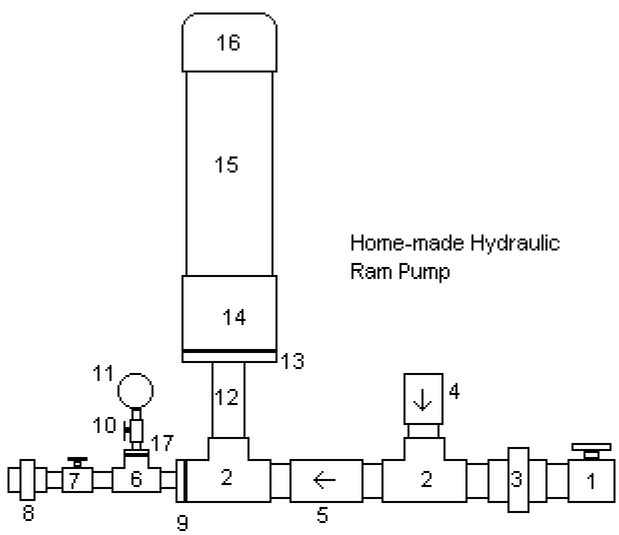
Ram pump plans

http://www.clemson.edu/irrig/equip/ram.htm

Home-made Hydraulic Ram Pump

Pump Plans	Assembly Notes	Performance	Links
How It Works	Operation	Test Installation	

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
7 3/4" valve
8 3/4" union
9 1-1/4" x 3/4" bushing
15 4" x 24" PR160 PVC pipe
16 4" PVC glue cap
17 3/4" x 1/4" 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.

Last modified on 10/15/07
This page created and maintained by [Bryan Smith],
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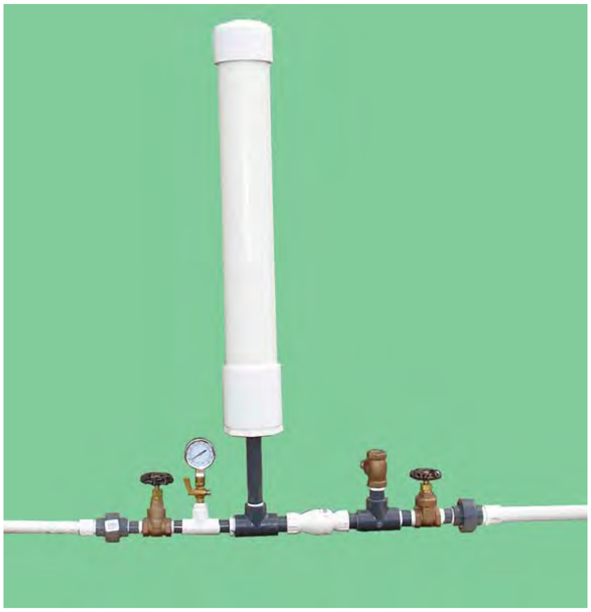
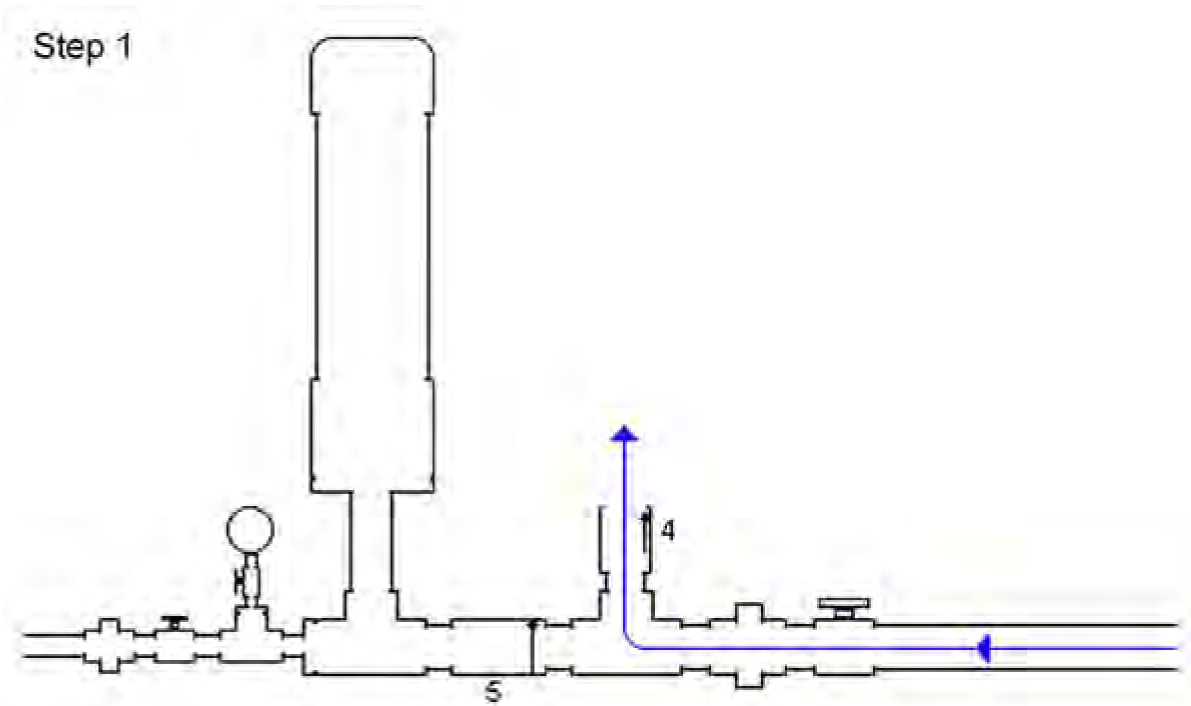


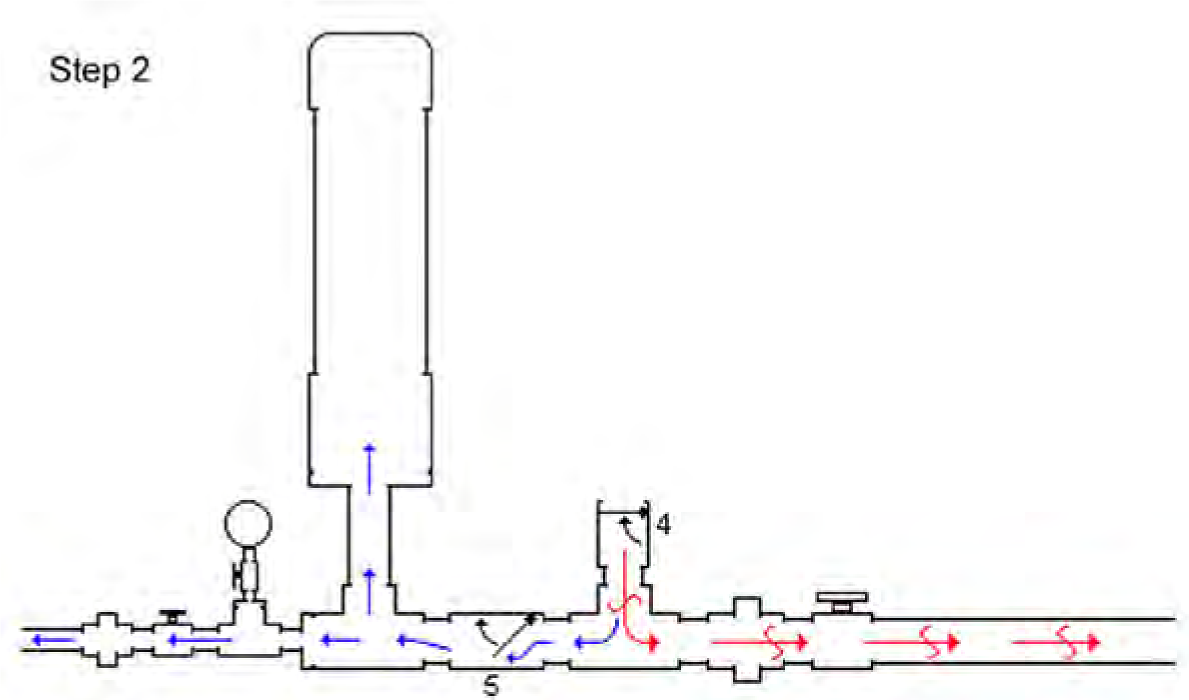
How a Hydraulic Ram Pump works

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.

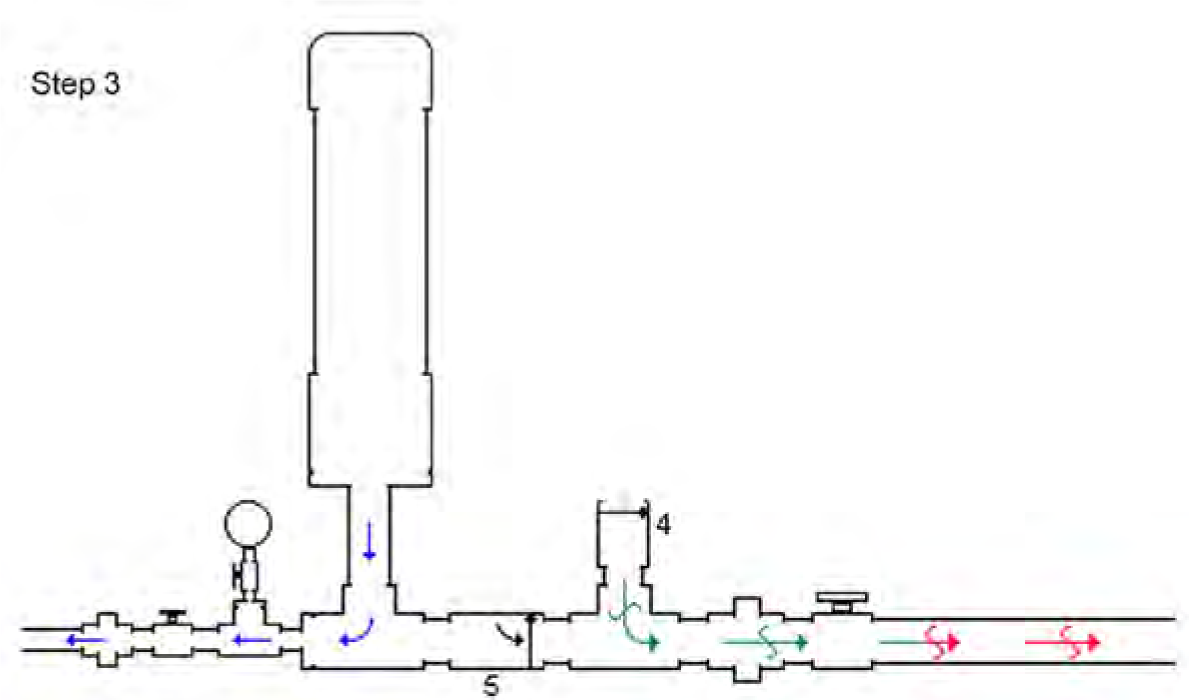
Here's how the hydraulic ram pump actually works, step-by-step:



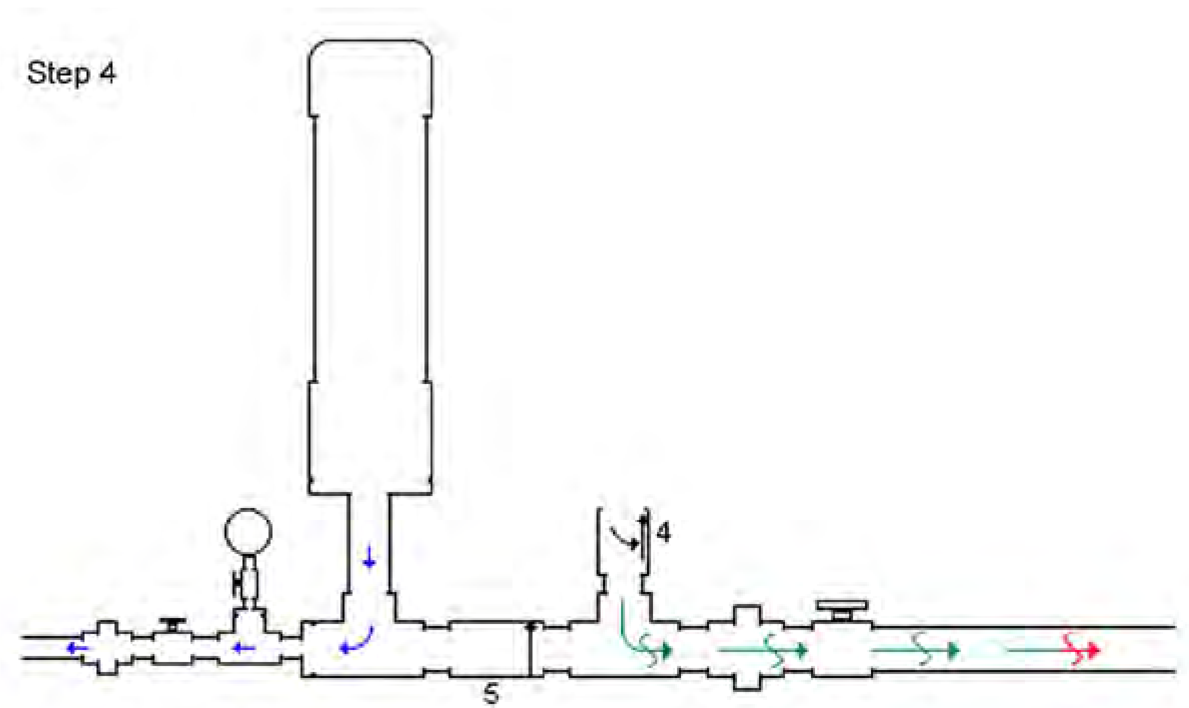
(1) Water (blue arrows) starts flowing through the drive pipe and out of the "waste" valve (#4 on the diagram), which is open initially. Water flows faster and faster through the pipe and out of the valve. (Click here to see an actual image of an operating ram pump for this step.)



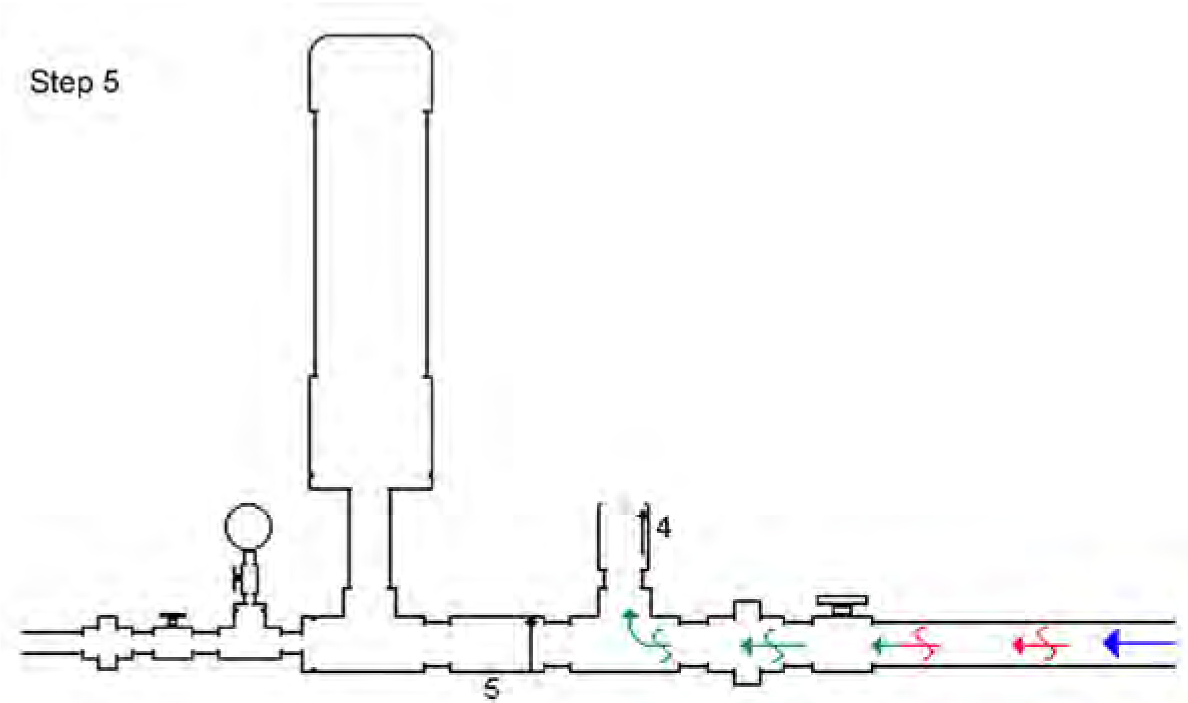
(2) At some point, water is moving so quickly through the brass swing check "waste" valve (#4) that it grabs the swing check's flapper, pulling it up and slamming it shut. The water in the pipe is moving quickly and doesn't want to stop. All that water weight and momentum is stopped, though, by the valve 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.*

Hydraulic Ram Pump System Sketches

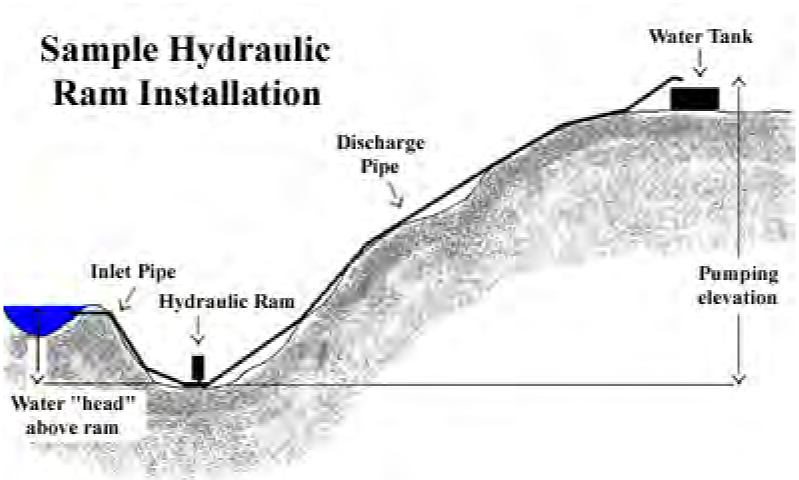


Figure 1. This installation is the "normal" ram system where the inlet pipe is less than the maximum length allowed. No stand pipe or open tank is required.

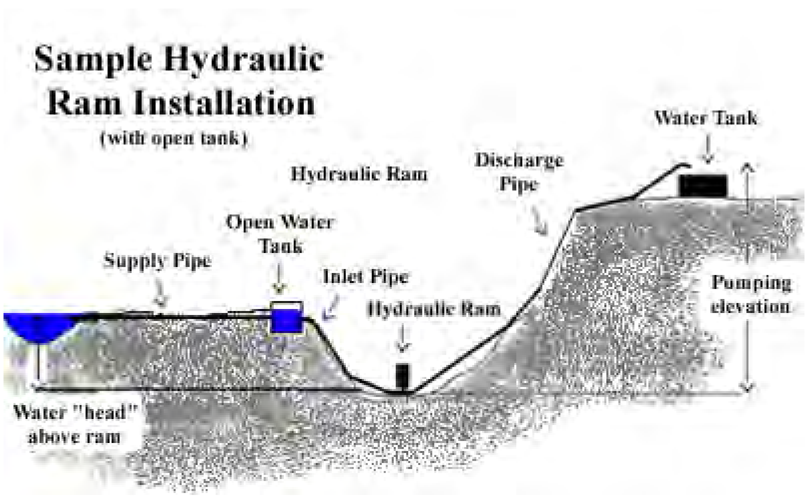


Figure 2. This installation is one option used where the inlet pipe is longer than the maximum length allowed. The open water tank is required to allow dissipation of the water hammer shock wave.

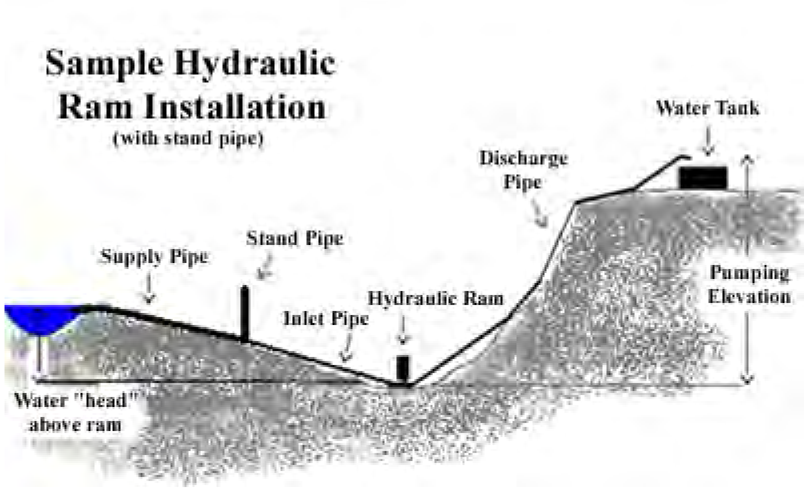


Figure 3. This installation is another option used where the inlet pipe is longer than the maximum length allowed. The stand pipe (open to atmosphere at the top) is required to allow dissipation of the water hammer shock wave.

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.

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http://www.homepower.com/article/?file=HP97_pg140_QandA_2

Q&A: Ram Pump

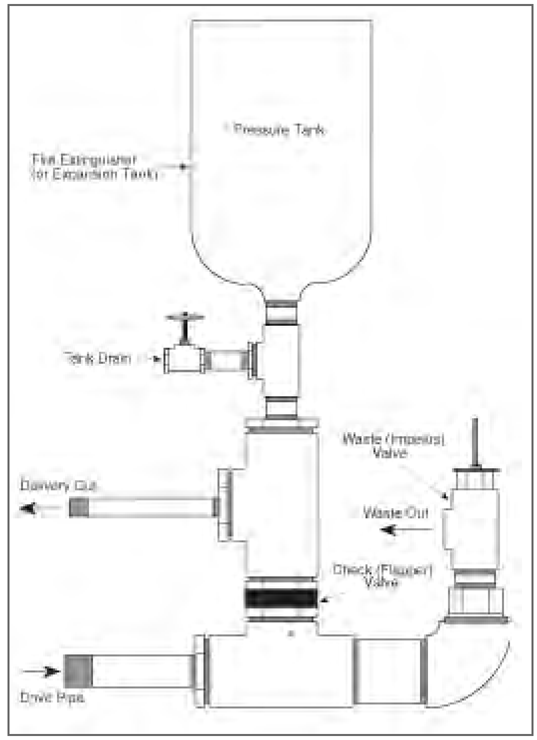
By Michael Welch

Oct/Nov 2003 (#97) pp. 140-141

Intermediate Level

Ram Pump

Dear Home Power, I live in northeast Scotland. I was very interested in an article you had in your magazine on how to build your own ram pump using basic plumbing fittings and a fire extinguisher (HP41). My water supply at present is fed to our house by a #2 Blake Hydram pump, which requires between 2.5 and 5 imperial gallons per minute falling 6 or 7 feet to enable it to pump to a height of 137 feet. This has worked reasonably well until now. The water supply has reduced to 2 imperial gallons per minute and the pump is 50 years old and has seen a lot of wear and tear. I can still manage to get it to pump to around 75 feet.



I endeavored to fabricate my own pump using your detailed instructions. Using the same flow rate and working fall, I got it to pump to a height of just under 60 feet. Do you think that the output I have obtained is reasonable and I'm expecting too much, or have I done something wrong somewhere? The only feature that differs in the pump I put together is that I used an expansion tank rather than a fire extinguisher.

I would appreciate any advice you could offer, since my house is becoming one of the driest places in Scotland. Regards,

Ian Black • via email

Hi Ian, I am really surprised to hear that you can only reach 60 feet with that pump, whereas the Blake was pumping to 137 feet. Actually, I am more surprised that you got that much pumping height from such a low drive head, even with the Blake. It must be a very nice pump.

Something may be amiss with the homebuilt pump. That pump successfully moved water to a height of 150 feet, but also had a drive head of greater than 20 feet at the time. Here are two things to check. First, the design of the waste (impetus) valve leaves much to be desired. If you are using the original design for this, I would not be surprised if it was trying to close a bit crooked since there is not enough of a guide for the stem. That would leave a small gap, and possibly reduce the amount of power the pump has. Also, the flapper valve inside can be a problem. We found that it would cup into the hole when it closed, losing efficiency. What we did to fix this was to put a large washer (called fender washers in the U.S.) that spanned the entire hole on top of the flapper, with a bolt all the way through, and a washer smaller than the diameter of the valve seat underneath. This increased the efficiency of the unit quite a bit.

It seems to me that the Blake should still be able to pump to the same height, except with fewer gallons per day, when adjusting it down to your lower flow rate from your source. Are you sure nothing else is wrong? Check for:

- Obstruction of the drive pipe or impetus valve inner area
- Corrosion in the drive pipe
- Leaks or cracks of the internal valve
- Water filling the bell, reducing the effective air chamber to the point that it will not work.

Michael Welch • Home

Ram pumps

Ram pumps can only be used in situations where falling water is available, which restricts them to use in three main applications:

- Lifting drinking water from springs in valleys to settlements on higher ground.
- Pumping drinking water from clean streams that have significant slope.
- Lifting irrigation water from streams or raised irrigation channels.

Water ram

Ram pumps are water pumping devices that are powered by falling water. The pump works by using the energy of a large amount of water falling a small height to lift a small amount of that water to a much greater height. In this way, water from a spring or stream in a valley can be pumped to a village or irrigation scheme on the hillside. Wherever a fall of water can be obtained, the ram pump can be used as a comparatively cheap, simple and reliable means of raising water to considerable heights.

Ram pumps have a cyclic pumping action that produces their characteristic beat during operation. The cycle can be divided into three phases: 'Acceleration', 'delivery' and 'recoil'.

Acceleration
When the impulse valve is open, water accelerates down the drive pipe and discharges through the open valve. The friction of the water flowing past the moving parts of the valve causes a force on the valve acting to close it. As the flow increases it reaches a speed where the drag force is sufficient to start closing the valve. Once it has begun to move, the valve closes very quickly.

Delivery
As the impulse valve slams shut, it stops the flow of water through it. The water that has been flowing in the drive pipe has considerable momentum, which has to be dissipated. For a fraction of a second, the water in the body of pump is compressed causing a large surge in pressure. This type of pressure rise is known as water hammer. As the pressure rises higher than that in the air vessel, it forces water through the delivery valve (a non-return valve). The delivery valve stays open until the water in the drive pipe has almost completely slowed down and the pressure in the pump body drops below the delivery pressure. The delivery valve then closes, stopping any back flow from the air vessel into the pump and drive pipe.

Recoil
The remaining flow in the drive pipe recoils against the closed delivery valve, rather like a ball bouncing back. This causes the pressure in the body of the pump to drop low enough for the impulse valve to reopen. The recoil also sucks a small amount of air in through the snifter valve. The air sits under the delivery valve until the next cycle when it is pumped with the delivery water into the air vessel. This ensures that the air vessel stays full of air. When the recoil energy is finished, water begins to accelerate down the drive pipe and out through the open impulse valve, starting the cycle again.

Efficiency and Power

The power required to raise water is proportional to the water's flow rate multiplied by the height through which it is lifted (in a ram pump q x h). Similarly, the power available from falling water is proportional to its flow rate multiplied by the distance dropped (Q x H). A ram pump works by transferring the power of a falling drive flow to a rising delivery flow.

By definition Efficiency = output power/input power = qh/QH.

Efficiency is always less than 1. It is useful to know the efficiency because we can use it to predict the delivery flow of a system and to compare two different pumps. Rearranging the equation above gives the formula:

Delivery flow (q) = QHn/h

To obtain a good delivery flow, the efficiency of the pump should be high, there should be a large drive flow, and the delivery head should not be too many times the drive head. The value of system efficiency to put into the formula depends upon many factors including the design of the pump and the system being used.

Suitable Areas

Although all watercourses slope downwards to some degree, the gradient of many is so shallow that many kilometres of feed pipe or canal would be needed to obtain a fall of water large enough to power a ram pump. Ram pumps can be made to run with drive heads of less than one metre but they are not normally considered viable unless heads of two metres or more are available. If it would take a long length of feed pipe or canal to achieve this head, a ram pump system would be prohibitively expensive. The best geographical area for ram pumps is one that is hilly, with rapidly dropping watercourses and, ideally, springs.

In some areas of the world good regional records of rainfall and flow from springs and in watercourses are kept in government offices and libraries. In others, another agency may have carried out recent relevant studies. If any hydrological studies are available for the region in which you plan to install ram pump systems, you can save time, effort and costly mistakes by consulting the records and using their findings in your site design.

After potential sites have been identified, they must be surveyed. The survey yields information about its dimensions and the materials required to construct the site as well as, when more than one site is surveyed, yielding a cost and performance comparison.

Designing a good drive and pump layout is crucial to achieving good system performance and limiting the amount of maintenance required. The aim is to be able to achieve a large head of water between the drive tank and pump, while using a short drive pipe to connect them. The best and cheapest sites are those where the land falls rapidly, allowing all pipe work to be short.

Life and Reliability

Imported ram pumps operated at fairly low throughput have proved extremely reliable in some developing countries. Some have run without stopping for ten years or more in systems supplied with clean water from a reservoir. This outstanding reliability has had a curious side effect - when such pumps finally stop the beneficiaries have no recall of their source, no knowledge of how to maintain them and no access to spare parts. Failures in ram pump systems often occur outside the pump itself - blockage of filter screens, damage to pipes, sedimentation of pipes and tanks etc. Poorly located drive pipes sometimes show perforation due to a process called cavitation.

Pumps made in local workshops are less durable than some of the imported machines made of cast iron, but their lower price usually makes them better value than either imported ram pumps or other pumps of comparable throughput. They also have the advantage of being locally repairable with ready access to spare parts.

Ram pumps run unattended for long periods, so running faults can go unattended for days or weeks. This can lead to expensive failures. For example, blockage of the output for long periods can cause fatigue failure of components (unless a costly pressure relief valve is fitted). The historical high reliability of ram pumps may reflect in part the social circumstances of their traditional use on large farms or mission stations where regular checks are made. The routine supervision of village systems may be much poorer and great care should be taken to ensure adequate caretaking.

Tuning to Suit Site Conditions

Any particular ram pump is normally capable of running under quite a wide range of conditions. Most manufacturers quote operating ranges of drive head (H), drive flow (Q) and delivery head (h) for each pump size and give some indication at a particular site. In situations where the water source has a larger flow than that required, each pump can be tuned to use as much drive water as possible to ensure minimum capital costs. When there is a limited amount of drive water available, the impulse valve has to be tuned to make the most efficient use of that water to produce the best possible output. At many sites there is a seasonal variation in the drive flow available and this is accommodated by varying the pump tuning or varying the number of pumps in use.

Economic Factors

One of the greatest benefits of ram pump systems is that they have extremely low running costs. There is no input of expensive petroleum fuels or electricity, making the systems very inexpensive to operate. The purchase cost of a pump, however, is usually only a fraction of the capital cost of a system: drive and delivery pipe work are usually the most expensive parts. Ram pump systems can be subject to economies of scale. For example, where there is enough drive flow, having several pumps at one site gives a lower unit cost then if the same pumps were installed at separate sites. In situations of plentiful drive flow, buying one large pump may be cheaper than buying several smaller ones, although this option does have disadvantages: having a single large pump involves a loss of system flexibility across a range of flows and if the pump needs maintenance or fails, 100% of the delivery is lost. With several smaller pumps, a pump can fail or be stopped for maintenance without stopping the entire delivery flow.

Prices of ram pumps available today vary enormously. If a pump is imported the costs of shipping and customs duty may significantly increase the actual cost of the pump to its users.

Social Factors

The significance of social factors to any development project cannot be over-emphasised. This is particularly true of community water supplies, which involve every member of the community on daily basis. A large amount of written material is available highlighting the importance of community involvement and detailing examples of participation in project initiation, design, management, and finance. It is strongly recommended that anyone exploring the possibility of initiating a community water supply should obtain some of the available literature and give great attention to the social aspects of the project. Good engineering is only one part of sustainable, economic and equitable water supply system. Without complete community involvement, even a water supply system that is technically perfect is likely to encounter serious problems and may fail altogether.

Adequate community involvement is particularly important during the period of system appraisal and design, and is dependent on good communication. When sufficient time and care is invested in producing a widely acceptable design, ram pump technology can be very appropriate to rural areas and be capable of true village-level operation and maintenance.

http://www.wot.utwente.nl/publications/articles/rampumps.html

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Hydraulic Rams -- Computer Simulation and Optimum Design

Although the hydraulic ram pump has been around for roughly 200 years, its design has been largely left to trial and error. Here is a computer-aided method for improving performance. Y.C. Chiang, Ali A. Seirig, Mechanical Engineering Department, University of Wisconsin, Madison, Wis.
-- From *Computers in Mechanical Engineering*, January 1985 (with thanks to Kirk McLoren)

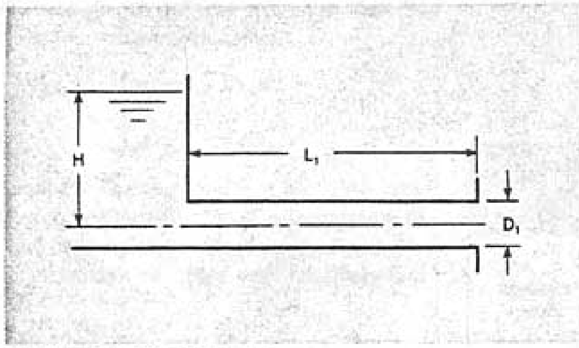


Fig. 2 Model of the drive pipe.

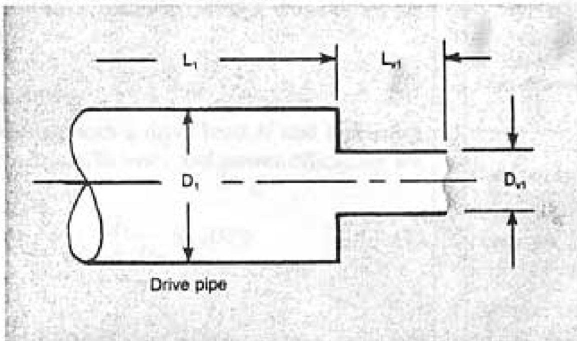


Fig. 3 Model of the waste valve.

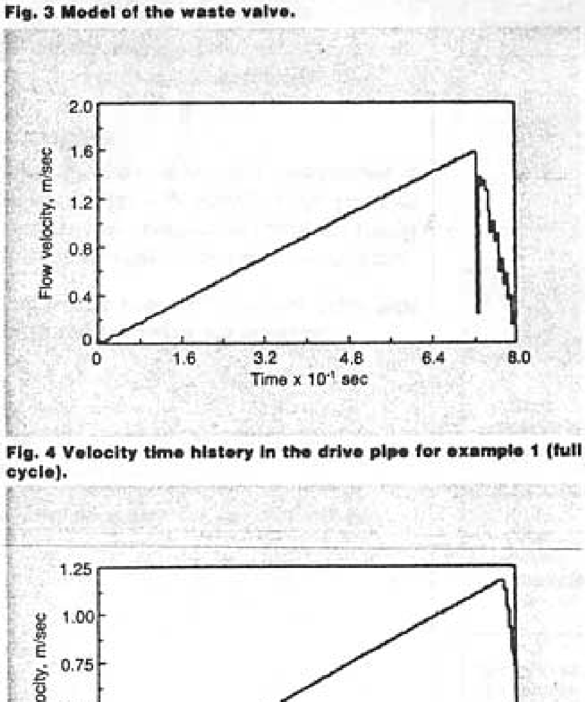


Fig. 4 Velocity time history in the drive pipe for example 1 (full cycle).

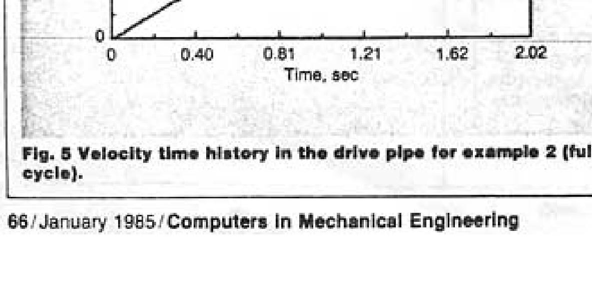


Fig. 5 Velocity time history in the drive pipe for example 2 (full cycle).

pipe [1–4] are rather incomplete and are usually derived from empirical experience rather than comprehensive experimentation or theory. In this article we will present a general method for the analysis and optimum design of hydraulic rams for any application. The technique used is the computer-aided analysis we introduced in the previous issue of *CIME* [5].

Modeling the Hydraulic Ram

A hydraulic ram is composed of five main parts: the drive pipe, waste valve, delivery valve, air vessel (or surge tank), and delivery pipe. To apply our scheme for analyzing fluid transients to the hydraulic ram, we must develop simplified models of the individual parts as follows:

Drive pipe. The drive pipe, with a drive head H, can be modeled as a pipeline connected to a reservoir of head H upstream, as shown in Figure 2.

Waste valve. We model the waste valve as a short pipe with variable diameter. The length of this pipe, L_{v1}, is taken equal to the stroke of the disk valve. The diameter, D_v, is then set to vary from 0 to the diameter of the drive pipe, D_1, in order to describe the change from the fully closed to fully opened valve. The model of the waste valve is shown in Figure 3.

If the relative valve opening τ is defined as

$$\tau = \left(\frac{D_v}{D_1}\right)^2 \tag{1}$$

Then,

$$D_v = D_1\sqrt{\tau} \tag{2}$$

The valve opening is controlled by the movement of the valve disk, which can be determined from:

$$\ddot{x} = -g + \frac{A_d}{M_v}\left(C_v\frac{1}{2}\rho V_1^2 + P_1 - P_2 + L_{v1}\rho g\right) \tag{3}$$

where: A_d is the effective area of the valve disk; P_1 and P_2 are pressures at the drive-pipe side and free side, respectively; V_1 is the flow velocity at the end of the drive pipe; M_v is the mass of the valve; and C_v is the valve coefficient, assumed to be 1.0.

By integrating equation (3), we can determine the value of τ according to the following equations:

$$\begin{aligned} \tau &= -x/L_{v1} && \text{for } -L_v < x < 0 \\ \tau &= 0 && \text{for } 0 < x \\ \tau &= 1 && \text{for } x < -L_v \end{aligned} \tag{4}$$

Delivery valve. Modeling of the delivery valve is similar to that of the waste valve. The equation of motion for the delivery valve can be written as:

$$\ddot{x} = -g + \frac{A_d}{M_v}\left[C_v\frac{1}{2}\rho(V_1^2 - V_2^2) + P_1 - P_2 + L_{v2}\rho g\right] \tag{5}$$

where V_1 and V_2 represent the velocity for the drive-pipe side and the surge-tank side, respectively.

The relative opening of the delivery valve can then be determined from the following relationships:

$$\begin{aligned} \tau &= x/L_{v2} && \text{for } -L_{v2} < x < 0 \\ \tau &= 0 && \text{for } 0 < x \\ \tau &= 1 && \text{for } x < -L_{v2} \end{aligned} \tag{6}$$

Surge tank (air vessel). The impedance of the surge tank is generally selected to be relatively small in comparison to that of the drive and delivery pipes. To simplify the analysis, we model the surge tank as a pipe with relatively low impedance.

Delivery pipe. The delivery pipe can be modeled as a pipeline connected to a reservoir with a head h at the downstream end.

Ram Performance

For a ram operating with a drive head H and a delivery head h, the volumetric efficiency and power efficiency are defined as:

$$\eta_V = \frac{Q_d}{Q_w + Q_d} \times 100\% \tag{7}$$

and

$$\eta_p = \frac{Q_d h}{Q_w H} \times 100\% \tag{8}$$

where Q_w and Q_d are the average flow rates through the waste valve and the delivery valve, respectively.

Numerical Examples

These pipe models for the ram are then incorporated in the pipeline transients program discussed in the previous issue. We will consider two examples to check the results of our model against those obtained by other investigators.

Example 1: the hydraulic ram with straight drive pipe analyzed in [4] with the following parameters:

$H = 3.54$ m
$h = 24.38$ m
$D_1 = 0.0262$ m
$L_1 = 15.04$ m

The additional data necessary for our analysis are assumed to be:

$D_2 = 0.2$ m
$L_2 = 0.5$ m
$D_3 = 0.0262$ m
$L_3 = 5.01$ m
$M_1 = 0.1$ kg
$M_2 = 0.25$ kg
$L_{v1} = 0.02$ m
$L_{v2} = 0.02$ m
$C_1 = 1443$ m/sec
$C_2 = 117$ m/sec
$C_3 = 1433$ m/sec
$A_{v1} = 0.00054$ m²
$A_{v2} = 0.00054$ m²

Table I
Performance of Ram In Examples 1 and 3
(H = 3.54 m, h = 24.38 m)

Performance of ram	Cycles per min.	Pump rate cc/sec	Volumetric efficiency η_v	Power efficiency η_p
Iversen's results	85.0	22.8	8.48%	58.39%
Our results from example 1	75.0	39.6	9.14%	69.3%
Optimum case for straight drive pipe (example 3)	52.4	66.2	11.50%	89.4%
Optimum case for stepped drive pipe (example 3)	50.6	73.7	12.14%	95.1%

Table II
Performance of Ram In Examples 2 and 4
(H = 0.65 m, h = 1.30 m)

Performance of ram	Cycles per min.	Pump rate cc/sec	Volumetric efficiency η_v	Power efficiency η_p
Baz's experimental data	24.0	26.0	3.36%	6.95%
Our results from example 2	29.6	28.66	4.15%	8.663%
Optimum case for straight drive pipe (example 4)	59.5	29.98	9.00%	19.77%
Optimum case for stepped drive pipe (example 4)	47.9	54.35	23.9 %	62.7%

The velocity time history in the drive pipe is shown in Figure 4. Table I compares the computed performance of the ram with Iversen's analytical results [4], which were obtained from the usual one-dimensional unsteady-flow approximation. The differences in the two sets of results point out that we lack enough information for a true comparison.

Example 2: hydraulic ram with a straight drive pipe operating with a low drive head and investigated experimentally by Baz and others [6]. The ram has the following characteristics:

$H = 0.65$ m
$h = 1.3$ m
$D_1 = 0.0381$ m
$L_1 = 10.0$ m

The other data necessary in the analysis are taken as:

$D_2 = 0.2$ m
$L_2 = 0.4$ m
$D_3 = 0.0381$ m
$L_3 = 5.0$ m
$M_1 = 0.25$ kg
$M_2 = 0.1$ kg
$L_{v1} = 0.025$ m
$L_{v2} = 0.025$ m
$C_1 = 1443$ m/sec
$C_2 = 117$ m/sec
$C_3 = 1433$ m/sec
$A_{v1} = 0.00114$ m^2
$A_{v2} = 0.00114$ m^2

Figure 5 shows the velocity time history in the drive pipe for this example. Comparison of the ram performance from our analysis and from the experimental data in [6] is shown in Table II. Better correlation is evident in this case.

Example 3: an optimum design of the hydraulic ram in example 1. Given in this case that the values of all variables are the same as those in the first example, we must determine the design parameters for M_1, M_2, D_2, and D_3 that maximize the ram's volumetric efficiency. The following constraints are imposed on the design:

$0.2 \text{ kg} < M_1 < 1.5 \text{ kg}$
$0.1 \text{ kg} < M_2 < 0.5 \text{ kg}$
$0.03 \text{ m} < D_2 < 0.3 \text{ m}$
$0.015 \text{ m} < D_3 < 0.05 \text{ m}$

Values for $M_1 = 0.1$ kg, $M_2 = 0.25$ kg, $D_2 = 0.2$ m, and $D_3 = 0.0262$ m, which correspond to example 1, are chosen as the initial base point for the search. Following the optimum search procedure described in the previous issue, the optimum solution gives these design parameters: $M_1 = 0.769$ kg, $M_2 = 0.1$ kg, $D_2 = 0.1053$ m, and $D_3 = 0.05$ m. The performance characteristics for the optimum design are shown in Table I for comparison.

Layered (or laminated) materials or elastic bars with variations in impedance have been shown to produce attenuation or amplification of the stress wave when subjected to impact or blast loading [7–10]. We use this concept in the optimum design of the ram by generating an optimal shape for the drive pipe in order to produce further improvement in the efficiency. A drive pipe with five equal segments is assumed in this case and the diameters corresponding to the optimum design are found to be:

$l_1 = 3.01$ m $d_1 = 0.0579$ m
$l_2 = 3.01$ m $d_2 = 0.0527$ m
$l_3 = 3.01$ m $d_3 = 0.0262$ m
$l_4 = 3.01$ m $d_4 = 0.0315$ m
$l_5 = 3.01$ m $d_5 = 0.0262$ m

The ram characteristics for this design are improved, as shown in Table I.

Example 4: optimum design of a hydraulic ram operating in low heads. The data for this example are the same as those used in example 2. The parameters obtained for the optimum design with a straight-drive-pipe ram are $M_1 = 0.05$ kg, $M_2 = 0.50$ kg, $D_2 = 0.012$ m, and $D_3 = 0.381$ m.

The optimum shape of a five-segment drive pipe corresponding to the optimum ram are also found to be:

$l_1 = 2.0$ m $d_1 = 0.032$ m
$l_2 = 2.0$ m $d_2 = 0.0381$ m
$l_3 = 2.0$ m $d_3 = 0.0603$ m
$l_4 = 2.0$ m $d_4 = 0.0032$ m
$l_5 = 2.0$ m $d_5 = 0.0032$ m

The performance characteristics for the stepped drive are a significant improvement, as shown in Table II. ■

References

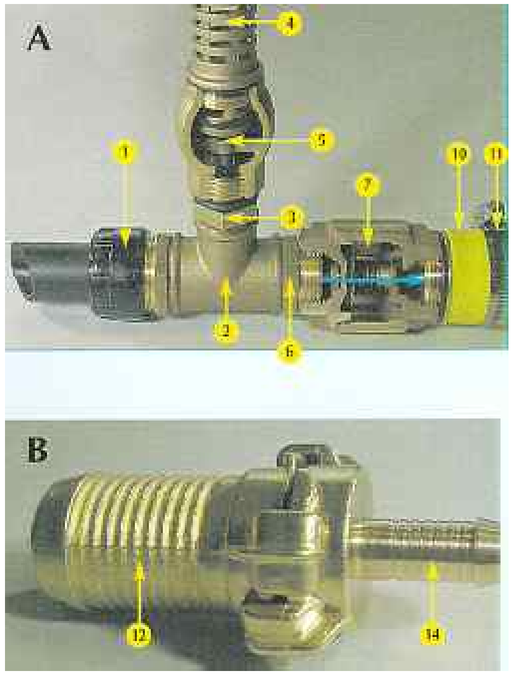
1 Graham, F.D., *Audel's Pumps, Hydraulics and Air Compressors*. New York: Thes. Audels & Co., 1957.
2 Blake, J., *Water Powered Pumps: Hydrams*. Accrington, Lancashire, U.K.: 1981.
3 Addison, H., *A Treatise on Applied Hydraulics*, 3rd ed. Chapman and Hill Ltd., 1944.
4 Iverson, H.W., "An Analyşis of the Hydraulic Ram," *J. of Fluids Eng.*, Trans. of the ASME, June 1975, pp. 191–196.
5 Chiang, Y.C., and Seireg, A.A., "Simulating Fluid Transients in Segmented Pipelines," *CIME*, Vol. 3, No. 3, Nov. 1984, pp. 31–35.
6 Baz, A., Micheal, S., El-Mankabadi, R., and Seireg, A.A., "Utilization of Hydro-Energy Across Hydraulic Structures in Egypt," *Progress Report No. 2*, Cairo University, Egypt, Sept. 1982.
7 Wallace, D., and Şeireg, A.A., "Optimum Design of Prismatic Bars Subjected to Longitudinal Impact," *J. of Eng. for Industry*, Trans. of the ASME, May 1971, pp. 659–666.
8 Hutchinson, J.R., "Stress Waves in Layered Materials," *AIAA Journal*, Vol. 7, No. 4, April 1969, pp. 786–788.
9 Lai, Y.S., "Analysis of Stress Wave in Layered Structure," in *Computers and Structures*, Vol. 4. U.K.: Pergamon Press, 1974, pp. 961–966.
10 Lai, Y.S., and Achenbachi, J.D., "Optimal Design of Layered Structures Under Dynamic Loading," in *Computers and Structures*, Vol. 3. U.K.: Pergamon Press, 1973, pp. 559–572.

Renewable Energy Fun and Water HomePower do-it-yourself projects!

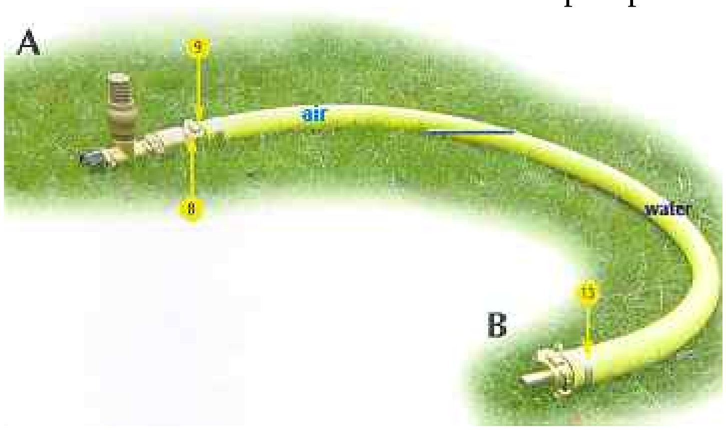
[Spanish text of Gert Breur's ram-pump](#)
[Gert Breur's water-powered suction ram-pump](#)
[New - Simple water-pump made even simpler: Rope-pump](#)

The Breur ROC-ON Ram pump

The large 2inch water-powered RAM pump is able to drive water up to more than 100 meters altitude, while it needs a flow of between 2 and 10 meters level to run. Best operation: delivery less than 10 times altitude of flow. Delivery output volume approximately 10% of flow through Ram. For more info on Ram pumps, go to the WOT homepages: WOT - Working group on Development Technology.
Breur has also developed a small ram pump, so easy to assemble and understand, that the main principle of operation should be clear to anyone that has assembled one. Furthermore, it uses standard "garden" materials except for some pressure tube. Bill of material should be less than $50 even with high-quality materials. I have put up a shopping list below (translated from Dutch, so I hope you understand). Below are the pictures of the assembled pump with numbers, to get an idea. I have made "exploded-view" photos, see further below. I hope they allow you to assemble the parts more easily.



The Breur low-cost 3/4inch Ram pump



The bottom picture shows the ram (A) and the delivery (B). Make sure the delivery is situated LOWER than the RAM, because the tube in between must stay partially filled with air for correct (smooth & efficient) operation.

Shopping List:
1. Clamp-connection SIMPLAST WISA 25 x 3/4inch thread
2. T-joint brass 3/4 inch inside thread
3. Brass reducing coupling 1 inch to 3/4 inch outside thread
4. Foot valve brass 1 inch inside thread (ball shape and used in reverse direction)
5. O-ring nitrilrubber 6.0 mm x 1.5 mm (to regulate pump frequency)
6. Brass reducing coupling 1 inch to 3/4 inch outside thread
7. Spring-loaded check valve brass 1 inch inside thread "EUROPA"
8. (optional) brass quick-connect coupling "GEKA" 1 inch outside thread
9. (optional) Hose quick-connect brass coupling "GEKA" 1 1/4 inch

8+9 may be replaced by brass converter from 1 inch thread to 1 1/4 inch hose coupling.

10. Pressure tube TRICOFLEX 1 1/4 inch x 150 cm (more than 10 bar)
11. Hose clamp "JUBILEE" stainless steel 30-40 mm
12. Hose quick-connect brass coupling "GEKA" 1 1/4 inch
13. Hose clamp "JUBILEE" stainless steel 30-40 mm
14. Hose quick-connect brass coupling "GEKA" 1/2 inch
Not numbered items: Enflontape 12 mm x 0.1 mm or fibre "WURTH" (like for central heating installations)
Further the drive-pipe is not specified, this is either a rigid (metal!) pipe or (easier and therefore preferred) tylene tube, also used in drinking water installations. The diameter must be at least as much as the ram, so 3/4 inch. The length is expected to be several meters, from water-supply to ram.

NOTE that the drive pipe water inlet) is not shown above, it should be connected to the open end of the T-joint. A self-wound spring for the waste-valve is shown on the photo, this is necessary when this valve doesn't point upward.

Considerations: If the water comes out the dilivery in sharp pulses, then there is no air in the thick pressure tube. Disconnect it and fill it with air, the ram will run more efficient and smooth.

The drive heigth should be at least half a meter, but the ram cannot pump up high in that case. No more than 10 meter supply is recommended, or the pressure might get too high when the delivery is blocked.

If the ram doesn't start when water runs through it or it doesn't seem to be very efficient, the O-ring on the stem of the waste valve might be changed (taken away or one more added). Another reason can be that the waste-valve must point upward, or you must spring-load it. Otherwise the valve doesn't open itself. Some experimenting is required to get the best operation.

Multiple rams might be connected parallel (each have its own drive pipe and a common delivery, connected at B) and this will increase both delivery and reliability. Also when the amount of input flow decreases (season), some rams can be shut down while still some water is delivered by the others. One big ram will completely stop. Another important factor: maintenance can be done one ram at a time.

WARNING! If the ram is used to pump more than 20 meters high, the thin delivery tube must also be able to withstand this pressure! Be careful when disconnecting the delivery output, because the full pressure is present even when the ram has stopped! Drain the delivery tube or make (add) a pressure release valve that can be opened safely.

Ram with a shadow of fertility. **Water** means life and growth.

Pictures above can be downloaded as zipped bitmaps: ram.zip (warning: 1331 kB!)

Last update: Feb 24, 2000
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DISCLAIMER:

http://www.geocities.com/ResearchTriangle/System/7014/index.html

Gert Breur's water-powered suction ram-pump

Gert Breur's water-powered ram-pump also sucks up water!

The well-known ram pump, invented two centuries ago by Montgolfier, can lift water to high altitude using the energy of a larger amount of water falling only a few feet. The Dutch inventor Gert Breur has added only one valve to the original two-valve ram, creating a novel design which can still pump water up, but also sucks water from a lower level into the main drive stream. One possible application for this pump is at a piece of land which is the lowest point around, gathering water and becoming too wet for use. With a stream passing by at a higher level, this ram can be powered to lift the water up from the land into the stream. At the same time the ram can pump up water from the stream to a higher level, for irrigation or drinking. The water pumped up from the lower level is not mixed with the water which is pumped to the higher level, because it enters the ram after the impulse valve. See picture 2 for reference.

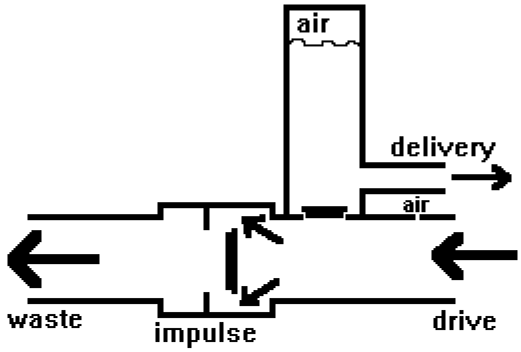


Figure 1a Acceleration

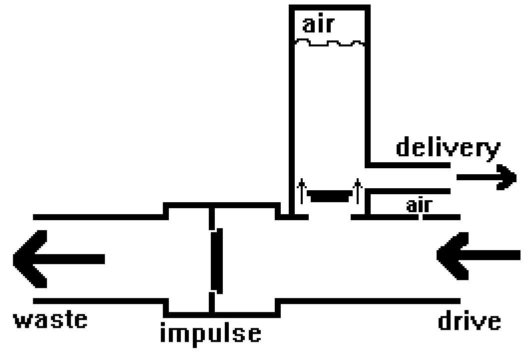


Figure 1b Compression

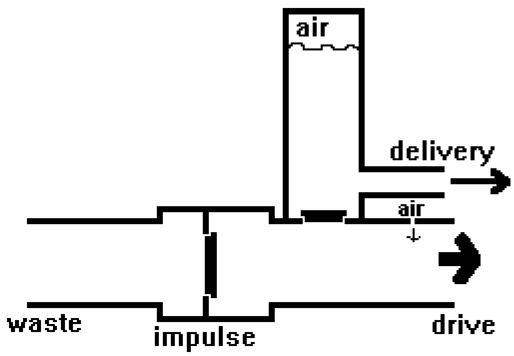


Figure 1c Recoil

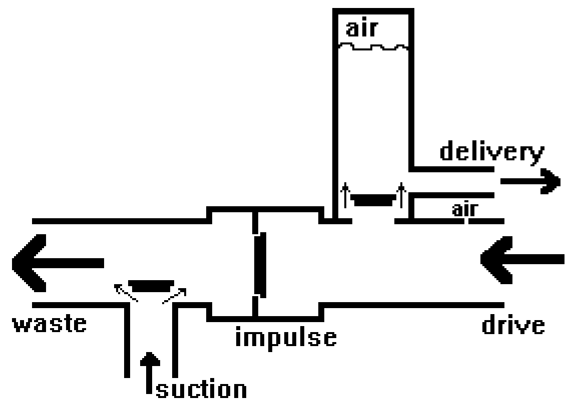


Figure 2 ram suction pump
Compression/Depression

The principle of Gert Breur's Ram pumps

Gert Breur has been experimenting with different materials to make the ram according his design criteria. These are:

- Simple operation, so everyone can grasp the working principle by looking at the parts and assembling them.
- Construction simplicity, so everyone can assemble one in a matter of minutes. Maintenance by local people is the goal.
- Easily obtainable materials, no special parts, so independence from suppliers. Local hardware store or garden centre should provide most or all material.
- No fees, no royalties. The inventor does not want to earn money, he wants people to enjoy the availability of clean water, saving lives and decreasing diseases. Therefore construction drawings and shopping list are free available, distribution is encouraged.

Common characteristic of all ram pumps is the operation using hydro power: a running stream or at least a waterlevel difference is needed. No electric, oil, gas or other energy is needed. This makes the operational cost very low: only the maintenance. Since the operating principle is so simple that local people can maintain the ram, this further reduces opertional cost. Combined with the use of standard materials for the Breur ram, this is an ideal choice for developing countries and for the many environmental aware do-it-yourselfers that want running water at their residence, but want to use renewable energy to bring it there.

Operation principle of the basic ram pump:
The cycle consists of three phases, see figure 1.
a. Acceleration Phase
Water running through the ram increases in speed until the flow through the impulse valve causes enough pressure difference to close it.
b. Compression Phase
The moving water causes a high pressure inside the ram, which opens the delivery valve until the movement of the water has stopped.
c. Recoil Phase
Depending on the type of ram, some air enters the ram during the recoil of the water, this air adds to the 'pressure bubble' in the delivery output, smoothing the operation of the ram. Fresh air is needed if this air can escape during the operation of the ram. At the end of the cycle the impulse valve is opened by its spring and a new cycle starts.

Operation principle of Gert Breur's suction ram pump: See figure 2. The same phases as in figure 1 apply for this ram. Additional action occurs in phase b: Compression/Depression Phase. The water that already passed the impulse valve causes a low pressure when it closes (vacuum). This opens the third valve, sucking in a small amount of water until the main water flow has been stopped, so the pressure rises and the third valve closes.

More information on the ram pumps of Gert Breur can be found at the Working Group On Development Techniques (WOT). This is a volunteer organisation of the University Twente, the Netherlands. They are advising developing countries on the use of Renewable Energy, preferably by knowledge transfer of the technology, so local support is guaranteed.

contact address:
WOT
Vrijhof 206
P.O. Box 217
7500 AE Enschede
the Netherlands
tel: +31 53 489 2845
fax: +31 53 489 2671
e-mail: wot@tdg.utwente.nl
http://www.student.utwente.nl/~wot

Last update: April 11, 1999
Webmaster: Cor van de Water

The Gravi-Chek pumps have been tested by the Center for Irrigation Technology at the California Agricultural Technology Institute. There are three models available, providing water at rates from 20 to 16,000 gallons per day, depending on the installation.

Easy to use:

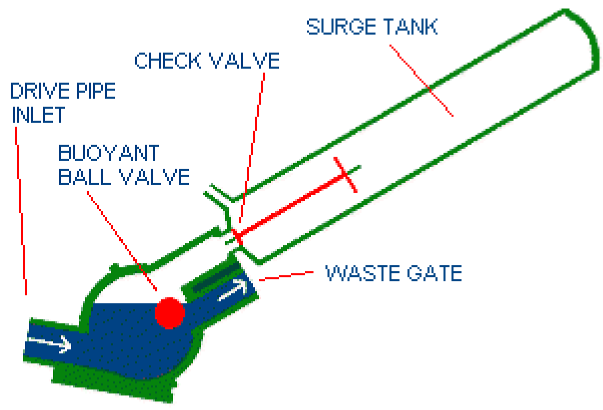
- Lightweight (35 lbs. or less), easy to carry and install in remote areas.
- Quick start up, no energy costs.
- Little or no maintenance.

Efficient and powerful:

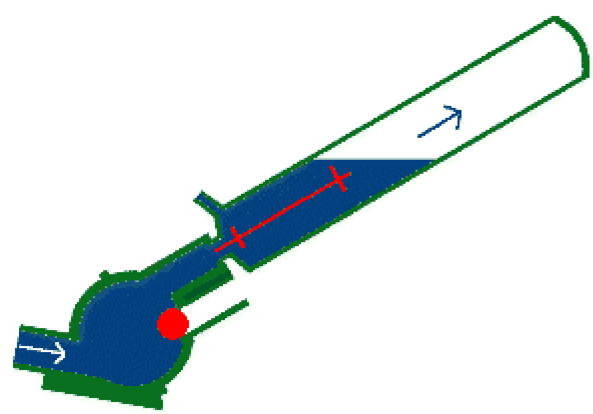
- Running water supplies pumping energy.
- Durable, only two moving parts.
- Made from tempered marine aluminum

THE MOTORLESS WATER PUMP

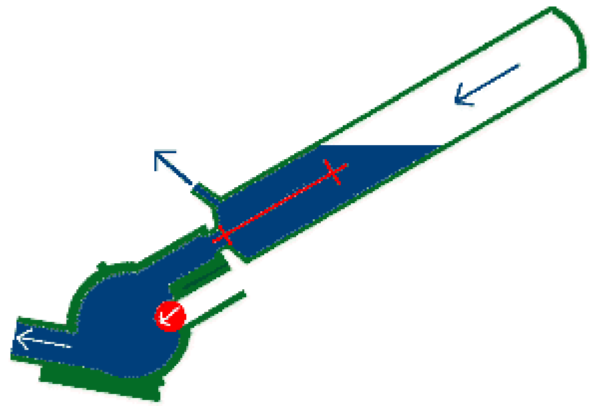
Water flows through the drive pipe into the pump and out through the waste gate. The buoyant ball will be pulled down by the flow of water and block the waste gate.



Here the ball has blocked the waste gate. The incoming water forces the spring loaded check valve open, allowing water to fill the surge tank, compressing the air in the tank.



When the pressure in the surge tank equals the pressure in the drive pipe, the water from the drive pipe can no longer flow into the pump, a ãbounce-backä effect happens. The check valve shuts and the compressed air in the surge tank forces water in the tank up to where it is needed. The bounce back causes the water to briefly flow back up the drive pipe, unseating the ball valve and letting the cycle begin again.



http://www.gravi-chek.com/index.html

----

http://journeytoforever.org/at_waterpump.html

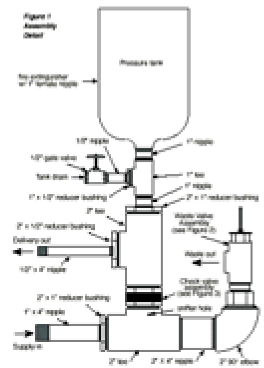
Water-powered water pumps

Hydraulic ram water pumps use downhill water pressure to pump water much higher than it started, with no other power needed. A 20ft fall is enough to push water 150 feet above the source or more. Or as little as a 2ft fall between the water source and the pump at a flow rate of 1 to 3 gallons per minute is enough to pump water 20ft higher than the source -- as much as 4,000 gallons a day, depending on the model.

No modern magic this -- ram pumps were invented more than 300 years ago. A more recent variation is the High Lifter pump, which uses different principles to do the same thing. Ram pumps are noisy, high lifters are silent and can work with less water, but the water has to be clean and grit free, while the ram pump is not so fussy.

Folk hydraulic ram pump

These pumps can be expensive. **Home Power** magazine has had several good articles on the pumps, including designs and instructions for a cheap ram pump you can build yourself using off-the-shelf materials and a recycled fire-extinguisher. See: **Hydraulic Ram Pump** -- adapted from "A Manual for Constructing and Operating a Hydraulic Ram Pump" by Kurt Janke & Louise Finger, "Homebrew", Home Power #41, June / July 1994. Digital back issues can be bought online:
http://www.homepower.com/



Build your own ram pump

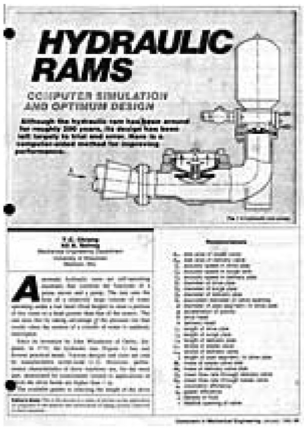
High Lifter pump maker Alternative Energy Engineering is now part of solar electric company Applied Power Corporation.
http://www.solarelectric.com/
More information on the High Lifter Pump
http://www.solarelectric.com/products/level3_179.htm

More information about **High Lifter** pumps from supplier Mark Snyder Electric -- Application & Installation, How High Lifters Work, Question & Answer, Not a Ram Pump (the differences). Also sells ram pumps.
http://www.marksnyderelectric.com/catalog/waterpoweredpumps.html

Fleming Hydro-Ram pumps are powerful, lightweight, practically maintenance-free, and cheaper. From The Ram Company:
http://www.theramcompany.com/

The **Bamford "Hi-Ram Pump"** is a simple, low-cost, self-powered water pump using new patented technology. The principle is similar to conventional ram pumps, but its construction and characteristics are different. The heart of the pump is a stainless steel adjustment tube, and a free-floating high-impact plastic ball. It is quickly adjusted using alternative tubes, and the plastic ball gives quiet operation. While much higher outlet pressures are possible, the 25 mm (1 inch) pump can lift about 1500 litres of water daily to a height of 20 metres, using 2 to 3 metres drive head and 20 litres a minute inlet flow. The pump will operate when totally underwater. It can be made to supply compressed air or to provide a direct mechanical output to drive other devices, and can also act as a suction pump. Made with an eye to the needs of developing countries. Priced from about US$125.
http://www.bamford.com.au/rampump/

Hydraulic Rams -- Computer Simulation and Optimum Design
Although the hydraulic ram pump has been around for roughly 200 years, its design has been largely left to trial and error. Here is a computer-aided method for improving performance. Y.C. Chiang, Ali A. Seirig, Mechanical Engineering Department, University of Wisconsin, Madison, Wis.
-- From *Computers in Mechanical Engineering*, January 1985 (with thanks to Kirk McLoren)


HYDRAULIC RAMS

COMPUTER SIMULATION AND OPTIMUM DESIGN

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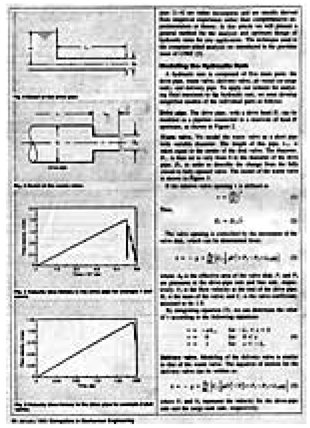

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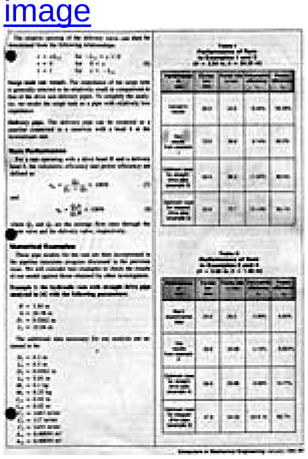

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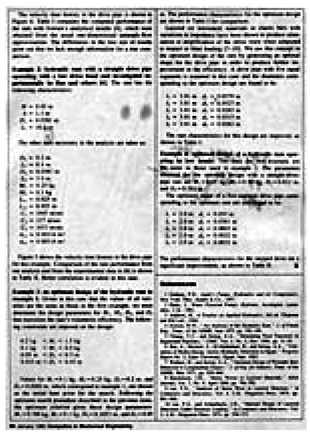

Page 4
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Good overview of ram pumps and their uses and restrictions from the **Working Group On Development Techniques** (WOT) in Holland (also rope pumps, windmills):
http://www.wot.utwente.nl/documents/articles/rampumps.html

Dutch engineer **Gert Breur's** ram pumps are simpler, and they not only pump, they can also suck water up from a low-lying area into a stream. Breur has also developed a small ram pump, easy to assemble, using standard "garden" materials except for some pressure tube. Materials list, numbered pictures and "exploded-view" photos show you how.
http://www.wot.utwente.nl/documents/articles/breurram/index.html

More about Gert Breur's water-powered suction ram pumps, including Spanish text; also rope-pump and more:
http://www.geocities.com/ResearchTriangle/System/7014/index.html

Updated ram design from **Gravi-Chek** -- The Gravi-Chek pump is the newest

technology available in the ram pump industry. The Gravi-Chek pumps have been tested by the Center for Irrigation Technology at the California Agricultural Technology Institute. There are three models available, providing water at rates from 20 to 16,000 gallons per day, depending on the installation
http://www.gravi-chek.com/

Hydraulic ram pumps -- 6-page Technical Brief, Practical Action (Intermediate Technology Development Group, ITDG), Acrobat file, 190 K
http://www.itdg.org/html/technical_enquiries/docs/hydraulic_ram_pumps.pdf

Overview of ram pumps (and hand pumps) with some useful diagrams, from the (ahem) "**Sourcebook of Alternative Technologies for Freshwater Augmentation in Small Island Developing States**/Part B - Technology Profile/2. Technologies Applicable To Very Small, Low Coral Islands/ 2.1 Freshwater Augmentation Technologies/2.1.3 Pumps":
http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8d/pumps.asp

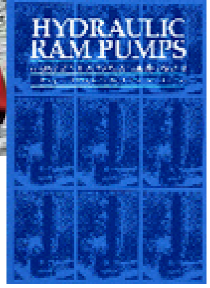
Ram Pump System Design Notes from the Development Technology Unit, School of Engineering, University of Warwick, UK: Online papers -- Introduction to hydraulic ram pumps, how ram pumps work, instructions for use and manufacture, designs, plans and drawings; also low-cost handpumps.
http://www.eng.warwick.ac.uk/DTU/lift/index.html

Another ram pump overview, more diagrams, equations, tables:
http://www2.ncsu.edu/eos/service/bae/www/programs/extension/publicat/wqwm/ebae161_92.html

Lifewater Canada -- Hydraulic ram pumps and Sling Pumps. Lots of great information at this site.
http://www.lifewater.ca/ram_pump.htm
See also Handpumps Resources -- Handpumps and water well drilling training for safe drinking water:
http://www.lifewater.ca/

Designing a Hydraulic Ram Pump -- US AID Water for the World Technical Notes
http://www.lifewater.org/wfw/rws4/rws4d5.htm

"All About Hydraulic Ram Pumps--How and Where They Work", Don R. Wilson, 1994 (updated), Atlas Pubns, ISBN 0963152629 -- This book explains in simple terms and with illustrations how the ram pump works, where it can be set up, and how to keep it going. The second section of the book gives step-by-step plans for building a fully operational Atlas ram pump from readily available plumbing fittings that requires NO welding, drilling, tapping or special tools. The final chapter shows how to build an inexpensive ferro-cement water storage unit with up to 15,000 gallon capacity. From Grove Enterprises, Inc.



http://www.grove.net/~atlas/

Rife Hydraulic Engine Mfg. Co. Inc. has specialized in pumping water without electricity or fuel for over 117 years -- one of the original Water Ram manufacturers and the oldest. Manufacture 19 different models of ram pumps, pumping up to 500 ft vertically and producing up to 350,000 gal/day. Rife also manufactures the Slingpump, which works on the flow of a stream, creek or river and can lift water up to 82 ft vertically and up to one mile away, 24 hours a day with no maintenance.
http://www.riferam.com/

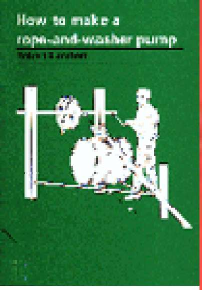
Needed by African farmers: simple water pumps -- Finding sufficient water for irrigation is one of the major challenges facing farmers in sub-Saharan Africa, where only 4% of arable land is irrigated, severely constraining agricultural productivity in a region where an estimated one third of the population is chronically undernourished. Locally produced low-cost treadle pumps instead could make an important difference and could boost food security in the region significantly, says a new report, "Treadle pumps for irrigation in Africa". Treadle pumps make it easier for farmers to retrieve water for their fields or vegetable gardens, and they are cheap and easy to handle. If pumps are produced locally, they can also create jobs and income.Many African farmers are still irrigating very small plots of land using bucket-lifting technologies, which are slow, cumbersome and labour intensive. Treadle pumps are far more efficient and user-friendly. They can be used in a comfortable way, the farmer stands on the treadles, pressing the pistons up and down, lifting up to five cubic metres per hour (5,000 litres).
http://www.fao.org/news/2001/010103-e.htm

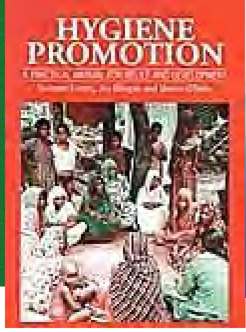
Practical Action books

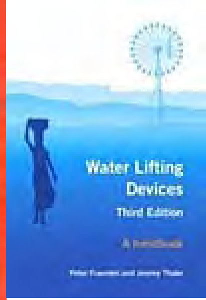
"Manual on the Automatic Hydraulic Ram for Pumping Water" by Simon B. Watt, 1978, Practical Action (Intermediate Technology Development Group, ITDG), ISBN 0903031159
Assumes no specialised knowledge of hydraulics, needs access only to basic machine tools and a few common engineering materials. Describes how to make a hydraulic ram from mild steel, some nuts and bolts and two rubber disks. Part One contains details of how to make and maintain a small hydraulic ram on a suitable site, Part Two takes a more technical look at ram performances and design considerations and also contains a useful bibliography. Excellent, clear plans for making your own hydraulic ram water pump from standard pipe fittings.
http://developmentbookshop.com/product_info.php?ref=13&products_id=239&affiliate_banner_id=1


Prototype ram pump in India -- built for one-tenth the commercial price

"Hydraulic Ram Pumps: A guide to ram pump water supply systems" by T.D. Jeffrey, T.H. Thomas, A.V. Smith, P.B. Glover and P.D. Fountain, Practical Action, ISBN 1853391727
Step-by-step instructions on designing, installing and operating hydraulic ram pumps. Illustrations and diagrams, details of a pump designed for a local manufacture, notes for







those developing their own model.
http://developmentbookshop.com/product_info.php?ref=13&products_id=235&affiliate_banner_id=1

"How to Make a Rope and Washer Pump" by Robert Lambert, 1989, Practical Action, ISBN 1853390224
How to make a simple, cheap pump which can raise water 18 feet from a stream or well at an output of 1 litre per second. Designed to irrigate small plots. A rope is pulled up through a pipe by means of a pulley wheel -- an old tyre. Fixed to the rope are flexible rubber washers (cut from another tyre) slightly narrower than the pipe; as the washers are pulled up through the pipe water is drawn up and discharged at the top. Rope and washers pass around the pulley wheel and return to the bottom of the pipe. Clever!
http://developmentbookshop.com/product_info.php?ref=13&products_id=236&affiliate_banner_id=1

"How to Make and Use the Treadle Irrigation Pump" by Carl Bielenberg and Hugh Allen, Practical Action, ISBN 1853393126
The treadle irrigation pump is able to lift up to 7,000 litres of water per hour using the power of the human body, and can be made locally at low cost in small-scale metalworking shops. Its acceptance in Bangladesh where it was first developed in 1984 is extraordinary, with over 500,000 pumps estimated now to be in use. The current design in this manual has evolved from the Bangladesh original into a fully portable pump with both lift and pressure capacity and is especially good for use in permeable soils where water cannot easily be distributed through channels.
http://developmentbookshop.com/product_info.php?ref=13&products_id=298&affiliate_banner_id=1

Water Lifting Devices: A Handbook, Third Edition, Peter Fraenkel and Jeremy Thake, Practical Action, ISBN 9781853395383
Updated and expanded new edition of Water Pumping Devices, long the authority on the subject. Detailed review of the water-lifting technologies available to smallholders for irrigation, along with new information covering drinking water for humans and livestock. Overview of the entire spectrum of pumps and water lifting devices for small-scale applications and a basis for comparing and choosing between them. Comprehensive single source of practical information.
http://developmentbookshop.com/product_info.php?ref=13&products_id=681&affiliate_banner_id=1

Designing a Hydraulic Ram Pump

Technical Note No. RWS.4.D.5

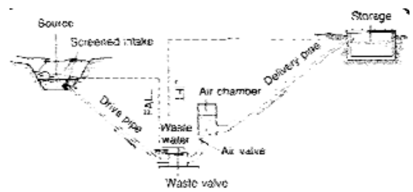


Figure 1. Hydraulic Ram Pump

[Index | Bottom]

A hydraulic ram or impulse pump is a device which uses the energy of falling water to lift a lesser amount of water to a higher elevation than the source. See Figure 1. There are only two moving parts, thus there is little to wear out. Hydraulic rams are relatively economical to purchase and install. One can be built with detailed plans and if properly installed, they will give many trouble-free years of service with no pumping costs. For these reasons, the hydraulic ram is an attractive solution where a large gravity flow exists. A ram should be considered when there is a source that can provide at least seven times more water than the ram is to pump and the water is, or can be made, free of trash and sand. There must be a site for the ram at least 0.5m below the water source and water must be needed at a level higher than the source.

Factors in Design

Before a ram can be selected, several design factors must be known. These are shown in Figure 1 and include:

1. The difference in height between the water source and the pump site (called vertical fall).
2. The difference in height between the pump site and the point of storage or use (lift).
3. The quantity (Q) of flow available from the source.
4. The quantity of water required.
5. The length of pipe from the source to the pump site (called the drive pipe).
6. The length of pipe from the pump to the storage site (called the delivery pipe).

Once this information has been obtained, a calculation can be made to see if the amount of water needed can be supplied by a ram. The formula is: $D=(S \times F \times E)/L$ Where:

D = Amount delivered in liters per 24 hours.
S = Quantity of water supplied in liters per minute.
F = The fall or height of the source above the ram in meters.

E = The efficiency of the ram (for commercial models use 0.66, for home built use 0.33 unless otherwise indicated).
L = The lift height of the point of use above the ram in meters.

Table 1 solves this formula for rams with efficiencies of 66 percent, a supply of 1 liter per minute, and with the working fall and lift shown in the table. For supplies greater than 1 liter/minute, simply multiply by the number of liters supplied.

Table 1. Ram Performance Data for a Supply of 1 liter/minute
Liters Delivered over 24 Hours

Working Fall (m)	Lift - Vertical Height to which Water is Raised Above the Ram (m)											
	5	7.5	10	15	20	30	40	50	60	80	100	125
1.0	144	77	65	33	29	19.5	12.5					
1.5		135	96.5	70	54	36	19	15				
2.0		220	156	105	79	53	33	25	19.5	12.5		
2.5		280	200	125	100	66	40.5	32.5	24	15.5	12	
3.0			260	180	130	87	65	51	40	27	17.5	12
3.5				215	150	100	75	60	46	31.5	20	14
4.0				255	173	115	86	69	53	36	23	16
5.0				310	236	155	118	94	71.5	50	36	23
6.0					282	185	140	112	93.5	64.5	47.5	34.5
7.0						216	163	130	109	82	60	48
8.0							187	149	125	94	69	55
9.0							212	168	140	105	84	62
10.0							245	187	156	117	93	69
12.0							295	225	187	140	113	83
14.0								265	218	167	132	97
16.0									250	187	150	110
18.0									280	210	169	124
20.0										237	188	140

Components of Hydraulic Ram

A hydraulic ram installation consists of a supply, a drive pipe, the ram, a supply line and usually a storage tank. These are shown in Figure 1. Each of these component parts is discussed below:

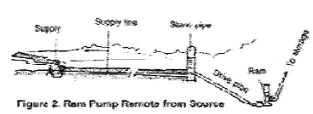


Figure 2. Ram Pump Remote from Source

Supply. The intake must be designed to keep trash and sand out of the supply since these can plug up the ram. If the water is not naturally free of these materials, the intake should be screened or a settling basin provided. When the source is remote from the ram site, the supply line can be designed to conduct the water to a drive pipe as shown in Figure 2. The supply line, if needed, should be at least one pipe diameter larger than the drive pipe.

Drive pipe. The drive pipe must be made of a non-flexible material for maximum efficiency. This is usually galvanized iron pipe, although other materials cased in concrete will work. In order to reduce head loss due to friction, the length of the pipe divided by the diameter of the pipe should be within the range of 150-1,000. Table 2 shows the minimum and maximum pipe lengths for various pipe sizes.

Table 2. Range of Drive Pipe Lengths for Various Pipe Diameters

Drive Pipe Size (mm)	Length (meters)	
	Minimum	Maximum
13	2	13
20	3	20
25	4	25
30	4.5	30
40	6	40
50	7.5	50
80	12	80
100	15	100

The drive pipe diameter is usually chosen based on the size of the ram and the manufacturer's recommendations as shown in Table 3. The length is four to six times the vertical fall.

Table 3. Drive Pipe Diameters by Hydram Manufacturer's Size Number

Hydram Size	1	2	3	3.5	4	5	6
Pipe Size (mm)	32	38	51	63.5	76	101	127

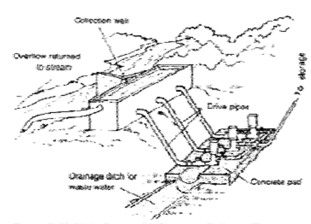


Figure 3. Multiple Rams with Common Delivery Pipe

Ram. Rams can be constructed using commercially available check valves or by fabricating check valves. They are also available as manufactured units in various sizes and pumping capacities. Rams can be used in tandem to pump water if one ram is not large enough to supply the need. Each ram must have its own drive pipe, but all can pump through a common delivery pipe as shown in Figure 3.

In installing the ram, it is important that it be level, securely attached to an immovable base, preferably concrete, and that the waste-water be drained away. The pump can-not operate when submerged. Since the ram usually operates on a 24-hour basis the size can be determined for delivery over a 24-hour period. Table 4 shows hydraulic ram capacities for one manufacturer's Hydrams.

Table 4. Hydram Capacity by Manufacturer's Size Number

	Size of Hydram								
	1	2	3	3.5	4	5X	6X	5Y	6Y
Volume of Drive Water Needed (liters/min)	7-16	12-25	27-55	45-96	68-137	136-270	180-410	136-270	180-410
Maximum Lift (m)	150	150	120	120	120	105	105	105	

Delivery Pipe. The delivery pipe can be of any material that can withstand the water pressure. The size of the line can be estimated using Table 5.

Table 5. Sizing the Delivery Pipe

Delivery Pipe Size (mm)	Flow (liters/min)
30	6-36
40	37-60
50	61-90
80	91-234
100	235-360

Storage Tank. This is located at a level to provide water to the point of use. The size is based on the maximum demand per day.

Sizing a Hydraulic Ram

A small community consists of 10 homes with a total of 60 people. There is a spring l0m lower than the village which drains to a wash which is 15m below the spring. The spring produces 30,000 liters of water per day. There is a location for a ram on the bank of the wash. This site is 5m higher than the wash and 35m from the spring. A public standpost is planned for the village 200m from the ram site. The lift required to the top of the storage tank is 23m. The following are the steps in design.

Identify the necessary design factors:

1. Vertical fall is 10m.

2. Lift is 23m to top of storage tank.

3. Quantity of flow available equals 30,000 liters per day divided by 1,440 minutes per day (30,000/1,440) = 20.8 liters per minute.

4. The quantity of water required assuming 40 liters per day per person as maximum use is 60 people x 40 liters per day = 2,400 liters per day.
2,400/1,440 = 1.66 liters per minute (use 2 liters per minute)

5. The length of the drive pipe is 35m.

6. The length of the delivery pipe is 200m.

The above data can be used to size the system. Using Table 1, for a fall of 10m and a lift of 80m, 117 liters can be pumped a day for each liter per minute supplied. Since 2,400 liters per day is required, the number of liters per minute needed can be found by dividing 2,400 by 117:

2,400/117 = 20.5 liters per minute supply required.

From item 3 above, the supply available is 20.8 liters per minute so the source is sufficient.

Table 3 can now be used to select a ram size. The volume of driving water or supply needed is 20.5 liters per minute. From Table 4, a No. 2 Hydram requires from 12 to 25 liters per minute. A No. 2 Hydram can lift water to a maximum height of 150m according to Table 4. This will be adequate since the lift to the top of the storage tank is 23m. Thus, a No. 2 Hydram would be selected.

Table 3 shows that for a No. 2 Hydram, the minimum drive pipe diameter is 38mm. Table 2 indicates that the minimum and maximum length for a 40mm pipe (the closest size to 38mm) is 6m-40m. Since the spring is 35m away, the length is all right. Table 5 can be used to select a delivery pipe 30mm in diameter which fits the supply needed, 20.5 liters per minute.

http://www.lifewater.org/resources/rws4/rws4d5.htm

HYDRAULIC RAM PUMP SYSTEM DESIGN AND APPLICATION

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ABSTRACT

Hydraulic ram pumps are water-lifting devices that are powered by filling water. Such pumps work by using the energy of water falling a small height to lift a small part of that amount of water to a much *greater height. In this way, water from a spring or stream in a valley can be pumped to a village or irrigation scheme on the hillside. The main and unique advantage of hydraulic ram pumps is that with a continuous flow of water, a hydram pump operates automatically and continuously **with no other external energy source - be it electricity or hydrocarbon fuel**. It uses a renewable energy source (stream of water) mid hence ensures low running cost. It imparts absolutely no harm to the environment Hydraulic ram pumps are simple, reliable and require minimal maintenance. All these advantages make hydraulic ram pumps suitable to rural community water supply mud backyard irrigation in developing countries. In this paper, different aspect of designing a hydraulic-rain pump system is discussed. Application and limitation of hydraulic-ram pump is presented. Alternative technologies which compete with hydraulic ram pump, are highlighted. Finally, the Research, Development and Technology Adaptation Center (RDTAC) work on hydraulic-rain pump is presented and discussed.*

INTRODUCTION

Ram Pumps have been used for over two centuries in many parts of the world. Their simplicity and reliability made them commercially successful, particularly in Europe, in the days before electrical power and the internal combustion engine become widely available. As technology advanced and become increasingly reliant on sources of power derived from fossil fuels, the ram pump was neglected. It was felt to have no relevance in an age of national electricity grids and large - scale water supplies. Big had become beautiful and small-scale ram pump technology was unfashionable. In recent years an increased interest in renewable energy devices and an awareness of the technological needs of a particular market in developing countries have prompted a reappraisal of ram pumps. In hilly areas with springs and streams, the potential for a simple and reliable pumping device is large. Although there are some examples of successful ram pump installation in developing countries, their use to date has merely scratched at the surface of their potential.

The main reason for this being, lack of wide spread local knowledge in the design and manufacture of ram pumps. Hence, the wide spread use of ram pumps will only occur if there is a local manufacturer to deliver quickly; give assistance in system design, installation, and provide an after-sales service.

HYDRAULIC RAM PUMP SYSTEM

Hydraulic Ram Pumps are water pumping devices that are powered by falling water. The pump works by using the energy of a large amount of water falling a small height to lift a small amount of that water to a much greater height. In this way, water from a spring or stream in a valley can be pumped to a village or irrigation scheme on the hillside. Wherever a fall of water can be obtained, the ram pump can be used as a comparatively cheap, simple and reliable means of raising water to considerable heights.

The diagram in Fig. 1 shows all the main components of a hydraulic ram pump system. Water is diverted from a flowing river or taken from intake structure of a spring. A drive tank is usually built between the ram pump and the intake to insure constant flow of water to the ram pump. The ram pump lifts part of the water coming through the drive pipe to a higher level at the delivery tank. A pump house is built to protect the ram pump and fittings from theft or accidental damage.

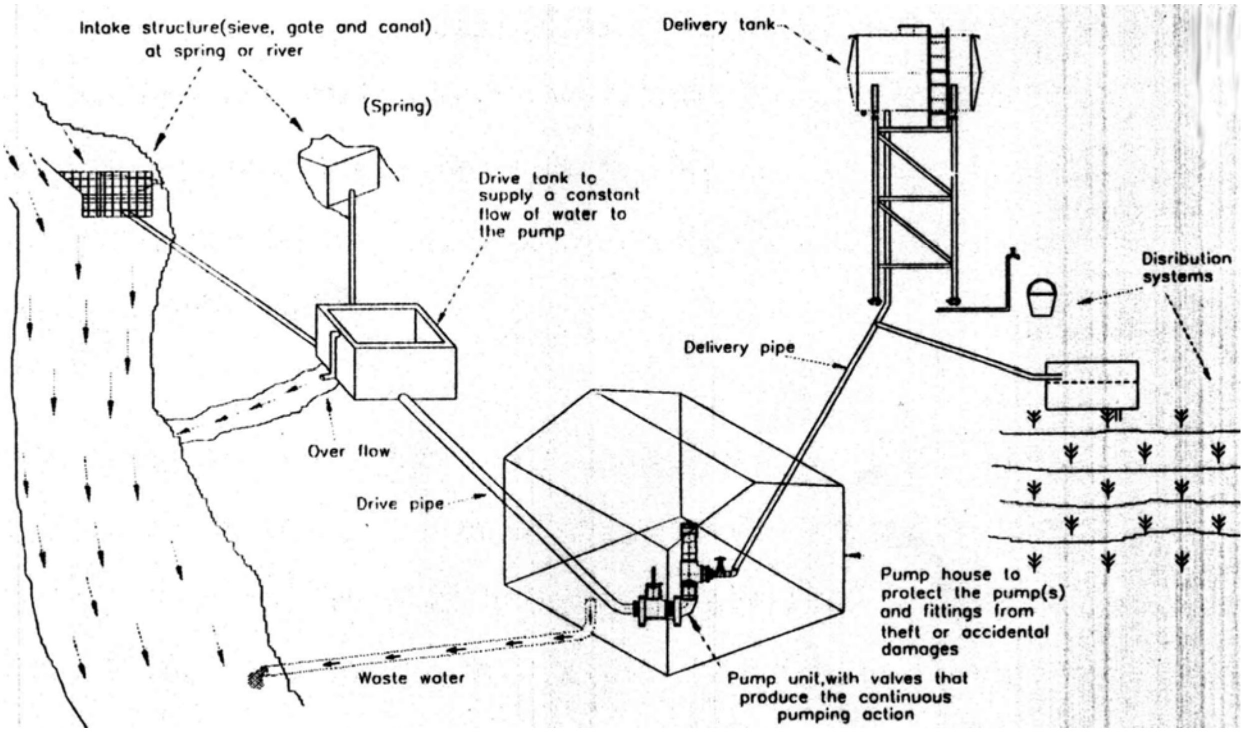

Fig. 1 Components of a Hydraulic Ram Pump Station

WORKING PRINCIPLE OF HYDRAULIC RAM PUMPS

Although hydraulic ram pumps come in a variety of shapes and sizes, they all have the same basic components as shown in Fig. 2. The main parts of a ram pump are Hydram body, Waste value snifter valve, delivery valve, air chamber and relief valve. Ram Pumps have a cyclic pumping action that produces their characteristic beat during operation. The cycle can be divided into three phases; acceleration, delivery and recoil.

Acceleration - When the waste valve is open, water accelerates down the drive pipe and discharges through the open valve. As the flow increases it reaches a speed where the drag force is sufficient to start closing the valve. Once it has begun to move, the valve closes very quickly.

Delivery - As the waste valve slams shut, it stops the flow of water through it. The water that has been flowing in the drive pipe has considerable momentum which has to be dissipated. For a fraction of a second, the water in the body of the pump is compressed causing a large~ surge in pressure. This type of pressure rise is known as water hammer. As the pressure rises higher than that in the air chamber, it forces water through the delivery valve (a non-return valve). The delivery valve stays open until the water in the drive pipe has almost completely slowed and the pressure in the pump body drops below the delivery pressure. The delivery valve then closes, stopping any back flow from the air vessel into the pump and drive pipe.

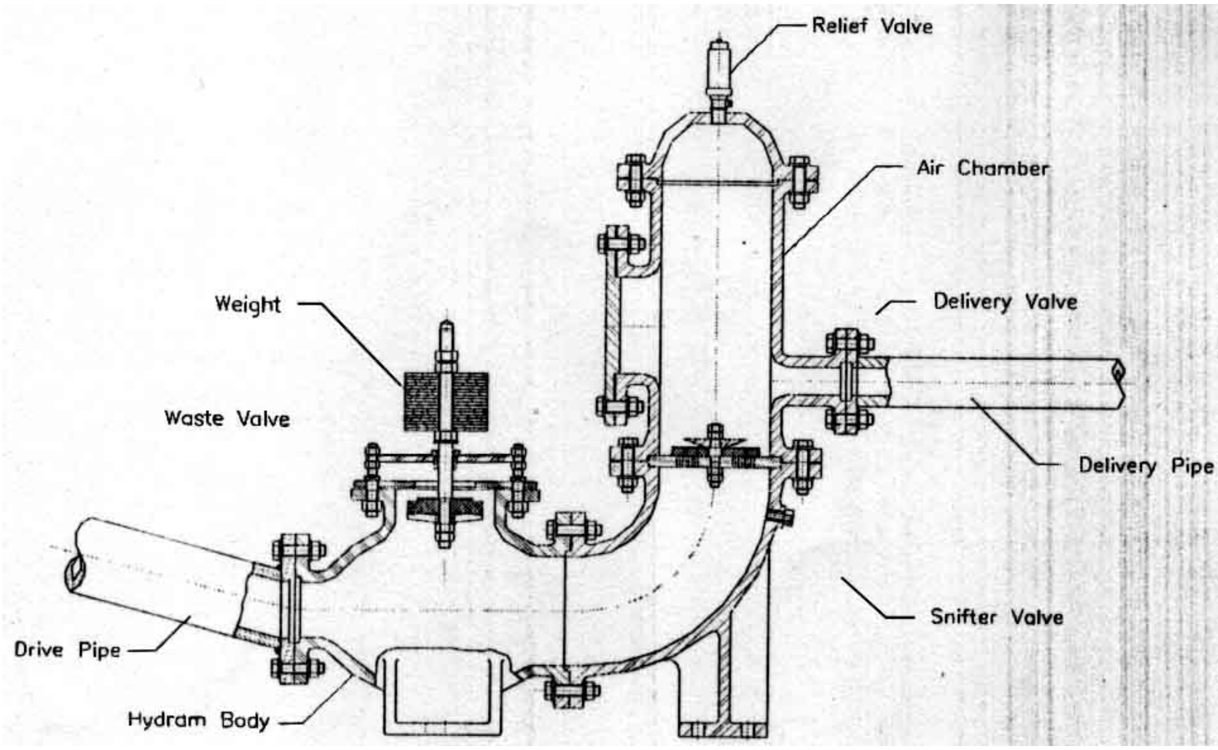

Fig. 2 Hydraulic Ram Pump

Recoil - The remaining flow in the drive pipe recoils against the closed delivery valve - rather like a ball bouncing back. This causes the pressure in the body of the pump to drop low enough for the waste vale to reopen. The recoil also sucks a small amount of air in through the snifter valve. The air sits under the delivery valve until the next cycle when it is pumped with the delivery water into the air vessel. This ensures that the air vessel stays full of air. When the recoil energy is finished, water begins to accelerate down the drive pipe and out through the open waste valve, starting the cycle again. Throughout the cycle the pressure in the air vessel steadily forces water up the delivery pipe. The air vessel smoothes the pulsing in flow through the delivery valve into an even outflow up the delivery pipe. The pumping cycle happens very quickly, typically 40 to 120 times per minute.

During each pumping cycle only a very small amount of water is pumped. However, with cycle after cycle continuing over 24 hours, a significant amount of water can be lifted. While the ram pump is operating, the water flowing out the waste valve splashes onto the floor or the pump house and is considered' waste' water. The term' waste' water needs to be understood. Although waste' water is not delivered by the ram pump, it is the energy of this water that pumps the water which is delivered.

APPLICATIONS AND LIMITATIONS OF HYDRAULIC RAM PUMPS

For any particular site, there are usually a number of potential water lifting options. Choosing between them involves consideration of many different factors. Ram pumps in certain conditions have many advantages over other forms of water-lifting, but in others, it can be completely inappropriate. The main advantages of ram pumps are:

- Use of a renewable energy source ensuring low running cost
- Pumping only a small proportion of the available flow has little environmental impact

- Simplicity and reliability give a low maintenance requirement
- There is good potential for local manufacture in the rural villages
- Automatic, continuous operation requires no supervision or human input.

The main limitations are:

- They are limited in hilly areas with a year-round water sources
- They pump only a small fraction of the available flow and therefore require source flows larger than actual water delivered
- Can have a high capital cost in relation to other technologies
- Are limited to small-scale applications, usually up to 1kW, but this requires economical and other considerations.

Specific situations in which other technologies may prove more appropriate are:

- In terrain where streams are falling very rapidly, it may be possible to extract water at a point above the village or irrigation site and feed it under gravity.

- If the water requirement is large and there is a large source of falling water (head and flow rate) nearby, turbine-pump sets can provide the best solution. Many ram pumps could be used in parallel to give the required output but at powers over 2kW, turbine-pump systems are normally cheaper.

- In small-scale domestic water supply, the choice can often be between using a ram pump on a stream or using cleaner groundwater. Surface water will often need to be filtered or treated for human consumption, increasing the cost of a system and requiring regular filter maintenance. Under these conditions, to select a hydram pump, economical considerations compared to other technologies has to be looked at.

http://home.att.net/~africantech/ESME/hydram2/HydRam2.htm

CONSIDERATIONS IN HYDRAULIC RAM PUMP SYSTEM DESIGN

The following factors need to be considered in hydraulic Ram pump system design.

- Area suitability (head and flow rate)
- Flow rate and head requirement
- Floods consideration
- Intake design
- Drive system
- Pump house location
- Delivery pipes routing
- Distribution system

For these considerations reference 1 is a good guide.

HYDRAULIC RAM PUMP DESIGN CONSIDERATIONS

- Manufacturing considerations - A choice between casting and welding method of manufacture has to be made. Cast ram pumps are less susceptible to corrosion and have longer life. On the other hand, cast ram pumps are costly and cannot be made in a simple rural setting workshop. Usually, for low and medium sized ram pumps welding method of manufacture is preferred because of simplicity and less cost.

- Maintenance and service life considerations - The critical parts that require frequent maintenance are bolts, studs and nuts. Therefore, it is usually preferable to have stainless steel bolts, studs and nuts, even though they are costly and difficult to source.

- Material availability

- General considerations
  - Shape of hydram has little effect on performance
  - Valve design considerations. The correct design of valves is a critical factor in the overall performance of ram pumps. Hence, this needs special consideration.
  - Strength considerations. This determines thickness of hydram body and air chamber.
  - Others - such as size of air chamber, size of valves, tuning devices need special considerations. Reference 2 is a good guide for design of hydraulic rain pump dimensions.

RDTAC'S WORK ON HYDRAULIC RAM PUMPS

Adami-Tulu Hydraulic Ram Pump Maintenance - During performance follow up of hand pumps developed by RDTAC and installed around Ziway, a station of hydraulic ram pumps which were installed about forty years ago were discovered. Five hydraulic ram pumps in this station were used to supply water to a ranch located about 20 km away. However, the then status of the pumps was that only one out of five pumps was operational. The following parts of the hydram pump station were in need of maintenance.

- Drive pipe - The drive pipes of the hydram station were 6" galvanized steel pipe. These drive pipes, due to long years of service, have been corroded and leak at many points. The drive pipes were replaced by new galvanized steel pipes. Flanged connections were made for ease of maintenance.

- Threaded parts of the hydram body (see Fig. 3). - The threaded parts of the hydram body were out of use due to corrosion. As a result, this required re-threading of the hydram body for fixing valve parts securely.

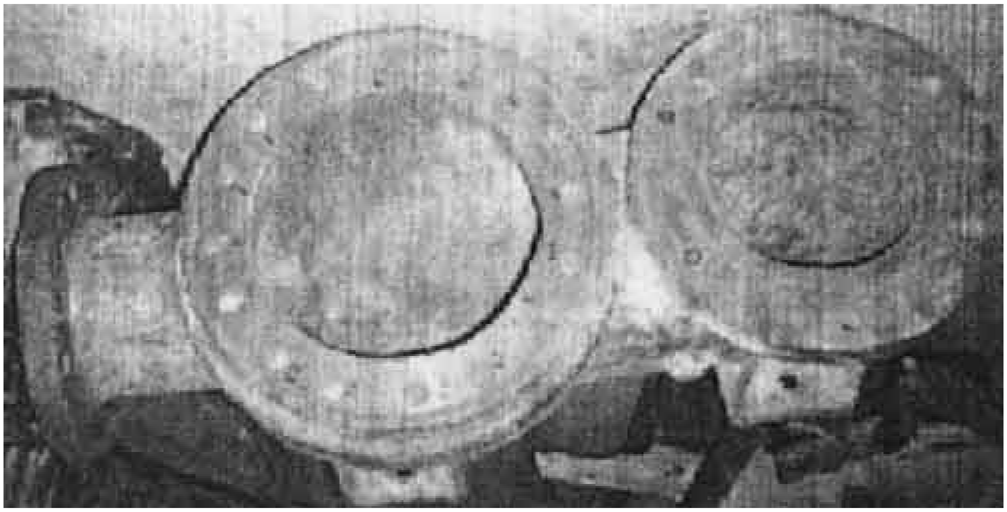

Fig. 3 Hydraulic Ram Pump Body

- Bolts, studs and nuts - These elements are the ones which had been replaced often during the service life of hydrams. Hence, the studs were made out of stainless steel and others were electro-galvanized for longer maintenance free operation.

- Waste valve perforated disk (see Fig. 4) - This part is made of bronze to prolong its life against corrosion. However, it was discovered that it is damaged mostly due to wear. The part needed to be cast out of bronze, machined and drilled. The bronze casting was made by subcontracting it to private foundries. Casting of the part without cavitation (porosity) had been a difficult task. The valve needed to be re-cast again and again to get it to acceptable quality standard.

- Waste valve-retaining ring (see Fig. 4) - Some of the retaining ring was broken due to repeated fatigue loading and corrosion. Hence, they were replaced as new.

- Rubber parts - Besides bolts and nuts, these parts were the ones which needed to be replaced often. When found, all the delivery and waste valve rubber parts were damaged due to wear and tear. To manufacture them, a rubber mold was designed and manufactured. Addis Tyre Enterprise made the rubber valve parts to the required standard using the molds.

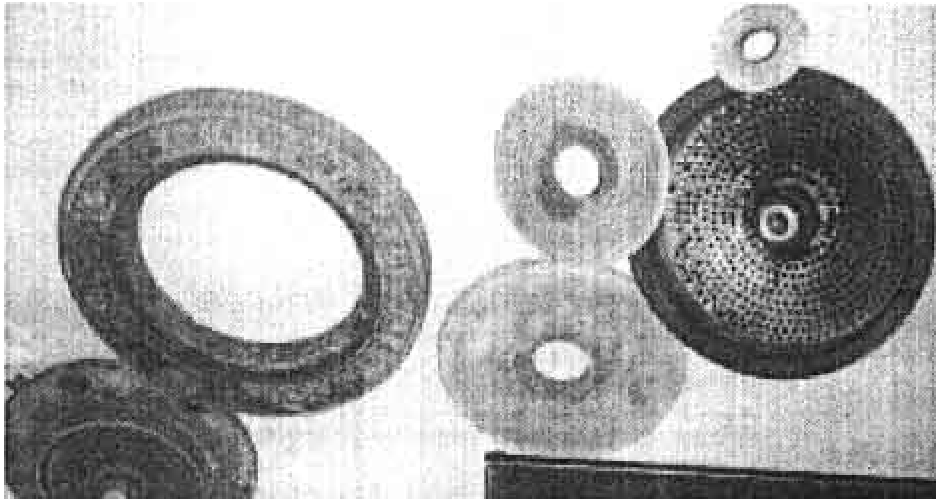

Fig. 4 Waste Valve, Retainer Ring and Rubber Parts of Adami-Tulu Hydraulic Ram Pump

- Other - Parts such as diversion canal gate, header pipes, intake valves were re-designed and manufactured.

The hydram pumps after renovated successfully are shown in Fig. 5.

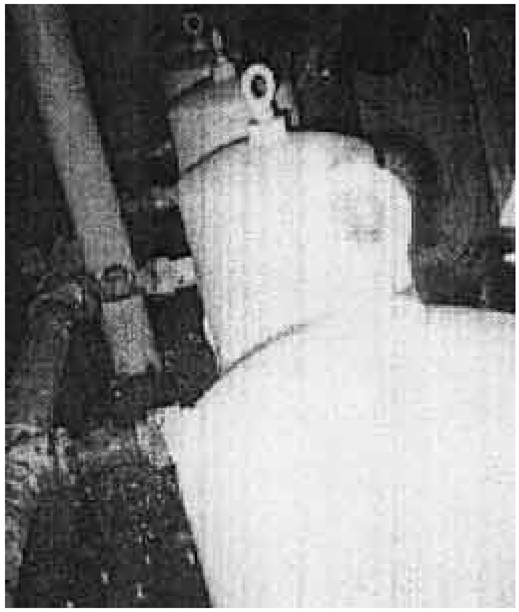

Fig.5 Renovated Adami-Tulu Hydraulic Ram Pumps

HYDRAULIC RAM PUMP DEVELOPMENT WORK OF RDTAC

Design - The design of hydraulic ram pump developed by RDTAC is shown in Fig. 2. The pump was 4" drive pipe designed to supply 80 litre/mm at a head of 45 m. This is sufficient for a village of 500 people and their cattle. In the design, casting technology was preferred for the main parts of the hydraulic ram pump for resistance to corrosion and long term maintenance free operation. Parts which are more prone to failure as a result of corrosion were made out of stainless steel or bronze based on experience obtained from the Adami-Tulu hydram maintenance project. Bolts and nuts were designed to be electro-galvanized. Parts of the hydram, the body, elbow and air chamber were made in separate pieces to facilitate easy handling during transportation and machining operation. Provisions for stroke and weight adjustment has been incorporated. The waste valve was designed for simple and less costly manufacturing method.

Fig. 6 RDTAC's Hydram installed At Adami-Tulu

Manufacturing - The hydraulic ram pump parts were manufactured in the RDTAC workshop, RADEL Foundry Pvt. Ltd. Company, Addis Tyre Enterprise and Gelan-Metal Products Factory. RADEL made all the casting parts. Addis Tyre Enterprise has made all rubber parts by moulds manufactured in RDTAC. Gelan Metal Products Factory performed electro-galvanization on bolts, studs and nuts. All the machining and welding of the hydraulic ram pump parts were made in RDTAC.

Installation - The hydraulic ram pump was installed in the pump house of Adami-Tulu hydraulic ram pump with the permission of the Abernosa Ranch (see Fig. 6). Existing civil work such as diversion canal, drive tank and pump house at Adami-Tulu was used for the project. This has resulted in considerable financial, time and labor saving. A delivery pipe of 2" was installed for 0.8 km from the pump house to a reservoir tank which is located in Dodicha Woreda (Oromia Region, Arsi Zone).

Performance - By now, the hydraulic ram pump successfully provides water for drinking and backyard irrigation. See Fig. 7.

Fig.7 Water Supply System at Dodicha Woreda, Arsi Zone, Oromia Region from RDTAC's Hydram

CONCLUSION

The following conclusions can be made from RDTAC's project work on Hydraulic Ram pumps.

- There is broad prospect of utilizing the country's abundant surface water run off potential for various purposes or requirements using locally designed and manufactured hydraulic ram pumps and other similar appropriate technologies.

- To disseminate hydrams at potential sites throughout the country, there is a need to create awareness through training and seek integrated work with rural community, government institutions like water, energy and mines bureau of local regions and non-governmental organizations.

- Hydraulic Ram pumps made by casting have many advantages, but they could be expensive. In addition, considering the cost of civil work and pipe installation, the initial investment could be very high. To reduce cost of hydrams made by casting, there is a need for standardization. Standardizing hydram pump size will also have an advantage to reduce cost of spare parts and facilitate their easy access when they are needed.

- The use of appropriate means of treating river water should be looked at in conjunction with any development project of domestic water supply using hydrams.

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Hydraulic Ram Pumps

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A hydraulic ram (or water ram) pump is a simple, motorless device for pumping water at low flow rates. It uses the energy of flowing water to lift water from a stream, pond, or spring to an elevated storage tank or to a discharge point. It is suitable for use where small quantities of water are required and power supplies are limited, such as for household, garden, or livestock water supply. A hydraulic ram pump is useful where the water source flows constantly and the usable fall from the water source to the pump location is at least 3 feet.

Principles of Operation

Components of a hydraulic ram pump are illustrated in Figure 1. Its operation is based on converting the velocity energy in flowing water into elevation lift. Water flows from the source through the drive pipe (A) and escapes through the waste valve (B) until it builds enough pressure to suddenly close the waste valve. Water then surges through the interior discharge valve (C) into the air chamber (D), compressing air trapped in the chamber. When the pressurized water reaches equilibrium with the trapped air, it rebounds, causing the discharge valve (C) to close. Pressurized water then escapes from the air chamber through a check valve and up the delivery pipe (E) to its destination. The closing of the discharge valve (C) causes a slight vacuum, allowing the waste valve (B) to open again, initiating a new cycle.

The cycle repeats between 20 and 100 times per minute, depending upon the flow rate. If properly installed, a hydraulic ram will operate continuously with a minimum of attention as long as the flowing water supply is continuous and excess water is drained away from the pump.

System Design

A typical hydraulic ram pump system layout is illustrated in Figure 2. Each of the following must be considered when designing a hydraulic ram pump system:

1. available water source
2. length and fall of the drive pipe for channeling water from the source to the pump
3. size of the hydraulic ram pump
4. elevation lift from the pump to the destination
5. desired pumping flow rate through the delivery pipe to the destination.

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A hydraulic ram pump system is designed to deliver the desired pumping flow rate for a given elevation lift. The range of available flow rates and elevation lifts is related to the flow quantity and velocity from the water source through the drive pipe. The mathematical relationship for pumping flow rate is based upon the flow rate through the drive pipe, the vertical fall from the source through the drive pipe, and the vertical elevation lift from the pump to the point of use. These variables are illustrated in Figure 2. Equation 1 is used to calculate pumping rate:

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where:

Q=pumping rate in gallons per day (gpd)
E=efficiency of a hydraulic ram pump installation, typically equal to 0.6
S=source flow rate through the drive pipe in gallons per minute (gpm)
L=vertical elevation lift from the pump to the destination in feet
F=vertical fall from the source through the drive pipe in feet.

To convert the p~umping rate expressed in gallons per day(gpd) to gallons per minute(gpm), divide by 1440. The following example illustrates an application of Equation 1.

Example.
A hydraulic ram will be used to pump water from a stream with an average flow rate of 20 gpm up to a water tank located 24 feet vertically above the pump. The vertical fall through the drive pipe in the stream to the pump is 4 feet. Assume a pumping efficiency of 0.6. What is the maximum pumping rate from the hydraulic ram pump?

In this example, E = 0.6, S = 20 gpm, L = 24 feet, and F = 4 feet. The resulting pumping rate, Q, is calculated as:

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The maximum pumping rate delivered by the hydraulic ram pump operating under these conditions is 2880 gallons per day, or 2 gallons per minute.

The example shows how the pumping rate, Q, is directly related to the source flow rate, S. If S were to double from 20 gpm to 40 gpm, the resulting pumping rate would also double to 5760 gpd, or 4 gpm.

The example also shows how the pumping rate, Q, is inversely related to the ratio of vertical elevation lift to vertical fall, L/F. If L were to double from 24 feet to 48 feet, the lift to fall ratio, L/F, would double from 6 to 12. The resulting pumping rate would decrease by half to 1440 gpd, or 1 gpm.

Table 1 lists maximum pumping rates, Q, for a range of source flow rates, S, and lift to fall ratios, L/F, calculated using Equation 1 with an assumed pumping efficiency, E, of 0.6. To illustrate the use of Table 1, consider a hydraulic ram system with S = 30 gpm, L

= 150 feet, and F = 5 feet. The calculated lift to fall ratio, L/F, is 30. The resulting value for Q is 864 gpd, or 0.6 gpm.

Table 1. Maximum pumping rates for a range of source flow rates and lift to fall ratios assuming a pumping efficiency of 0.6.

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Hydraulic ram pumps are sized based upon drive pipe diameter. The size of drive pipe selected depends upon the available source water flow rate. All makes of pumps built for a given size drive pipe use about the same source flow rate. Available sizes range from 3/4-inch to 6-inch diameters, with drive pipe water flow requirements of 2 to 150 gpm. Hydraulic ram pumps typically can pump up to a maximum of 50 gpm (72,000 gpd) with maximum elevation lifts of up to 400 feet.

Approximate characteristics of hydraulic ram pumps for use in selecting pumps are listed in Table 2. The recommended delivery pipe diameter is normally half the drive pipe diameter. For the system described in the example above, the available source water flow rate is 10 gpm. From Table 2, a pump with a 1-inch drive pipe diameter and a 1/2-inch delivery pipe diameter is selected for this system.

Table 2. Hydraulic ram pump sizes and approximate pumping characteristics.
Consult manufacturer's literature for specific pumping characteristics.

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-------Pipe Diameter-------		**---------------Flow rate--------------**	
Min. Drive	**Min. Discharge**	**Min. Required Source**	**Maximum Pumping**
-----------inches----------		**---------gpm--------**	**------gpd------**
3/4	1/2	2	1,000
1	1/2	6	2,000
1 1/2	3/4	14	4,000
2	1	25	7,000
2 1/2	1 1/4	35	10,000
3	1 1/2	60	20,000
6	3	150	72,000

Installation

The location of the water source in relation to the desired point of water use determines how the hydraulic ram pump will be installed. The length of drive pipe should be at least 5 times the vertical fall to ensure proper operation. The length of delivery pipe is not usually considered important because friction losses in the delivery pipe are normally small due to low flow rates. For very long delivery pipes or high flow rates, friction losses will have an impact on the performance of the hydraulic ram pump. The diameter of the delivery pipe should never be reduced below that recommended by the manufacturer.

To measure the available source water flow rate from a spring or stream, build a small earthen dam with an outlet pipe for water to run through. Place a large bucket or barrel of known volume below the outlet pipe, and measure the number of seconds it takes to fill the container. Then calculate the number of gallons per minute flowing through the outlet. For example, if it takes 30 seconds to fill a 5-gallon bucket, the available source water flow rate is 10 gpm. The lowest flow rates are typically in the summer months. Measure the flow rate during this period to ensure that the year-round capacity of the system is adequate.

Purchasing a System

Prices for hydraulic ram pumps range from several hundred to several thousand dollars depending on size and performance characteristics. Contact manufacturers to determine prices and ordering specifications. Send the information listed in Table 3 to the manufacturer to assist in sizing your system properly.

Table 3: Information to provide to the manufacturer for sizing your system.

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1. Available water supply in gpm __________
2. Vertical fall in feet measured from the source water level to the foundation on which the ram pump will rest __________
3. Distance from the water source to the ram pump in feet __________
4. Vertical elevation lift in feet measured from the ram pump foundation to the highest point to which water is delivered _________
5. Distance from the ram pump to the destination tank in feet __________
6. Desired pumping flow rate to the destination tank in gpd __________

This fact sheet adapted from materials prepared by the California, Florida, and South Carolina Cooperative Extension Services.

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http://www.bae.ncsu.edu/programs/extension/publicat/wqwm/ebae161_92.html

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http://www.i4at.org/lib2/hydrpump.htm

Hydraulic Ram Pump

A hydraulic ram or impulse pump is a device which uses the energy of falling water to lift a lesser amount of water to a higher elevation than the source. See Figure 1. There are only two moving parts, thus there is little to wear out. Hydraulic rams are relatively economical to purchase and install. One can be built with detailed plans and if properly installed, they will give many trouble-free years of service with no pumping costs. For these reasons, the hydraulic ram is an attractive solution where a large gravity flow exists. A ram should be considered when there is a source that can provide at least seven times more water than the ram is to pump and the water is, or can be made, free of trash and sand. There must be a site for the ram at least 0.5m below the water source and water must be needed at a level higher than the source.

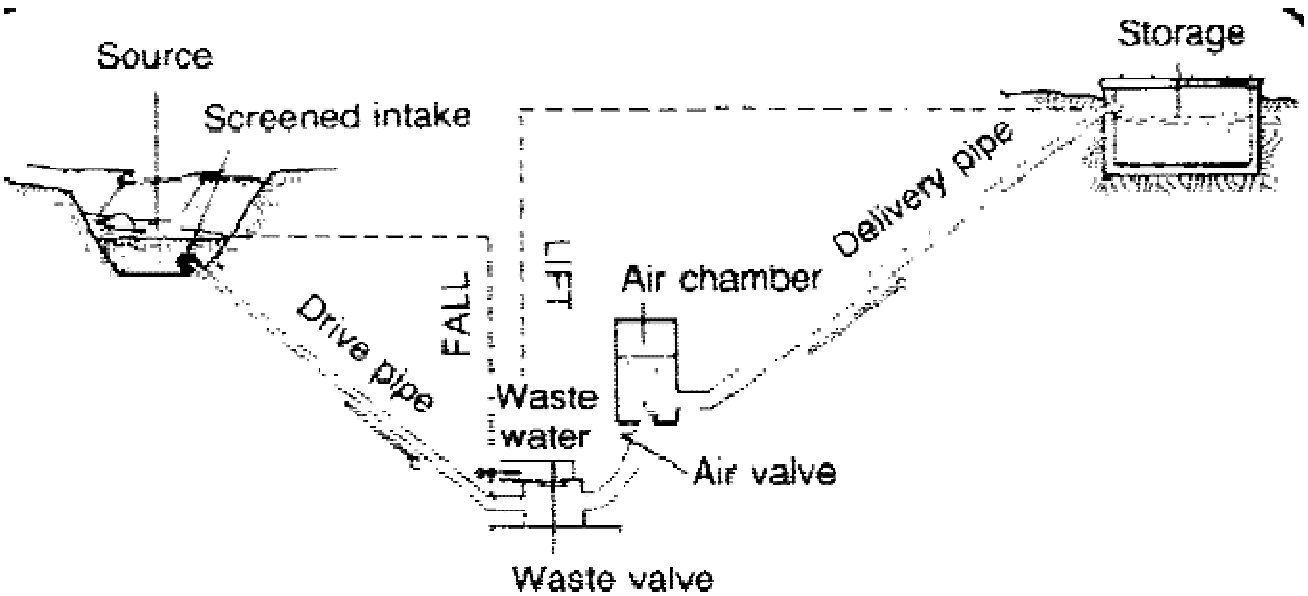

Figure 1. Hydraulic Ram Pump

Factors in Design

Before a ram can be selected, several design factors must be known. These are shown in Figure 1 and include:

1. The difference in height between the water source and the pump site (called vertical fall).
2. The difference in height between the pump site and the point of storage or use (lift).
3. The quantity (Q) of flow available from the source.
4. The quantity of water required.

5. The length of pipe from the source to the pump site (called the drive pipe).
6. The length of pipe from the pump to the storage site (called the delivery pipe).

Once this information has been obtained, a calculation can be made to see if the amount of water needed can be supplied by a ram. The formula is: $D=(S \times F \times E)/L$ Where:

D = Amount delivered in liters per 24 hours.
S = Quantity of water supplied in liters per minute.
F = The fall or height of the source above the ram in meters.
E = The efficiency of the ram (for commercial models use 0.66, for home built use 0.33 unless otherwise indicated).
L = The lift height of the point of use above the ram in meters.

Table 1 solves this formula for rams with efficiencies of 66 percent, a supply of 1 liter per minute, and with the working fall and lift shown in the table. For supplies greater than 1 liter/minute, simply multiply by the number of liters supplied.

Table 1. Ram Performance Data for a Supply of 1 liter/minute
Liters Delivered over 24 Hours

Working Fall (m)	Lift - Vertical Height to which Water is Raised Above the Ram (m)											
	5	7.5	10	15	20	30	40	50	60	80	100	125
1.0	144	77	65	33	29	19.5	12.5					
1.5		135	96.5	70	54	36	19	15				
2.0		220	156	105	79	53	33	25	19.5	12.5		
2.5		280	200	125	100	66	40.5	32.5	24	15.5	12	
3.0			260	180	130	87	65	51	40	27	17.5	12
3.5				215	150	100	75	60	46	31.5	20	14
4.0				255	173	115	86	69	53	36	23	16
5.0				310	236	155	118	94	71.5	50	36	23
6.0					282	185	140	112	93.5	64.5	47.5	34.5
7.0						216	163	130	109	82	60	48
8.0							187	149	125	94	69	55
9.0							212	168	140	105	84	62
10.0							245	187	156	117	93	69
12.0							295	225	187	140	113	83
14.0								265	218	167	132	97
16.0									250	187	150	110
18.0									280	210	169	124
20.0										237	188	140

Components of Hydraulic Ram

A hydraulic ram installation consists of a supply, a drive pipe, the ram, a supply line and usually a storage tank. These are shown in Figure 1. Each of these component parts is discussed below:

Supply. The intake must be designed to keep trash and sand out of the supply since these can plug up the ram. If the water is not naturally free of these materials, the intake should be screened or a settling basin provided. When the source is remote from the ram site, the supply line can be designed to conduct the water to a drive pipe as shown in Figure 2. The supply line, if needed, should be at least one pipe diameter larger than the drive pipe.

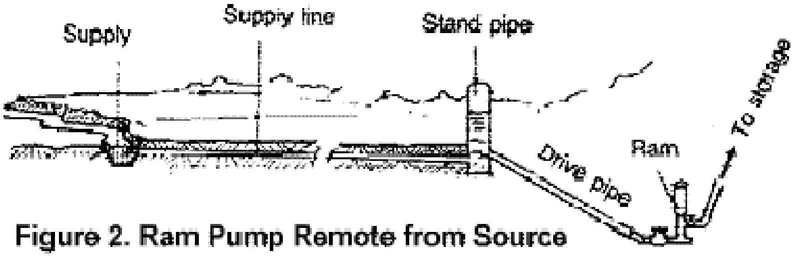

Figure 2. Ram Pump Remote from Source

Drive pipe. The drive pipe must be made of a non-flexible material for maximum efficiency. This is usually galvanized iron pipe, although other materials cased in concrete will work. In order to reduce head loss due to friction, the length of the pipe divided by the diameter of the pipe should be within the range of 150-1,000. Table 2 shows the minimum and maximum pipe lengths for various pipe sizes.

Table 2. Range of Drive Pipe Lengths for Various Pipe Diameters

Drive Pipe Size (mm)	Length (meters)	
	Minimum	Maximum
13	2	13
20	3	20
25	4	25
30	4.5	30
40	6	40
50	7.5	50
80	12	80
100	15	100

The drive pipe diameter is usually chosen based on the size of the ram and the manufacturer's recommendations as shown in Table 3. The length is four to six times the vertical fall.

Table 3. Drive Pipe Diameters by Hydram Manufacturer's Size Number							
Hydram Size	1	2	3	3.5	4	5	6
Pipe Size (mm)	32	38	51	63.5	76	101	127

Ram. Rams can be constructed using commercially available check valves or by fabricating check valves. They are also available as manufactured units in various sizes and pumping capacities. Rams can be used in tandem to pump water if one ram is not large enough to supply the need. Each ram must have its own drive pipe, but all can pump through a common delivery pipe as shown in Figure 3.

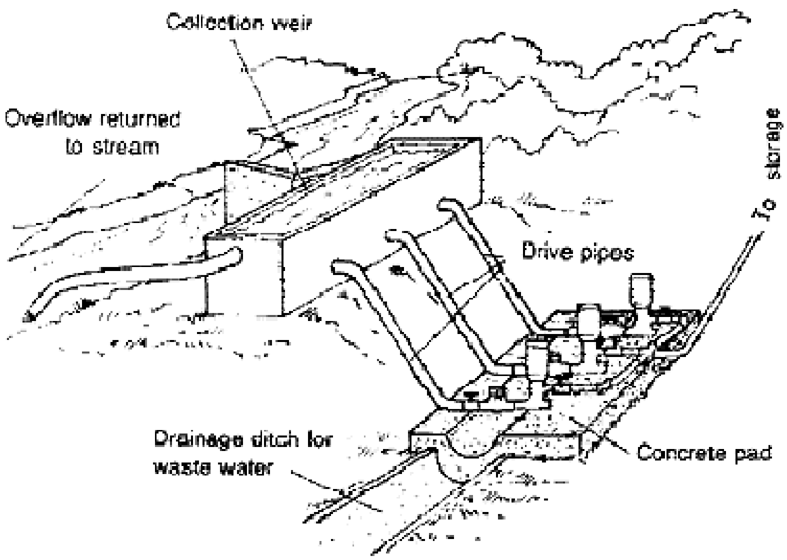

Figure 3. Multiple Rams with Common Delivery Pipe

In installing the ram, it is important that it be level, securely attached to an immovable base, preferably concrete, and that the waste-water be drained away. The pump can-not operate when submerged. Since the ram usually operates on a 24-hour basis the size can be determined for delivery over a 24-hour period. Table 4 shows hydraulic ram capacities for one manufacturer's Hydrams.

Table 4. Hydram Capacity by Manufacturer's Size Number									
	Size of Hydram								
	1	2	3	3.5	4	5X	6X	5Y	6Y
Volume of Drive Water Needed (liters/min)	7-16	12-25	27-55	45-96	68-137	136-270	180-410	136-270	180-410
Maximum Lift (m)	150	150	120	120	120	105	105	105	

Delivery Pipe. The delivery pipe can be of any material that can withstand the water pressure. The size of the line can be estimated using Table 5.

Table 5. Sizing the Delivery Pipe	
Delivery Pipe Size (mm)	Flow (liters/min)
30	6-36
40	37-60
50	61-90
80	91-234
100	235-360

Storage Tank. This is located at a level to provide water to the point of use. The size is based on the maximum demand per day.

Sizing a Hydraulic Ram

A small community consists of 10 homes with a total of 60 people. There is a spring l0m lower than the village which drains to a wash which is 15m below the spring. The spring produces 30,000 liters of water per day. There is a location for a ram on the bank of the wash. This site is 5m higher than the wash and 35m from the spring. A public standpost is planned for the village 200m from the ram site. The lift required to the top of the storage tank is 23m. The following are the steps in design.

Identify the necessary design factors:

1. Vertical fall is 10m.

2. Lift is 23m to top of storage tank.

3. Quantity of flow available equals 30,000 liters per day divided by 11,440 minutes per day (30,000/11,440) = 20.8 liters per minute.

4. The quantity of water required assuming 40 liters per day per person as maximum use is 60 people x 40 liters per day = 2,400 liters per day.
2,400/1,440 = 1.66 liters per minute (use 2 liters per minute)

5. The length of the drive pipe is 35m.

6. The length of the delivery pipe is 200m.

The above data can be used to size the system. Using Table 1, for a fall of 10m and a lift of 80m, 117 liters can be pumped a day for each liter per minute supplied. Since 2,400 liters per day is required, the number of liters per minute needed can be found by dividing 2,400 by 117:

2,400/117 = 20.5 liters per minute supply required.

From item 3 above, the supply available is 20.8 liters per minute so the source is sufficient.

Table 3 can now be used to select a ram size. The volume of driving water or supply needed is 20.5 liters per minute. From Table 4, a No. 2 Hydram requires from 12 to 25 liters per minute. A No. 2 Hydram can lift water to a maximum height of 250m according to Table 4. This will be adequate since the lift to the top of the storage tank is 23m. Thus, a No. 2 Hydram would be selected.

Table 3 shows that for a No. 2 Hydram, the minimum drive pipe diameter is 38mm. Table 2 indicates that the minimum and maximum length for a 40mm pipe (the closest size to 38mm) is 6m-40m. Since the spring is 35m away, the length is all right. Table 5 can be used to select a delivery pipe 30mm in diameter which fits the supply needed, 20.5 liters per minute.

Home Hydraulic Ram Pumps Crayfish Farming Red Claw Crayfish Farming

Atlas Ram Pump Parts

The Atlas Ram Pump parts shown here shows everything needed to build the Atlas Ram. Only the concrete for the base and PVC glue is needed. The drive and delivery pipes are not part of the detail. The plans now call for heavy-duty US made valves (Simmons, 400 psi) although other brands can be used, and larger clack valves as well. The air dome uses Heavy Duty 220 psi PVC well casing. The cost of the parts is about $75-$100 at most hardware stores.

Check valve to clack valve Conversion Pack

PARTS ARE NOW AVAILABLE

Check / Tank Mount Unit

The check / tank mount unit shown to the right is the only fabrication required in the design. Made by molding a 1" galvanized street ell inside of a 2" street ell with fiberglass or epoxy resin. This allows a lower profile & center of gravity, and gives standard pipe threads for both the check valve and the pressure tank (air dome).

The check / tank mount unit shown to the right is available from Atlas Publications.
The price is $45 each + $8.00 shipping (Up to 3 units);
The conversion pack is included with each unit free of charge.
Please note the conversion pack is for the 1" Simmons check valve only.

Send check or MO to:

Atlas Publications
P.O. Box 265
Murphy, NC 28906

Or use this handy PRINTABLE ORDER FORM

The best check valves to use are made by Simmons Manufacturing
and are available from amazon.com (see below)
They are called Brass in-line spring loaded check valves, are rated at 400 psi, and the bushing need not be replaced by the plastic sleeve mentioned in the book.

For a detail of the clack valve conversion process, see pgs. 22 & 23 of the book
clik HERE.

SIMMONS CHECK VALVE ORDERING
(use your BACK button to return from these pages)
Silicon Bronze Lead Free Check Valves; Silicon Bronze Cast Poppet, Female Pipe Thread.

SIMMONS MFG CO #503-SB, 1", 1.1 pounds. Price: $16.08
This is the valve for the check valve, part # 11, pg.9 in the book,
and for the clack valve for a 1" Ram.
Click here to view and/or order: Simmons 1" Check Valve

SIMMONS MFG CO #504-SB, 1-1/4", 1.5 pounds. Price: $22.05
Can be used for a clack valve for a 1 1/4" Ram.
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SIMMONS MFG CO #505-SB, 1-1/2" 1.8 pounds. Price: $30.08
Can be used for a clack valve for a 1 1/2" Ram.

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SIMMONS MFG CO #506-SB, 2", 3.6 pounds. Price: $48.65
Can be used for a clack valve for a 2" Ram.
Click here to view and/or order: Simmons 2" Check Valve

NEW! Online store for the best selection of Brass Check Valves!

There are a lot of other suitable check valves available online,
some quite a bit less expensive than Simmons.

Click on this link to go to our online store for a selection. ..Brass Check Valves

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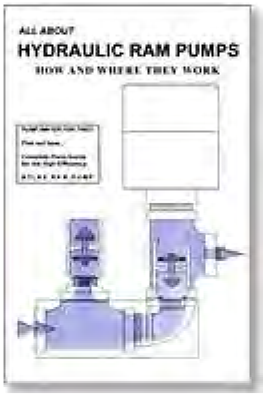
(LEFT) This is the Base...the 'base fittings' with fiberglass reinforced concrete ('quick-wall') molded around them, ready for the valves, tank and drive pipe to be attached. After completing this step, it is only a matter of attaching the fittings and air dome. Drive pipe attaches on the left, clack valve on the first hole from the left, check valve and air dome attach on the hole to the right.

Completed pump!!

Here is a picture of a 2" Atlas Ram Pump, assembled.
The only difference from a 1" Atlas Ram is the size of the clack valve (brass colored). This 2" check valve (converted to a *clack valve*) is quite expensive, and usually the 1" pump is sufficient (sometimes more than) for most applications.
The Drive pipe attatches at the left of the base and delivery pipe on the right out of the 'T' fitting.
One of the most efficient and inexpensive Hydraulic Ram Water Pumps available today, simple to build and easy to keep running!

This book includes assembly instructions for the ram pump, simple plans for a ferro-cement water storage tank, as well as complete set-up and maintenence information.



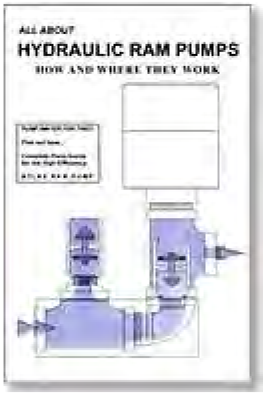
The book ***'The Original! HYDRAULIC RAM PUMPS how and where they work'*** contains complete plans and instructions for assembling the pump, and explains in simple terms and with illustrations how the ram pump works, where and how it can be set up, and how to keep it working year after year with a minimum of time and energy for upkeep. With this book, the Atlas Ram is now easier to build, more reliable and efficient than ever, with NO welding, drilling, tapping or special tools needed. The design has evolved to a point where low maintenance and long term reliable service is almost certain, even by a novice. A great resource for self-reliant types, homesteaders, alternative energy users or anyone curious about this 'old-tech' device that has been around for so long and works so well. The final chapter shows how to build an inexpensive ferro-cement water storage tank up to 15,000 gallon capacity.

Also included is the authors personal e-mail for any questions...
The book is US $10.95 + $1.00 shipping
(Canadian & overseas orders, go to Amazon, see below)

Some people have a ram pump for a summer cabin, shut the pump off for the winter when they leave...and set it back up when they return. Here's a review by one of them...

Ernie Samson writes again: "Hi, it is Ernie Samson again. I just set our pump up for the year, and it is working wonderfully... thought you would like to know. Everyone who comes and sees it working can't believe how well it works! Thanks again!"

INFORMATION.
Questions? Feel free to e-mail for specific information about this pump, parts, ram pump applications.



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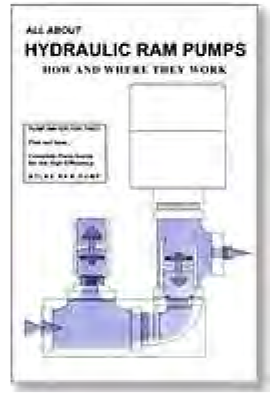

Shopping Cart

Brass Check Valves

Here are the most popular check valves for the Atlas Ram Pump.
We have checked all over and this is the best online site for ordering these Check Valves.

Simmons #503SB 1" Bronze CHK Valve
$17.90
This is the best valve for the Atlas Ram Pump (400 psi).You need 2 per pump, unless you want a larger clack valve.

Merrill Mfg. CVR100 Brass Check Valve
$10.34
Merrill Mfg. 1" Brass Check Valve, tapered self cleaning valve seat. Delrin guide bearing for the poppet stem.

2 Pack of TC2502 1 IN. BRASS CHECK VALVE
$25.22
By FLOTECH. Slightly less expensive option to the Simmons valve, pack of 2, needed for a 1" Atlas Ram

[Merrill Mfg. CVR125 Brass Check Valve]
$14.55
Merrill Mfg.1-1/4" Brass Check Valve, for a larger CLACK Valve. Abrasion resistant O-ring, tapered self-cleaning valve seat. ...

[Merrill Mfg. CVR150 Brass Check Valve]
$16.07
Merrill Mfg.1-1/2" Brass Check Valve, for a larger CLACK Valve. Abrasion resistant O-ring, tapered self-cleaning valve seat. D...

[Merrill Mfg. CVR200 Brass Check Valve]
$30.06
Merrill Mfg. 2" Brass Check Valve, for the largest CLACK Valve. Abrasion resistant O-ring, tapered self-cleaning valve seat. D...

[CAMPBELL MANUFACTURING CV-5T BRASS CHECK VA...]
$23.75
Campbell-1 1/4" Brass Check Valve. 200 PSI, Neoprene O-ring, Non-corroding delrin stem guide, Stainless steel springs.

[Valve, Check - Spring (Brass) 1"]

OEM 1" check valve, less expensive option to the Simmons valve

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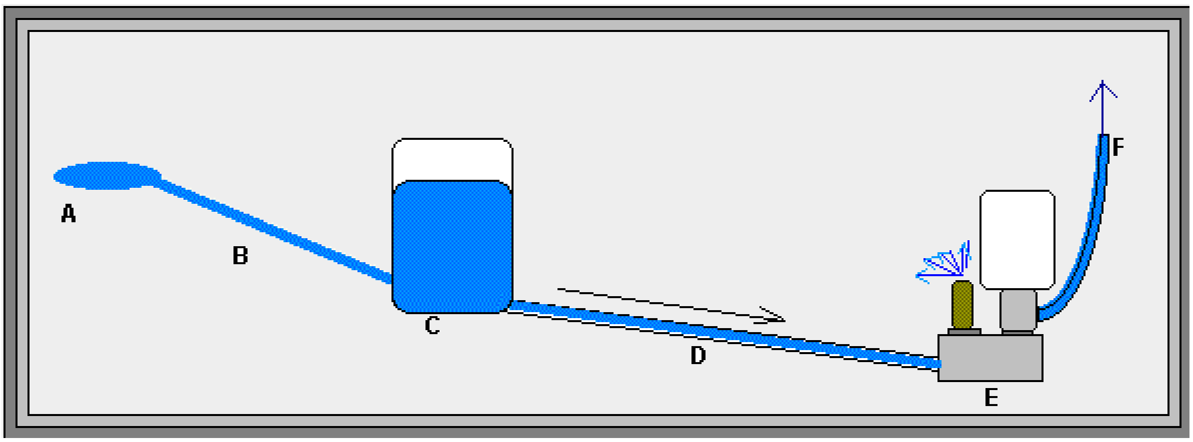
http://www.atlaspub.20m.com/rampg.htm

WHAT IS A RAM PUMP?

The hydraulic ram pump is a reliable, old-time water pump that works just as well today as ever. **Ongoing research indicates the Great Pyramid may actually have been a**

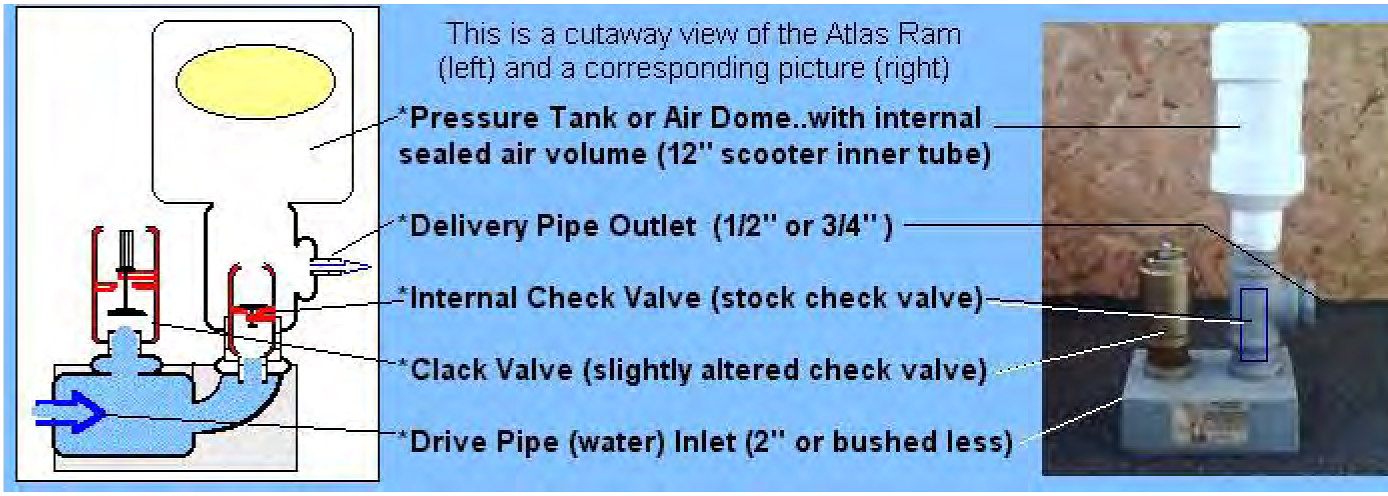
gigantic ram pump..built to pump drinking water to public water fountains in the cities above the Nile flood plain! (Pyramid Pump) Often called a water ram, one of these simple devices can **pump water from a flowing source of water (spring, creek, river, etc.) to any point above the source, *and this without any power requirement* except the force of water moving downhill,** contained inside a ‘drive pipe‘. This rugged and dependable device is typically installed today at remote home sites and cabins that are off the power grid and would otherwise be without a water supply. Sometimes a ram is used as a backup water system, or for watering livestock, gardens, decorative lily ponds, water wheels or fountains. Simply because a ram uses no power opens up a world of possibilities for using water that would otherwise flow on downstream,wasted. All that is really required is the surface water source. The water has to be moving...not much, but some. The creek need not be large either - 4 gallons per minute is the minimum.

TYPICAL RAM PUMP SETUP

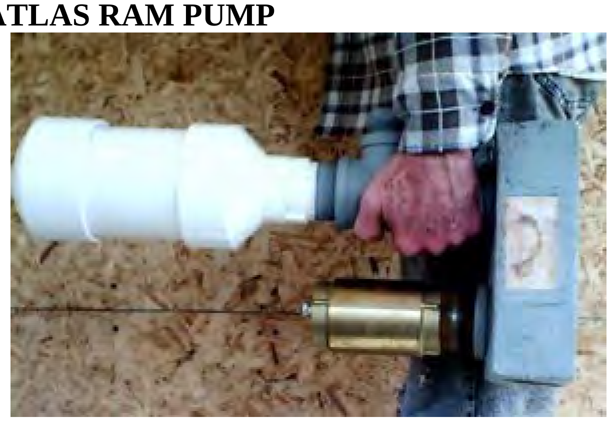


(A) Water source; can be a river, stream, spring, or pond.
(B) Supply pipe. Goes from the source to the collection barrel downstream (below the source).
(C) Collection barrel or intake barrel. The water is collected here. Water level stays at the level of the source.
(D) Drive pipe. About 100 ft. long; brings the water to the pump and provides the power to the pump, somewhat like a battering ram. Probably the least understood and most important part of the ram pump system. Typically black plastic pipe, 1" to 2" dia., generally matched to the size of the clack valve on the pump.
(E) Ram Pump. Starts and stops the movement of the water column in the drive pipe through the clack valve (gold colored). Also redirects a portion of the water (10%-15%) to the pressure tank through the internal check valve or one-way valve. This portion leaves the pump and rises to the end use area through the...
(F) Delivery pipe which goes to the storage tank, garden, house...wherever the water is needed. Typically of 1/2" or 3/4" black plastic pipe.

ATLAS RAM PUMP CUTAWAY



ABOUT THE ATLAS RAM PUMP



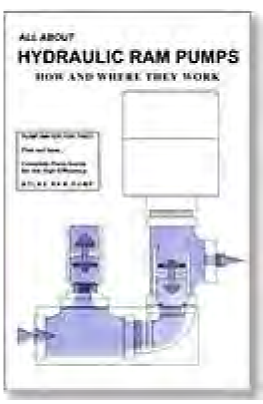
The Atlas Ram Pump is the simplest and most efficient low flow / fall ram pump available today. Designed to be simple to build-- with NO drilling, tapping or welding involved in its construction; the materials and fittings are readily available at most hardware stores. (LEFT) The Atlas Ram Pump...water enters from the right through the drive pipe, delivery out the left. 'Waste' water out the clack valve (brass). (RIGHT) The Atlas Ram is compact, rugged and easily carried.

(LEFT) The 'air dome' or 'pressure tank' removes easily to

access the 'sealed air volume'. The air dome is of heavy-duty 220 psi PVC well-casing. (RIGHT) The sealed air volume, in this case a 12" scooter inner tube, eliminates the possibility of an air-logged or water-logged condition inside the air dome. This promotes the overall reliability and efficiency of the Atlas ram pump.

(LEFT) The tank-mount 'tee' fitting removes easily to access the check valve. This is rarely if ever needed, unless to remove debris if the intake screen is breached.

(RIGHT) The clack valve removes easily for checking or maintenence, very rarely needed also.



To place an order for this book, send check or MO for $10.95 + $1.00 shipping per book (Canadian & overseas orders, go to amazon.com, see below)to:

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http://www.judyofthewoods.net/ram_pump.html

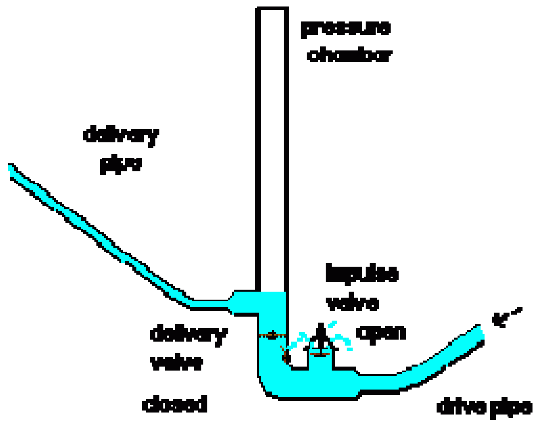
Low cost, low flow, home made hydraulic ram pump (no welding required)

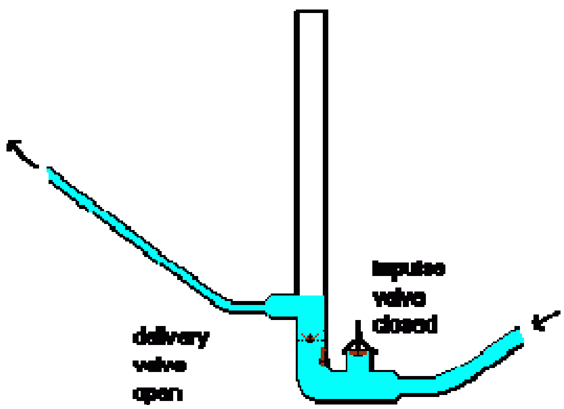
If you have a water supply (spring, brook or river) below the point where you need the water, and the source is higher than the lowest part of the property, then a hydraulic ram pump may be the solution. Hydraulic ram pumps are powered by a portion of the water running through it. If the cost of a commercial pump puts you off, or the water volume is too little to operate the pump, you can make one to suit your conditions at very little cost. There are two excellent books published by Intermediate Technology on making your own ram pump. One is "Hydraulic Ram Pumps: A Guide to Ram Pump Water Supply Systems" by T.D. Jeffrey, T.H. Thomas, A.V. Smith, and P.B. Glover. The other is "A Manual on the Hydraulic Ram for Pumping Water" by S. B. Watt. I would recommend you get both; they do complement each other. They also explain how to design and build the whole system. The pumps featured in the books do require welding and threading equipment, and the smallest pump has a 2" diameter body which requires a fair amount of water to operate. However, the principle also works on a smaller scale, and I have made a pump from standard brass 28 mm compression fittings, with 28mm, 22 mm and 15 mm pipe (all readily available) and with soldering equipment. It is not scientifically worked out, but it works and is about as efficient as a commercial pump, and it takes the elbow grease out of pumping by hand or the expense and complications of an electric pump. I don't know what the maximum lift would be with a pump this size, but in a test with my own it pumped water approximately 15 - 20 feet up with a drive head of about 5 - 6 feet. Even in such a small pump the pressure is enormous, and I believe it could pump water much higher. This pump also works on relatively small volumes of water. Even the smallest commercial pump requires large volumes of water to power it, making a ram pump unsuitable for many situations, where this smaller pump would still be able to operate. I have even operated the pump on about 25 gallons a day during a dry summer by running it intermittently from a holding tank. However, the pump only delivers about one 10th of the volume, wasting the rest, so I only ended up with about two gallons out of that tank. It also required manually opening and closing the stop cock or some complicated automated system (self-siphoning may be a possibility I have not yet tested, but the tight pipe bends may hinder the flow too much).

I built this pump nearly 12 years ago, and did not take pictures during the build. Due to limited material choice, some parts have corroded, and some of the information is based on memory, so the instructions are a little incomplete, but hopefully there is enough information to build your own. A lot of the measurements for this pump were indeed rule of thumb - "that looks about right", and it worked. Of course, your thumb may differ in size from mine, but you get the idea.....


click to enlarge, and drag corners
for large annotated pictures go to my Flickr page

How the hydraulic ram pump works





Water enters the ram from the thick drive pipe and runs out of the impulse valve, which is held open by a spring (or weight in larger pumps). As the momentum increases, the pressure of the water will drag the impulse valve shut. This creates a shock wave inside the ram body, pushing water past the delivery valve (a non-return valve). As the pressure subsides the impulse valve opens and the cycle begins again. This takes place more than 100 times a minute, depending on the head pressure and tuning of the impulse valve, and each pulse pushes up a small quantity of water through the thinner delivery pipe. The air chamber cushions the flow. The tiny snifter valve below the chamber allows a small quantity of air into the air chamber with every pulse to replace air lost into the deliver pipe. A small squirt of water will come out on the recoil.

Building the pump

Materials

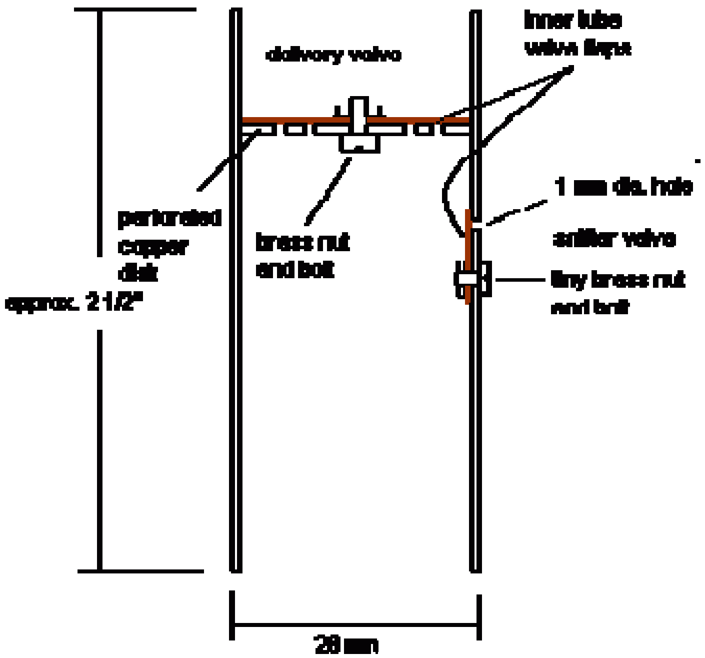
approx. 1 meter of 28 mm copper pipe for body and pressure chamber
22 mm copper pipe for supply pipe
15 mm copper pipe for delivery pipe
connectors as needed
two 28 mm compression 'T's
one 28 mm compression elbow
one 28 mm solder blank end (optional) one 15 mm ball valve
one 28 mm to 15 mm reducer (solder type)

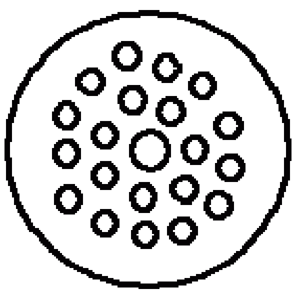
one 28 mm to 22 mm reducer (solder type)
flat piece copper for valves (pipe cut open and hammered flat on metal surface)
small bore pipe to form guide for impulse valve
inner tube for delivery and snifter valves and mounting shock absorbers
rubber and copper disk (psst! don't tell Her Madge - a coin) for impulse valve
tiny nut and bolt cut from earth connector of light switch for snifter valve flap
two nuts and bolts for the impulse and the delivery valve (brass or s/s)
a steel spring removed from a cabinet ball and spring closure (brass would be better if found) for the impulse valve
1/2 tea strainer (wire globe type) clipped to tank outlet
approx 1 ft of 22 mm i/d reinforced automotive rubber pipe as shock absorbing section in supply pipe
two hose clamps for above
one 20 gallon tank as buffer and filter at spring
one 22 mm tank connector
two exhaust pipe brackets to hold pump body to base
section of steel I-beam for base
concrete to hold pump base
solder, flux

Note on fittings - these compression fittings are typical for the UK, and are somewhat different from those available in other countries. Your fitting may look different, but should still work. It is important to use threaded fittings, as the rubber gaskets in the pump body would be damaged when assembling a pump made with solder fittings. Threaded fittings also allow access to the inside of the pump in case of debris entering it, or to replace worn gaskets. Although I used joint tape, it is probably not necessary, as a slight seepage is of no consequence in the pump setting, and the amount of water lost miniscule.

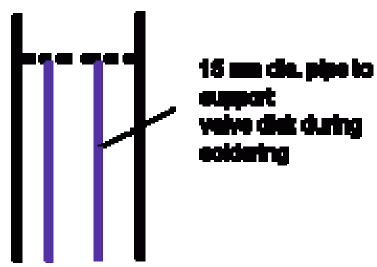
You may be able to obtain the short length of pipe and fittings for the body from a plumber doing a remodeling job. If you buy new materials, shop around. I have bought the fittings at an agricultural iron mongers for about one third the price a builder's merchant charged! The most difficult thing to obtain is the right size brass nuts, bolts, and spring. DIY shops have very little choice - if you get the right length bolt, it may be too thin. You may be able to scavenge them from some old electrical equipment, as did I, if only I could remember what from. Make sure it is solid brass as any plating will soon wear off. Valve gaskets can be cut from inner tube, preferably car tube, as it makes flatter gaskets. Avoid seams. The spring for the impulse valve came from a cabinet ball snap closure. It was just the right size and tension, but made of galvanized wire, which did not last long. You may be able to make one from s/s or brass wire. This is the part which needs some experimentation.

Delivery and snifter valve assembly



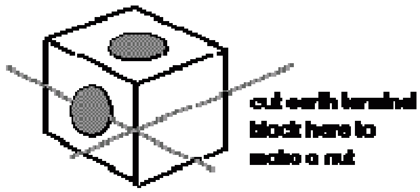


disk perforations



Cut a disk of sheet copper (a piece of opened up pipe, hammered flat) to fit inside the approx. 2 1/2 inch section of 28 mm pipe. Drill one hole in the center to take a small bolt, and holes all around to allow as much water through as possible, but not so many to weaken the disk. Leave a solid edge for the gasket to overlap enough to prevent leakage. File the holes clean with a round needle file and rub surface with abrasive paper to prevent sharp edges and to ensure the gasket makes good contact. Solder the disk into the pipe about 1/2 inch below the edge. Rest the disk on a piece of 15 mm pipe cut to the hight of the disk position. Keep it to the center and avoid excess solder, or you will solder this pipe to the disk too.

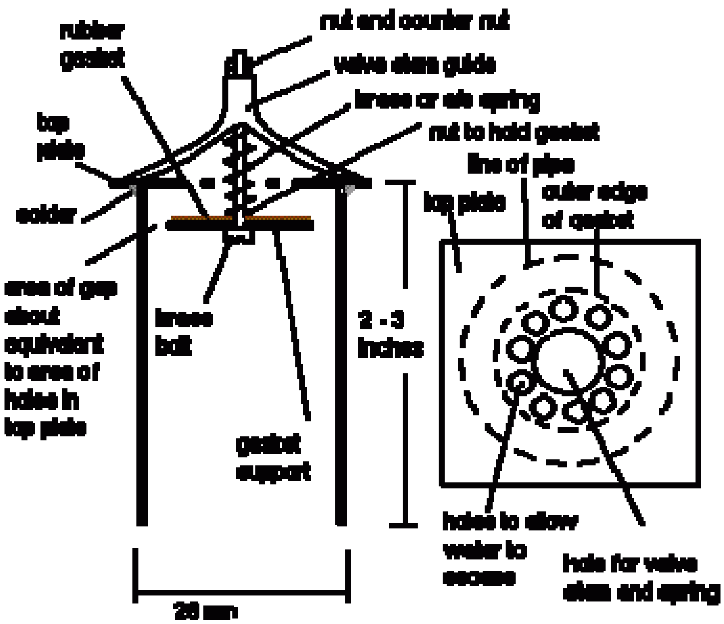
Drill a 1 mm diameter hole about halfway down the pipe, and clean the edges. Drill another hole about 1/4 inch below, making it the size of a tiny bolt. Cut a small flap of inner tube to cover the 1 mm hole and extend beyond the bolt hole, and cut a small hole in the rubber for the bolt. Attach the rubber flap with the bolt and nut. If you can't find a tiny brass nut and bolt, you can improvise with the small grub screw and the threaded counterpart of the earth terminal of a redundant plastic electrical socket. The threaded brass block should be sawn in half to reduce drag.



Cut a disk of inner tube to fit snuggly inside the pipe, but not touching the pipe, as the flap must be able to move freely. Cut a small hole in the center and bolt it on top of the metal valve disk with a small washer between the gasket and the nut.

Impulse valve assembly

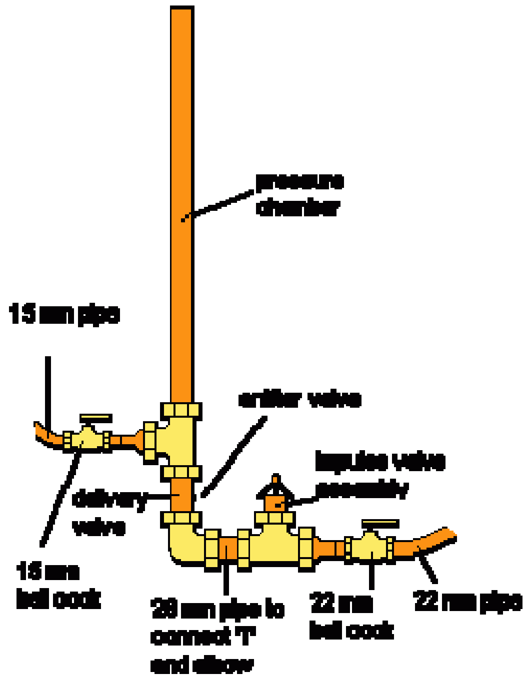
This one is more tricky to make, and will need some experimenting and improvising with available materials. I will describe the one I made, but there are many ways of doing it. The main principle is a rigid disk with a rubber surface (for good contact) on a guided support which allows the disk to travel in a straight line. The disk is held away from the opening with a spring or weights, which should not prevent the shock wave from slamming the valve shut. The valve disk should be smaller than the inside diameter of the valve body to allow water to pass around it to exit from the outlet holes which need to be big enough to allow the water to pass through with as little resistance as possible to build up momentum. In practice this is a compromise between the disk size and the outlet holes. If the outlet holes are too big, then the disk would have to be correspondingly big to cover the holes in the shut position, thereby allowing little water to pass around the disk when open. The area of the holes should be about equal to the area of the space around the disk, taking into account a small area where the disk overlaps the outlet plate to ensure a tight seal.



Cut a section of 28 mm pipe to about 2 - 3 inch length. Make a flat piece of copper to cover the top which overlaps the edge to give a sufficient mounting surface for the valve stem guide. Shape is not important, though square is probably easier, unless you already happen to have a suitable round disk. Drill a large enough hole in the center to allow the spring to pass through without catching the edge, and drill more smaller holes around this big one, using the above thumb formula. I am not sure why I did not make a larger hole instead. The reason may have been drill size. I suppose, one large hole should work as well, as long as it is a smaller than the valve disk to allow the sealing overlap. Make sure the holes and surface are smooth. Solder a frame to the top of the plate to hold a piece of tube just big enough to allow the bolt to pass through and guide it in a straight line. I happen to have had some thin copper tube scavenged from a gas installation of an old caravan. There were two diameters, one fitted snuggly inside the other. The inner was just big enough for the bolt (taking into account that the thread will be filed off the bolt inside the guide tube), but did not have enough substance to split it into four extended legs to support it above the plate, but the larger tube served that purpose. I then soldered the legs to the top plate. The guide tube should also be small enough for the spring to but against it, and not slip inside. The height should allow for the spring to be in the relaxed position with the valve disk about the same distance below the top plate in the open position as the space around the disk. It should also allow room for compression of the spring when the valve shuts, i.e. the spring should also be long enough to allow this compression without the bunched up wires crowding the small space between the guide and the top of the plate, which would happen with a short and tightly coiled spring. To assemble the valve drop a copper or brass disk onto the bolt head followed by a rubber disk, a washer and a nut to secure the disks. Measure the length of the spring and the guide tube and file the thread off the bolt for this length to prevent snagging, and leave thread on the last section for the nut and counter nut. Drop the spring onto the bolt and feed the bolt from inside the valve body through the center hole and the guide tube and secure the bolt in place with the nut and counter nut.

Assembling and installing the pump

Assembling is very easy, just follow the diagram. One point to watch out for is the location of the snifter valve. When inserting the deliver valve assembly between the elbow and 'T' make sure the snifter valve is on the **opposite side of the delivery pipe exit** to prevent the air being lost up the delivery pipe. The top of the pressure chamber can be capped with a blank end or simply hammered flat, bent over like a toothpaste tube, and sealed with solder run into the joint. It is critical that there is enough water to power the pump, as any reduced flow would simply trickle out of the open impulse valve without causing the shock wave to slam it shut. The pipes need to be filled and no air should enter the pipe. It is also important that no debris enters the pump as it can easily jam the valve open. Some kind of intake tank is advisable, and a filter at the tank exit. I used a 25 gallon plastic tank and clipped one half of a s/s fine wire mesh tea strainer (the wire globe type with sprung handle) over the tank connector nut - just happened to be perfect fit. The water also came from a covered spring with very little debris entering it. The drive pipe needs to be as straight as possible, with any bends kept very gradual. Stop cocks must not hinder the flow, therefore a ball valve would be best suited. The jolt of the valve slamming shut creates a fair amount of pressure in the pipe, and it needs to have some shock absorbing section of strong reinforced rubber hose in the upper section. The pump body must be fixed to a base rigidly, but with some cushioning. I clamped the pump to a section of 'I' beam which is embedded in concrete, and used exhaust pipe clamps, cushioned with some inner tube wrapped around the pump body. There is a stop cock on both pipes entering and leaving the pump. For the longer delivery pipe Medium Density Polyethylene is best suited for longer sections, and can easily be joined at or near the stop cock with a copper to MDPE adapter.



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Disseminating ram-pump technology

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FOR BOTH IRRIGATION and domestic supply, gravity feed is not always possible: water often needs lifting. The power to lift a flow of water can conveniently be expressed as

power =

constant x mean x flowrate x height lifted

duty x efficiency

where 'duty' is a time fraction (pumping hours per day) and 'efficiency' is a product of the efficiencies of the hydraulic circuit, the pump and the prime mover. Pipes are sized to give tolerable hydraulic efficiency and pumps are chosen to match the hydraulic conditions and the energy source available. Duty can also be varied to achieve better matching of the prime mover to the hydraulic circuit: high duties such as continuous 24-hour operation result in low power requirements and cheap piping (see Box on next page).

Whilst in general the power for water-lifting can come from engines, electrical mains, animals, humans or renewable (climatic) sources, in the particular context of rural areas in poor countries the choice is more constrained. In many such countries there are virtually no rural electrical mains, engines pose problems of both fuelling and maintenance, draught animals may be unavailable or difficult to apply to water lifting, renewables are erratic, complex and import intensive. Therefore human-powered lifting and transporting of water is still common, despite the very high cost of human energy (US$ 2 to 20 per kW hour).

Of the renewables, water power has the longest history, and under favourable conditions is the easiest to use. Several Asian and Latin American countries have developed the capability of building hydro-power systems. Although sites where power can be economically extracted from falling water are rather rare, they generally occur in the same terrain (mountainous) as the greatest water-lifting needs. The use of water power to pump water is therefore an interesting option. Figure 1 shows the main ways of doing this and illustrates the relative simplicity of the hydraulic ram-pump system. A typical such system is shown in Figure 2.

Ram-pumps (invented 200 years ago) are still manufactured in over ten countries and were once commonplace in Europe, The Americas, Africa and some parts of Asia. They have however been largely displaced by motorized pumping in richer countries, whilst in developing countries their use is concentrated in China, Nepal and Colombia. Ram-pump technology is not trivial: designing systems that are reliable, economic and durable (e.g. against flood, theft, silt ....) takes some experience. Generally, in rural areas of developing countries, this skill has been lost since about 1950, and the intermediaries that used to connect ram-pump manufacturers to pump users have disappeared. Old systems lie broken for lack of fairly simple maintenance: new systems are few.

For various reasons, discussed later, the potential for using ram-pumps seems to be increasing worldwide. Working, primarily in Africa, since 1985 the Development Technology Unit of Warwick University has identified several obstacles to this potential being realized, and has been trying to remove them. This paper records that experience.

The niche of the ram-pump

In suitable terrain, ram-pumps can be used to provide low-power unsupervised pumping. Typical individual ram-pumps can deliver 10 to 200 watts for lifting water; several small pumps can be operated in parallel to feed a single delivery pipe, larger pumps are available from some manufacturers. The power requirements of rural water lifting are illustrated by the following examples, which all assume pipe head losses are 10 per cent of lift. The powers quoted are 'water watts' assuming 24 hours pumping.

domestic supply to a prosperous house 5W

(500 litres per day lifted 75m)

village supply 62W

(l0 000 litres per day lifted 50m)

irrigated garden (0.5 hectare) 87W

(35 000 litres per day lifted 20m)

As the ram pump's system efficiency including its drive pipe is 50 per cent to 75 per cent, the hydro-power inputs for the examples above need to be up to twice the figures shown. The ram-pump is therefore well power-matched to these applications. These inputs are obtained at comparatively low drive heads - typically 10 per cent of the delivery head - so the drive flows to ram-pumps are typically twenty times their delivery flows. (In the examples above the drive flow would be typically 7, 140 and 500 litres per minute respectively). This high flow requirement is clearly a constraint on location. On the positive side, however, no ram-pump user can extract more than a small fraction (e.g. five per cent) of any source flow, the bulk of it being passed on downstream to other users: this has some social advantages.

Three other technical constraints require mention. Firstly there is only a limited range of head ratios (delivery height divided by drive head) of 5 to 30 over which a ram-pump is efficient and economic. Secondly neither drive head nor delivery head should exceed the particular pump's rating (often 20m and 100m respectively, but much less for cheap plastic ram-pumps). Thirdly it must be acceptable that the water lifted is derived from - and hence is of the same quality as - the drive water: a ram-pump cannot derive energy from a dirty stream to pump water from a different (cleaner) source.

Disregarding social and organizational factors, we can therefore describe the technical niche of the ram-pump as moist hilly rural areas where there is no mains electricity but a need for lifting water from streams or springs. The source must be of adequate quality and have a flow many times that to be lifted.

The problem of minor technologies

One of the more accessible concepts from 20th Century physics has been that of 'critical mass'. If the mass of a radioactive material or the size of an organization is below some threshold its activity dies away; above that threshold the activity sustains itself and may even grow. For most technologies there is similarly a critical scale of application below which the activities needed to sustain it may die away. Such activities include manufacture of components, training of new users and specialist maintenance.

In the case of ram-pump systems, specific skills are needed in manufacture, system design, installation and operation. The skills are not especially high and overlap those needed to manufacture, install etc. other devices. Sometimes such skills are preserved in inanimate form. Thus many ram-pump manufacturers employ steel castings whose foundry patterns were made decades ago. Documents preserve design procedures. Existing installations are available as models for new systems. The critical throughput to sustain commercial manufacture is perhaps 50 pumps per year, it is usually achieved via selling into more than one country. A throughput of only one or two new systems a year might sustain system design and installation skills in a general water contractor. However, a specialist installer might need to put in at least 20 pumps a year to survive.

In reviving an old technology or introducing a new one, the 'critical mass' throughputs need to be estimated. If they are higher than the area of sales or of installer operation can sustain, any intervention to promote the technology will ultimately fail. More important, if the likely demand is thought to be close to such a threshold of sustainability it is worth effort to lower the threshold.

With the technology of hydro-electricity we are used to having separate organisations making turbines, designing systems, building them and operating them. Maintenance may require a fifth agency. Even though some of these organisations operate internationally via local agents, such complexity entails uncertainties that tend to raise the critical size for each of them. Micro-hydropower utilisation has lagged behind its apparent economic potential for these reasons in most countries. Ram-pumping faces similar difficulties.

Often there is a key agency that effectively leads the others involved in a technology. For example a manufacturer of equipment may set up training for its installers, users and maintainers; alternatively a consultant may co-ordinate and supplement the existing skills of the other parties. A low value rural technology does not lend itself to the latter approach.

Experiences in Africa

The author and his DTU colleagues have been trying to revive ram-pump usage in Africa since 1985. An early analysis suggested that foreign (e.g. European) manufacturers selling a few pumps a year via agents could not and would not provide adequate training for local installers. Moreover imported pumps are expensive and difficult to source spares for. In colonial times there were few technical alternatives for water lifting to plantations, mission hospitals and large schools and it was worth the cost of bringing a ram-pump installer from another continent. Today that is an unacceptably expensive option for a village or farm needing pumped water or for a small-scale pumped irrigation scheme.

In the absence of a design consultant (again unlikely for this scenario), the options for sustainability appeared to be

either to build up the design capability of installation contractors *and/or* to encourage local manufacture by an organisation also capable of providing back-up to installers.

The DTU chose the 'and' option, first spending several years in developing simple and cheap pump designs suitable for provincial manufacture and codifying system design and installation procedures. Since 1990 the DTU has been training both producers and installers from nine African and one Asian country, usually using its demonstration centre in the Eastern Highlands of Zimbabwe. There is an ongoing debate about what is the right level of manufacturing technology (hand tool, workshop with electricity, factory), whether manufacture and installation should be undertaken by the same organization, whether low-lift irrigation or high-lift water supply should be given priority, whether installer training should be directed towards governmental, NGO or private organizations and what fraction of possible sites are 'easy' sites suitable for beginners to tackle.

The results have been mixed. Easy sites (with modest lifts, plentiful water, favourable stream geometry and well-organised customers) are perhaps only a few percent of technically feasible sites. The process of system design has proved intimidating to technicians for whom even sizing a pipe for gravity flow is at the limit of their understanding. The input of (expatriate) man and woman power to bring an installation organisation up to the level of competence and confidence to stand alone with this technology has been expensively high. The 'successes' have been with unusually well-resourced NGOs. Commercial manufacture, for example in Kinshasa (Zaire) and Mutare (Zimbabwe) has been started but self-sustaining manufacturer-installer arrangements have not been developed. Of some 30 pumps installed, too many have been 'demonstrations' rather than built to meet real water needs.

Clearly training on courses alone is not enough. Installers and manufacturers need to be visited and helped/encouraged with production of their first systems. A ram-pump has a certain 'something-for-nothing' magic about it that impresses onlookers and causes any installation to yield many enquiries from neighbouring villages or farms. However the technology's uncertainties, using very cheaply produced pumps in the hands of novice installers, makes it much easier to apply to individual 'rich' farms or institutions than to villages or communal dry-season gardens.

Ram-pump technology has a fascination for enginers and users out of proportion to its current commercial importance. The DTU's 1992 book on system design must have sold more copies worldwide than there have been new systems built! A 1993 day school on ram-pumps in Sri Lanka attracted fifty engineers but so far has resulted in no new systems.

Prospects

Ram-pumping will never be a major technology comparable with motorized pumping from rivers or hand pumping from boreholes. Its particular niche is described above: worldwide there is a potential for between perhaps 10 000 and 200 000 systems. Much of that potential lies in areas where there are currently no system design skills. Availability of pumps need not be a major problem (despite the DTU's local manufacture strategy in Africa), since even though good imported machines cost over $10,000 per kilowatt the pump itself rarely accounts for more than 40 per cent of system costs.

Certain trends worsen the prospects for ram-pumps. Worldwide, water sources are becoming both dirtier and weaker. Some historical ram-pump systems no longer operate because of declining drive flow. Clean spring water is usually associated with very low power levels - in Rwanda for example, the DTU had to design for 80 metre lifts from drive flows under 10 litres per minute, which is on the limits of the technology.

Factors increasing likely demand are the movement of rural populations uphill (under population growth pressures), the expansion in micro-irrigation, the introduction of local ram-pump manufacture (especially in South America) and the availability, apparently for the first time in decades, of both trustable handbooks and training courses.

In Africa the prospects for ram-pump usage seem to depend largely on the confidence of potential installers. Despite much individual innovation there, Africa is not a continent where organizations readily take risks with unknown technology. Elsewhere in the developing world continuation of the current slow expansion of ram-pump usage will depend upon developments in photo-voltaic pumping, its most immediate rival.

The scope for technical improvement of a simple device already used for 200 years is rather small. However, modern materials may permit the pressure vessel (required to smooth the pulsating flow through the delivery valve into a steady flow up the delivery pipe) to be replaced by a pressured bladder. This will allow pumps to be operated slightly under water which has advantages for both efficiency and reliability. Understanding of the causes of erratic pump behavious and of inefficiency is now better than in the past, which designers of pumps and 'trouble-shooters' of systems can draw upon. It is not possible to totally design away temperamental behaviour, during for example system start-up, but its incidence can certainly be reduced.

For the ram-pump to fully occupy its niche, efforts must continue both to simplify the design of reliable systems and to propogate design skills. Although water-powered pumping will never attain the simplicity of drop the suction pipe in the stream and switch on that motorized pumping offers, as users of a renewable energy source, ram-pumps may have time on their side.

http://info.lut.ac.uk/departments/cv/wedc/papers/thomas2.html

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