CLEMSON UNIVERSITY Cooperative Extension Service

Home-made Hydraulic Ram Pump

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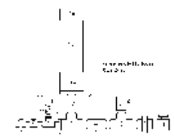
This information is provided as a service to those wanting to build their own hydraulic ram pump. The data from our experiences with one of these home-made hydraulic ram pumps is listed in Table 4 near the bottom of this document. The typical cost of fittings for an 1-1/4" pump is currently $120.00 (U.S.A.) regardless of whether galvanized or PVC fittings are used.



Click here to see a picture of an assembled ram pump

Table 1. Image Key

1	1-1/4" valve	10	1/4" pipe cock
2	1-1/4" tee	11	100 psi gauge
3	1-1/4" union	12	1-1/4" x 6" nipple
4	1-1/4" brass swing check valve (picture)	13	4" x 1-1/4" bushing
5	1-1/4" spring check valve	14	4" coupling
6	3/4" tee	15	4" x 24" PR160 PVC pipe
7	3/4" valve	16	4" PVC glue cap
8	3/4" union	17	3/4" x 1/4" bushing
9	1-1/4" x 3/4" bushing		

All connectors between the fittings are threaded pipe nipples - usually 2" in length or shorter. This pump can be made from PVC fittings or galvanized steel. In either case, it is recommended that the 4" diameter fittings be PVC fittings to conserve weight.

Conversion Note: 1" (1 inch) = 2.54 cm; 1 PSI (pound/square inch) = 6.895 KPa or 0.06895 bar; 1 gallon per minute = 3.78 liter per minute. PR160 PVC pipe is PVC pipe rated at 160 psi pressure.

Click here to see an image-by-image explanation of how a hydraulic ram pump works

Click here to see a short mpeg movie of an operating ram pump
*(**Note - this is a 6.2 mb movie clip**. On slower systems (11 mbps, etc.), it will load "piece-meal" the first time. Allow it to finish playing in this fashion, then press the play button again to see it in full motion with no "buffering" stops. Dial-up users may have to download the file to see it - simply right-click on the link, then select "Save Target As..." to save it to your computer. Downloading may take considerable time if you are on a slower dial-up system.)*

Assembly Notes:

Pressure Chamber - A bicycle or "scooter tire" inner tube is placed inside the pressure chamber (part 15) as an "air bladder" to prevent water-logging or air-logging. Inflate the tube until it is "spongy" when squeezed, then insert it in the chamber. It should not be inflated very tightly, but have some "give" to it. Note that water will absorb air over time, so the inner tube is used to help prevent much of this absorbtion. You may find it necessary, however, to drain the ram pump occasionally to allow more air into the chamber. *(The University of Warwick design (link below, pages 12-13) suggests the use of a "snifter" to allow air to be re-introduced to the ram during operation. Their design, however, is substantially different from the one offered here and provides a location (the branch of a tee) where the addition of a snifter is logical. This design does not. Also, correctly sizing the snifter valve (or hole as the case may be) can be problematical and may allow the addition of too much air, resulting in air in the drive pipe and ceasing of pumping operation. For these reasons we have elected not to include one in this design.)*

According to information provided by the University of Warwick (UK) (http://www.eng.warwick.ac.uk/dtu/pubs/tr/lift/rptr12/tr12.pdf , page 14), the pressure chamber should have a minimum volume of 20 times the expected delivery flow per "cycle" of the pump, with 50 times the expected delivery being a better selection. The chart below provides some recommended minimum pressure chamber sizes based on 50 times the expected delivery flow per "cycle." Note that larger pressure chambers will have not have any negative impact on the pump performance (other than perhaps requiring a little more time to initially start the pump). Some of the lengths indicated are quite excessive, so you may prefer to use two or three pipes connected together in parallel to provide the required pressure chamber volume. Well pump pressure tanks will also work well - just make sure they have at least the minimum volume required.

Table 2. Suggested Minimum Pressure Chamber Sizes
(Based on ram pumps operating at 60 cycles per minute.)

Drive Pipe Diameter (inches)	**Expected Flow Per Cycle** (gallons)	**Pressure Chamber Volume Required** (gallons)	**Length of Pipe Required for Pressure Chamber (for indicated pipe diameter)** (lengths are in inches)							
			2 inch	2-1/2 inch	3 inch	4 inch	6 inch	8 inch	10 inch	12 inch
3/4	0.0042	0.21	15	11	7	--	--	--	--	--
1	0.0125	0.63	45	32	21	--	--	--	--	--
1-1/4	0.020	1.0	72	51	33	19	--	--	--	--
1-1/2	0.030	1.5	105	74	48	27	--	--	--	--
2	0.067	3.4	--	170	110	62	27	16	--	--
2-1/2	0.09	4.5	--	230	148	85	37	22	14	--
3	0.15	7.5	--	--	245	140	61	36	23	16
4	0.30	15	--	--	--	280	122	72	45	32
6	0.80	40	--	--	--	--	325	190	122	85
8	1.60	80	--	--	--	--	--	380	242	170

(Note - it is quite difficult to push a partially-inflated 16 inch bicycle inner tube into a 3 inch PVC pipe. Due to this we suggest the pressure chamber be a minimum of 3 inches in diameter.)

A 4" threaded plug and 4" female adapter were originally used instead of the 4" glue-on cap shown in the image, This combination leaked regardless of how tightly it was tightened or how much teflon tape sealant was used, resulting in water-logging of the pressure chamber. This in turn dramatically increased the shock waves and could possibly have shortened pump life. If the bicycle tube should need to be serviced when using the glue cap design, the pipe may be cut in half then re-glued together using a coupling.

Valve Operation Descriptions - Valve #1 is the drive water inlet for the pump. Union #8 is the exit point for the pressurized water. Swing check valve #4 is also known as the "impetus" or "waste" valve - the extra drive water exits here during operation. The "impetus" valve is the valve that is operated manually at the beginning (by pushing it in with a finger) to charge the ram and start normal operation.

Valves #1 and #7 could be ball valves instead of gate valves. Ball valves may withstand the shock waves of the pump better over a long period of time.

The swing check valve (part 4 - also known as the impetus valve) *can* be adjusted to vary the length of stroke (please note that maximum flow and pressure head will be achieved with this valve positioned vertically, with the opening facing up). Turn the valve on the threads until the pin in the clapper hinge of the valve is in line with the pipe (instead of perpendicular to it). Then move the tee the valve is attached to slightly away from vertical, making sure the clapper hinge in the swing check is toward the top of the valve as you do this. The larger the angle from vertical, the shorter the stroke period (and the less potential pressure, since the water will not reach as high a velocity before shutting the valve). For maximum flow and pressure valve #4 should be in a vertical position (the outlet pointed straight up).

Swing check valve #4 should always be brass (or some metal) and not plastic. Experiences with plastic or PVC swing check valves have shown that the "flapper" or "clapper" in these valves is very light weight and therefore closes much earlier than the "flapper" of a comparable brass swing check. This in turn would mean lower flow rates and lower pressure heads.

The pipe cock (part 10) is in place to protect the gauge after the pump is started. It is turned off after the pump has been started and is operating normally. Turn it on if needed to check the outlet pressure, then turn it back off to protect the gauge.

Drive Pipe - The length of the drive pipe (from water source to pump) also affects the stroke period. A longer drive pipe provides a longer stroke period. There are maximum and minimum lengths for the drive pipe (see the paragraph below Table 2). The drive pipe is best made from galvanized steel (more rigid is better) but schedule 40 PVC can be used with good results. The more rigid galvanized pipe will result in a higher pumping efficiency and allow higher pumping heights. Rigidity of the drive pipe seems to be more important in this efficiency than straightness of the drive pipe.

Drive pipe length and size ratios are apparently based on empirical data. Information from University of Georgia publications (see footnote) provides an equation from Calvert (1958), which describes the output and stability of ram pump installations based on the ratio of the drive pipe length (L) to the drive pipe diameter (D). The best range is an L/D ratio of between 150 and 1000 (L/D = 150 to L/D = 1000). Equations to use to determine these lengths are:

Minimum inlet pipe length: L = 150 x (inlet pipe size)

Maximum inlet pipe length: L = 1000 x (inlet pipe size)

If the inlet pipe size is in inches, then the length (L) will also be presented in inches. If inlet pipe size is in mm, then L will be presented in mm.

Drive Pipe Length Example: If the drive pipe is 1-1/4 inches (1.25 inches) in diameter, then the minimum length should be L = 150 x 1.25 = 187.5 inches (or about 15.6 feet). The maximum length for the same 1-1/4 inch drive pipe would be L = 1000 x 1.25 = 1250 inches (104 feet). The drive pipe should be as rigid and as straight as possible.

Stand pipe or no stand pipe? Many hydraulic ram installations show a "stand pipe" installed on the inlet pipe. The purpose of this pipe is to allow the water hammer shock wave to dissipate at a given point. Stand pipes are only necessary if the inlet pipe will be longer than the recommended maximum length (for instance, in the previous example a stand pipe may be required if the inlet pipe were to be 150 feet in length, but the maximum inlet length was determined to be only 104 feet). The stand pipe - if needed - is generally placed in the line the same distance from the ram as the recommended maximum length indicated.

The stand pipe must be vertical and extend vertically at least 1 foot (0.3 meter) higher than the elevation of the water source - no water should exit the pipe during operation (or perhaps only a few drops during each shock wave cycle at most). Many recommendations suggest that the stand pipe should be 3 sizes larger than the inlet pipe. The supply pipe (between the stand pipe and the water source) should be 1 size larger than the inlet pipe.

The reason behind this is simple - if the inlet pipe is too long, the water hammer shock wave will travel farther, slowing down the pumping pulses of the ram. Also, in many instances there may actually be interference with the operation of the pump due to the length of travel of the shock wave. The stand pipe simply allows an outlet to the atmosphere to allow the shock wave to release or dissipate. Remember, the stand pipe is not necessary unless the inlet pipe will have to be longer than the recommended maximum length.

Another option would be to pipe the water to an open tank (with the top of the tank at least 1 foot (0.3 meter) higher than the vertical elevation of the water source), then attach the inlet pipe to the tank. The tank will act as a dissipation chamber for the water hammer shock wave just as the stand pipe would. This option may not be viable if the tank placement would require some sort of tower, but if the topography allows this may be a more attractive option.

Click here to view sketches of these types of hydraulic ram pump installations
(loads in 70 seconds over 28.8 modem)

Operation:

The pump will require some back pressure to begin working. A back pressure of 10 psi or more should be sufficient. If this is not provided by elevation-induced back pressure from pumping the water uphill to the delivery point (water trough, etc.), use the 3/4" valve (part 7) to throttle the flow somewhat to provide this backpressure.

As an alternative to throttling valve part 7 you may consider running the outlet pipe into the air in a loop, and then back down to the trough to provide the necessary back pressure. A total of 23 feet of vertical elevation above the pump outlet should be sufficient to provide the necessary back pressure. This may not be practical in all cases, but adding 8 feet of pipe after piping up a hill of 15 feet in elevation should not be a major problem. This will allow you to open valve #7 completely, preventing stoppage of flow by trash or sediment blocking the partially-closed valve. It is a good idea to include a tee at the outlet of the pump with a ball valve to allow periodic "flushing" of the sediment just in case.

The pump will have to be manually started several times when first placed in operation to remove the air from the ram pump piping. Start the pump by opening valve 1 and leaving valve 7 closed. Then, when the swing check (#4) shuts, manually push it open again. (The pump will start with valve 7 closed completely, pumping up to some maximum pressure before stopping operation.) After the pump begins operation, slowly open valve 7, but do not allow the discharge pressure (shown on gauge #11) to drop below 10 psi. You may have to push valve #4 open repeatedly to re-start the pump in the first few minutes (10 to 20 times is not abnormal) - air in the system will stop operation until it is purged.

The unions, gate (or ball) valves, and pressure gauge assembly are not absolutely required to make the pump run, but they sure do help in installing, removing, and starting the pump as well as regulating the flow.

Pump Performance:

Some information suggests that typical ram pumps discharge approximately 7 gallons of water through the waste valve for every gallon pressurized and pumped. The percentage of the drive water delivered actually varies based on the ram construction, vertical fall to pump, and elevation to the water outlet. The percentage of the drive water pumped to the desired point may be approximately 22% when the vertical fall from the water source to the pump is half of the elevation lift from the ram to the water outlet. It may be as low as 2% or less when the vertical fall from the water source to the pump is 4% of the elevation lift from the ram to the water outlet. Rife Hydraulic Engine Manufacturing Company literature (http://www.riferam.com/) offers the following equation:

$$0.6 \times Q \times F/E = D$$

Q is the available drive flow in gallons per minute, F is the fall in feet from the water source to the ram, E is the elevation from the ram to the water outlet, and D is the flow rate of the delivery water in gallons per minute. 0.6 is an efficiency factor and will differ somewhat between various ram pumps. For instance, if 12 gallons per minute is available to operate a ram pump (D), the pump is placed 6 feet below the water source (F), and the water will be pumped up an elevation of 20 feet to the outlet point (E), the amount of water that may be pumped with an appropriately-sized ram pump is

$$0.6 \times 12 \text{ gpm} \times 6 \text{ ft} / 20 \text{ ft} = 2.16 \text{ gpm}$$

The same pump with the same drive flow will provide less flow if the water is to be pumped up a higher elevation. For instance, using the data in the previous example but increasing the elevation lift to 40 feet (E):

$$0.6 \times 12 \text{ gpm} \times 6 \text{ ft} / 40 \text{ ft} = 1.08 \text{ gpm}$$

Table 3. Typical Hydraulic Ram specifications *(Expected water output will be approximately 1/8 of the input flow, but will vary with installation fall (F) and elevation lift (E) as noted above. This chart is based on 5 feet of lift (E) per 1 foot of fall (F).)*

Drive Pipe Diameter (inches)	**Delivery Pipe Diameter** (inches)	**At Minimum Inflow**		**At Maximum Inflow**	
		Pump Inflow (gallons per minute)	**Expected Output** (gallons per minute)	**Pump Inflow** (gallons per minute)	**Expected Output** (gallons per minute)
3/4	1/2	3/4	1/10	2	1/4
1	1/2	1-1/2	1/5	6	3/4
1-1/4	1/2	2	1/4	10	1-1/5
1-1/2	3/4	2-1/2	3/10	15	1-3/4
2	1	3	3/8	33	4
2-1/2	1-1/4	12	1-1/2	45	5-2/5
3	1-1/2	20	2-1/2	75	9
4	2	30	3-5/8	150	18
6	3	75	9	400	48

8	4	400	48	800	96

Table 4. Test Installation Information

Drive Pipe Size	1-1/4 inch Schedule 40 PVC
Outlet Pipe Size	3/4 inch Schedule 40 PVC
Pressure Chamber size	4 inch PR160 PVC
Pressure Chamber Length	36 inches
Inlet Pipe Length	100 feet
Outlet Pipe Length	40 feet
Drive Water (Inlet) elevation above pump	4 feet
Elevation from pump outlet to delivery outlet	12 feet

Click here to see pictures of the test installation (loads in 38 seconds over 28.8 modem)

Table 5. Trial 1 Performance Data

	Expected Performance	At Installation (5/17/99)	After Installation (with water-log) (5/21/99)	After Clearing Water-log (6/20/99)
Shutoff Head	5 to 17 psi	22 psi	50 psi	22 psi
Operating Head	10 psi	10 psi	10 psi	10 psi
Operating Flow Rate	0.50 to 1.00 gpm	0.28 gpm	1.50 gpm	0.33 gpm

Note that we used a 4" threaded plug and a 4" female adapter for our test pump (instead of the recommended 4" glue cap (#16) shown in the figure). Two days after installation the pump air chamber was effectively water-logged due to leakage past the threads of these two fittings, which was shown by the pronounced impulse pumping at the outlet discharge point. If the pump were allowed to remain waterlogged, it would shortly cease to operate - and may introduce damage to the pipe or other components due to pronounced water hammer pressure surges.

The large range of expected values for shutoff head is due to the unknown efficiency of the pump. Typical efficiencies for ram pumps range from 3 feet to 10 feet of lift for every 1 foot of elevation drop from the water inlet to the pump.

Hydraulic Ram Web Sites

Bamford Pumps
CAT Hydraulic Ram Tipsheet
Green and Carter
Lifewater Rams
NC State's EBAE 161-92, "Hydraulic Ram Pumps"
RamPumps.com
Rife Rams
Schott Solar Electric
University of Warwick (UK) Ram Pump Publications
University of Warwick (UK) Ram pump system design notes

Some information for this web page - and the initial information concerning construction of a home-made hydraulic ram pump - was provided by University of Georgia Extension publications #ENG98-002 and #ENG98-003 (both Acrobat "pdf" files) by Frank Henning. Publication #ENG98-002 also describes the pumping volume equations for hydraulic ram pumps.

Irrigation Home

Last modified on 10/15/07
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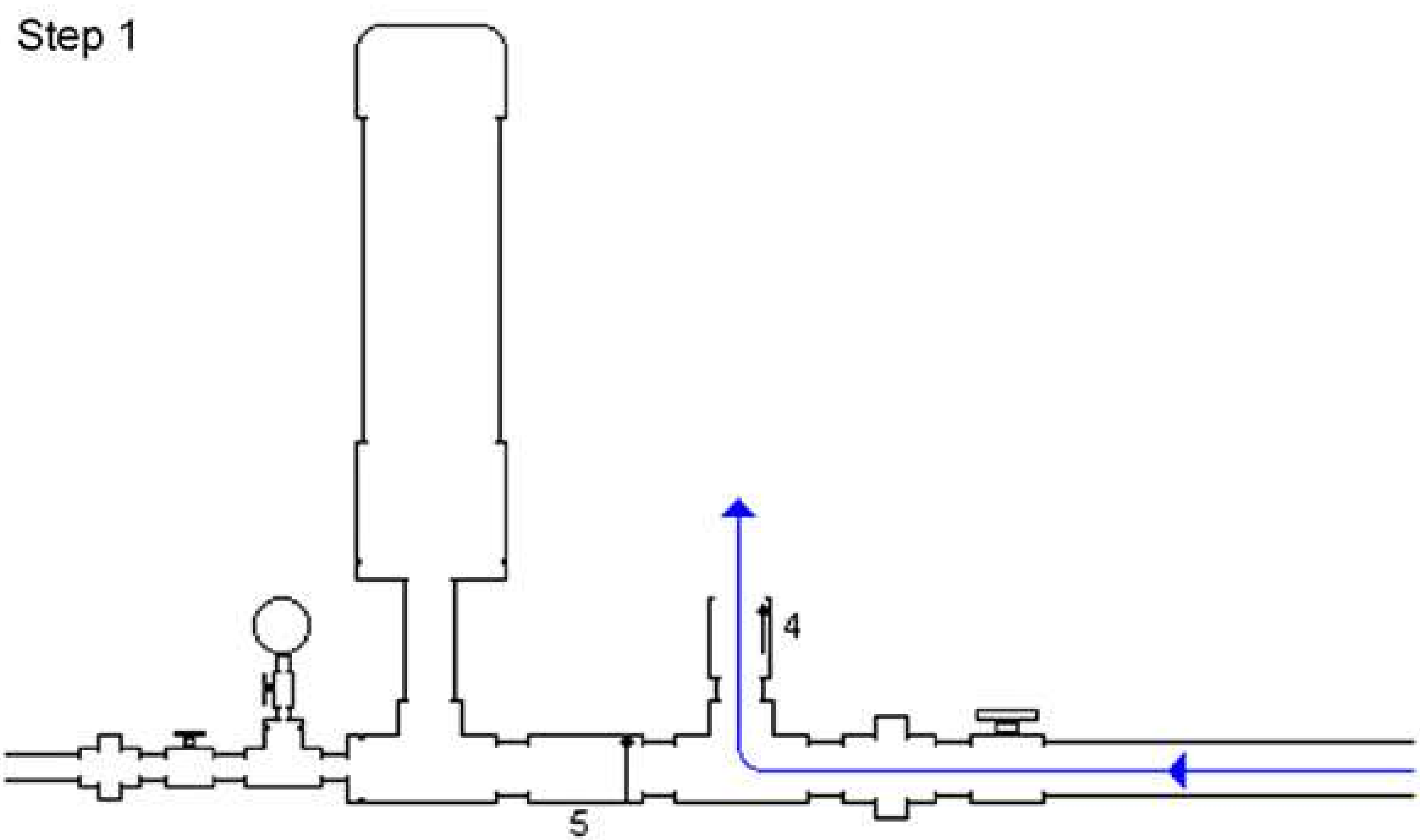
CLEMSON UNIVERSITY Cooperative Extension Service

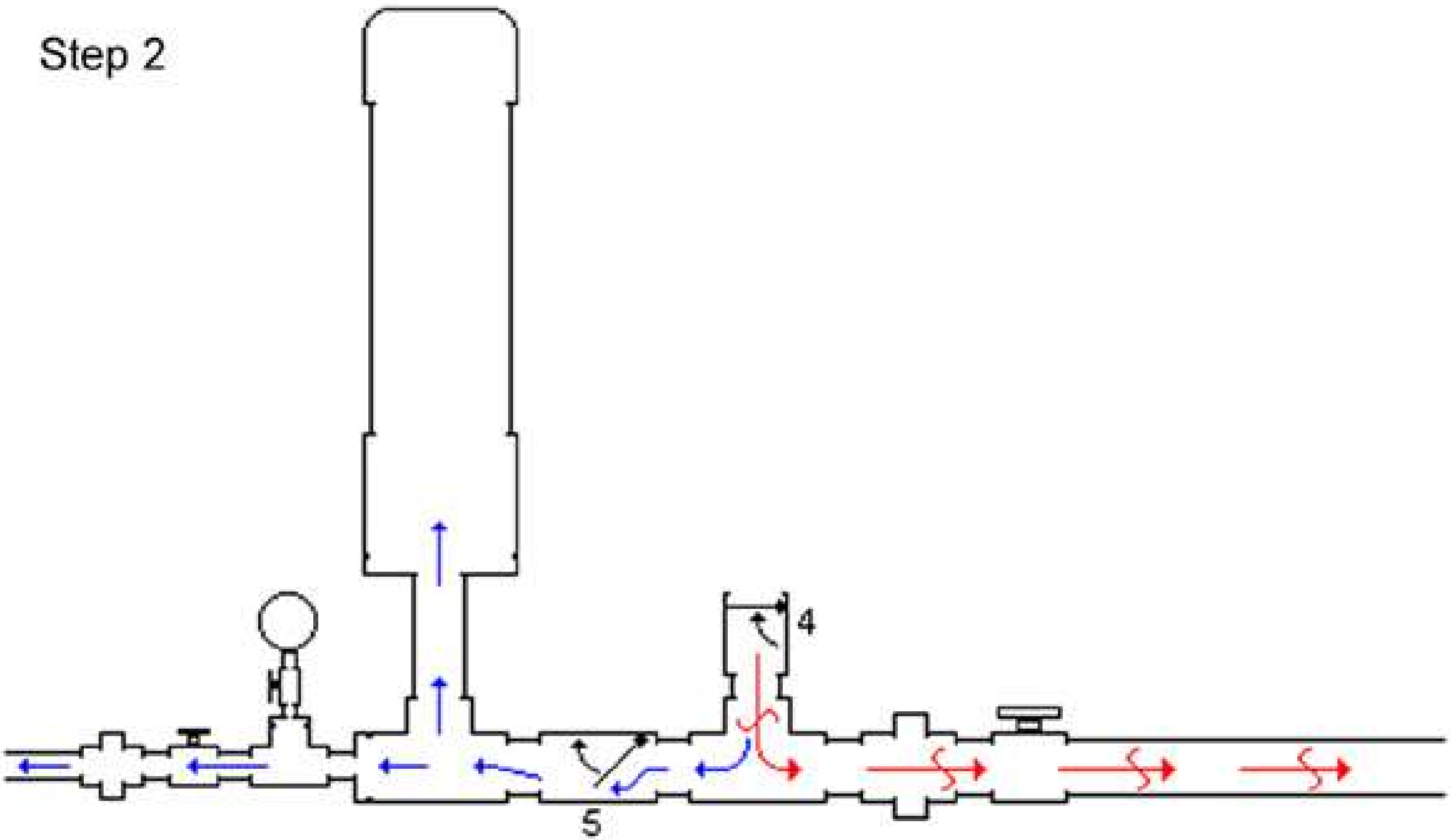
How a Hydraulic Ram Pump works

The concept behind the ram idea is a "water hammer" shock wave. Water has weight, so a volume of water moving at a certain speed has momentum - it doesn't want to stop immediately. If a car runs into a brick wall the result is crumpled metal. If a moving water flow in a pipe encounters a suddenly closed valve, a pressure "spike" or increase suddenly appears due to all the water being stopped abruptly (that's what water hammer is - the pressure spike). If you turn a valve off in your house quickly, you may hear a small "thump" in the pipes. That's water hammer.

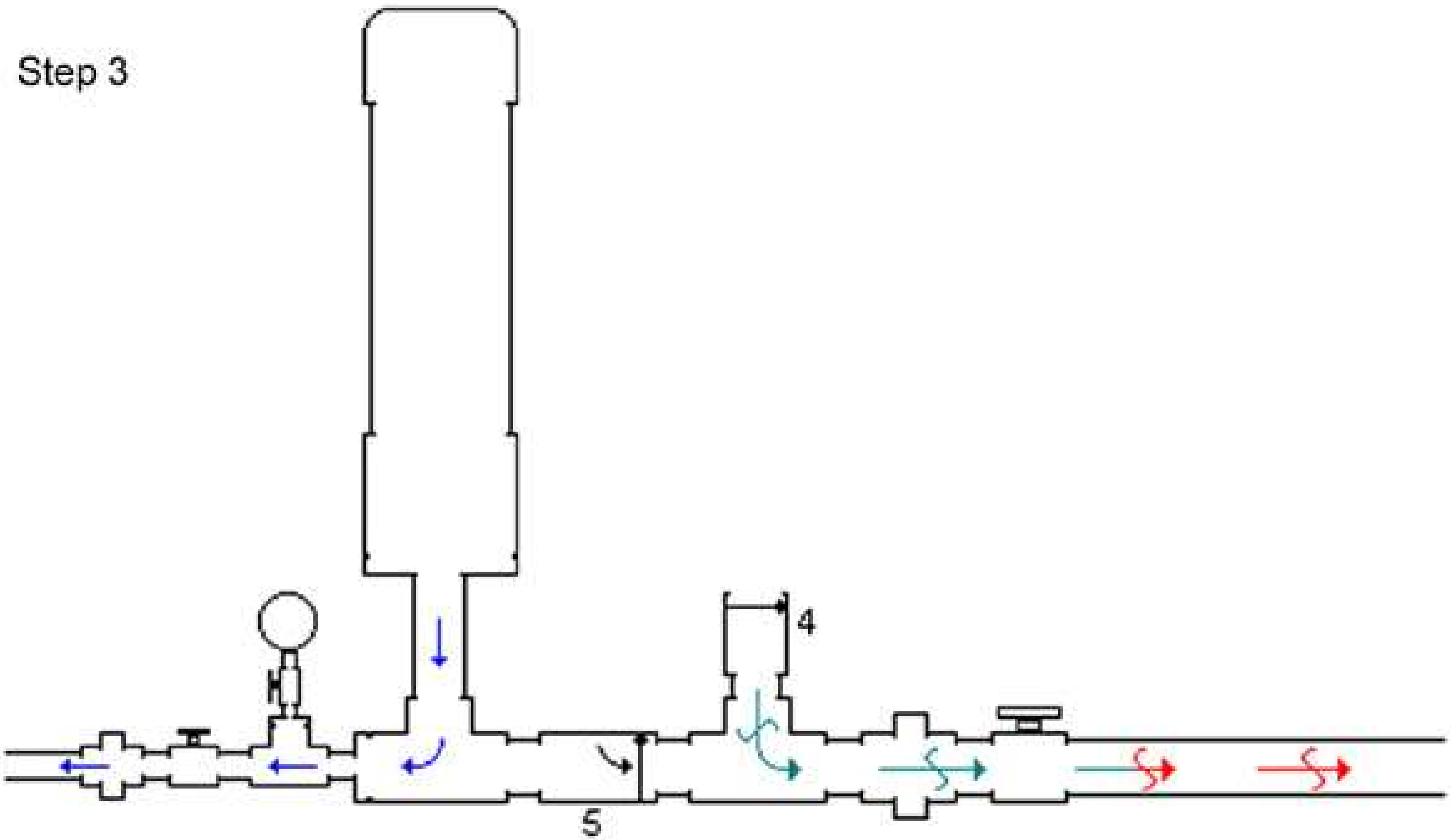
Here's how the hydraulic ram pump actually works, step-by-step:



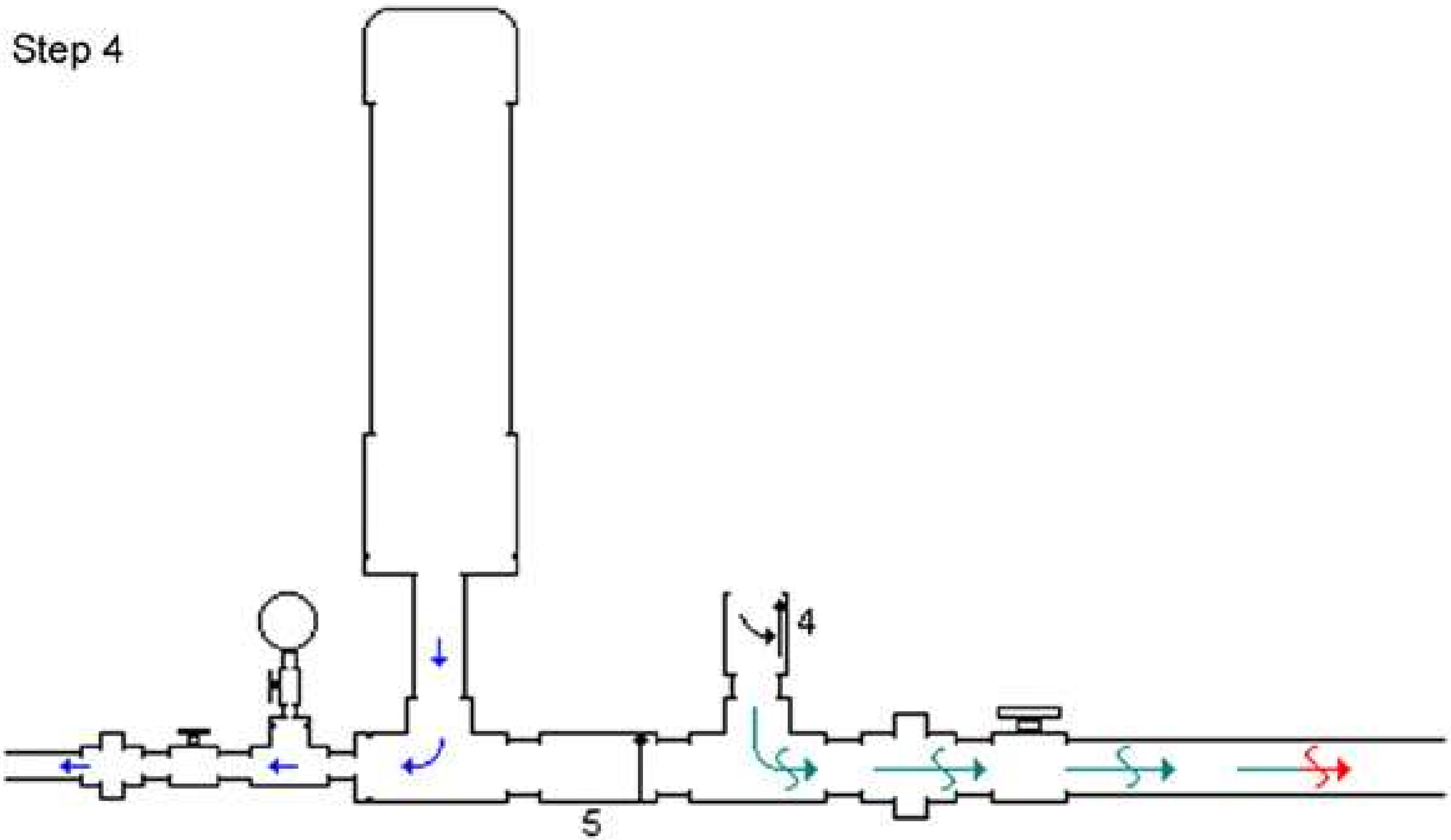
(1) Water (blue arrows) starts flowing through the drive pipe and out of the "waste" valve (#4 on the diagram), which is open initially. Water flows faster and faster through the pipe and out of the valve. (Click here to see an actual image of an operating ram pump for this step.)



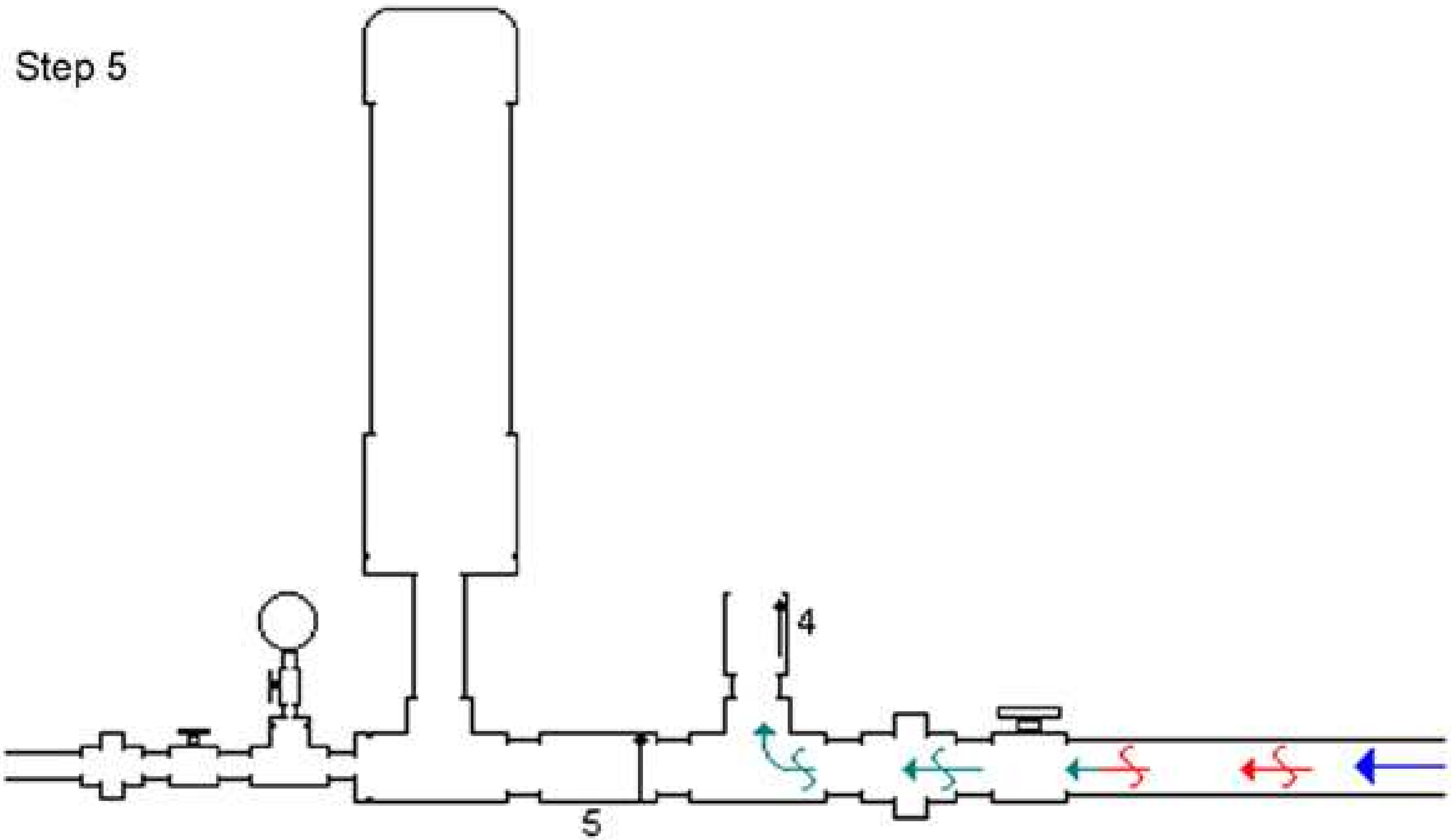
(2) At some point, water is moving so quickly through the brass swing check "waste" valve (#4) that it grabs the swing check's flapper, pulling it up and slamming it shut. The water in the pipe is moving quickly and doesn't want to stop. All that water weight and momentum is stopped, though, by the valve slamming shut. That makes a high pressure spike (red arrows) at the closed valve. The high pressure spike forces some water (blue arrows) through the spring check valve (#5 on the diagram) and into the pressure chamber. This increases the pressure in that chamber slightly. The pressure "spike" the pipe has nowhere else to go, so it begins moving away from the waste valve and back up the pipe (red arrows). It actually generates a very small velocity *backward* in the pipe. (Click here to see an actual image of an operating ram pump for this step. Note the drops of water still falling to the ground in the image.)



(3) As the pressure wave or spike (red arrows) moves back up the pipe, it creates a lower pressure situation (green arrows) at the waste valve. The spring-loaded check valve (#5) closes as the pressure drops, retaining the pressure in the pressure chamber.



(4) At some point this pressure (green arrows) becomes low enough that the flapper in the waste valve (#4) falls back down, opening the waste valve again. (Click here to see an actual image of a ram pump for this step.)



(5) Most of the water hammer high pressure shock wave (red arrows) will release at the drive pipe inlet, which is open to the source water body. Some small portion *may* travel back down the drive pipe, but in any case after the shock wave has released, pressure begins to build again at the waste valve (#4) simply due to the elevation of the source water above the ram, and water begins to flow toward the hydraulic ram again.

(6) Water begins to flow out of the waste valve (#4), and the process starts over once again.

Steps 1 through 6 describe in layman's terms a complete cycle of a hydraulic ram pump. Pressure wave theory will explain the technical details of why a hydraulic ram pump works, but we only need to know it works. (One American company has been manufacturing and selling hydraulic rams since the 1880's). The ram pump will usually go through this cycle about once a second, perhaps somewhat more quickly or more slowly depending on the installation.

Each "pulse" or cycle pushes a little more pressure into the pressure chamber. If the outlet valve is left shut, the ram will build up to some maximum pressure (called shutoff head on pumps) and stop working.

The ram is quite inefficient. Usually 8 gallons of water must pass through the waste valve for each 1 gallon of water pumped by the ram. That is acceptable for a creek or river situation, but may not be a good option for a pond that does not have a good spring flow.

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DTU

Ram Pump Programme

DTU P90 PUMP

TECHNICAL
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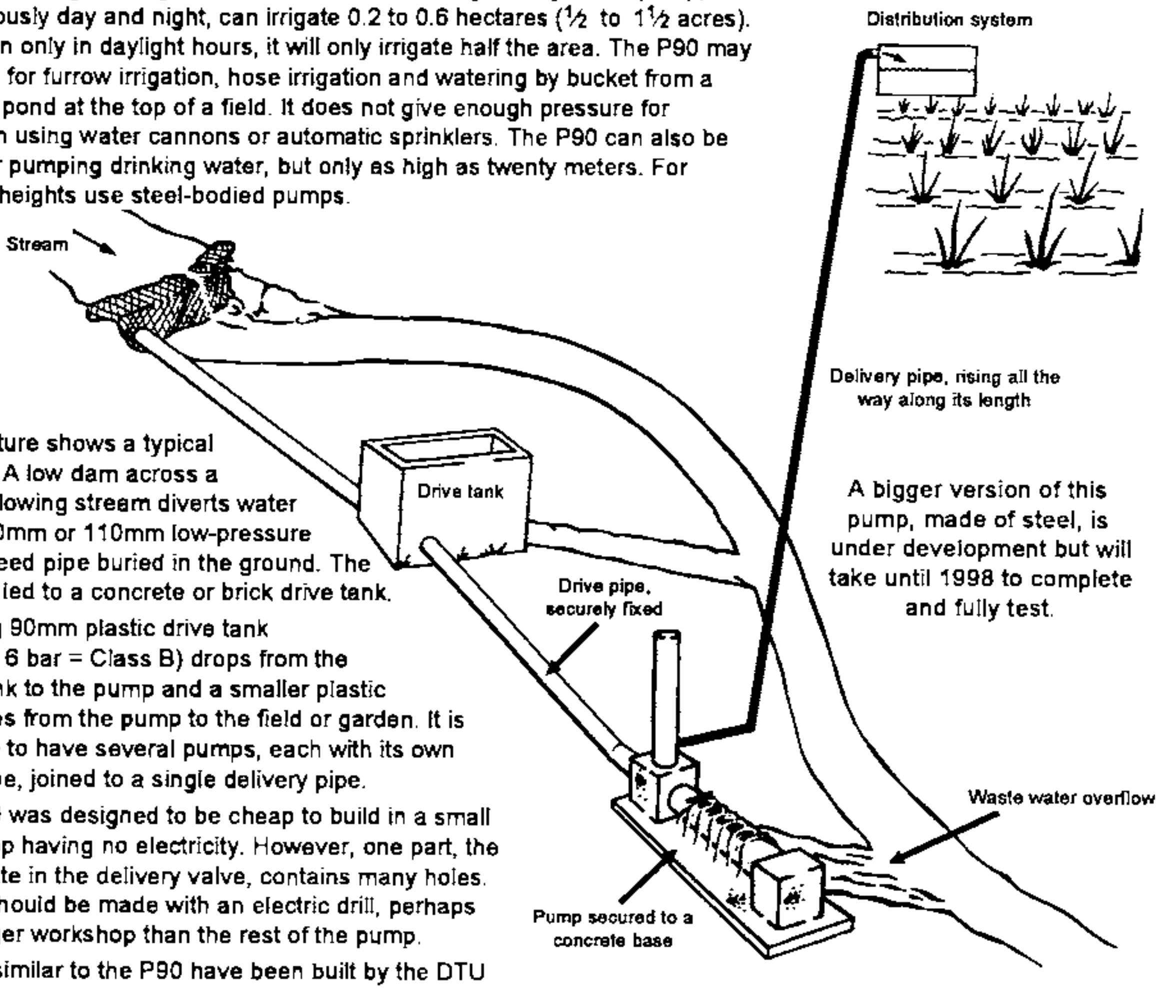
RELEASE

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.



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

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.

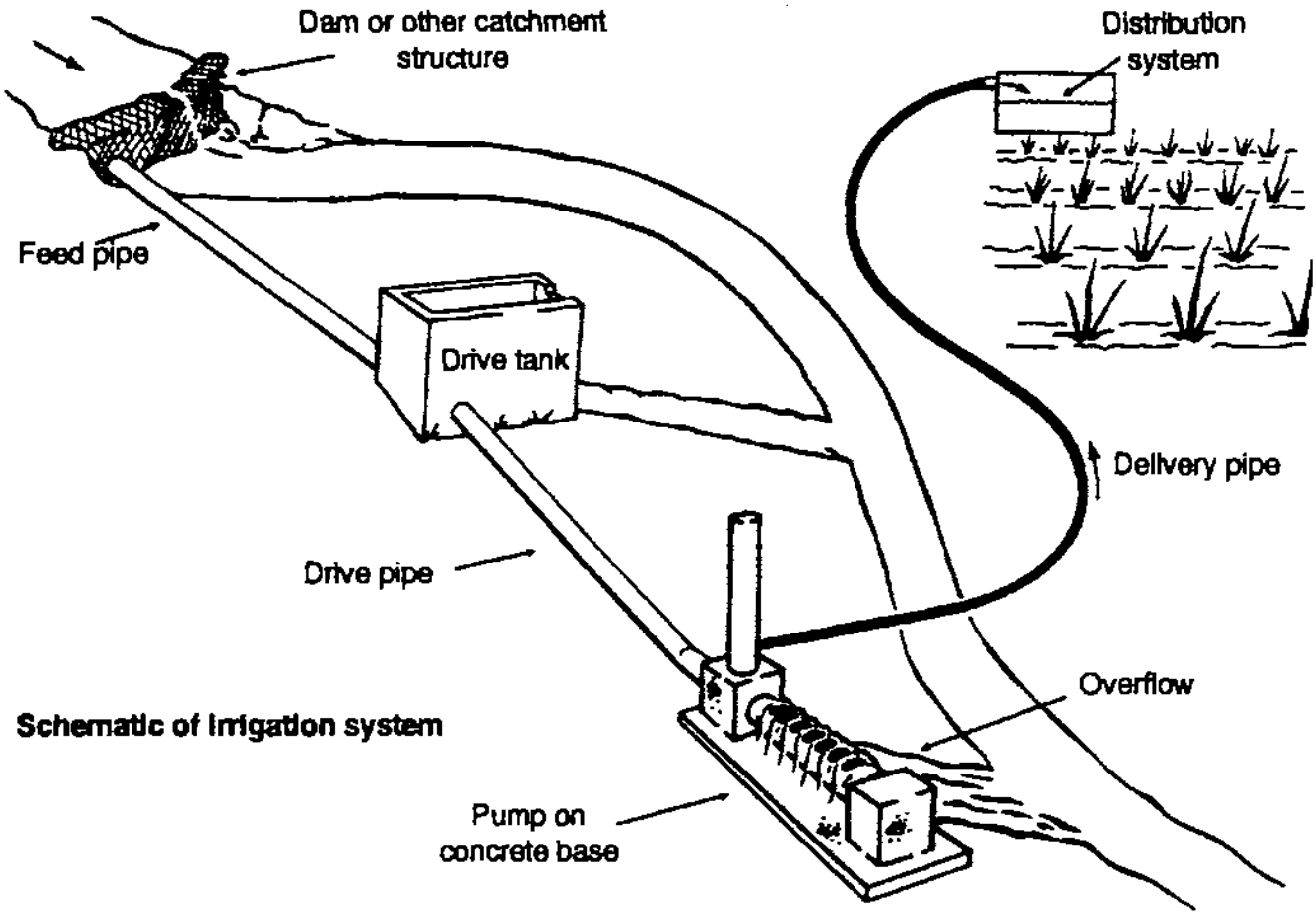
DTU P90 ram pump specifications

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

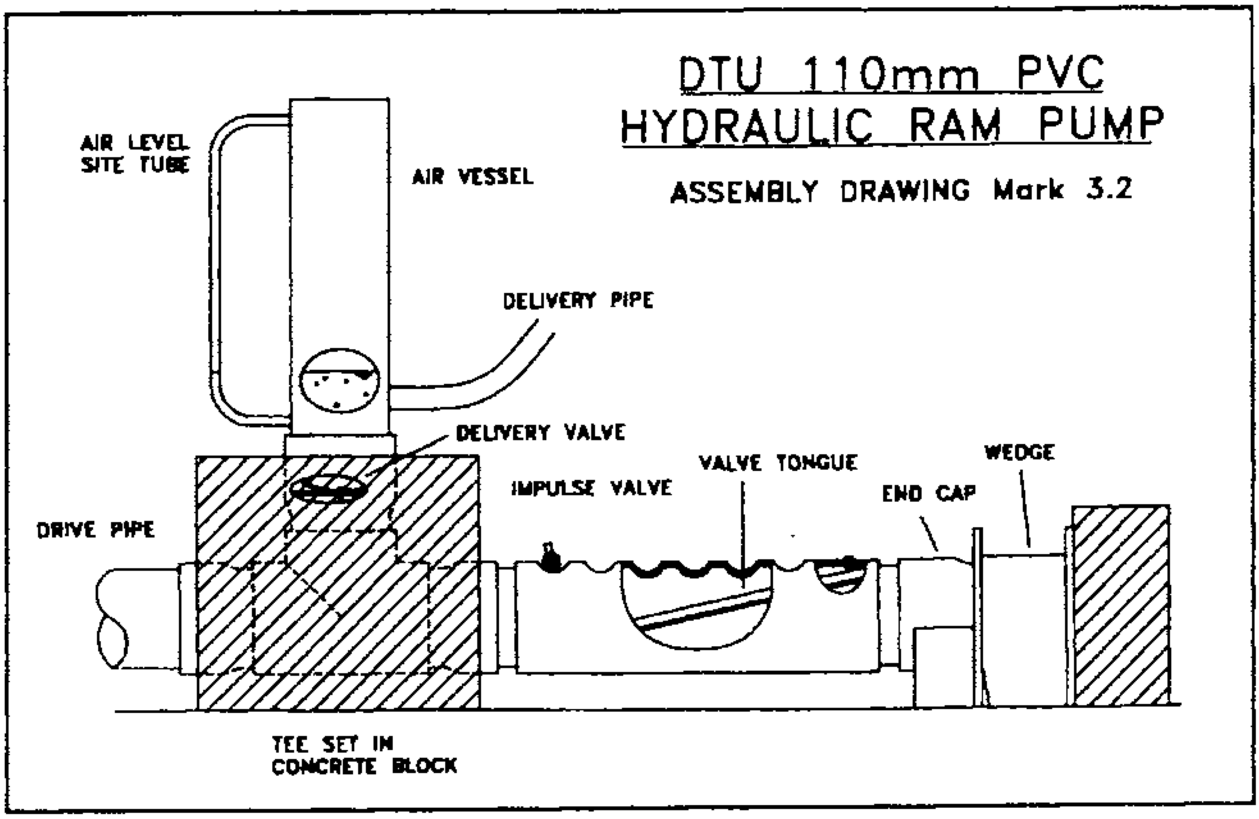
The DTU plastic irrigation pump

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.



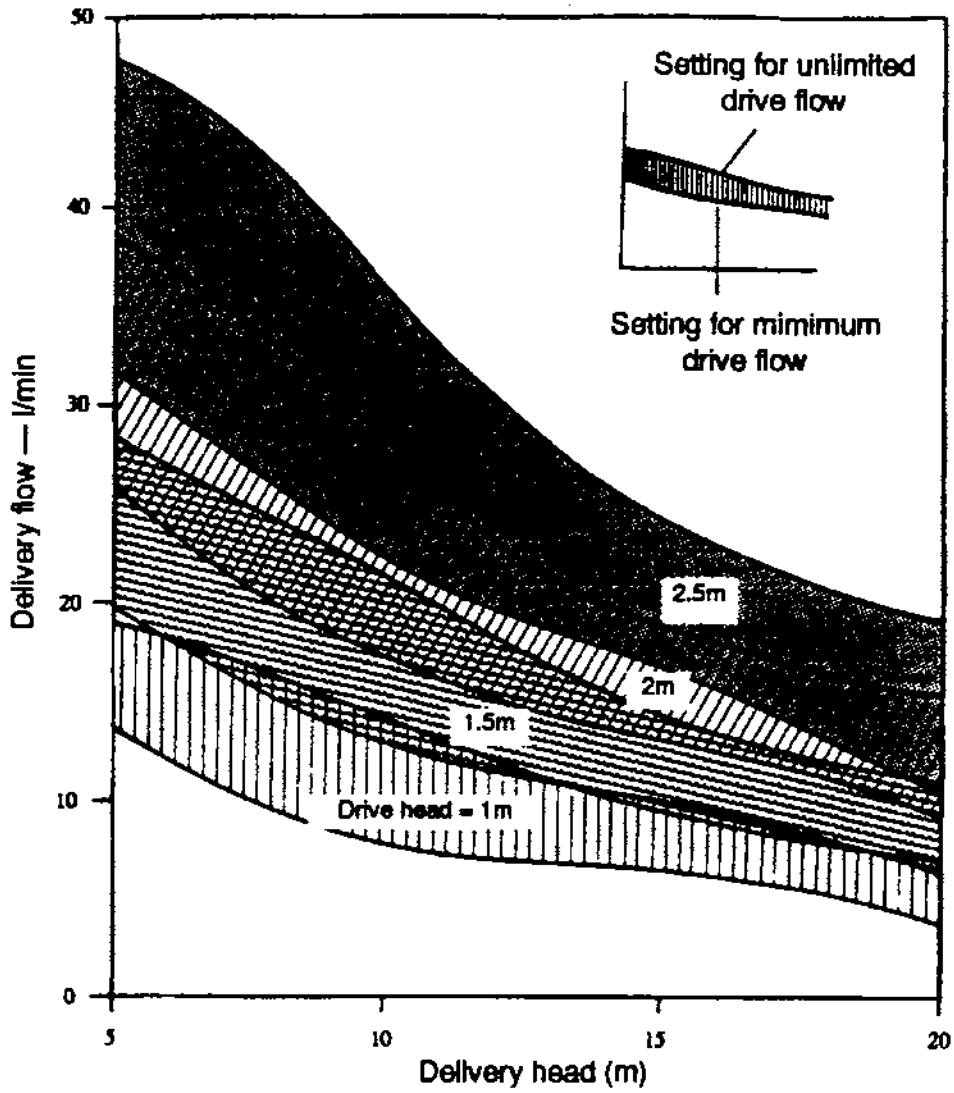
The DTU pump has the following specification:

- 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.

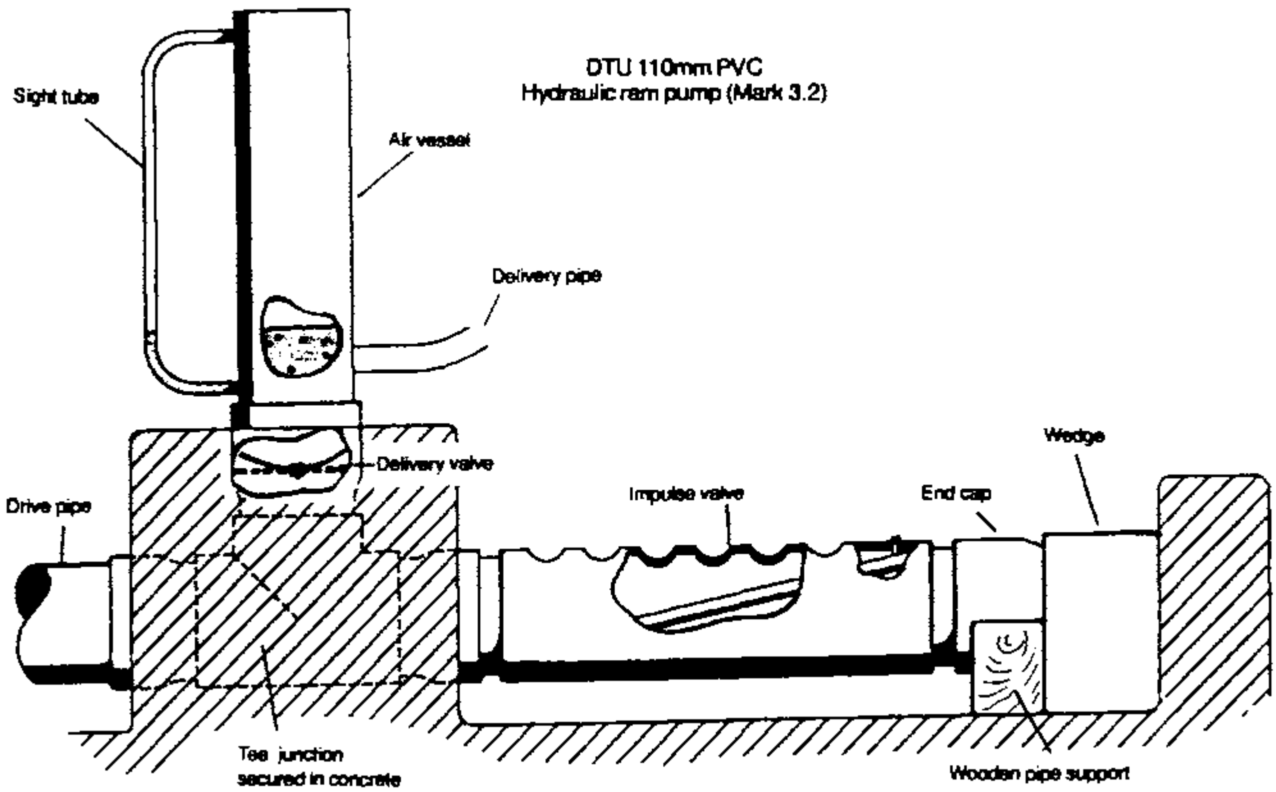
Pump designs have been developed over a number of years with increasing performance and component life. Plastic pipe is more prone to fatigue failure than steel, reducing the life of some components to two years. The current design has been extensively tested in Zimbabwe but is still (1993) at the proving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

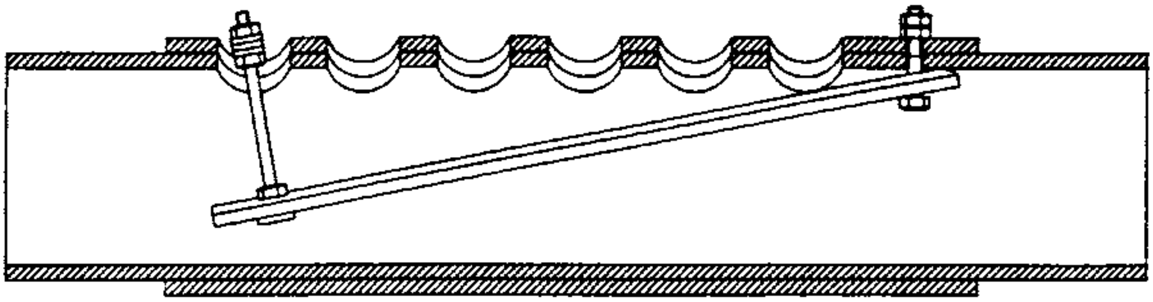
Plastic ram pumps can provide a cheap and simple means of supplying water to elevations of less than 15m. The scale of flow produced and the limitations on their pumping head make them ideal for local manufacture and use for small scale irrigation in developing countries.

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.

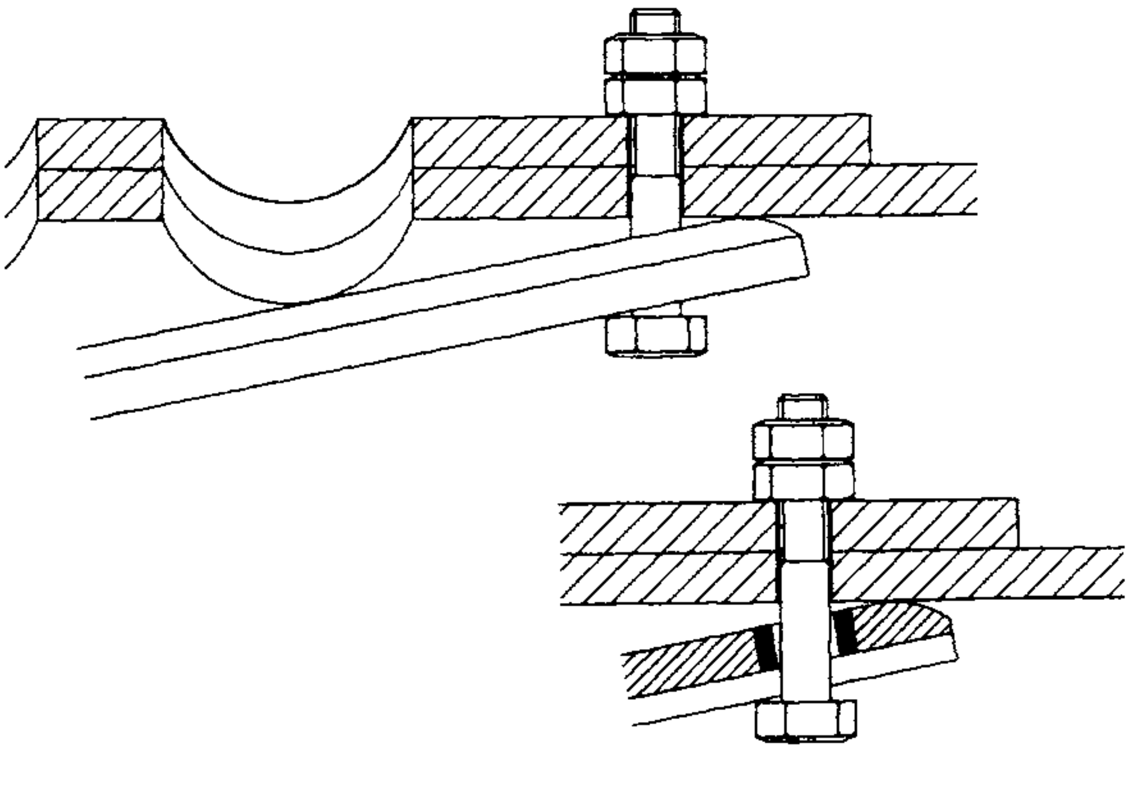


Diagram showing hinge arrangement of impulse valve tongue

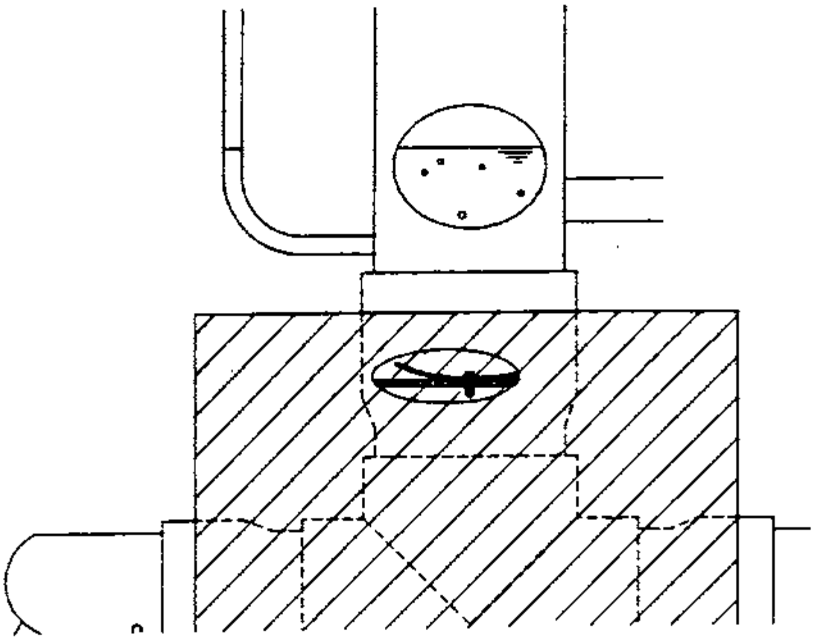
Delivery Valve Design

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.

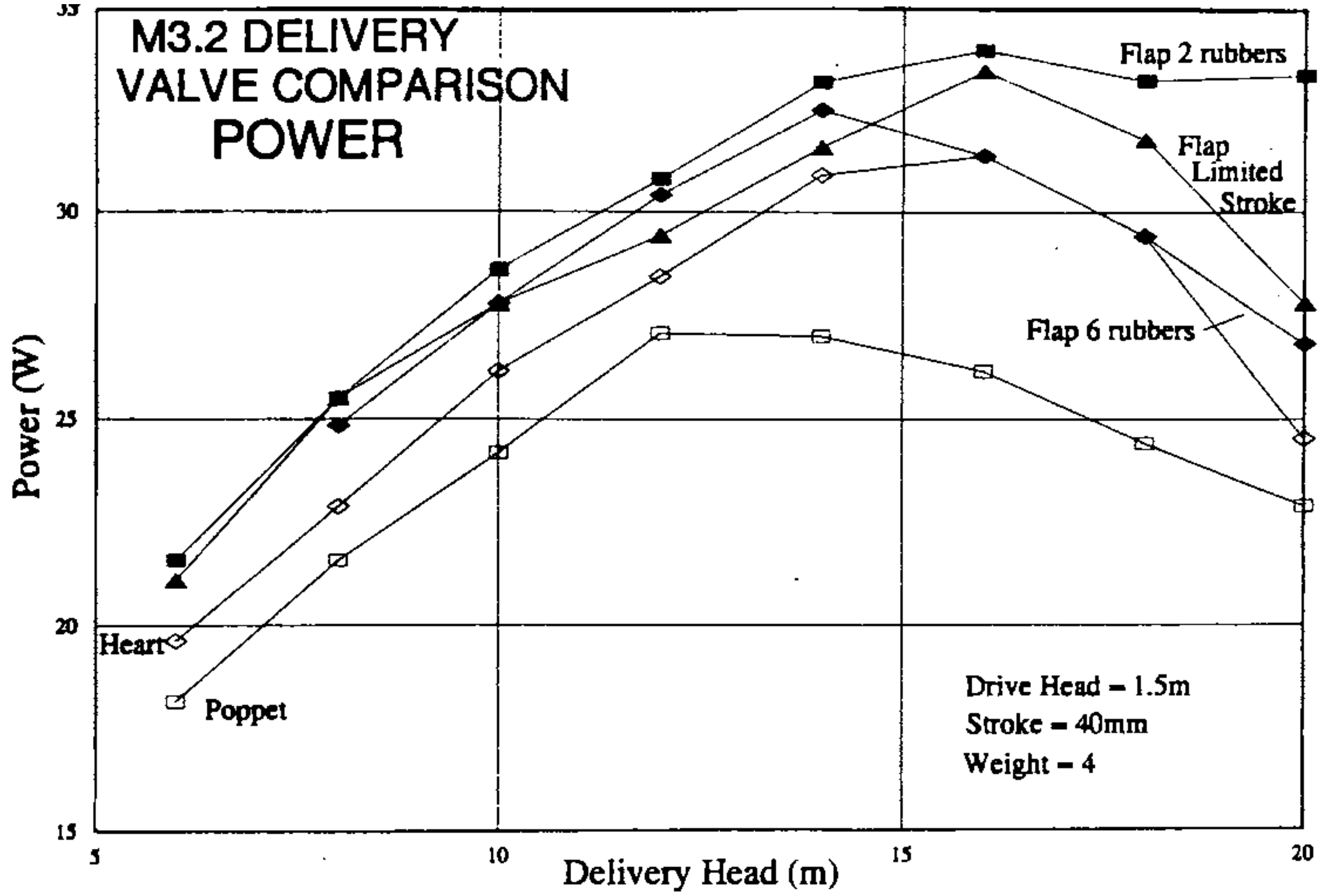
3) be cheap and simple to manufacture.

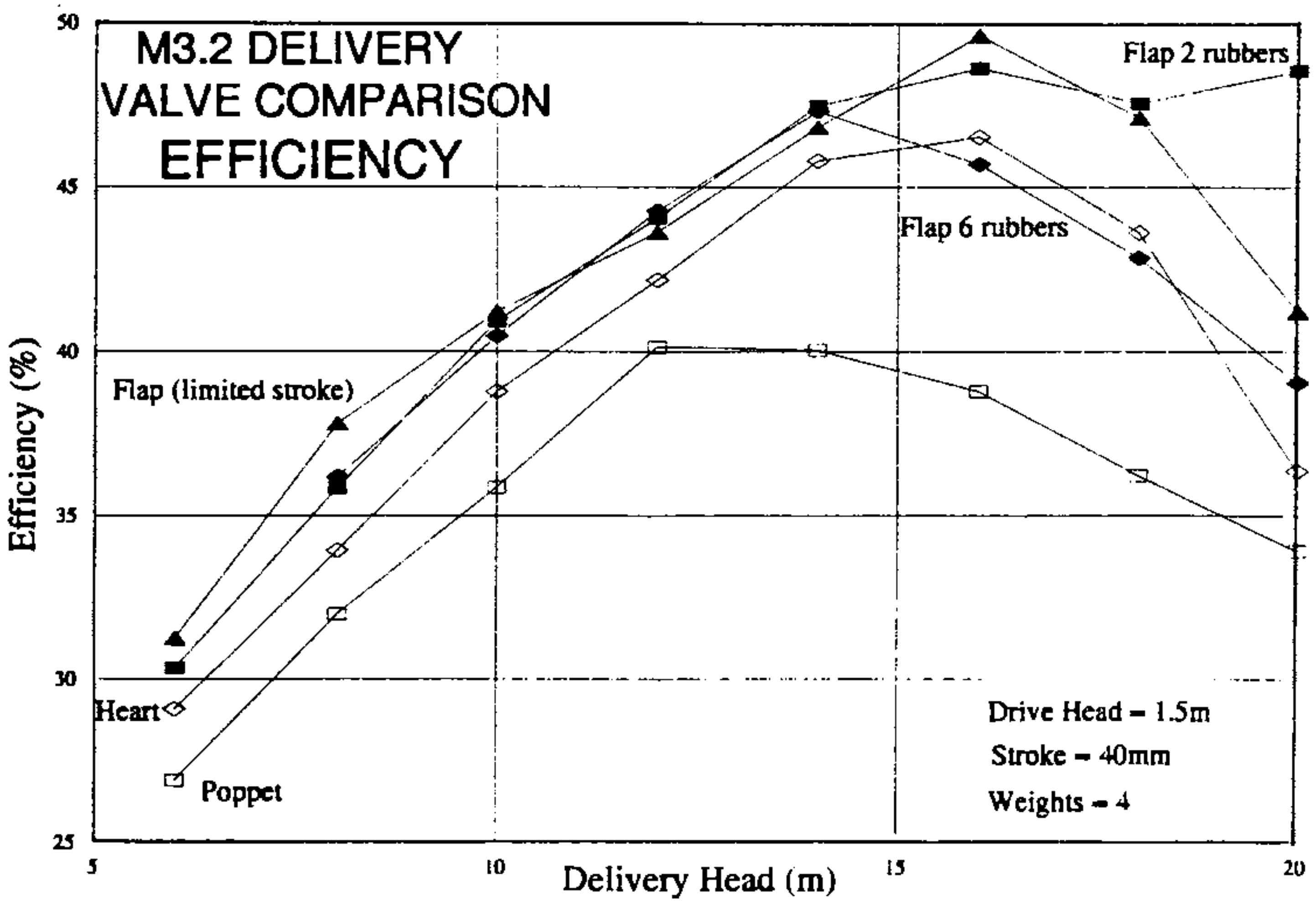


Position of the Delivery Valve

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


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

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.

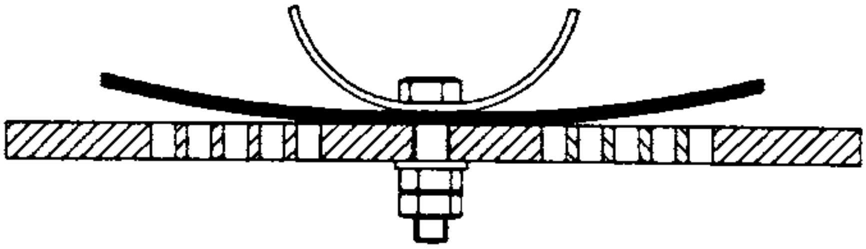


Diagram showing curved washer used in delivery valve.

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.

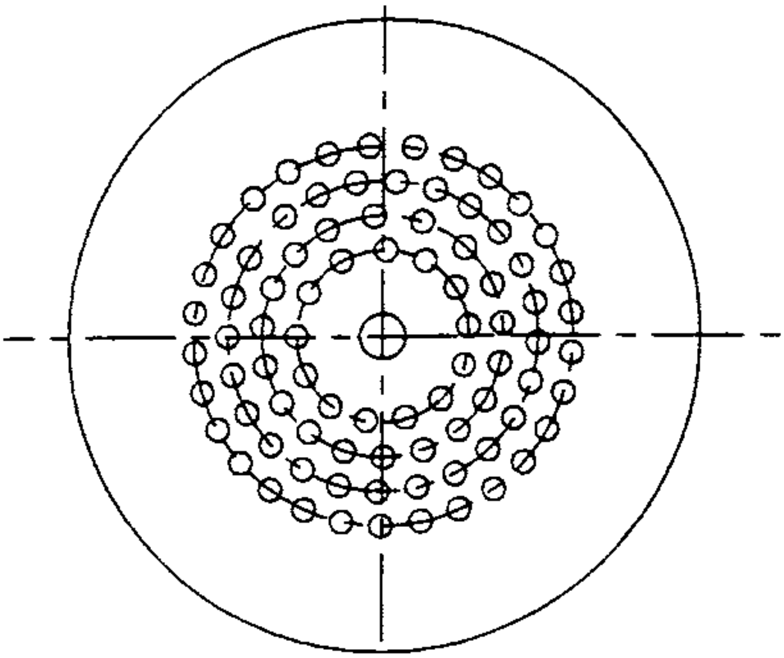


Diagram showing arrangement of delivery valve holes

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.

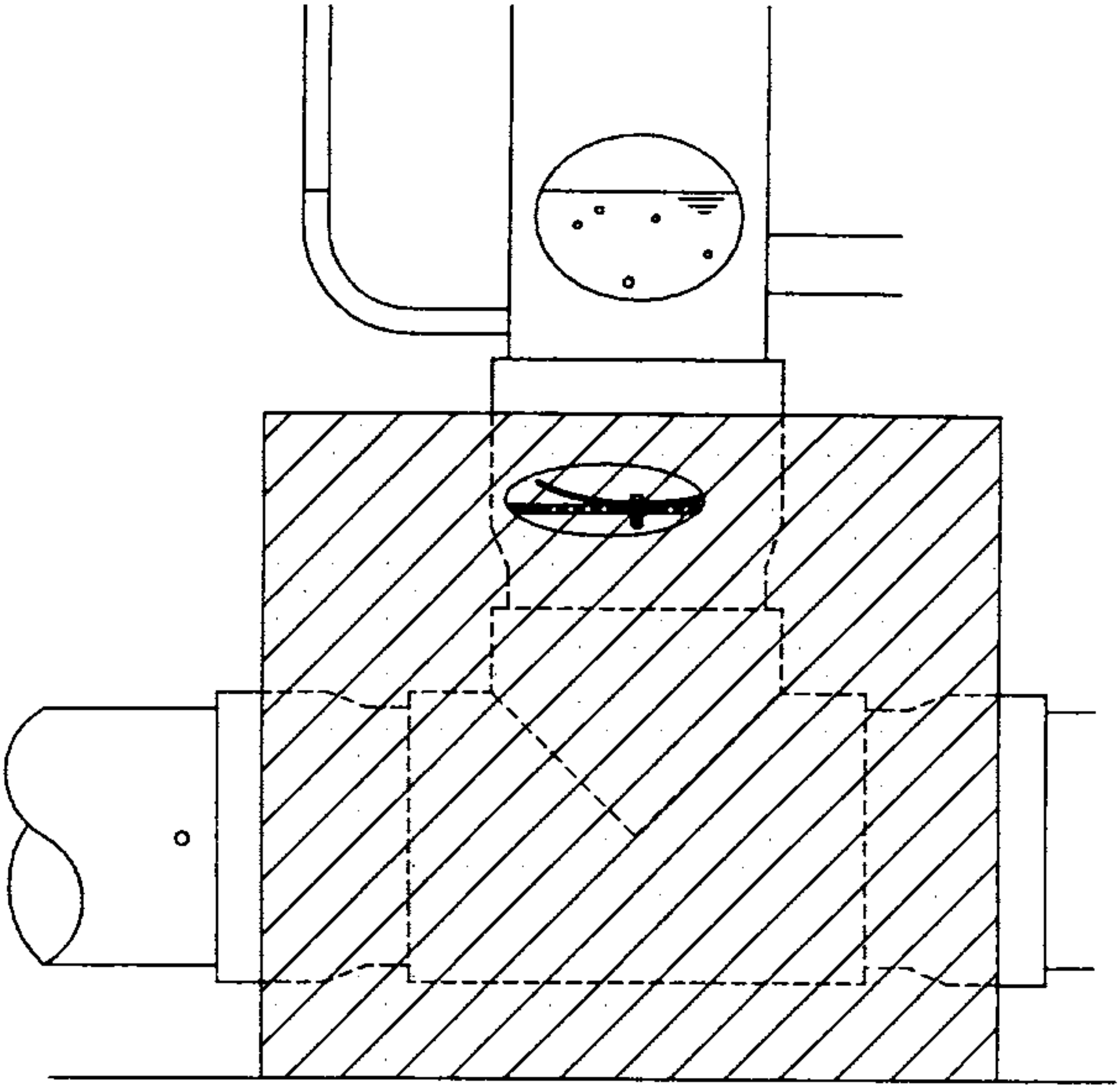
Valve plates using thick plastic material have been tested in an attempt to do without the need for a metal component. The life of such discs however was found to be too short under the loading experienced.

Marking out and accurately drilling 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.

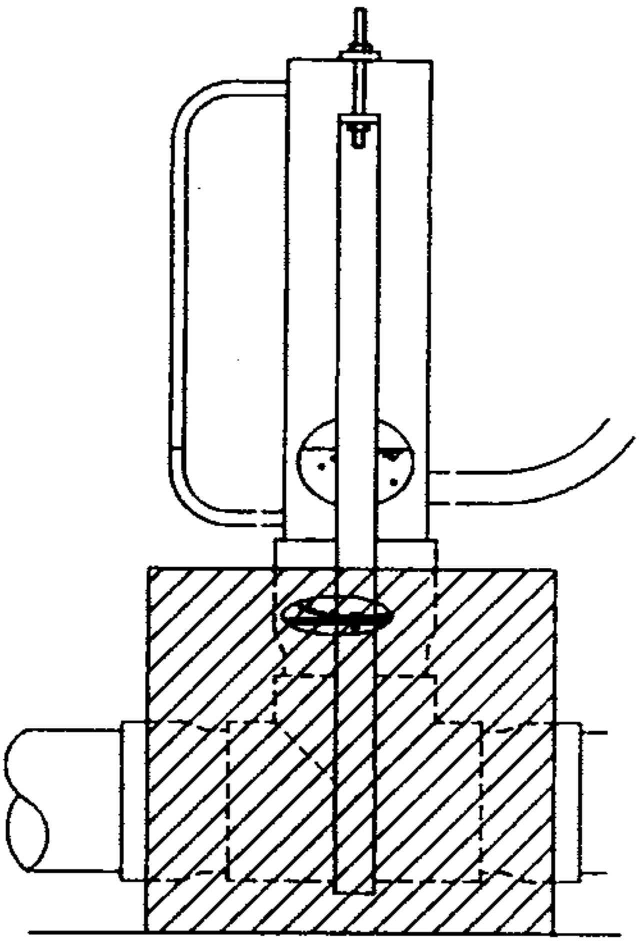
4) Wait for 30 mins to 1 hour to see if the amount of air changes. If the air level continues to increase until it reaches the top of the delivery pipe connection, then the snifter valve is probably about the right size. If the amount of air remains constant or reduces then increase the hole diameter 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:

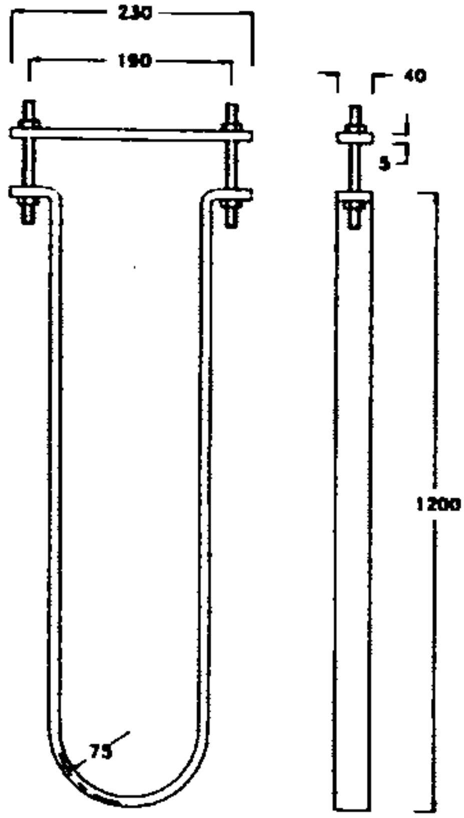
1) Small bore, 'see-through' plastic tubing is not always easy to find.

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

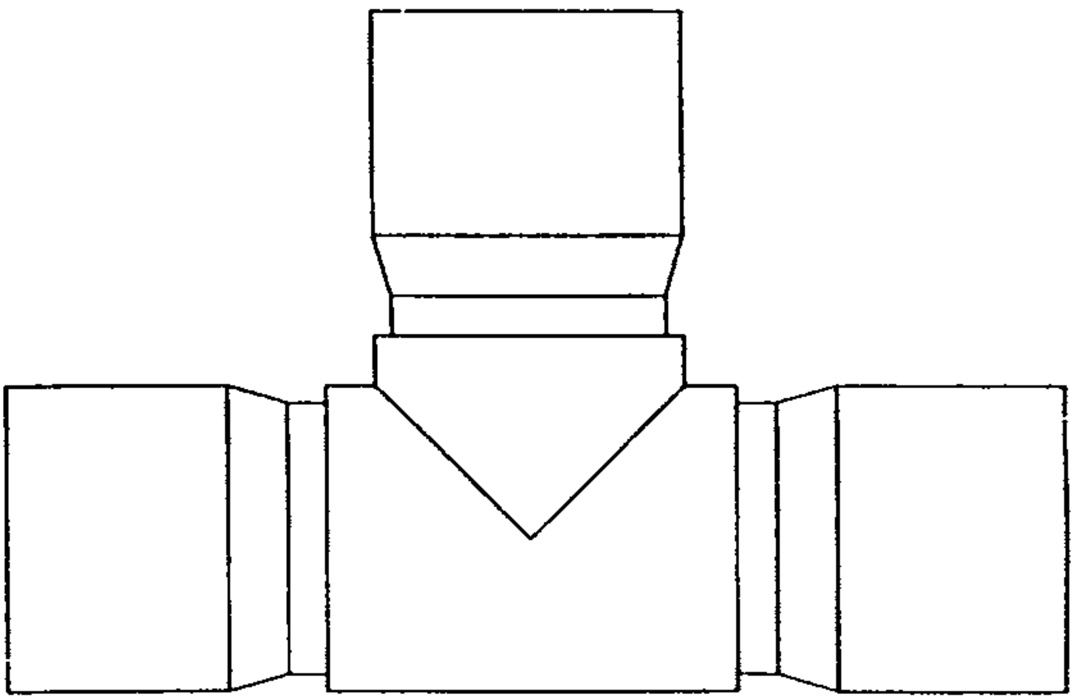
The air vessel has to be held down to prevent the pressure inside it blowing out from the tee piece. The concrete block holding the tee piece makes a good solid anchor for this strap and allows the air vessel to be securely clamped. A variety of types of clamp have been used and the one shown in the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



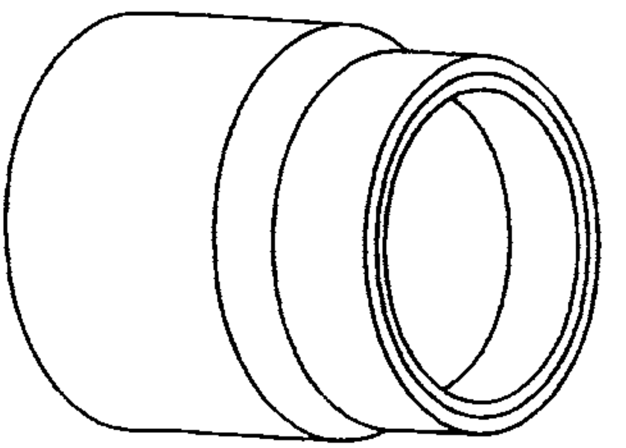
With the elbow solidly fixed downstream of the impulse valve the shocks during each pump cycle were transfered through the elbow into the concrete block. This provided good anchoring for the pump but led in some instances to cracking of the elbow. As the end of the drive pipe entering the drive tank 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.

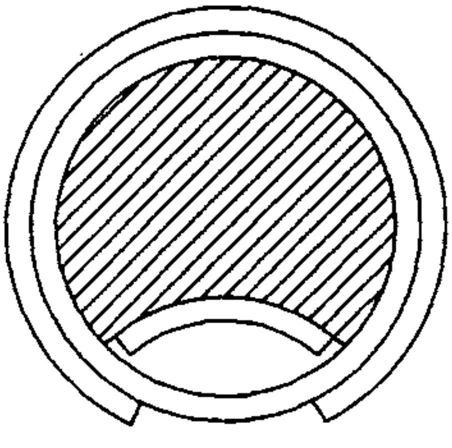


Drive Pipe

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 hy around 20%. This is illustrated in the diagram below.

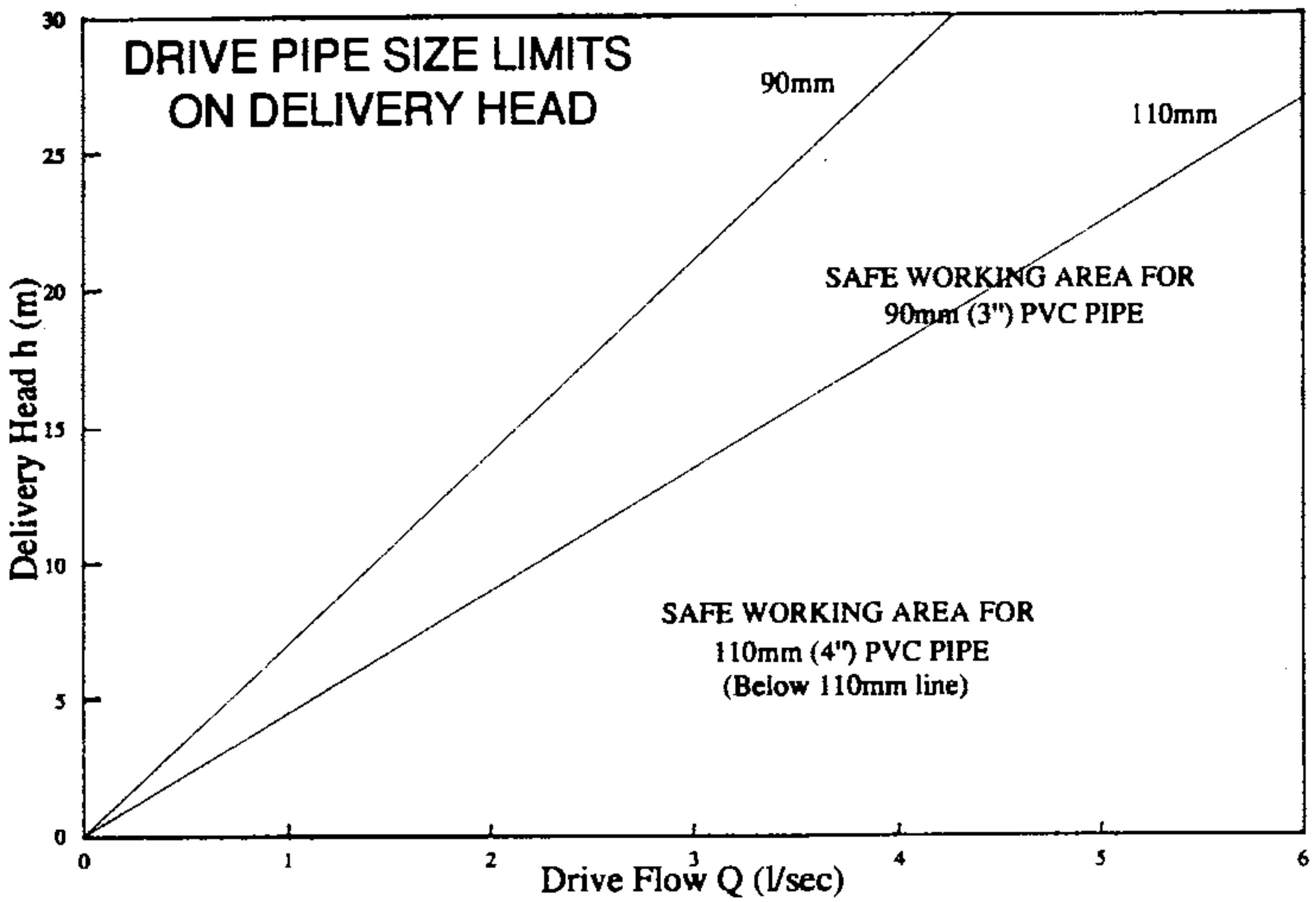


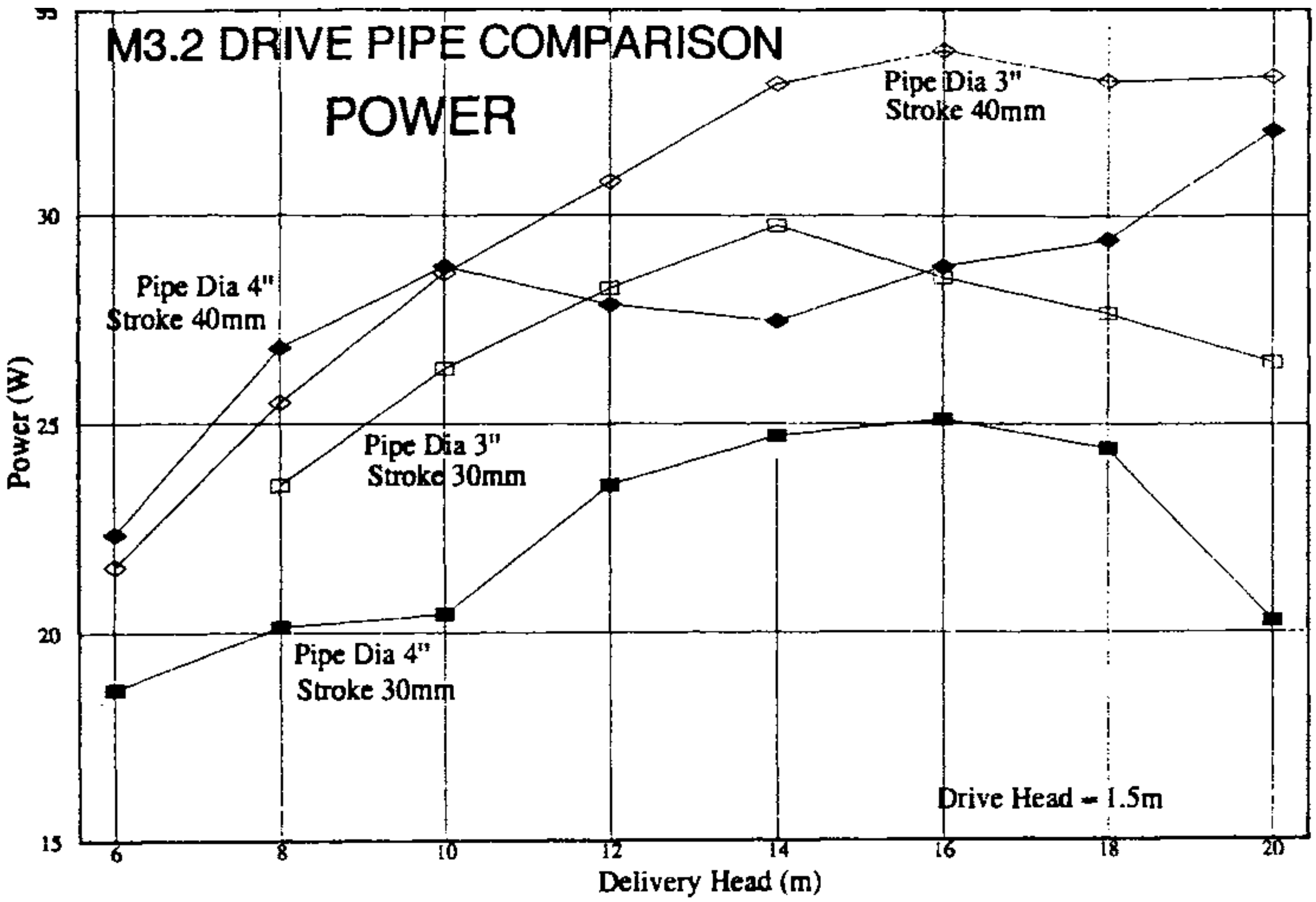
Cross-section of Impulse Valve showing restriction to flow.

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.

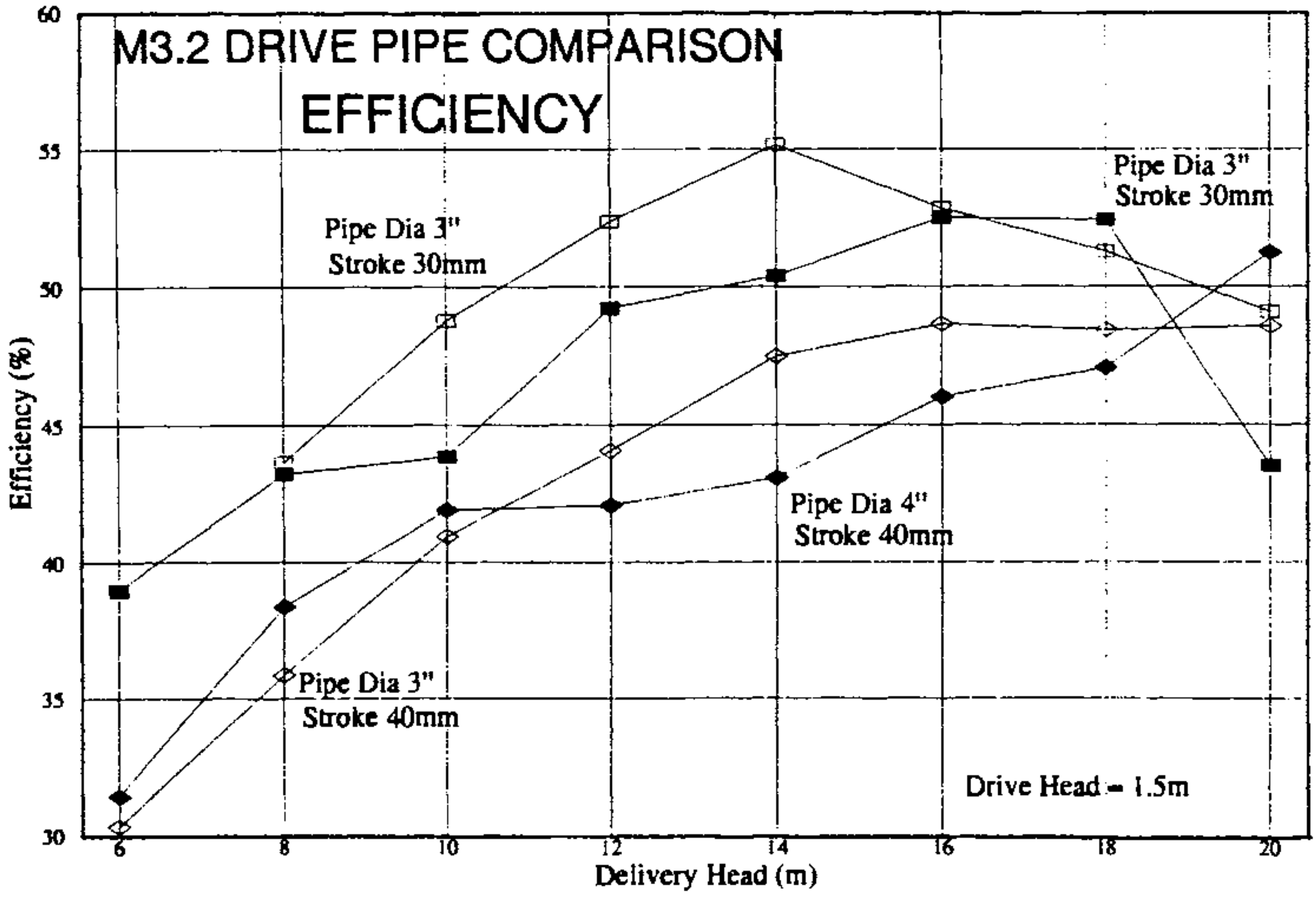
Laboratory tests have been carried out in order to compare the 110mm drive pipe with the next common size down: 90mm. The results of these tests are summarised in Graph Nos X,X and show quite clearly that under most conditions both the efficiency and power output of the pump are improved by using the 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)
Delivery Head (m)
15
20
25
30
6
8
10
12
14
16
18
20

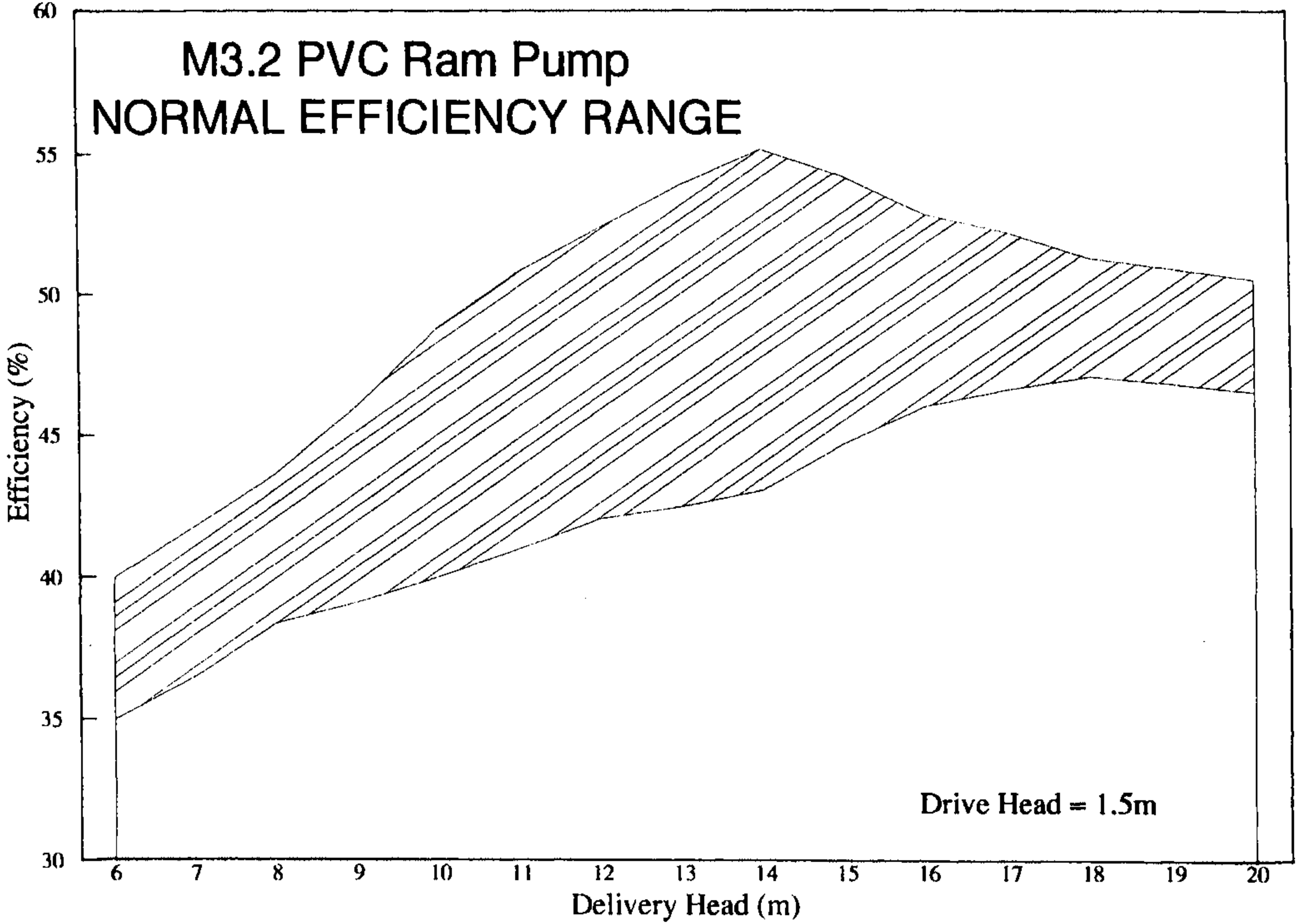


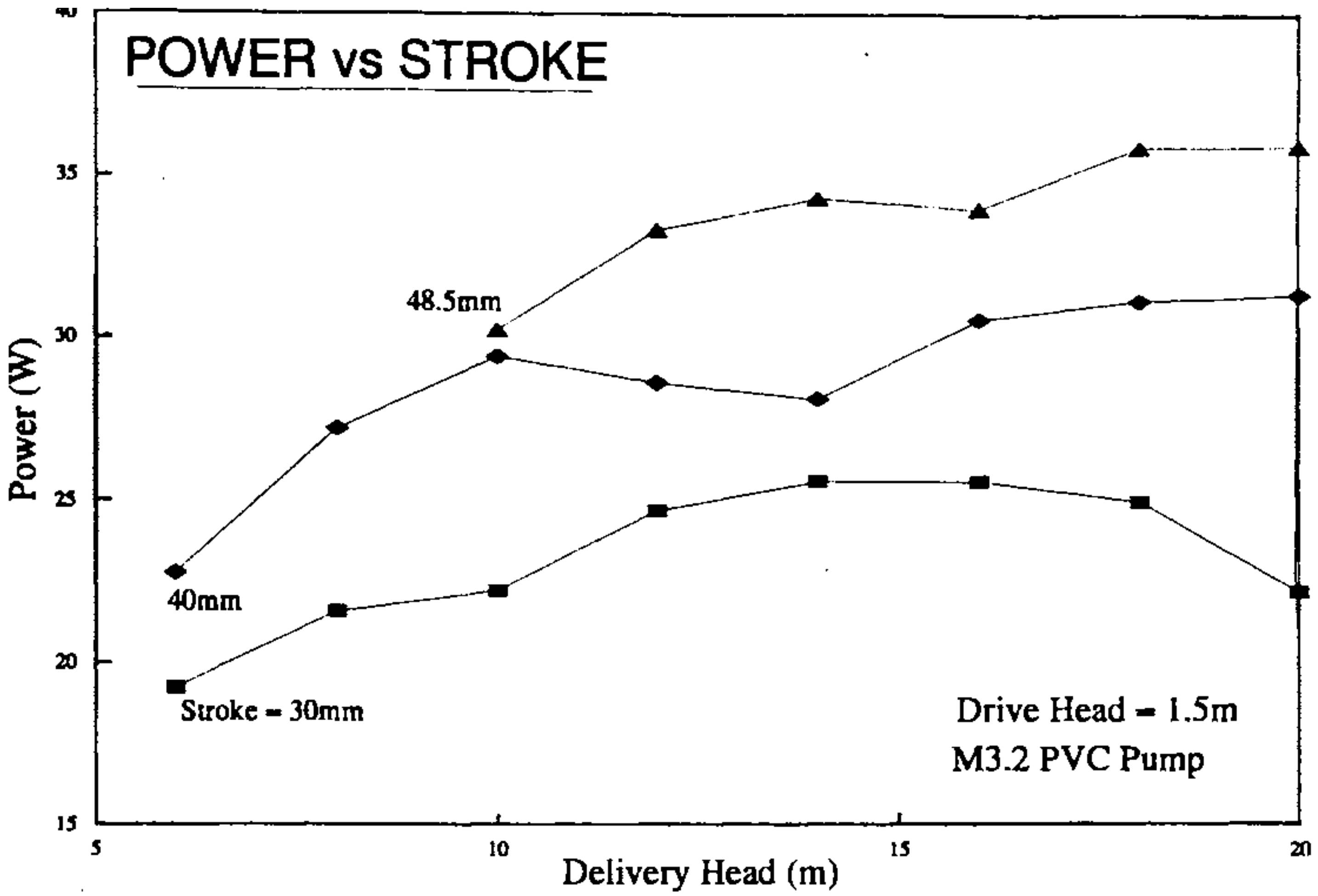
M3.2 DRIVE PIPE COMPARISON
EFFICIENCY
Pipe Dia 3"
Stroke 30mm
Pipe Dia 3"
Stroke 30mm
Pipe Dia 4"
Stroke 40mm
Pipe Dia 3"
Stroke 40mm
Drive Head = 1.5m
Efficiency (%)
Delivery Head (m)
30
35
40
45
50
55
60
6
8
10
12
14
16
18
20

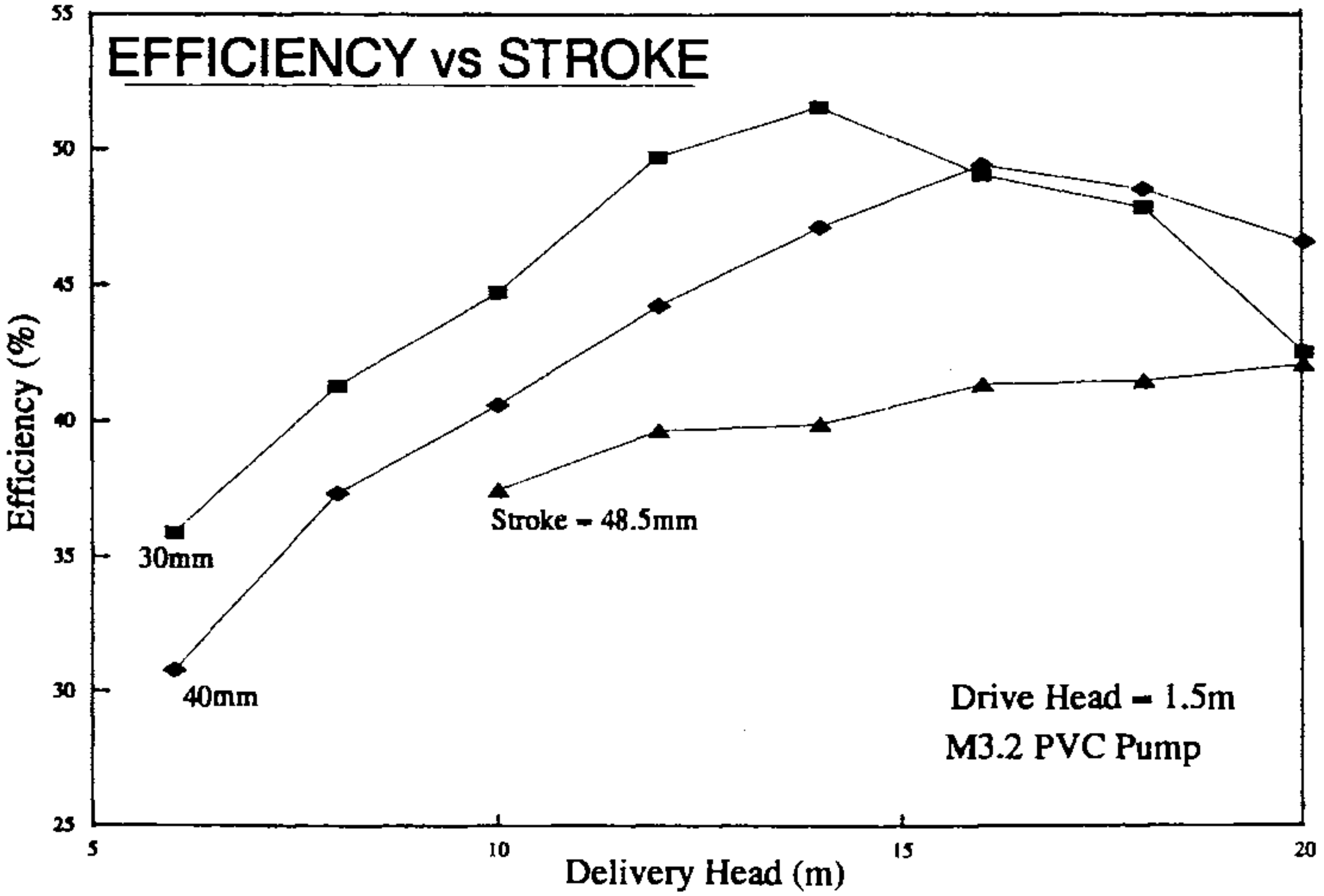
Drive Pipe Length

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
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Delivery Head (m)
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
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

DEVELOPMENT TECHNOLOGY UNIT
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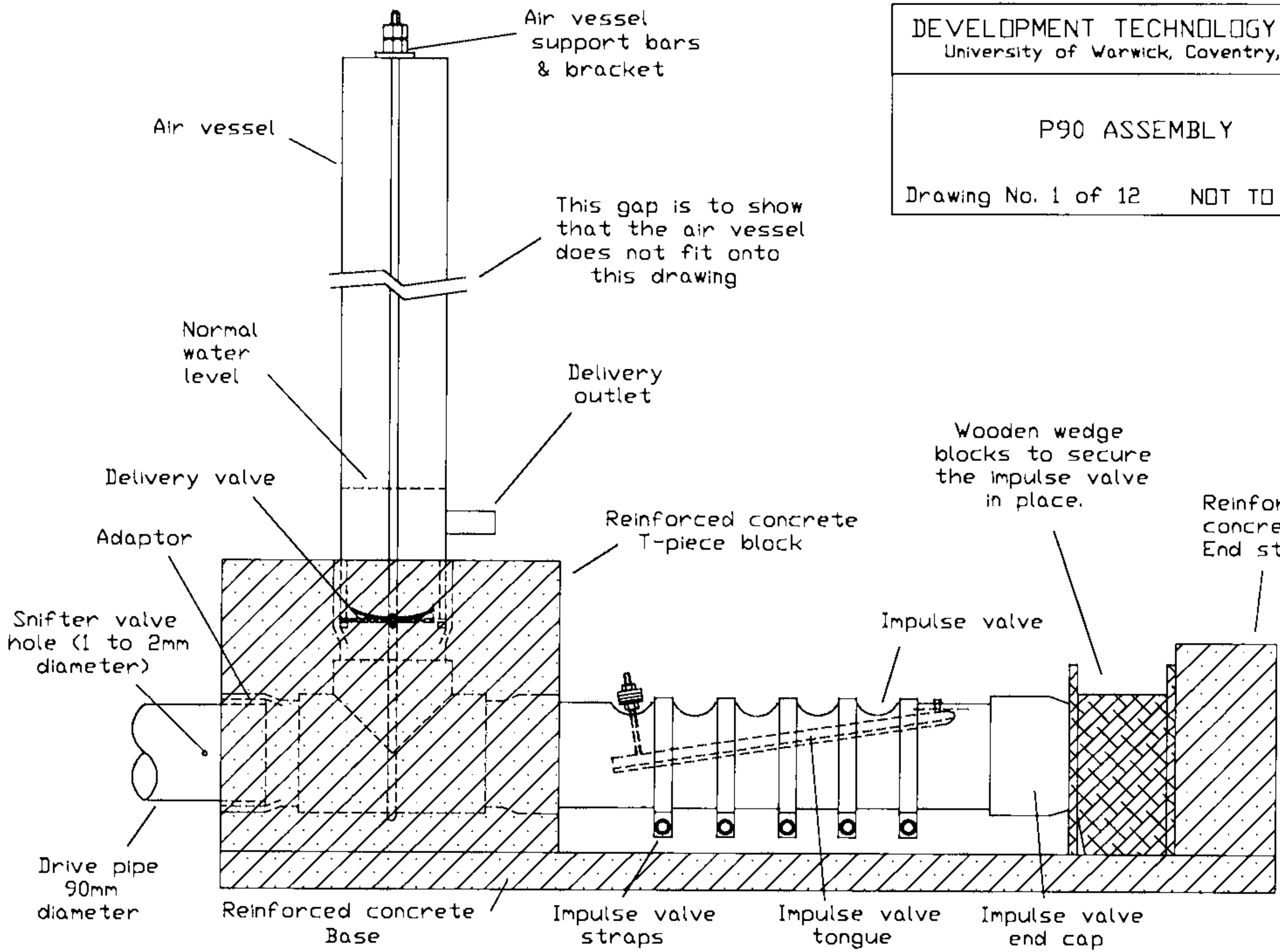
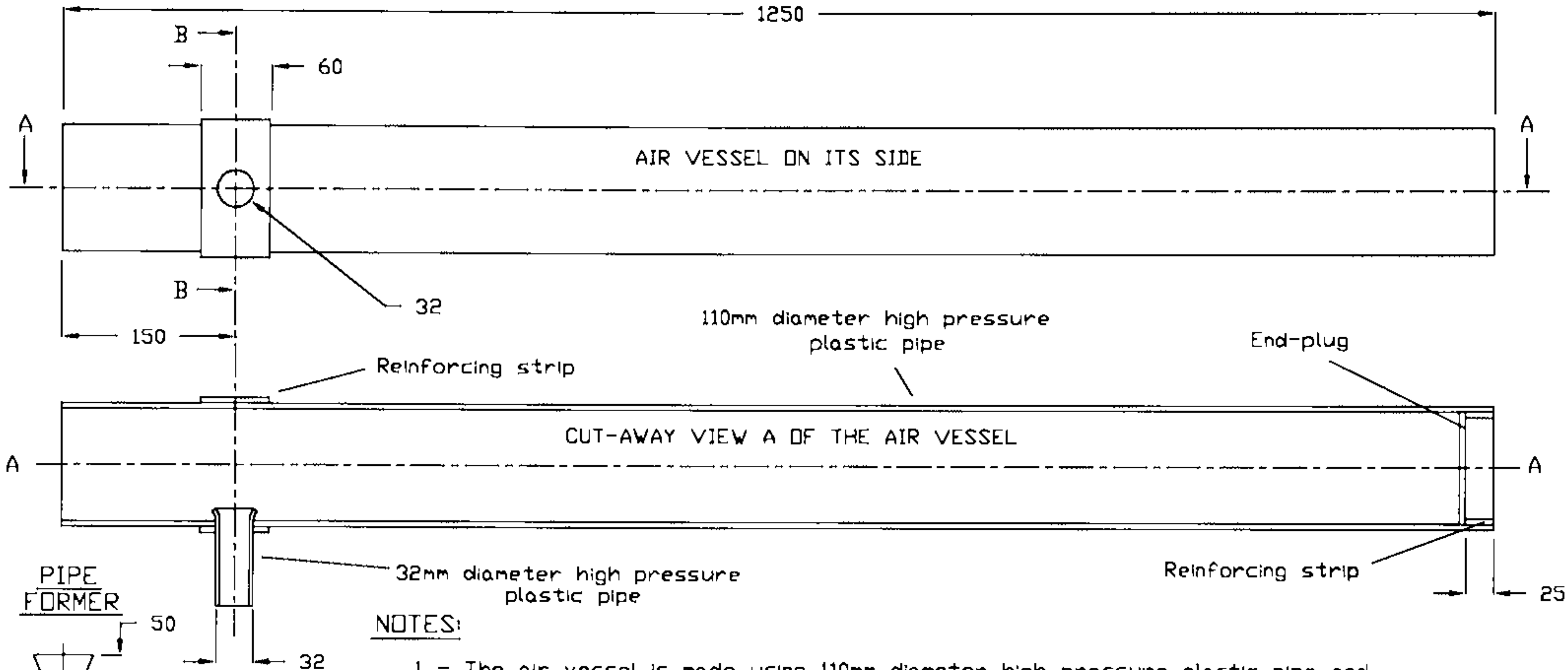
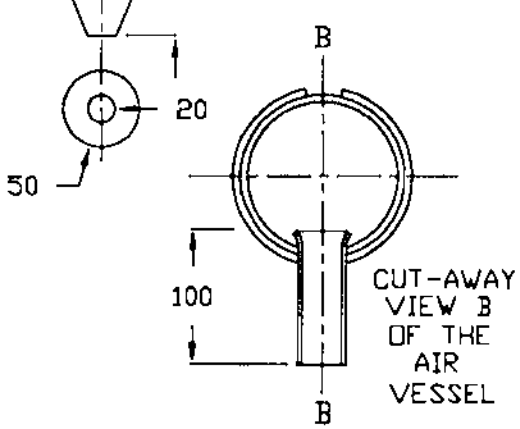
P90 ASSEMBLY

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

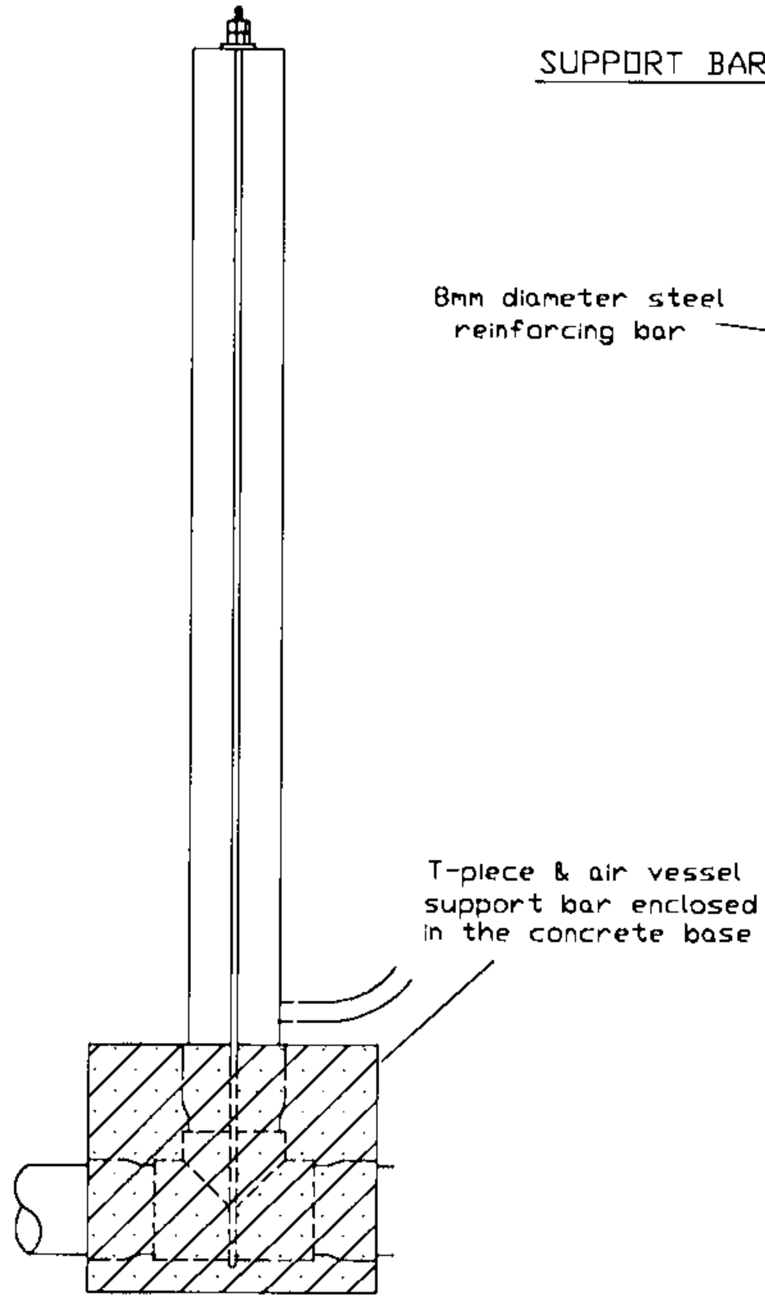
3 - To make the end-plug, a section of pipe is cut along its length, heated and flattened. Once cooled, a disc is cut out of this to form the correct shape.

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.

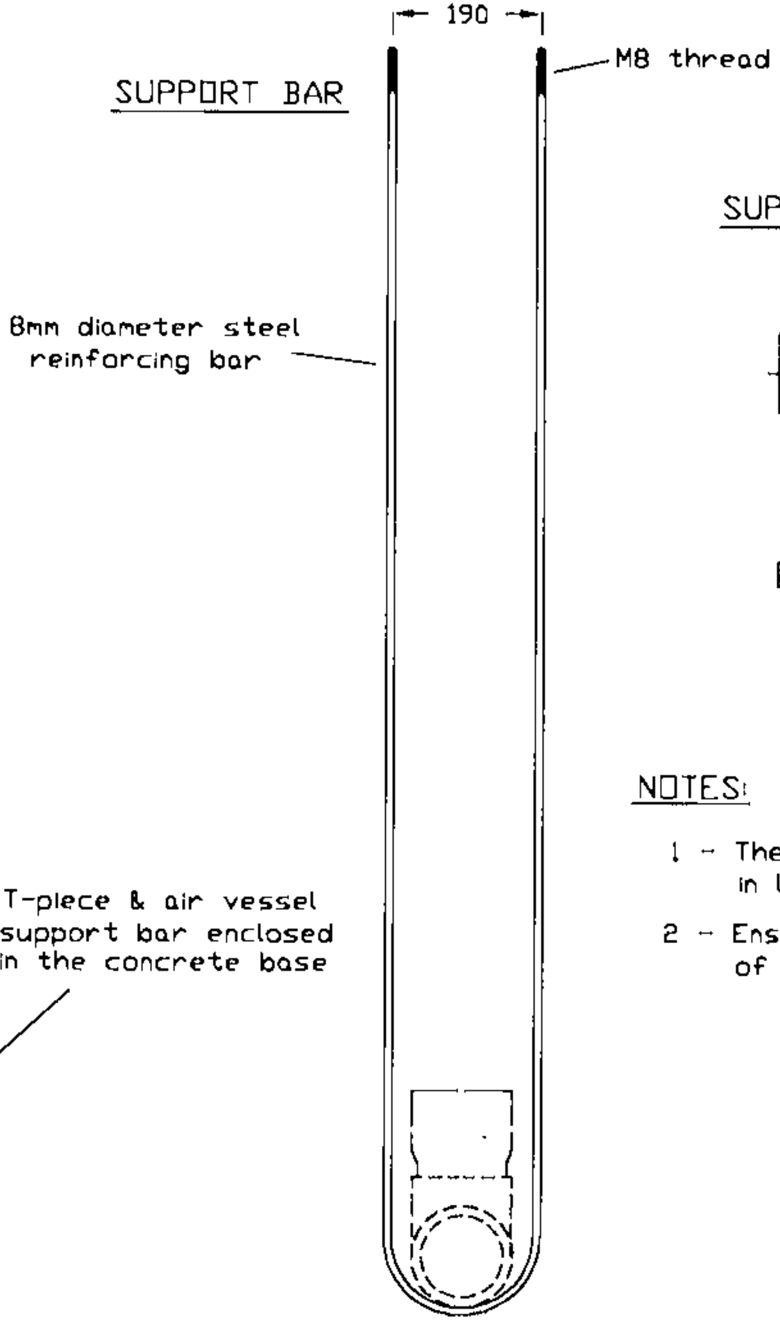
DEVELOPMENT TECHNOLOGY UNIT University of Warwick, Coventry, UK
P90 AIR VESSEL
Drawing No. 2 of 12   NOT TO SCALE

AIR VESSEL ASSEMBLY

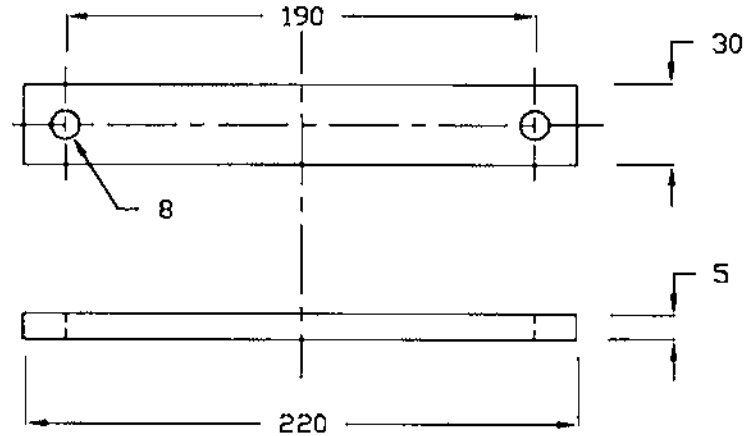


ALL DIMENSIONS IN mm

SUPPORT BAR



SUPPORT BRACKET



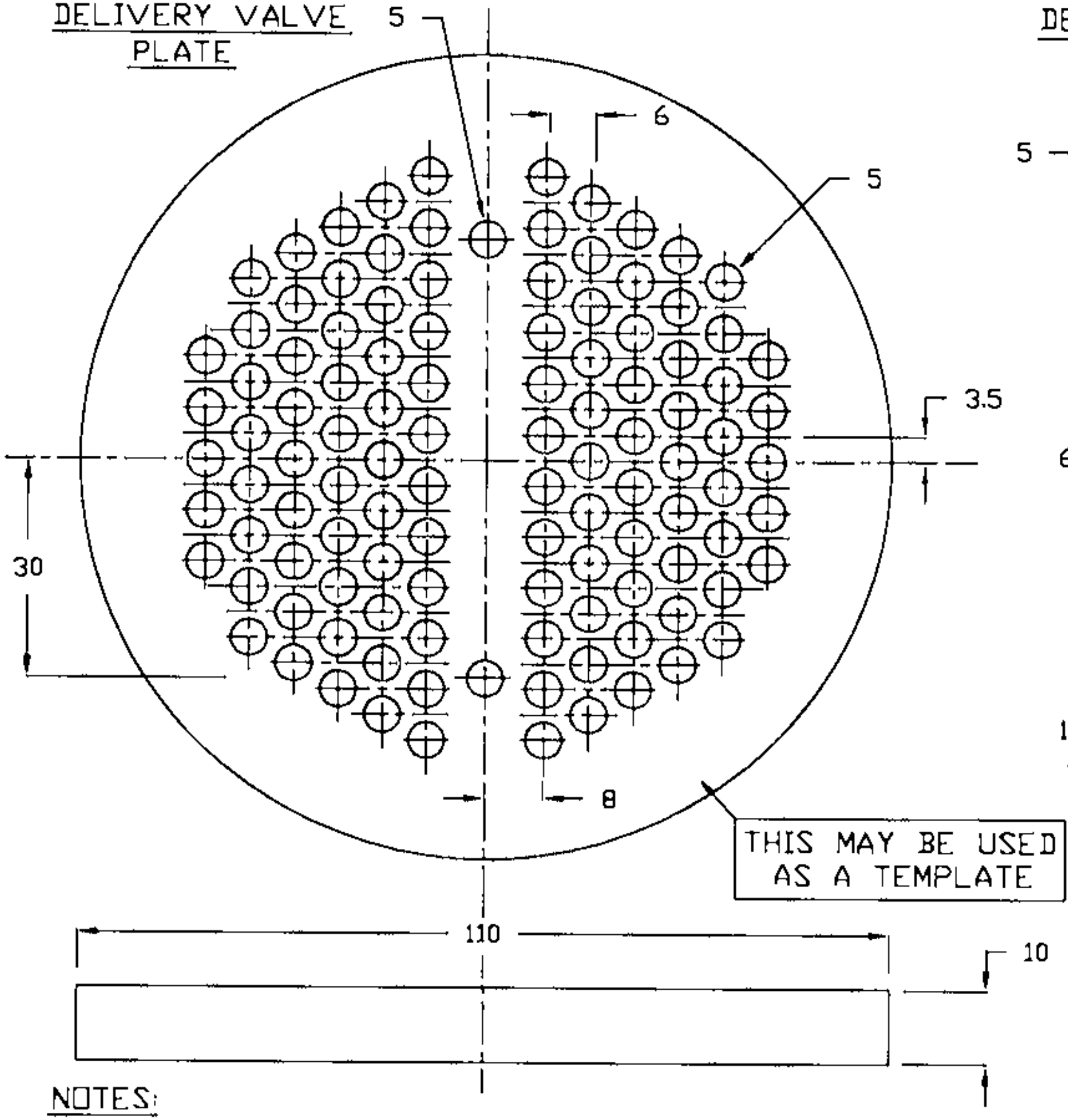
NOTES:

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

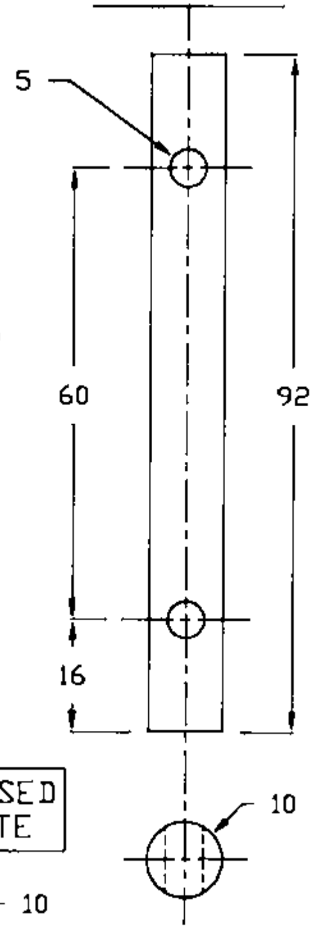
2 - Ensure a secondary lock nut is used on each end of the support bar when assembling the pump

DEVELOPMENT TECHNOLOGY UNIT University of Warwick, Coventry, UK
P90 AIR VESSEL SUPPORT BAR & BRACKET Drawing No. 3 of 12 NOT TO SCALE

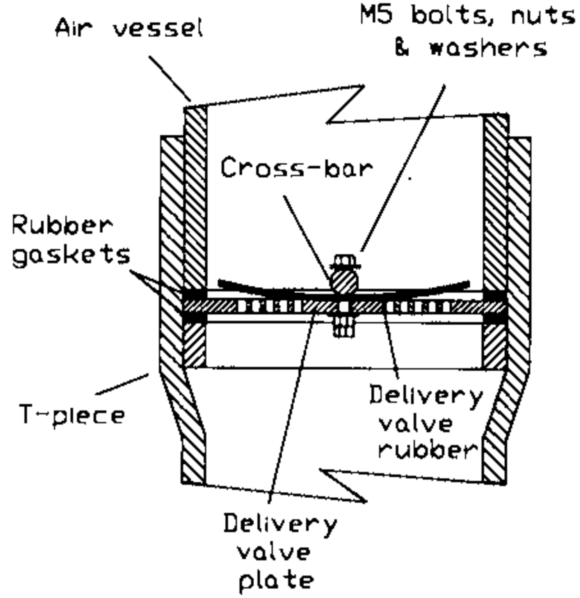
DELIVERY VALVE PLATE



DELIVERY VALVE CROSS-BAR



DELIVERY VALVE ASSEMBLY



ASSEMBLY INSTRUCTIONS

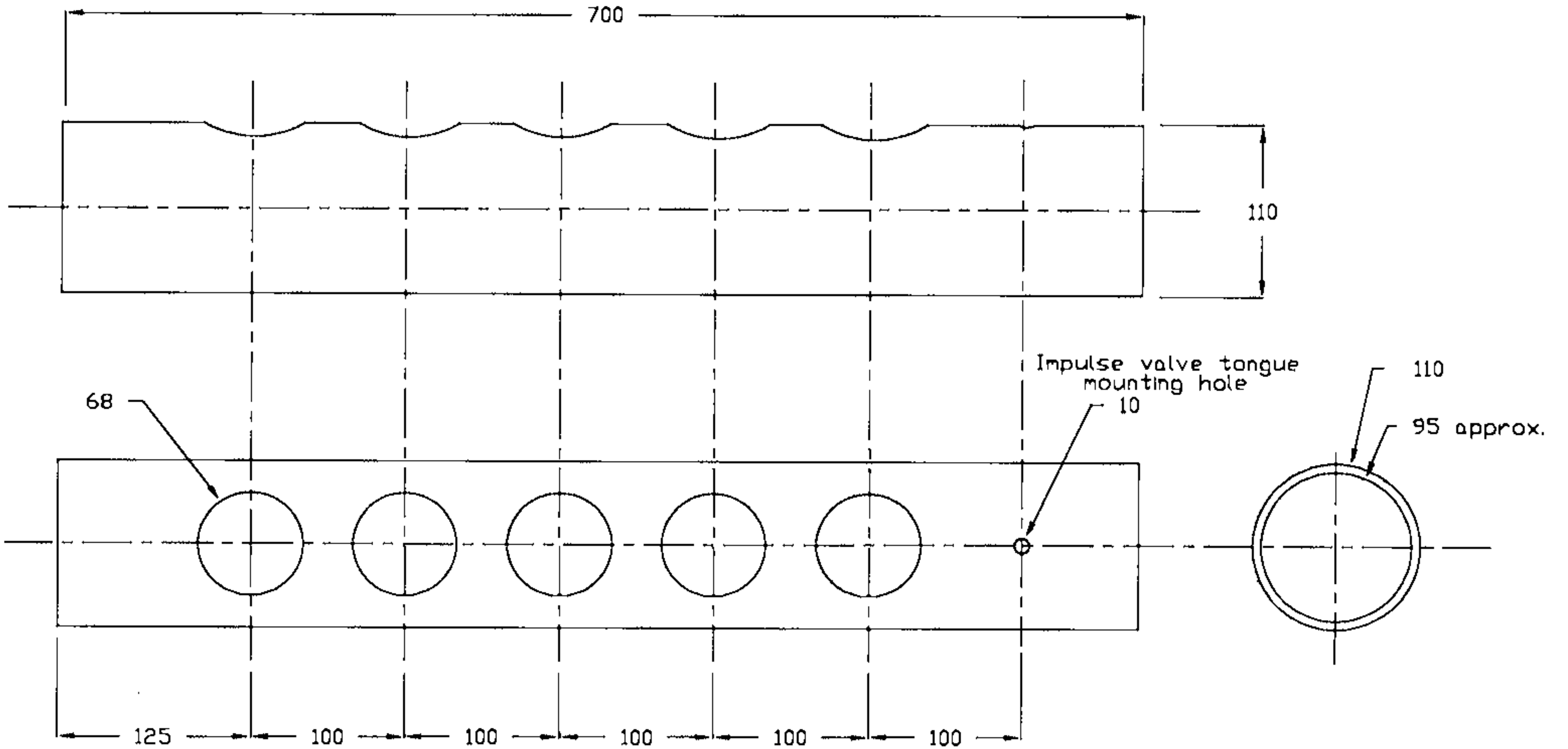
1 - Place the valve rubber on the unchamfered side of the plate
2 - Push the bolts through the cross-bar, rubber and plate
3 - Add a nut onto each bolt and just finger tighten
4 - Add a second nut onto each bolt and tighten each pair of nuts securely together

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

DEVELOPMENT TECHNOLOGY UNIT University of Warwick, Coventry, UK
P90 DELIVERY VALVE Drawing No. 4 of 12



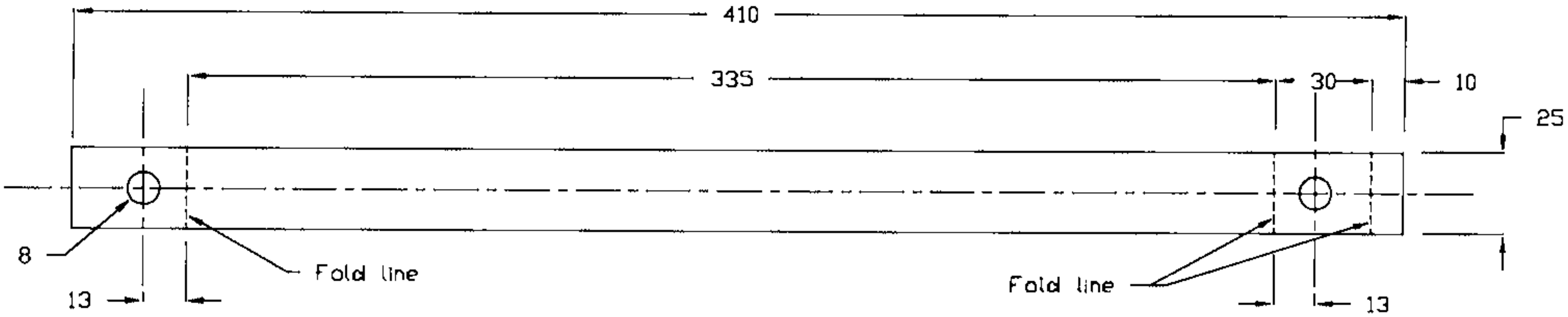
NOTES:

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.

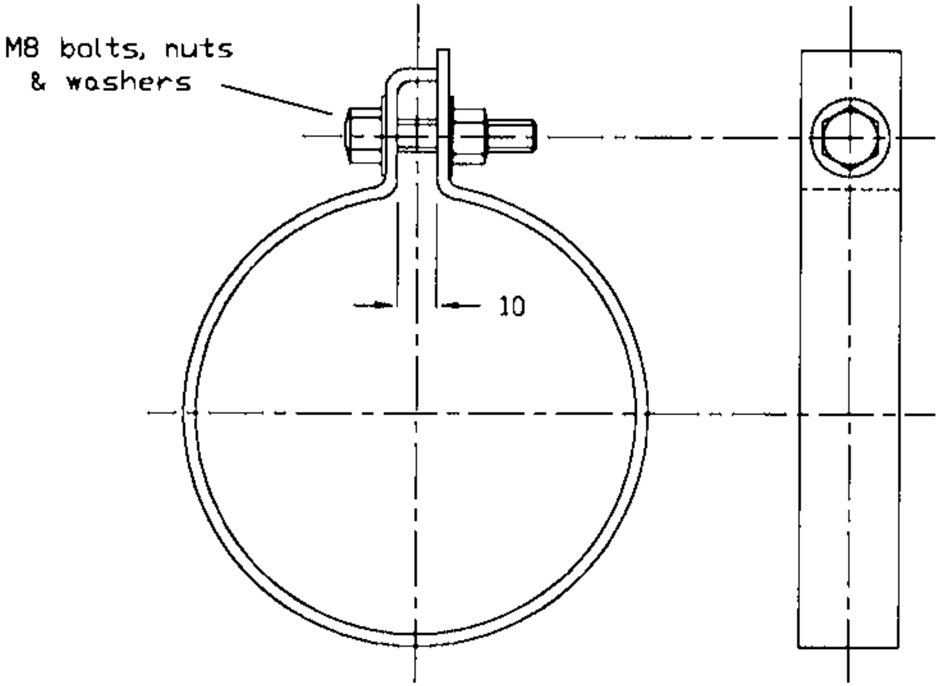
2 - A tank cutter of between 66 and 70mm may be used to cut out the large impulse valve holes.

ALL DIMENSIONS IN mm

DEVELOPMENT TECHNOLOGY UNIT University of Warwick, Coventry, UK	
P90 IMPULSE VALVE	
Drawing No. 5 of 12	NOT TO SCALE



ASSEMBLED IMPULSE VALVE STRAP



ALL DIMENSIONS IN mm

NOTES:

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

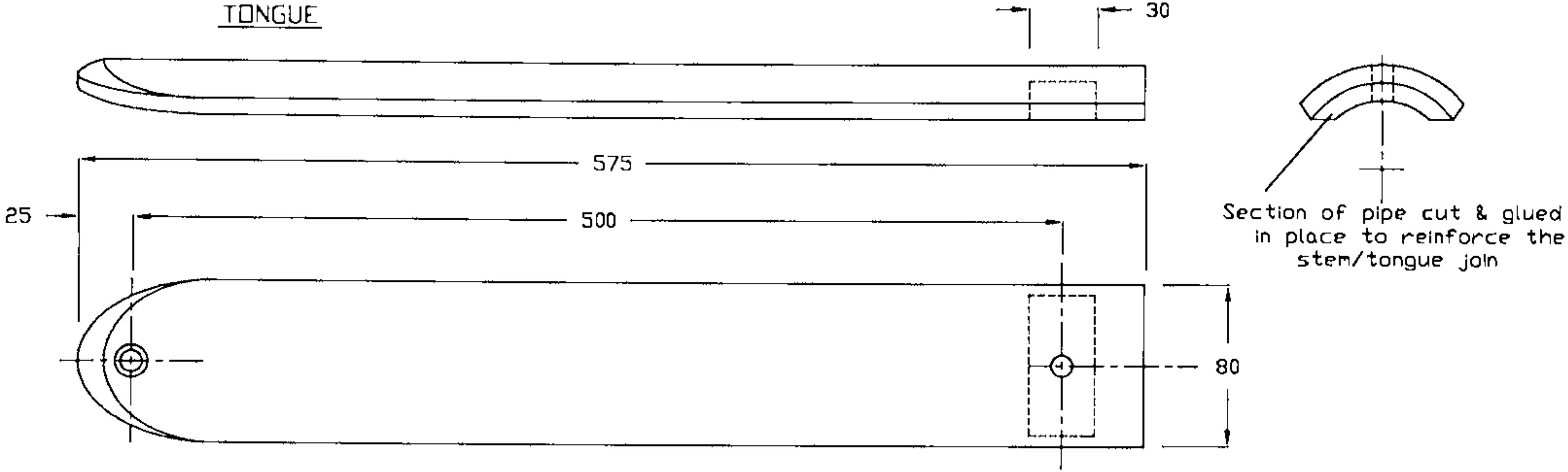
2 - 5 straps are needed for the impulse valve.

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.

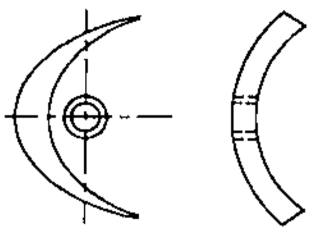
4 - When the straps are assembled, paint them before adding them to the impulse valve.

DEVELOPMENT TECHNOLOGY UNIT University of Warwick, Coventry, UK
P90 IMPULSE VALVE STRAP
Drawing No. 6 of 12 NOT TO SCALE

TONGUE

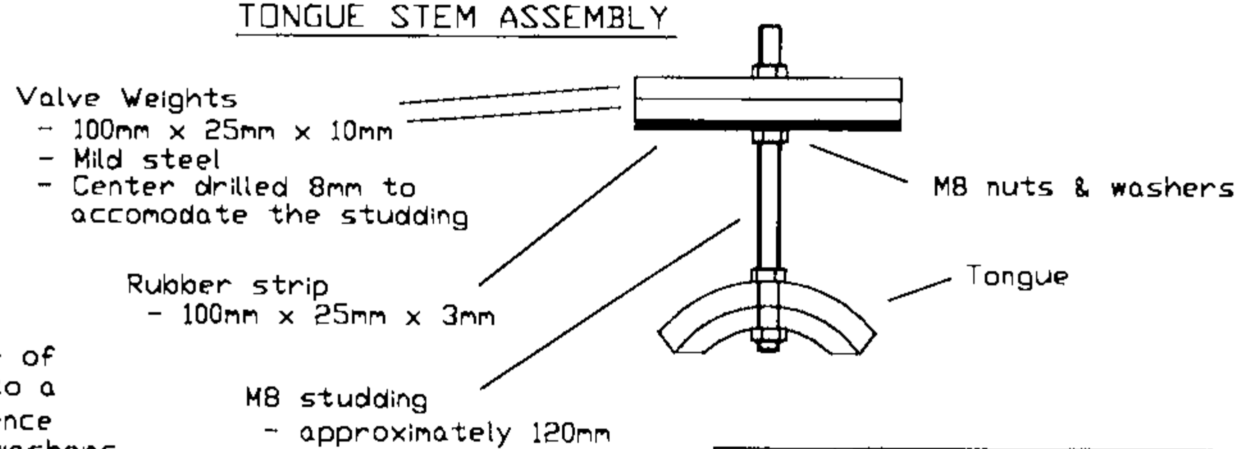


TONGUE MOUNTING



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

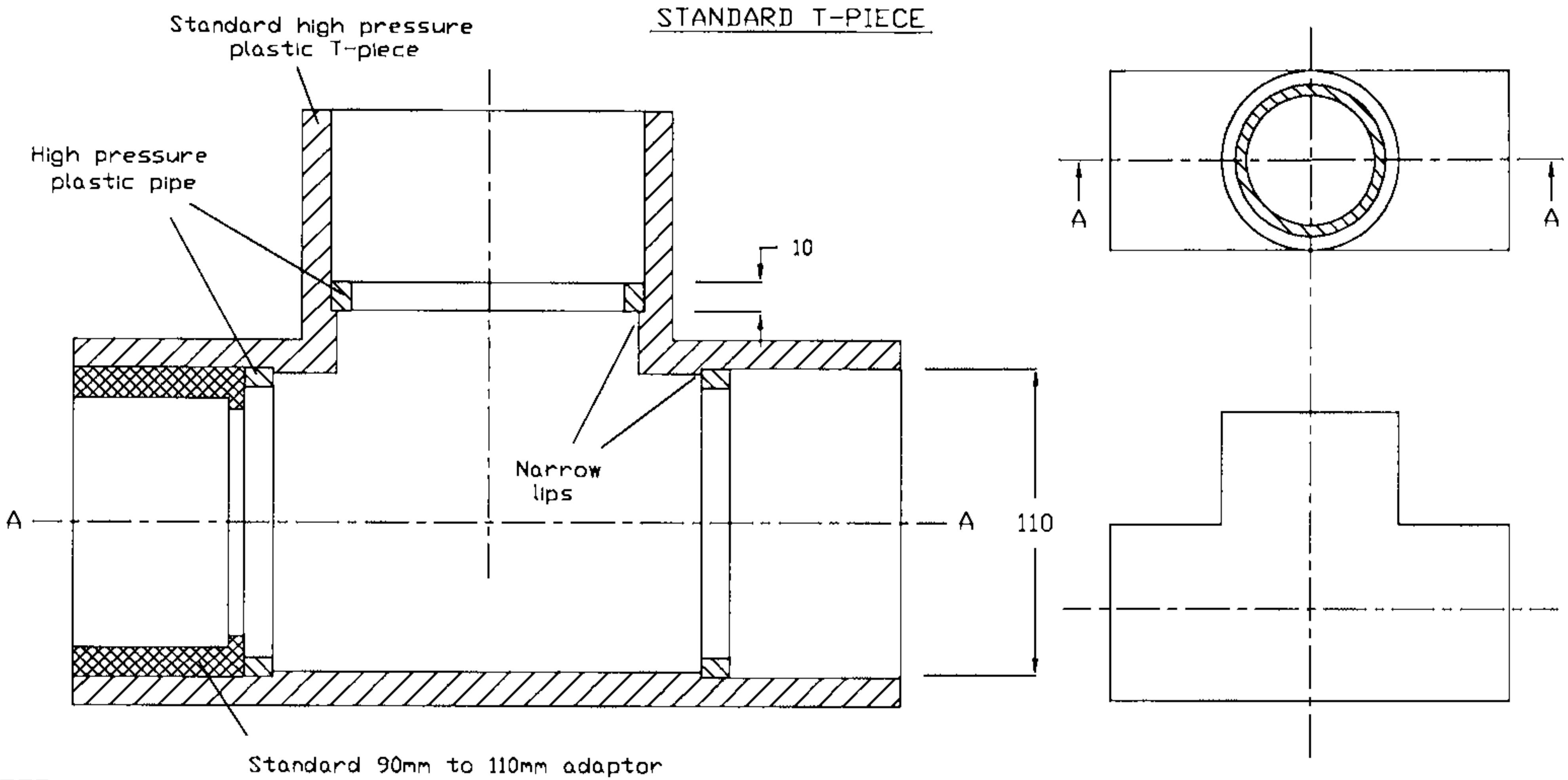


FITTING THE TONGUE

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

DEVELOPMENT TECHNOLOGY UNIT University of Warwick, Coventry, UK
P90 IMPULSE VALVE TONGUE & ASSEMBLY
Drawing No. 7 of 12 NOT TO SCALE



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.

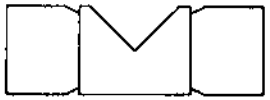
ALL DIMENSIONS IN mm

DEVELOPMENT TECHNOLOGY UNIT University of Warwick, Coventry, UK
P90 - USING A STANDARD T-PIECE & ADAPTOR
Drawing No. 8 of 12 NOT TO SCALE

MAKING A T-PIECE

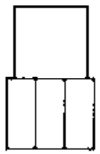
PART A

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.

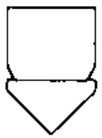


Using the T-piece former, form sockets at each end of PART A. Next, cut out a 90 degree 'V-Notch as shown. Make sure the gap on the shorter outter pipe is opposite the @V-Notch'.

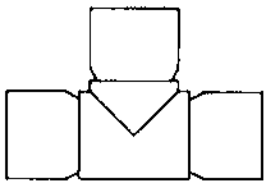
PART B



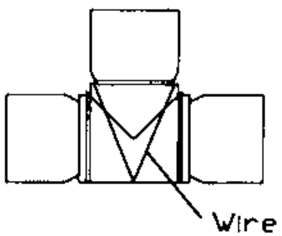
Cut 75 & 200mm lengths of pipe. Cut, heat & glue the shorter pipe flush with one end of the longer. Cut a piece of pipe to fit the gap left on the outer pipe. Heat & glue this into place.



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



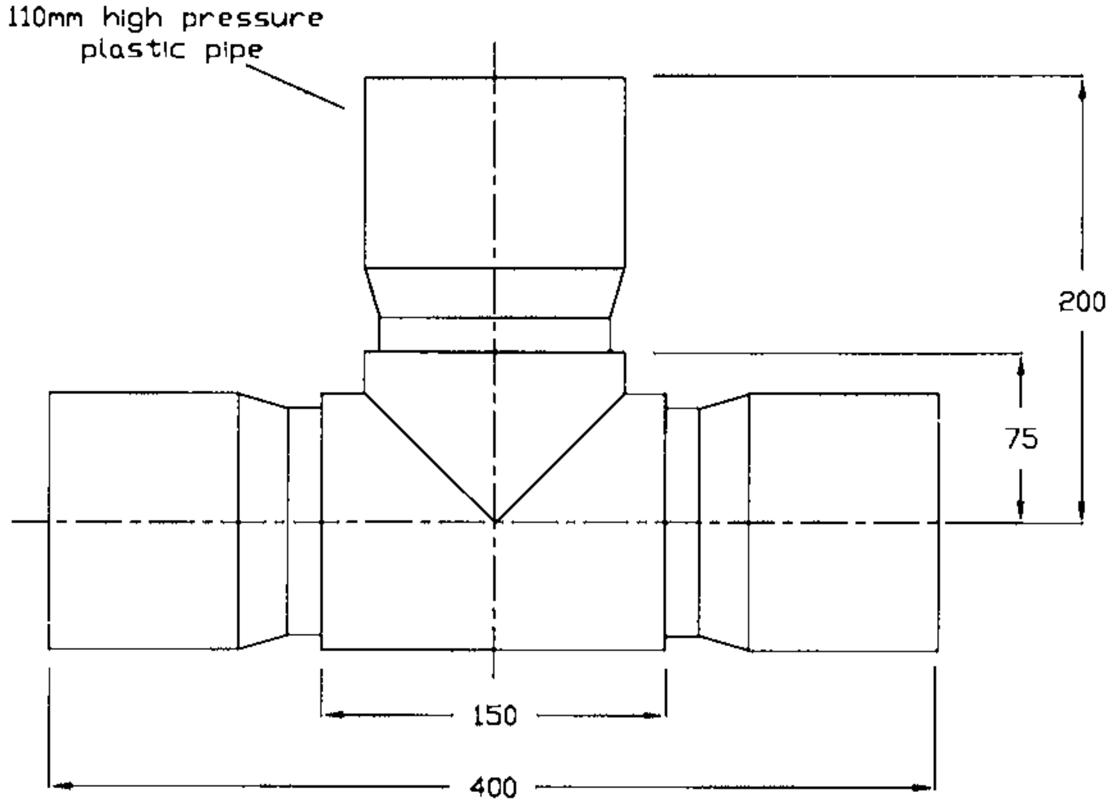
File both PARTS A & B until a reasonable fit is obtained. Glue together both parts using a mixture of PVC glue and pipe shavings to fill the gaps.



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.

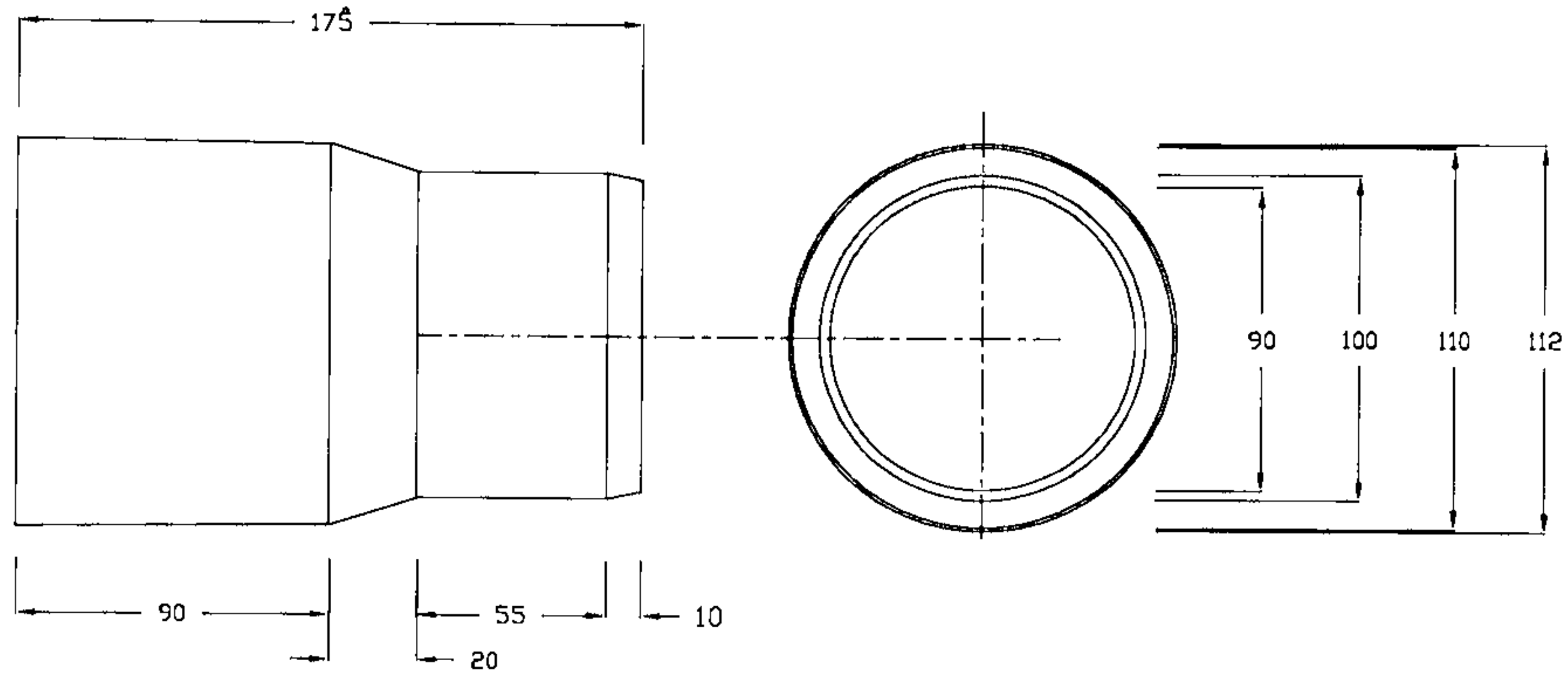
ALL DIMENSIONS IN mm

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.

DEVELOPMENT TECHNOLOGY UNIT University of Warwick, Coventry, UK	
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.

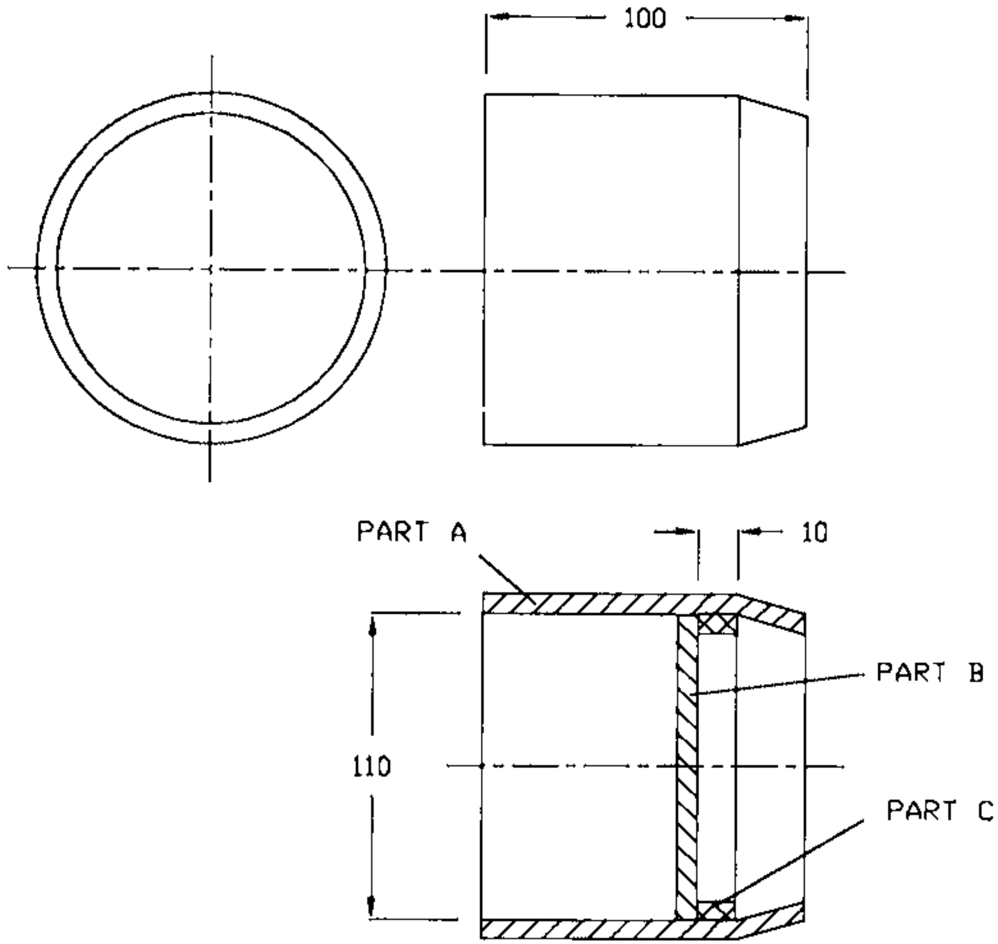
2 - When the pipe is soft enough push it quickly and firmly over the former.

3 - Let the pipe cool and harden before removing it from the former.

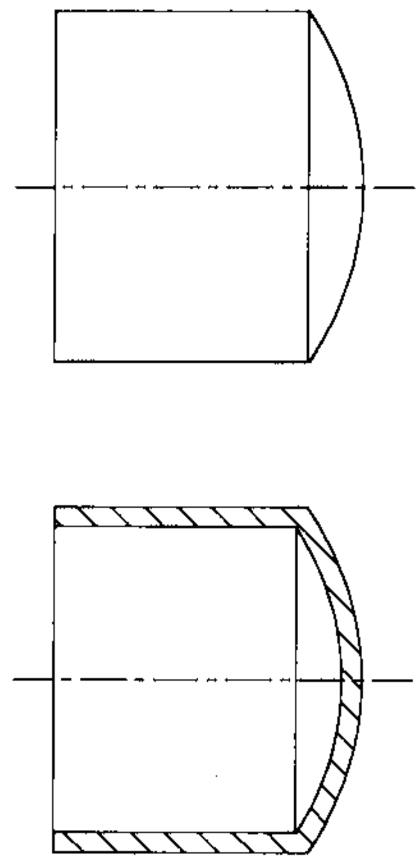
ALL DIMENSIONS IN mm

DEVELOPMENT TECHNOLOGY UNIT University of Warwick, Coventry, UK
P90 SOCKET FORMER Drawing No. 10 of 12 NOT TO SCALE

MAKING AN END CAP



STANDARD END CAP



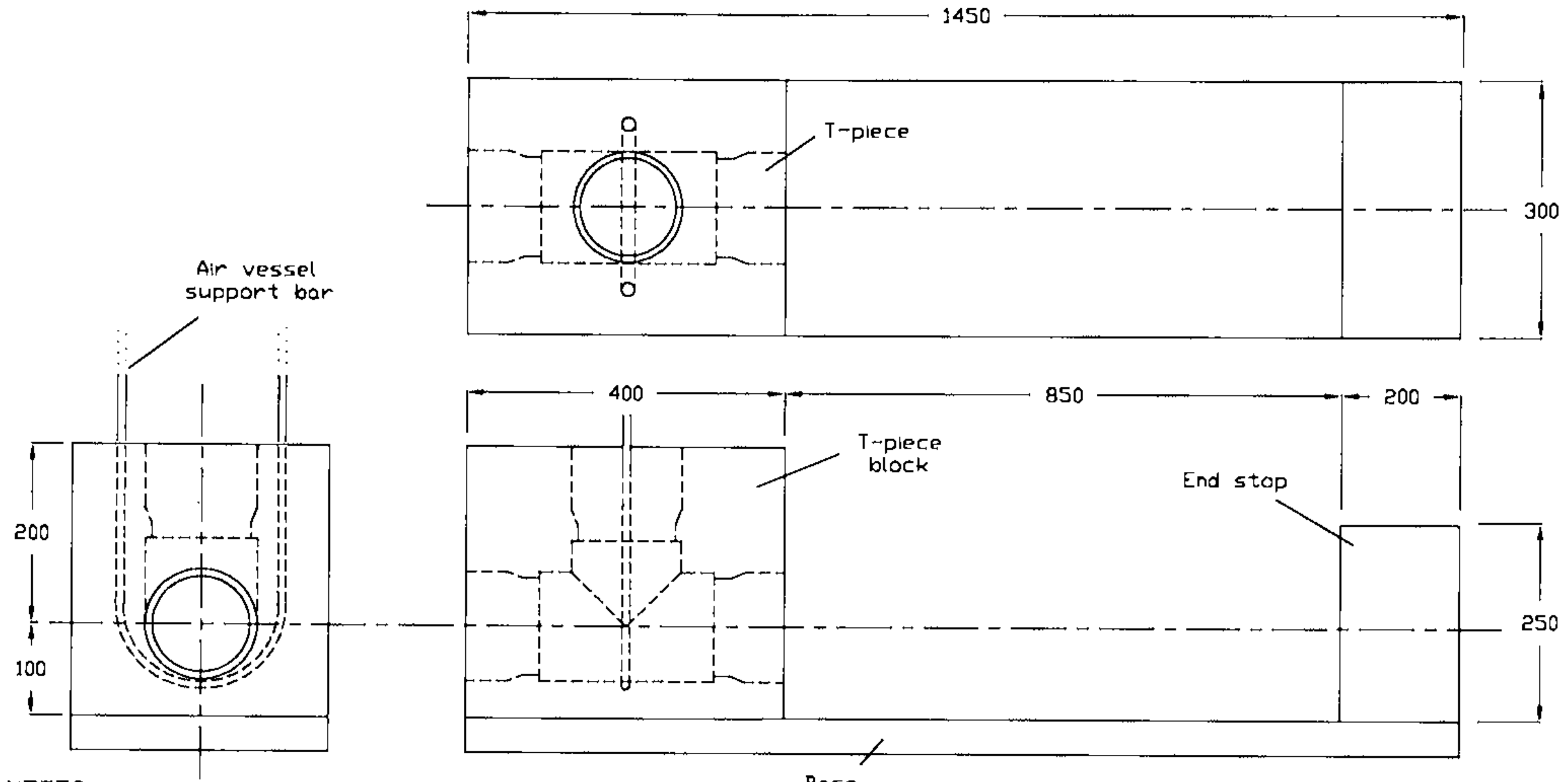
NOTE: The End cap may be purchased commercially or made as shown.

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

DEVELOPMENT TECHNOLOGY UNIT University of Warwick, Coventry, UK
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

DEVELOPMENT TECHNOLOGY UNIT University of Warwick, Coventry, UK
P90 REINFORCED CONCRETE BASE, T-PIECE BLOCK & END STOP
Drawing No. 12 of 12 NOT TO SCALE

Hydraulic Ram Pump System Sketches

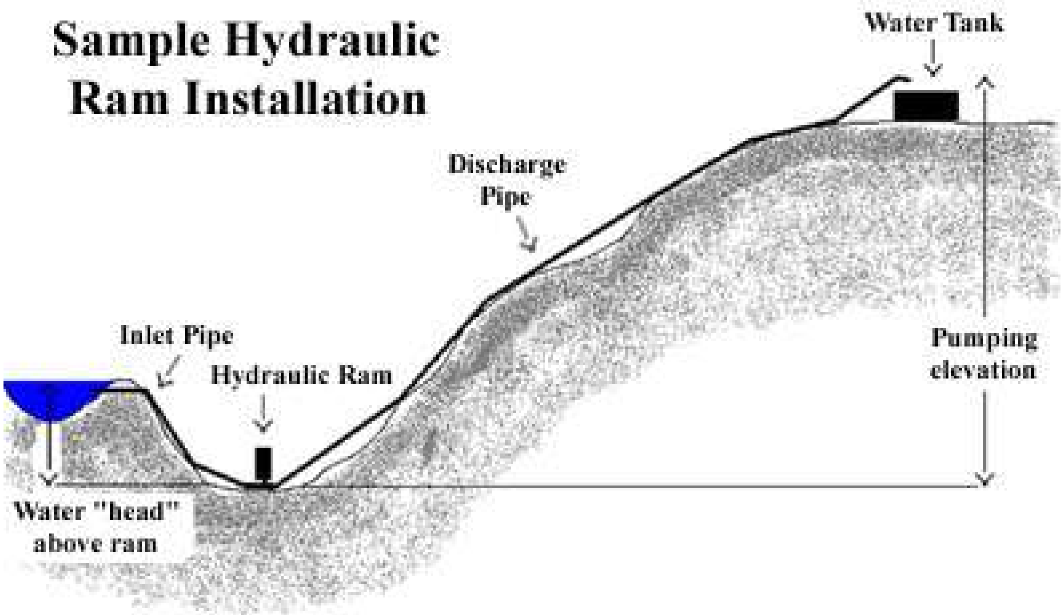


Figure 1. This installation is the "normal" ram system where the inlet pipe is less than the maximum length allowed. No stand pipe or open tank is required.

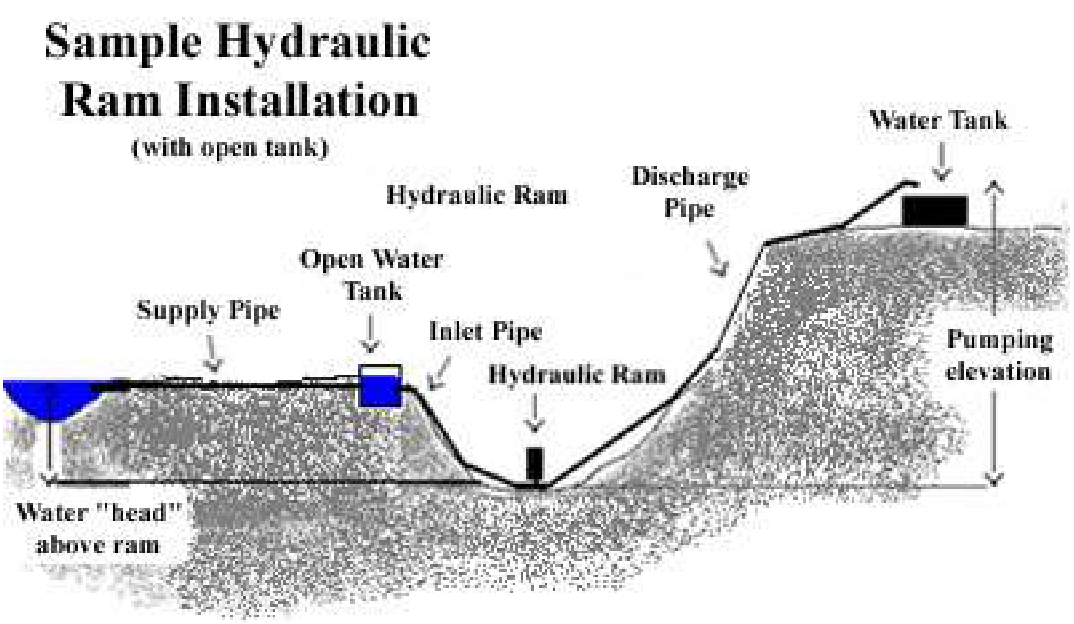


Figure 2. This installation is one option used where the inlet pipe is longer than the maximum length allowed. The open water tank is required to allow dissipation of the water hammer shock wave.

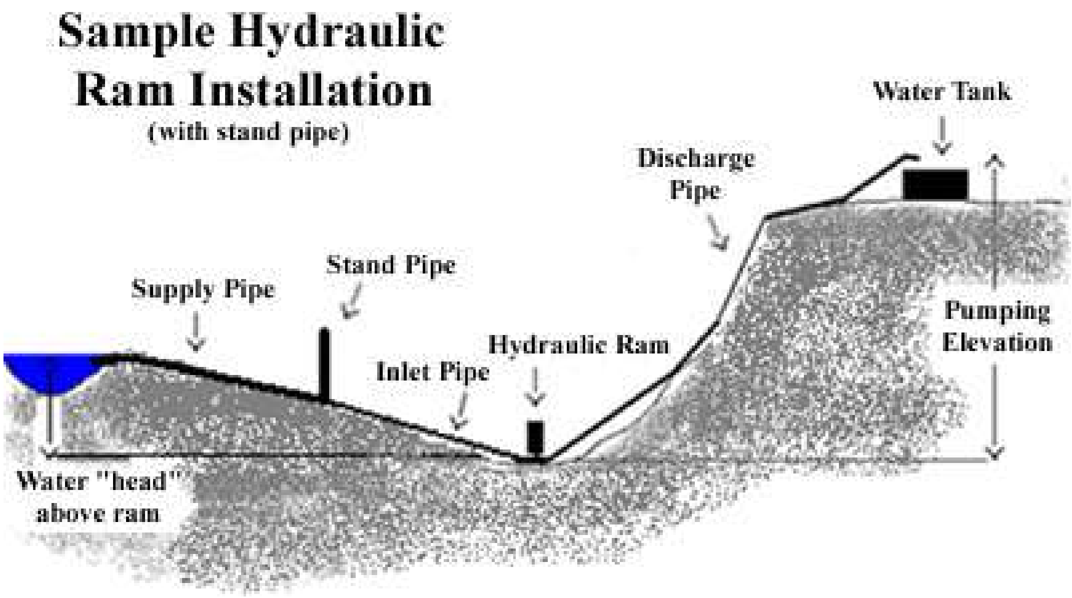


Figure 3. This installation is another option used where the inlet pipe is longer than the maximum length allowed. The stand pipe (open to atmosphere at the top) is required to allow dissipation of the water hammer shock wave.

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Home-made Hydraulic Ram Test Installation

Figure 1. The ram pump installed and operating. Note the water exiting the waste valve and the rock used to hold the pump upright and anchor it.

Figure 2. The 1-1/4 inch Schedule 40 PVC drive pipe supplying the ram pump. Note the curves in the pipe due to the geometry of the stream channel. The pump worked quite well despite the lack of straightness of the pipe.

Back to Hydraulic Ram Page

The Bamford "Hi-Ram Pump ®"

Introduction

[Introduction] [Latest News] [About the Pump] [Questions & Answers] [Prices]
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"Hi-Ram Pump ®" - A New, Simple and Economical Pump - Powered by Water.
An Australian Invention - Australian Patent No. 741896

The pump is quiet and is operated solely by
the energy in a flow of water entering from above the pump.
It uses no external source of power such as electricity, petrol or diesel.

A basic version of the "Hi-Ram Pump"
(The steel pipe on the left is the drive pipe entering the pump)

Particularly in developing countries, the choices for pumping water are often limited because reliable or affordable sources of power are not available. The idea of a water pump powered by water is not new, but is very relevant in a world where energy conservation is increasingly important. The hydraulic ram pump, invented more than 200 years ago, is one such pump.

Although the principle of operation of the Bamford Hi-Ram Pump is similar to that of a traditional hydraulic ram pump, the new pump is considerably different in its construction and

operating characteristics.

As is described in the section "About the Pump", the Bamford Hi-Ram Pump uses an inlet flow of water at low pressure to pump some of that water to a higher pressure or height. The pump has a self-sustaining cycle of operation about one second long. One typical installation is where water diverted from a stream drives the pump, with some of the water going up hill to a greater height, and the remaining water going to waste back to the stream.

The basis of the pump is a new waste valve mechanism with two moving parts, both of which can be very easily removed for maintenance or to adjust the pump.

In comparison with conventional hydraulic ram pumps, some of the different characteristics of the Bamford Hi-Ram Pump are as follows:

Its performance can be quickly adjusted for different pumping conditions, by using alternative moving parts in the valve mechanism.

Although the basic pump is very simple, additional components can be used to improve its performance in special roles.

It will work against both high and low output heads, thereby covering a much wider range of operating conditions.

The pump will operate when totally underwater (but the inlet flow of water to operate the pump must come from another source above the surface of the water).

The water going to waste need not spill out around the pump, but can be piped away for further use.

Depending on the operating conditions, the pump can be constructed wholly or partly from metal, plastics or other materials.

When constructed of non-metallic materials, the pump emits little noise.

The pump can be arranged to supply compressed air (but needs an air inlet pipe if underwater).

The pump can be arranged to provide a direct mechanical output to drive other devices.

The capability of the pump to "suck in" air can also be used to suck in water so that the pump acts

as a suction pump for small suction heads.

Production pumps are now available as a basic water pump of the type shown above. Additional parts for the pump to product compressed air, or provide a mechanical output, or act as a suction pump are normally not provided. Provision of pumps for special applications needs to be the subject of a special order.

However, just in case of misunderstanding, you cannot pump water from a well or pool of water by just lowering the pump into the water - the pump must be driven by a flow of water coming from above the pump.

The Bamford Hi-Ram Pump considerably extends the usefulness of such devices for developing countries. Its ability to produce compressed air could be of particular use. Its ability to give a mechanical output could provide a means to pump clean drinking water from another source.

With reduced manufacturing costs and simplicity, the Bamford Hi-Ram Pump also has the potential to establish new roles in developed countries, and significantly increase the market for pumps using the hydraulic ram principle.

Queries from potential manufacturers or licensees are welcome.

Pumps are available for export, and more information about price and availability is shown in the "Latest News" Page.

Email hi-ram@bamford.com.au
Bamfords, Post Office Box 11, HALL ACT 2618, AUSTRALIA
Phone +(61 2) 6227 5532 Fax +(61 2) 6227 5995
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