

# [Design and fabrication of a hydraulic ram pump engineering essay](https://assignbuster.com/design-and-fabrication-of-a-hydraulic-ram-pump-engineering-essay/)

## Abstract

The Design and Fabrication of a Hydraulic Ram Pump (Hydram) is undertaken. It is meant to lift water from a depth of 5 feet below the surface with no other external energy source required. The overall cost of fabrication of this hydram shows that the pump is relatively cheaper than the existing pumps.

## Chapter 1

## INTRODUCTION

1. 1 Historical Background:

The first hydraulic ram pump was invented by John Whitehurst in England in 1772. This pump was non-self-acting. In 1796 a Frenchman, Joseph Michael Montgolfier, had added a valve, which made the device self-acting.

In 1809, the first American patent was issued to J. Cerneau and S. S. Hallet . Prior to the 1840's most ram pumps in America were imported from Europe, but in 1843, H. H. Strawbridge of Louisiana put an American made model into use.

Rural communities in America found the features of the pump very attractive. Articles in magazines brought further recognition and understanding of the ram and its possibilities. A detailed book on the ram, published in 1842, was in its 16th edition by 1870.

In 1879, The People's Cyclopedia included the hydraulic ram among the 55 most important inventions in the history of mankind. It defined the hydraulic ram as: " A simple and conveniently applied mechanism by which the weight of falling water can be made available for raising a portion of itself to a considerable height."

Patents on the ram abounded in the 1840's and 1850's, but after 1858 none were secured until 1870 when another burst of interest saw four patents awarded in 3 years.

Cost was a major factor in the growth of ram use. Not only were the machines inexpensive to buy, but they also were simple to install and were almost maintenance-free.

For more than 100 years rams were major movers of water to homes, farms, industries, railroads and towns. They contributed to improved crop production, introduction of extensive landscaping and, perhaps most importantly, to health and sanitation.

With the advent of electrical pumps, interest in the hydraulic rams became dormant. Ram pumps were allowed to rust in the stream until expensive parts, fossil fuel shortages, and environmental concerns brought back to the public's mind the need for a pump that is

inexpensive, requires almost no repairs or maintenance is self-acting, and can raise water to a considerable height vertically. Ram pumps are again becoming increasing popular in both developing and developed countries. They are being operated successfully worldwide.

800px-Roscheiderhof-lambachpumpe

Figure An early Hydraulic Ram Pump

1. 2 Hydraulic Ram Pump:

The hydram uses energy of falling water to lift water. There is no separate motor or mechanism that operates the pump. In real life application water is diverted from a water source and made to flow in a straight and sloping pipe, called the drive pipe. The falling action of water causes a gain in its kinetic energy. The gain in energy increases with increase in velocity of water.

The hydram is located at the bottom of the drive pipe. The water flows through its main valve. When this valve closes water is brought to a sudden stop. The kinetic energy gained by water while falling down is converted to pressure energy. This is the energy which all pumps use to lift water. Some amount of the water is pushed into the delivery pipe due to this pressure and delivered where it required is.

Essentially, a hydram is an automatic pumping device which utilizes a small fall of water to lift a fraction of the supply flow to a much greater height; ie it uses a larger flow of water falling through a small head to lift a small flow of water through a higher head.

All hydrams need a large amount of falling water to provide the energy utilized by them. This is why they can only be used when the source is very large compared to the amount of water required to be pumped. Usually, 5 to 10% of the water from the drive pipe is pumped. The rest goes back to the main water source

1. 3 Advantages and Application:

The hydraulic ram pump can be used with great effectiveness in communities which are located at a higher elevation than their source of water. The hydram pump uses the power of falling water to pump a small portion of that water uphill. It requires absolutely no fuel or electricity and operate only water pressure.

There are only two moving parts which are lubricated by the water itself thus making a hydram a very simple device. Hydrams can be used in many diverse situations for example for domestic purposes or irrigation

The source of water supply to the hydram could be a stream, a spring, an irrigation canal, an artesian well, or even an existing gravity flow water system. In the mountainous topography, there are many places where, if a hydram were installed, much time spent hauling water could be used for other purposes.

Formerly unproductive or unused land could be made suitable for cultivation and yields will be increased in existing fields. Wide scale usage can benefit many people.

Because this simple pump works 24 hours per day, for many years and requires little attention, it is suitable for areas where people have little technical expertise. Because hydram installations are inexpensive and quickly installed, they are well suited for remote areas where there are extreme transportation difficulties, as well as for sparsely populated villages which often make gravity flow water supply system financially unfeasible. The ability to incorporate a hydram in an existing gravity flow water supply system has also proved very useful.

1. 4 Limitations:

The use of hydrams has certain constraints associated with it. These are:

Hydrams can only be used in mountainous topography. Where there is enough elevation distance between the water source and the community to which water is to be supplied. Generally the place for pumps should not be more than 100 meters below the place where water must be delivered.

In areas which are prone to inundation, the hydram should be located so that the waste valve (a component of the pump) is always located above flood water level, as the pump will cease to function if the waste valve becomes submerged.

The hydrams pump only a small portion of the water which is supplied to them therefore the source supplying hydram with water should be much larger than the amount of water which is desired to be delivered.

The water source should not be seasonal and be present year-round if continuous supply of water is desired.

Although hydrams are a very cheap technology compared to the more common used electric pumps they can have a high capital cost in relation to other technologies.

Hydrams are limited to small scale applications, usually up to 1kW.

A willingness for system care and maintenance to be provided by the community that uses the water.

## Chapter 2

## WORKING PRINCPLE

## 2. 1 Water hammer.

Water hammer (or, more generally, fluid hammer) is a pressure surge or wave resulting when a fluid (usually a liquid but sometimes also a gas) in motion is forced to stop or change direction suddenly. Water hammer commonly occurs when a valve is closed suddenly at an end of a pipeline system, and a pressure wave propagates in the pipe. If the pipe is suddenly closed at the outlet (downstream), the mass of water before the closure is still moving forward with some velocity, building up a high pressure.

When a valve in a pipe is closed, the water downstream of the valve will attempt to continue flowing, creating a vacuum that may cause the pipe to collapse or implode. Here water hammer has a negative impact. Nevertheless, the same phenomenon is used to life water in a hydram

There are two main Physics concepts.

2. 2 Momentum and Impulse.

When an object is moving at some velocity, v, it has a momentum equal to its mass times its velocity, m\*v . In our system, when the waste valve closes, the velocity of the water goes quickly to zero. This change in velocity causes a change in momentum equal to m\*Î” v. If you divide the change in momentum, also known as impulse, by the amount of time that has elapsed during the change in momentum, you get:

Impulse = m \* Î” v / Î” t

Noting that force = m\*a, impulse / time equals a force. This force is a constant that can be used to determine the amount of work that can be done on the system.

2. 3 Conservation of Mechanical Energy.

During any type of physical interaction, the energy of the system remains constant. The only type of energy that is applicable here is mechanical energy. Mechanical energy is defined as the sum of kinetic energy and potential energy.

To find the theoretical maximum height the pump can pump to, the final mechanical energy should be all potential energy and no kinetic energy. Therefore we take the equation

1/2 \* m \* v2 + m \* g \* hi = m \* g \* hf

Water enters through the inlet pipe and exits through the waste valve. As it moves through the waste valve it builds up speed / momentum / kinetic energy. When the water gets going fast enough, it pushes the plunger on the waste valve closed. The moment the waste valve closes, the water creates an impulse and pushes up through the one way valve and out towards its destination. Once this built up pressure is released, the one way valve closes and the waste valve opens, starting a new cycle

## Chapter 3

## OPERATION SEQUENCE OF HYDRAM

The hydraulic ram pump operates in a cycle. The time each cycle takes to complete is very less, often one second. Each cycle of the pump can be divided in four phases. These are explained as follows

3. 1 Acceleration:

Water enters the hydram through the drive pipe and fills the pump body and starts flowing out of the waste or impulse valve. The water flowing past this valve tries to close it. The flow accelerates. During this time the delivery or check valve remains closed and no water is entering the delivery pipe.

## A

Drive Pipe

## B

Impulse Valve

## C

Delivery Valve

## D

Air Chamber

## E

Delivery Pipe

1

Figure 3. 1 Acceleration

3. 2 Compression:

The velocity and pressure of the column of water exiting from the impulse valve is overcome and the impulse valve closes. This creates a high pressure, compressing the water inside the pump body. This rise in pressure is called 'water hammer'. The effect of water hammer is to open the check valve.

## A

Drive Pipe

## B

Impulse Valve

## C

Delivery Valve

## D

Air Chamber

## E

Delivery Pipe

2

Figure 3. 2 Compression

## 3. 3 Delivery:

The water starts flowing through the check valve in the air chamber. Air trapped in the air chamber is simultaneously compressed to a pressure exceeding the delivery pressure. Once the pressure in the air chamber exceeds the static delivery head due to reexpansion, water is forced up the delivery pipe. The pressure in the pump body drops quickly to equal the pressure in the air chamber thus closing the delivery valve.

## A

Drive Pipe

## B

Impulse Valve

## C

Delivery Valve

## D

Air Chamber

## E

Delivery Pipe

3

Figure 3. 3 Delivery

3. 4 Recoil:

After the delivery valve has closed, a shockwave is created and causes the water to flow back up the drive pipe. This results in a drop of pressure low enough for the impulse valve to open. Flow through drive pipe starts. The air volume in the air chamber stabilizes by this point and the flow from the delivery pipe stops.

## A

Drive Pipe

## B

Impulse Valve

## C

Delivery Valve

## D

Air Chamber

## E

Delivery Pipe

4

Figure 3. 4 Recoil

## Chapter 4

## DESIGN

## 4. 1 Designs

## Design 1

Hydraulic\_Ram\_Pump\_p04a

Figure 4. 1 Design - 01

They tend to be made from heavy castings and have been known to function reliably for 50 years or more. However, although a number of such design is still manufactured in Europe and the USA in small numbers, they are relatively expensive, although generally speaking the drive-pipe, delivery pipe and civil workings will be significantly more expensive than even the heaviest types of hydram.

## Design 2

Capture

Figure 4. 2 Design - 02

This design is very low in cost but the pipes in the end cost considerably more than the

hydram. They are not always as reliable as previous design, but are usually acceptably

reliable with failures separated by many months rather than days, and are easy to repair when they fail.

Table Comparison between Designs

## Features

## Design 1

## Design 2

Fabrication

Difficult

Medium

Weight

Heavy

Not too much heavy

Reliability

Yes

To some extent

Fabrication cost

High

Low

Maintenance required

Yes

Yes

Complexity

High

low

## Weighting matrix of designs

Not Important

Important

Table Weighting matrix of Designs

## Features

## A

## B

## C

## D

## E

## F

## TOTAL

## WEIGHT

A

## -

1

1

1

0

1

4

0. 21

B

1

## -

0

1

1

1

4

0. 21

C

0

0

## -

1

1

0

2

0. 1

D

1

1

1

## -

0

1

4

0. 21

E

0

0

0

0

## -

1

1

0. 06

F

1

1

1

1

0

## -

4

0. 21

âˆ‘= 19

âˆ‘= 1

A- Ease of Fabrication

B- Weight

C- Reliable

D- Fabrication cost

E- Maintenance required

F- Complexity

## Rating matrix of Design

0 - Does not meet requirement

1 - Meets requirement partially

2 - Fully meets requirement

3 - Significantly above requirement

Table Rating matrix of Designs

## Features

## Weighting

## Design

## Rating

## I

## II

## I

## II

A

0. 21

1

3

0. 21

0. 63

B

0. 21

1

3

0. 21

0. 63

C

0. 1

3

1

0. 3

0. 1

D

0. 21

2

3

0. 42

0. 63

E

0. 06

1

1

0. 06

0. 06

F

0. 21

1

2

0. 21

0. 42

âˆ‘= 1. 41

âˆ‘= 2. 47

A- Ease of Fabrication

B- Weight

C- Reliable

D- Fabrication cost

E- Maintenance required

F- Complexity

Considering fabrication, weight, cost, complexity design 2 is selected.

Design 2:

Capture1

## 4. 2 Parts of Hydram

Tanks

Pipes

Impulse and delivery valve

Air chamber

pump

throttling valve

rubber washers

Pipe Elbows

Pipe collar

## 4. 2. 1Tanks

We will be using three tanks

Supply tank

Waste water tank

Delivered tank

Supply tank:

The water that to be elevated will be supplied from the supply tank. A pipe with a throttling valve will be connected with it. this tank will be 5 feet from ground and have capacity of 10 gallons.

Waste water tank:

The water that comes out from the impulsive valve will go to waste water tank.

Delivered tank:

This tank would be at the height of 10-12 feet. The water from the delivery tank will go to the delivered tank.

## 4. 2. 2 Pipes

There are two pipes

Drive pipe

Delivery pipe

Drive pipe:

The water coming from the Supply tank will flow in drive pipe. The flow in this pipe can be controlled through a valve.

Delivery Pipe:

The water at the delivered tank will be delivered through delivery pipe.

Table Price list of different material for pipes

## Materials

## Length (Feet)

## 2 in. Dia Cost (Rs)

## 3 in. Dia Cost (Rs)

PVC

13

560

900

GI (M)

20

3060

4500

GI (L)

20

2600

3250

GI (EL)

20

2350

2900

CI

6

1100

1500

## Weighting matrix of pipe

0- Not Important

1- Important

Table Weighting matrix of Pipe

## Design feature

## A

## B

## C

## D

## E

## TOTAL

## WEIGHT

A

## -

0

1

0

1

2

0. 15

B

1

## -

1

1

1

4

0. 30

C

1

0

## -

1

1

3

0. 23

D

1

0

1

## -

1

3

0. 23

E

0

0

1

0

## -

1

0. 07

âˆ‘= 13

âˆ‘= 1

## Design Factors

A - Weight

B - Friction factor

C - Cost

D - Assembling

E - Resistance to corrosion

According to matrix friction factor, cost, assembling are important factors.

## Rating matrix of pipes

0 - Does not meet requirement

1 - Meets requirement partially

2 - Fully meets requirement

3 - Significantly above requirement

Table Rating matrix of Pipes

## Design Factors

## Weighting

## Concepts

## Rating

## I

## II

## III

## I

## II

## III

A

0. 15

3

2

2

0. 45

0. 3

0. 3

B

0. 30

3

3

0

0. 9

0. 9

0

C

0. 23

3

2

2

0. 69

0. 46

0. 46

D

0. 23

1

3

2

0. 23

0. 69

0. 46

E

0. 07

3

3

1

0. 21

0. 21

. 07

âˆ‘= 2. 48

âˆ‘= 2. 56

âˆ‘= 1. 29

## Concepts

I - PVC

II - GI (Galvanized iron)

III - CI (cast iron)

## Design Factors

A - Weight

B - Friction factor

C - Cost

D - Assembling

E - Resistance to corrosion

According to matrix we might use PVC or galvanized iron

## 4. 2. 3 Air chamber

Air chamber is to turn the intermittent flow through the delivery valve into steady, continuous flow up the delivery pipe. the air chamber provide the pump with a constant head to pump against and removes the inefficiencies associated with intermittent flow in the delivery pipe . The size of the air chamber therefore should ensure the conditions in the air vessel are little affected by the sudden inflow of water each cycle coming through the delivery valve.

The volume of the air in the air chamber therefore should be at least 20 and preferably nearer 50 times the expected delivery flow per cycle . An air chamber with a volume many times that of the water entering per cycle will experience little change in condition at each delivery. Pump running to low heads with large delivery flows therefore actually require air chamber than ones pumping smaller flows to high delivery head.

## 4. 2. 4 Pump

A pump will be connected with waste tank that will pump the waste water and delivers it to the supply tank so that if the water level in supply tank gets low , the waste water will be pumped to the supply tank.

## 4. 2. 5 Throttling valve

A valve will be connected with drive pipe to control the flow of water.

## 4. 2. 6 Rubber washers

When the valve will close, water should not leak out from it. In order to prevent leakage rubber washer will be used.

## 4. 2. 7 Pipe elbows & collars

To connect different pipes we will use pipe elbow. Mostly we will use 90o elbow. We will also use welding technology if required.

## Price list of different elbow of different materials

## Materials

## 2 inch 90o elbow

## 3 inch 45o elbow

## 2 inch 45o elbow

## 3 inch 45o elbow

PVC

Rs. 50

Rs. 50

Rs. 110

Rs. 110

GI (M)

Rs. 150

Rs. 170

Rs. 210

Rs. 260

GI (L)

Rs. 140

Rs. 160

Rs. 170

Rs. 210

GI (EL)

Rs. 120

Rs. 150

Rs. 165

Rs. 190

CI

Rs. 295

Rs. 295

Rs. 330

Rs. 350

Table List of different elbow of different materials

## 4. 3 Estimated Cost

## Estimated cost of hydram from different materials

MATERIALS

ESTIMATED COST (Rs.)

PVC

10000 - 15000

GI (M)

23000 - 26000

GI (L)

22000 - 24000

GI (EL)

18000 - 23000

CI

16000 - 20000

Table Estimated cost of Hydram from different materials

## List of Abbreviation

A1 cross sectional area of supply pipe

A2 cross sectional area of delivery pipe

D1 diameter of supply pipe

D2 diameter of delivery pipe

D Diameter of waste water inlet

d Diameter of waste water outlet

Dv Diameter of valve poppet

F force on waste valve poppet

H supply head

h delivered head

L1 length of supply pipe

L2 length of delivery pipe

âˆ†L Distance of waste valve poppet from the centerline of drive pipe

mass flowrate in supply pipe

mv mass of waste valve poppet

P0 pressure on supply tank

P1 pressure developed due to fall of water

P2 pressure on waste valve poppet

Q volume flowrate

V velocity of water in supply pipe

V1 velocity of water entering hydram

V2 velocity of water leaving hydram

power gained by falling water

Ï density of water = 1000 kg/m3

g acceleration of free fall = 9. 81 m/s2

Î¼ viscosity of water = 1. 12 x10-3 Ns/m2

Î³ specific weight of water = 9810 N/m3

## Abstract

The Design and Fabrication of a Hydraulic Ram Pump (Hydram) is undertaken. It is meant to lift water from a depth of 5 feet below the surface with no other external energy source required. The overall cost of fabrication of this hydram shows that the pump is relatively cheaper than the existing pumps.

Design Selection

During the selection of deign for the hydram the following were considered

Ease of Fabrication

Weight

Reliable

Fabrication cost

Maintenance required

Complexity.

The design was chosen giving priority to fabrication, weight, cost and complexity. The hydram will be fabricated from PVC.

## Chapter 5

## TECHNICAL DRAWINGS

Capture8

Figure 5.: 3D view of pump

Capture9

Figure 5. : (a) Front view of pump

Capture10

Figure 5.: Front View of Pump

Capture1

Figure 5.: 3D view of waste valveCapture2

Figure . 5 Front view of Waste valve

Capture3

Figure 5. 3D view of Delivery Valve

Capture5

Figure 5. Front view of Delivery Valve

Capture6

Figure 5. 3D view of Air ChamberCapture7

Figure 5. Front View of Air Chamber

## Chapter 6

## MATERIAL PROPERTIES AND JOINING METHODS

## 6. 1 PVC pipes and fittings

The difference between Schedule 40 and Schedule 80 PVC Pipe is the thickness of the pipe wall. Schedule 40 has a thinner wall than Schedule 80. This makes Schedule 80 PVC Pipes perfect for applications with very high water pressures.

The outside diameter of the pipes is constant for different sizes and therefore they are interchangeable (provided that they meet the correct strength requirements).

PVC Pipe Fittings differ similarly to PVC Pipe, except that they maintain the same inner diameter with the outer diameter differing based on the Schedule. This means that these are all interchangeable so long as they meet the requirements.

## Maximum Pressure

Maximum operating and required minimum bursting pressures at 73oF (23oC) for PVC pipe fittings according ASTM D1785 " Standard Specification for Poly Vinyl Chloride (PVC) Plastic Pipes Schedules 40 and 80 are indicated in the diagram and table below:

pvc pipes - bursting and operating pressure limits diagram

Figure 6. 1 Graph for the Max. Pressure

PVC

Nominal Pipe Size

(inches)

Required Minimum Burst Pressure

(psi)

Maximum Operating Pressure

(psi)

Schedule 40[1]

Schedule 80[2]

Schedule 40

Schedule 80

1/2

1910

2720

358

509

3/4

1540

2200

289

413

1

1440

2020

270

378

1 1/4

1180

1660

221

312

1 1/2

1060

1510

198

282

2

890

1290

166

243

2 1/2

870

1360

182

255

3

840

1200

158

225

Table 6.: Table Pipe sizes and Max. Pressure

## 1 psi (lb/in2) = 6, 894. 8 Pa (N/m2)

## Chemical Resistance:

PVC pressure pipe and fittings are inert to attack by a wide variety of strong acids, alkalis, salt solutions, alcohols, and many other chemicals. They are dependable in corrosive applications and impart no tastes or odors to materials carried in them. They do not react with materials carried, nor act as a catalyst.

## Strength

PVC Schedule 40 and Schedule 80 pipe and fittings are highly tough and durable products that have high-tensile and high-impact strength. They withstand high pressure for long time.

## Fire Resistance

PVC pressure pipe and fittings are self-extinguishing, and do not support combustion..

## Internal Corrosion Resistance

PVC Schedule 40 and Schedule 80 pipe and fittings resist chemical attack by most acids, alkalis, salts, and organic media such as alcohols and aliphatic hydrocarbons, within certain limits of temperature and pressure.

## External Corrosion Resistance

Industrial fumes, humidity, salt water, weather, atmospheric, or underground conditions - regardless of soil type or moisture - cannot harm PVC pressure pipe and fittings. Scratches or surface abrasions do not provide points which corrosive elements can attack.

## .

## Low Friction Loss

The smooth interior surfaces of PVC Schedule 40 and Schedule 80 pipe and fittings assure low friction loss and high flow rate. Because PVC pipe and fittings do not rust, pit, scale, or corrode, the high flow rate continues for the life of the piping system.

## Low Thermal Conductivity

PVC pressure pipe and fittings have a much lower thermal conductivity factor than metal pipe. This ensures that fluids maintain a more constant temperature. In most cases, pipe insulation is not required. [3]

## .

## 6. 2 Joining Methods

There are several techniques for the joining the pipes and fittings.

Solvent cement

Threaded connections

## Solvent cement

For joining solvent cement will be used. It is simple and reliable if procedures are followed correctly. Since variables of temperature, humidity, pipe size, time, and other conditions have a significant effect on solvent cement joints, it is important to understand the principles of each step and make adjustments for actual conditions.

A wide variety of solvent cements and primers are commercially available. Selection of specific type, grade and consistency of solvent cement should take into account pipe type, size, installation conditions and chemical compatibility of cement and system fluids.

For best results, installation should be made at temperatures between 10°C and 45°C. All joint components should be inspected for any breaking, chipping, gouging or other visible damage before

Threaded Connections

Threading reduces the effective wall thickness of pipe, pressure ratings of the pipe are reduced to one-half that of unthreaded pipe using solvent cement welded joints. By threading different parts specially the valves can be joined.

## Chapter 7

## CALCULATIONS

The calculations for the design parameter have been done after carrying out a market survey of the components and materials available. Our aim is to achieve a delivered head of 4 meters from a fall of maximum 1. 5 meters from the supply tank.

The height of the supply tank has been varied to see if the desired delivery head is achieved or not. The calculations are theoretical and the situation will be different practically. The calculations only give a rough estimate of the design parameters. Trial and error will be used to start the operation of the hydram.

The pre defined parameters include

Diameter of drive pipe = 1 inch = 0. 0254 m

Diameter of delivery pipe = 0. 5 inch = 0. 0127 m

Distance of waste valve poppet from the centerline of drive pipe = 0. 1 m

Diameter of waste water inlet = 2. 5 inch = 0. 0635 m

Diameter of waste water outlet = 1. 35 inch = 0. 0345 m

Schematic of Hydraulic Ram Pump Setup

h0Delivery Tank

## P0

(1)

## L

## Hf

<