DTU

Ram Pump Programme

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

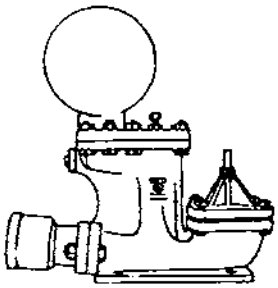
TECHNICAL
16
RELEASE

An introduction to hydraulic ram pumps

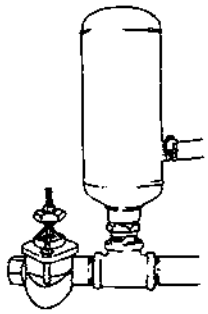
This Technical Release explains briefly what ram pumps are, how they work, and how you might select them. It finishes with a catalogue of the current DTU designs of pump for local manufacture in developing countries.

Contents

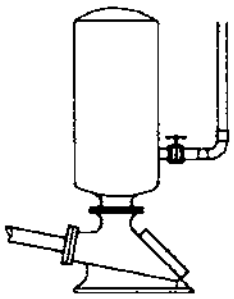
A much fuller description of how to design and install ram pumps systems can be found in the book *Ram pumps and the design of ram pump systems*, DTU, UK 1995, which is available from the DTU at the address on the back cover of this Technical Release. A list of Working Papers and other Technical Releases,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



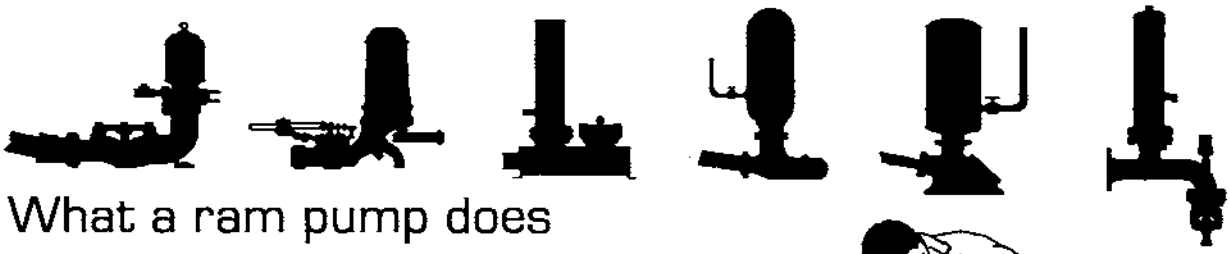
AN EASTON RAM PUMP
UK



A GAVIOTAS RAM PUMP
Columbia



A "PREMIER" RAM PUMP
India



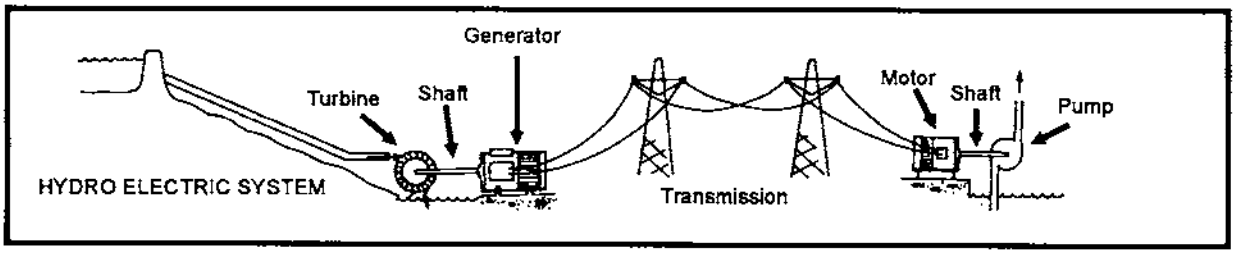
What a ram pump does

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.

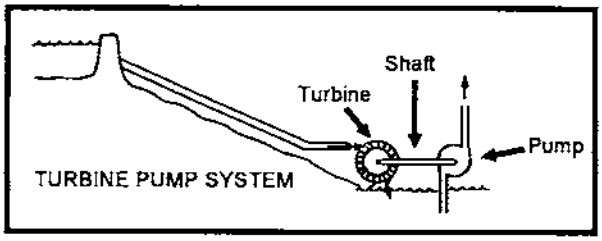
Many people are surprised when they first see a ram pump working. They think that it is driven by a hidden motor, or by magic. They watch it pumping and are amazed.

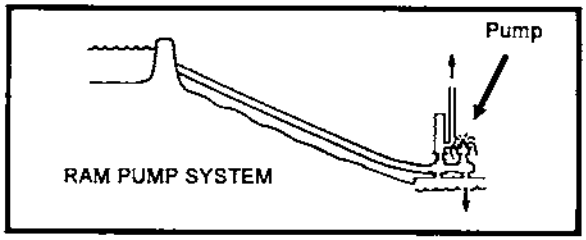
Every kind of pump needs a source of power. They can be powered by people or animals, the wind, falling water, electricity , or fuels such as diesel and petrol. The source of power is often separate from the actual water pump and the two can be joined together by, for example, a shaft. The ram pump uses 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

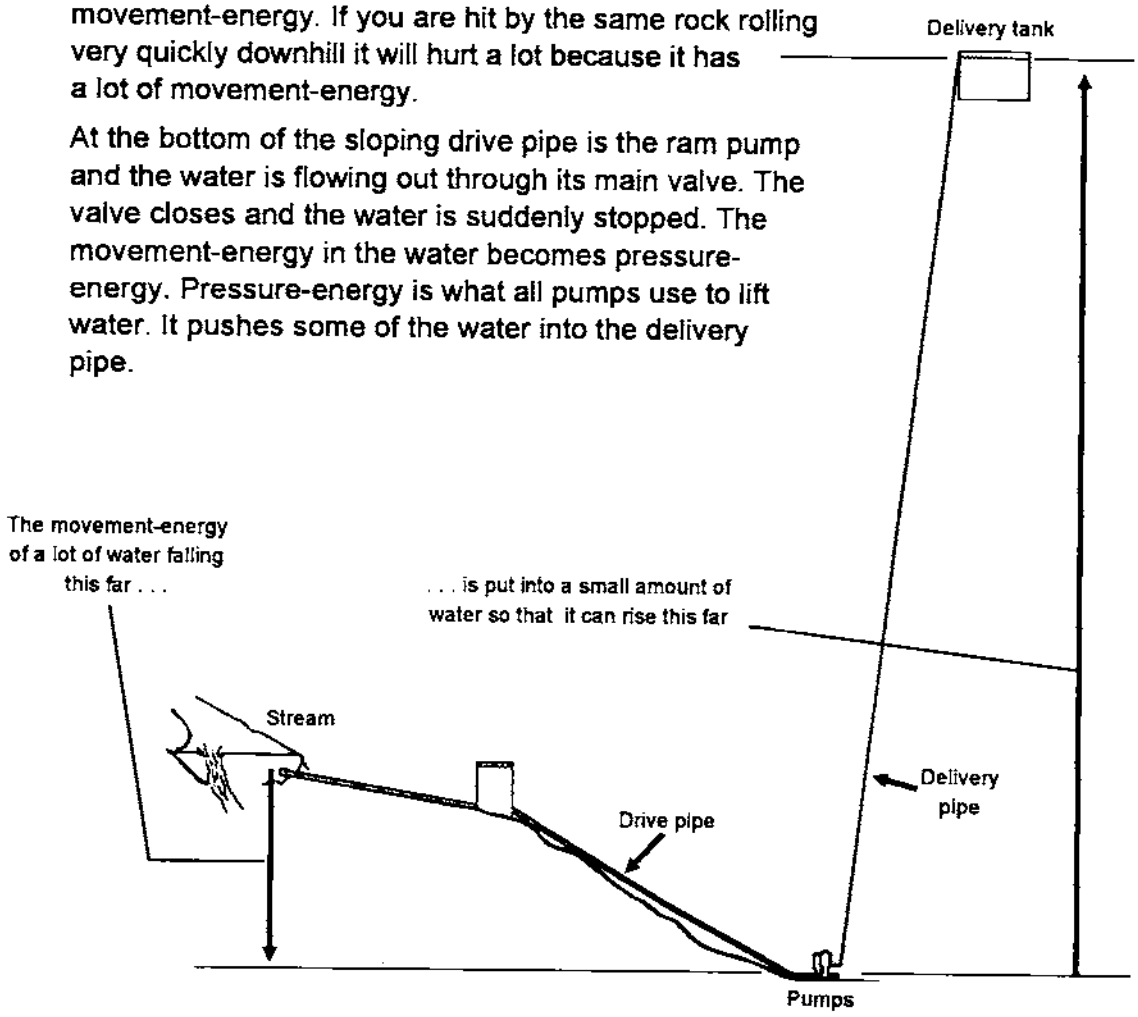




As far as we know, the ram pump was first discovered or invented 200 years ago. Since then it has been rediscovered many times.

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.



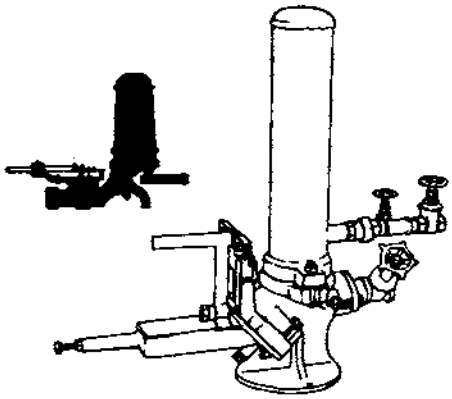
SKETCH OF A RAM PUMP SYSTEM

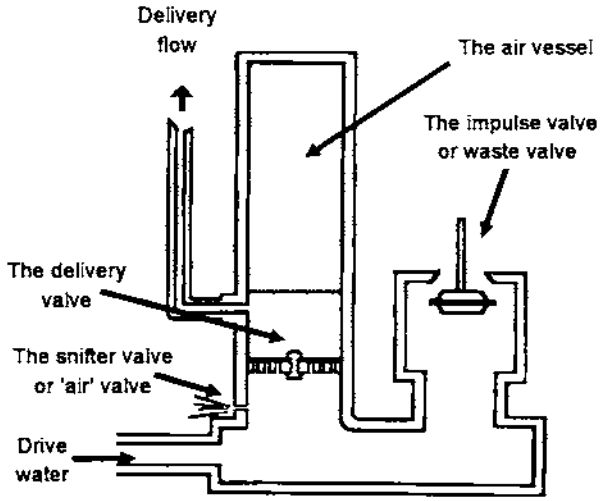
The movement-energy of all the water falling down the drive pipe is put into a small part of that water. The small part of water then has enough pressure energy in it to be 'delivered' to the place where it is needed.

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.



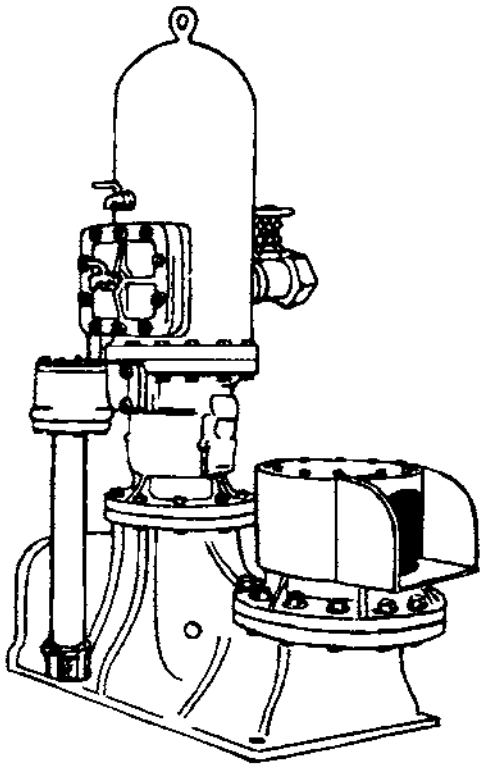


A DRAWING OF A RAM PUMP CUT IN HALF

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.

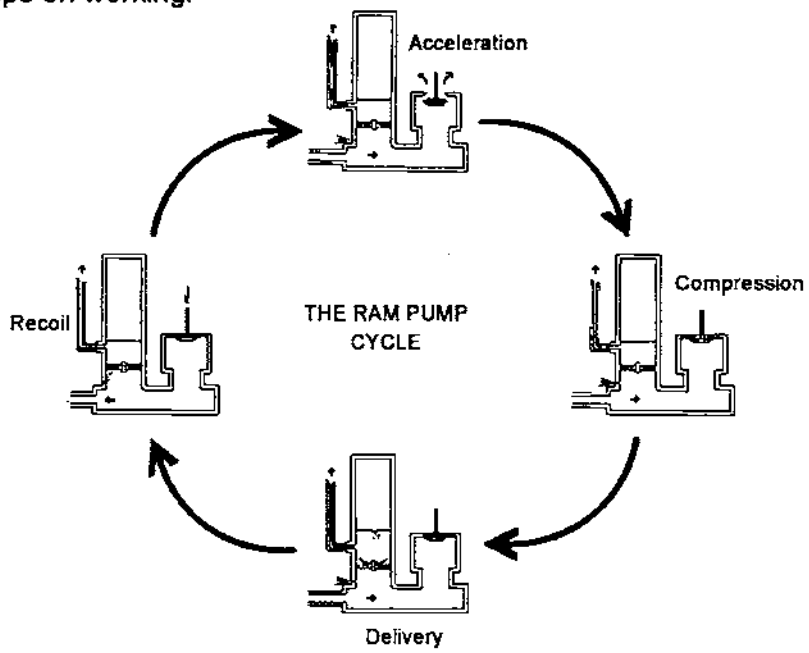
A few pump makers build ram pumps that keep the water that is pumped separate from the drive water. This allows you to pump clean water from a nearby spring while using the power of dirty water from a river or stream. These are sometimes called 'compound' rams. The pumps are more complicated and expensive 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.

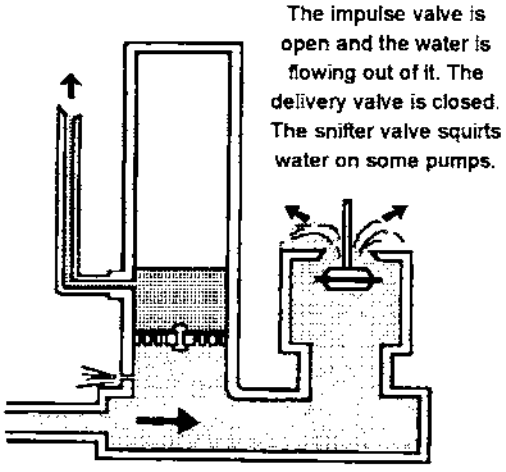


Each cycle happens very quickly, often about once a second. This means that there is no time to see what is happening. The time each stage takes is usually measured in 'milliseconds', which are thousandths of a second. A mosquito flaps its wings about 1000 times a second, so a millisecond is roughly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

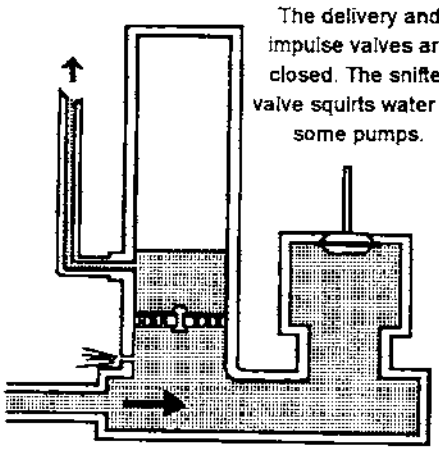
Acceleration (about 900 flaps of a mosquito's wing)
When the impulse valve on the pump is open, water flows down the drive pipe and comes out through the open valve. The water flowing past the open valve drags past it, trying to close it. The flow down the drive pipe and out through the impulse valve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



The impulse valve is open and the water is flowing out of it. The delivery valve is closed. The snifter valve squirts water on some pumps.

ACCELERATION

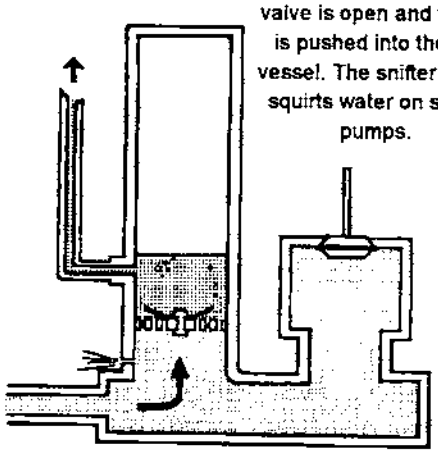
Compression (1 or 2 flaps of a mosquito's wing) When the impulse valve shuts, the water flowing down the drive pipe cannot come out through it. At the moment the valve closes, the water is travelling very fast and suddenly it has nowhere to go. As it got faster, it gathered movement-energy like the rock 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

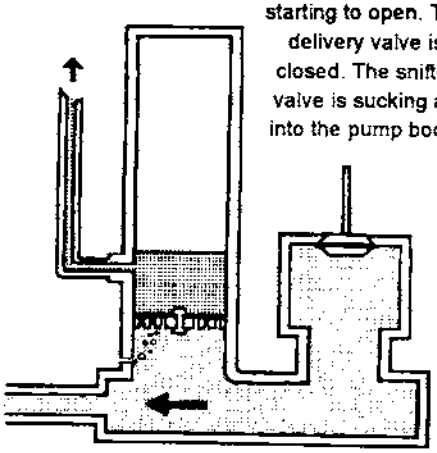
Delivery (about 50 flaps of a mosquito's wing) Because the pressure rises higher than the pressure in the air vessel, the delivery valve is pushed open and water flows through it. The pressure in the pump body drops quickly to equal the pressure in the air vessel. The water coming down the drive pipe 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.

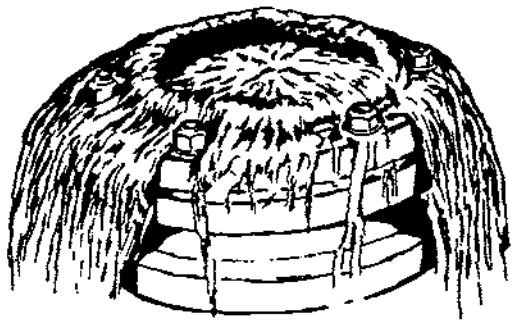
RECOIL

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.

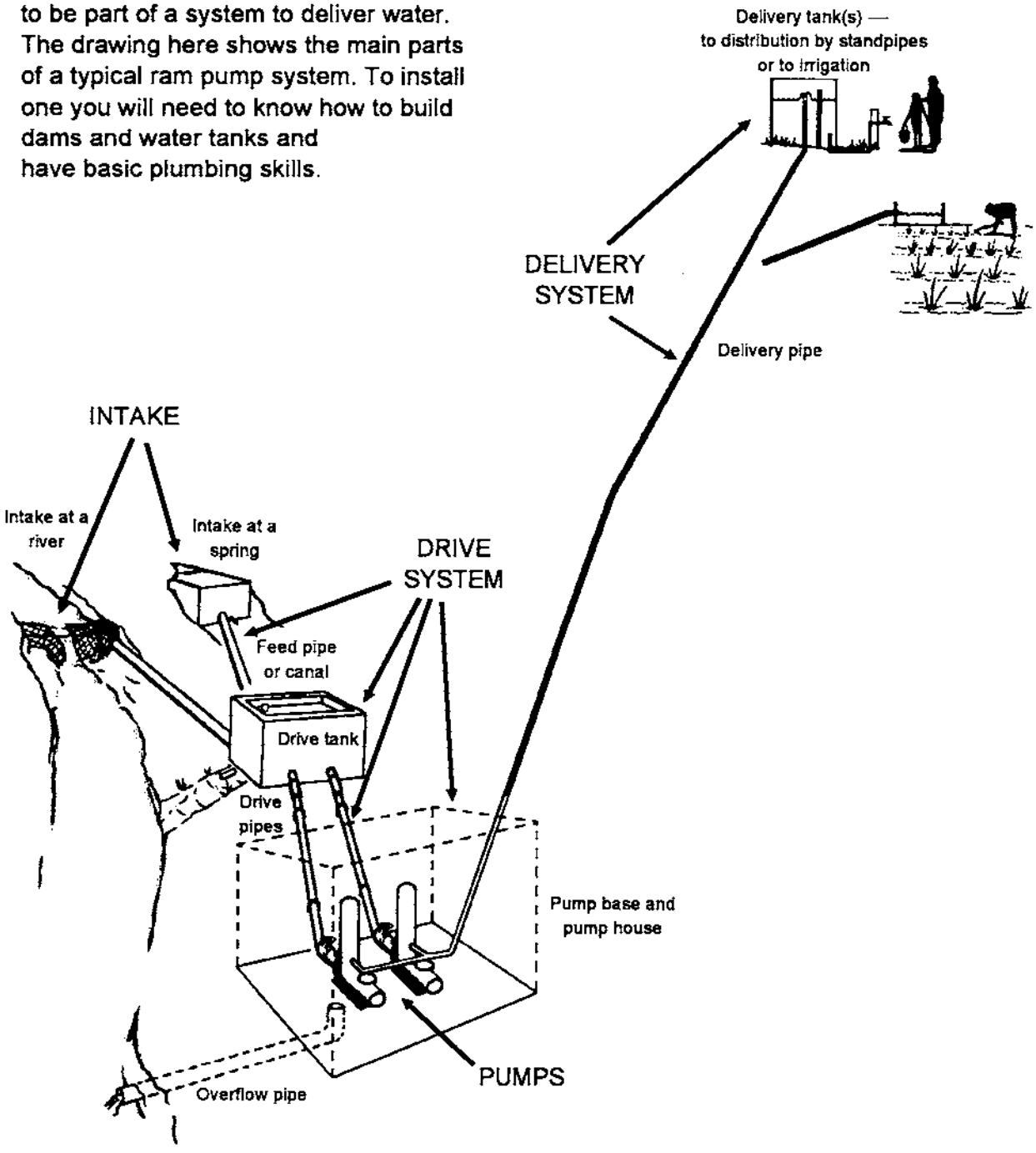


THE IMPULSE VALVE OF A BLAKES RAM PUMP
This has no moving metal parts. It pulses gently and is fairly quiet

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.

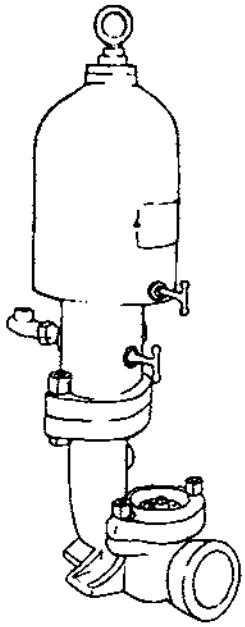
If a site meets these conditions, it is probably worth carrying out a site design survey. A design survey will give a good idea of the amount of water that can be delivered and how much a system will cost.

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.

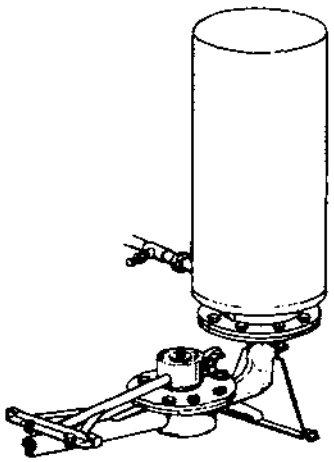
Some of the traditional ram pump makers are still in business at the time this is written. The most famous is perhaps John Blake in the UK. The basic design of their pumps has been so successful that it has been copied by a number of makers from China to Africa.



A SMALL 'JOHN BLAKE' RAM PUMP, UK

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.

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.



A 'DCS' RAM PUMP
Nepal

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.

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).

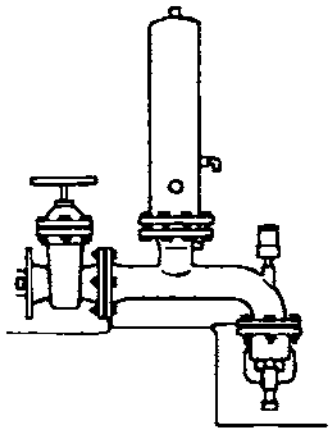
  ☛ *If you choose a pump with a drive pipe bigger than 4" you should get the manufacturers to help design the system.*

- 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.

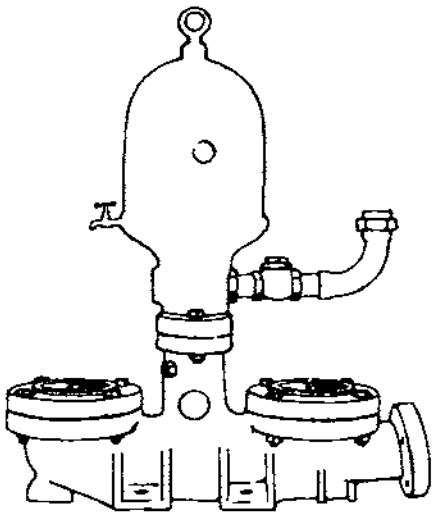


A PFISTER AND LLANGHAUS RAM PUMP, Switzerland

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.



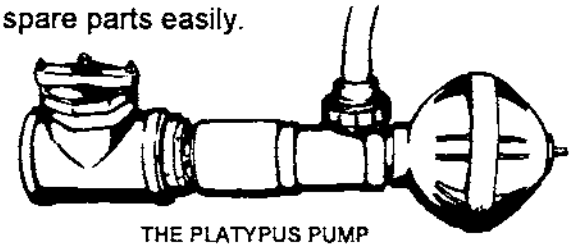
A JANDU PLUMBERS TWIN-IMPULSE RAM PUMP Tanzania

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

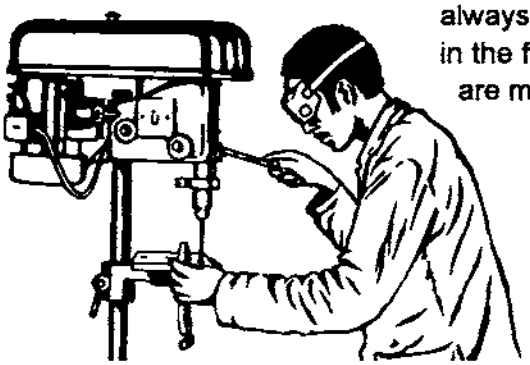
Using an old ram pump

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.

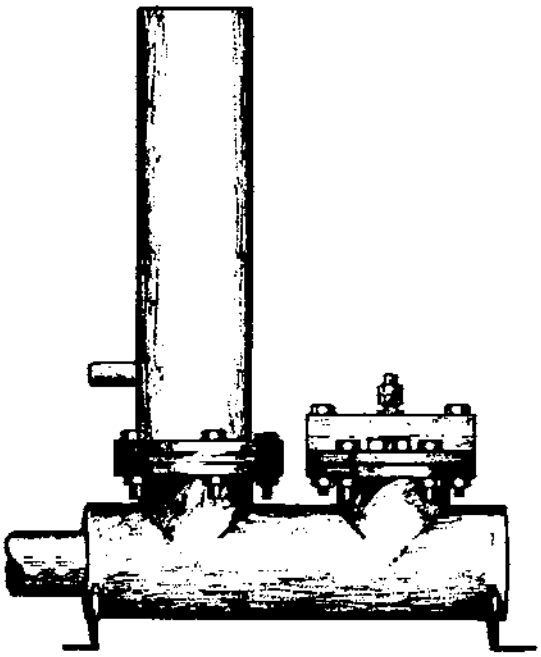
Making a ram pump in a small workshop

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

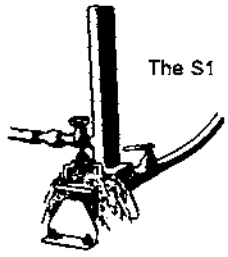
Note that if two pumps are used in parallel, the drive flow and delivery flow of the system will be doubled

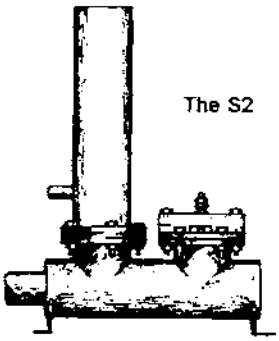
S1 pump. This small pump is normally used to supply drinking water to a house or small group of houses. The drive flow is usually taken from a spring.

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