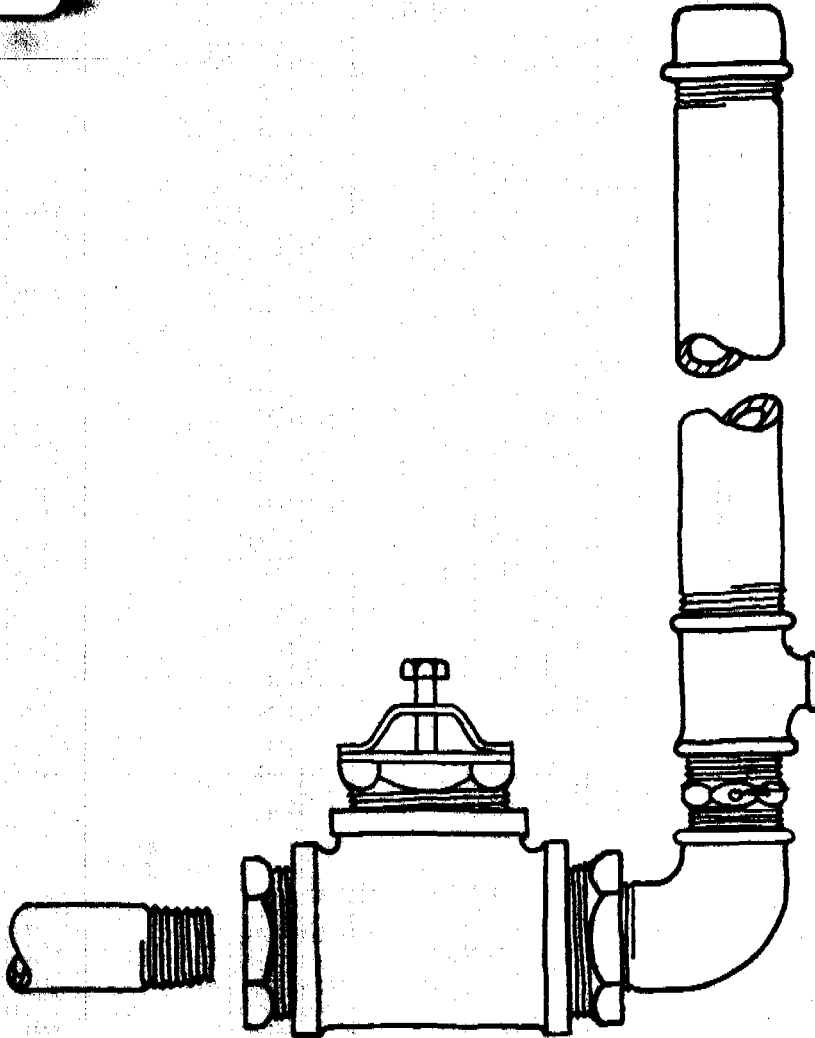


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HYDRAULIC RAM

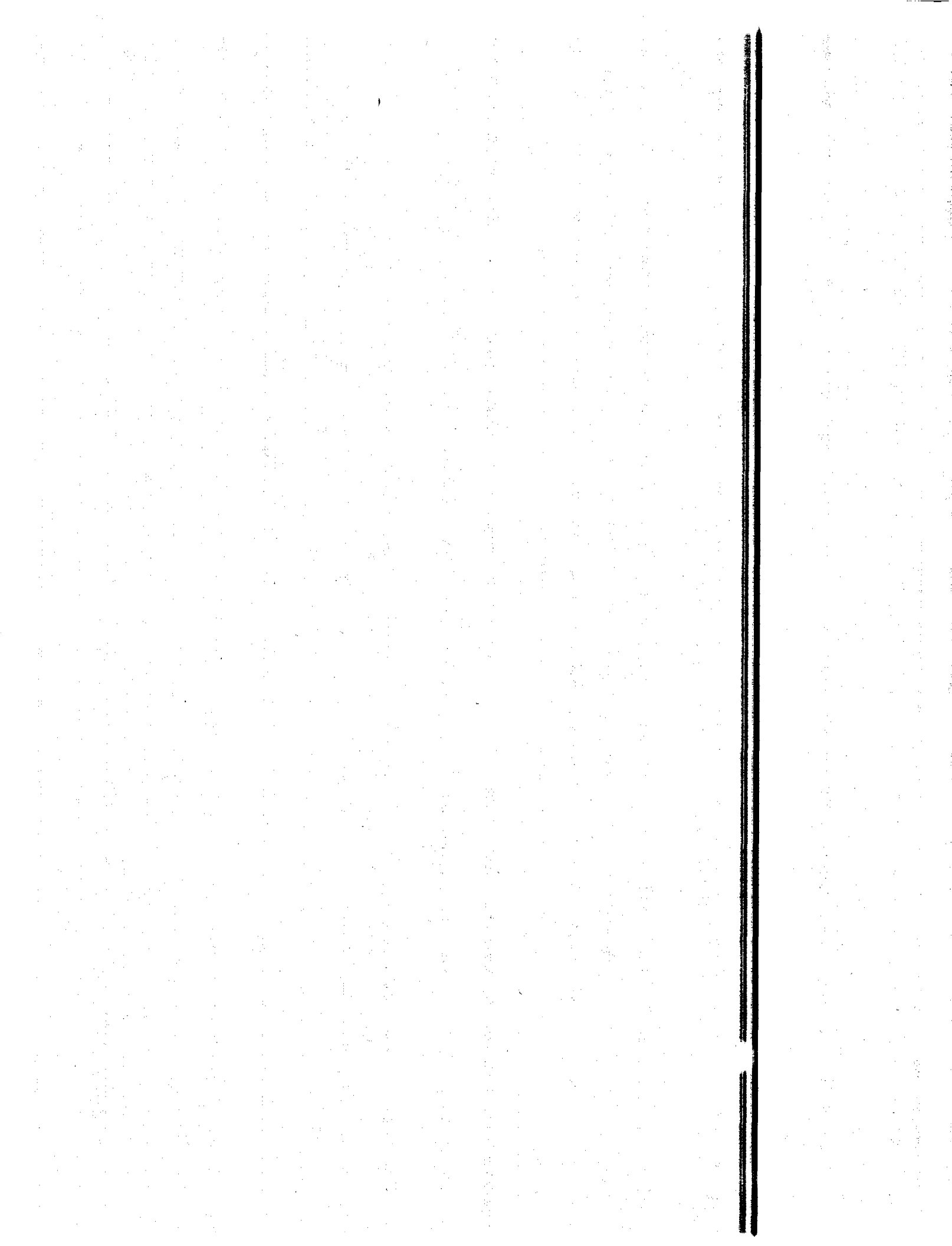


by Allen Inversin

Illustrated by George R. Clark

a **VITA** publication

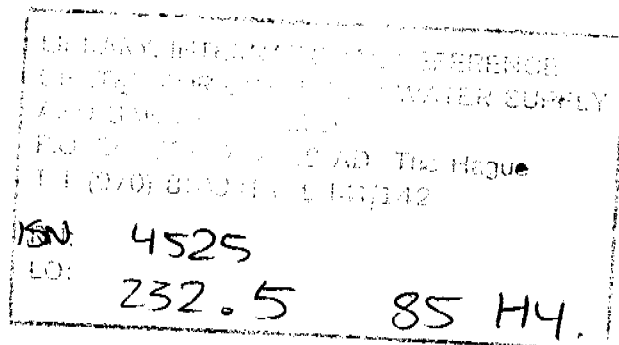
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by:
Allen Inversin

Illustrated by:
George R. Clark



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HYDRAULIC RAM

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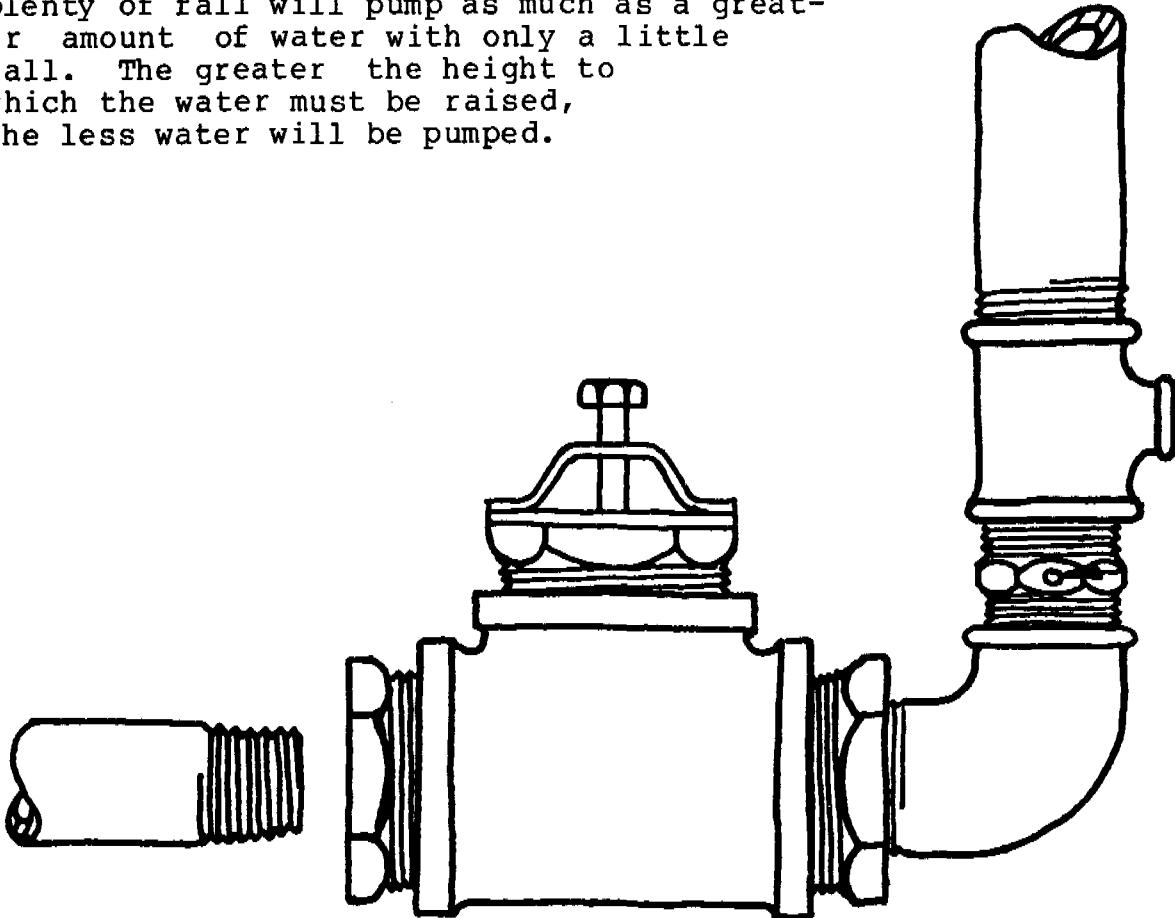
I. INTRODUCTION

WHAT IT IS AND HOW IT IS USED

A hydraulic ram is a pump that uses the power of falling water to force a small portion of the water to a height greater than the source. Water can be forced about as far horizontally as desired, but greater distances require larger pipe, due to friction. No external power is necessary.

With only two working parts, little maintenance is needed. Leaves and trash must be cleaned away from the strainer on the intake and the clack (automatic valve) and nonreturn or delivery valve rubbers must be replaced if they get worn. The original cost is almost the only cost.

Two things are needed to make the ram work: (1) enough water to run the ram, and (2) enough height for water to fall through the drive pipe to work the ram. A small amount of water with plenty of fall will pump as much as a greater amount of water with only a little fall. The greater the height to which the water must be raised, the less water will be pumped.



BACKGROUND ON THE PAPUA NEW GUINEA RAM

The hydraulic ram presented here was developed in Papua New Guinea by Allen R. Inversin, an International Voluntary Services (IVS) volunteer and Volunteers in Technical Assistance (VITA) representative. The ram is made of commercially available pipe fittings and two homemade valves that require only a drill press and simple hand tools to construct. It has been tested at drive heads of 5-4.0 and delivers up to a 70-head, or 20 times the drive head. It will deliver several thousand liters per day.

The ram has been extensively tested and is being used successfully in field conditions.

To introduce the ram in Papua New Guinea, working rams were set up at demonstration sites near communities so that the community members could see the ram at work. Meanwhile the construction design for the ram was distributed by a local appropriate technology group. And, in an important initiative, the ram was manufactured locally as part of a small business effort.

DECISION FACTORS

The ram can fill a number of water-supply needs in situations where water has to be lifted from a water source at a lower level to a higher level. All that is required to make the ram work is enough water falling fast enough to drive the water through the pipe. And if the fall of water does not occur naturally (and this is often the case), the fall can be created by running the water down an inclined pipe so that momentum is created solely within the pipe.

The features of this ram include the following:

- o Water pumping.
- o Water lifting.
- o Capable of lifting/pumping water to higher levels.
- o Non-polluting and energy-saving--it does not rely on fossil fuel energy.
- o Easy to maintain--it has only two moving parts.
- o Inexpensive--the major cost is determined by the amount of pipe needed.

- o Easy to build, install, and operate.
- o The intake must be kept unclogged--this could be a problem if the water source is unusually turbid or hard to keep free of debris, even when the intake is screened.
- o The amount of water capable of being delivered to the higher level may be too small a quantity to meet the need and/or to justify expenses.
- o Use of a storage tank for water collection is a necessity.
- o Technical/mechanical difficulties arise with flows under 2 gallons/minute and heads* of less than 1.5 meters.
- o A drill press is needed for construction of several parts.

MAKING THE DECISION AND FOLLOWING THROUGH

When determining whether a project is worth the time, effort, and expense involved, consider social, cultural, and environmental factors as well as economic ones. What is the purpose of the effort? Who will benefit most? What will the consequences be if the effort is successful? And if it fails?

Having made an informed technology choice, it's important to keep good records. It is helpful from the beginning to keep data on needs, site selection, resource availability, construction progress, labor and materials costs, test findings, etc. The information may prove an important reference if existing plans and methods need to be altered. It can be helpful in pinpointing "what went wrong?" And, of course, it's important to share data with other people. The technologies presented in this and the other manuals in this series have been tested carefully, and are actually used in many parts of the world. However, extensive and controlled field tests have not been conducted for many of them, even some of the most common ones. Even though we know that these technologies work well in some situations, it's important to gather specific information on why they perform properly in one place and not in another.

*Head is the distance the water falls before hitting the ram.

Well-documented models of field activities provide important information for the development worker. It is obviously important for a development worker in Colombia to have the technical design for a ram built and used in Senegal. But it is even more important to have a full narrative about the ram that provides details on materials, labor design changes, and so forth. This model can provide a useful frame of reference.

A reliable bank of such field information is now growing. It exists to help spread the word about these and other technologies, lessening the dependence of the developing world on expensive and finite energy resources.

A practical decision-making work sheet and record-keeping format can be found in Appendix III and IV respectively.

II. PRE-CONSTRUCTION CONSIDERATIONS

The ram works as water runs down through the drive pipe, picking up speed until it forces an automatic valve to close suddenly. The weight of the moving water, suddenly stopped, creates a very high pressure and forces some of the moving water past the nonreturn or delivery valve into the air chamber, compressing the air more and more until the energy of the moving water is spent. This compressed air forces the water up the delivery pipe to the storage tank in a steady stream.

It takes a lot of falling water to pump a little water up a hill: only one/tenth or so of the water will reach the storage tank at the top of the delivery pipe. So, while a working fall from 50cm to 30 meters can be used to "power" a ram, a general rule remains: "The more working fall available, the better." Remember that fall can occur naturally or it can be achieved by running the water down an inclined pipe so that it gathers momentum.

The hydraulic ram described in this manual:

- o Requires only commercially available pipe fittings and two homemade valves.
- o Can be constructed by following simple, step-by-step instructions requiring no special skills.
- o Requires the use of only hand tools and a drill press. (The use of a lathe and grinder might simplify some aspects of the work but are not necessary).
- o Requires no welding, brazing, or soldering. Studs and nuts and bolts are the primary load-carrying members. Epoxy adhesive serves primarily as a sealant and is not subject to large stresses.
- o Should cost about \$50 (US) (excluding the costs of drive and delivery pipes, the ram foundation and housing, and gate valves since these costs are part of any ram installation, whether homemade or commercial).
- o Shows efficiency comparable to that of commercial rams. The amount of water required to operate the pump and the amount of water delivered depend on a number of factors. For delivery heads about ten times the drive head, the pump can deliver about 2.5 liters/minute (3,600 liters/day). Under usual operating conditions, the ram would use 30-40 liters/minute though it is possible to adjust the pump so

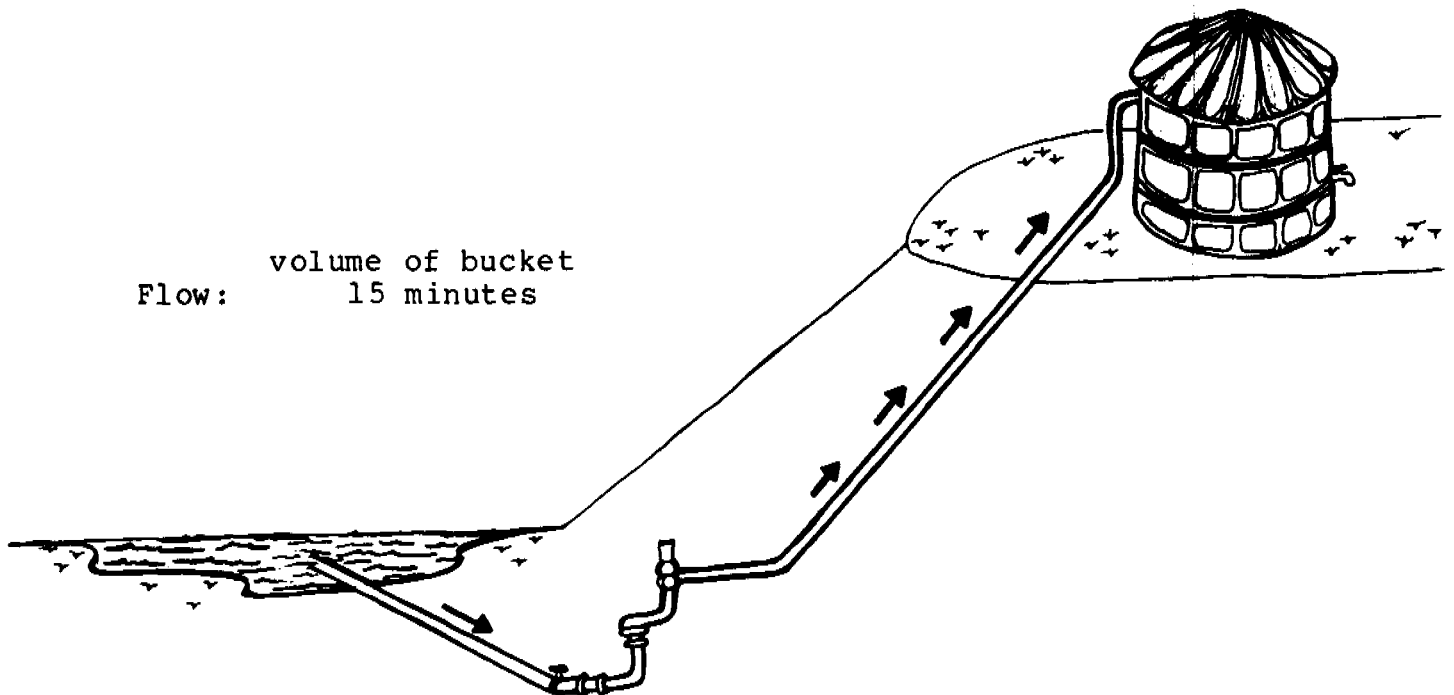
that less water is used. Under these conditions, efficiencies of 65-75 percent are attainable.

SITE SELECTION

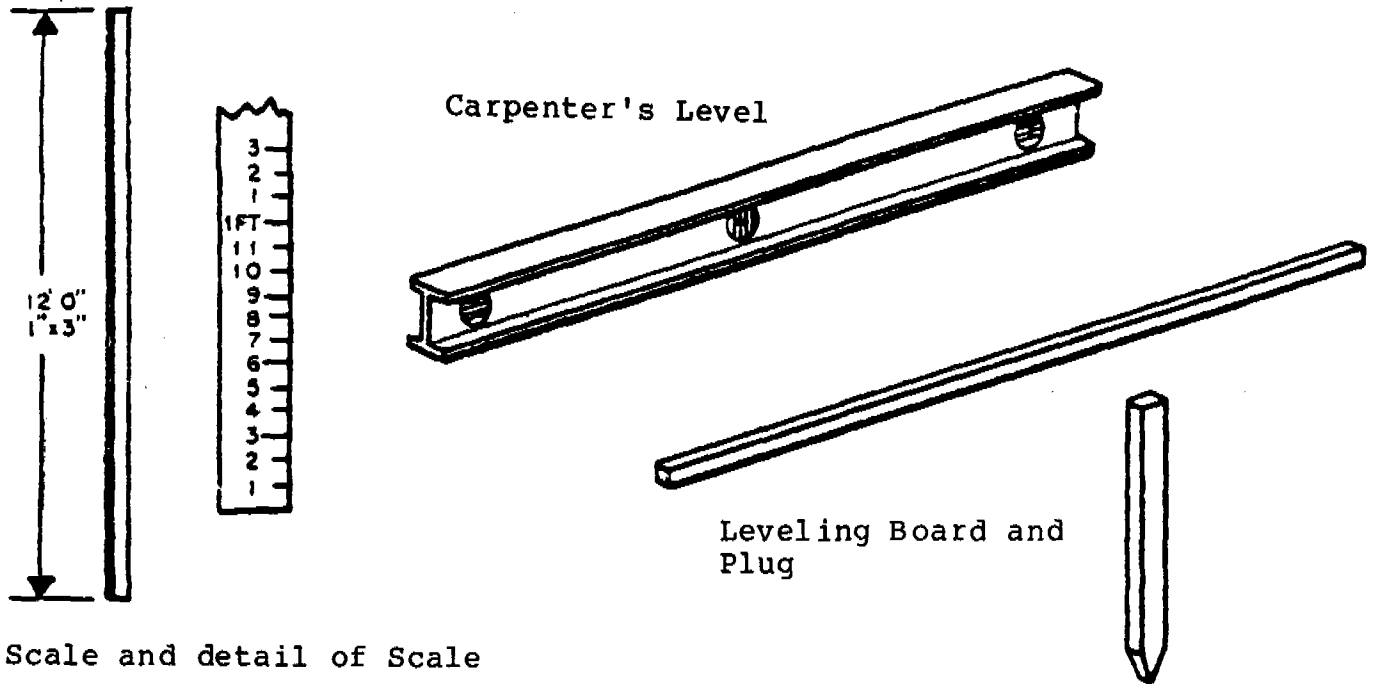
The most important pre-construction activity is determining the suitability of a given water supply site for use with a hydraulic ram.

Water may come from a spring on a hillside or from a river. The water must be led into a position where it can pass through a relatively short supply pipe to the ram, at a fairly steep angle (about 30° from the horizontal is good). A catch basin or cistern can be used as the source for the drive pipe. In this case, it is necessary to control the fall by length and angle of the drive pipe. An open ditch such as one that supplies a water wheel could be used. Be sure to put a strainer on top of the drive pipe to keep trash out of the pipe and ram.

When water is to come from a natural flow, it is necessary to measure flow and fall. Flow can be measured by making a temporary dam and putting a large pipe or two through it. Then catch and measure the water with a bucket of known volume for approximately 15 minutes. This method will give a rough approximation on the drawing water available per minute.

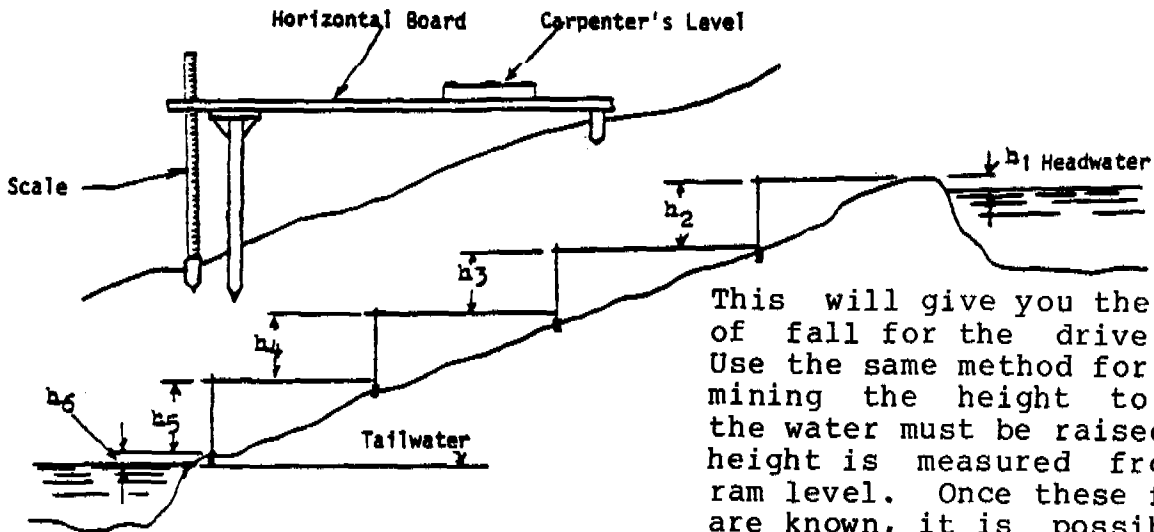


To measure the fall of water at the water site, you will need:



Scale and detail of Scale

Place the board horizontally at headwater level and place the level on top of it for accurate leveling. At the downstream end of the board, the distance to a wooden plug set into the ground is measured with a scale.



This will give you the amount of fall for the drive pipe. Use the same method for determining the height to which the water must be raised. This height is measured from the ram level. Once these figures are known, it is possible to determine how much water can be raised to a given height.

Expressed as an equation,

Amount of water raised by ram =

$$\frac{\text{Flow per minute (gallons)} \times \text{twice the fall (feet)}}{\text{Three times the (meters) lift above ram (feet)}}$$

It may be useful to use a particular problem:

A water supply site has a fall of three feet. The ram has to lift the water 150 feet. The available flow is 100 gallons per minute.

How much water will actually be delivered by a ram operating under these conditions?

$$\text{Water delivered} = \frac{100 \times 2(3)}{3 \times 150}$$

$$\text{Water delivered} = \frac{600}{450}$$

1.3 gallons per minute

OR

$$\text{Water delivered} = 78 \text{ gallons per hour}$$

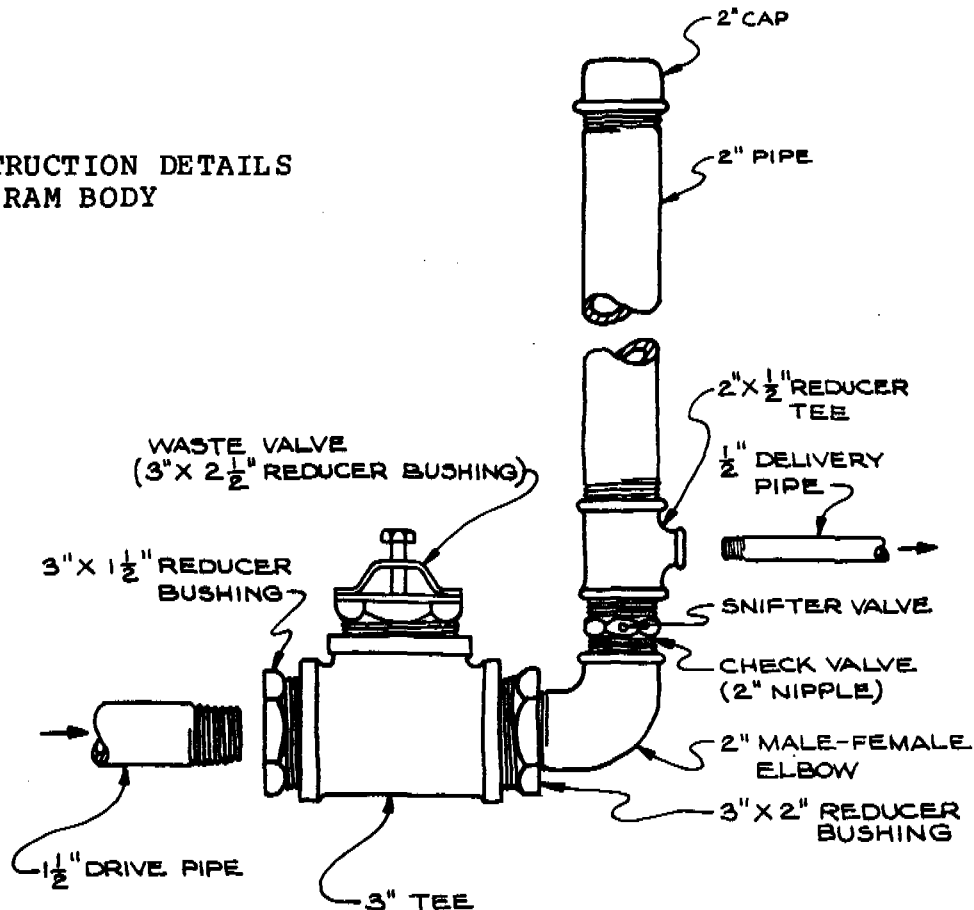
OR

1872 gallons per day

This is the information necessary for you to determine if the ram can deliver enough water to meet your need. If there are any questions at this point as to the amount of water actually needed for a given purpose, e.g., village water supply, make sure these questions are resolved before construction begins. If more water is required than previously estimated, it may be possible to increase the fall and/or the size of the drive and delivery pipes. But it will be far harder to make such changes after ram construction and installation have begun.

The actual techniques used in construction of the ram will depend on what tools are available. The method described here is low-cost and simple, yet rugged and efficient. Those who have had machine shop experience may choose other techniques of construction.

CONSTRUCTION DETAILS
RAM BODY



MATERIALS

The following list of galvanized pipe fittings is for the ram only. Note: The ram was designed and built originally with pipe fittings in standard American sizes. These sizes do not translate directly into metric units. Where metric or other standard pipe is available, equivalent sizes should be used. All other measurements are metric.

3" x 1-1/2" reducer bushing (another size reducer bushing may be required if a drive pipe smaller or larger than 1-1/2" is used, see the comments on drive pipe diameter on page 42).

2" x 1/2" reducer tee (if the delivery pipe is longer than about a hundred meters, using a 2" x 3/4" or 2" x 1" tee and the corresponding size delivery pipe would reduce friction losses and permit more water to be delivered).

2" pipe, about 50 cm long,
threaded at both ends

2" male-female elbow (90°)

2" cap

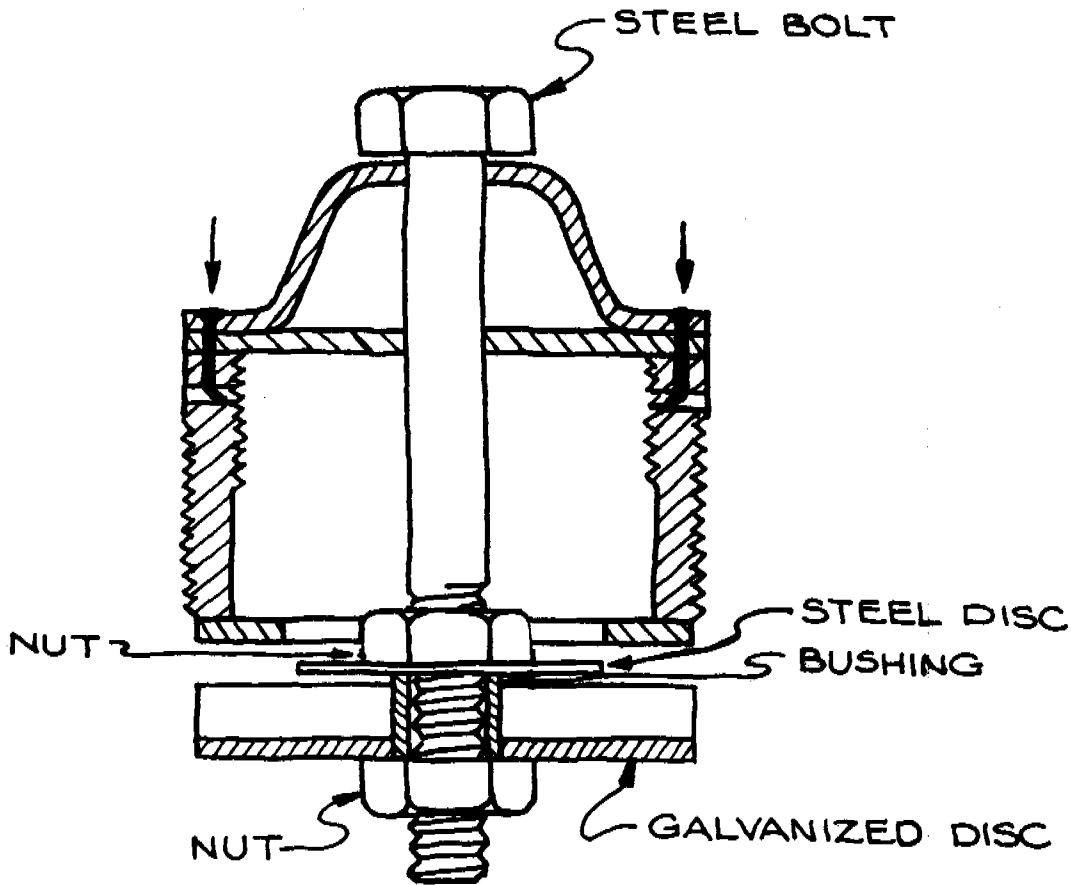
3" x 2" reducer bushing

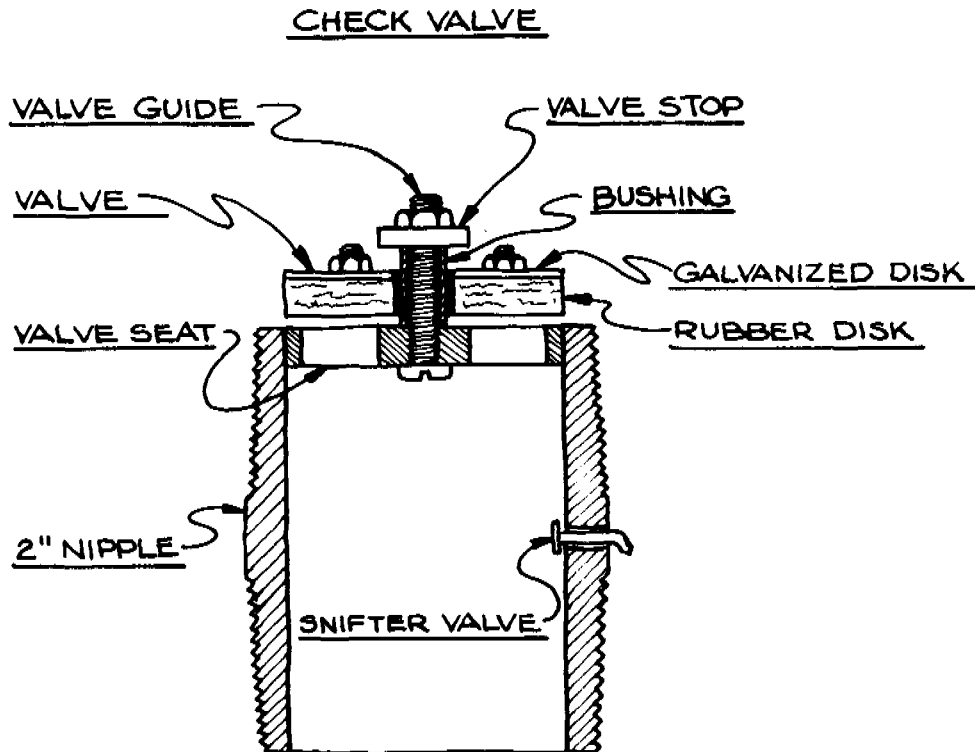
3" tee

WASTE AND CHECK VALVES

The only two parts of the pump that have to be built are the two valves--the waste valve and the check valve. Sectional views of these valves are shown below and on the next page. One method for the construction of each valve is described; alternative methods for their construction may be preferred.

WASTE VALVE





MATERIALS REQUIRED FOR BOTH VALVES

- A. 3" x 2-1/2" reducer bushing.
- B. 3mm (1/8") steel plate, two pieces each about 10cm square square (thicker plate can be used but it may make construction a little more difficult).
- C. Several steel nails about 2mm in diameter (not larger).
- D. Epoxy adhesive.
- E. 1.90cm (3/4") x 3mm (1/8") flat mild steel strip at least 21cm long (a 4.5 mm (3/16") thick strip can be used but it is more difficult to bend).
- F. 11.43cm (4-1/2") x 9mm (3/8") steel bolt and two nuts.
- G. 1.27cm (1/2") diameter steel bolt with a portion of the shank unthreaded or a short length of 1.27cm (1/2") round rod.
- H. Galvanized sheet about 1mm thick, about 5cm x 10cm.
- I. 6mm (1/4") piece of insertion rubber about 7cm x 12 cm.
- J. 2" nipple.
- K. 6mm (1/4") steel plate, about 5cm square.

- L. 6mm (1/4") diameter steel bolt with a portion of the shank unthreaded or a short length of 6mm (1/4") round rod.
- M. Three 9mm (3/8") x 3mm (1/8") countersunk metal thread bolts (or longer) and nuts.
- N. 3.81cm (1-1/2") x 4.5mm (3/16") round head bolt and nut.
- O. Cotter pin or nail 1-2 mm diameter.

TOOLS

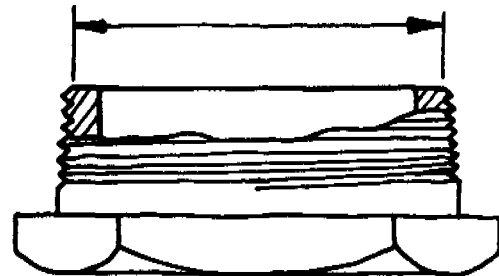
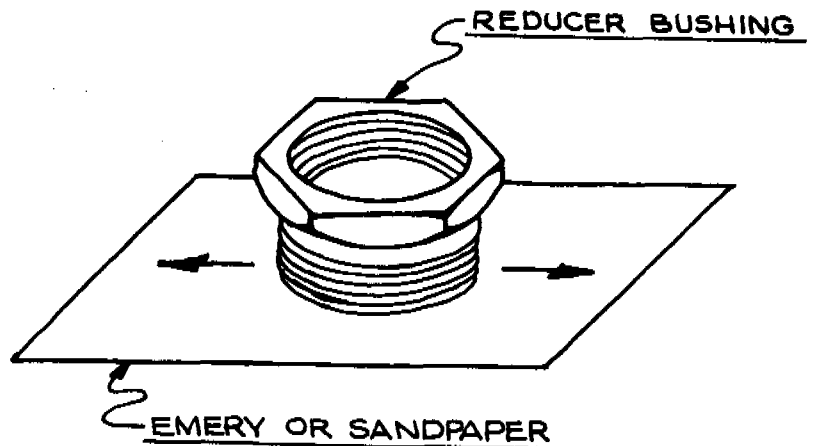
- o Drill press with complete set of drills
- o Drill press vise or clamps
- o Hacksaw
- o Tin snips, sharp knife, or razor blade (to cut insertion rubber)
- o Hammer (preferably ball peen)
- o Center punch
- o Table vise
- o Files, round and flat (a set of small files would also be useful)
- o Scribing compass
- o Pliers
- o Emery or sandpaper
- o Ruler
- o Square

III. CONSTRUCTION

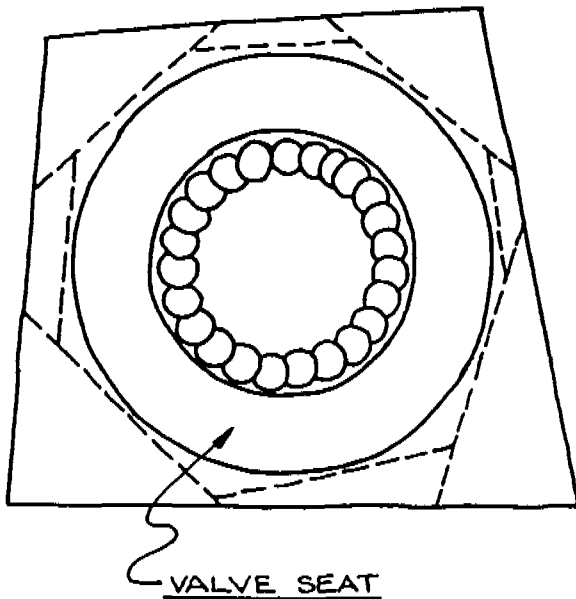
WASTE VALVE CONSTRUCTION

Make Valve Seat

- o Smooth both faces of the reducer bushing (A) by rubbing each face on emery or sandpaper resting on a flat surface. Remove any high spots with a file.
- o Measure the inside diameter. Note that this measurement does not include the width of the threads.
- o Draw a circle with a diameter equal to the measurement made in the previous step on a flat piece of 3mm steel plate (B).



REDUCER BUSHING



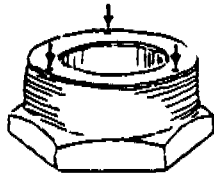
- o Draw another circle with a radius of 5.0cm using the same center.
- o Drill a circle of holes to remove the center portion and file the inner circle smooth.
- o Cut around the circle with a hacksaw and file the outside circle smooth.

The remaining circle of 3mm steel plate is the valve seat.

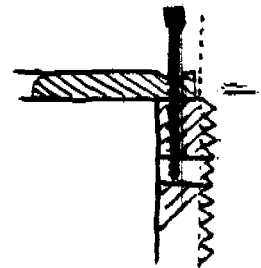
- o Round off and smooth one edge of the inner circle of the valve seat.

Fasten the Valve Seat to the Reducer Bushing

- o Center--carefully--the valve seat on the bushing and then drill three holes the size of the nails (C) around the outside of the valve seat into the center of the bushing wall as shown and countersink slightly.

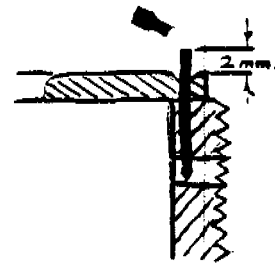


To ensure that the holes in the valve seat and bushing are aligned, as each hole is drilled, insert a nail to hold the valve seat in place.



- o Drill three holes through the side of the bushing as shown. Use a drill several times larger than nails.

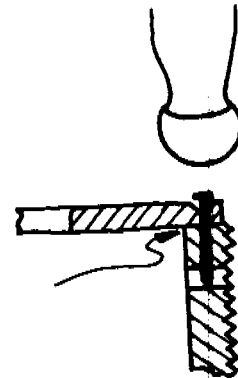
- o Put the valve seat and nails in place. Make sure that the outside edge of the valve set does not extend beyond the root of the threads. Check this by screwing the reducer bushing (with the valve seat in place) into a 3" tee--feel if there is any resistance as it is screwed in. File any portion that extends beyond.



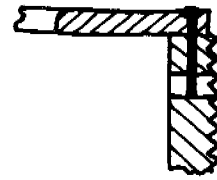
- o Cut off the upper portion of each of the three nails as shown.

- o Prepare the surfaces of the valve seat and reducer bushing to be glued (remove any grease and roughen the surfaces).

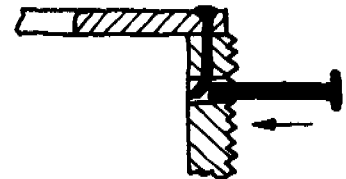
- o Apply epoxy (D) on nails and on surfaces that touch and hammer nails with a ball peen hammer to make rivet heads.



- o Hammer a larger nail with a rounded point through the three holes as shown to bend the foot of the nail rivets. Do not bend the nail rivets too much because they may break.

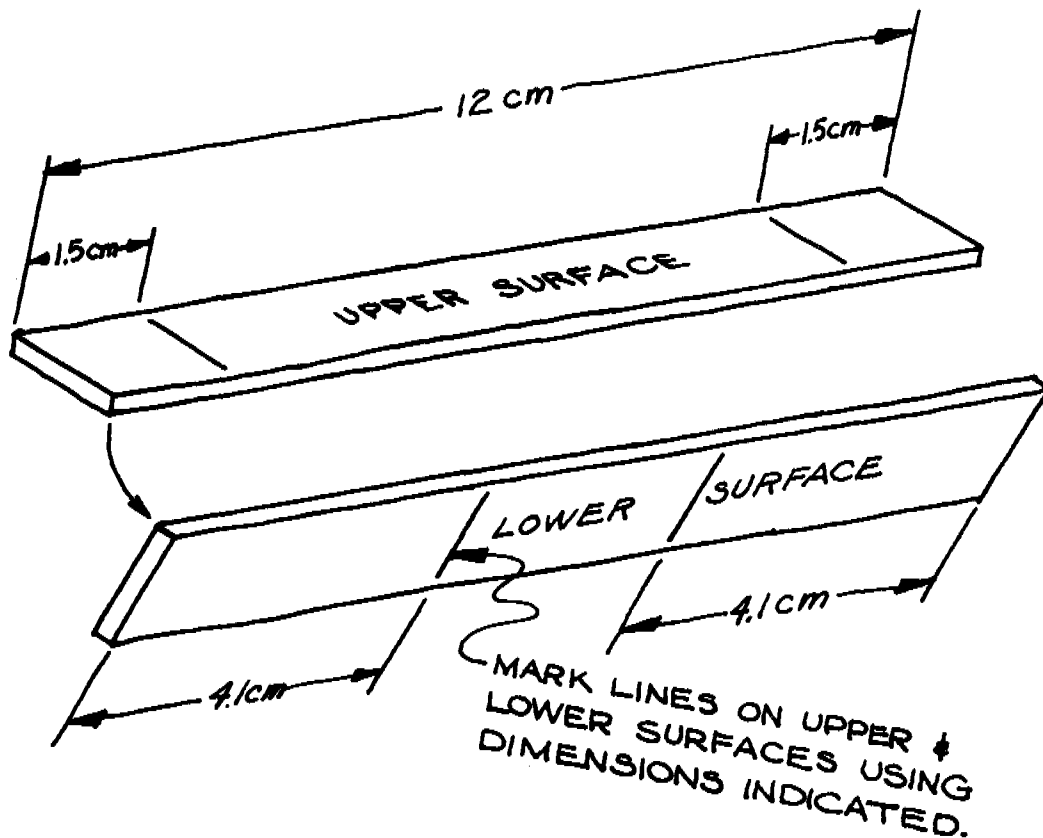
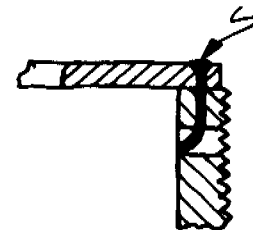


- o File the heads of the nail rivets when the epoxy has dried. Avoid making deep scratches on the valve seat.



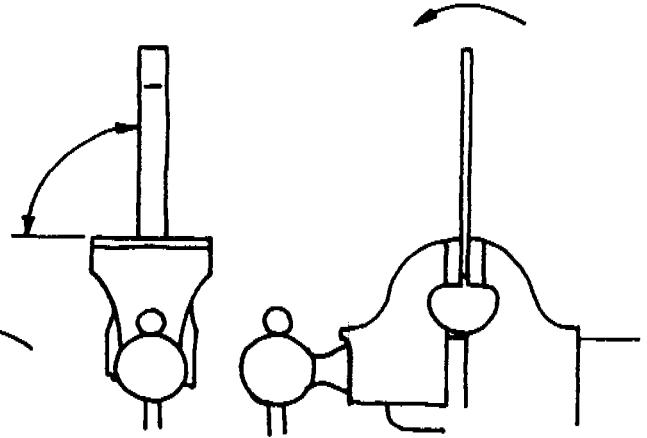
Make the Valve Guide

- o Cut two lengths of the flat strip (E), one 9cm long, the other 12cm long.
- o Mark the longer length as follows:

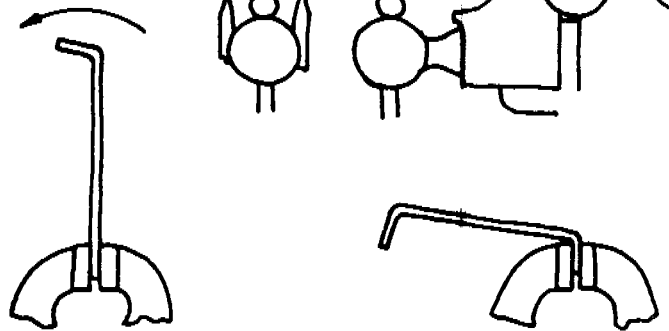


- o Use a vise and hammer to bend this longer length. Note the position of the marks.

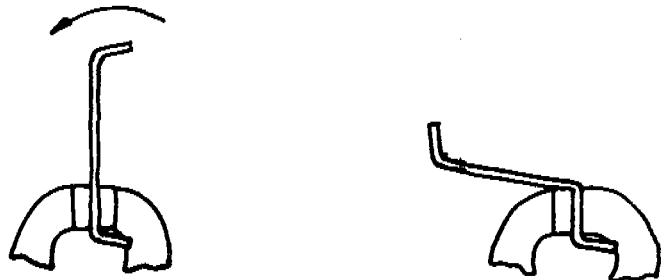
- (a) Always keep this piece at right angles to the vise.



- (b) Reverse the strip's position in the vise. Make the second bend.



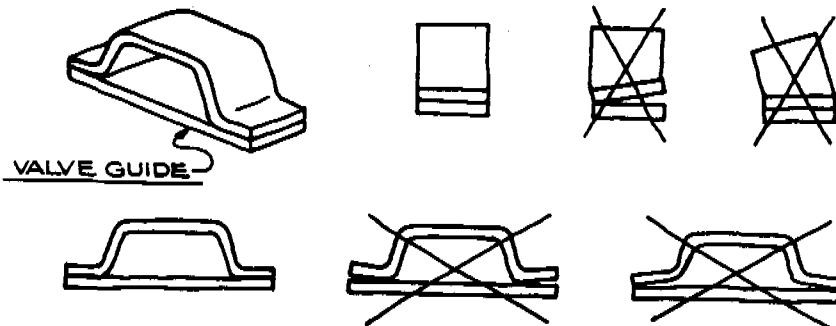
- (c) Place strip in vise as shown and make the third bend.



- (d) Put the opposite end of the strip in the vise for the fourth bend.

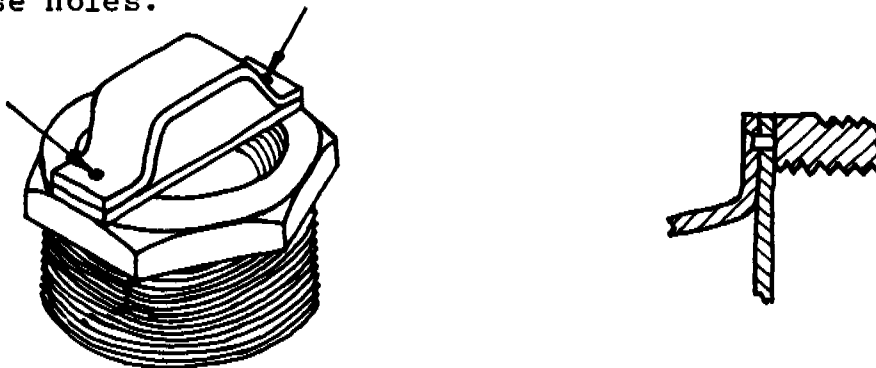


After bending this long piece, it should fit flat over the shorter, flat piece. If not, rebend until it does.



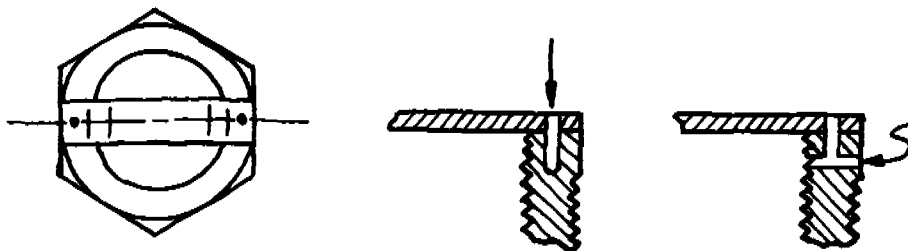
Fasten the Valve Guide to the Reducer Bushing

- o Drill a hole the size of the nails (C) in the center of each end of the valve guide so that each hole ends up above the center of the wall of the reducer bushing (see drawing below). Make a slight depression around these holes.

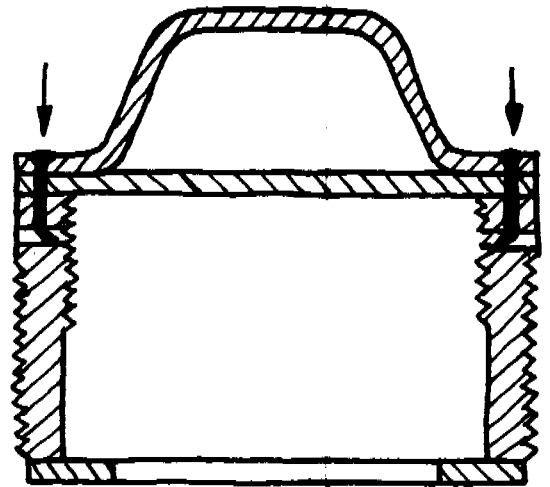


- o Place the flat portion of the valve-guide as close to the center of the bushing as possible and continue drilling the holes into the bushing ...

... then drill through the wall of the bushing as done previously.



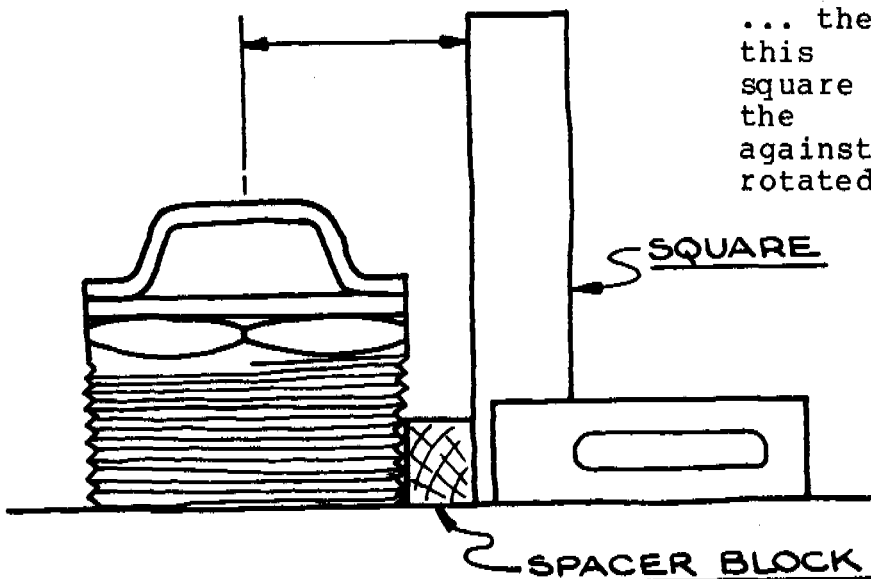
- o Cut the nails to the proper length and prepare the surfaces to be glued as before. Glue the two portions of the valve guide to the bushing with epoxy. Hammer rivet heads on the nails. Bend the foot of the nail rivets as before. Set aside to dry.



Drill the Valve Guide

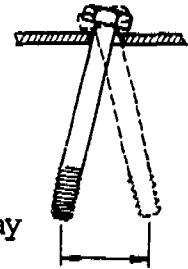
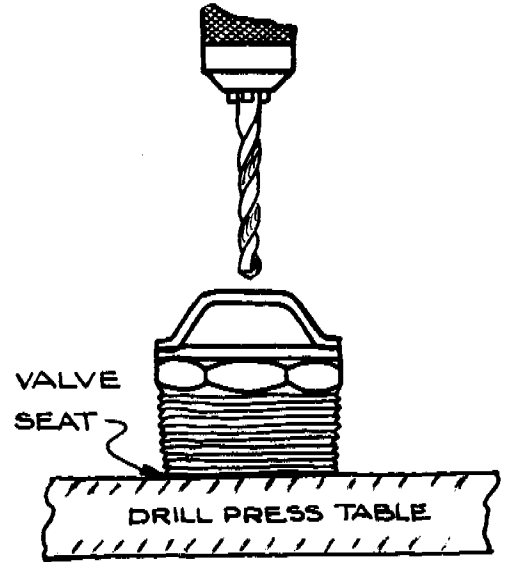
- o Locate the center of the valve guide by placing the bushing on a flat surface pushed up against a spacer block and a square.

This point is the center of the valve guide if ...



... the distance between this point and the square is constant as the bushing is held against the block and rotated.

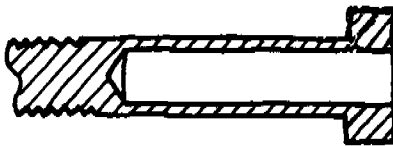
- o Center punch the center and drill a hole about 0.25mm (.010") larger than the diameter of the shank of the 9mm (3/8") bolt (F) through both portions of the valve-guide. Make sure that the valve seat lies completely flat on the drill press table so that the drill is perpendicular to the valve seat.
- o Through a piece of scrap metal the same thickness as used in making the valve guide, drill a hole and insert the 9mm (3/8") bolt almost all the way. Measure the maximum distance the end of the bolt can move from side to side if the piece of scrap metal is held firm. If a 3mm flat strip was used to make the valve-guide, this distance should be 2 - 3cm if the hole is of the proper size. If the proper drill is not available, an undersized hole can be filed larger. Be very careful not to overfile the hole.



(A micrometer or vernier caliper, if available, may be used to select the right size drill).

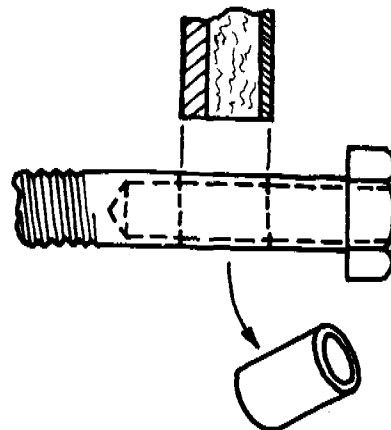
Make the Valve Bushing

- o Use the 1.27cm (1/2") bolt or round rod (G).



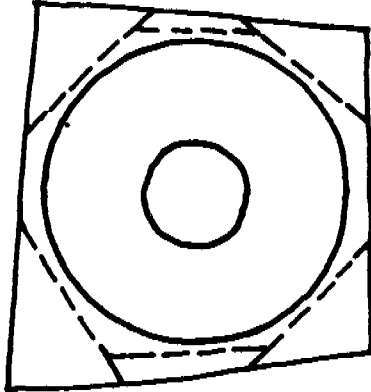
- o Drill a hole in the center whose diameter is equal to the diameter of the threaded portion of the 9mm (3/8") bolt (F).

- o Cut off a length slightly greater than the sum of the thickness of the steel plate (B), the galvanized sheet (H), and rubber (I).



Galvanized Disc

- o Draw a circle with a diameter of 4.0cm on a piece of galvanized sheet (H).



- o Drill a hole in the center whose diameter is slightly larger than the diameter of the bushing just completed.

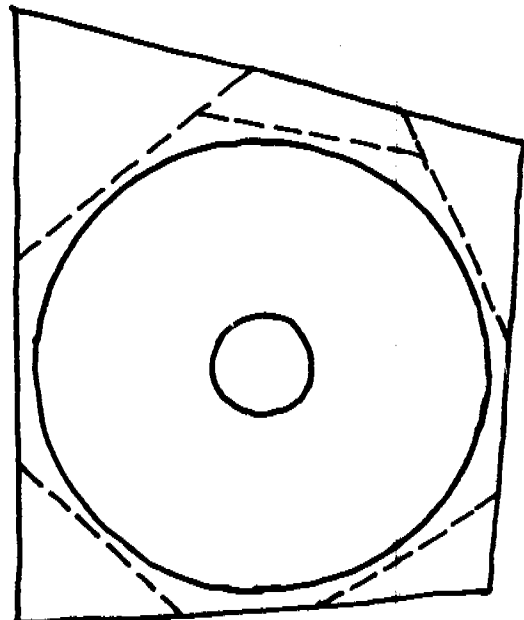
- o Cut around the circle with a hacksaw and file smooth.

Steel Disc

- o Draw a circle with a diameter equal to 6.5cm on a piece of 3mm steel plate (B).

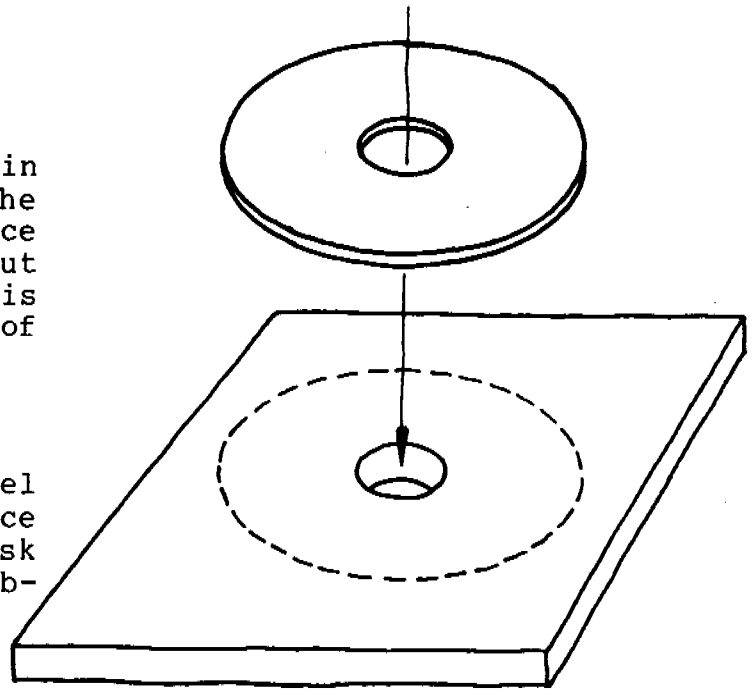
- o Drill a hole in the center the same size as that just drilled.

- o Cut around the circle with a hacksaw and file smooth.



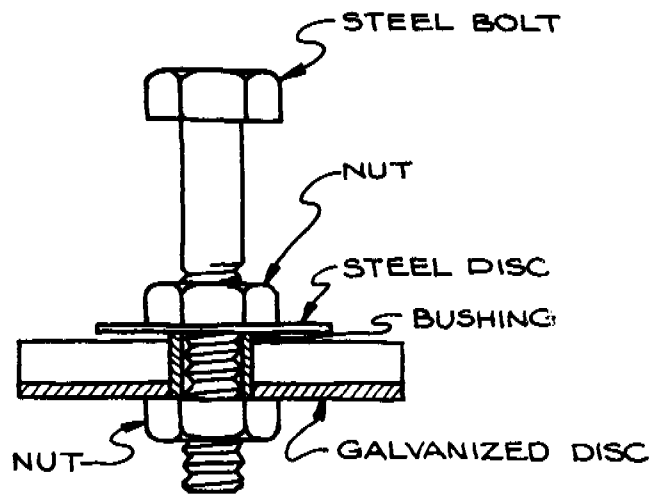
Rubber Disc

- o Drill the same size hole as in just completed steps in the center of a 7cm-square piece of rubber (I). A cleaner cut can be made if the rubber is clamped between two pieces of wood before drilling.
- o Align the holes in the steel disc and the rubber disc. Trace the outline of the steel disc on the rubber and cut out rubber disc.



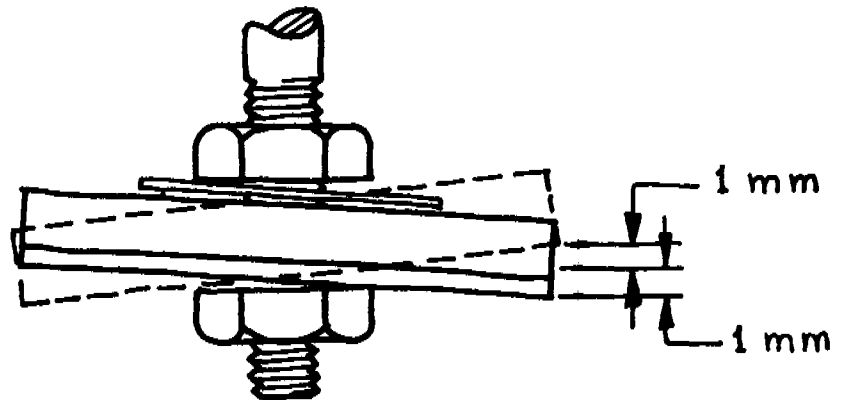
Valve Assembly and Adjustment

- o Assemble the valve as shown.



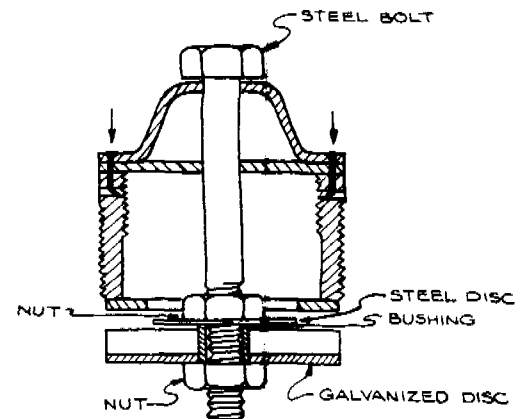
- o The bushing should be of such a length that when the two nuts are tightened against each other, the disks are free to twist about 1mm up or down from the horizontal. If the bushing is too long, shorten it.

(drawing exaggerated for illustrative purposes)



Assemble the Waste Valve

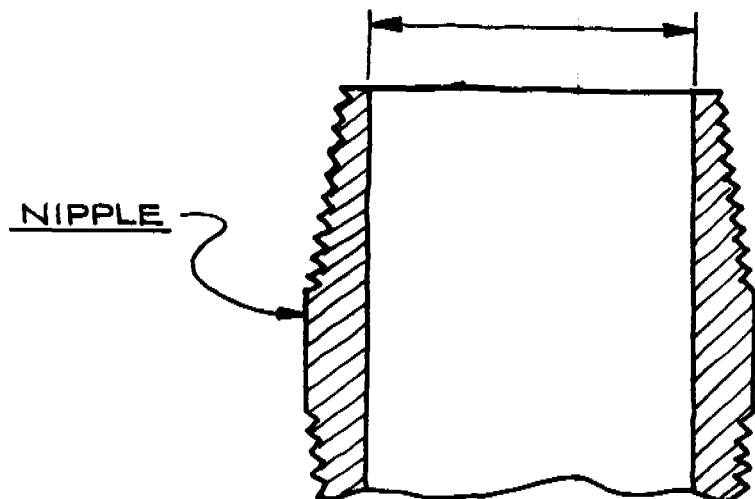
- o Assemble the entire valve assembly. The valve must be able to move up and down completely freely in the valve guide. If the shank of the bolt has any irregularities or burrs that prevent perfectly free motion, file them off. Also file off any epoxy remaining in the threads of the bushing so that it screws easily into the 3" tee.



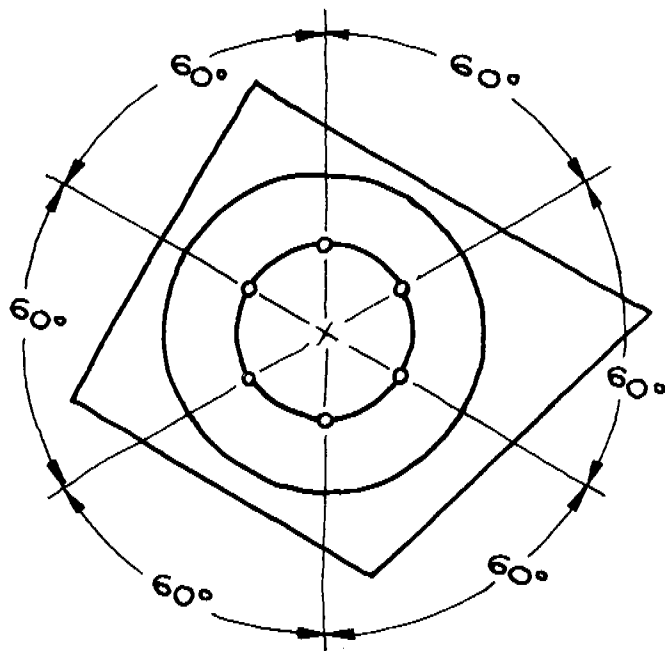
CHECK VALVE CONSTRUCTION

Make the Valve Seat

- o Measure the inner diameter of nipple (J) and smooth the inside of one end of the nipple with a round file.

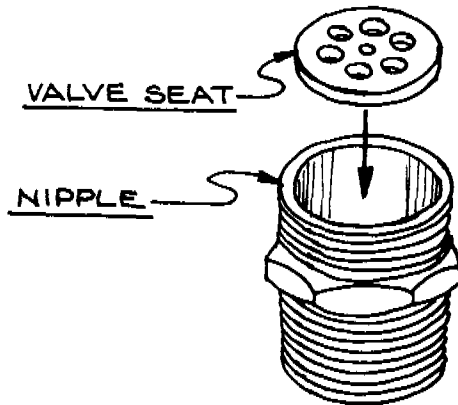


- o Draw a circle on a piece of 6mm (1/4") steel plate (K) with a diameter equal to the measurement just made.
- o Center punch the center of the circle.
- o Draw another circle with a radius of 1.4cm.
- o Take a blank sheet of paper and draw circles of the same size on it.
- o With a pencil divide the inner circle into two half circles.
- o Using a protractor and the dividing line as a reference, plot a point every 60°. Six points total 360°.
- o Draw a straight line from each point to the center of the inner circle.
- o Cut out the inner circle of the paper drawing and place directly on the top of the scribed inner circle of the steel plate.



- o Mark the points on the steel plate and carefully center punch these points.

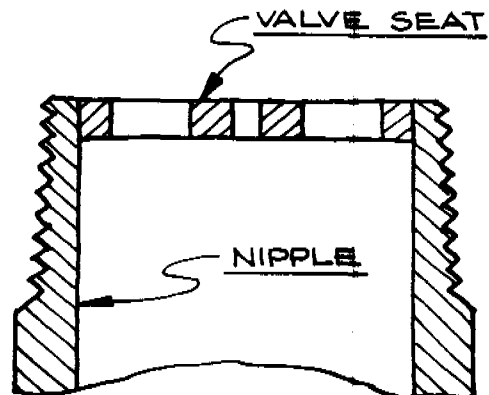
- o Drill six 1.27cm (1/2") holes on the same piece.
- o Drill a 0.47cm (3/16") hole in the center.

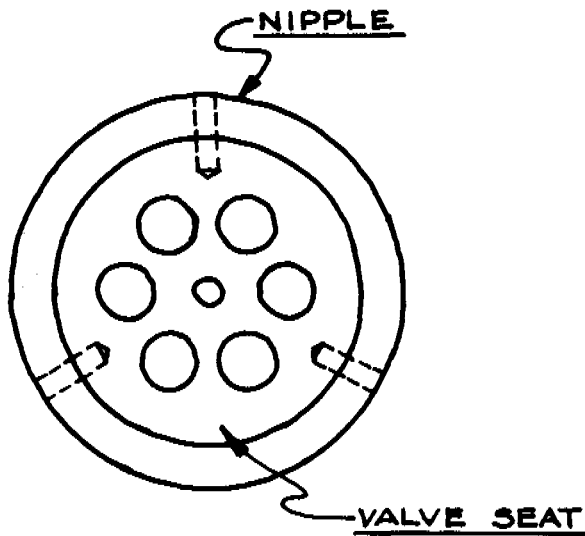


- o Cut around the circle with a hacksaw and file this circle smooth so that this piece fits snugly into the end of nipple.

Fasten the Valve Seat in the Nipple

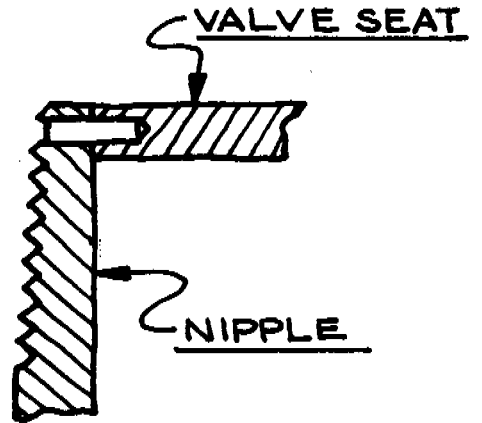
- o Prepare the surfaces by removing any grease and glue from the valve seat so that it is flush with the the top of the nipple.
- o Set the nipple upside down on a flat surface to dry.



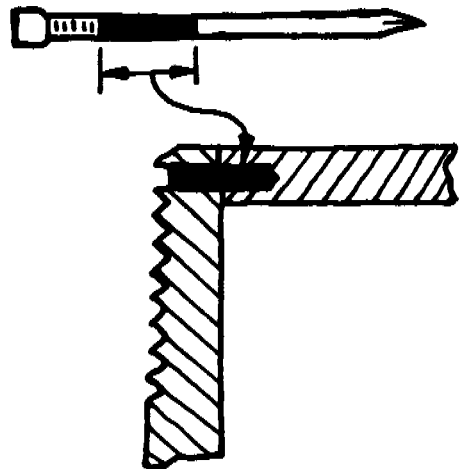


- o Using the drill press, drill three holes the diameter of the nails (C) partially through the valve seat. Be sure the epoxy is dry first.

- o Cut three nails (C) long enough to fit into these holes but not so long that they interfere with the threads of the nipple. Glue these nails in position with epoxy and let dry.

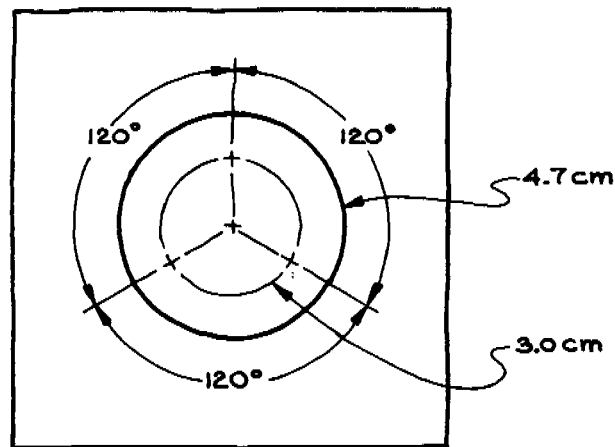


- o File the top of the valve seat so that it is completely flat and file away any epoxy that remains in the threads.

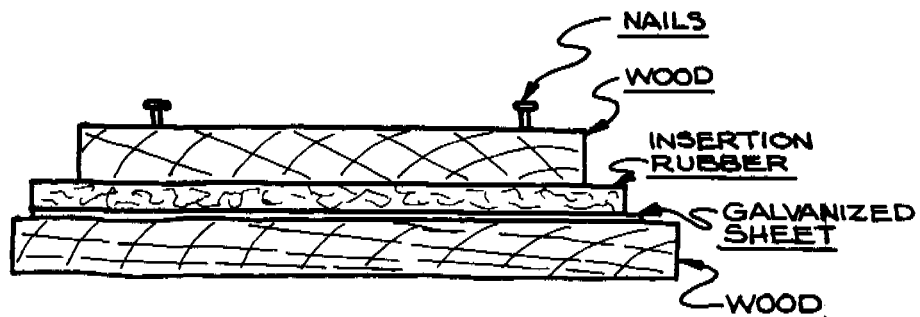


Make the Valve Prepare a Jig for Drilling

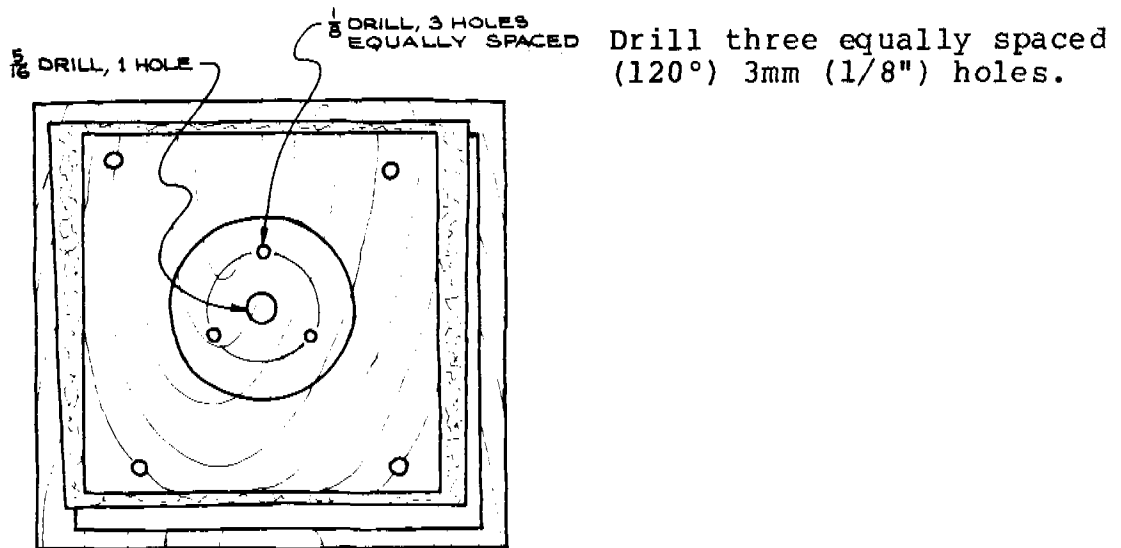
- o On a small scrap of wood, draw a circle with a diameter of 4.7cm.
- o Draw a circle using the same center with a diameter of about 3.0cm and with the same compass setting, divide this circle by six equally spaced points.



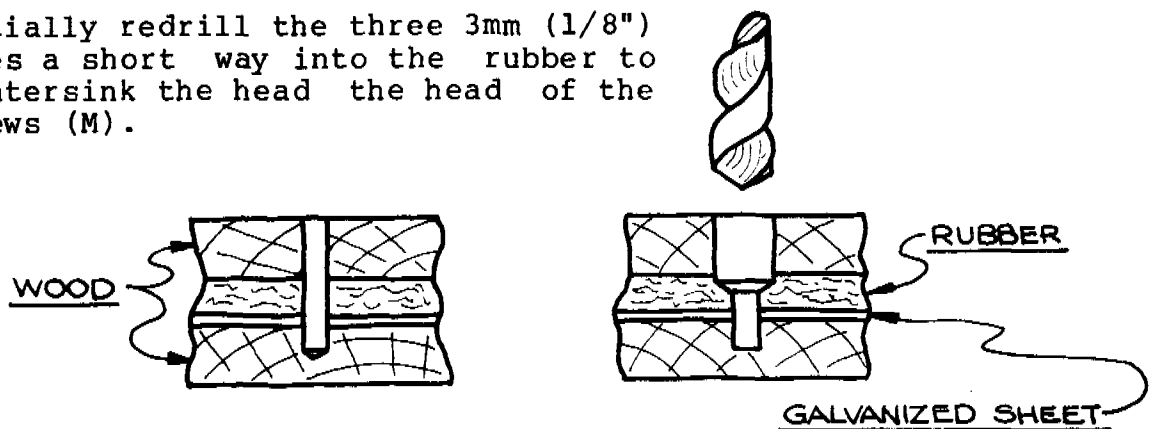
- o Sandwich a piece of insertion rubber (I) and a piece of galvanized sheet (H) between the piece of wood with circles on it and another piece of scrap wood about the same size, as shown. This sandwich should either be clamped to the drill press table, or drive a few nails in around the outside to hold it all together.



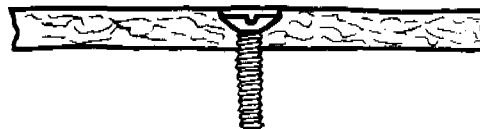
- o Take the sandwich made in the previous step and drill a 7.5mm (5/16") hole in the center.



- o Partially redrill the three 3mm (1/8") holes a short way into the rubber to countersink the head of the screws (M).

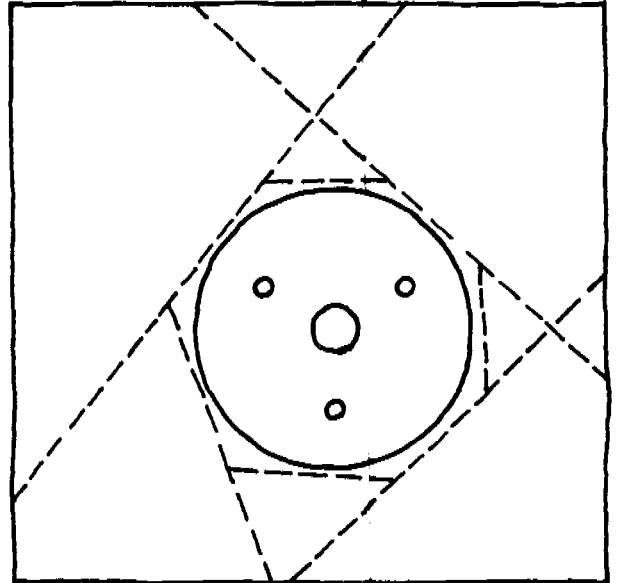


The holes must be countersunk so that the heads of the screws (M) will end up below the surface of the rubber when assembled.



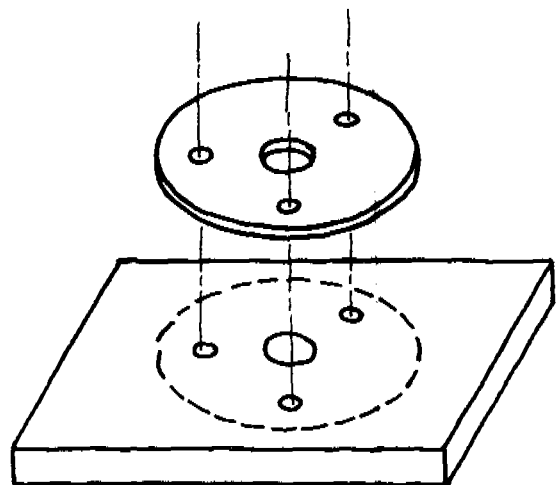
Galvanized Disc

- o Take the sandwich apart and draw on the galvanized sheet a circle a diameter of 4.7cm with the 7.5mm (5/16") hole as its center.
- o Cut around the circle with a hacksaw and file smooth.



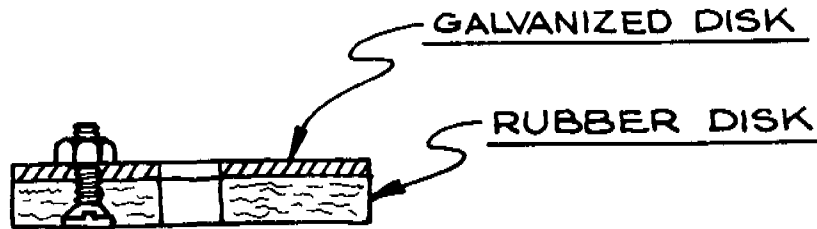
Rubber Disc

- o Align the holes in the galvanized disk with the holes in the rubber.
- o Trace its outline on the rubber.
- o Cut the rubber slightly larger than this outline.



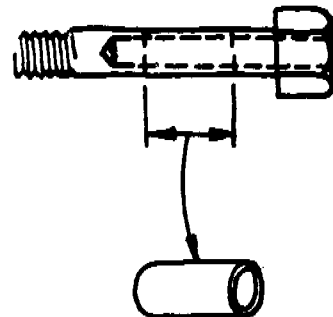
Assembly

- o Assemble the valve from the galvanized and rubber discs. Push the three 3mm (1/8") bolts (M) all the way into the depressed holes in the rubber and loosely put on the nuts. Tighten them finger tight. Do not use a screwdriver to tighten the bolts. If they are tightened too much, the rubber will not remain flat.
- o Put a drop of epoxy adhesive on the nuts to hold them in place.
- o Trim excess rubber off the outside edge making sure that this edge is straight.
- o Trim excess rubber from the center hole with a small file.



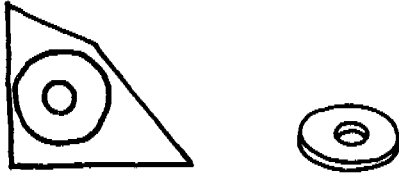
Make the Valve Guide - Bushing

- o Locate the center and drill a 4.5mm (3/16") hole using the 6mm (1/4") bolt or round rod (L).
- o Cut off a section about 1.3cm long from this 1/4 inch bolt or round rod (L).



Valve Stop

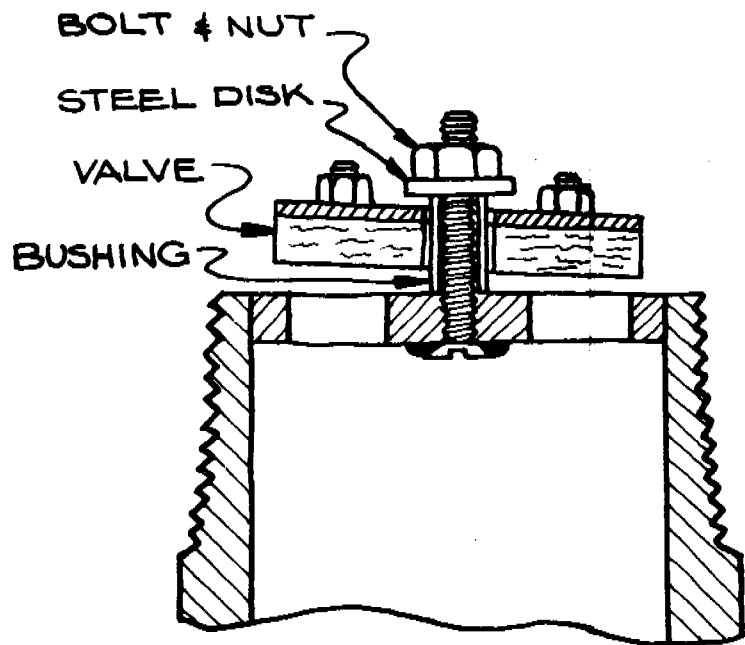
- o Draw a circle whose diameter is 1.5cm on a scrap piece of 3mm steel plate (B).



- o Punch the center and drill a 4.5mm (3/16") hole.
- o Cut around the circle with a hacksaw and file smooth, making a steel disc.

Assemble the Check Valve

- o Put together the entire valve assembly as shown below.

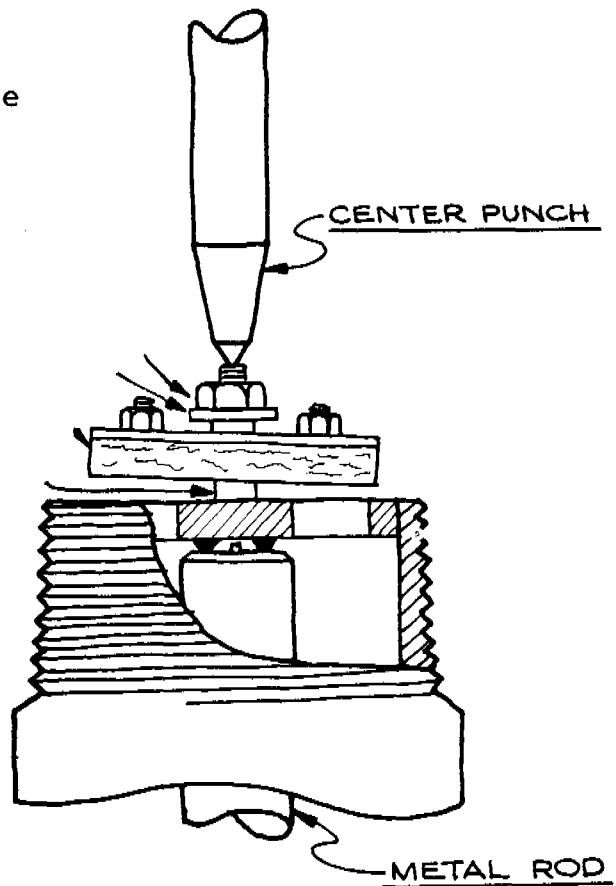


The valve should move up and down very freely.

The bolt and nut (N) should be well tightened.

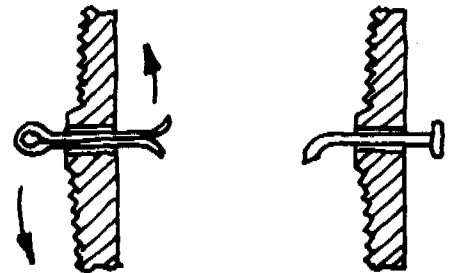
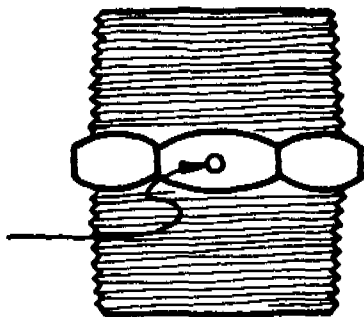
- o Use both a screwdriver and a wrench to tighten the nut securely. The screwdriver is necessary since the epoxy itself may not hold the bolt in place.

- o Cut the bolt a little above the nut and use a center punch to widen the end of the bolt slightly. This will prevent the nut from unwinding. When center punching, rest the head of the bolt on a securely held metal rod.



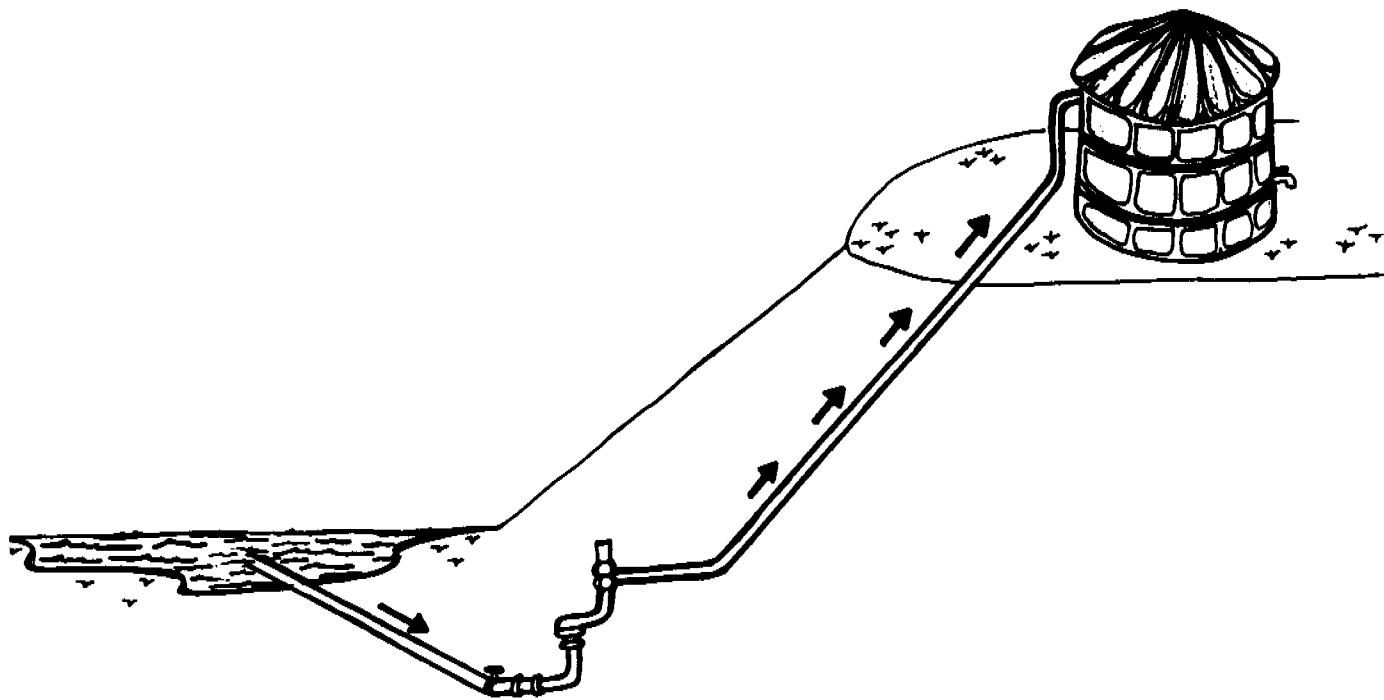
Make the Snifter Valve

- o Measure or estimate carefully the diameter of the cotter pin or nail (O) and through one side of the nipple, drill a hole slightly larger than this measurement.
- o Insert the cotter pin or nail through this hole and bend the end. This piece should be free to move easily in and out of the hole about 0.5 cm.



VII. INSTALLATION, OPERATION, AND MAINTENANCE

The pipe fittings and the two valves should be assembled as illustrated previously. The nipple is installed so that the check valve is on top. Teflon tape or a joint compound should be used on all threads before screwing the fittings together. The joints at both ends of the half-meter length of pipe must be completely leakproof, otherwise the pump will fail to operate properly. Probably the easiest way to verify that the joints are leakproof is to observe the joints for signs of leaking while the pump is in operation. While not as critical, all other joints should also be water tight.



When installed on site, the body of the ram should be secured firmly to the ground and both the waste and check valves must be maintained in a vertical position.

The drive pipe should have a strainer attached made of 1.5cm screen wire, hardware cloth, or anything suitable. The strainer keeps out the trash, frogs, leaves, and fish, any of which will stop the ram if they get inside. The drive pipe should be 4cm diameter or larger and, if possible, new, solidly put together, straight, and well supported throughout its length. A gate valve on the drive pipe about 1.5m (4 feet) from the ram is a great convenience but not necessary. Another gate valve on the delivery pipe is helpful to avoid draining the delivery pipe whenever the ram is cleaned. The ram should not be welded to the delivery and drive pipes so it can be removed for cleaning. If you use two or more rams, each must have separate drive pipes but the delivery pipes can be joined, provided the pipe is large enough to carry the water.

The delivery pipe should start from the ram with about two lengths of 2.5cm galvanized iron pipe. After this, 2cm pipe can be used. The iron pipe will give the ram better support, but plastic pipe is smoother inside and can be a size smaller than the iron pipe. Although plastic pipe can be used and is cheaper, it must be protected from mechanical injury and sunlight. It is best to have all the water pumped by the ram to run directly into a storage tank, to be used from there.

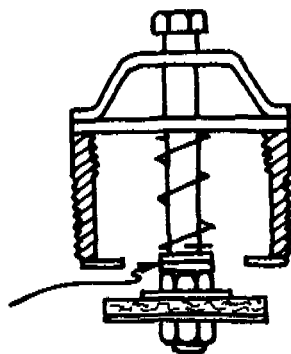
Rams have an exceptionally good reputation for trouble free operation and are practically maintenance-free. The way in which the necessary maintenance is arranged depends very much on who is available to carry it out. There should be someone familiar with ram operations who could have a look at the ram at least once every week.

Tuning and adjustment of valves and bolts may need to be done more frequently with this ram than with some commercial models made from purpose-designed alloys and components. The need for maintenance may become greater as the ram gets older.

Below are some steps that should be taken on a regular basis for trouble-free maintenance. Start with this list when the ram is not working properly.

- o See that the clack valve closes squarely, evenly, and completely. If it does not, the clack spring may have been bent somehow, and will have to be straightened.

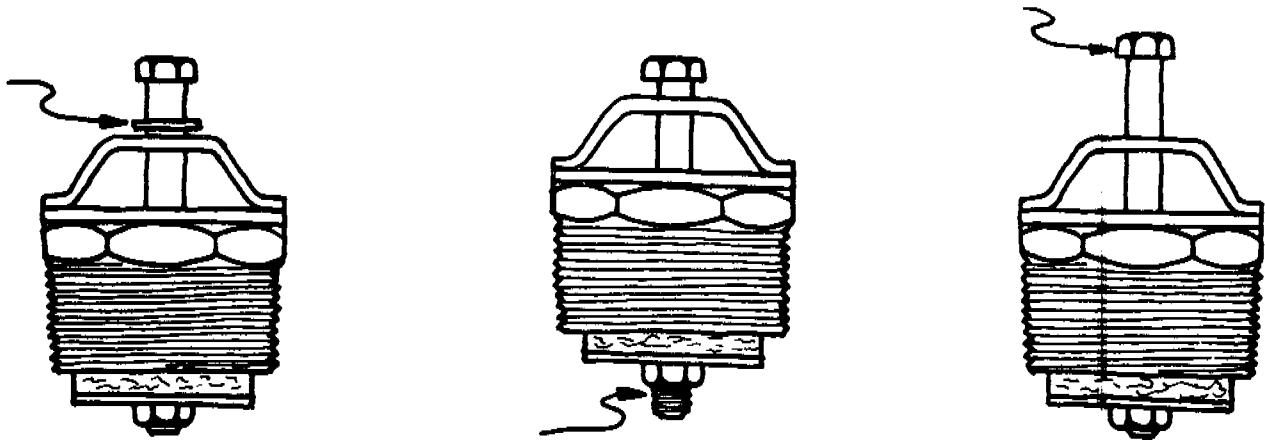
- o See that the clack valve does not rub on the front, side, or back of the valve body inside.
- o Check for trash in the ram, delivery valve, or snifter hole.
- o Check to see that the air dome is not filled with water. It must not be full of water or the ram will knock loudly and may break something. The snifter lets in a bit of air between each of the strokes and this keeps the dome full of compressed air.
- o Check rubber clack and delivery valve for wear or looseness.
- o If drive water is in short supply, speed up the stroke by loosening the spring tension and shorten the stroke by lowering the stroke adjusting bolt. More water is delivered by a faster stroke and continuous running than a slower stroke. (See also p. 46.)



- o Check for leaks in the drive pipe. If air bubbles come out of the drive pipe after it has been stopped for a while it is leaking air. Air in the drive pipe causes the ram action to become inefficient.
- o Clean the ram once in a while. Protect it from outside injury and inquisitive children.
- o When the ram runs out of water, it will usually stop, remain open, and lose all the water available until it is closed again. You can listen at the storage tank to hear if it is still running; and, if it isn't, go to the ram and close the drive pipe until water has accumulated in the cistern.

- o Long delivery distances require a larger pipe to reduce friction(known as pressure drop).
- o A cistern (container) is a good thing to have at the top of the drive pipe to let dirt in the water settle. The outlet from the cistern to the ram should be a foot or so above the bottom to allow room for dirt to settle. A cleaning drain in the bottom of the cistern is a good feature. The cistern should be cleaned periodically.

The actual delivery rate can be changed somewhat by varying this stroke. This can be done either by:



- (1) adding or removing washers
- (2) moving the valve up and down along the threaded portion of the bolt
- (3) using a longer or shorter bolt

NOTE: Generally, given a site with a specific drive and delivery heads, the rate at which water is delivered and the rate at which water is used by the pump are both increased by increasing the valve stroke. They will both decrease by decreasing the valve stroke. However, the rate at which water is delivered by this pump cannot be increased indefinitely by increasing the valve stroke. With increasing the valve stroke, the pump's efficiency decreases and the rate at which water is delivered reaches a maximum and then decreases.

V. FURTHER INFORMATION RESOURCES

- o P. D. Stevens-Guille. "How to Make and Install a Low-Cost Water Ram Pump for Domestic and Irrigation Use," Department of Mechanical Engineering, University of Cape Town, August 1977. Instructions for building a hydraulic ram pump from pipe fittings and valves. Contains some information on how it works and how to set it up. Includes parts of lists, diagrams, and tables. Not comprehensive, but clearly written.
- o W. H. Sheldon. "The Hydraulic Ram," Michigan State College Extension Service, Michigan State College of Agriculture and Applied Science, Michigan State University, East Lansing, Michigan 48823 USA. Bulletin 171, July 1943. Has some basic information on ram operation and installation. some good illustrations of different methods of installing hydraulic ram systems. Also list of information required for installing a ram.
- o T. G. Behrends. "The Farm Water Supply Part II. The Use of the Hydraulic Ram," Cornell University Extension Bulletin 145, June 1926. New York State College of Agriculture, Cornell University, Ithaca, New York USA. A fairly comprehensive, well-illustrated booklet. Includes basic information as well as sections on storage tanks, different types of rams, etc. Although rather dated, this is one of the most useful booklets on the subject.

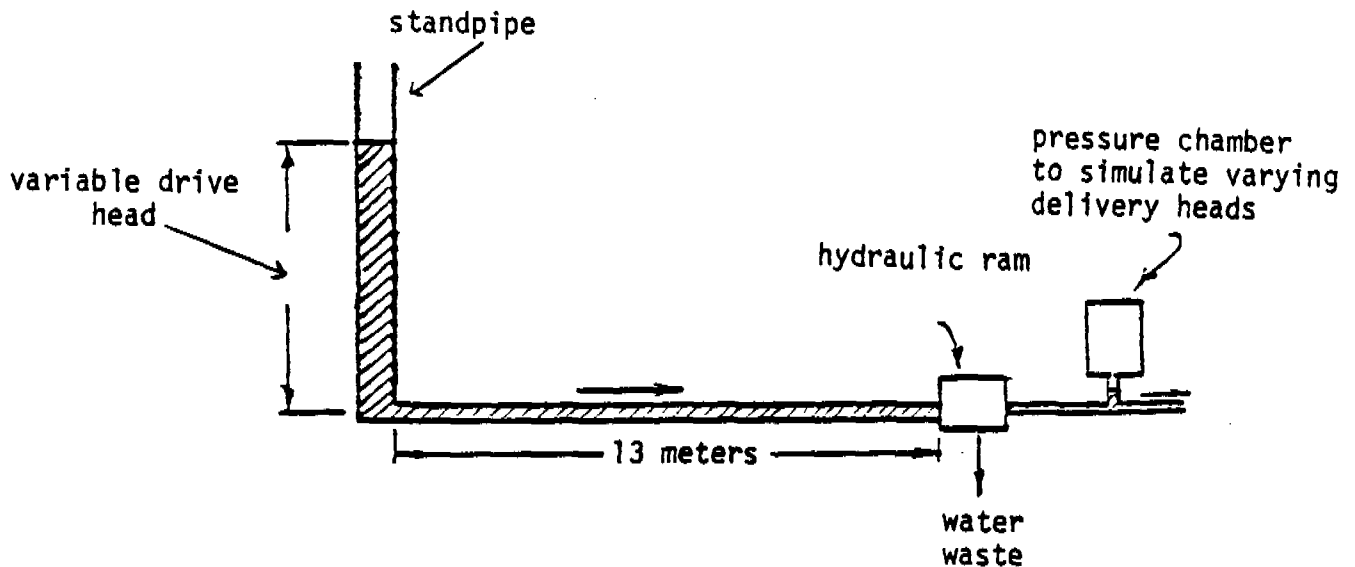
APPENDIX I

ADDITIONAL PERFORMANCE CONSIDERATIONS

The following pages provide guidelines on the ram and its performance. Several of the suggestions for design changes, such as those relating to the possible use of plastic pipe and to work with higher heads, should be read carefully before construction begins.

TEST INSTALLATION

This hydraulic ram was installed for testing as illustrated below. This level of water in the standpipe was maintained at the desired drive head. The drive pipe consisted of about two lengths of galvanized iron pipe leading to the pump. Variable delivery heads were simulated by imposing a known pressure (corresponding to the desired delivery head) on the output.

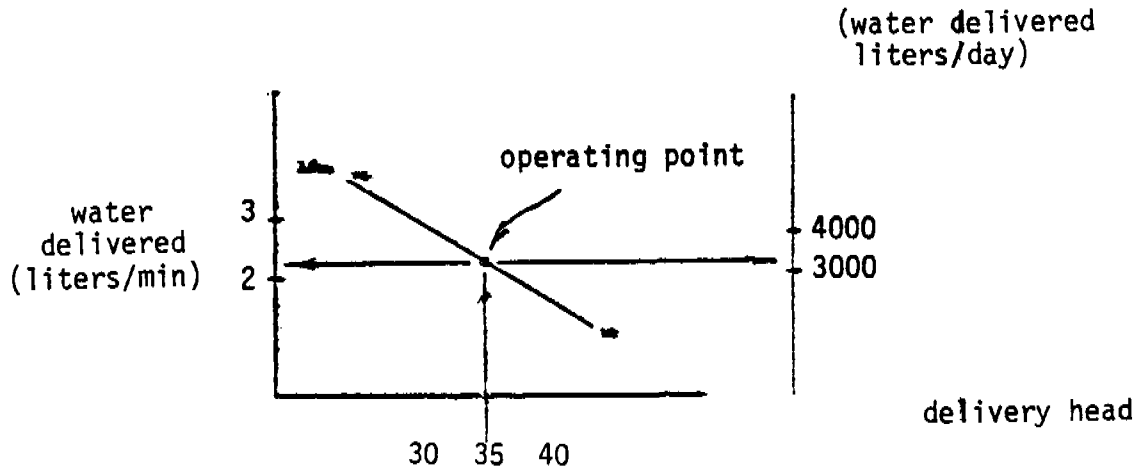


PERFORMANCE DATA

The data presented in the graph on the following page are for the ram operating with a 10mm valve stroke. This valve stroke is the distance the waste valve is permitted to move up and down. It can easily be adjusted either to increase or to decrease the rate at which water is used and the rate at which water is delivered by the pump from the values from the graph. Adjustment of the valve stroke is explained on page 36.

HOW TO USE THE GRAPH

Suppose that a ram with a 1-1/2" drive pipe is to be located so that the drive head down to the pump is 3.0 meters and the water has to be pumped up to a height of 35 meters above the pump. (Note that the actual length of the delivery pipe may be much longer than 35 meters.)

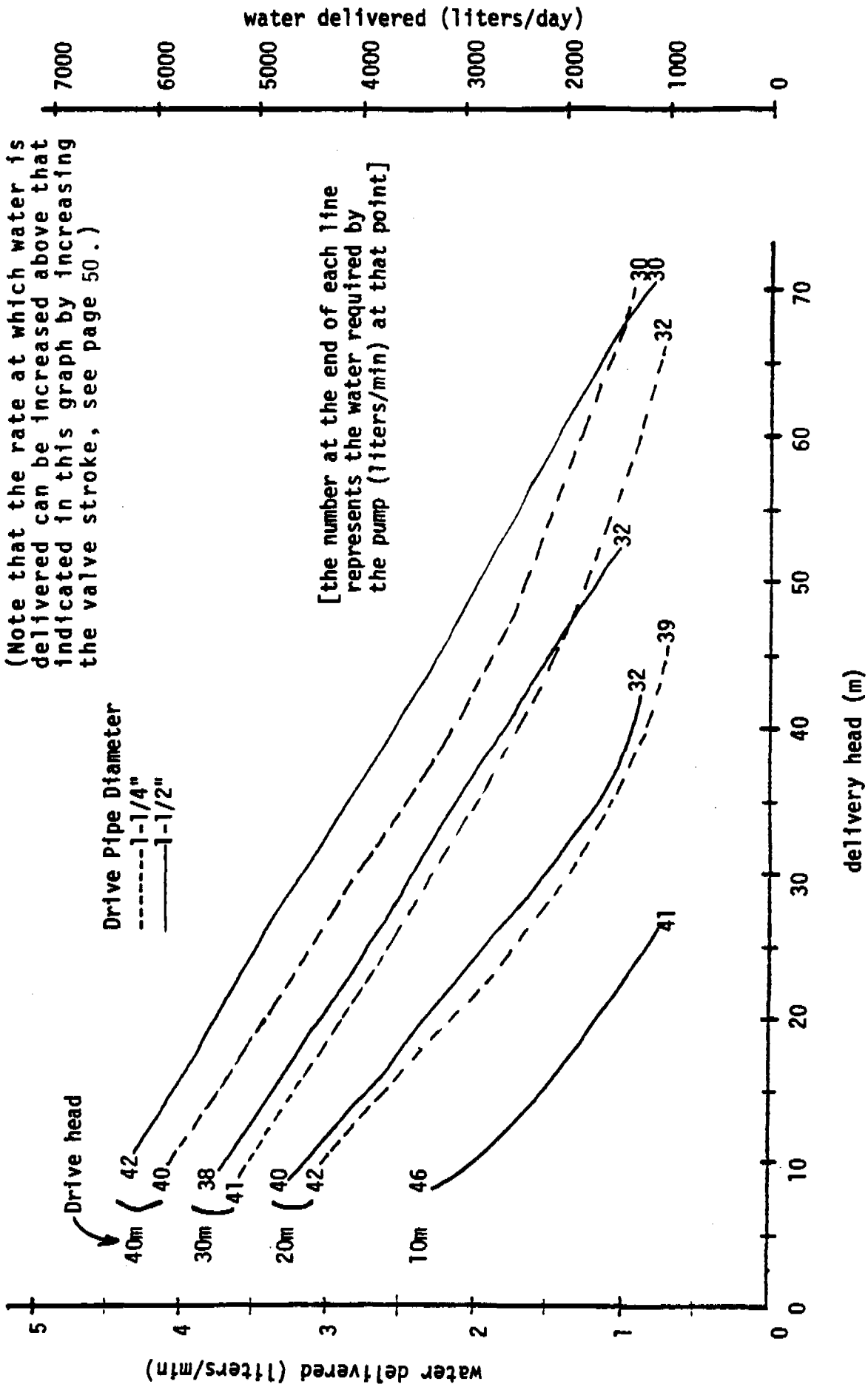


- o Find the delivery head along the bottom of the graph.
- o Move straight up until the appropriate curve for a drive head of 3.0 meters is reached. This locates the operating point.
- o To determine the delivery rate, read the scale directly to the left (about 2.2 liters/minute) or to the right (about 3,200 liters/day).
- o To obtain an estimate of how much water will be used by the pump, note the position of the operating point between the two numbers at the end points of the curve and interpolate (about 35 liters/minute).

RAM OUTPUT

with the valve stroke set at 10mm

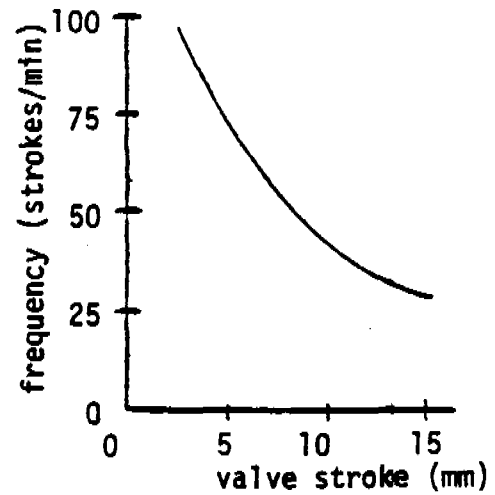
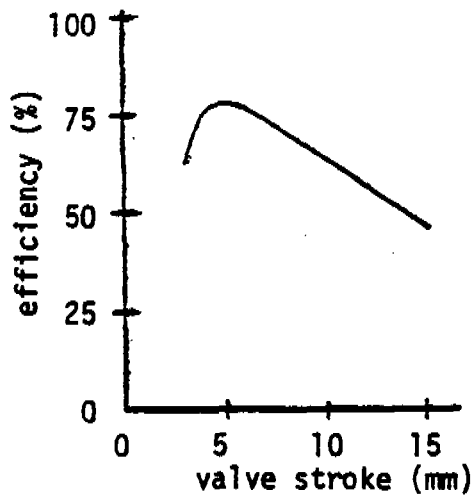
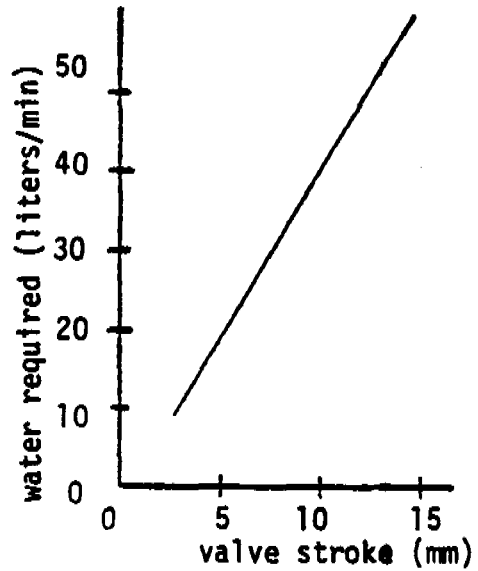
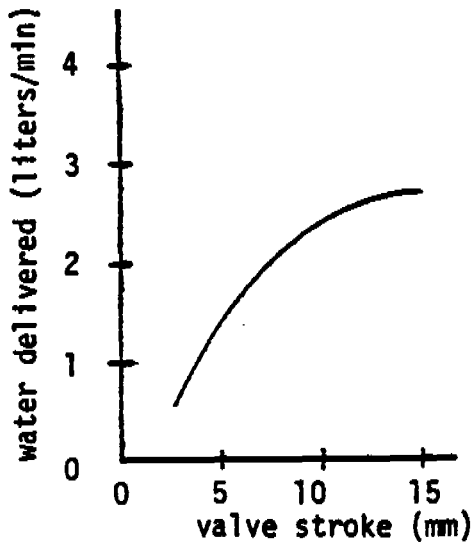
(Note that the rate at which water is delivered can be increased above that indicated in this graph by increasing the valve stroke, see page 50.)



The exact drive and delivery rates for another installation depend on the length and diameter of the drive pipe and delivery pipe. A good estimate of the pump's performance should still be available from the values of the graph.

The graphs below are included to illustrate a typical variation of drive and delivery rates, efficiency, and frequency (strokes per minute) with valve stroke.

Drive Head = 2.0m
 Delivery Head = 20m



EFFECTS OF OTHER VARIABLES

Size of Air Chamber

The half-meter length of 2" pipe used as the air chamber for this ram seems to be perfectly adequate for the flows delivered by this pump. Increasing the size of the air chamber seems to have negligible effect on its performance.

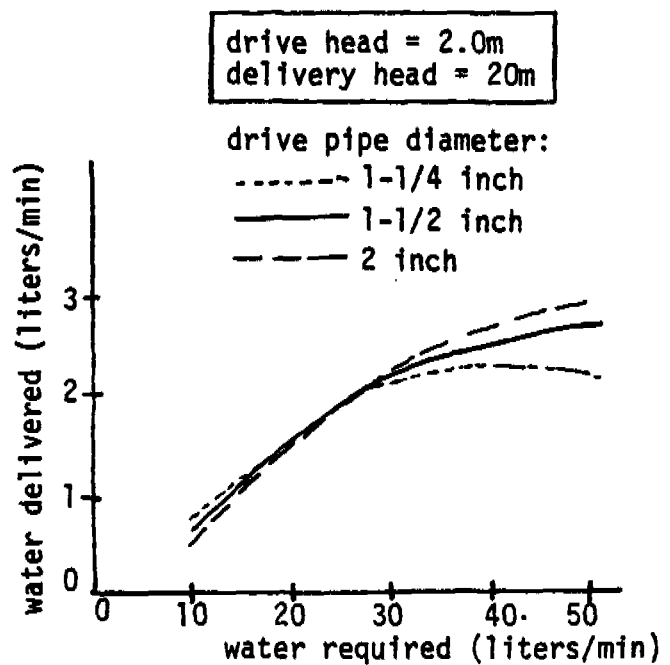
Drive Pipe Diameter

For cost and weight efficiency, the smaller the diameter of the drive pipe, the better. However, drive pipe diameter also affects the ram's performance. A drive pipe with too small a diameter restricts the flow of water to the pump with the result that the pump delivers less water.

The graph below illustrates the effect of the diameter of the drive pipe at the test installation on the rate at which water is delivered by the pump. A large diameter pipe proves an advantage only in cases where larger flows are desired.

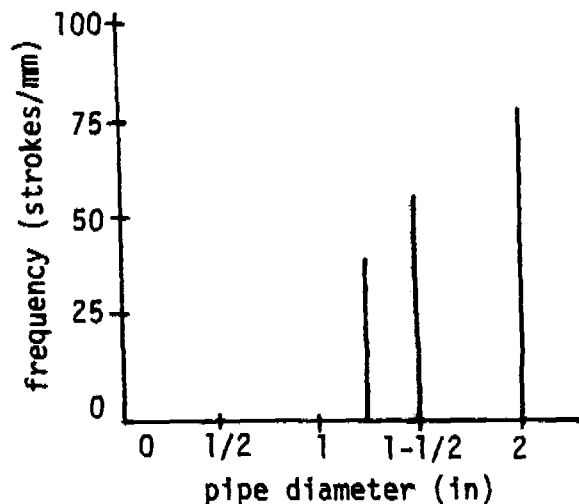
The length of the drive pipe also affects the ram's performance. If a much longer drive pipe is used, its diameter must also be larger to keep losses down.

When low drive heads are used (about a meter or less), friction losses in the drive pipe become more important since there is less head available to overcome them. A larger diameter drive pipe is then necessary to reduce losses and permit sufficient water to reach the pump. (The reason there is no curve for a drive head of 10 meters on the graph on page 41, when using a 1-1/4" drive pipe, is that there is insufficient water flowing through to the pump to operate it. This problem is overcome by using a larger diameter drive pipe.)



Pipe diameter also has an effect on the valve stroke frequency as is illustrated by the graph at the right. Higher valve stroke frequencies are encountered with larger diameter drive pipes. This may imply a faster wear of the valve shaft and seating rubber (this is probably of little consequence if the parts can easily be replaced).

drive head = 2.0m
 delivery head = 20m
 water delivered = 2.0 liters/min



Mounting of the Ram

It is important to mount the ram securely so that it will remain in its proper operating position in spite of tampering, heavy rains, floods, etc.

Mass of the Waste Valve Plunger

Increasing the mass of the waste valve plunger by using larger and therefore heavier components has the same effect on the pump's performance as increasing the valve stroke, i.e., it reduces the operating frequency of the ram and generally increases both the quantity of water used by the ram and the quantity delivered by the ram. But for low drive heads or for a drive pipe of too small a diameter, too heavy a plunger might prevent the operation of the pump altogether.

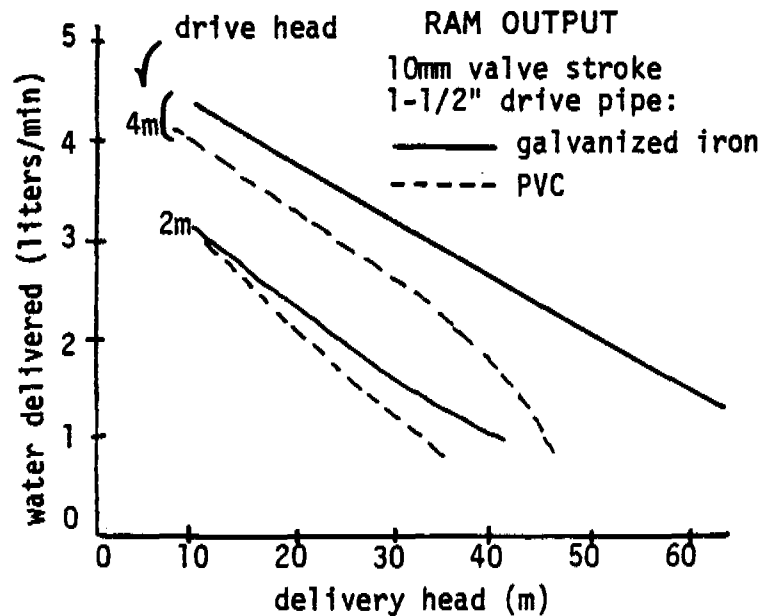
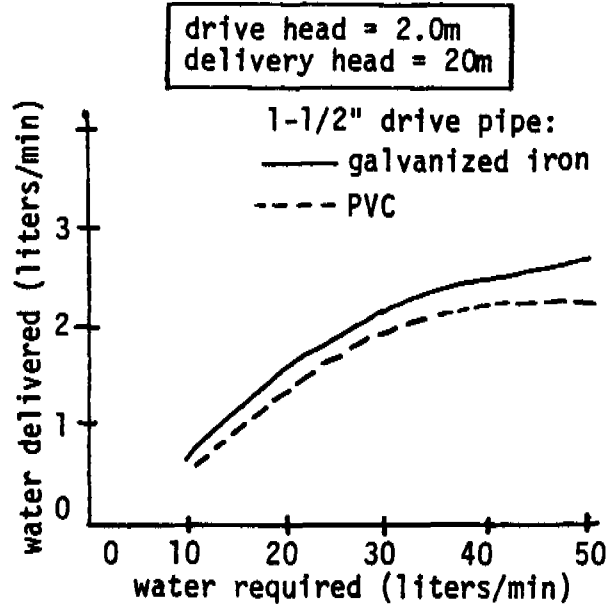
If operating frequencies prove too high (as might be the case with drive heads much larger than 4 meters), the quantity of water delivered by the ram would be small. Though increasing the mass of the plunger would decrease the frequency and increase the rate at which water is delivered, this might possibly reduce the life of the valve because of the increased forces as the valve closes repeatedly. For such operating conditions, use of a spring, as explained later, would be a better solution.

Use of PVC Drive Pipe

Several trial runs were made using a 1-1/2"-diameter, class 12 rigid PVC pressure pipe (pressure rated to a head of 120 meters). Though it is known that the commonly used galvanized iron pipe is more efficient than PVC, it was felt that use of PVC could prove advantageous on occasions when ram components have to be carried on foot to remote areas.

From testing, it is apparent that the PVC drive pipe is slightly less efficient. The graphs at the right compare the pump's performance using 1-1/2"-diameter drive pipes of galvanized iron and PVC. Note that in the second graph, the valve stroke is set at 10mm and that it is possible to increase somewhat the rate at which water is delivered by increasing this valve stroke.

These data imply that rigid pressure PVC pipe could be used for a drive pipe if necessary. However, since durability tests have not been carried out with the PVC drive pipe, it is difficult to state here how much, if any, the life of the pipe would be reduced by the operation of the ram.



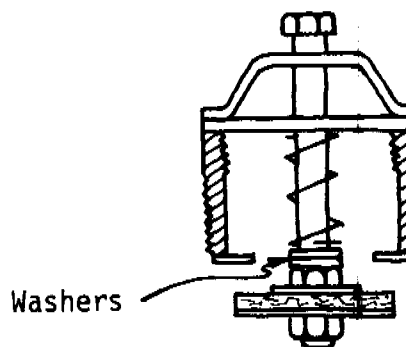
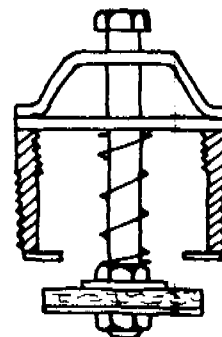
If PVC is used, it must be covered, with earth or otherwise, both to lend some rigidity to the pipe and to protect it from the sunlight, which tends to reduce its life considerably.

NOTES

Spring Loading the Waste Valve

If the ram is to be used for drive heads over 4 meters, operating frequencies become high and the rate at which water is delivered consequently decreases. To increase this rate, a square ground square ground compression spring can be inserted as shown. This spring should be made of stainless steel or other rust-free alloy. This spring will keep the valve open longer, increase the quantity of water used by the pump, and increase, to a point, the quantity of water delivered. If it is desired to increase the tension, washers need simply be used as illustrated in the second drawing at the right.

The spring should have a spring constant of about 10 newtons/cm or 5 pounds/inch. Such springs can be custom-made at low cost by spring-makers if the spring constant, the length, and the diameter of the spring are specified.



Size of the Snifter Valve

If the snifter valve is too small, the air chamber will fill with water and the ram will pump with a loud, metallic sound. If this should happen, either drill the hole of the snifter valve slightly larger or use a nail or cotter pin with a slightly smaller diameter.

If the snifter valve hole is too large, the ram will operate less efficiently.

APPENDIX II

CONVERSION TABLES

Units of Length

1 Mile	= 1760 Yards	= 5280 Feet
1 Kilometer	= 1000 Meters	= 0.6214 Mile
1 Mile	= 1.607 Kilometers	
1 Foot	= 0.3048 Meter	
1 Meter	= 3.2808 Feet	= 39.37 Inches
1 Inch	= 2.54 Centimeters	
1 Centimeter	= 0.3937 Inch	

Units of Area

1 Square Mile	= 640 Acres	= 2.5899 Sq. Kilometers
1 Square Kilometer	= 1,000,000 Sq. Meters	= 0.3861 Square Mile
1 Acre	= 43,560 Square Feet	
1 Square Foot	= 144 Square Inches	= 0.0929 Square Meter
1 Square Inch	= 6.452 Square Centimeters	
1 Square Meter	= 10.764 Square Feet	
1 Square Centimeter	= 0.155 Square Inch	

Units of Volume

1.0 Cubic Foot	= 1728 Cubic Inches	= 7.48 U.S. Gallons
1.0 British Imperial Gallon	= 1.2 U.S. Gallon	
1.0 Cubic Meter	= 35.314 Cubic Feet	= 264.2 U.S. Gallons
1.0 Liter	= 1000 Cubic Centimeters	= 0.2642 U.S. Gallons

Units of Weight

1.0 Metric Ton	= 1000 Kilograms	= 2204.6 Pounds
1.0 Kilogram	= 1000 Grams	= 2.2046 Pounds
1.0 Short Ton	= 2000 Pounds	= 2.2046 Pounds

Units of Pressure

1.0 Pounds per square inch*	= 144 Pounds per square foot
1.0 Pounds per square inch*	= 27.7 Inches of Water*
1.0 Pounds per square inch*	= 2.31 Feet of Water*
1.0 Pounds per square inch*	= 2.042 Inches of Mercury*
1.0 Atmosphere	= 14.7 Pounds per square inch (PSI)
1.0 Atmosphere	= 33.95 Feet of Water*
1.0 Foot of Water = 0.433 PSI	= 62.355 Pounds per square foot
1.0 Kilogram per square centimeter	= 14.223 Pounds per square inch
1.0 Pounds per square inch*	= 0.0703 kilogram per square centimeter

*at 62 F or 16.6 C

Units of Power

1.0 Horsepower (English)	= 746 Watt = 0.746 Kilowatt (kw)
1.0 Horsepower (English)	= 550 Foot pounds per second
1.0 Horsepower (English)	= 33,000 Foot pounds per minute
1.0 Kilowatt (KW) = 1000 Watt	= 1.34 Horsepower (HP) English
1.0 Horsepower (English)	= 1.0139 Metric Horsepower (cheval-vapeur)
1.0 Metric Horsepower	= 75 Meter X Kilogram/second
1.0 Metric Horsepower	= 0.736 Kilowatt = 736 Watt

APPENDIX III

DECISION-MAKING WORK SHEET

If you are using this as a guideline for using the Hydraulic Ram in a development effort, collect as much information as possible and if you need assistance with the project, write VITA. A report on your experiences and the uses of this handbook will help VITA both improve the book and aid other similar efforts.

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CURRENT USE AND AVAILABILITY

- o Describe current agricultural and domestic practices that rely on water at some point.
- o What water sources are available? Note whether sources are small but fast-flowing, large but slow-flowing, etc.
- o Are there dams already built in the area? If so, what has been the effect of the damming? Note particularly are there evidence having to do with the amount of sediment carried by the water—too much sediment can create a swamp.
- o If water resources are not now harnessed, what seem to be the limiting factors? Does the cost of the effort seem prohibitive? Does the lack of knowledge of water power potential limit its use?

NEEDS AND RESOURCES

- o How is the problem identified? Who sees it as a problem?
- o Has any local person expressed the need for a water lifting or pumping technology? If so, can someone be found to help the technology introduction process? Are there local officials who could be involved and tapped as resources?
- o How will you get the community involved with the decision of which technology is appropriate for them?

- o Based on current agricultural and domestic practices, what seem to be the areas of greatest need? Is irrigation water needed some distance from the water supply? Are stock watering tanks or ponds required?
- o Are tools and materials for constructing the ram and its associated equipment available locally? Are local skills sufficient? Some applications demand a rather high degree of construction skill, although less maintenance skill is required.
- o Is there a possibility of providing a basis for small business enterprise?
- o What kinds of skills are available locally to assist with construction and maintenance? How much skill is necessary for construction and maintenance? Do you need to train people? Can you meet the following needs?
 - o Some aspects of the project require someone with experience in surveying.
 - o Estimated labor time for full-time workers is:
 - 8 hours skilled labor
 - 40 hours unskilled labor
 - o If this is a part-time project, adjust the times accordingly.
- o Do a cost estimate of labor, parts, and materials needed.
- o How will the project be financed?
- o What is your schedule? Are you aware of holidays and planting or harvesting seasons that may affect timing?
- o How will you spread information on and promote use of the technology?

IDENTIFY THE APPROPRIATE TECHNOLOGY

- o Is more than one water supply technology applicable? Weight the costs of various technologies--relative to each other--fully, in terms of labor, skill required, materials, installation, and operation costs. While one technology may appear to be much more expensive in the beginning, it could work, out to be less expensive after all costs are weighed.

- o Are there choices to be made between, say, a ram and a windmill? Again, weigh all the costs: feasibility, economics of tools and labor, operation and maintenance, social and cultural dilemmas.
- o Are there local skilled resources to guide the introduction of this technology? Dam building, and irrigation equipment, for example, should be considered carefully before beginning work.
- o Could a technology such as the hydraulic ram be usefully manufactured and distributed locally?
- o What changes would the proposed technology make on the economic, social, and cultural structure of the area?
- o Are there environmental consequences to the use of this technology? What are they?

FINAL DECISION

- o How was the final decision reached to go ahead with this technology? Or, why was it decided against?

APPENDIX IV

RECORD-KEEPING WORK SHEET

CONSTRUCTION

Photographs of the construction process, as well as the finished result, are helpful. They add interest and detail that might be overlooked in the narrative.

A report on the construction process will include much very specific information. This kind of detail can often be monitored most easily in charts (see below). Some other things to record include:

- o Specification of materials used in construction.
- o Adaptations or changes made in design to fit local conditions.
- o Equipment costs.
- o Time spent in construction--include volunteer time as well as paid labor; full- or part-time.
- o Problems--labor shortage, work shortage, training difficulties, materials shortage, terrain, transport, vandalism.

Labor Account

Name	Job	Hours Worked							Total	Rate?	Pay?
		M	T	W	T	F	S	S			
1											
2											
3											
4											
5											
Totals											

Materials Account

Item	Cost	Reason Replaced	Date	Comments
1				
2				
3				
4				
5				
Totals (by week or month)				

MAINTENANCE

Maintenance records enable keeping track of where breakdowns occur most frequently and may suggest areas for improvement or strengthening weakness in the design. Furthermore, these records will give a good idea of how well the project is working out by accurately recording how much of the time it's working and how often it breaks down. Routine maintenance records should be kept for a minimum of six months to one year after the project goes into operation.

Labor Account

Name	Hours & Date	Repair Done	Also down time Rate?	Pay?
1				
2				
3				
4				
5				
Totals (by week or month)				

Materials Account

Item	Cost Per Item	# Items	Total Costs
1			
2			
3			
4			
5			
Total Costs			

OPERATION

Keep log of operations for at least the first six weeks, then periodically for several days every few months. This log will vary with the technology, but should include full requirements, outputs, duration of operation, training of operators, etc. Include special problems that may come up--a damper that won't close, gear that won't catch, procedures that don't seem to make sense to workers.

SPECIAL COSTS

This category includes damage caused by weather, natural disasters, vandalism, etc. Pattern the records after the routine maintenance records. Describe for each separate incident:

- o Cause and extent of damage.
- o Labor costs of repair (like maintenance account).
- o Material costs of repair (like maintenance account).
- o Measures taken to prevent recurrence.

ABOUT VITA

Volunteers in Technical Assistance (VITA) is a private, non-profit, international development organization. It makes available to individuals and groups in developing countries a variety of information and technical resources aimed at fostering self-sufficiency--needs assessment and program development support; by-mail and on-site consulting services; information systems training.

VITA promotes the use of appropriate small-scale technologies, especially in the area of renewable energy. VITA's extensive documentation center and worldwide roster of volunteer technical inquiries each year. It also publishes a quarterly newsletter and a variety of technical manuals and bulletins.

VITA's documentation center is the storehouse for over 40,000 documents related almost exclusively to small- and medium- scale technologies in subjects from agriculture to wind power. This wealth of information has been gathered for almost 25 years as VITA has worked to answer inquiries for technical information from people in the developing world. Many of the documents contained in the Center were developed by VITA's network of technical experts in response to specific inquiries; much of the information is not available elsewhere. For this reason, VITA wishes to make this information available to the public.

For more information, contact VITA, 1815 North Lynn Street, Suite 200, Arlington, Virginia 22209-2079, USA.



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