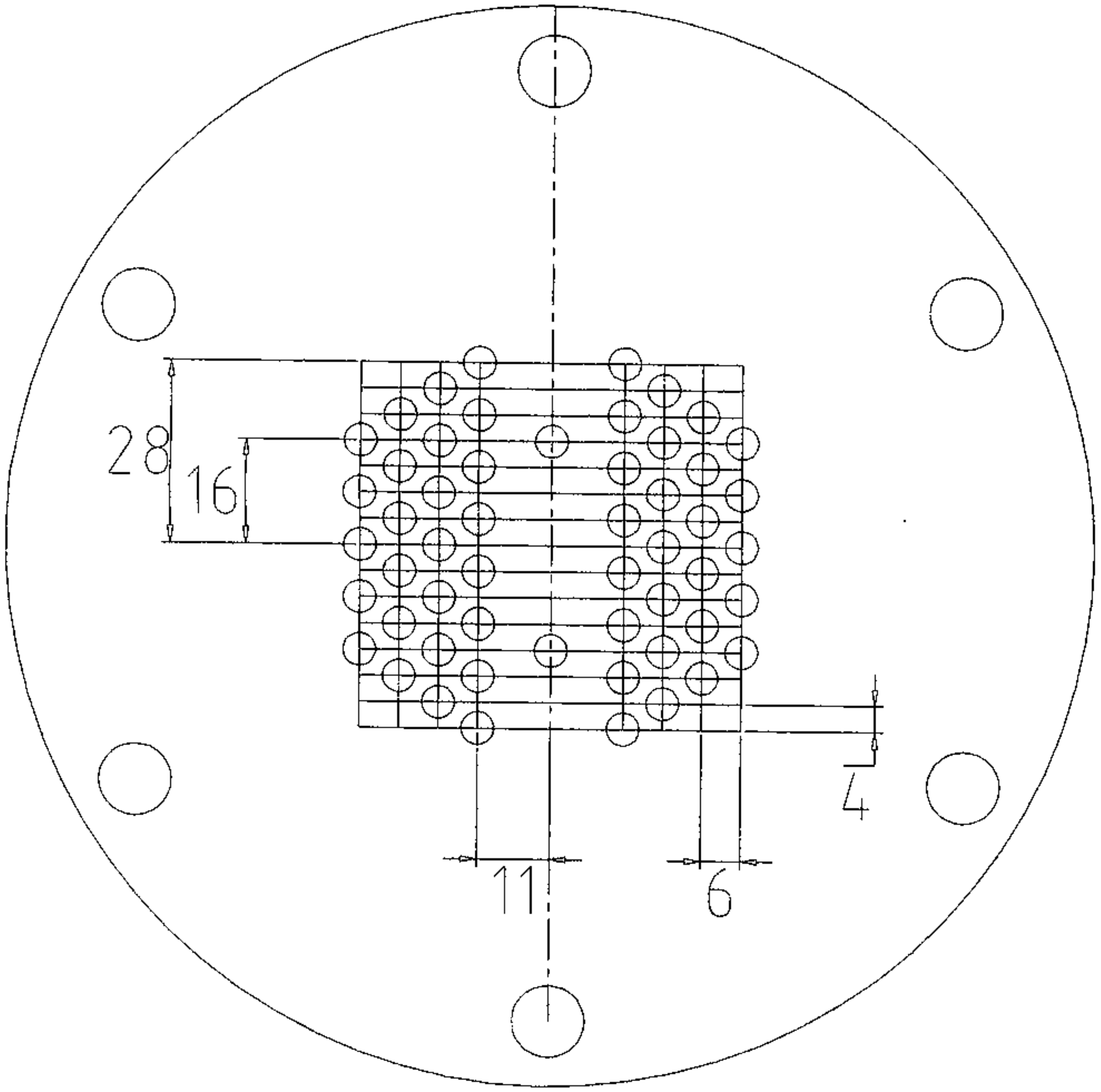
DRAWING NUMBER 12



Inner diameter 96.0 mm
Outside diameter 165 mm

DTU S2 GASKET

DRAWING NUMBER 13
DRAWN TO SCALE 1:1



Delivery Holes 52 off
4.5 mm dia. High Head
5.0 mm dia. Low Head

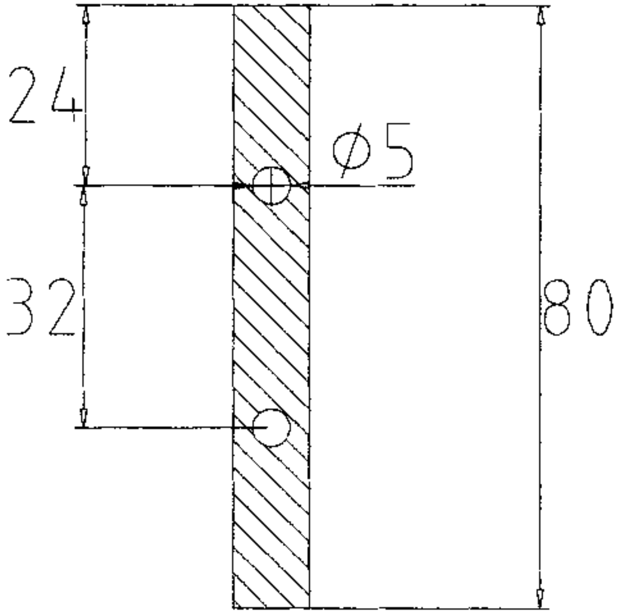
Centre Holes
5.0 mm dia.

PLATE FOR ALTERNATIVE
DELIVERY VALVE

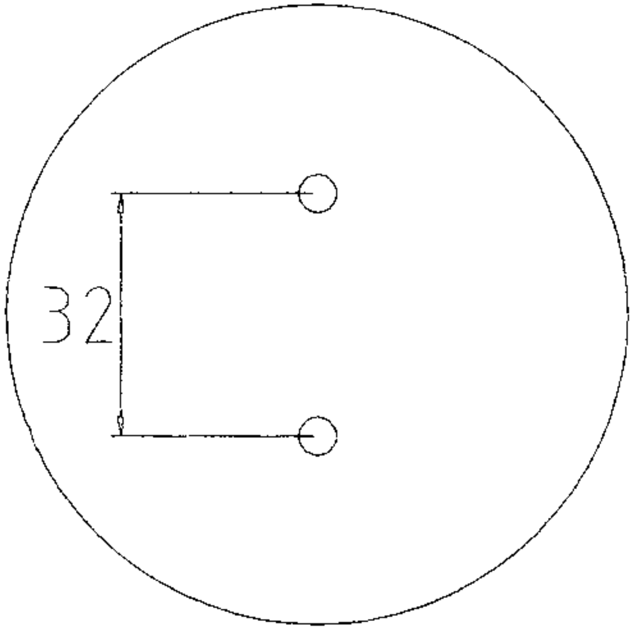
DRAWING NUMBER 14

DRAWN TO SCALE 1:1

Steel Retaining Bar
5 mm thick
10 mm wide



Delivery valve rubber
Diameter 82 mm
3 mm thick for low heads
6 mm thick for high heads



DELIVERY VALVE RUBBER AND RETAINING BAR
FOR ALTERNATIVE DELIVERY VALVE

DRAWING NUMBER 14a
DRAWN TO SCALE 1:1

Hydraulic Ram Pump
Research Programme

NEW DEVELOPMENTS IN HYDRAULIC RAM PUMPING

Technical Release 13

1996

Development Technology Unit
School of Engineering, University of Warwick

This technical release has been written more for ram pump enthusiasts, researchers and manufacturers than for installers and users. It describes the main current trends in system and pump design.

1 GENERAL TRENDS

The ram pump is a 'mature' technology. Over the last two centuries pump designs have stabilised and many variations to the basic configuration (of drive pipe, pump, pump house and delivery pipe) have been tried. One might think that no further significant change was likely in the ram pump itself or in the system in which it is used. However there are changes occurring in both pumping needs and in materials.

Before the invention of petrol engines or the arrival of electricity on farms, the ram pump was in many locations the only feasible way of lifting water from streams or springs to neighbouring hillsides. In consequence a high cost was tolerated; strong but expensive pumps made from cast steel, gunmetal and brass were used. Today there are more alternatives, so that ram pumping can only hold its 'market share' in water supply for humans and for cattle by becoming cheaper and simpler.

All over the world water is getting scarcer and dirtier. In consequence ideal sites for rarn pumping - where a large flow of clean water drops steeply - are becoming fewer. Quite often the water requires cleaning if it is to be used for domestic purposes. There are various possible responses to this problem of polluted drive flow. One is to filter the delivery flow. A second is to use an indirect ram pump that permits falling dirty water to power the raising of clean water from a nearby source. A third is to concentrate on applications like cattle watering and irrigation where water quality is less important.

Filtering and disinfection are well understood, and the technical options for applying them are increasing in number. The availability of only one or two watts of electricity, say from a small photo-voltaic panel, now enables chemical or ultra-violet sterilisation to be performed at a household or village scale. Adding such processes to a ram pumping system may require other design adjustments, for example those to permit delivery flow only in day light hours.

Indirect pumping is a technique known for a hundred years or more. Indirect pumps are still manufactured but they are complex and hence costly. They have more wearing parts than normal ram pumps and they require a source of clean water close to the dirtier flow that drives them. One might argue that to require such elaboration in system installation and maintenance is to head in the wrong direction. Field experience suggests that the use of ram pump technology is already severely limited by people thinking it is 'too complicated'.

It is the authors' experience, mostly in an African context, that even after a 3 weeks' training course many water technicians do not have the confidence to survey, design and install a ram pump system. The design rules seem complex and they fear making any mistake that might cause a system to fail. Yet systems do occasionally fail - through wear and corrosion, insufficient drive flow or flood damage, siltation or blockage, theft or malicious damage. It is not possible to build a perfect system.

With petrol-engine pumping at its simplest, the user carries the pump to site, drops a suction hose into the water source, rolls out the delivery hose and starts the pump. With electric powered pumping using mains, photo-voltaics or transported batteries, the procedure is a little more complex. Ram pumping is more complex again. There has therefore been a growing interest in simplifying the technology, especially in order to serve irrigation operated by peasant farmers.

2 SIMPLER PUMPS

A pump normally comprises an adjustable impulse valve, a (non-return) delivery valve, a pressure vessel to smooth out the pulsating delivery flow and an anchorage or cradle. Where 'free' air is the buffering medium in the pressure vessel (which must be vertical to work properly), a third ('snifter') valve is needed to replenish this air.

Simplifications can take a number of forms, but the main ones of current interest are

- removing the mechanism to adjust the drive flow,
- replacing 'free' air by 'contained' air,
- simplifying the anchorage of the pump and its attachment to drive pipe and delivery.

Removing the tuning mechanism of course removes all the benefits of tuning, namely the ability to adjust the pump to match the drive flow locally available. Under some circumstances, especially when only a small fraction of stream flow is needed, there is no great merit in being able to tune. Where a manufacturer produces a range of pumps it is normal for each step up in size to correspond to a two or three fold increase in maximum drive flow. An untuned pump is effectively permanently set to its maximum (or 'rated') drive flow. Thus using such pumps singly will restrict the drive flow, and hence delivery, to one of a few widely spaced values. If however several (say three) identical pumps, or two pumps of different size, are used in parallel, it is usually possible to get within 25% of any ideal drive flow. In fact there are four distinct alternatives to on-site tuning for matching pumps to available flow, two of them applicable when the system is installed and two when it is in use.

During *installation* the drive flow capacity of a system can be roughly selected by choosing the right number and size of pumps to be run in parallel. Alternatively pump(s) can be used that are 'preset' to a particular drive flow. This lower level of adjustability not only simplifies pump design (e.g. it can be provided by having two or three different weights of impulse valve), but removes the possibility that the user completely mistunes his pump. Such mistuning through operator ignorance is quite common in high technology systems as well as in the simple ram pump ones we are discussing here.

During *operation*, there may be a need to respond to a fall in available stream flow. If pumps are not tunable this can only be done by reducing the number of pumps in operation or by running them all intermittently. Using the 'three same size pumps' or 'two different size pumps' arrangement recommended above, it is possible to follow any changes in stream flow by changing the number of pumps in use. Intermittent operation by contrast can be used with only a single pump but requires much more operator activity and also a reservoir capable of storing at least 2 hours drive flow. In practice intermittent operation, where the user turns on the pump when the reservoir is full and off when it is empty, is very rare. It could become more common where small-farm irrigation is the pumping application. Technically it should also be possible to use a self-priming siphon to achieve intermittent operation without human intervention: the authors know of no example of this being done.

Given the desirability of having more than one pump running in parallel for reliability reasons, the relative rarity of requiring very close matching of system drive flow to stream flow (often extremely variable) and the likelihood of mistuning by inexperienced operators - we may expect to see more simple pumps that are untunable or are tuned ('preset') only during manufacture.

Using "contained " air to buffer the pulsations in delivery flow has real advantages over using a conventional air vessel. By "contained" air or "air packet" we mean air in a bladder or closed-cell foam. Normal commercial pressure-surge limiters in water pipelines use diaphragms to separate the air from the water, however such diaphragms are difficult to make and to seal and are therefore expensive. By contrast closed-cell foam such as bubble-wrap has already been used in a number of small ram pumps. The advantages of substituting air packets for the free air of a conventional pressure vessel are several. The containing chamber need no longer be vertical, air cannot be lost through tiny holes in welds or fittings, the snifter valve is no longer necessary, the pump can be operated under water. Disadvantages are the possible fatigue failure of the air-containment materials, slow loss of air through the walls of bladders or foam and the significant reduction in air volume at start up.

Consider a conventional air vessel of volume 10 litres in a pump delivering to 90 meters. Initially, before start-up, the air is at atmospheric pressure (1 bar). At start-up the absolute pressure rises rapidly to 10 bar (9 bar 'gauge') as the air is warmed and compressed. It then cools until its volume is about 1 litre, namely one tenth of its initial value: the air vessel is now nearly full of water. Over a period of hours however the air is replenished via the snifter valve to its original volume of 10 litres. The pump may run rather noisily until this has taken place.

If however a closed air packet replaces the conventional free air, there is no replenishment mechanism, so throughout the run time it remains at 1 litre. It therefore is necessary to provide an air packet whose initial volume is equal to:

V_{init} = air volume required in operation (V_{op}) × delivery pressure in bars absolute.

(Note that 10 meters delivery head corresponds to 2 bars absolute, 20 meters to 3 bars etc.)

Recent research and experimentation suggest that the air volume in operation (V_{op}) can safely be as little as twice the volume of water delivered per cycle. [The pump efficiency does not fall significantly compared with when V_{op} is large, and the overpressure of about 30% is usually also tolerable from a fatigue point of view.] An irrigation pump may only lift to 20 meters, so initial air volume V_{init}, is only 3 times V_{op}, whereas a domestic supply pump may lift to 80 meters (V_{init} = 9 times V_{op}) or higher. We would therefore expect this air compression problem to be more severe with high-lift pumps. However as the delivery head is increased (while the drive head and drive flow are kept constant) the volume delivered per cycle goes down. The combination of these effects means that for a given size of pump, the appropriate initial air packet size does not vary much with delivery head. In practical terms, the minimum initial packet size relates to pump size roughly as shown in Table 1:

This table indicates an initial air packet volume, and therefore vessel size, equivalent to 1 m of drive pipe (or less length of a larger diameter) should be sufficient: this is a tolerable size.

With an air packet, pump design can be simplified to essentially an impulse valve followed by a packet-enclosing horizontal tube entered via the non-return delivery valve. This results in a fairly compact design of pump that can be placed under water to maximise drive head and to reduce noise. Although there are some particular problems that can arise when operating under water – for example sucking debris in through the impulse valve, increased vulnerability of flood damages and difficulty of access for tuning – in many situations the advantages outweigh the disadvantages.

As materials further improve we may expect more ram pumps to incorporate air packets or even a diaphragm instead of traditional air vessels.

Simplifying the pump attachment is a particular requirement for irrigation use where ram pumps and even drive pipes may be removed at night and will certainly need to be removed at the end of the dry season. The shock forces on pumps when they are in use are large, so any anchorage has to be sturdy. Already it is usual to bolt pumps onto a permanent (i.e. concreted-in) cradle. There is now interest in providing clip-on arrangements both between pump and cradle and between pump and drive pipe, rather than using nuts, bolts or wedges.

3 NEW MATERIALS, LOWER COSTS AND HIGHER PERFORMANCE

Materials For long-life pumps, traditional construction materials are largely suitable. By contrast, new materials have particularly found their place in cheap ram pumps of modest but adequate performance. During the last twenty years metal piping has largely been superseded by plastic, especially PVC, ABS and HDPE. It is therefore

Table 1

Drive pipe size (ID)	mm	25	50	75	100
Assumed driveflow	litres/min	25	100	250	500
Packet size (for *drive* head of 2 meters)	litres	0.15	0.60	1.50	3
of 6 meters)	litres	0.45	1.80	4.50	9
Volume of I meter of drive pipe for comparison	*litres*	*0.5*	*2.0*	*4.4*	*8*

tempting to use these rust-proof and easily worked materials for constructing ram pump bodies. Unfortunately the poor stiffness, fatigue strength and sunlight resistance of plastics poses problems.

The water-hammer effect that underlies ram pump operation is dissipated in very elastic, or worse energy absorbing, materials. For this reason we try to avoid accumulation of air in drive pipes and we look for a high level of wall stiffness in them. The maximum height a ram pump can deliver to is approximately $h_{max}=\nu \ C_{dp}/g$. Where ν is the maximum water velocity in the drive pipe and C_{dp} is the velocity of sound in that water. It can be shown that for an infinitely stiff pipe, C_{dp}/g is about 140 meters height per meter/second, in a steel pipe it is typically 120 but in a plastic pipe it is only about 30.

[The formula normally used is:

$$C_{dp} = C\sqrt{\frac{1}{1+\frac{DG}{tE}}}$$

Where C is the velocity of sound in water, D and t the diameter and thickness of the plastic pipe, G the stiffness of water and E the stiffness of the plastic.]

This effect shows itself in a plastic system being only able to deliver to about 30% the height of an all-steel system. For really high head deliveries steel drive pipe is essential. For delivery height under 50 meters, plastic drive pipe is adequate

All materials show 'fatigue' in that a loading that they can tolerate easily if it is applied only a few times may cause failure if applied millions of times. In a ram pumping system, the pump and drive pipe experience between 15 million and 100 million pressure pulses per year, so fatigue failure is a real danger. For plastic drive pipes it is usually sufficient to select a pipe pressure rating of 3 times the delivery pressure. For plastic pumps, fatigue failure is so likely that either they are metal reinforced or they are restricted to use with very low delivery heads. Apparently no one is making pumps out of glass reinforced plastics (GRP) despite this material having suitable stiffness and fatigue performance.

Injection moulded plastics are used in centrifugal pumps and hand pumps. They could be used for ram pumps too, but the small production runs do not at present justify the high tooling costs. A few experimental pump bodies have even been made of concrete whose inertia may act as a substitute for strength in the face of sudden forces. The material is cheap, though heavy, but the problems of getting really high densities and of sealing the joints between concrete sections have apparently defeated concrete pump designers.

Certainly the use of simple plastics in small or low-lift ram pumps is now well established alongside that of metals for higher lifts. It seems unlikely that more complex materials or processes will be soon employed to make these devices.

Lower costs come from use of fewer, cheaper or 'easier' materials, from mass production and from design simplifications. Understanding of ram pumps is better than in the past and this had led to a few design changes leading to lower costs.

Mass production of complete pumps is constrained by small markets, while attempts to assemble the pumps from mass-produced fittings have not generally led to either high performance or to much lower costs. Fittings are not cheap if used in any number: pumps made from them are generally clumsy and have too many parts.

For fabricated steel pumps the now ready availability of square section tubing offers simplification of design and assembly compared with traditional round tubing. Square tubing is not efficient at containing high pressures but this is not normally a problem at all but the highest delivery heads. Fabrication is better suited to some pump-using countries than employing iron casting, machining, forging or threaded connectors. Welded joints can be opened again if necessary by cutting them out with an angle grinder

Probably the greatest need for cost cutting is in irrigation applications. If a siphon drive pipe could be developed (requiring the pump to be submerged), the installation costs of irrigation pumps could be reduced substantially. Some effort is being applied to designing essentially portable systems for use with dams as low as 500 millimeters, where the pump and its drive pipe can be quickly disconnected from anchorage and dam respectively.

High performance takes various forms, such as higher efficiency, higher delivery head, quieter operation and greater durability. It seems that little theory was used in the past when designing either pumps, or complete systems. Today ram pumps have something of a fascination for analysts so that there are several publications that aid high-performance design. For example the main sources of inefficiency are well documented and it is not hard to devise an economical system with an overall efficiency as high as 70%.

In Nepal, the Andes, Rwanda and elsewhere there is some need for pumps that lift as high as 200 meters, well beyond the limit of normal machines. The procedures and materials for achieving very high heads are known, but so far the market for such pumps has been too small to cover the costs of fully developing them. DCS, Butwal in the Himalayas have reached 180 meters lift with some reliability.

Quiet operation has been traditionally achieved by placing pumps and drive pipes underground. For years some pumps (for example the Blake's machines) have used rubber impulse valves in otherwise metal systems to reduce noise. The move towards plastic drive pipes may lower efficiency a little, but it beneficially converts high-frequency 'clanging' into less intrusive low-frequency 'thumping'.

Only in the area of durability can one find no significant improvement. Perhaps the lifespan of cheap pumps has increased a little from its former low level, but it is still far below that achievable with traditional 'over-designed' machines.

DTU

Ram Pump Programme

TECHNICAL
12
RELEASE

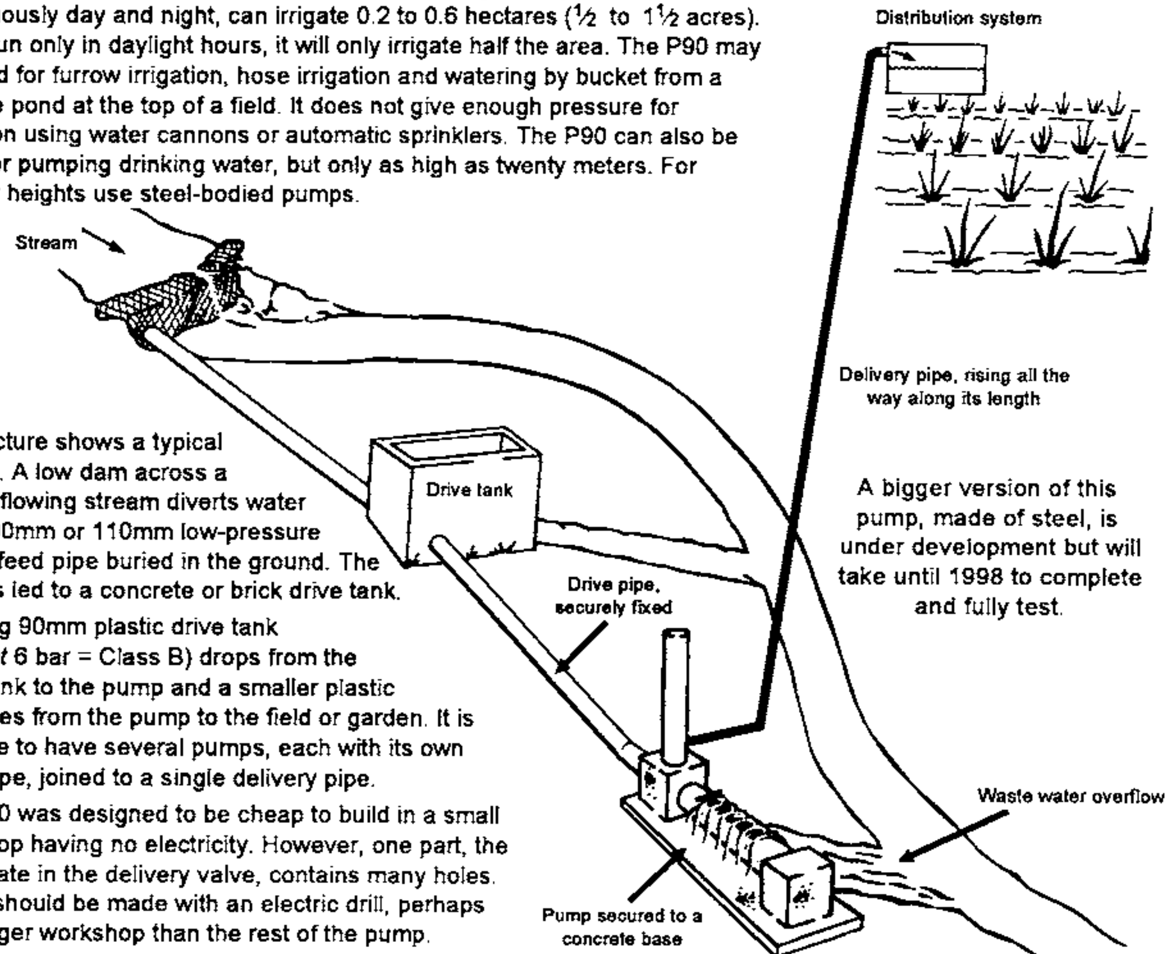
DTU P90 PUMP

DTU P90

The name "P90" stands for a Plastic pump with a drive pipe of 90mm in diameter.

hydraulic ram pump

The P90 is a plastic-bodied hydraulic ram pump designed mainly for the irrigation of vegetable gardens from streams running nearby. Each pump, used continuously day and night, can irrigate 0.2 to 0.6 hectares (½ to 1½ acres). If it is run only in daylight hours, it will only irrigate half the area. The P90 may be used for furrow irrigation, hose irrigation and watering by bucket from a storage pond at the top of a field. It does not give enough pressure for irrigation using water cannons or automatic sprinklers. The P90 can also be used for pumping drinking water, but only as high as twenty meters. For greater heights use steel-bodied pumps.



This picture shows a typical system. A low dam across a rapidly flowing stream diverts water into a 90mm or 110mm low-pressure plastic feed pipe buried in the ground. The water is led to a concrete or brick drive tank.

A strong 90mm plastic drive tank (*at least* 6 bar = Class B) drops from the drive tank to the pump and a smaller plastic pipe rises from the pump to the field or garden. It is possible to have several pumps, each with its own drive pipe, joined to a single delivery pipe.

The P90 was designed to be cheap to build in a small workshop having no electricity. However, one part, the steel plate in the delivery valve, contains many holes. These should be made with an electric drill, perhaps in a bigger workshop than the rest of the pump.

Pumps similar to the P90 have been built by the DTU in several countries. Although the DTU believes the P90 will operate for two years, only one pump trial (in Zimbabwe) has been run for that long.

A bigger version of this pump, made of steel, is under development but will take until 1998 to complete and fully test.

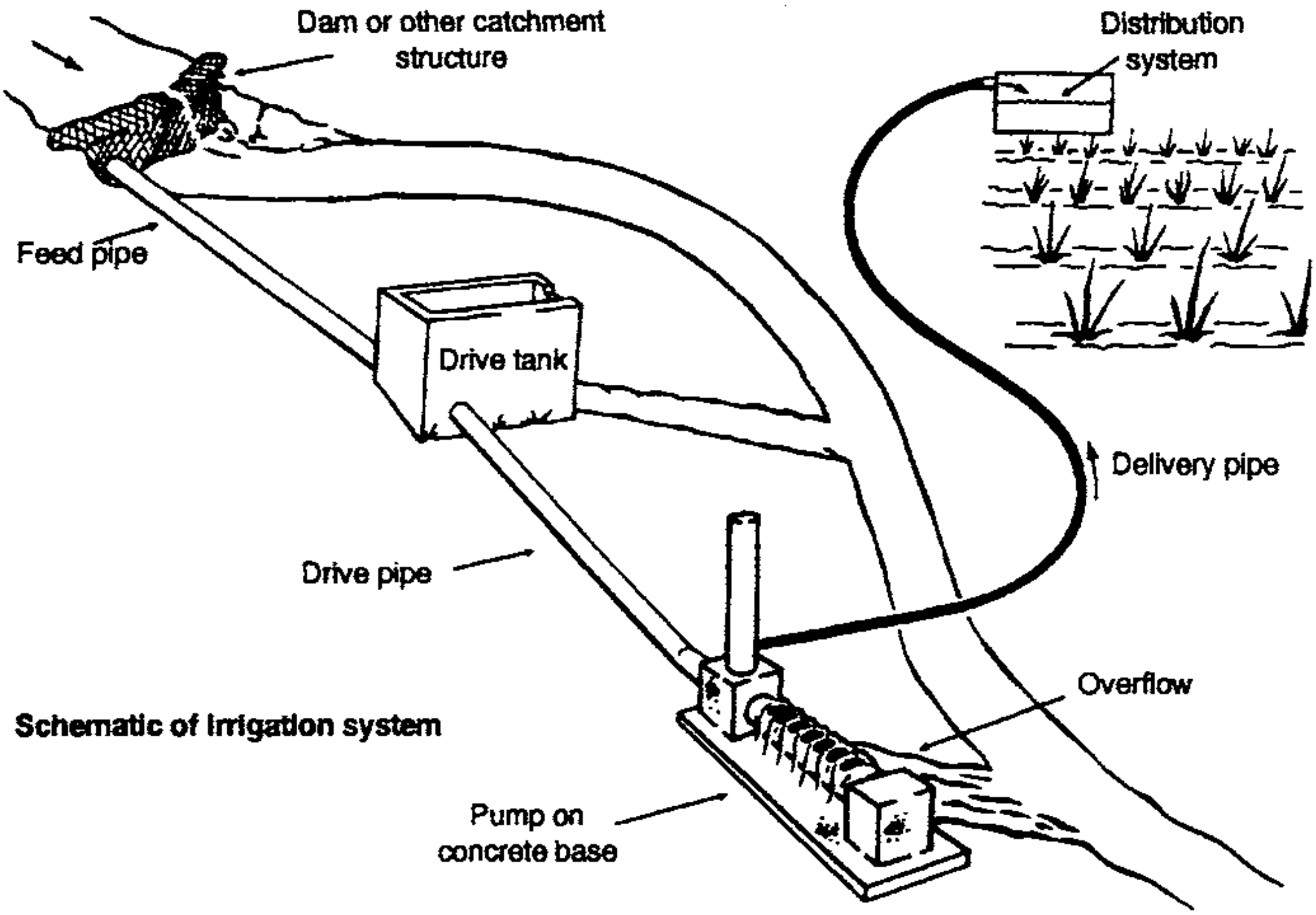
DTU P90 ram pump specifications

The normal specifications of the DTU P90 ram pump are given here. Sometimes you can operate pumps outside these limits, but they may not work well.

drive head range	—	up to 3 meters
drive flow range	—	100 to 360 liters a minute
drive pipe material	—	PVC or ABS (*at least* 6 bar or Class B)
drive pipe diameter	—	90mm
delivery head range	—	up to 20 meters
typical delivery range	—	3 to 40 liters a minute
delivery pipe diameter	—	25mm

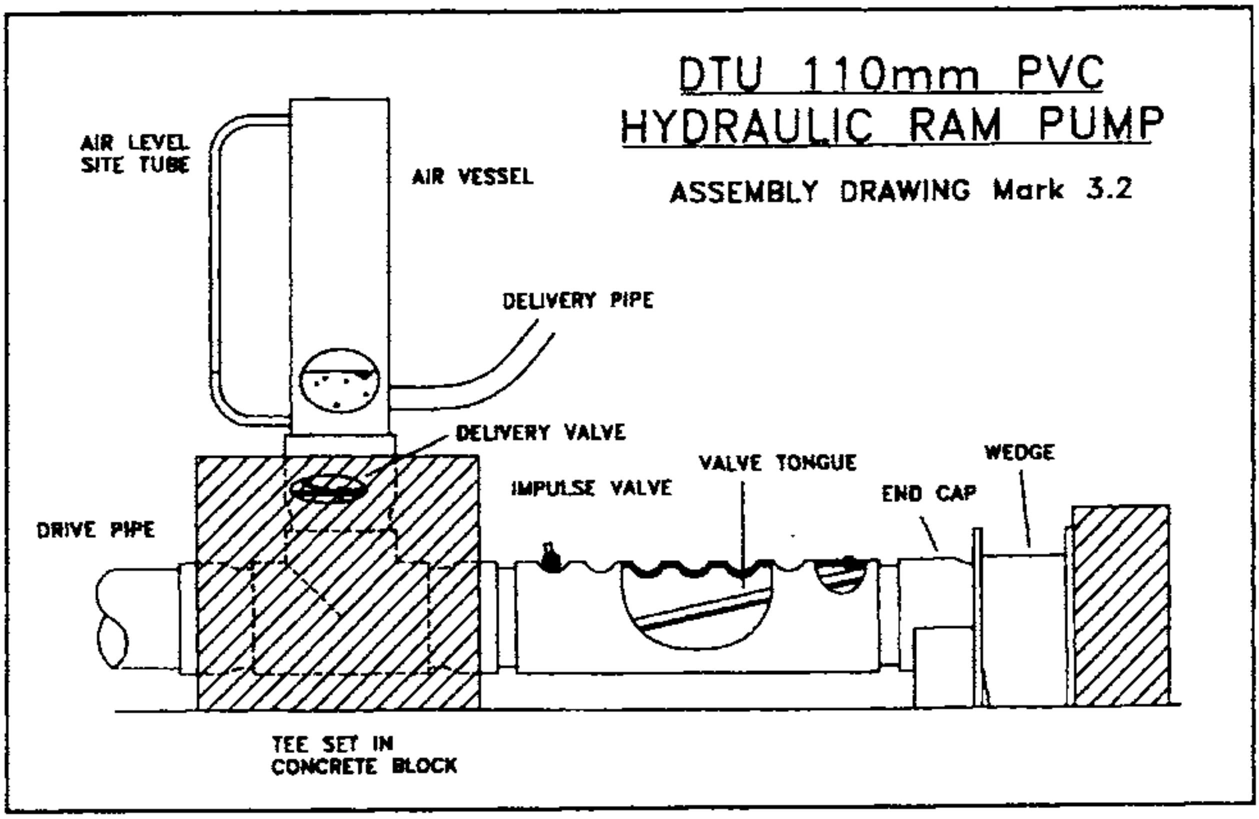
The DTU plastic irrigation pump

Most ram pumps being manufactured are designed to supply water for domestic use because the low flows produced and the costs generally make ram pump systems unsuitable for small-scale crop irrigation. Sufficient water for 1000-1500 people, for example, would only irrigate a plot of around 1 hectare! Some very large bore (12") ram pumps have been built to supply water for irrigation but the capital costs of such schemes restricts their application. In many parts of the world there is a large potential for low-lift, low-cost irrigation of small garden plots to improve yields, allow alternative crops to be grown and increase crop security in unpredictable weather conditions.



Schematic of irrigation system

The material the DTU selected as the only viable alternative to steel is plastic pipe. PVC 110mm (4") diameter pipe is now widely available in many developing countries and provides the scale of flow necessary for small-scale irrigation.



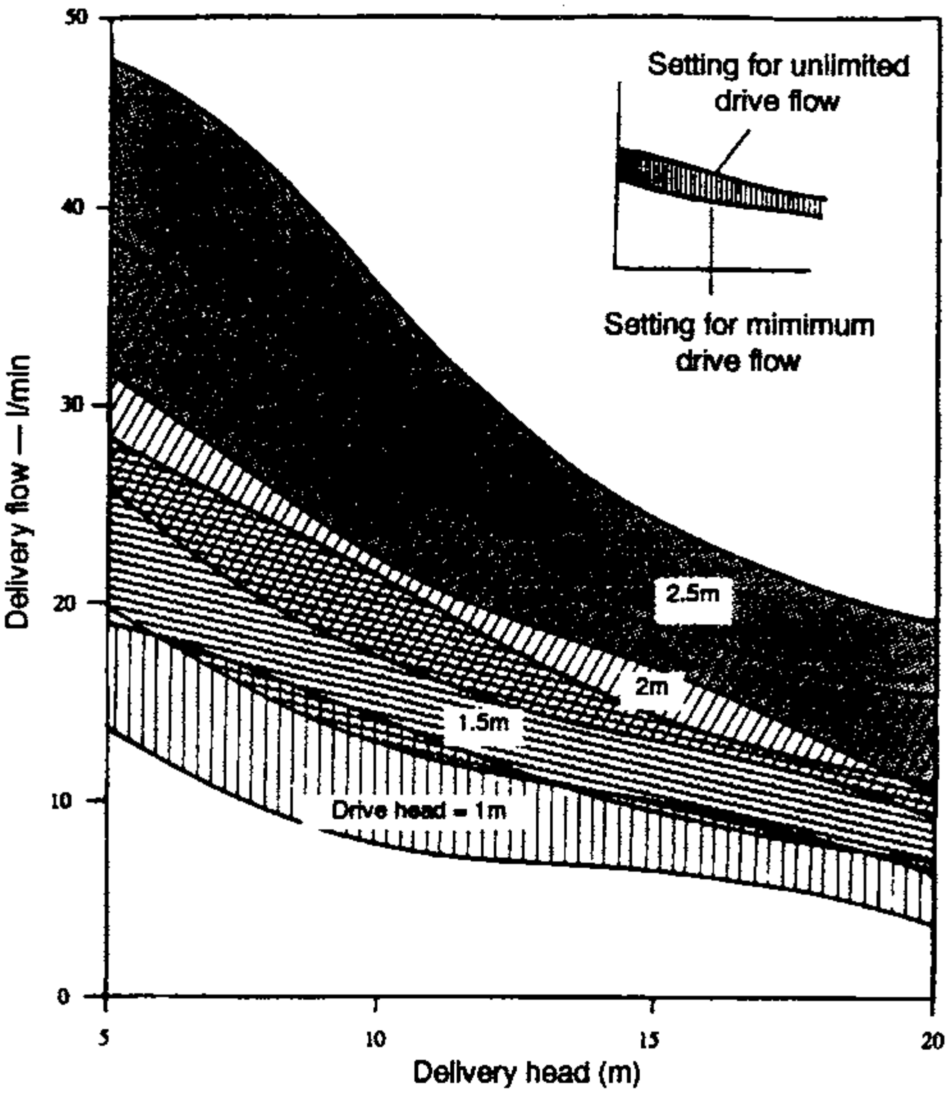
The DTU pump has the following specification:

- all major parts can be manufactured from 110mm pipe (with a minimum of other materials such as bolts, rubber, etc.);
- all parts can be manufactured using hand tools in small rural workshops;
- the system can be maintained by the user and all parts are capable of simple replacement in case of wear, damage or theft;
- designs have been extensively tested for performance and endurance (including extensive field tests);
- pumps should be easy to tune to suit a broad range of site conditions.

It meets the following performance specifications:

1. The drive head (fall of water) can be between 1 and 3 metres.
2. The drive flow available can be between 3 and 7 litres/second.
3. The maximum delivery head is 12m.
4. The energy efficiency exceeds 50%.

At 2 metres drive head, maximum delivery to 15 metres is 35,000 litres per day, adequate to irrigate ⅔ of a hectare.



DTU PVC ram pump — Typical performance data

The shaded areas on the performance data chart above indicate the normal operating range for different values of drive head.

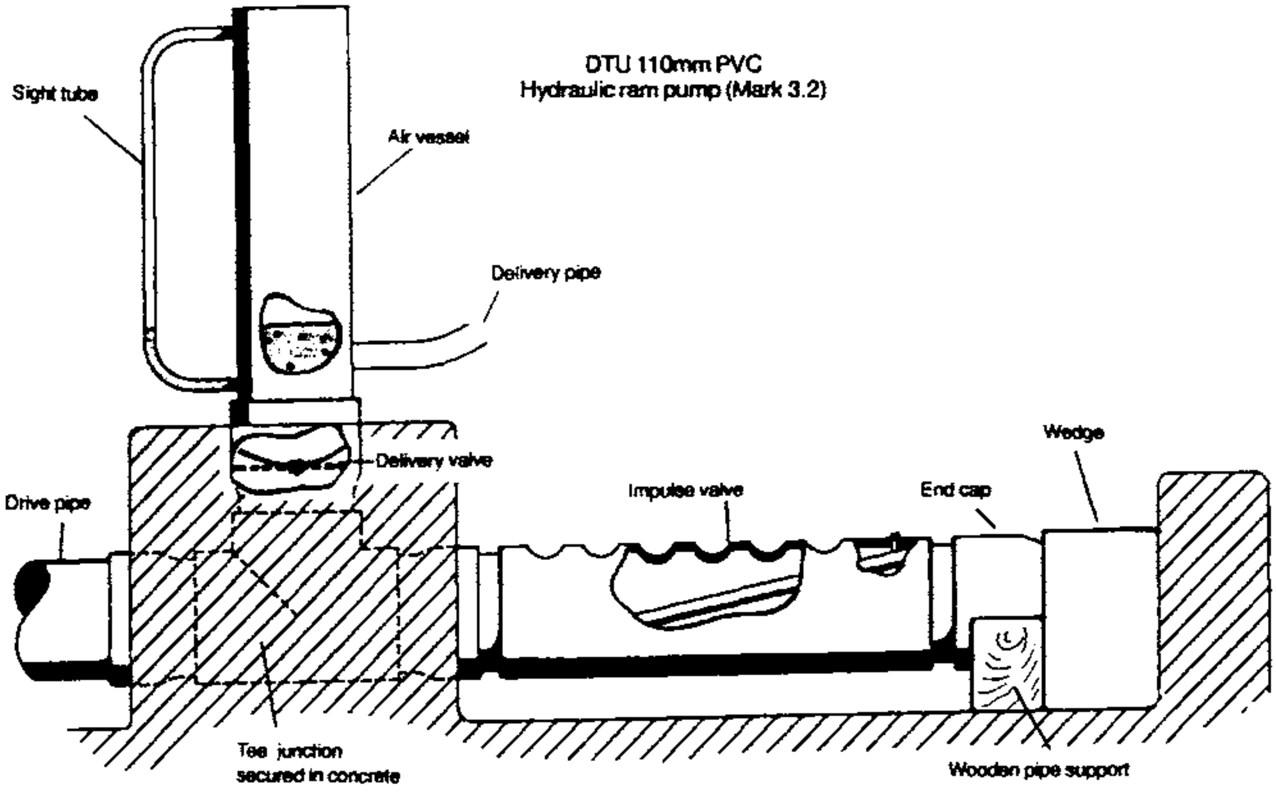
Pump designs have been developed over a number of years with increasing performance and component life. Plastic pipe is more prone to fatigue failure than steel, reducing the life of some components to two years. The current design has been extensively tested in Zimbabwe but is still (1993) at the proving stage of development.

Manufacturing notes

The first DTU ram pump to be built using plastic materials was tested in 1986 as part of an undergraduate project. It was constructed largely from standard PVC drain pipe fittings with a wooden impulse valve. The major interest in the use of plastic for ram pumps stemmed from the low cost of materials and the ease of manufacture using plastic components. There was some question initially whether the thin PVC material would withstand the continual fatigue loading and simply break under the first cycles. With the success of this first design, research was continued on its development and the horizontal axis impulse valve was introduced. Since then laboratory tests and field trials have significantly refined the design of the pump and produced data concerning its durability and pumping limitations.

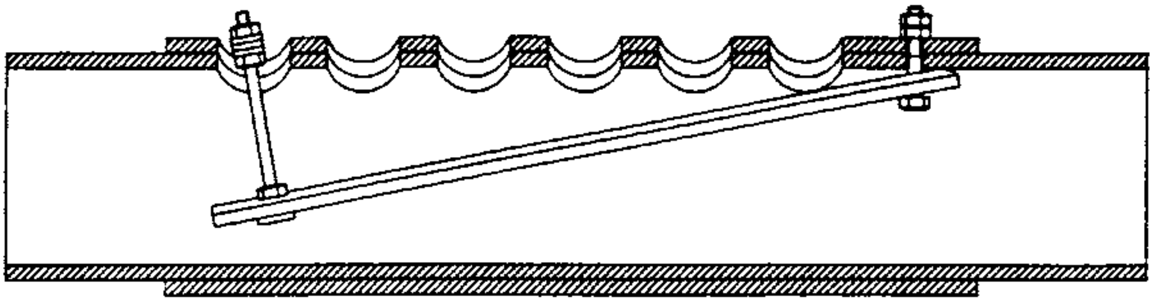
Plastic ram pumps can provide a cheap and simple means of supplying water to elevations of less than 15m. The scale of flow produced and the limitations on their pumping head make them ideal for local manufacture and use for small scale irrigation in developing countries.

This Working Paper details the design of the M3.2 pump. It lists each component and describes any significant features and considerations. Drawings of all the components are also included along with some graphs showing the typical performance of the pump.



Impulse Valve

The design of impulse valve on the DTU M3.2 is unique amongst current ram pump designs. It aims to achieve a flow area through the valve equal to, or greater than, the area of the drive pipe whilst using the drive pipe material for its construction. This greatly simplifies the materials required for pump construction and reduces the need for steel components.



The M3.2 impulse valve

The valve operates under conditions similar to those that cause the aerodynamic lift of an aircraft wing. The velocity of the water flowing over the top of the tongue and out to waste, creates a slightly lower pressure on the top side than that underneath it. As the water accelerates, this pressure differential across the tongue increases until it is sufficient to begin to close the valve. As the tongue rises the velocity over it is increased, which in turn increases the pressure differential, causing the valve to close faster and further increasing the velocity. In this way the tongue accelerates and closes very rapidly producing the sudden deceleration of the water necessary to raise the pressure in the pump body to the delivery pressure.

The valve design works well using PVC materials due to its slight flexibility. When the valve closes the subsequent pressure rise actually flexes the tongue ensuring a good seal even though the tongue may not fit perfectly to the valve body. The same valve design has been tried using steel pipe material but was found not to work well as the tongue could not easily be contoured to the exact shape of the inside of the valve body and didn't have sufficient flexibility to deform under the normal working pressure. Provided that the tongue of a PVC pump fits sufficiently well to just operate it will deform over a number of days of operation until it seals properly.

The development of the this design from the basic concept has taken some time in using different configurations; hole sizes, spacing, valve length and in finding a design with sufficient strength to withstand the continual loading. PVC is not a material recommended for use in situations where a high fatigue loading is likely. Its use would therefore not normally be advisable in ram pumps where there is a highly fluctuating load from the pressure transients in the pump and drive pipe. Research has shown that provided the delivery pressure is kept within recommended limits, the pump and pipe material are sufficiently thick, and the pump well manufactured with no potential stress concentrators, that the normal fatigue loading experienced is well within the tolerance of the material. A Working Paper is available from the DTU detailing the research and findings of work undertaken on fatigue in PVC.

Impulse Valve Design and Manufacture Notes

1) Great care is needed in the manufacture of the holes in the valve body to ensure that there are no small cuts, indentations or cracks from the initial shaping of the holes. Once the holes have been roughly shaped they should be carefully filed until they are completely smooth to the touch and show no visual defects. This will help prevent the formation and propagation of cracks.

2) The tongue hinge is a potential source of rapid wear of the PVC material used both for the tongue and the valve body. The hinge is simply a bolt about which the tongue has some freedom to move. To prevent wear of the tongue, the hole that goes through it is lined with a piece of metal, either a small section of pipe with the correct I/D or a specially fabricated liner made from sheet steel.

3) On two occasions impulse valve cracks were found running down the valve parallel to the pipe axis at the upstream end that was pushed into the tee piece. These cracks were caused by the valve being wedged too hard into the tee piece socket. This created a significant additional hoop stress at that end of the valve and led to a crack propagating from some small imperfection in the first valve hole back to the end of the pipe. The main cause of this problem was the method of wedging the impulse valve into the tee piece against the concrete end block. It is possible to prevent this type of cracking by wedging the impulse valve more carefully. However this does not provide a fool proof solution and still allows the possibility of valve failure. The simplest method of preventing this problem is to shorten the length of the pipe that can fit into the tee socket so that the double skin of the impulse valve butts up against the tee before the valve is pushed in too tight.

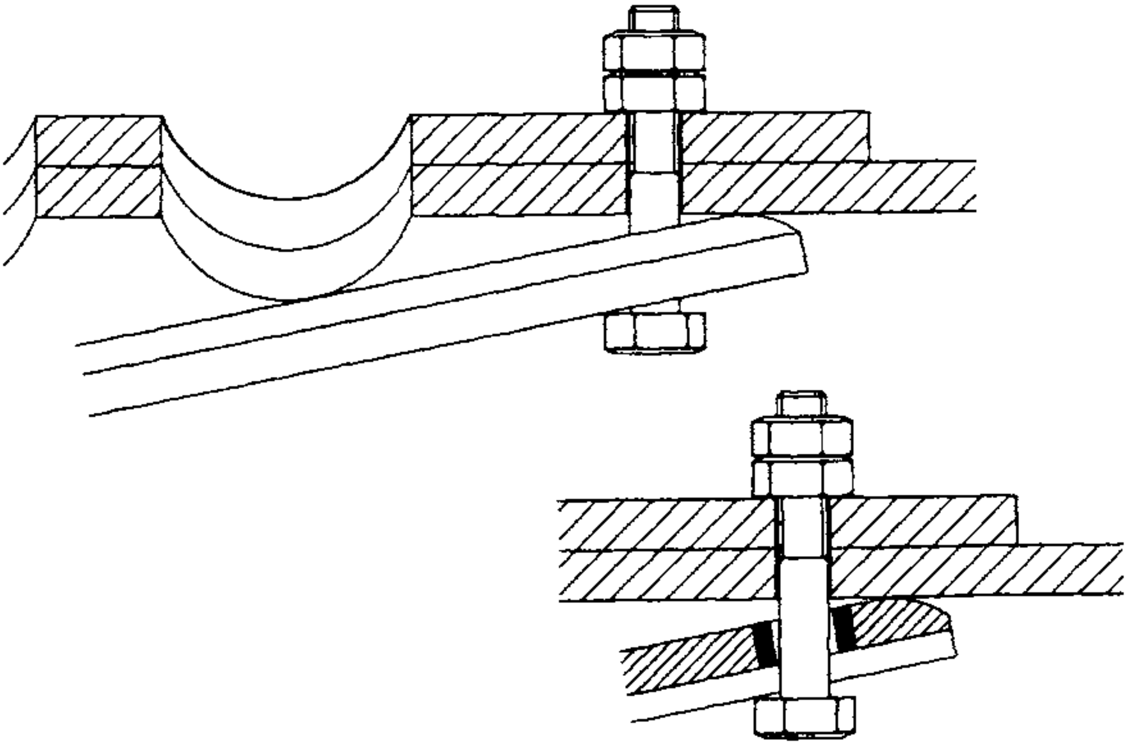


Diagram showing hinge arrangement of impulse valve tongue

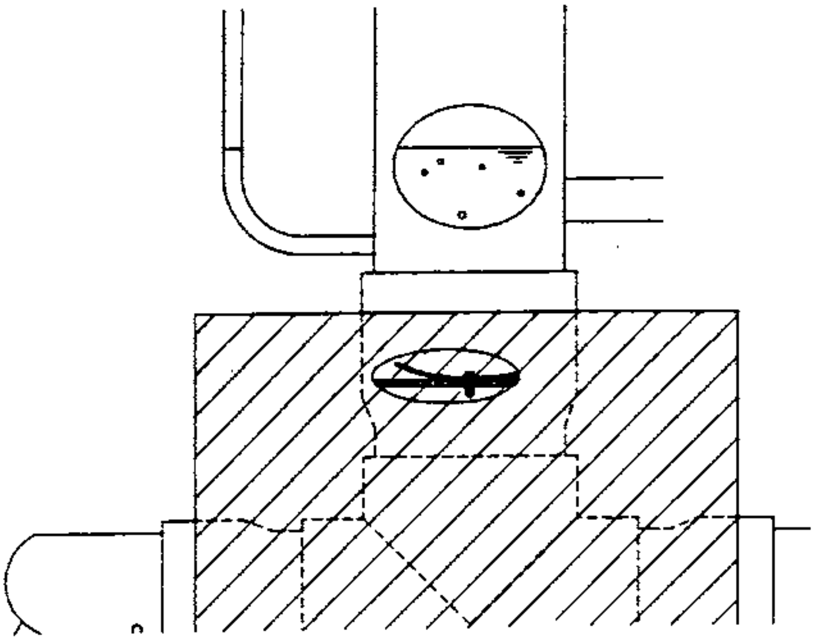
Delivery Valve Design

The delivery valve for a low cost ram pump must satisfy all of the following requirements;

1) produce good performance by; opening quickly with a low pressure differential across it; have a low resistance to flow through it; allow little backflow by closing quickly with a small pressure differential.

2) have an acceptable working life with any disposable rubber parts lasting a minimum of 6 months.

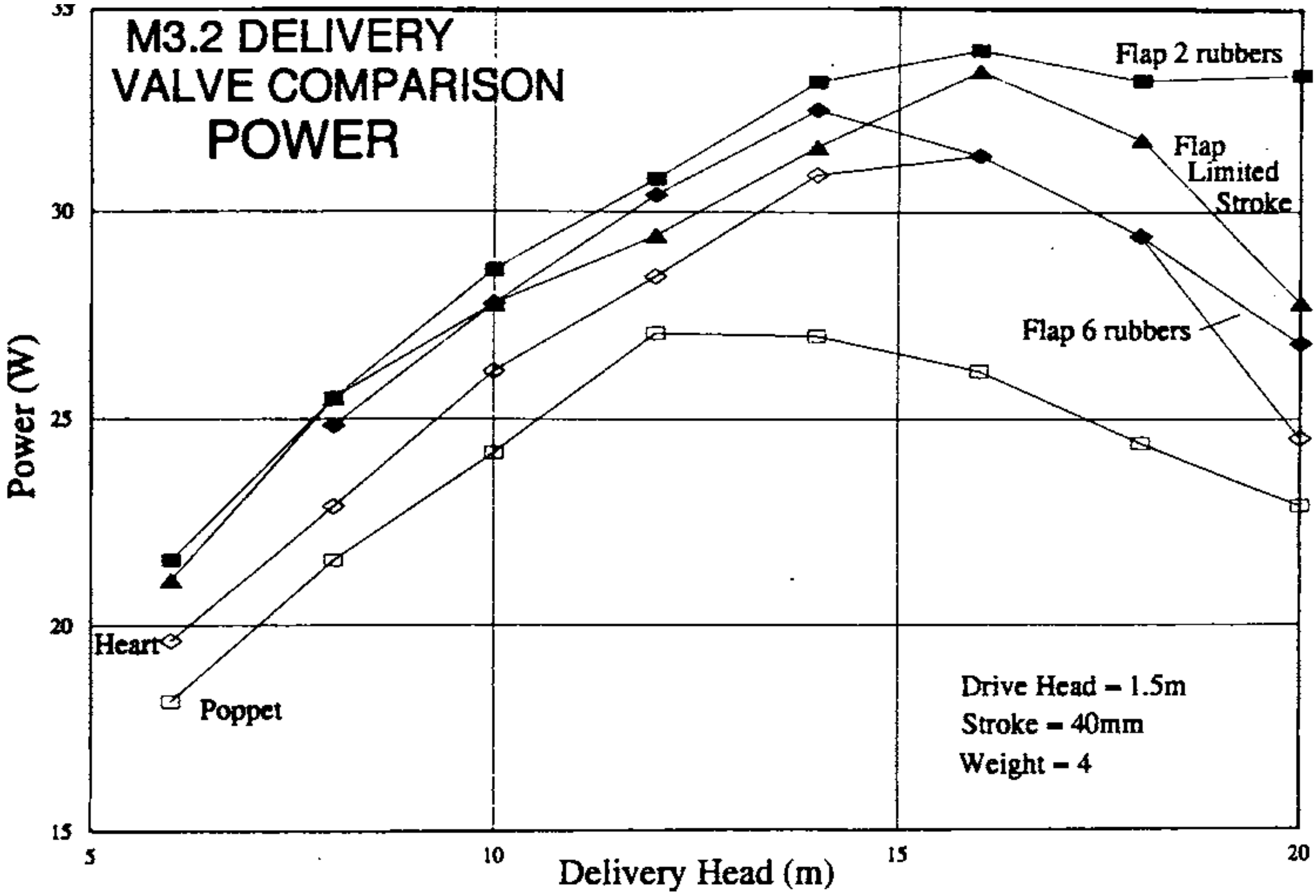
3) be cheap and simple to manufacture.

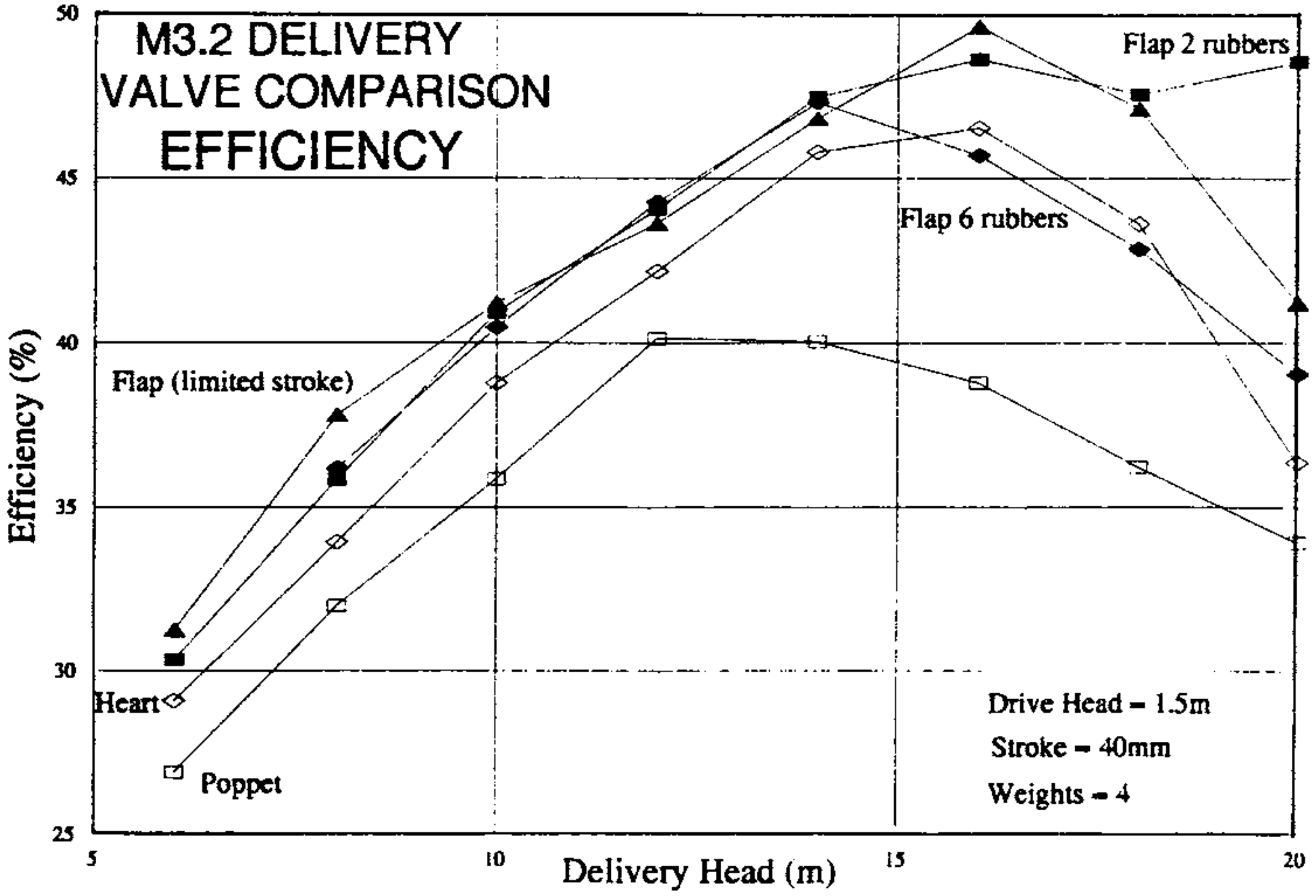


Position of the Delivery Valve

Laboratory tests have been carried out on a number of different types of delivery valve to assess their performance. These were simply designed to compare the throughput of the valve under a controlled set of conditions. Backflow of water through the valve from the air vessel during the period of recoil had been found to be significant on tests of steel ram pumps, reducing the delivery flow by up to 40% in the worst cases. With identical impulse valve settings, the delivery head and flows were measured for 5 different delivery valves. The results of the tests are shown in the following graphs.

The original flap type delivery valve proved to give the best performance over a wide range of conditions with two thicknesses of rubber to increase the rigidity of the valve. The rubber used in the tests was 3mm thick commercial sheet. One thickness of rubber gives lower performance due to its lower response to closure allowing more backflow to occur. Increasing the number of rubbers above 2 also reduces the delivery flow as the resistance of the valve to opening increases and the friction through the valve during delivery reduces the flow. Unfortuneately the quality and availability of rubber sheet varies enormously around the world and it is important to be able to make use of locally available materials to guarantee access to spare parts. Good quality inner tube from truck wheels is often the most available and reliable source of rubber. It is recommended that a number of thicknesses be used to make the total thickness of rubber between 4 and 6mm. Some experimentation with the materials available is advised. measuring performance with varying amounts of rubber to find an optimum and assess the rubbers' vulnerability to tearing and stretching.


M3.2 DELIVERY
VALVE COMPARISON
POWER
Power (W)
Delivery Head (m)
35
30
25
20
15
5
10
15
20
Flap 2 rubbers
Flap
Limited
Stroke
Flap 6 rubbers
Heart
Poppet
Drive Head = 1.5m
Stroke = 40mm
Weight = 4


M3.2 DELIVERY
VALVE COMPARISON
EFFICIENCY
Efficiency (%)
Delivery Head (m)
50
45
40
35
30
25
5
10
15
20
Flap 2 rubbers
Flap 6 rubbers
Flap (limited stroke)
Heart
Poppet
Drive Head = 1.5m
Stroke = 40mm
Weights = 4

One problem experienced with the standard flap type valve, that has been extensively used, is splitting of the rubber at the point where it is clamped. The continual movement of the valve has often been found to lead to a stress related failure at the point about which the rubber trys to hinge. This occurs most frequently when the retaining bolt holding the valve rubber is over tightened, compressing the rubber. Using a curved washer reduces the problem by not having a sharp edge about which the rubber bends and eventually is cut. The rubber instead follows a more gentle curve along its length reducing the likelihood of stress concentration and splitting of the rubber.

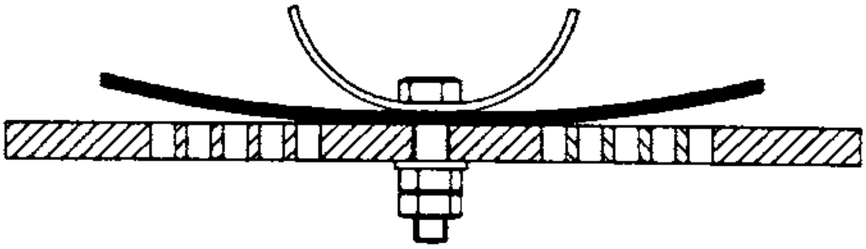


Diagram showing curved washer used in delivery valve.

Another important factor in manufacturing the rubber discs is the cutting of the central hole. This must be done cleanly with no ragged edges or flaws where cracks could start and then spread with the continual movement and stretching of the rubber. To do this it is recommended that a hole punch be bought or manufactured ensuring holes with clean edges can be accurately and repeatably made.

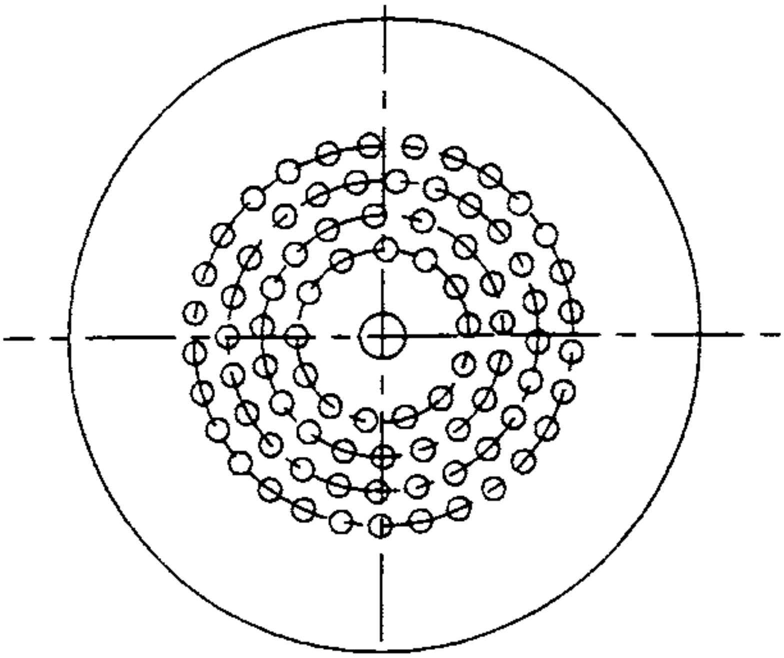


Diagram showing arrangement of delivery valve holes

The valve disc itself should be manufactured from steel plate with a minimum thickness of 3mm (10 swg) and preferably be up to 6mm. The arrangement and size of the holes in the plate is important for a number of reasons;

1) The hole size must be large enough to allow high flows with little resistance.

2) The hole size must be small enough to prevent the pressure of water in the air vessel from pushing the rubber into the holes thus deforming it and causing potential cracks.

3) The radius from the center in which the holes are confined needs to be as large as possible to maximise throughput but limited to allow sealing of the rubber around the outside of the valve plate.

4) The holes should not be too close together to prevent cracking of the valve disc between holes due to the continuous fatigue loading.

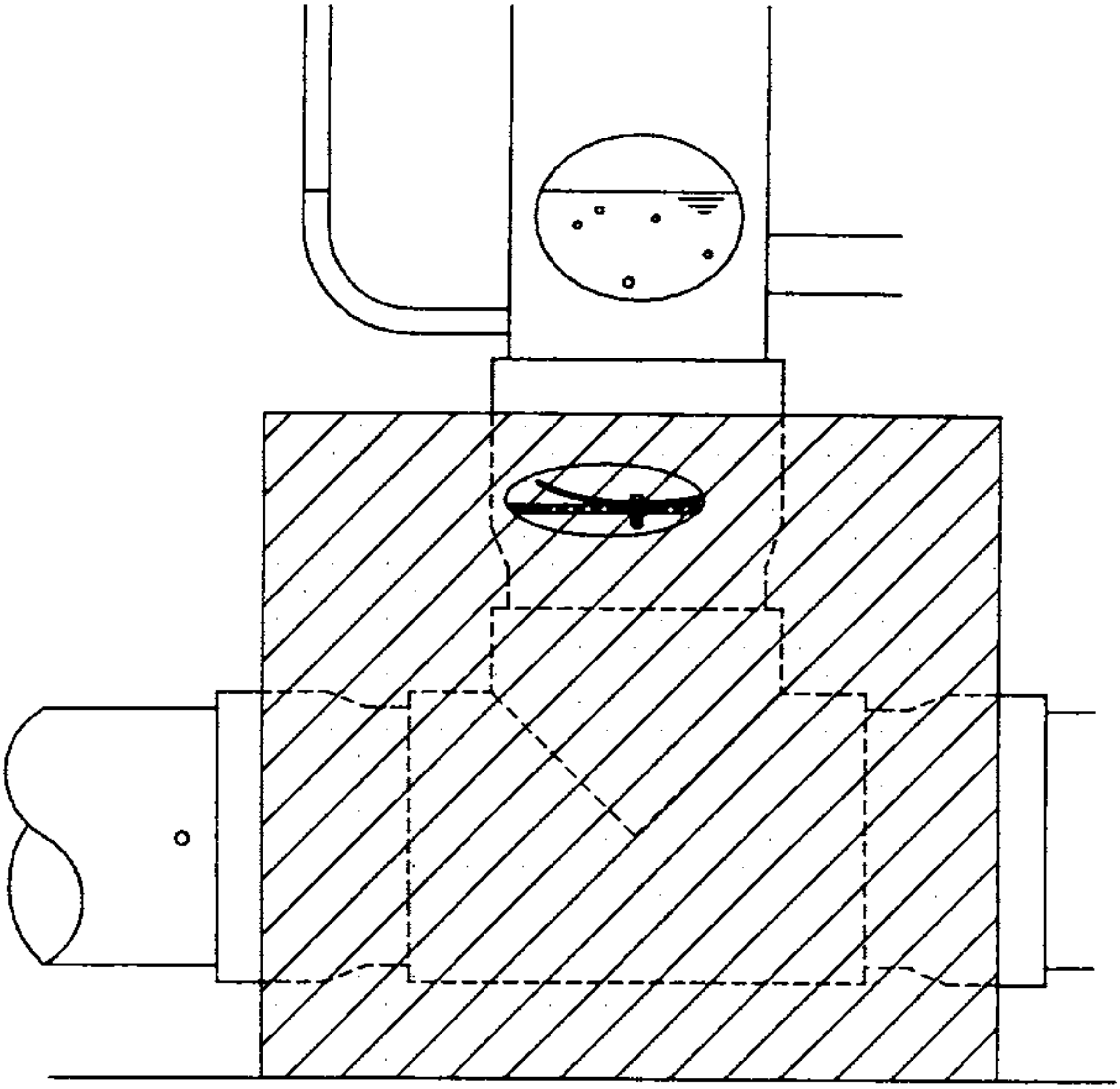
Valve plates using thick plastic material have been tested in an attempt to do without the need for a metal component. The life of such discs however was found to be too short under the loading experienced.

Marking out and accurately driling the arrangement of the large number of holes required in the valve plate can be an arduous and time consuming process. If a number of pumps are to be made it is well worth making a jig, both to cut down on the time taken and to ensure accuracy. Under the manufacturing aids section there is a drawing of one design of a valve plate jig. It ensures both the accuracy of the circumference of the plate and the accuracy of the spacing and number of holes.

Snifter Valve

During operation of the pump, air will be constantly taken into solution at the air/water interface in the air vessel. This slowly reduces the amount of air in the air vessel leading to inefficient operation and pressure spikes significantly higher than the static delivery head. Air therefore has to be constantly and reliably introduced into the air vessel to replenish that being lost in order to keep the air vessel full and the pump working at peak efficiency. This is done by the snifter valve allowing air to enter into the body of the pump each time the pressure recoil opens the impulse valve. The slight negative pressure during the recoil phase of the cycle draws air in through the snifter valve. It is placed to enable the air to travel to the under side of the delivery valve waiting to enter the air vessel at the next delivery cycle.

There are a number of types of snifter valve that have been used on ram pumps over the years. The main design considerations are that the valve is reliable and lets in the correct amount of air each cycle. On initial start-up of the pump the volume of air in the air vessel (at atmospheric pressure) is compressed as the delivery pressure builds up. The flow of air into the air vessel from the snifter valve needs to be sufficient to re-fill the air vessel over a period of time. If too much air is entering through the snifter, the air vessel will fill up quickly and then the excess air will simply be taken up the delivery pipe where it may create problems of air locks. The snifter therefore needs to be large enough to allow sufficient air to ensure replenishment of the air vessel but not so large that the delivery pipe has a large amount of air travelling in it.



The simplest type of snifter is a hole drilled in the pump body close to the underside of the delivery valve. In the DTU M3.2 the best place for this is just upstream of the tee piece that connects the drive pipe to the pump. A small jet of water will squirt through the hole with the pressure inside the pipe until the recoil cycle occurs when air will be sucked through the hole into the pipe. As the water accelerates beginning the next cycle, some of the air rises up and sits under the delivery valve. This snifter hole should be drilled in the side of the pipe after the pump has been started for the first time.

Use the following procedure;

1) On initial start-up of the pump allow it to settle and stabalise at the system delivery pressure.

2) Make a note of the level of the air in the air vessel using the air sight tube.

3) Drill a 1.5mm dia hole in the tee/pipe as specified above.

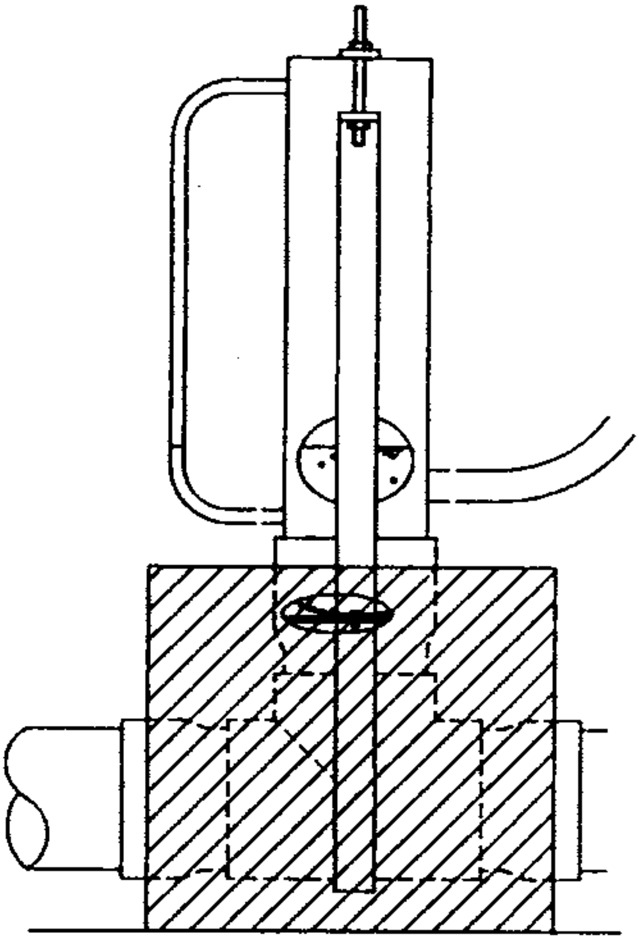
4) Wait for 30 mins to 1 hour to see if the amount of air changes. If the air level continues to increase until it reaches the top of the delivery pipe connection, then the snifter valve is probably about the right size. If the amount of air remains constant or reduces then increase the hole diameter to 2mm. Repeat this process until the hole is big enough to allow the air level to drop down to the delivery pipe connection.

Air Vessel Size.

Over the years that ram pumps have been used there have been a number of different theories proposed and used to design air vessels. One purpose of the air vessel is to turn the intermittent flow through the delivery valve into a steady, continous flow up the delivery pipe. The air vessel provides the pump with a constant head to pump against, limits the size of the damaging pressure spikes, and removes the inefficiencies associated with intermittent flow in the delivery pipe. The size of the air vessel therefore should ensure that conditions (ie pressure) in the air vessel are little affected by the sudden inflow of water each cycle coming through the delivery valve. The volume of air in the air vessel therefore should be at least 20 and preferably nearer 50 times the expected delivery flow per cycle. An air vessel with a volume many times that of the water entering per cycle will experience little change in conditions at each delivery. Pumps running to low heads with large delivery flows therefore actually require air vessels larger than ones pumping smaller flows to high delivery heads.

For example; A pump delivering 30 l/min and operating at 60 cycles per minute has a flow per cycle of 0.5 litres. The minmum air vessel volume for this case should be 20 x 0.5 = 10 litres.

The design of the DTU M3.2 110mm PVC pump is attempting to use the fewest number of components possible. The air vessel has therefore been restricted to the same 110mm pipe used in the rest of the pump. This pipe typically has an internal cross sectional area of around 7500mm^2 and therefore a 130mm length of pipe is required per litre volume of air vessel. The maximum expected delivery flow under normal conditions is 0.5 litres per cycle requiring a 10 litre air vessel that is 1300mm long.



Sight tubes on an air vessel provide a very simple way of checking the level of air and therefore the effectiveness of the snifter valve. A number of problems have been encountered with the manufacture and use of air vessels that are worth mentioning:

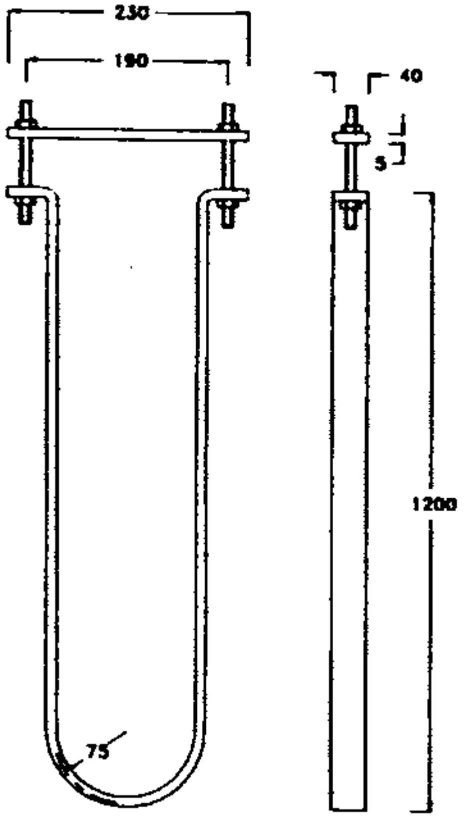
1) Small bore, 'see-through' plastic tubing is not always easy to find.

2) Most tubing that is available deteriorates over a few months, becoming cloudy so that it is very difficult to distinguish the water level inside. Fitting a sight tube is still worthwhile under these circumstances as it is during commissioning of the pump and sizing the snifter valve that the sight tube is most useful.

3) Making connections onto the air vessel can be quite difficult. Reinforcing strips of pipe can be used over areas where the connections are to be made to increase the wall thickness of the pipe for glueing or threading.

Air Vessel Strap

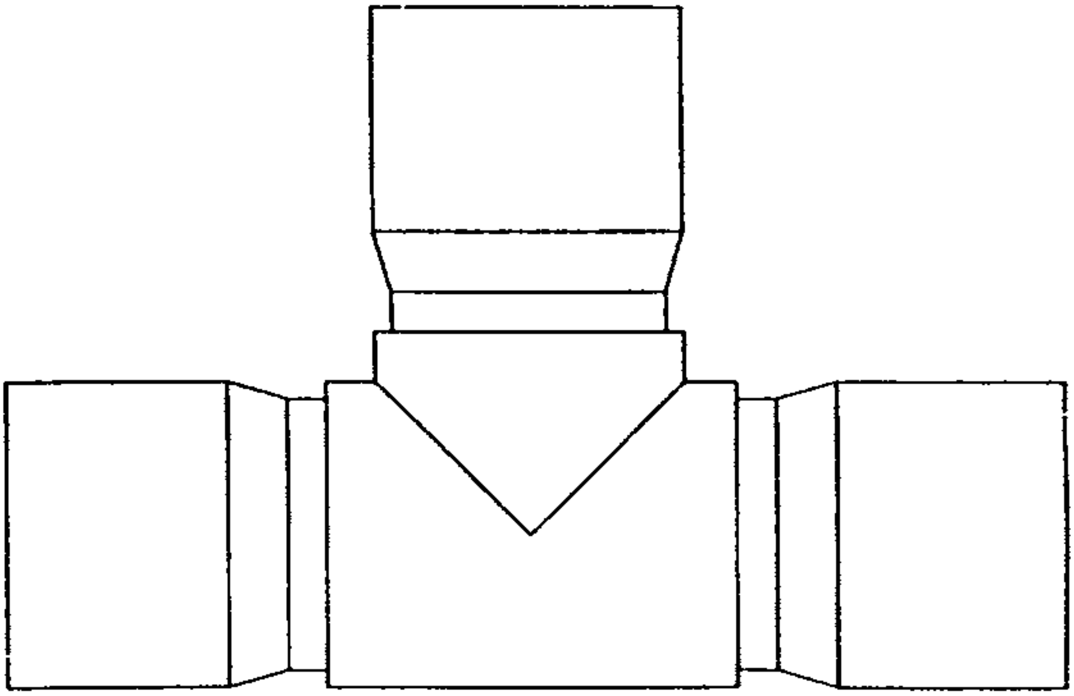
The air vessel has to be held down to prevent the pressure inside it blowing out from the tee piece. The concrete block holding the tee piece makes a good solid anchor for this strap and allows the air vessel to be securely clamped. A variety of types of clamp have been used and the one shown in the drawings section of this paper is probably the simplest.



Pipe Fittings

Tee Piece

The original design of the DTU PVC ram pump had the drive pipe connected directly with the impulse valve. The impulse valve then pushed into an elbow that was incased in concrete and fixed to the concrete pump base. The delivery valve sat in the top of the elbow and the air vessel was pushed down on top of it. With an increased understanding of pump operation and after some laboratory testing it was decided to place the delivery valve and air vessel upstream of the impulse valve. On the DTU steel pumps this had given a number of operational advantages, particularly in reducing peak pressures and so it was also applied to the plastic pumps. This altered configuration overcame some installation problems but created others.



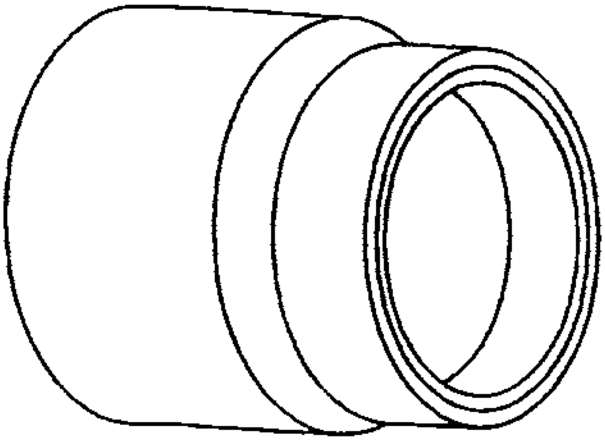
With the elbow solidly fixed downstream of the impulse valve the shocks during each pump cycle were transfered through the elbow into the concrete block. This provided good anchoring for the pump but led in some instances to cracking of the elbow. As the end of the drive pipe entering the drive tank is also fixed (and the pipe often buried) a removable section of pipe was required to allow fitting and removal of the impulse valve. This often proved to be a weak point as a good seal had to be made once the impulse valve was installed. With the revised arrangement the impulse valve is downstream of the concrete block and so provides no anchorage to prevent movement of the valve. So a further anchoring block has to be installed at the end of the impulse valve leaving enough room to allow the valve to be slid in and out of the tee piece. The gap between this second anchoring block and the valve is filled using a wedge once the valve is in place. The end of the valve also required an end cap for sealing (see below) which had to be capable of withstanding the constant shock loading. The elbow that previously experienced a substantial shock loading from the movement of the impulse valve was replaced by a tee piece that was free of this fatigue problem.

Tee fittings are commonly used in plastic pipework installations and are normally made by injection moulding. These fittings are often available in developing countries but in many cases, even where plastic pipe is manufactured, they have to be imported. They tend to be extremely expensive and are often of low quality. Experience of installations in Zimbabwe showed that the cost of a suitable tee piece was the equivalent to 3-4 meters of drive pipe - a significant cost. Such fittings were not only expensive but also in very short supply. In line with the goal of manufacturing pumps from standard pipe material a method for tee manufacture using small sections of pipe was developed. Sockets for the connection of pipes are formed by heating the ends of the pipe in an oven or oil bath and forcing them over a specially made, tapered former. Diagonal cuts are then made at 90 degress and the two sections glued together. (see drawing section). Fittings made in this way are much cheaper than those available commercially and overcome the problems of availability.

End Cap

The new pump configuration required that the end of the impulse valve be sealed with a cap. Commercially manufactured end caps are generally available and provide a good seal. However the constant movement of the impulse valve at each pump cycle crushes the end cap between the valve body and the solid end block.

It is not possible to significantly prevent this movement as the plastic material has a high degree of flexibility and so joints tend to move under the pulsing pressure experienced in the pump. Thin walled, injection moulded end caps were found to last a very short time before cracking due to the high fatigue loading experienced. On the first site installed in Zimbabwe with this configuration a number of end caps of increasing strength were fabricated. The final solution was to make a thick walled socket using the socket former, reinforced at the end with a number of extra rings of pipe. A 5mm metal disc was then shaped to fit into the end of the socket and sealed firmly in place using plumbers putty.

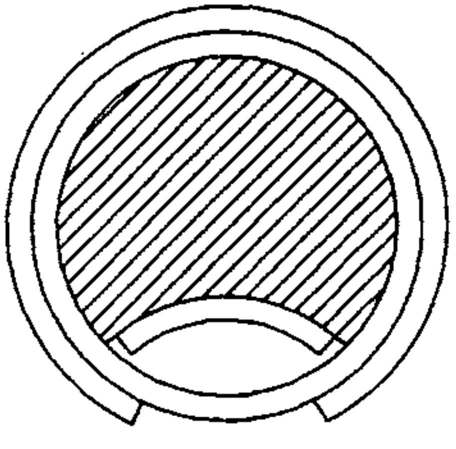


Drive Pipe

Drive Pipe Diameter

Throughout the DTU research into PVC ram pumps, the diameter of drive pipes used has been standard 4" 110mm O/D. Pumps have been designed specifically for this common size of pipe that has been found to be widely available in developing countries. The pump components themselves are now made almost entirely from this basic pipe material in order to reduce cost and simplify the raw material requirement.

The body of most ram pumps, and particularly the section housing the impulse valve, tend to be of a larger cross-sectional area than the recommended drive pipe. In the DTU steel designs for instance a 4" diameter body is used to match a 2" drive pipe diameter. This ensures that the frictional loss of water flowing through the impulse valve is low enough to allow sufficient flow in the drive pipe thus matching pump to drive pipe. A general rule that simplifies the initial sizing and design of an impulse valve is to ensure that, at all points through the pump body and impulse valve the area available for water flow is equal to, or greater than the area of the drive pipe. The design of the DTU PVC rams however is restricted to using the same 110mm pipe for the body of the impulse valve as is used for the drive pipe. The flow area through the holes of the valve is greater than the area of the drive pipe but at the leading edge of the tongue even at maximum stroke the flow area is reduced by around 20%. This is illustrated in the diagram below.

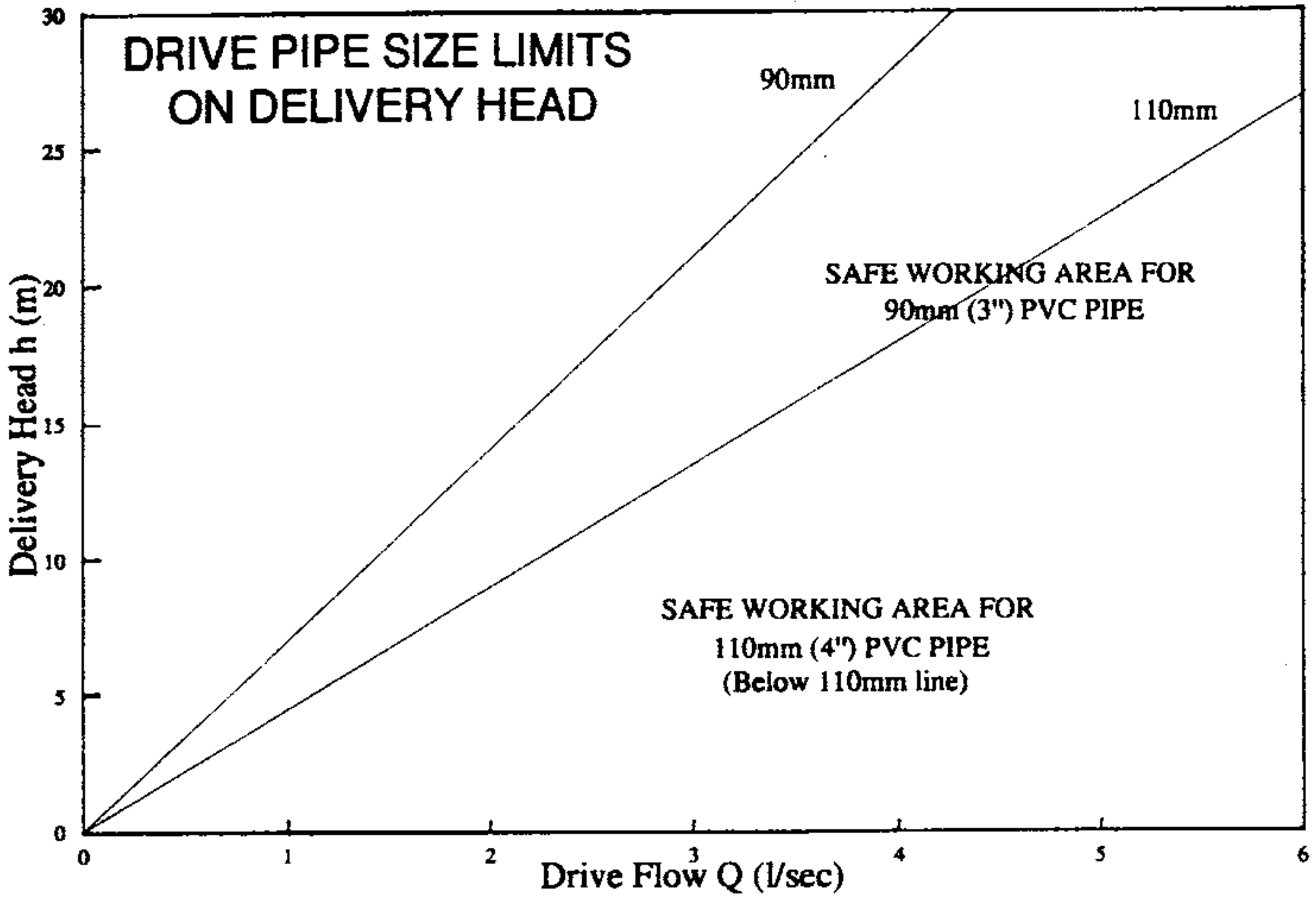


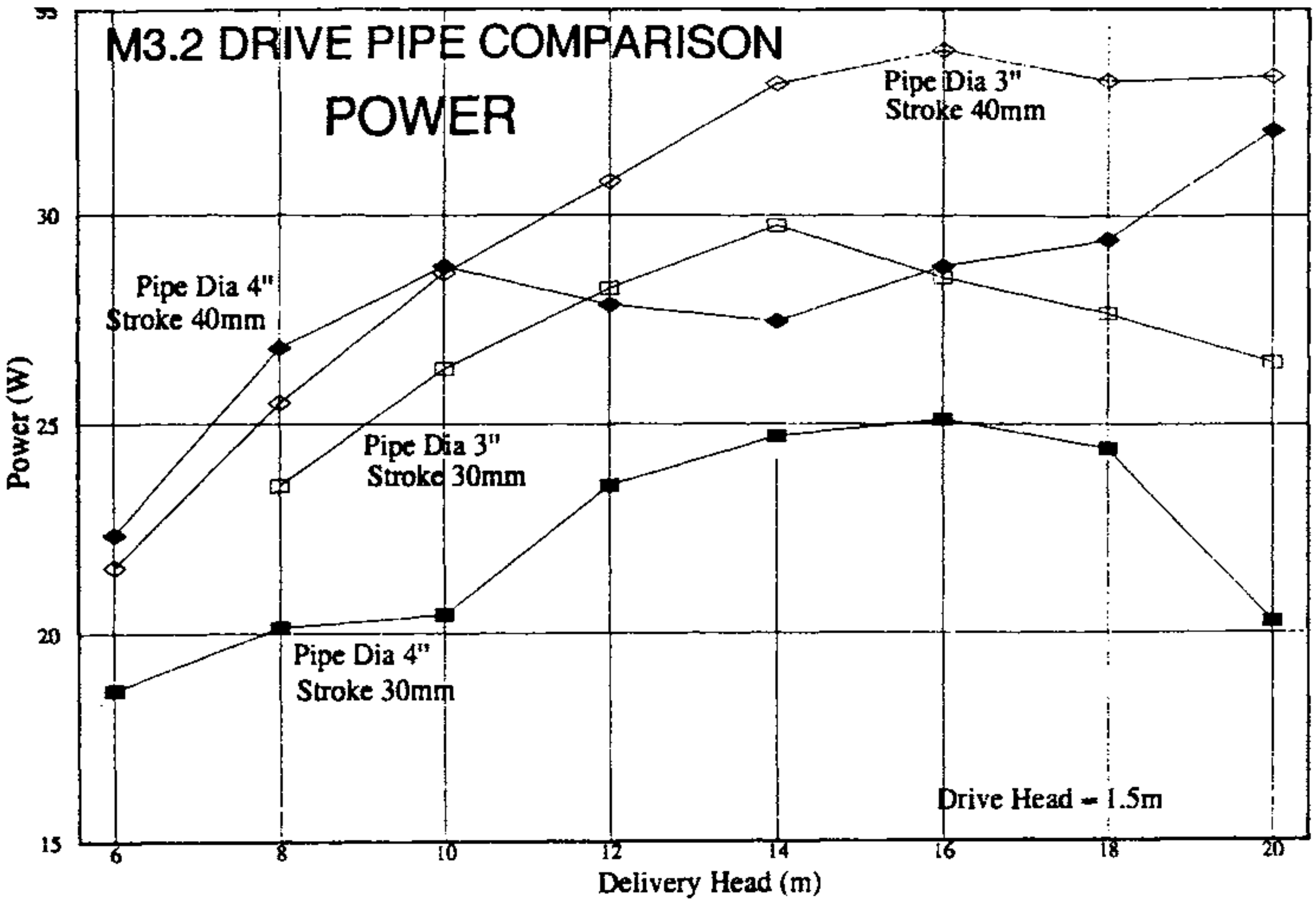
Cross-section of Impulse Valve showing restriction to flow.

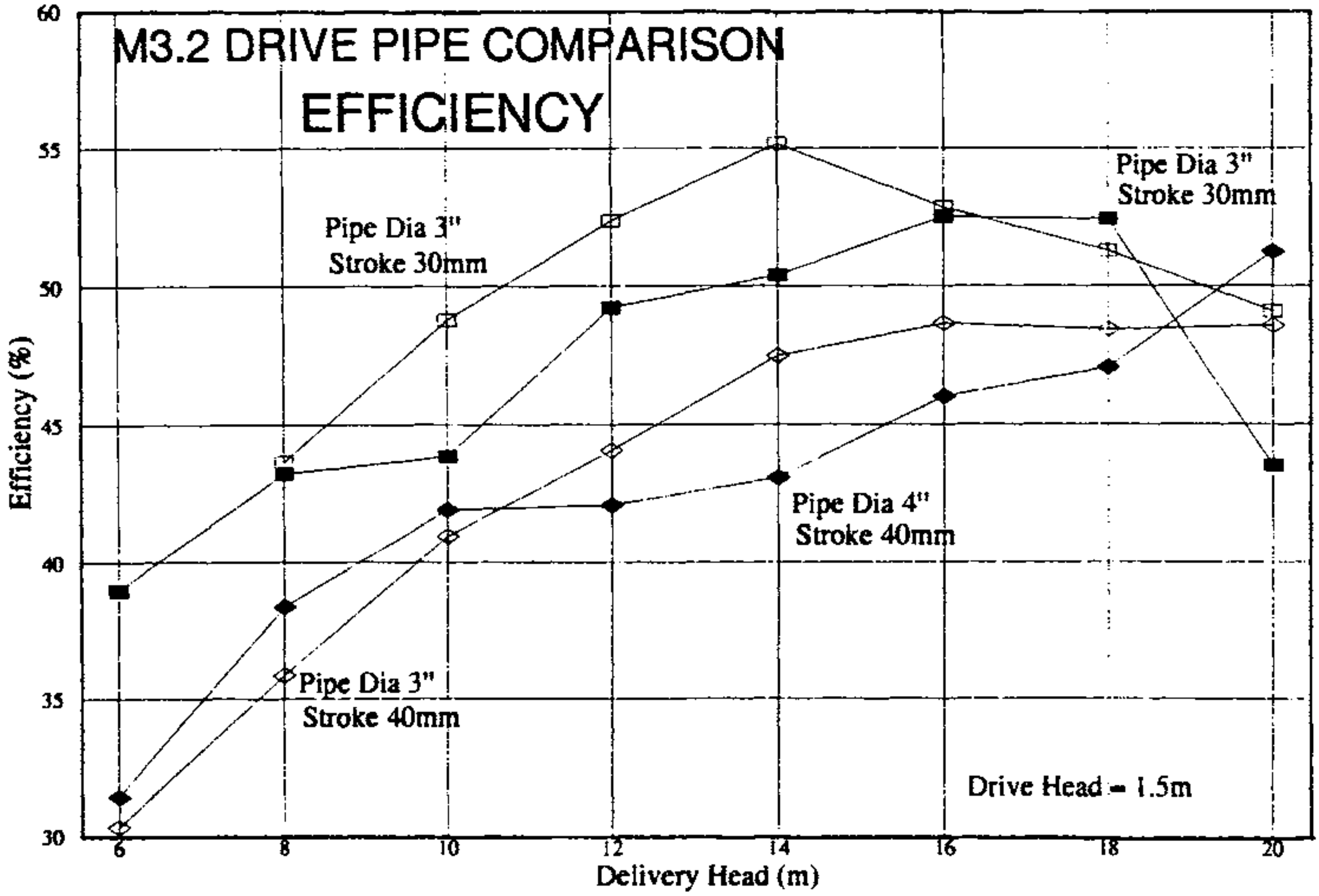
Whilst it is possible to achieve drive flows in excess of 350 l/min with this arangement it became clear that particularly at low strokes the size and design of the impulse valve was not allowing full use of the diameter of the drive pipe. This situation is greatly exaggerated at lower strokes when the pump is tuned down in order to use less drive water. In effect the velocity of water in the drive pipe when the valve begins to shut is considerably lower than the maximum capacity of the pipe. As the kinetic energy available for pumping is proportional to the mass of the water and to its velocity squared, it makes sense to keep velocities high and lose a little mass by reducing pipe diameter.

Laboratory tests have been carried out in order to compare the 110mm drive pipe with the next common size down: 90mm. The results of these tests are summarised in Graph Nos X,X and show quite clearly that under most conditions both the efficiency and power output of the pump are improved by using the smaller drive pipe size.

Whilst the pump will work perfectly well with a 110mm drive pipe over the complete range of operating conditions it is now recommended that a 90mm pipe be used if available. This may also give a small saving in system cost and gives a greater potential range of pipe that can be used if one size is not available. In situations of particularly low drive flow the pump may not actually be able to operate with the larger sizes of drive pipe. The maximum head to which a pump can deliver is dependant upon the velocity of the water in the drive pipe. To reach a given delivery head there has to be a corresponding drop in velocity turning kinetic energy to potential energy. If the velocity drop required to reach a given pressure is larger than the maximum velocity of the water in the drive pipe then the pump will never reach the required delivery head although it can appear to be operating. Smaller diameter drive pipes will have a higher water velocity for a given flow and therefore will permit operation in situations where larger diameter pipes would not work. The graph below shows the typical lower boundary of the commonest pipes used for DTU M3.2 PVC pumps



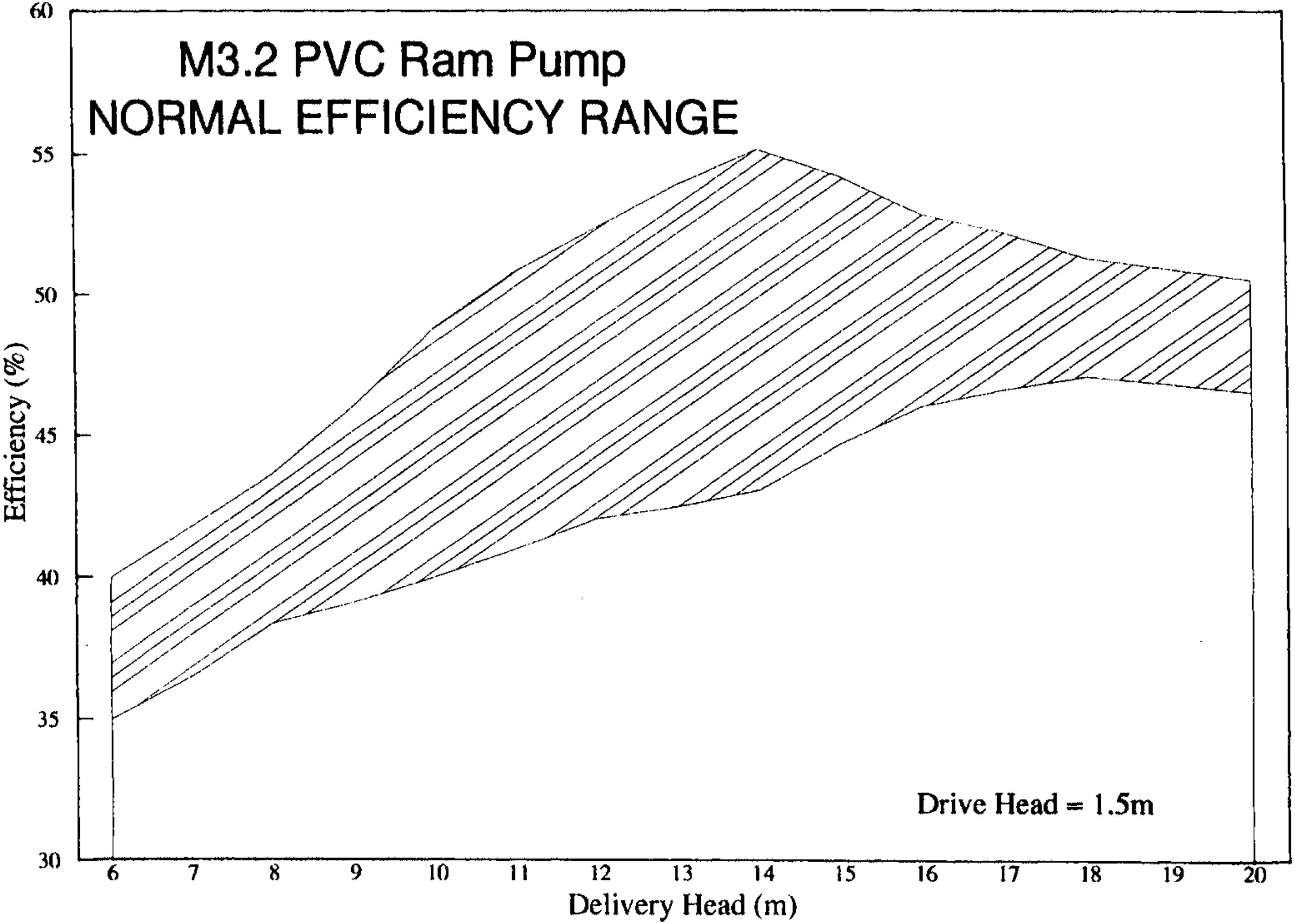

M3.2 DRIVE PIPE COMPARISON
POWER
Pipe Dia 3"
Stroke 40mm
Pipe Dia 4"
Stroke 40mm
Pipe Dia 3"
Stroke 30mm
Pipe Dia 4"
Stroke 30mm
Drive Head = 1.5m
Power (W)
30
25
20
15
6
8
10
12
14
16
18
20
Delivery Head (m)

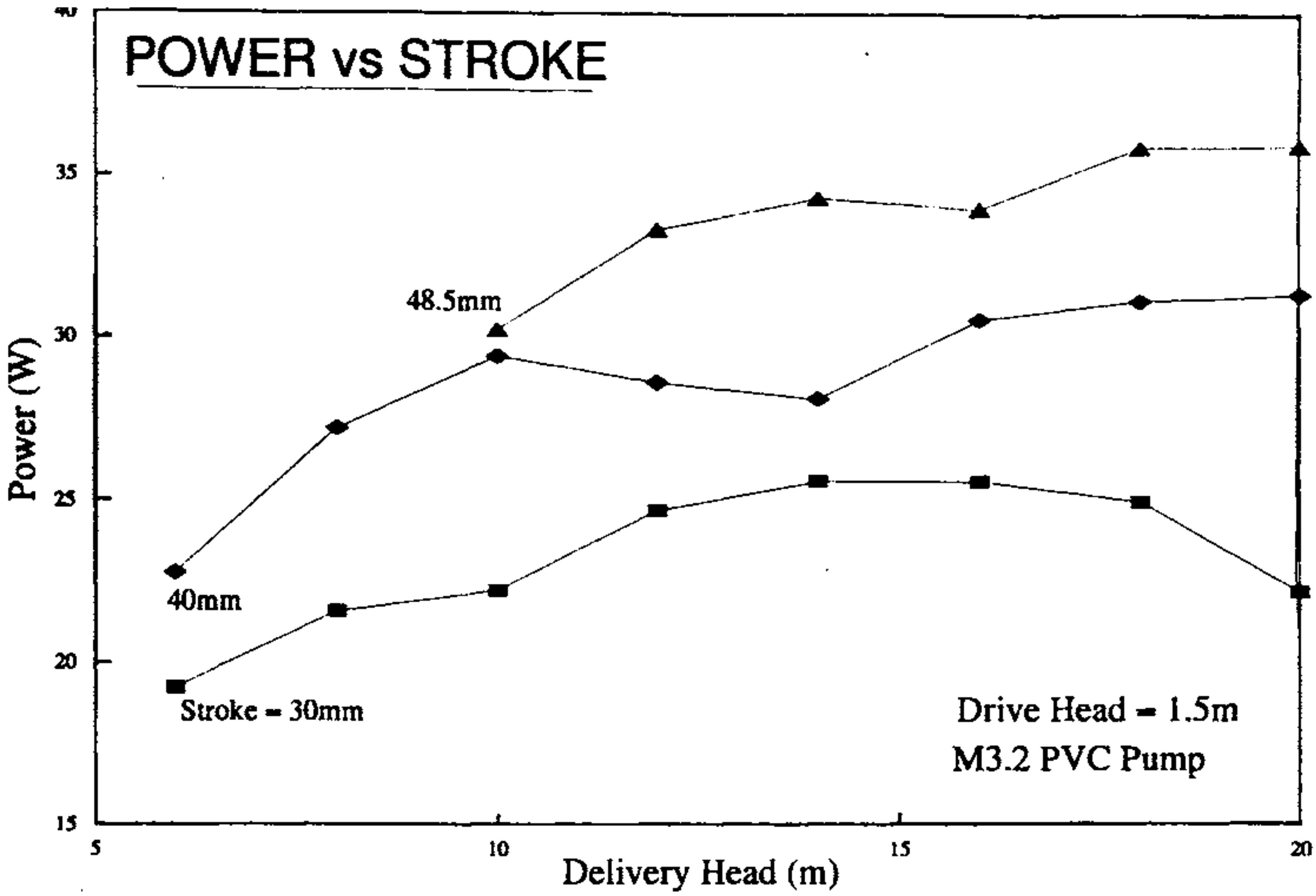

M3.2 DRIVE PIPE COMPARISON
EFFICIENCY
Pipe Dia 3"
Stroke 30mm
Pipe Dia 3"
Stroke 30mm
Pipe Dia 4"
Stroke 40mm
Pipe Dia 3"
Stroke 40mm
Drive Head = 1.5m
Efficiency (%)
60
55
50
45
40
35
30
6
8
10
12
14
16
18
20
Delivery Head (m)

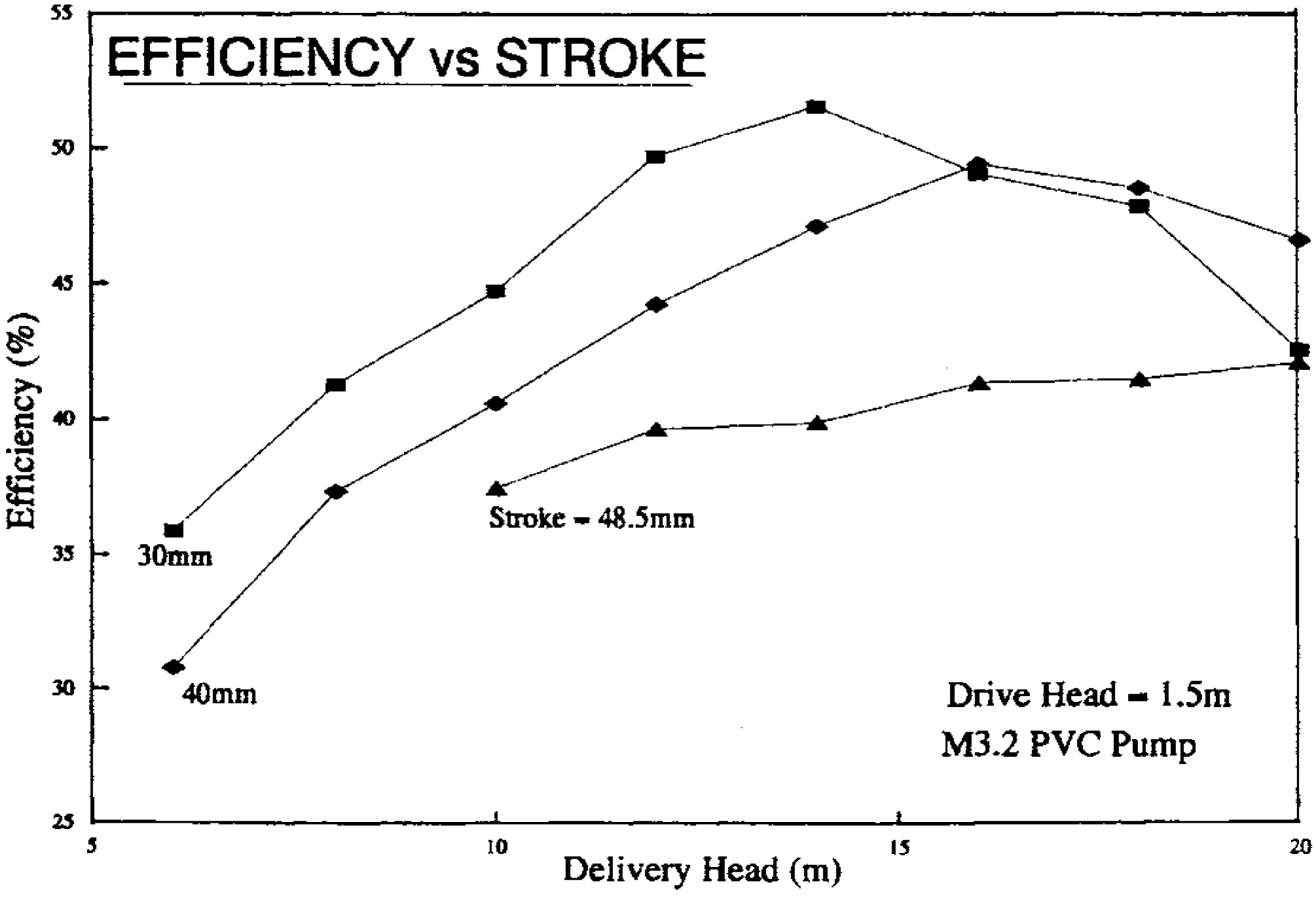
Drive Pipe Length

One critical factor with PVC ram pumps for small irrigation schemes is cost. The pump and system constraints have been designed to give good performance, reliability, local manufacture, availability of spare parts, all for the smallest possible cost. One of the major cost components of any ram pump system is the drive pipe which can often equal or even exceed the cost of the pump unit itself! As drive heads are comparatively small for PVC pumps, the physical layout of the site can often allow drive pipe lengths to be very short. Systems have been installed and successfully run with drive pipe lengths of only 6m. Plastic pumps generally can utilise shorter drive pipes than their steel equivalents due to the much lower wave speeds of the transients moving in them. Longer drive pipes can increase the pumping energy available by increasing the mass of water moving in the drive pipe and increasing the length of the delivery cycle during operation. Longer drive pipes introduce greater friction into the system so that less of the drive head is available to the pump. This consideration of pipe friction imposes an upper limit on the length of drive pipe that can be used for a given drive head.

Bearing the all important cost factor in mind it is recommended that drive pipe length normally be kept in the range 6 to 30m with 12m being a rough guide to the optimum when balancing cost and performance. If a combination of a necessarily long drive pipe (greater than 20m), high drive flow (greater than 300l/min), and low delivery head (less than 8m) occurs it is recommended that a 110mm rather than the standard 90mm drive pipe be used as the friction in a 90mm pipe would be more significant in such a situation.


M3.2 PVC Ram Pump
NORMAL EFFICIENCY RANGE
Efficiency (%)
60
55
50
45
40
35
30
Delivery Head (m)
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Drive Head = 1.5m


POWER vs STROKE
Power (W)
Delivery Head (m)
48.5mm
40mm
Stroke = 30mm
Drive Head = 1.5m
M3.2 PVC Pump
40
35
30
25
20
15
5
10
15
20


EFFICIENCY vs STROKE
Efficiency (%)
Delivery Head (m)
30mm
40mm
Stroke = 48.5mm
Drive Head = 1.5m
M3.2 PVC Pump
55
50
45
40
35
30
25
5
10
15
20

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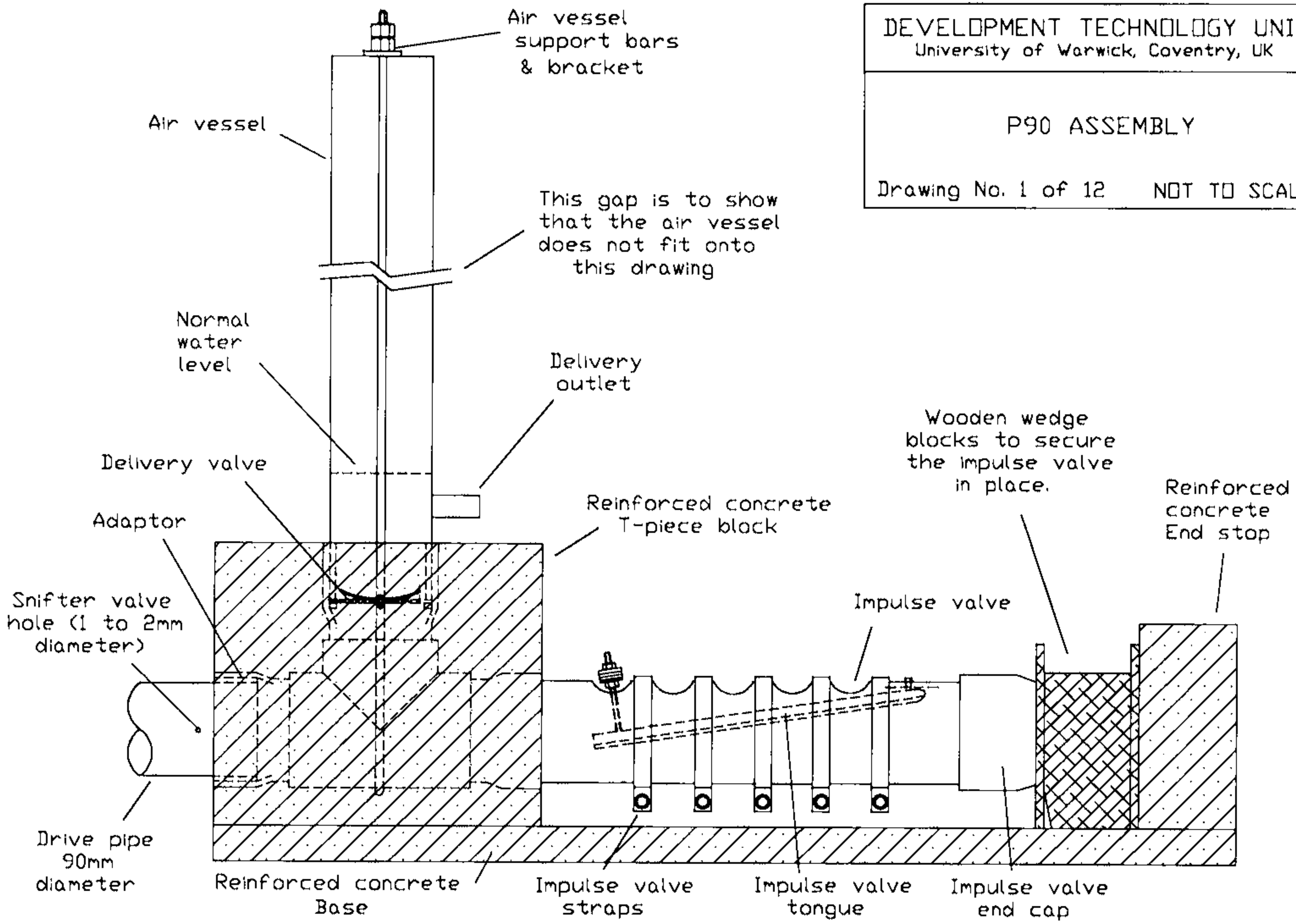
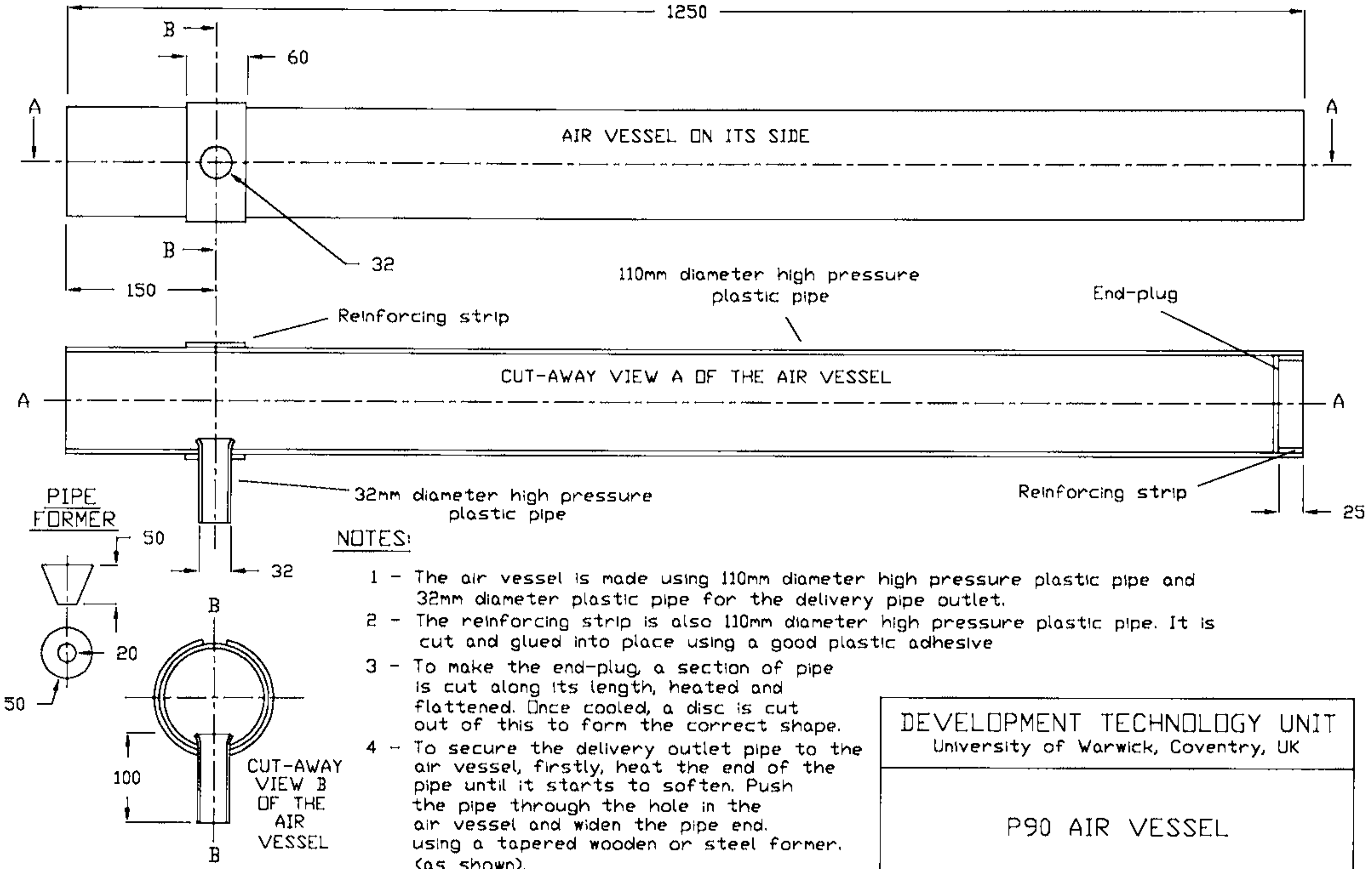
P90 ASSEMBLY

Drawing No. 1 of 12 NOT TO SCALE





ALL DIMENSIONS IN mm

NOTES:

1 - The air vessel is made using 110mm diameter high pressure plastic pipe and 32mm diameter plastic pipe for the delivery pipe outlet.

2 - The reinforcing strip is also 110mm diameter high pressure plastic pipe. It is cut and glued into place using a good plastic adhesive

3 - To make the end-plug, a section of pipe is cut along its length, heated and flattened. Once cooled, a disc is cut out of this to form the correct shape.

4 - To secure the delivery outlet pipe to the air vessel, firstly, heat the end of the pipe until it starts to soften. Push the pipe through the hole in the air vessel and widen the pipe end. using a tapered wooden or steel former. (as shown).

5 - Use a good plastic adhesive to bond all the sections together.

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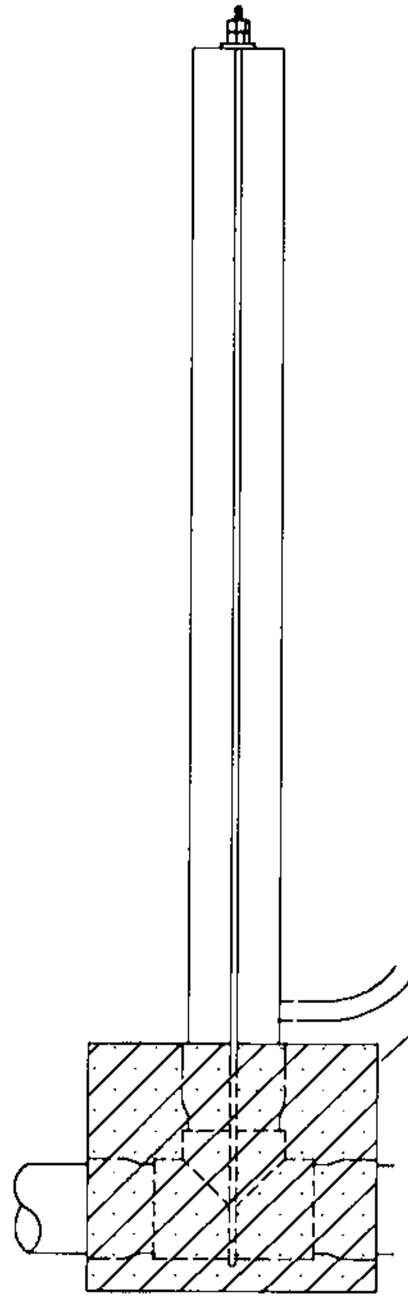
P90 AIR VESSEL

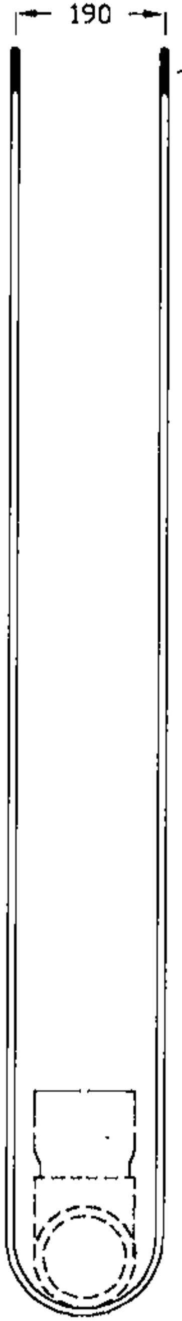
Drawing No. 2 of 12 NOT TO SCALE

AIR VESSEL ASSEMBLY

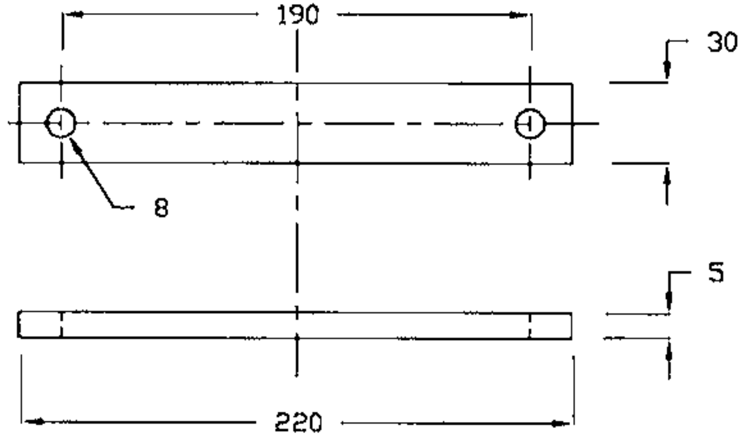


ALL DIMENSIONS IN mm

SUPPORT BAR



SUPPORT BRACKET



NOTES:

1 - The support bar is approximately 3.5 meters in length threaded at the ends (M8 thread)

2 - Ensure a secondary lock nut is used on each end of the support bar when assembling the pump

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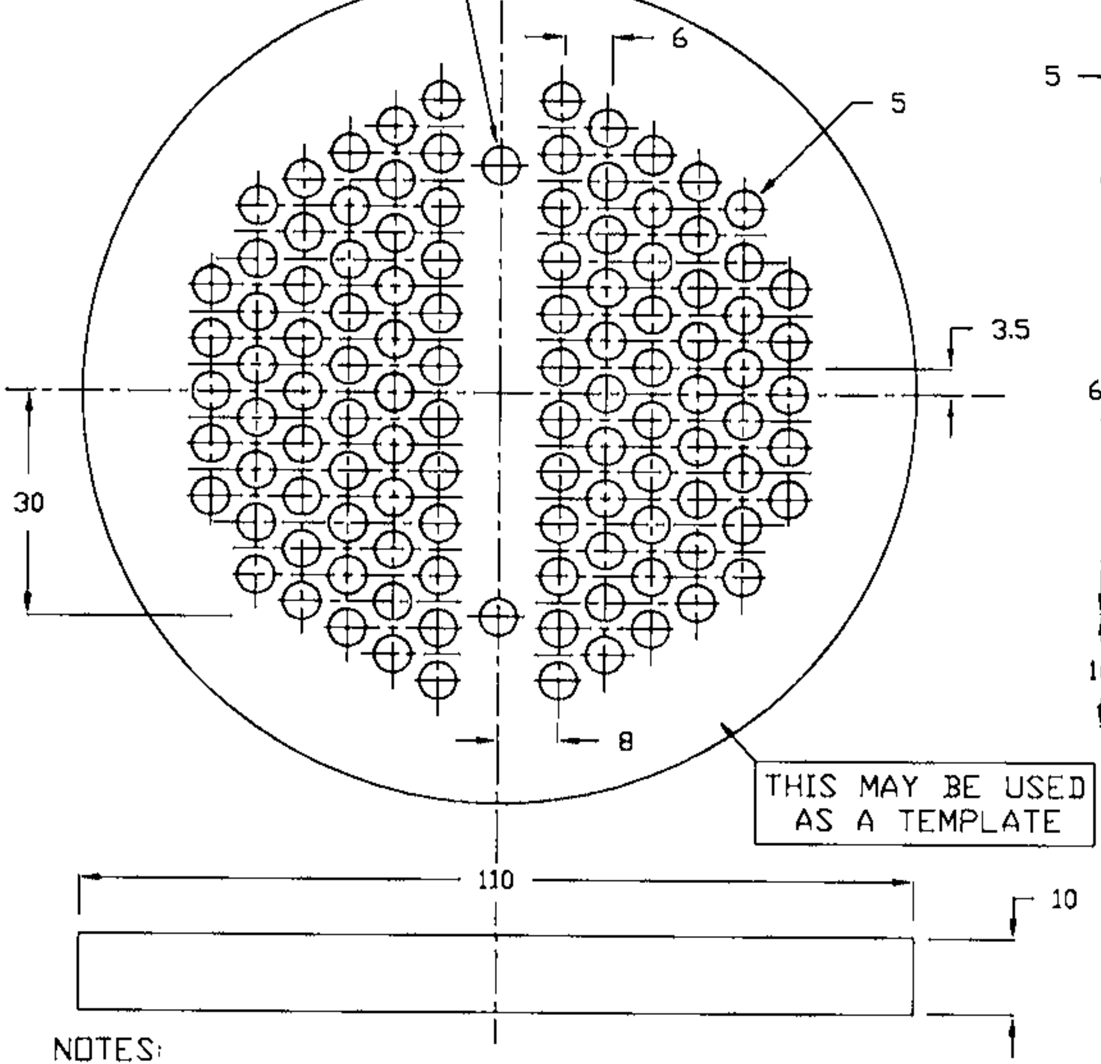
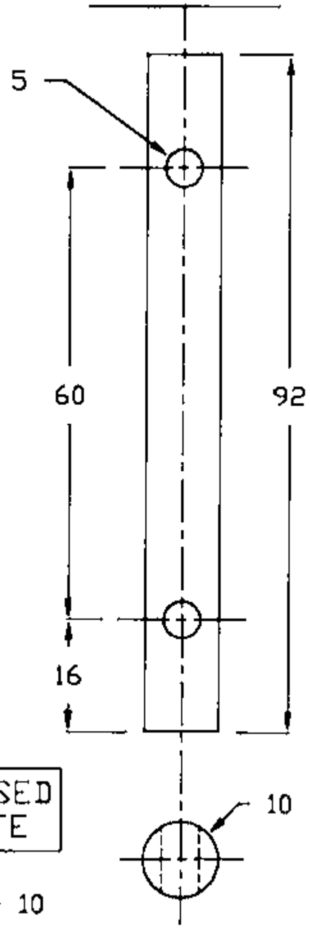
P90 AIR VESSEL
SUPPORT BAR & BRACKET

Drawing No. 3 of 12 NOT TO SCALE

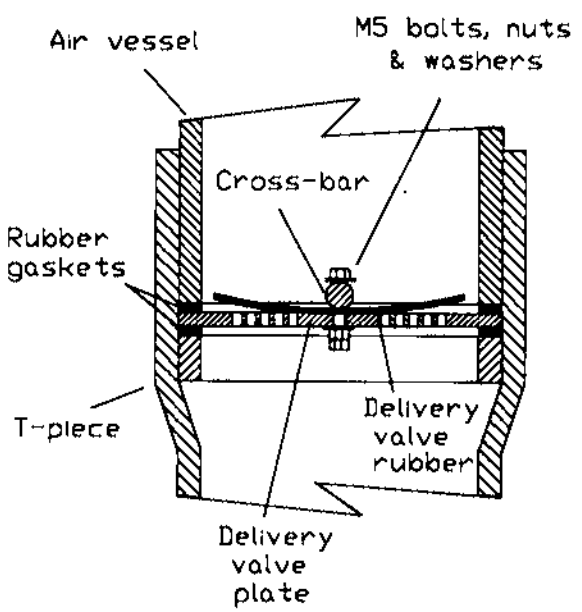
DELIVERY VALVE PLATE



DELIVERY VALVE CROSS-BAR



DELIVERY VALVE ASSEMBLY



ASSEMBLY INSTRUCTIONS

1 - Place the valve rubber on the unchamfered side of the plate
2 - Push the bolts through the cross-bar, rubber and plate
3 - Add a nut onto each bolt and just finger tighten
4 - Add a second nut onto each bolt and tighten each pair of nuts securely together

NOTES:

1 - Delivery valve plate is 8 or 10mm mild steel plate
All holes should be chamfered on one side of the plate
2 - Delivery valve cross-bar is 10mm diameter steel reinforcing bar
3 - The delivery valve rubber has a diameter of 92mm and should be about 3mm thick

ALL DIMENSIONS IN mm

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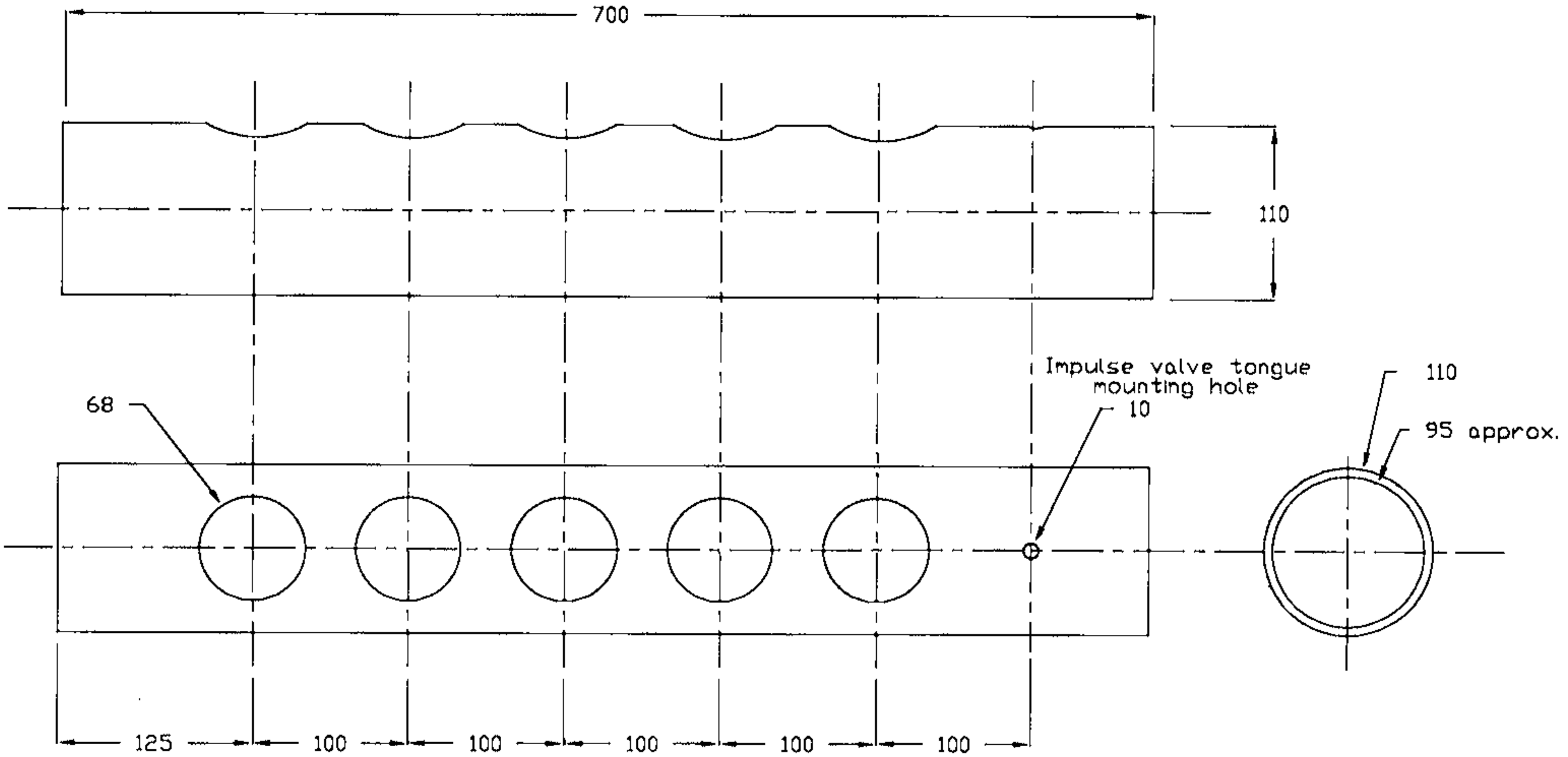
P90 DELIVERY VALVE

Drawing No. 4 of 12



NOTES:

1 - The material used for the impulse valve is CLASS 16 high pressure PVC pipe. The wall thickness of the pipe is usually about 7mm.

2 - A tank cutter of between 66 and 70mm may be used to cut out the large impulse valve holes.

ALL DIMENSIONS IN mm

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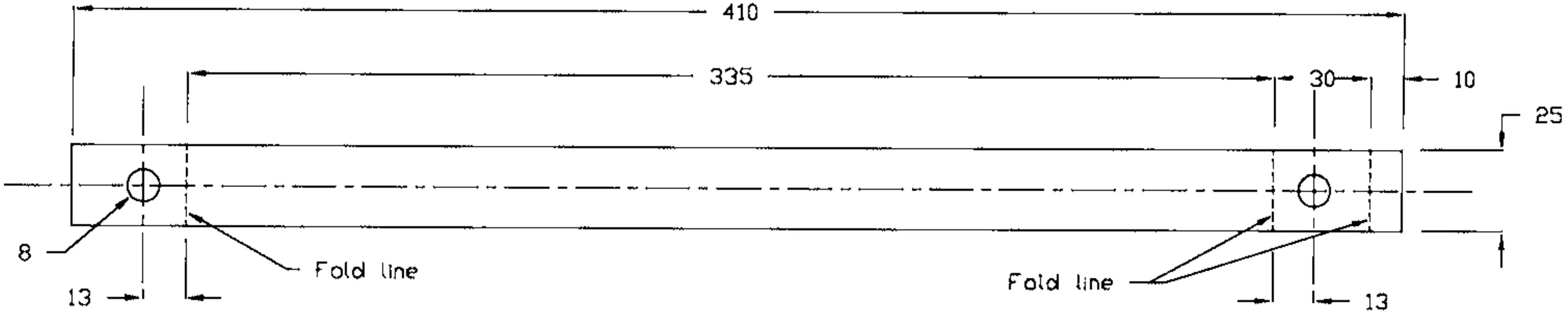
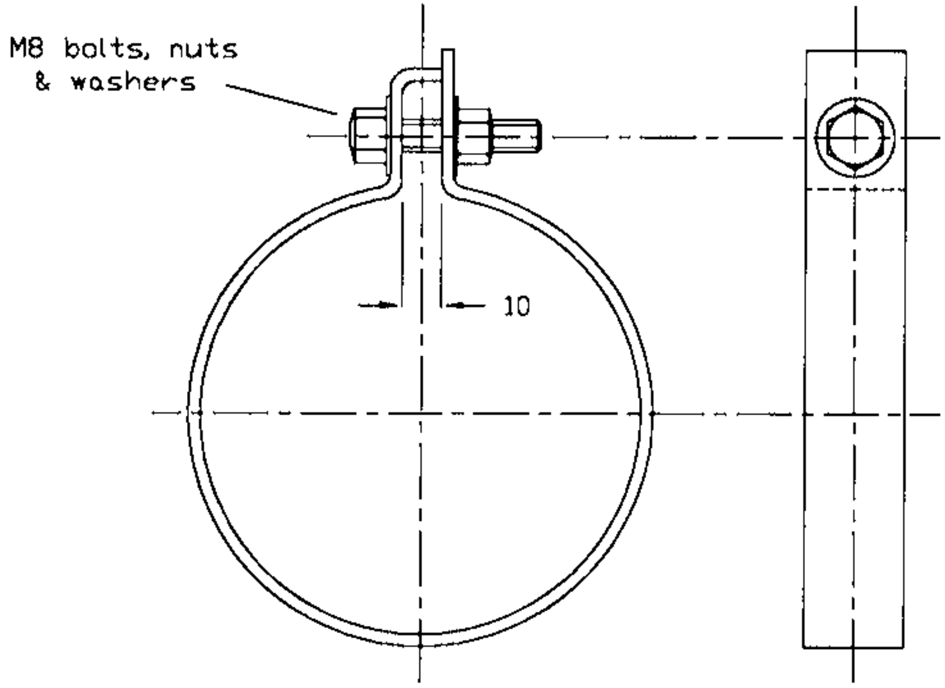
P90 IMPULSE VALVE

Drawing No. 5 of 12   NOT TO SCALE



ASSEMBLED IMPULSE VALVE STRAP



NOTES:

1 - The material used to make the strap is 25 x 3mm mild steel.

2 - 5 straps are needed for the impulse valve.

3 - Mark the measured fold lines on the cut lengths of steel. After folding the straps wrap them around the impulse valve and check that there is a minimum gap of about 10mm between the folded up-rights.

4 - When the straps are assembled, paint them before adding them to the impulse valve.

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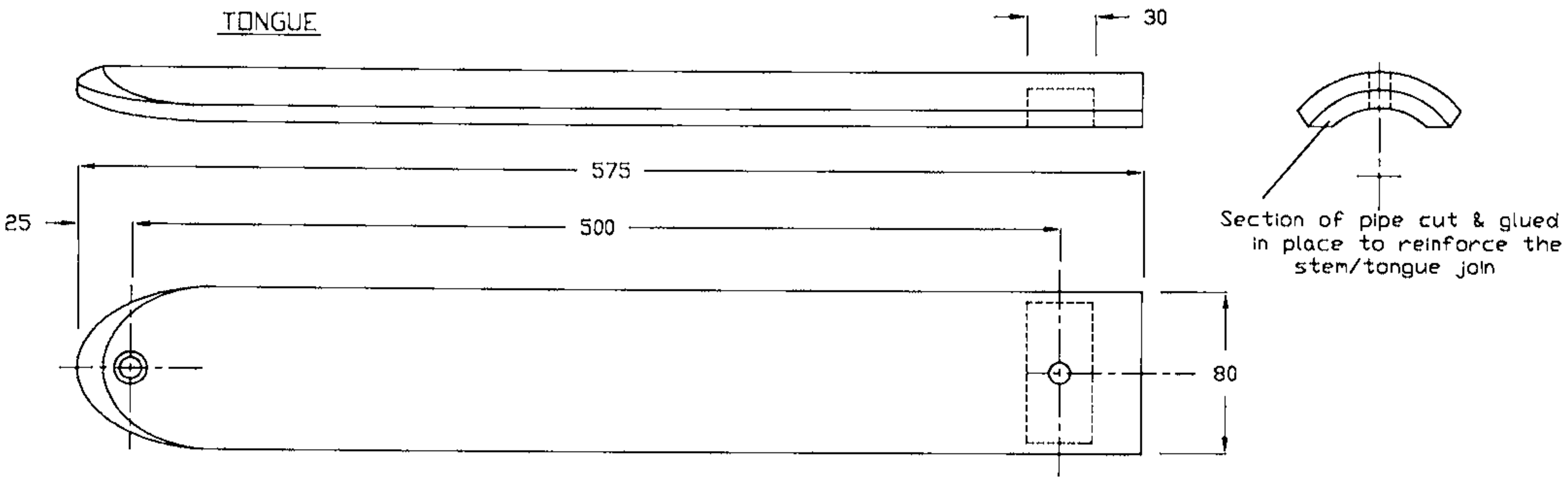
P90 IMPULSE VALVE
STRAP

Drawing No. 6 of 12 NOT TO SCALE

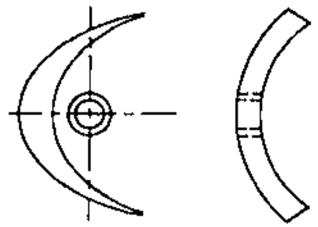
ALL DIMENSIONS IN mm

TONGUE



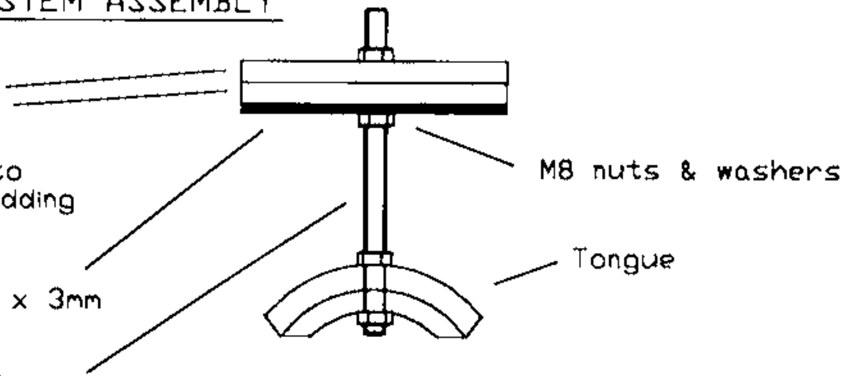
Section of pipe cut & glued in place to reinforce the stem/tongue join

TONGUE MOUNTING



A steel ring with an internal diameter of approx. 10mm (3/8' pipe) is pushed into a hole in the tongue using an interference fit. Use a 50mm M8 bolt, 2 nuts and washers to fit the tongue to the impulse valve.

TONGUE STEM ASSEMBLY



Valve Weights
- 100mm x 25mm x 10mm
- Mild steel
- Center drilled 8mm to accomodate the studding

M8 nuts & washers

Tongue

Rubber strip
- 100mm x 25mm x 3mm

M8 studding
- approximately 120mm

FITTING THE TONGUE

Hold the tongue in place inside the impulse valve. Feed the bolt through a washer and through the impulse valve and tongue mounting holes. Hold the tongue in the 'full-open' position, add another washer onto the bolt and screw on a nut until it just touches the tongue. Add a second nut and tighten the two nuts securely together.

ALL DIMENSIONS IN mm

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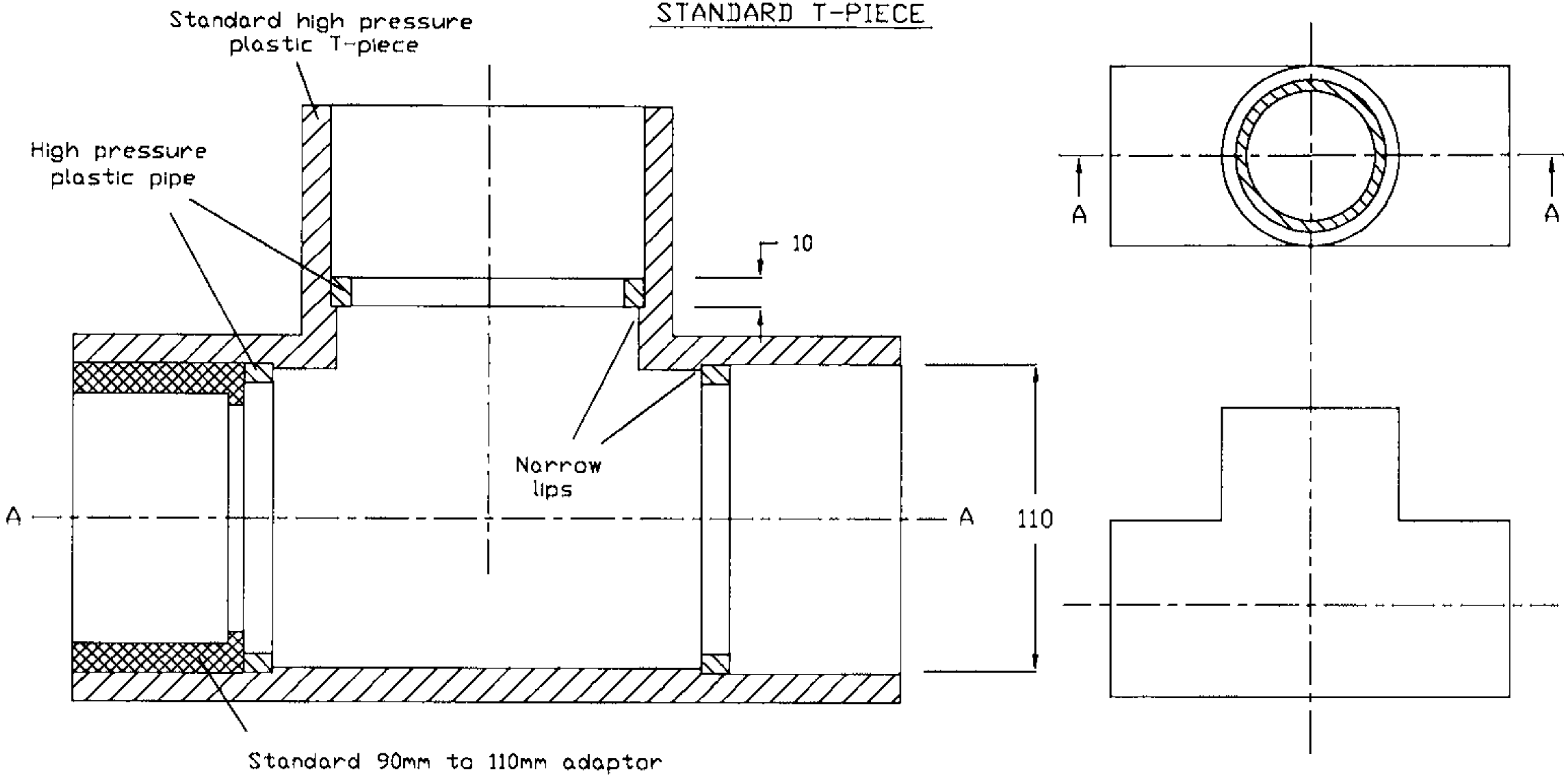
P90 IMPULSE VALVE TONGUE
& ASSEMBLY

Drawing No. 7 of 12 NOT TO SCALE

STANDARD T-PIECE



NOTES:

1 - The T-piece for the P90 may be bought commercially or made by hand. The drawing above shows an example of a commercial T-piece (high pressure plastic) that is suitable for 110mm diameter pipe.

2 - T-pieces available on the market tend to have narrow support lips as shown above. These need to be reinforced and this is done by gluing into place a 10mm length of high pressure plastic pipe as shown.

3 - When purchasing a 110mm high pressure plastic T-piece, also buy a 90mm to 110mm adaptor. This is because the drive pipe for the pump has a 90mm diameter and will have to be adapted to fit the T-piece.

ALL DIMENSIONS IN mm

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P90 - USING A STANDARD
T-PIECE & ADAPTOR

Drawing No. 8 of 12   NOT TO SCALE

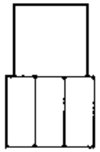
MAKING A T-PIECE

PART A

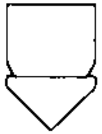
Cut 150 & 400mm lengths of pipe. Cut the shorter pipe down its length and heat it until workable. Open the heated shorter pipe and fit it over the center of the longer section using glue and clamp it in place.

Using the T-piece former, form sockets at each end of PART A. Next, cut out a 90 degree 'V-Notch as shown. Make sure the gap on the shorter outter pipe is opposite the @V-Notch'.

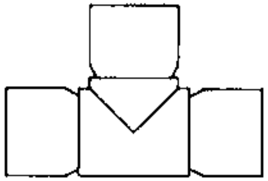
PART B



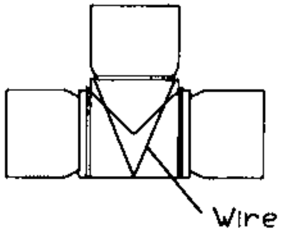
Cut 75 & 200mm lengths of pipe. Cut, heat & glue the shorter pipe flush with one end of the longer. Cut a piece of pipe to fit the gap left on the outer pipe. Heat & glue this into place.



Form the socket on the end of PART B and cut the other end to fit the 'V-Notch' on PART A.



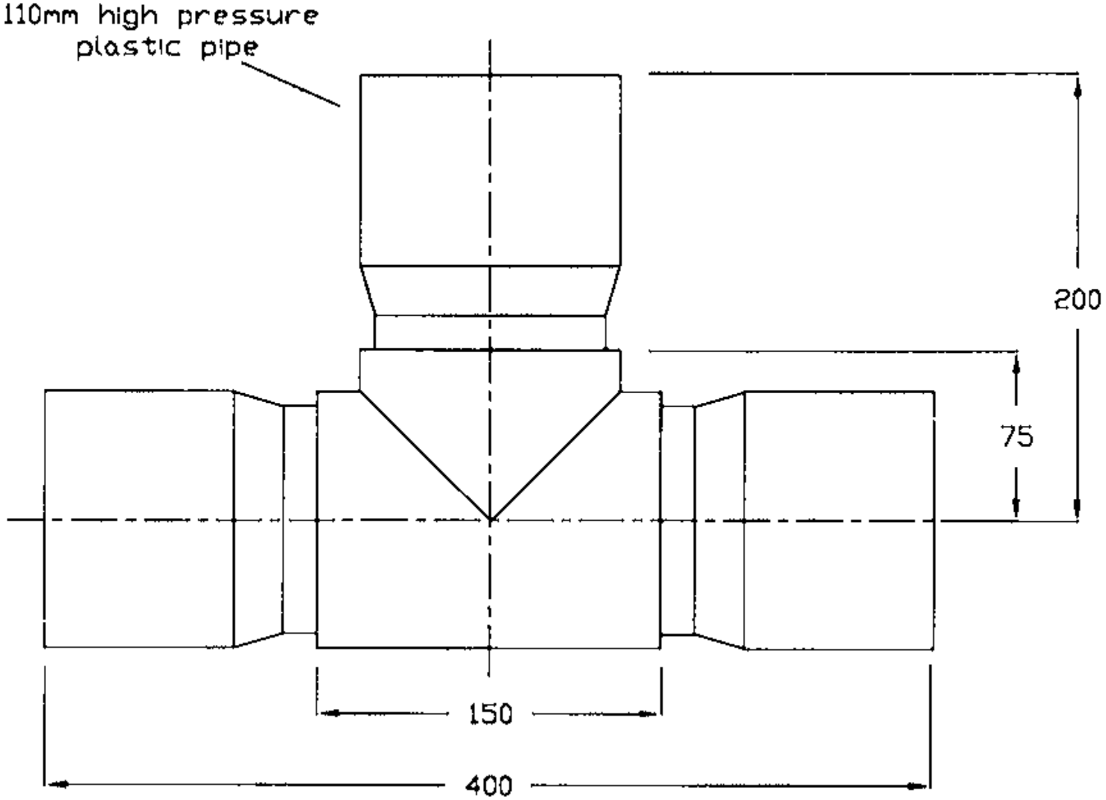
File both PARTS A & B until a reasonable fit is obtained. Glue together both parts using a mixture of PVC glue and pipe shavings to fill the gaps.



Wire may be wrapped around the glued parts to hold them more securely together. The T-piece is now ready to be set into a concrete base.

ALL DIMENSIONS IN mm

COMPLETED T-PIECE



NOTE: The drive pipe for the P90 has a diameter of 90mm. Therefore, to fit the drive pipe into this T-piece, a 100mm to 90mm adaptor should be purchased or made up using available pipe.

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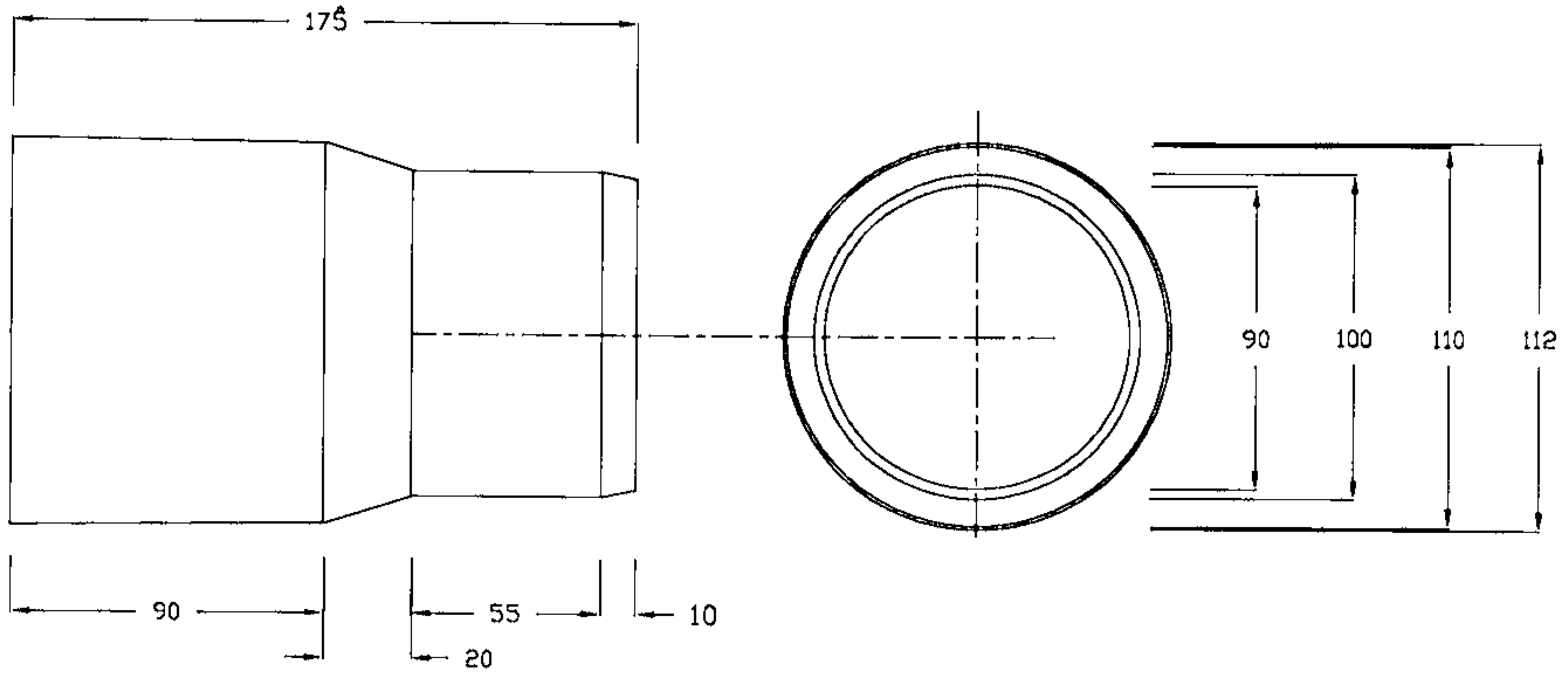
P90 T-PIECE
MANUFACTURE

Drawing No. 9 of 12 NOT TO SCALE



NOTES:

1 - This socket former is designed to be used with 110mm outside diameter plastic pipe.
2 - This former may be made from steel, aluminium or wood.
3 - The former is used to to make both the pump T-piece and End cap.

INSTRUCTIONS FOR USE

1 - The first step is to heat up the plastic pipe to make it soft and workable. This may be done by immersing the pipe in hot oil at about 130 C or by rotating the pipe slowly over a heat source.
2 - When the pipe is soft enough push it quickly and firmly over the former.
3 - Let the pipe cool and harden before removing it from the former.

ALL DIMENSIONS IN mm

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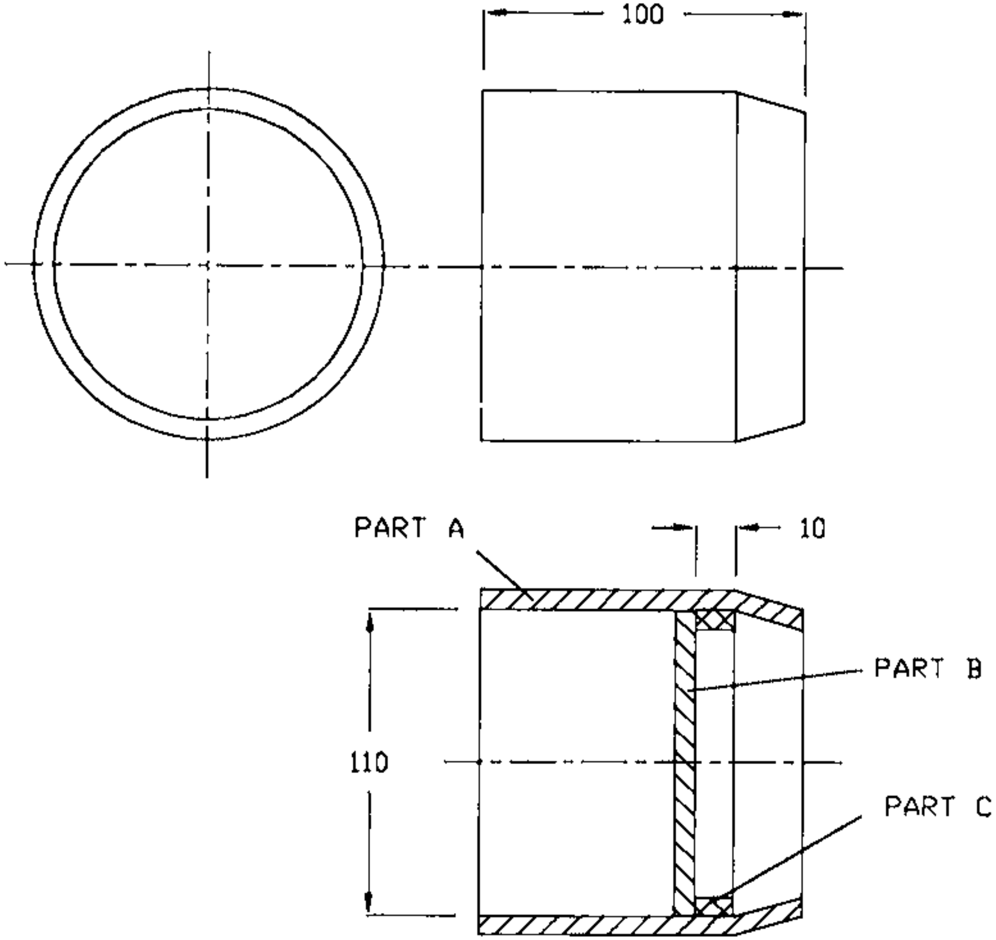
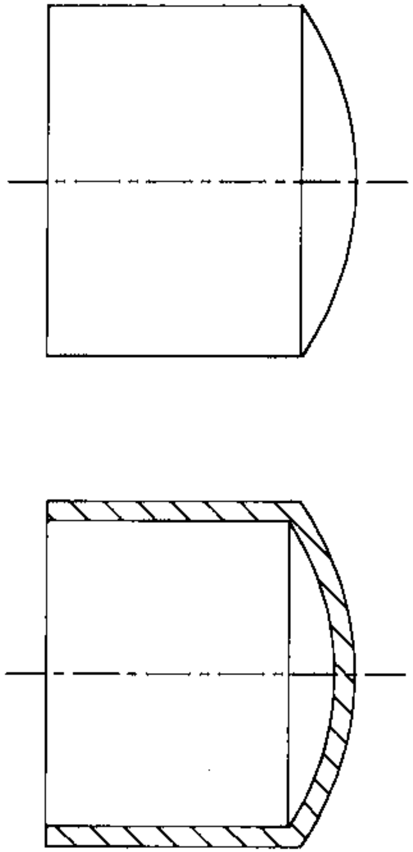
P90 SOCKET FORMER

Drawing No. 10 of 12 NOT TO SCALE

MAKING AN END CAP



STANDARD END CAP



NOTE: The End cap may be purchased commercially or made as shown.

MANUFACTURE INSTRUCTIONS

1 - Cut a 100mm length of high pressure plastic pipe and heat it as per the socket former instructions.
2 - Push the softened pipe quickly and firmly over the socket former to shape PART A.
3 - PART B, the end cap plug, and PART C, the reinforcing strip are made by the same methods used to make the Air vessel.
4 - When PART A has cooled, use a good plastic adhesive to glue in the reinforcing strip followed by the end cap disc. When dry the end is ready for use.

ALL DIMENSIONS IN mm

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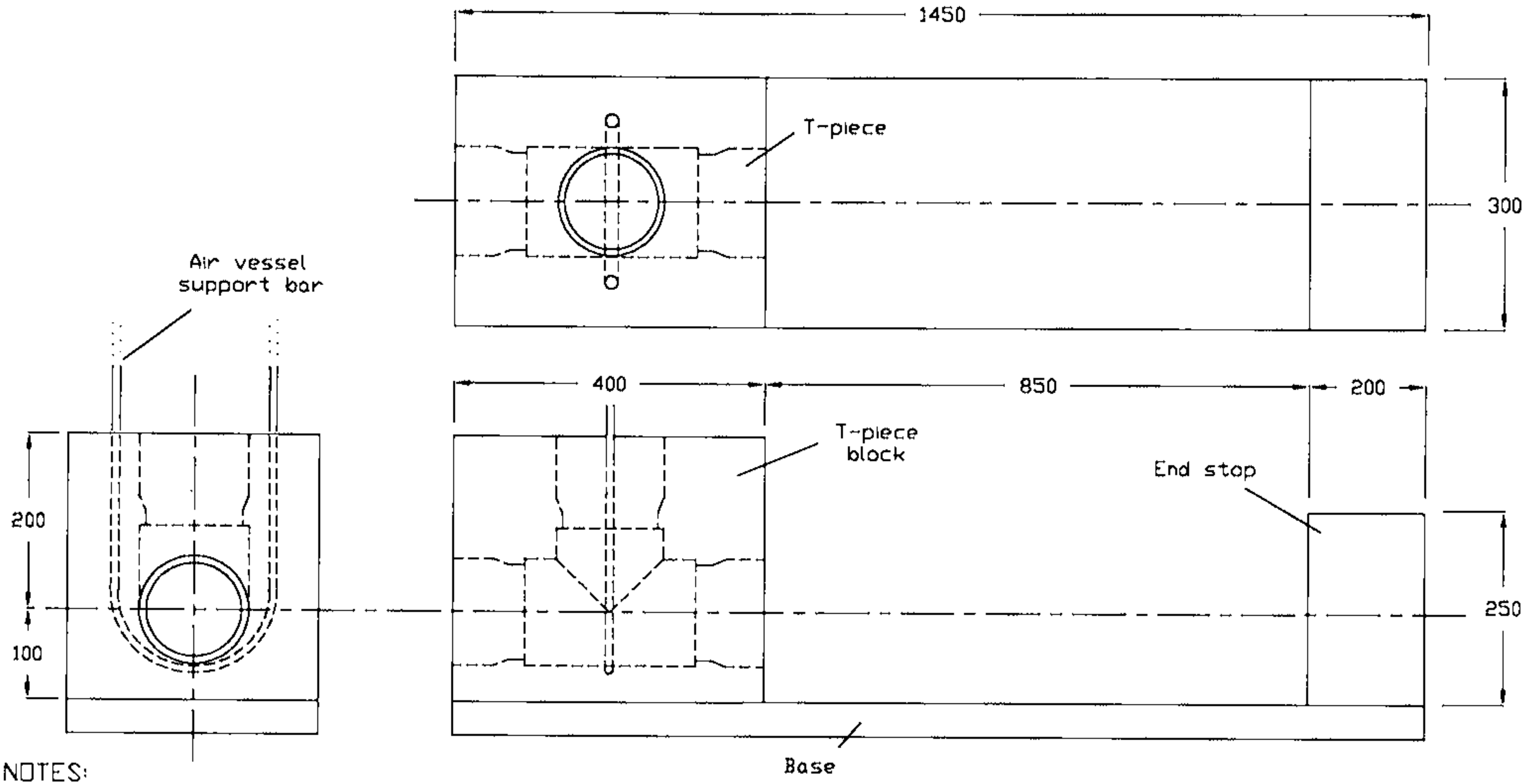
P90 IMPULSE VALVE
END CAP

Drawing No. 11 of 12 NOT TO SCALE



NOTES:

1 - The height and length of the T-piece block will be shorter when a standard T-piece is used. If a standard T-piece is used make sure the bottom of the T-piece is about 50mm above the top of the base.

2 - The depth of the base should be at least 75mm. The depth may be greater if a more solid foundation is needed.

3 - Use steel reinforcing in the base, T-piece block and end stop to join the three sections together and to reinforce each section. A local builder will know how to do this.

ALL DIMENSIONS IN mm

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P90 REINFORCED CONCRETE
BASE, T-PIECE BLOCK
& END STOP

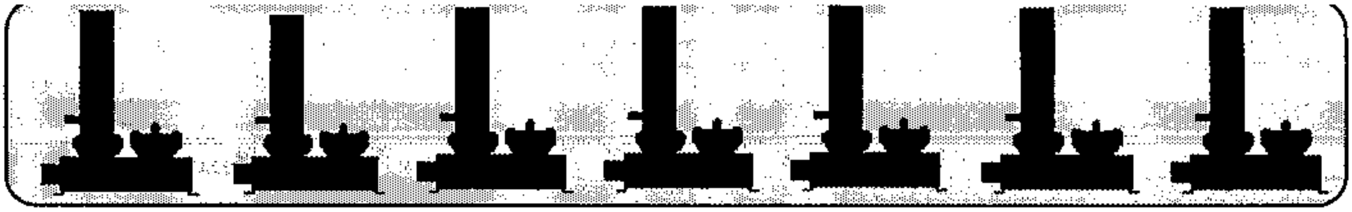
Drawing No. 12 of 12 NOT TO SCALE

DTU

Ram Pump Programme

DTU S1 PUMP

TECHNICAL
11
RELEASE



DTU S1

The name "S1" stands for a Steel pump with a drive pipe up to 1" in diameter.

hydraulic ram pump

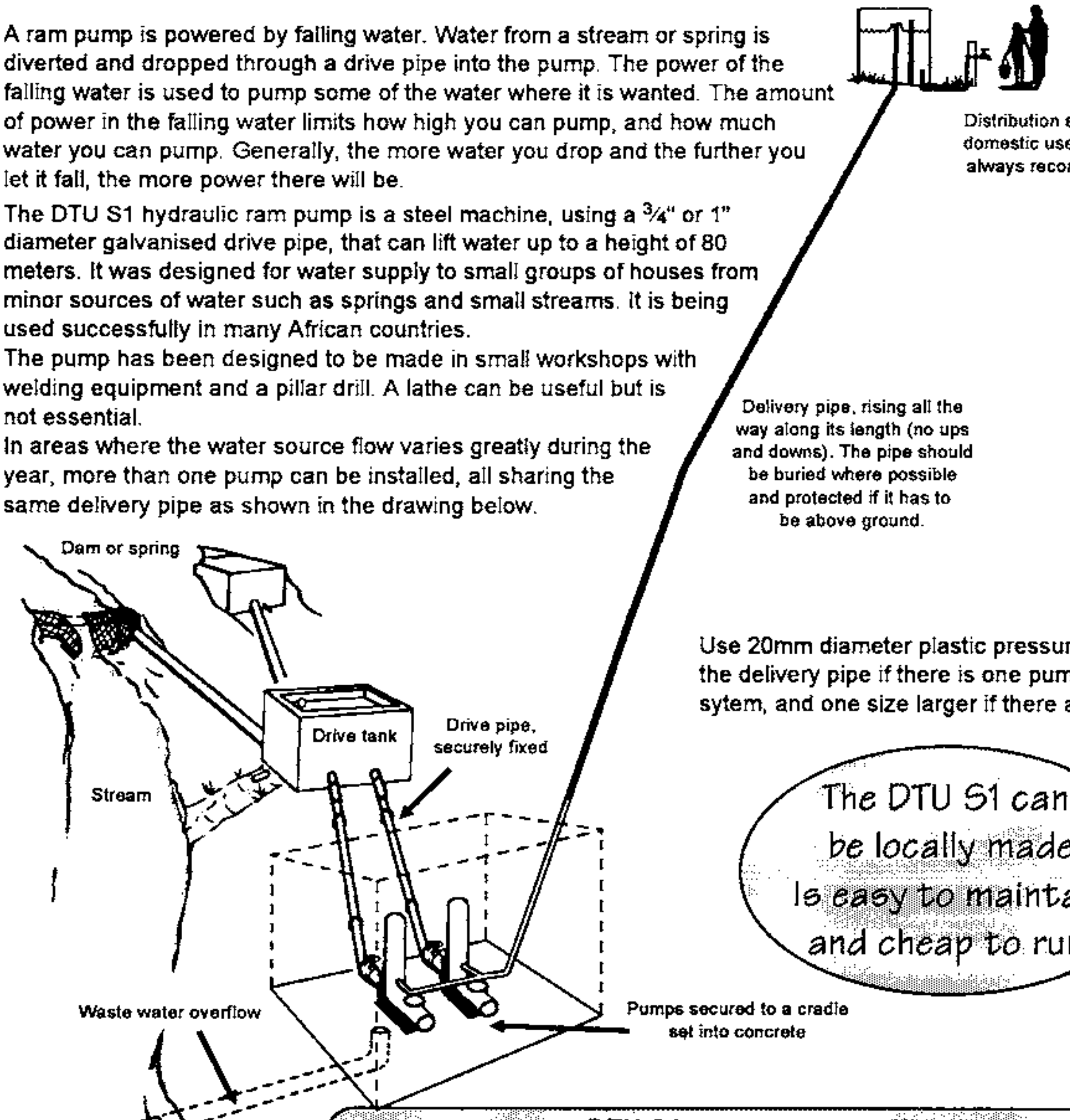
DTU S1 PUMP: USER INSTRUCTIONS

A ram pump is powered by falling water. Water from a stream or spring is diverted and dropped through a drive pipe into the pump. The power of the falling water is used to pump some of the water where it is wanted. The amount of power in the falling water limits how high you can pump, and how much water you can pump. Generally, the more water you drop and the further you let it fall, the more power there will be.

The DTU S1 hydraulic ram pump is a steel machine, using a ¾" or 1" diameter galvanised drive pipe, that can lift water up to a height of 80 meters. It was designed for water supply to small groups of houses from minor sources of water such as springs and small streams. It is being used successfully in many African countries.

The pump has been designed to be made in small workshops with welding equipment and a pillar drill. A lathe can be useful but is not essential.

In areas where the water source flow varies greatly during the year, more than one pump can be installed, all sharing the same delivery pipe as shown in the drawing below.



Distribution system, for domestic use. A tank is always recommended.

Delivery pipe, rising all the way along its length (no ups and downs). The pipe should be buried where possible and protected if it has to be above ground.

Use 20mm diameter plastic pressure pipe for the delivery pipe if there is one pump in the sytem, and one size larger if there are two.

The DTU S1 can
be locally made
Is easy to maintain
and cheap to run!

DTU S1 ram pump specifications

The normal specifications of the DTU S1 ram pump are given here.
Sometimes you can operate pumps outside these limits, but they may not work well.

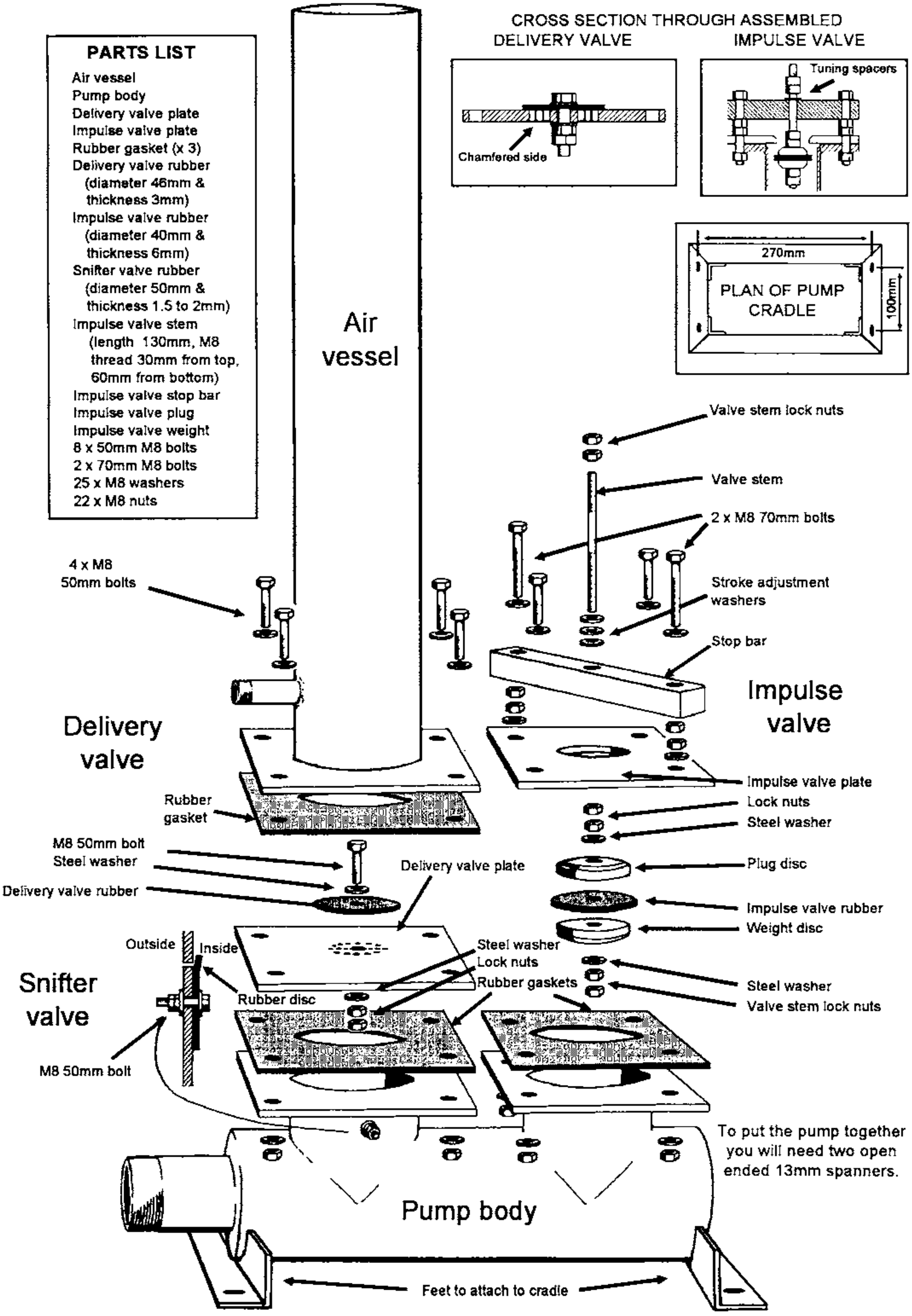
drive head range — 2 to 15 meters
drive flow range — 20 to 60 liters a minute
drive pipe material — Galvanised iron
drive pipe diameter — ¾" for flows from 20 to 35 liters a minute
drive pipe diameter — 1" for flows from 30 to 60 liters a minue
delivery head range — up to 80 meters
typical delivery range — 0.5 to 10 liters a minute
delivery pipe diameter — 20mm

TECHNICAL
11
RELEASE

AN EXPLODED VIEW OF THE DTU S1 PUMP

PARTS LIST

- Air vessel
- Pump body
- Delivery valve plate
- Impulse valve plate
- Rubber gasket (x 3)
- Delivery valve rubber
  (diameter 46mm & thickness 3mm)
- Impulse valve rubber
  (diameter 40mm & thickness 6mm)
- Snifter valve rubber
  (diameter 50mm & thickness 1.5 to 2mm)
- Impulse valve stem
  (length 130mm, M8 thread 30mm from top, 60mm from bottom)
- Impulse valve stop bar
- Impulse valve plug
- Impulse valve weight
- 8 x 50mm M8 bolts
- 2 x 70mm M8 bolts
- 25 x M8 washers
- 22 x M8 nuts



To put the pump together you will need two open ended 13mm spanners.

Pump repair

If the pump stops or starts delivering less water than usual, it may require adjustment or repair.

Look at the pump and if there is no obvious fault start it again if you can. Watch the pump and listen for irregular pumping or unusual noises. A worn impulse valve, for example, is usually obvious because water squirts through when the valve is closed. Some parts of your ram pump may need occasional replacement. the frequency of this will depend on how hard the pump is working and on the cleanliness of the drive water.

Tools you will need:

2 x 13mm ring/open end spanners to disassemble and assemble the pump
2 x Adjustable wrenches - to loosen a union joint on the delivery pipe (if fitted)

Taking the pump apart

Depending on the fault it may be necessary to disassemble the impulse valve and/or the air vessel. Before attempting to take apart the pump:

1. Make sure that the drive pipe valve is closed and the impulse valve is open. This will allow you to work on the impulse valve ONLY.
2. Depressurise the air vessel.

WARNING - Before attempting to remove the air vessel, always release the pressure in it slowly. An ideal system will have a gate valve or one-way valve and a union fitted between the air vessel and the bottom of the delivery pipe and the optional bleed screw fitted to the air vessel. With the pump stopped, close the gate valve in the delivery pipe to stop it draining back. If a one-way valve is fitted it will close automatically. Then loosen the bleed screw to release the pressure in the air vessel. If none of the above are fitted, the only other way to release the pressure in the air vessel is to loosen each of the air vessel flange bolts one turn at a time until the water and air escapes through the join at the flange. You will certainly get wet this way.

Checks

1. Check the delivery valve rubber for wear and blockage of the valve holes.
2. Check that the snifter valve is in good condition.
3. Remove the impulse valve and check the impulse valve rubber. Check the nuts on the valve stem and check for excessive wear of the stem. Replace things if necessary.
4. Check the pump body is firmly bolted down, then reassemble the pump, ensuring that all bolts are greased.

Putting the pump back together

Assembly of the pump is shown in the exploded view drawing, but the following important points need to be kept in mind:

1. Assembling the delivery valve

   Put together the delivery valve plate, the rubber and the bolt. Make sure the side of the plate with the chamfered holes is on the opposite side to the rubber, and that the rubber is on top.

   Screw on the first nut until it is finger tight and then undo it by one turn. Care must be taken not to overtighten the bolt and nuts as this will affect the performance of the valve. Next, screw on the other nut and tighten it up against the first. Use the spanners to tighten them firmly together. This will lock them together, and also allow a small up-and-down movement of the bolt and rubber.

2. Assembling the snifter valve

   Put the 'shaped' bolt and washer together, feed the bolt through the valve rubber, then push this through the pump body. Make sure that the shaped curve of the bolt head and washer align with the curvature of the body.

   Screw on the first nut until it is only finger tight. If the nut is on too tight the rubber will curl away from the pump body and will need to be slackened off slightly. Then screw on the second nut and tighten the two nuts firmly together using the spanners. Then check that the rubber has not distorted. If it has, slacken the nuts half a turn and tighten the outer one again.

3. Assembling the air vessel and delivery valve

   Align the delivery valve, air vessel, pump body and rubber gasket mounting holes and feed through the bolts. Make sure the delivery valve is the correct way up (the valve rubber facing upwards) and then tighten the nuts by hand. Use the spanners to tighten each nut and bolt a little at a time, working around the flange. This will draw the assembly together evenly.

4. Assembling the impulse valve

   The first parts to assemble are the valve stem, discs and rubber. Screw two nuts onto the longer threaded end of the stem up to the end of the thread. Push a steel washer on up to the nuts. Follow this with the valve plug disc, with the chamfered side towards the nut. Slide the valve rubber up against this, then the weight disk with the chamfered side facing away from the rubber. Follow this with another steel washer. Screw a nut up to them until it is finger tight. Thread on another nut and use the spanners to tighten the nuts together. This part of the assembly is sometimes known as the valve plug.

   Hold the impulse valve plate and the valve plug together, with the chamfered side of the plate opposite to the side against which the valve rubber presses. Slide the stop bar onto the top of the stem and thread a nut loosely on the stem.

   Push the two longer bolts through the ends of the stop bar and thread two nuts onto each. Use spanners to lock the nuts tightly. Align the valve assembly, pump body and rubber gasket and feed through the flange bolts.

   Thread on the four washers and nuts by hand, then use the spanners to tighten the two shorter bolts that hold down the valve plate. Again care must be taken to ensure that these nuts are tightened evenly. The next step is to make sure the closed valve plug is centred in the valve plate hole before tightening down the two remaining nuts that secure the stop bar. To check the alignment, open and close the valve manually turning the valve plug to make sure it does not catch on the hole in the valve plate.

Now you only need to set the stroke length of the valve for the pump to be ready for use.

Spare parts to keep on the site

- impulse, delivery and snifter valve rubbers
- an impulse valve stem
- a few spare M8 nuts, bolts and washers

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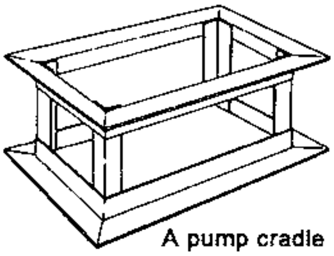
FAX: 44 (0)1203 418922

Installation notes


A pump cradle

The DTU S1 pump should be installed in a properly designed system. To prevent vibration causing breakages, it should be firmly bolted to a steel frame (called a pump cradle) that is half buried in a concrete base. The cradle is usually made from 40 x 40mm angle iron and will vary in size depending on the number of pumps installed. Hole locations for just one pump are shown on the previous page.
All pipes in the system should be supported firmly, and buried where possible. The drive and delivery tanks should be constructed on good foundations by experienced tradesmen. Pipe joints to the drive tank should allow the pipes to move slightly without damaging the tank walls or leaking badly.

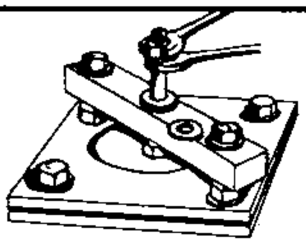
Starting and stopping the ram pump

Although ram pumps often start very easily, they can be awkward the first time they are run.
To start the pump:

1. Make sure that any valve fitted on the delivery pipe is open and then open the drive pipe valve. Water will flow out of the open impulse valve until it suddenly shuts. If it reopens automatically, the pump should continue to run on its own. If it does not, you must prime the delivery system as described in Step 2 alongside.
2. Push down on the top of the impulse valve stem with your foot to reopen it (wear strong boots). Again, water will flow out of the open impulse valve until it suddenly shuts, then push down immediately to re-open the valve. Keep helping the valve to re-open until it will do so by itself.

To stop the pump, hold the impulse valve stem up to close it or shut the valve at the bottom of the drive pipe.

Tuning for best performance



The DTU S1 can be tuned to adjust performance. This is done by changing the up and down movement of the impulse valve, which is normally set to about 12mm. Tuning is usually done to achieve either the maximum delivery flow or the most efficient use of the drive water available.

Maximum delivery

When there is plenty of drive water available, the pump can be tuned to deliver as much water as possible. To do this, remove all washers from the impulse valve stem so that the valve has as much up and down movement as possible.

WARNING: - this also puts the pump parts under greater stress and makes them wear more quickly.

Low drive flow

If the pump uses more drive flow than is available it will soon stop. If this happens it must be tuned to use less. The impulse valve should be tuned down to use 90-95% of the water available from the source. To tune the pump down, add washers onto the impulse valve stem so that the valve has less up and down movement. The shorter the stroke, the smaller the amount of drive flow needed, and the less water is delivered. The minimum stroke length is about 7mm.

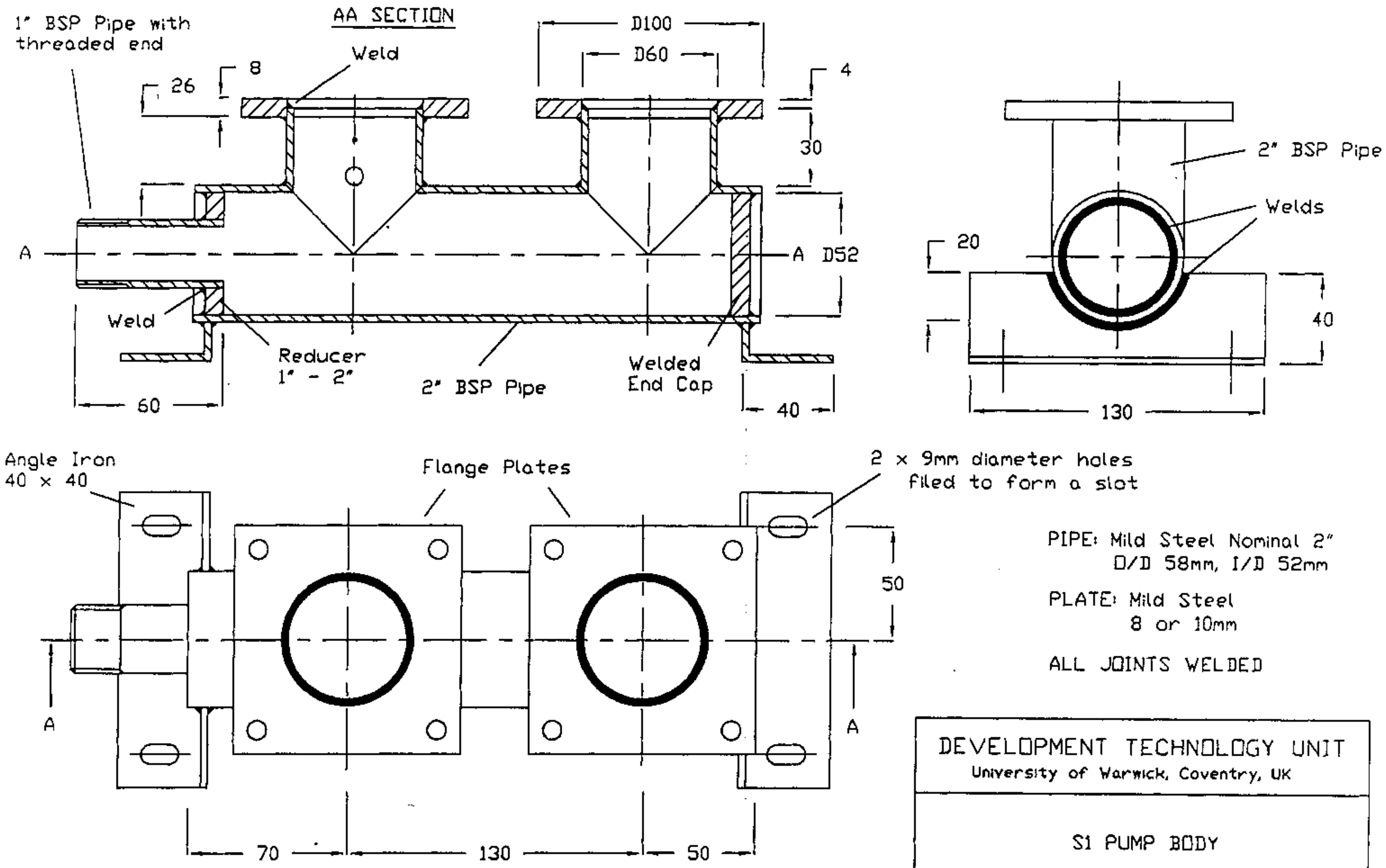
Routine maintenance

While the pump is running normally, a visit should be made once a week to check that bolts are tight and that there are no leaks. Once a month an inspection of the whole system should be carried out. It is also recommended that a log book is kept to record the checks and repairs that have been made.

Monthly maintenance check list (without stopping the pump):

1. Inspect all the joints to check for leaks.
2. Check if there is sufficient air in the air vessel. This can be done by listening carefully to the pump. If there is insufficient air in the air vessel, the pump will be much louder than usual. This means that the snifter valve is probably blocked and will need to be cleared.
3. Clean any filters installed in the system.
4. Remove excess silt or debree from tanks or from behind the intake dam or weir if necessary.
5. Walk along all pipes looking for damage. Also, inspect the tanks for leaks, particularly at pipe joints.

The following Technical release contains more information about making the DTU S1 pump
TR 11b DTU S1 pump drawings
Similar information is available for the other DTU pumps.



PIPE: Mild Steel Nominal 2"
O/D 58mm, I/D 52mm

PLATE: Mild Steel
8 or 10mm

ALL JOINTS WELDED

ALL DIMENSIONS IN mm

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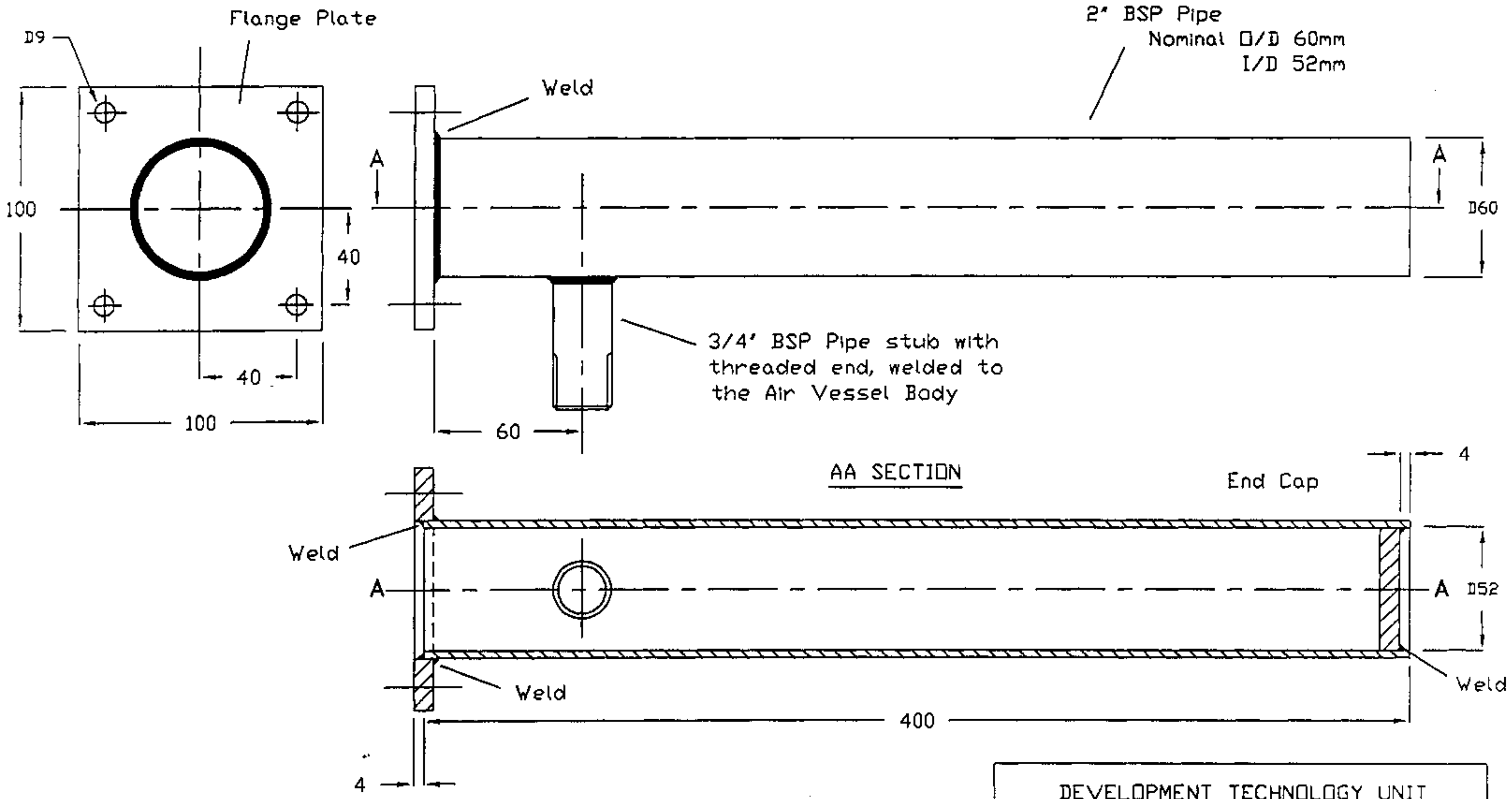
S1 PUMP BODY

Drawing number 1 of 7 NOT TO SCALE



NOTE

The Flange Plate & End Cap are 8 to 10mm in thickness

To make the Flange Plate See the separate Drawing/Template

ALL DIMENSIONS IN mm

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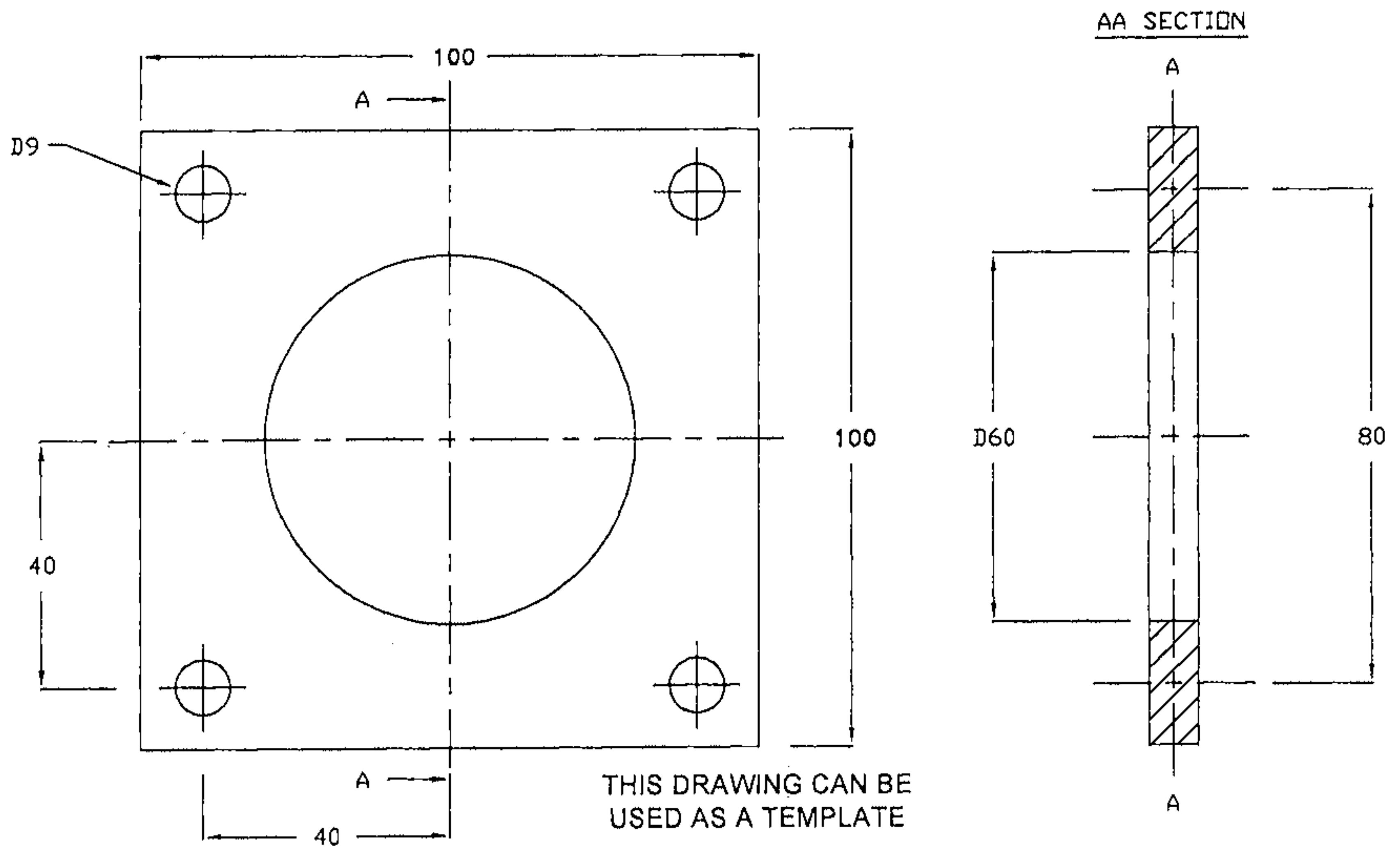
S1 AIR VESSEL

Drawing number 2 of 7

NOT TO SCALE



THIS DRAWING CAN BE
USED AS A TEMPLATE

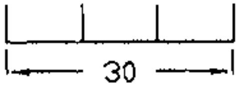
NOTE

Flange Plate thickness is 8 to 10mm

The internal diameter of the Flange Plate (60mm) may need to be different depending on the outside diameter of the steel pipe used for the pump body.

ALL DIMENSIONS IN mm

Measurement
Check



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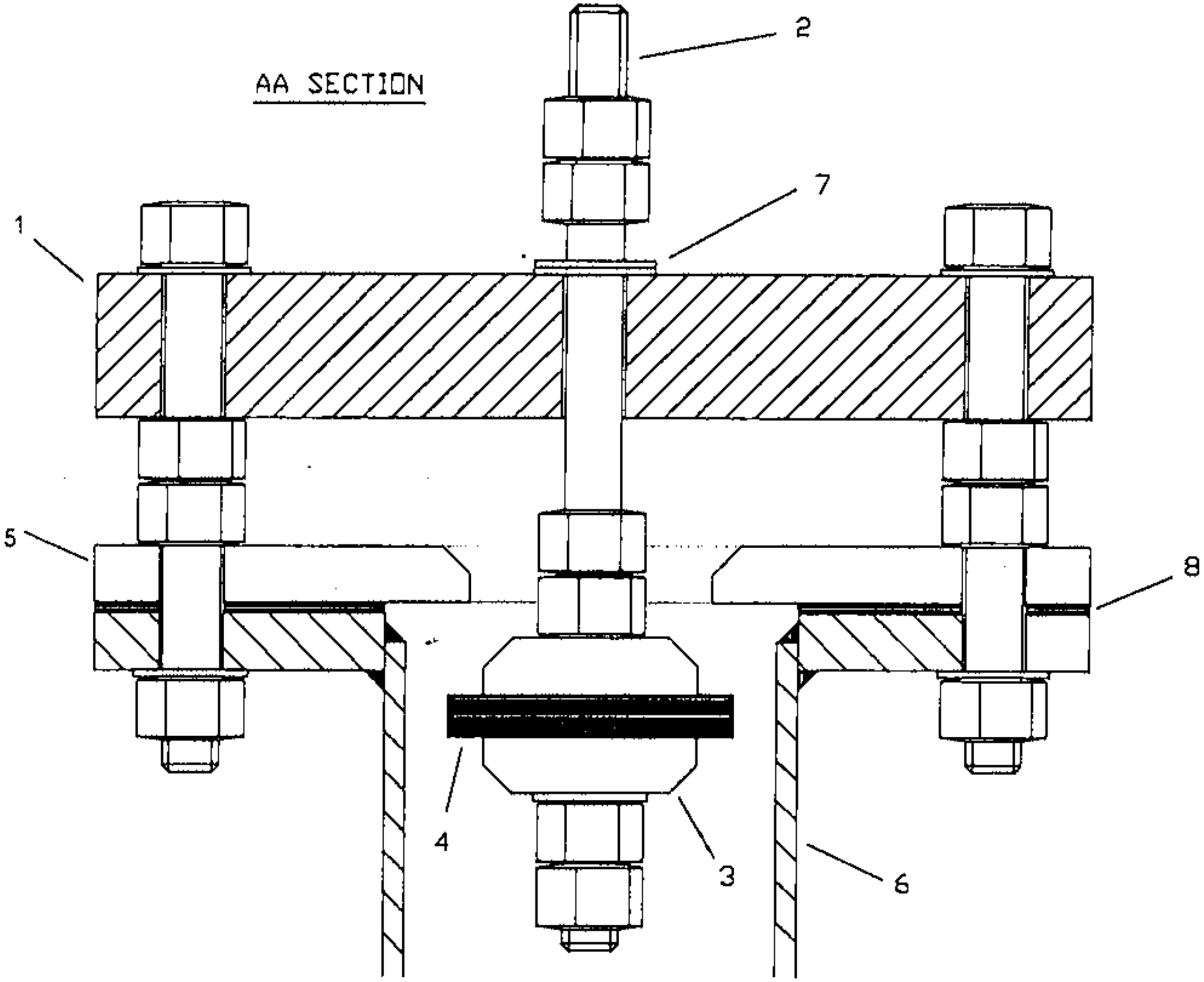
S1 FLANGE PLATE

Drawing number 3 of 7 SCALE 1:1

AA SECTION

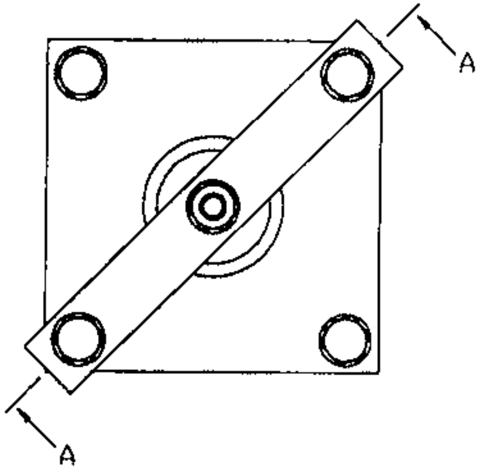


NOTE

The Rubber Disc (4) is 40mm in diameter and 6mm thick DO NOT use a diameter larger than this as the flow through the valve will be restricted

The Rubber Gasket (8) can be 1.5 to 3mm thick and is cut to match the Pump Body Flange

IMPULSE VALVE TOP VIEW



PARTS LIST

1 - Cross-bar
2 - Valve Stem
3 - Valve Disc (x2)
4 - Rubber Disc
5 - Valve Plate
6 - Pump Body
7 - Stroke Adjustment Washers
8 - Rubber Gasket
9 - M8 Bolts, Nuts and Washers
Bolts: M8 x 70mm (2 of)
M8 x 50mm (2 of)

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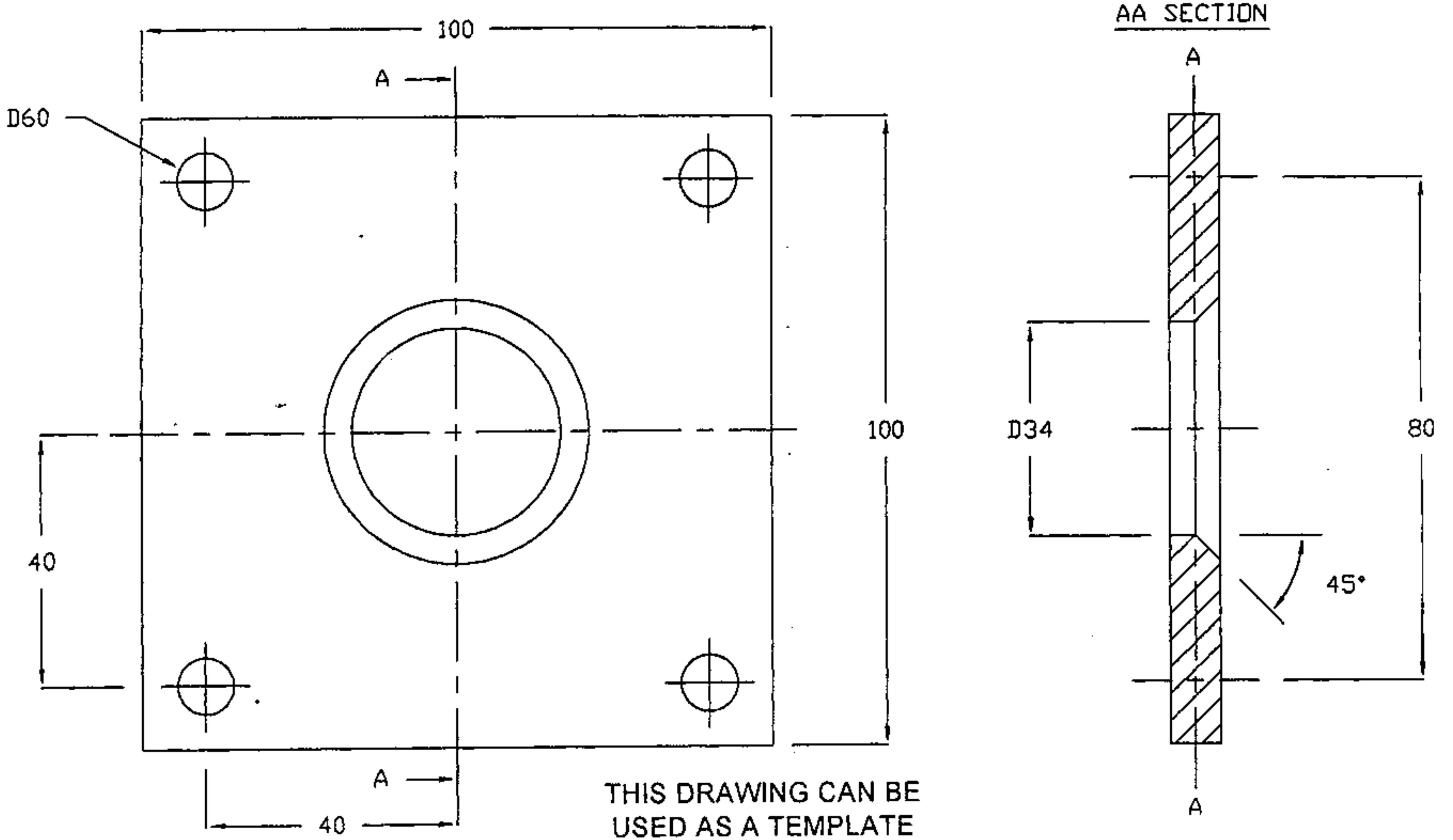
S1 IMPULSE VALVE ASSEMBLY
Drawing number 4 of 7
AA SECTION - SCALE 1:1



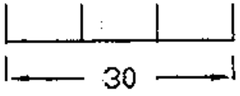
THIS DRAWING CAN BE
USED AS A TEMPLATE

NOTE

The impulse valve plate thickness is 8 to 10mm.
It is important to ensure that the Impulse Valve Plate and the Impulse Valve Discs are of the same thickness.

ALL DIMENSIONS IN mm

Measurement
Check



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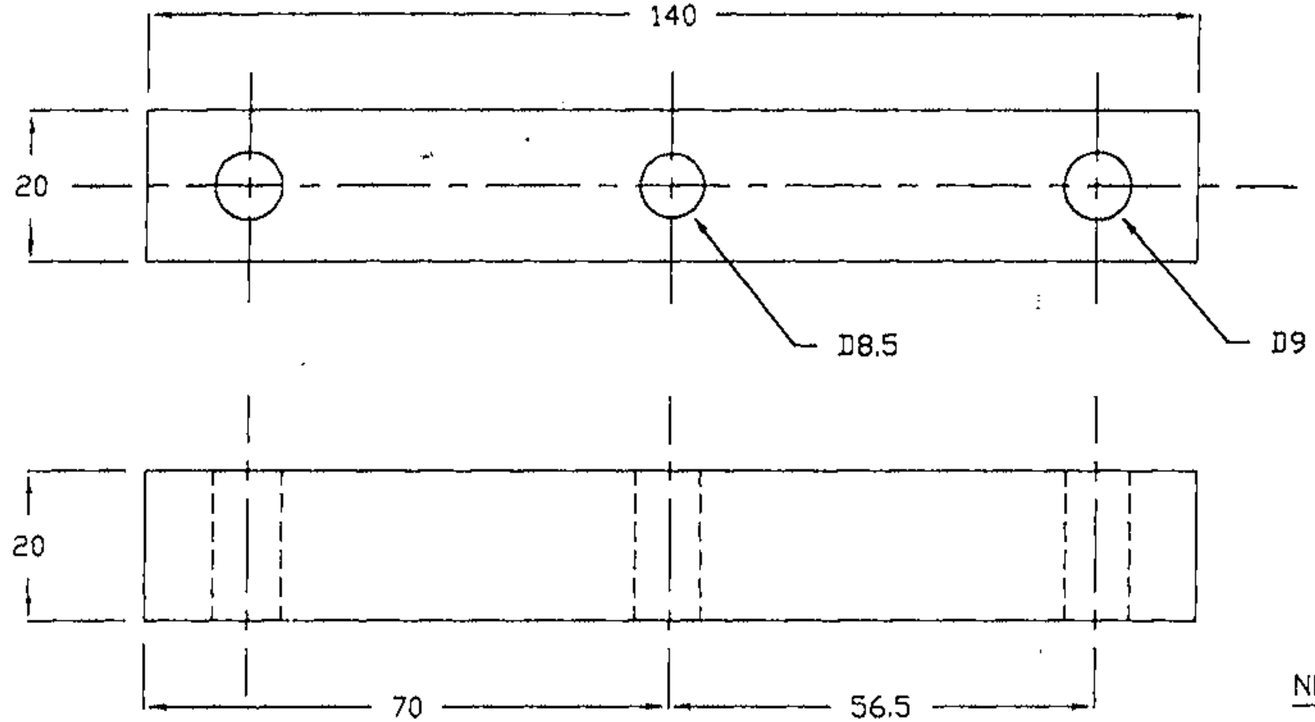
S1 IMPULSE VALVE PLATE

Drawing number 5 of 7

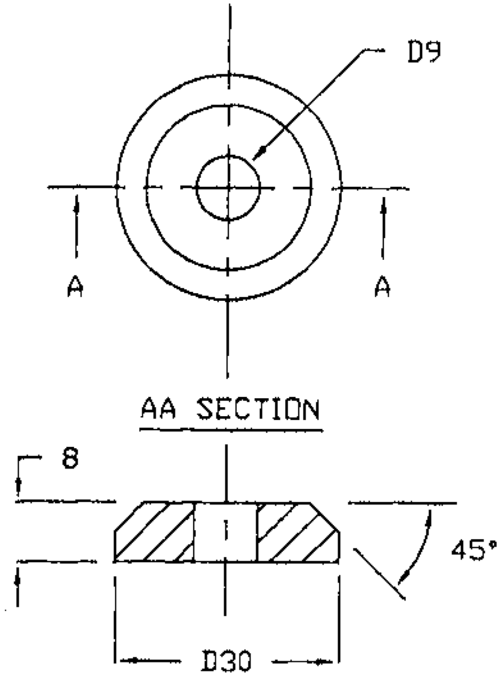
SCALE 1:1

IMPULSE VALVE CROSS-BAR



NOTE
Cross-bar is mild steel

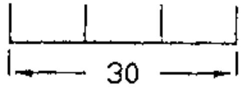
IMPULSE VALVE DISCS



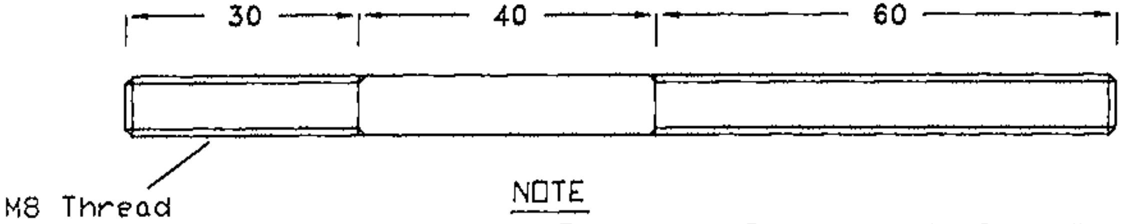
NOTE
2 Impulse Valve Discs are required.
Discs are of mild steel

THIS DRAWING CAN
BE USED AS A TEMPLATE

Measurement
Check



IMPULSE VALVE STEM



NOTE
The Valve Stem is made from 8mm steel
bar or reinforcing bar. Use Stainless
steel if possible

ALL DIMENSIONS IN mm

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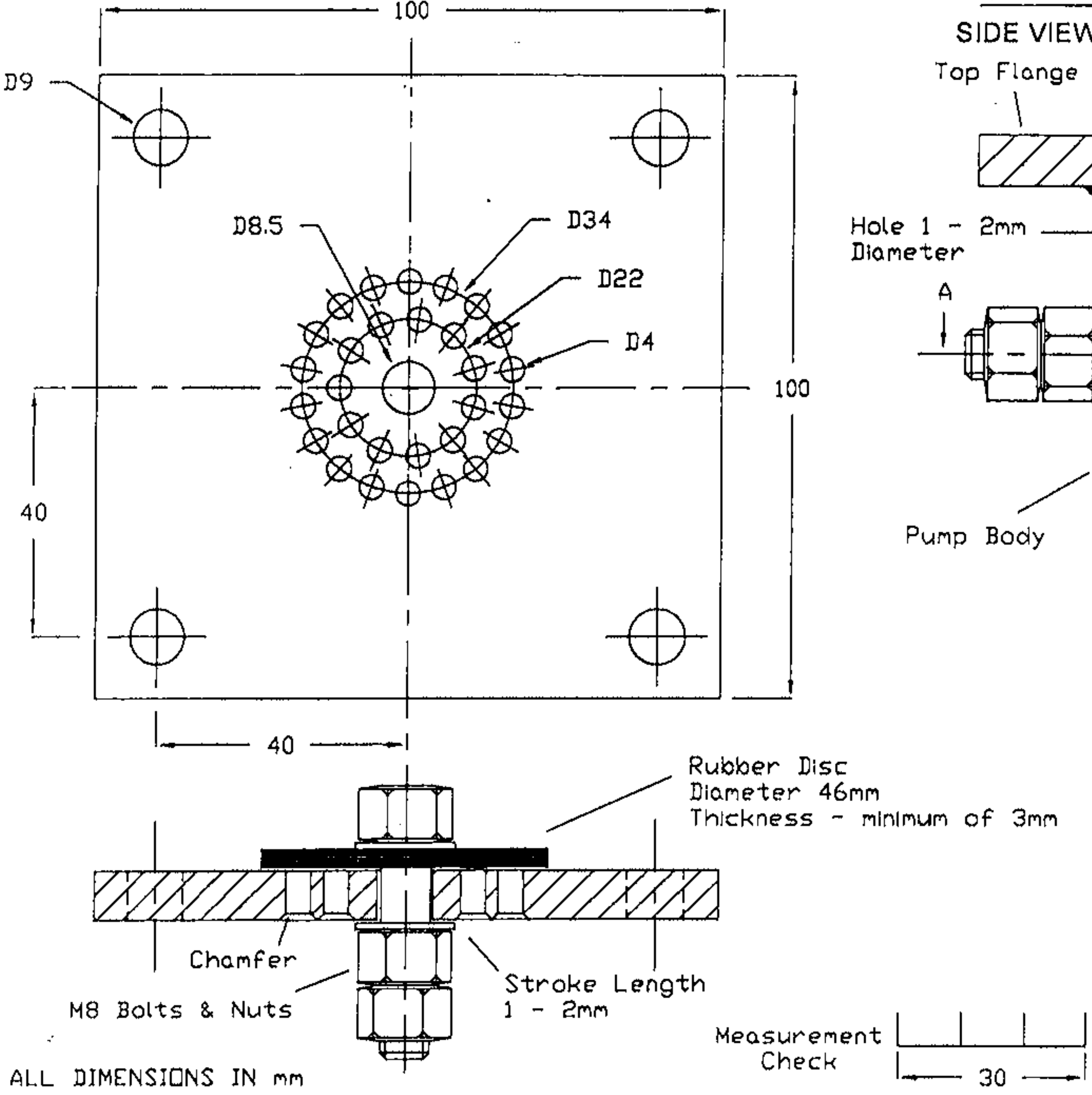
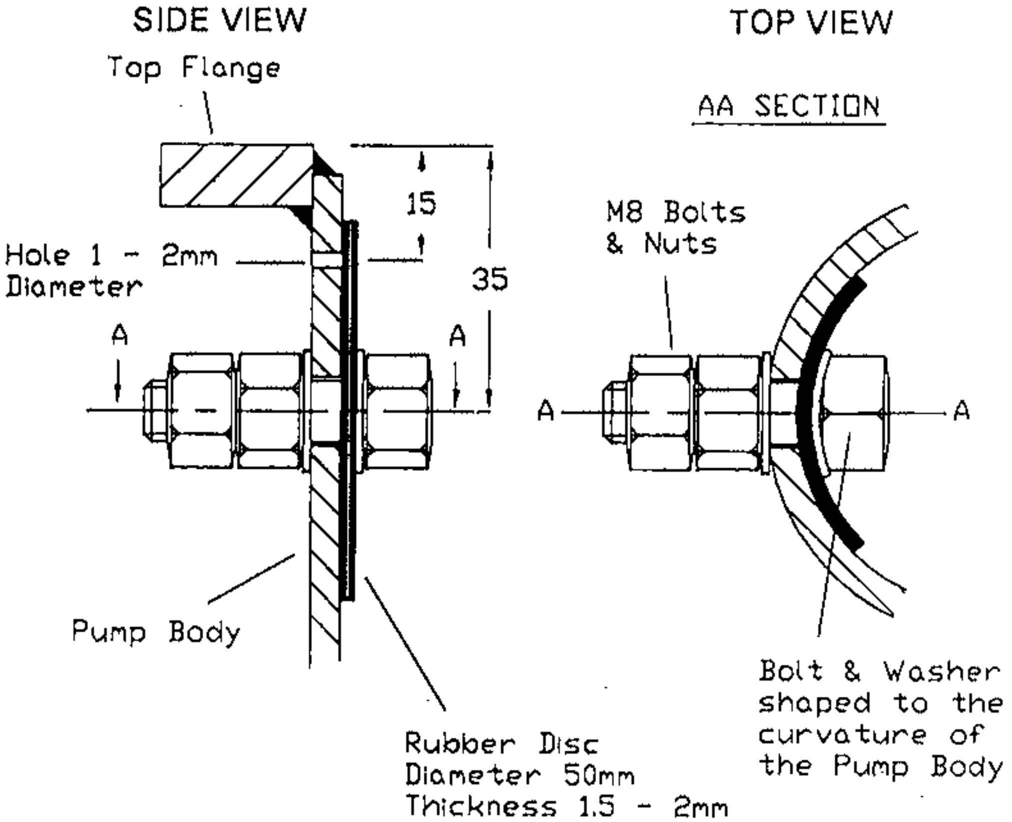
S1 IMPULSE VALVE COMPONENTS

Drawing number 6 of 7
SCALE 1:1

DELIVERY VALVE PLATE & ASSEMBLY



SNIFTER VALVE ASSEMBLY



**THIS DRAWING CAN
BE USED AS A TEMPLATE**

DEVELOPMENT TECHNOLOGY UNIT
University of Warwick, Coventry, UK

DELIVERY & SNIFTER VALVE
ASSEMBLIES

Drawing number 7 of 7 SCALE 1:1

ALL DIMENSIONS IN mm

DTU

Ram Pump Programme

RAM PUMP SYSTEM CALCULATORS

TECHNICAL
10
RELEASE

DTU Technical Release TR10 *1996*

Cardboard Calculators for Designing Ram Pump Systems

1 INTRODUCTION

In the Development Technology Unit we have for many years been designing water systems that use hydraulic ram pumps. We have also trained water specialists from over 10 countries how to make the pumps and design systems to put them in. To design a good system, you have to do some calculations. We have found that most people do not enjoy using formulas or doing maths, so we have developed special cardboard 'calculators' that can be used instead of formulas. They give the same answers as the formulas in books but are much easier and quicker to use.

When we design a water system using ram pumps, we like to be able to know *before* we build it how much water it will deliver. This is called the "delivery flow". The first DTU calculator is the *Ram Pump System Design Calculator* and is meant mainly for working out such delivery flows.

The second cardboard calculator is called the *Friction Headloss Calculator*. We use it to help select the right sizes for the different pipes in a ram pump system. It can also be used for choosing the pipe sizes in a gravity-feed water system.

In this Technical Release we describe how to make the two calculators and how to use them.

The last three pages of this Technical Release are single-sided master pages to be photo-copied each time you make a calculator. We suggest that the first photo-copy you make should be attached to this Release in case the copy masters get separated and lost.

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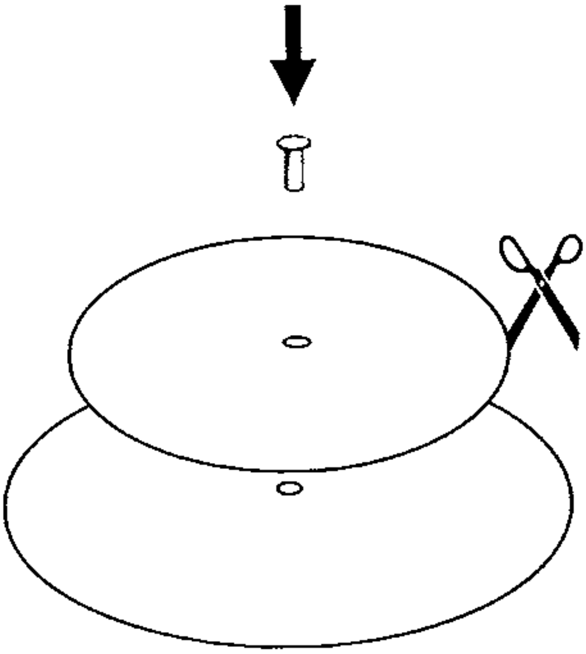
2 MAKING THE CALCULATORS

Start by photo-copying the calculator parts printed on the 3 pages at the end of this Release. The thicker the paper or card you can use for these copies, the better; card as thick as 180 gpm can be fed through some slow photo-copiers. The *Delivery Flow Calculator* has 2 parts, both on the same page. The *Friction Headloss Calculator* has 3 parts, spread over the two following pages.

Carefully cut out the parts of the *Delivery Flow Calculator.* You will be assembling them by pushing a rivet through the centre holes and turning the ends over, so the cut-out circles for these centre holes should be the same size as the rivet you will be using. It is important to make these holes round and put them in exactly the right place on the disc.



The rivet can be of plastic or soft metal. We have successfully made rivets from short strips cut from thick plastic piping, rolled on sandpaper to make them round and then turned over at the ends with a hot iron. You could also use a short plastic or steel bolt with washers and two nuts: the nuts have to be tightened against each other so that they hold the discs not quite tight.The holes can be reinforced with self adhesive "ring reinforcements" sold in some stationery shops to strengthen the holes on paper sheets held in ring-binders.

If the calculator is always to be used in one office, the 2 discs can be held by a drawing pin (through their exact centres) onto a notice board. The pin must be loose enough to allow the discs to rotate freely.

If the calculators are to be carried around or taken out of doors, they will soon get torn or dirty. If at all possible you should cover each one on both sides with transparent plastic. Clear adhesive plastic sheet is sometimes sold in stationery shops for use to protect schoolbooks. If you place any hole-strengthener under the plastic, this will help prevent it falling off. It also helps if you can make a waterproof pocket to carry the calculators in.

The *Friction Headloss Calculator* is made in the same way as the *Delivery Flow Calculator.* except that there are now 3 parts free to rotate on the same rivet or pin.

3 USING THE 'RAM PUMP SYSTEM DESIGN CALCULATOR'

The *Ram Pump System Design Calculator* has two discs and a swinging arm. It carries four scales

Feed head *H*	Range 1.5 to 30 meters
Delivery head *h*	Range 10 to 120 meters
Feed flow *Q*	Range 10 to 800 litres/minute
Delivery flow *q*	Range 0.5 to 80 litres/minute

Check that you can find each of these scales.

The last scale is in three parts called "efficiency = 50%", "efficiency = 60%" and "efficiency = 70%". If you do not know what your system efficiency might be, use the "60%" part. If you think it might be rather low, use the "50%" part and if it might be very good use the "70%" part.

The calculator is for calculating the flow from a complete *system*, not just from a single pump. If your system has several pumps working side by side, you should use as *Q* the feed flow to the whole system, not the drive flow to just one of the pumps. The calculator will then tell you the delivery flow from the whole system and not just the output of one pump. If your system does have only one pump in it, there is no problem; the feed flow you use will all go through that one pump.

To learn how to use the calculator we suggest you practice with the following example.

Suppose you have a system in which
feed head = 4 meters,
delivery head = 40 meters,
feed flow = 50 litres per minute,
efficiency is unknown so we use 60%,
then the calculator should show a delivery flow of 3 litres per minute.

Here are the two steps.

Step 1 Hold the outside disk and turn the inside disk until 50 litres per minute on scale *Q* is exactly in line with 4 meters on scale *H*.

Step 2 Pinch the two discs together with your fingers so that one cannot slip past the other and then turn both disks together until the *q* scale is at the top. Find 40 meters on scale *h* and read the flow above it on the "efficiency = 50%" part of scale *q*. You should get close to 3 litres per minute.

The calculator is not super-accurate. It will give you an answer that is "close enough". If you followed the example above and got an answer that was not close to 3 litres/min it might be that

- you let the disks slip past each other,
- you used the wrong scales,
- the holes in the middle of your disks have become badly worn and the disks are very loose.

4 USING THE 'FRICTION HEADLOSS CALCULATOR'

When water flows through a pipe there is some friction between the water and the pipe walls. This causes something called "friction headloss" which is measured in meters. A pipe with a small diameter has a bigger headloss than a larger pipe for the same flow of water. A big headloss usually means that the system delivers less water than it should.

The *Friction Headloss Calculator* has two disks and a swinging arm. It carries four scales which you might look for:

Length of pipe	Range 2 to 3000 meters
Flow through pipe	Range 1 to 500 litres per minute
Bore of pipe ("Bore" is the same as "Inside diameter")	Range 16mm to 200mm
Headloss	Range 10cm to 100 meters

and the two small arrows on the swinging arm called "steel" and "plastic". At the top of the swinging arm is a big arrow labelled "flow through pipe".

You can use this headloss calculator to help you choose the best size for the delivery pipe, the feed pipe and the drive pipes in a ram pump system. You can also use it for pipes in gravity feed systems. We will now describe each of these four uses.

Use 1: Delivery pipes

When you come to choose the size of a delivery pipe, you will usually already know how long it is, how high it rises and how much water is to flow through it.

Suppose for example you know that at a particular site:

pipe length = 500 meters,

flow through the pipe = 10 litres per minute and the pipe is plastic,

the delivery height *h* = 60 meters.

Standard pipe sizes (*outside* diameters) are 20 mm, 25 mm, 32 mm and 40 mm. For medium pressure pipes, their bores (their *inside* diameters) will be about 2 mm smaller - typically 18 mm, 23 mm, 30 mm and 37 mm. Your problem is to decide which size is right.

Suppose you think that the 30 mm bore pipe might be suitable. The calculator lets you find out if it is. The calculation goes as follows:

Step 1 Hold the outer disk and rotate the inner disk until 500 m on the Length scale is touching 30 mm on the Bore scale.

Step 2 Pinching the two disks together so that they do not slip, move the swinging arm until the big arrow at its top is touching 10 litres per minute on the Flow scale.

Step 3 Read the headloss scale underneath the "plastic" arrow. You should find about 1.6 m.

You now have to decide whether this headloss is OK. It should normally be between one fiftieth and one tenth of the delivery head *h*. If headloss is more than *h*/10 your system will be quite inefficient, so you should try a larger pipe. If it is less than *h*/50 you are using a delivery pipe that is too big: you could save money by trying a smaller pipe. In our example the headloss *is* between *h*/50 (1.2 m) and *h*/10 (6 m), so our pipe size of 30mm is OK.

Use 2: Feed pipes

Your ram pump system may have a feed pipe connecting a stream or spring to a drive tank from which drive pipes lead to each pump. The calculation for feed pipes is just like that for delivery pipes except that the flow is now the feed flow to the drive tank, and of course the length and diameter we use are those of the feed pipe. Feed pipes are usually plastic, so use the "plastic" arrow on the swinging arm. Common pipe sizes for feed pipes are 50 mm, 63mm, 75mm, 90 mm and 110mm outside diameter. The bores of these sizes for low-pressure pipe are about 47 mm, 59 mm, 72 mm, 86 mm and 105 mm. So first decide which bore you should try for the feedpipe, then use the calculator to work out its headloss.

When you have found the headloss, you should compare it with the *feed* head *H*). If it is over H/10, the feed pipe should be larger. If it less than *H*/50 the feed pipe could be smaller.

Use 3: Drive pipes

Each drive pipe carries the drive flow to a single pump: this is usually equal to the feed flow *Q* divided by the number of pumps running side by side. As the drive flow is not steady like the feed flow, but is constantly starting and stopping, the head loss in a drive pipe is higher than for other types of pipe. The *Friction Headloss Calculator* gives the right head loss for a steady flow. For a drive pipe with its unsteady flow we have to multiply the steady flow headloss by 2.

So choose a likely pipe size and for it calculate the steady flow headloss in the same way as for the delivery pipe, but using the length, bore, material and flow that belong to *one* drive pipe. Next multiply the calculator's answer by 2 to get the true headloss. Lastly check whether this true headloss lies between *H*/50 and *H*/10. If it lies outside this band, you should think of changing the drivepipe size. Notice that, as with the feed pipe headloss, we are comparing the drive pipe headloss with the *feed* head *H*.

Use 4: Pipes in gravity feed systems

In a gravity feed system, pipes are laid so that they slope downwards. The drop in height between where water enters a pipe and where it leaves it is what pulls the water through. For any one size of pipe, a bigger drop in height gives a bigger flow. We can use the *Friction Headloss Calculator* to work out what the flow will be. This is because in a gravity feed system, the friction headloss is exactly *equal* to the drop in height.

Let us take as an example a 1" galvanised iron pipe, whose length is 2 kilometres and which drops by 100 meters from one end to the other. We can now work out the flow through the pipe. The calculation goes as follows:

Step 1 Hold the outer disk still and turn the inner disk until 2 km on the length scale touches 26 mm on the bore scale. (A 1" GI pipe has a bore of about 26 mm)

Step 2 Keeping the two disks clamped together in your fingers, move the swinging arm until the "steel" arrow is touching 100 m on the Headloss scale.

Step 3 Read the flow opposite the big arrow on the Flow scale. You should get about litres/min.

If the flow is more than you wanted, try again with a smaller pipe. If the flow is too small, try a bigger pipe. Of course the flow through the pipe cannot be higher than the flow available at the entry to the pipe. So making the pipe bigger will only increase the flow if it is the pipe, and not the source, that is limiting it.

5 NOTE FOR ENGINEERS

The *Ram Pump System Design Calculator* is based on the simple formula:

delivery flow = efficiency x feed flow x feed head / delivery head ($q = Eff \times Q \times H/h$).

Most well-designed ram pump systems have an efficiency of between 0.5 and 0.7. Some pump manufacturers issue design tables based on the assumption that system efficiency is always 0.6. However you may meet systems that use undersize pipes or ram pumps operated at the very top of their drive-flow range or their delivery head range, where system efficiency is as low as 0.3.

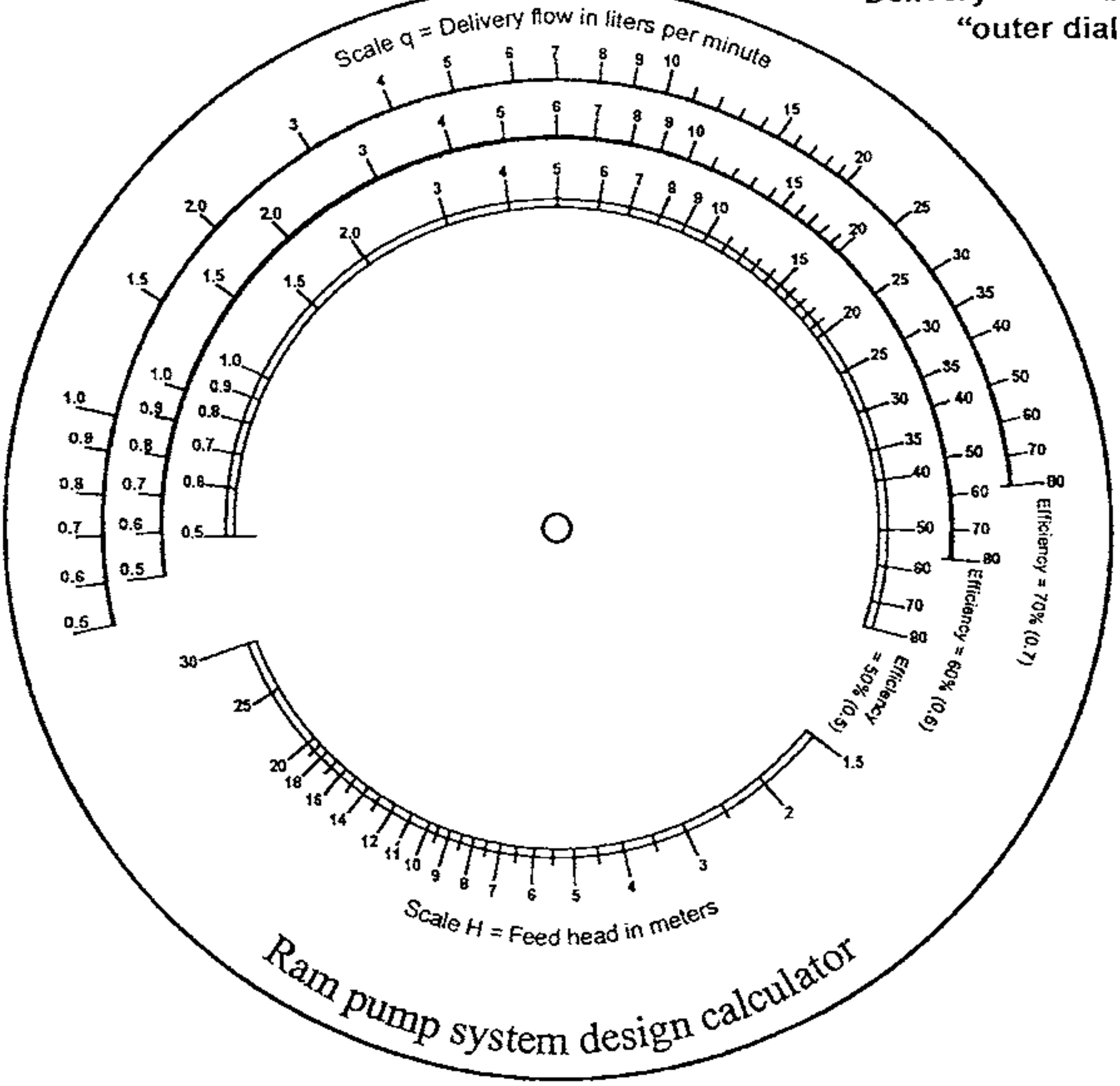
The *Friction Headloss Calculator* is based on an approximate formula because a more exact formula would be too complex to convert into a slide rule (which is what these cardboard calculators are). The flow in pipes in practical water systems is always highly turbulent. In the range of flows of interest to system designers it is safe to use the approximate turbulent flow formula:

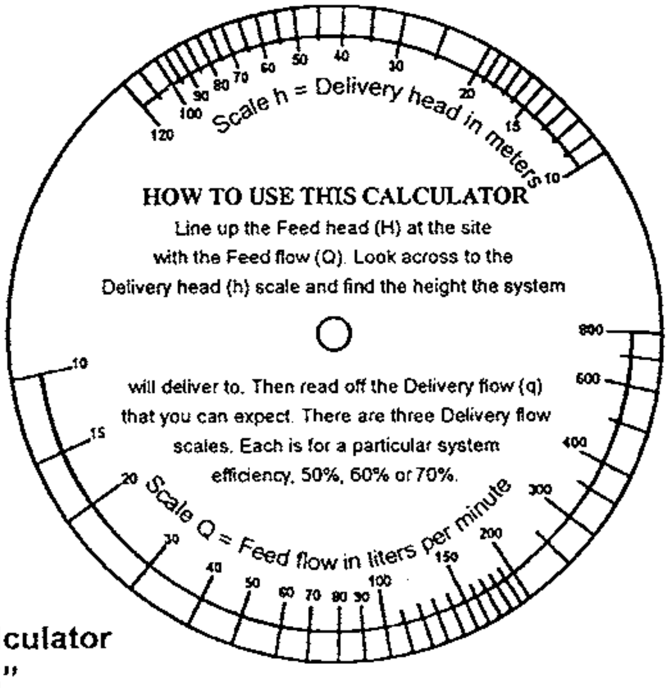
friction headloss = K x pipelength x flow $^{1.85}$ / internal diameter $^{4.9}$

If headloss and pipelength are measured in meters, diameter in mm and flow in litres per minute, then $K = 650$ for smooth plastic pipes and $K = 800$ for steel or GI pipes.

Headloss formulas are not very precise. The headloss may differ by +/-25% of the value predicted by the *Friction Headloss Calculator*. If you are using the calculator to predict flow in a pipe, you can expect to get within +/-10% of the actual value.

Delivery flow calculator
“outer dial”

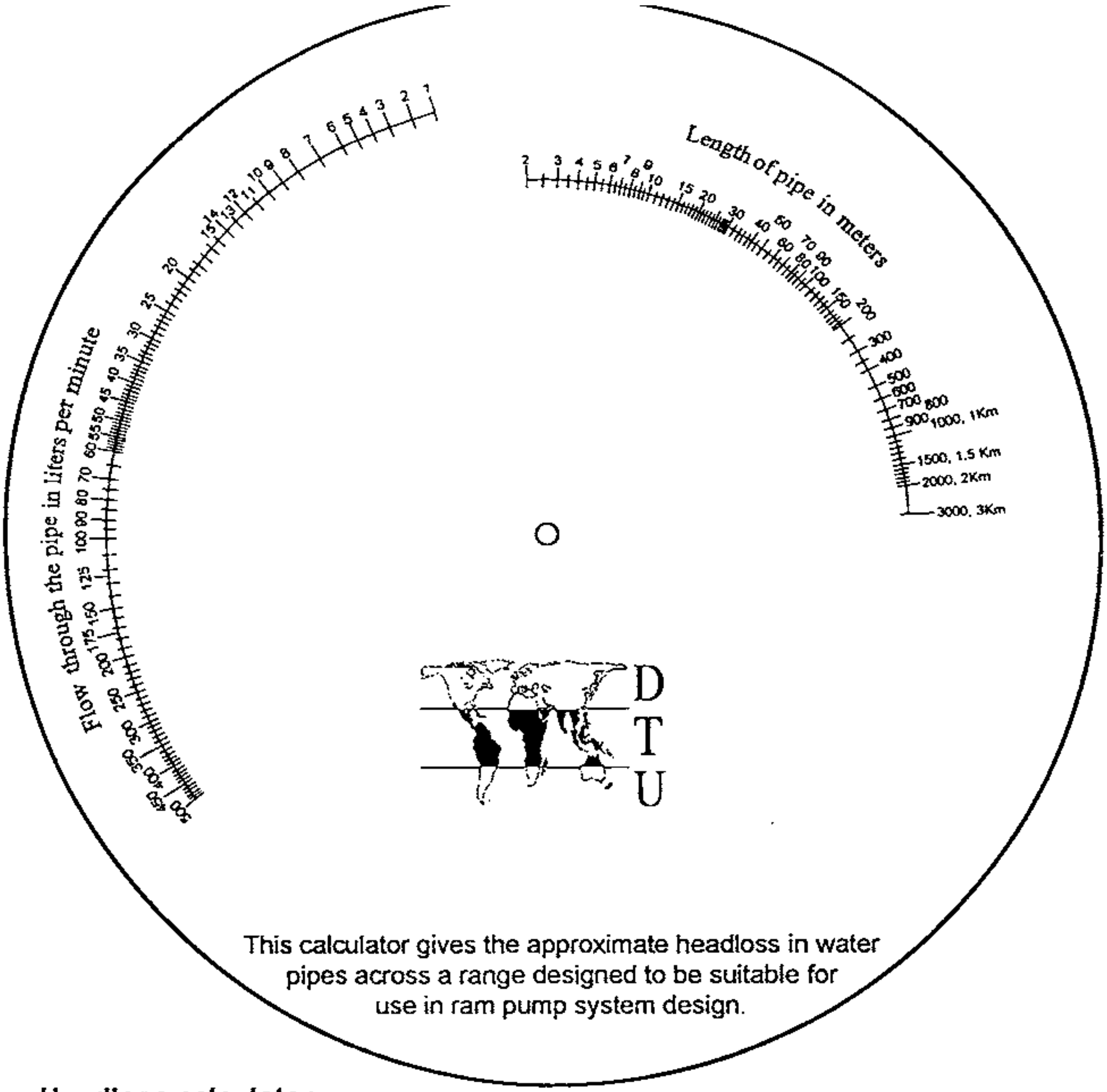




HOW TO USE THIS CALCULATOR

Line up the Feed head (H) at the site with the Feed flow (Q). Look across to the Delivery head (h) scale and find the height the system will deliver to. Then read off the Delivery flow (q) that you can expect. There are three Delivery flow scales. Each is for a particular system efficiency, 50%, 60% or 70%.

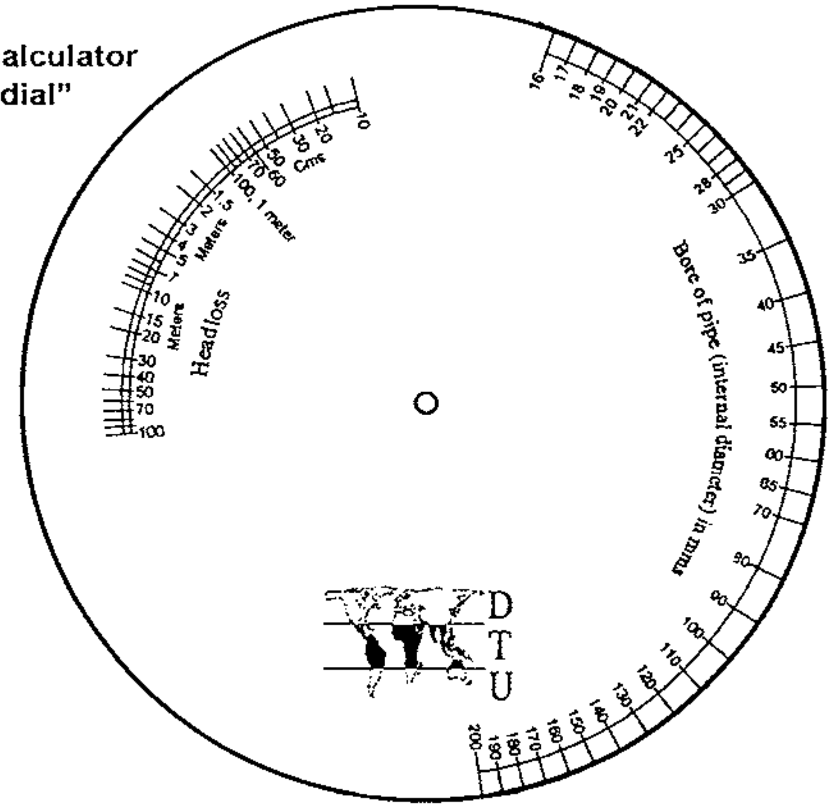
Delivery flow calculator
“inner dial”



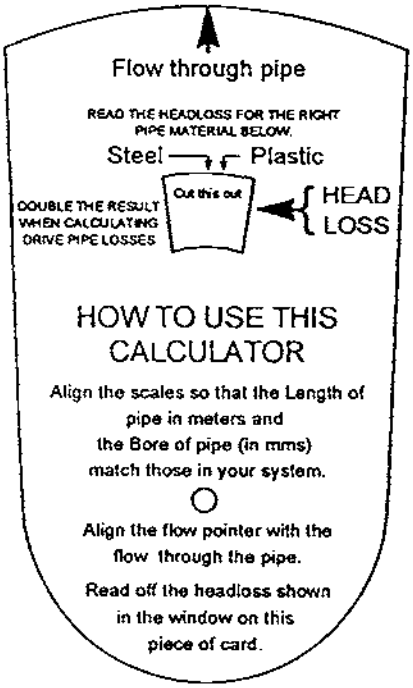
This calculator gives the approximate headloss in water pipes across a range designed to be suitable for use in ram pump system design.

Headloss calculator
"outer dial"

Headloss calculator
“inner dial”



Headloss calculator
“swinging arm”



READ THE HEADLOSS FOR THE RIGHT PIPE MATERIAL BELOW.

DOUBLE THE RESULT WHEN CALCULATING DRIVE PIPE LOSSES

HOW TO USE THIS CALCULATOR

Align the scales so that the Length of pipe in meters and the Bore of pipe (in mms) match those in your system.

Align the flow pointer with the flow through the pipe.

Read off the headloss shown in the window on this piece of card.