HYDRAM PUMPS

CHAPTER 1:
INTRODUCTION

Recognizing that the hydraulic ram pump (hydram) can be a viable and appropriate renewable energy water pumping technology in developing countries, our project team decided to design and manufacture more efficient and durable hydram so that it could solve major problems by providing adequate domestic water supply to scattered rural populations, as it was difficult to serve water to them by conventional piped water systems.

Our project team organized a meeting with chief executive of "Godavari Sugar Mills Ltd" to implement our technology in Sameerwadi, Karnataka so that the people in that region would be benefited by our project.

Godavari Sugar Mills Ltd sponsored our project and also made provision of all kind of facilities that would be required to fabricate our project from manufacturing point of view.

It was in this context that a research project for development of an appropriate locally made hydraulic ram pump for Sameerwadi conditions was started

The project funded by Godavari Sugar Mills Ltd had a noble objective of developing a locally made hydram using readily available materials, light weight, low cost and durable with operating characteristics comparable to commercially available types. Experimental tests and analytical modeling were expected to facilitate the development of generalized performance charts to enable user's select appropriate sizes for their needs. The project was expected to end in March 2007.

By it completion, the project had achieved all its objectives as below.

1) Existing hydram installations were surveyed, inventoried and rehabilitated using spares provided under this project.

2) A design for a durable locally made hydraulic ram pump using readily available materials was developed.

3) Theoretical analysis from fluid machinery point of view was carried out.

4) To visualize the true conditions simulation and analysis was carried using computational fluid dynamics method.

5) Prototype modeling was done in order to check the results and to locate the discrepancies so that they could be eliminated from the actual model.

6) Actual model was fabricated and was tested to give the successful results.

1.1 Background

A hydraulic ram (also called hydram) is a pump that uses energy from a falling quantity of water to pump some of it to an elevation much higher than the original level at the source. No other energy is required and as long as there is a continuous flow of falling water, the pump will work continuously and automatically.

Provision of adequate domestic water supply for scattered rural populations is a major problem in many developing countries. Fuel and maintenance costs to operate conventional pumping systems are becoming prohibitive. The hydraulic ram pump (hydram) is an alternative pumping device that is relatively simple technology that uses renewable energy, and is durable. The hydram has only to moving parts and can be easily maintained.

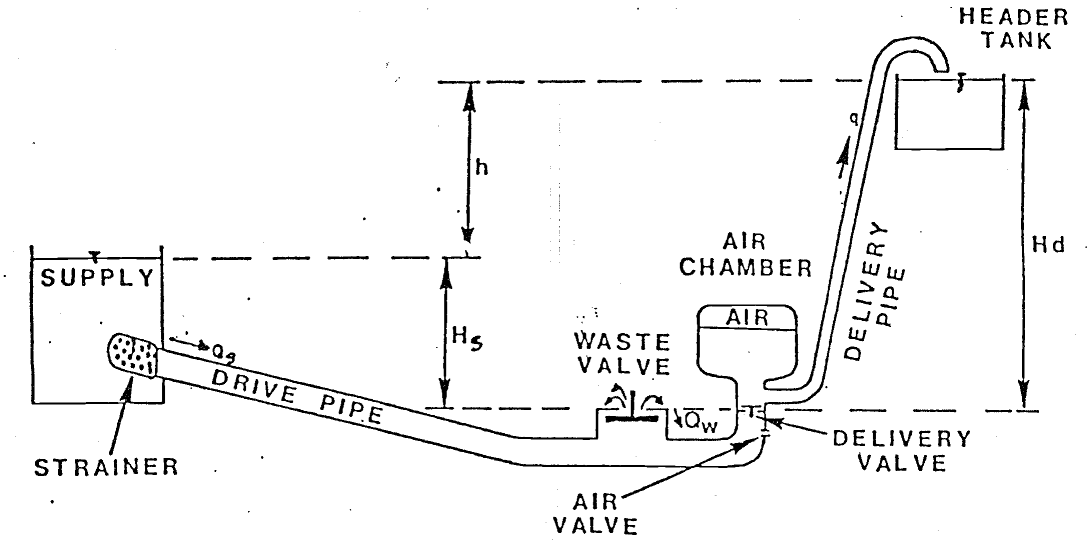


Fig 1: Components of hydraulic ram installations

With reference to fig 1, the momentum provided by the flow (Qs), caused by the low supply head (Hs), is used to pump a part of flow (q) to a higher elevation (hd) Qw is the wasted flow which may be considered as the "drive flow" and h is the head gained by the suction of the pump.

The hydram can be used in places where there is a steady and reliable supply of water with a fall sufficient to operate it. Commercial hydram's which are mainly manufactured in developed countries are known for many years. However, commercial hydram's are expensive and there is a growing trend to develop and design smaller, lighter and low cost model which can be fabricated in developing countries.

The hydraulic ram pump (hydram) though simple in design with only two moving parts, its operation is not well understood. As a result, it has attracted many researchers who have tried to derive analytical models for its operation. Because the researchers have been based in developed countries, the developing countries did not get access to the information readily and the hydram technology is therefore not widely used and the research has not benefited the developing countries. This project was intended to redress this anomaly.

A hamlet in a village setting can be supplied with water using hydram as below. The system includes storage and in some cases may include a treatment (chlorination, filtration etc) plant.

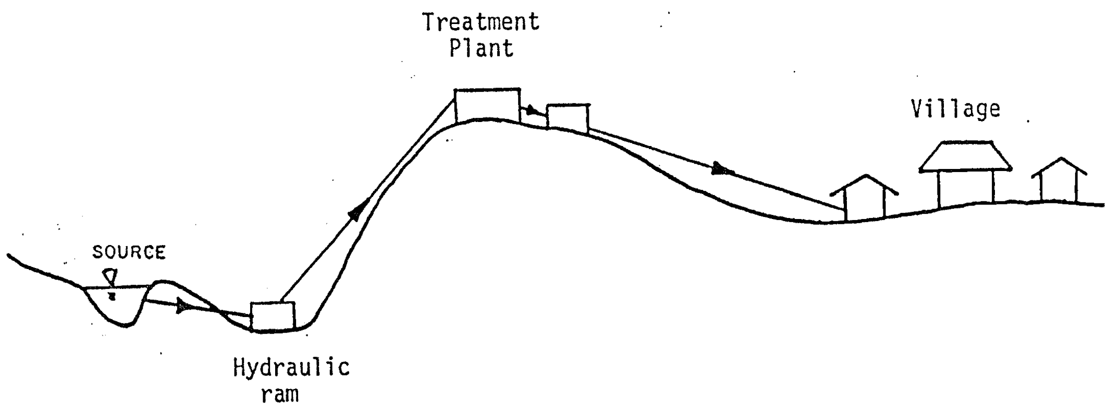


Fig 2: Schematic cross section of village water supply with a hydram.

This report is on the work undertaken in Sameerwadi, Karnataka for development of a light weight and low cost hydram for Sameerwadi conditions and assessment of potential for hydram as a viable alternative pumping device in the country.

1 PROJECT OBJECTIVES:

The overall objective was to assess the hydram potential in Sameerwadi, Karnataka and develop a new generation of efficient, durable locally made types. Specific objectives were:

a) To identify the potential for hydram installations in Sameerwadi.

b) To make survey of design and results of existing hydram installations

c) To develop a computerized hydram model and to assist in preparing designs for a new generation of light weight, durable, and more efficient hydram's.

d) To construct a demonstration/testing facility consisting hydram.

e) To manufacture and test selected size of the optimized design.

1.3 ABOUT THE SPONSOR

Our project is sponsored by Godavari Sugar Mills ltd, Somaiya trust.

The region Sameerwadi, Bagalkot located in Karnataka possess a Sugar Mill factory named – Godavari Sugar Mills Ltd, thereby employing no. of people in Sameerwadi. The place Sameerwadi is a rural area where main occupation of people is cultivating sugar canes and other agriculture products. Water is the main requirement for carrying out this occupation. Usage of conventional pumping system adds lots of cost to there pockets, thus hydram is a good solution for them. Hydram pump would greatly benefit them by fulfilling there water demand free of cost. As availability of water was not a big issue, the site could be ideally utilized for making a bank for hydram.

The noble cause of Godavari Sugar Mills Ltd was to facilitate there village people with water thereby sponsoring our project.

2.4 ALLOWING FOR FLOOD

It is important to fin how the watercourses changes during a flood. Although spring based systems are less susceptible to the extremes of flooding, it is still worth investigating and being aware of flooding as potential problem when using a spring.

In very heavy rainfall, watercourses can swell to many times their normal flow within a short space of time. Design of drive system must take account of these worst weather conditions, even if they only last few hours each year. Ask local people how far the water rises during a big flood and look for evidence such as deposited rocks and stream erosion on the banks to help to confirm their reports. Keep the pump system as possible above the maximum flood water level to avoid unnecessary damage.

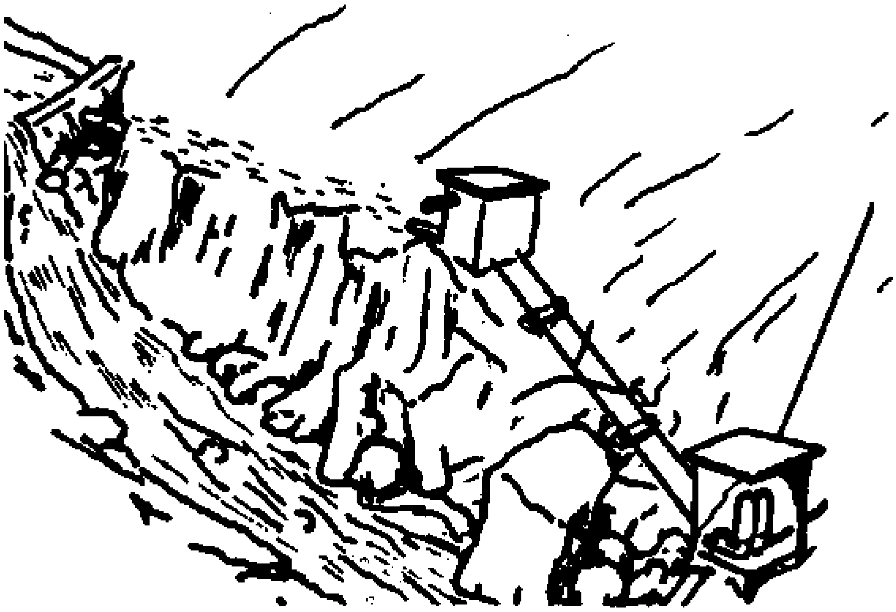


Fig 6:- In the system sketched here, the main flow of flood water and debris is guided past the pumps by the large boulder or outcrop. Whilst the pumps may be submerged in a very high flood they will be protected from damage by most water borne debris.

The one part of the system that will always be in the path of a flood is dam or diversion structure. Bearing the expense in mind, this must either be built to withstand the worst flood conditions or built to be easily repairable. Some protection against the worst damage to a dam should be included in the design, including a cage protection for the system intake, a flood water overflow in the dam wall and boulder anchored into the stream bed above the dam to reduce the impetus of rolling stones.

Normally the pumps should be sited above flood water level, but in some cases (particularly where drive head available is marginal) this can be impractical. In these circumstances the pumps need to be sited so that they are protected from any debris in the flood, Or so that they can be easily removed when flood is expected.

2.5 SITE SURVEYING

Surveying should be in two stages, a preliminary assessment to locate potential sites, and a full survey to select the best option. In brief, the preliminary survey will involve the following:

- Consulting any relevant maps and hydrology studies;
- Traveling to potential sites to make a preliminary assessment and consult local people;
- Selecting one or more sites with a high potential that will be surveyed fully.

The full survey of selected sites must be sufficiently detailed to provide all the information necessary for accurate system design.
The following information will be required:

Water source flow: the figure must reflect the minimum flow of water source in a normal year and so the measurement must be taken during the dry season. In order to ensure that the figure represents a typical minimum, local people should be consulted about the flow patterns over recent years. Some indications of maximum expected flows also are obtained.

Drive head: The maximum possible drive head of the site or the average angle of the sloe below the water source should be measured.

Deliver head: The height from the water source to the expected point of deliver should be measured. This will provide a rough estimate of delivery head but to be accurate the drive head should be added to this figure to give the actual delivery head.

Water requirement: This should be estimated with the reference to the population to be served (allowing for growth) or the area of land to be irrigated.

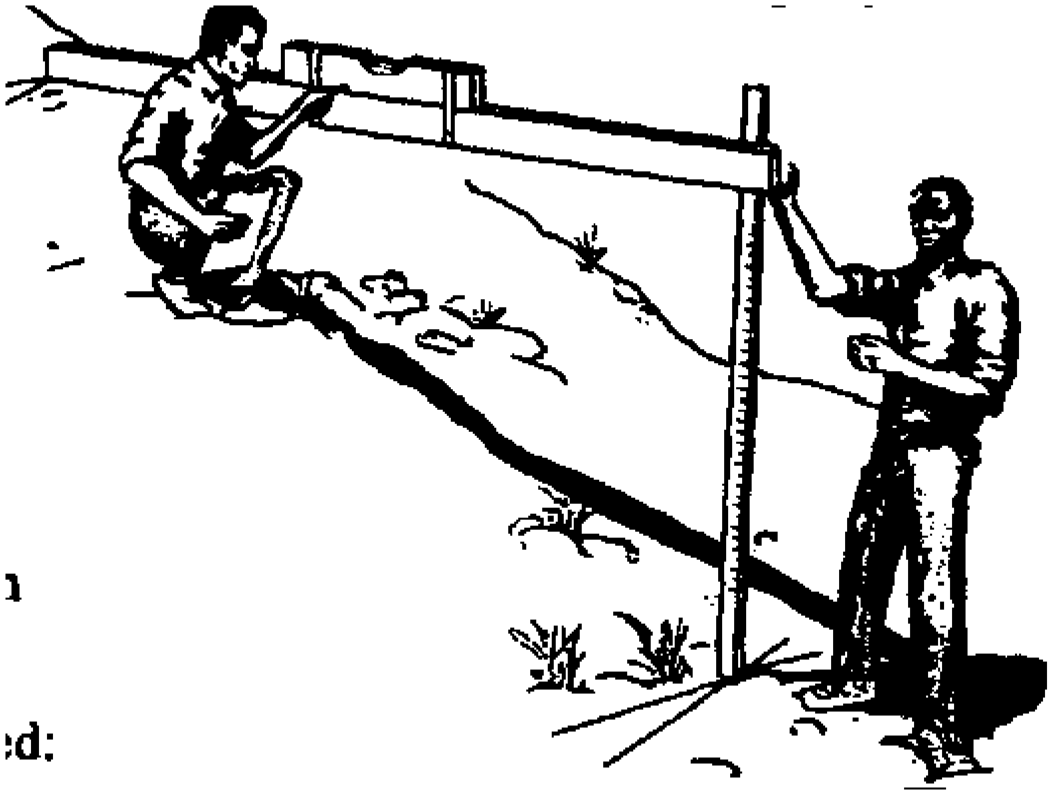


Fig 7: Simple methods of determining the height

CHAPTER 3:
WORKING OF HYRDAM PUMP

As already discussed in previous section hydram is a unique device that uses the energy from a stream of water falling from a low head as the driving power to pump part of the water to a head much higher than the supply head. With a continuous flow of water, a hydram operates automatically and continuously with no other external energy source.

We will see operational and constructional features if the Hydram in this section.

A hydram is a structurally simple unit consisting of two moving parts: refer fig: the waste valve and delivery (check) valve. The unit also consist an air chamber and an air (snifter) valve. The operation of a hydram is intermittent due to the cyclic opening and closing of the waste and delivery valves. The closure of the waste valve creates a high pressure rise in the drive pipe. An air chamber is necessary to prevent these high intermittent pumped flows into a continuous stream of flow. The air valve allows air into the hydram to replace the air absorbed by the water due to the high pressures and mixing in the air chamber.

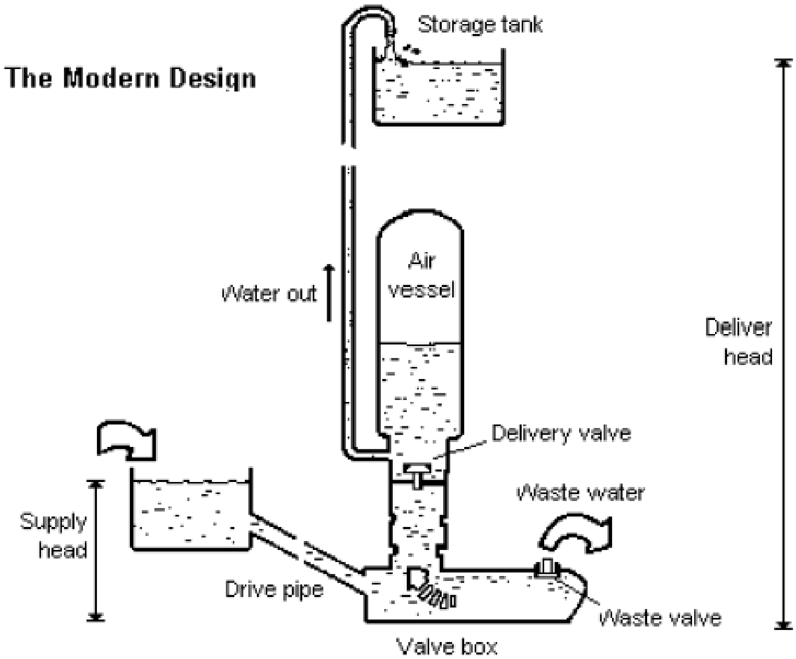
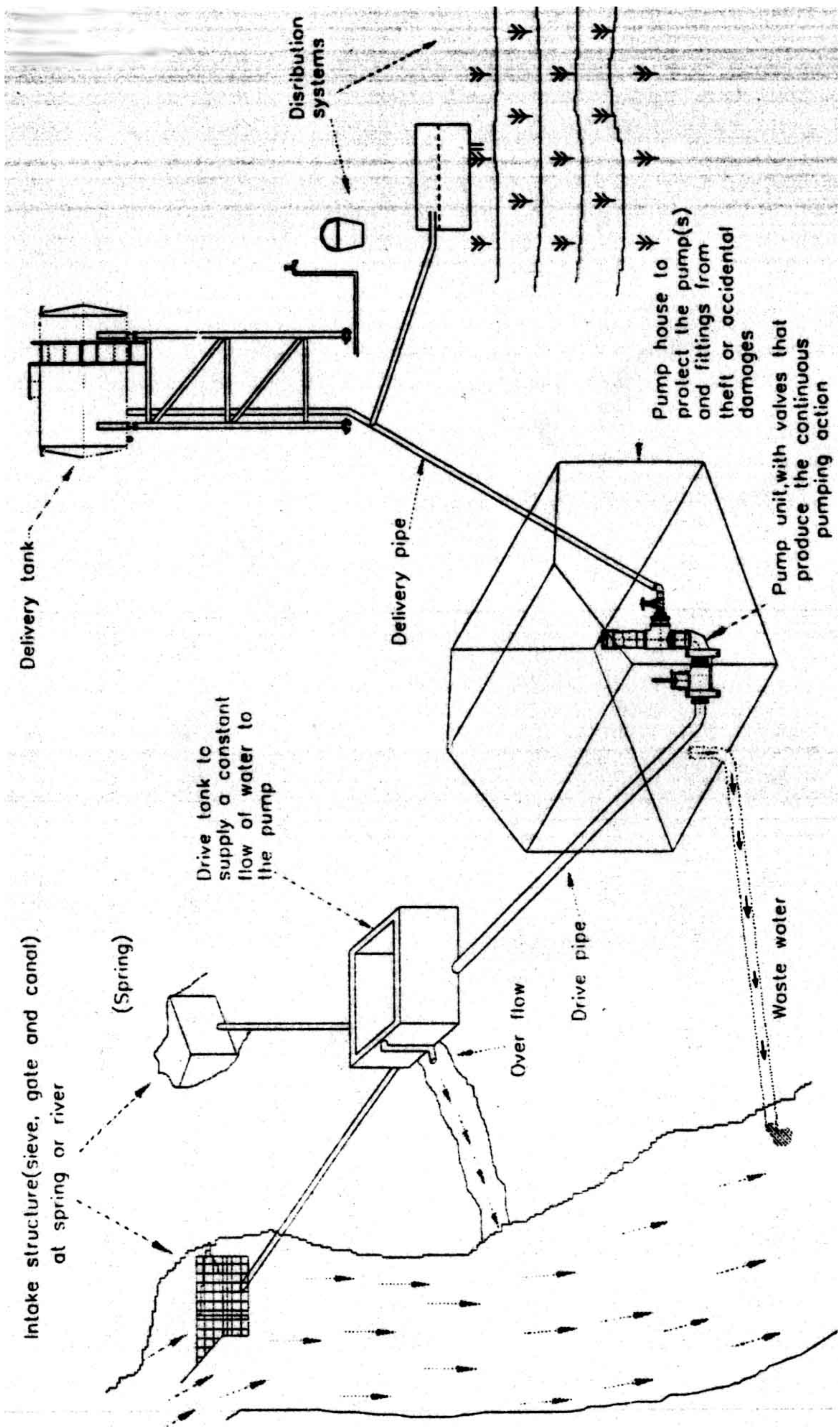


Fig 27: schematic diagram of hydram pump.

Fig 28 Components of a Hydraulic Ram Pump Station



Intake structure(sieve, gate and canal) at spring or river
(Spring)
Drive tank to supply a constant flow of water to the pump
Over flow
Drive pipe
Waste water
Delivery tank
Delivery pipe
Disribution systems
Pump house to protect the pump(s) and fittings from theft or accidental damages
Pump unit,with valves that produce the continuous pumping action

3.1 Water hammer & surge tanks

To explain the principle of operation of a hydram, it greatly helps to have an insight into the function of a Surge Tank in a hydropower generation system.

In hydropower generation, whenever there is an abrupt load rejection by the power system, the turbine governors regulate the water entering into the turbines in a matter of few seconds, so as to avoid change in frequency. The sudden closure of the valve creates high pressure oscillations in the penstock often accompanied by a heavy hammering sound known as a water hammer

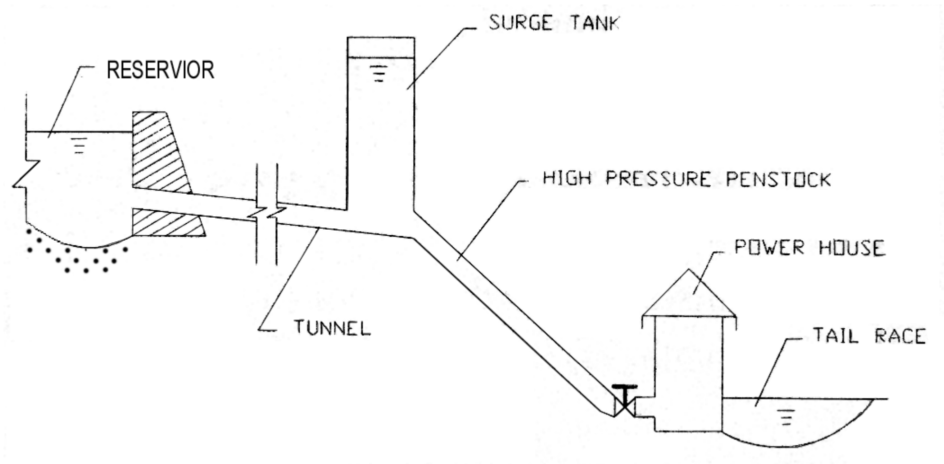


Fig 29: Surge tank

To avoid water hammer, a surge tank is installed between the dam and the powerhouse at the water entry of the penstock. The main function of the surge tank is to protect the low pressure conduit system/tunnel from high internal pressures. The Surge Tank, therefore, enables us to use thinner section conduit or tunnel, usually running for a few kilometers of length, making the system less expensive. However, unavoidably, the penstock must be designed to sustain the high pressure that will be created by water hammer, requiring the use of thick walled pipes. Here, water hammer has a negative impact. Nevertheless, this same phenomenon is used to lift water in a hydram.

3.2 Working principle of hydraulic ram pumps

The cycle can be divided into three phases; acceleration, delivery and recoil.

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

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

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

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

3.3 Operating sequence of hydram

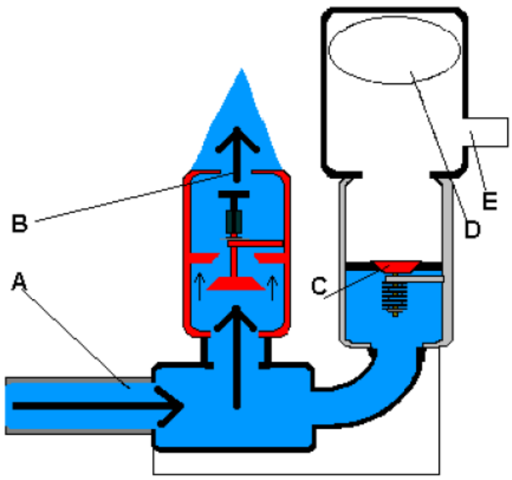


Fig 30: sequence 1

Sequence 1:

Water from the source flows through the drive pipe (A) into the ram pump body, fills it and begins to exit through the waste or "impetus" valve (B).

The Check Valve (C) remains in its normally closed position by both the attached spring and water pressure in the Tank (D) and the Delivery Pipe (E).

(No water in the tank prior to startup) At this starting point there is no pressure in Tank (D) and no water is being delivered through exit Pipe (E) to the holding tank destination.

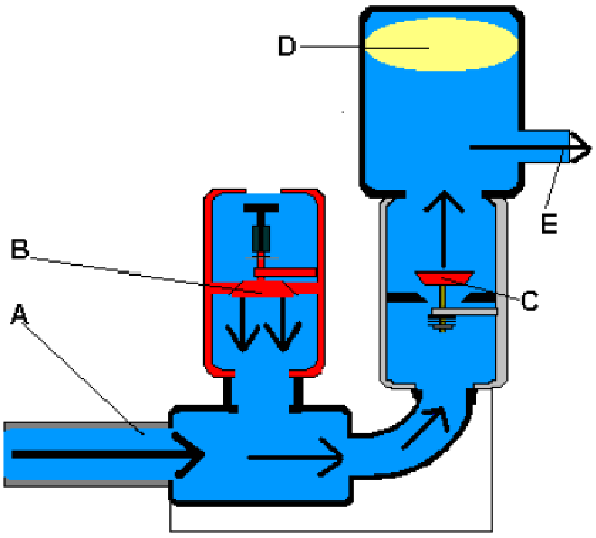


Fig 31: sequence 2

Sequence 2:

Water is entering the pump through the Drive Pipe (A). The velocity and pressure of this column of water is being directed out the Waste Valve (B) which is overcome, causing it to close suddenly. This creates a momentary high pressure "water hammer" that in turn forces the Check Valve (C) to open allowing a high pressure "pulse" of water to enter the Pressure Tank (D). The air volume in the pressure tank is compressed causing water to begin flowing out of the Delivery Pipe (E) and at the same time closing the Check Valve (C) not allowing the water a path back into the pump body. As the air volume in the Pressure Tank (D) continues to re-expand, water is forced out of the Delivery Pipe (E) to the holding tank.

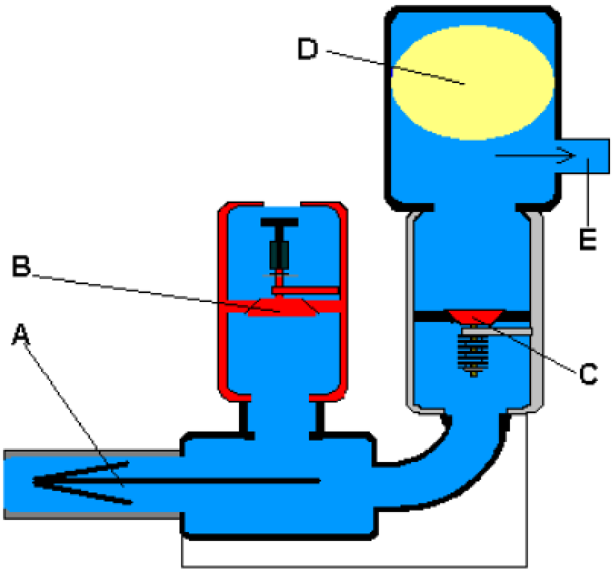


Fig 32: sequence 3

Sequence 3:

Water has stopped flowing through the Drive Pipe (A) as a "shock wave" created by the "water hammer" travels back up the Drive Pipe to the settling tank (depicted earlier). The Waste Valve (B) is closed. Air volume in the Pressure Tank (D) continues expanding to equalize pressure, pushing a small amount of water out the Delivery Pipe (E).

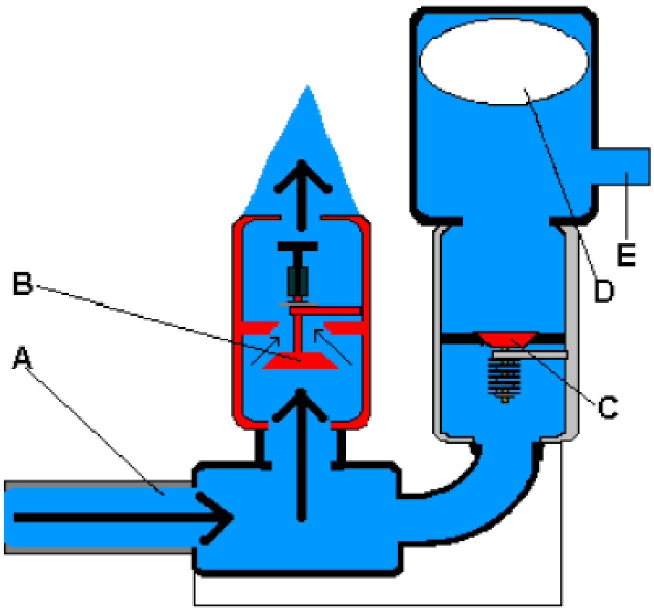


Fig 33: sequence 4

Sequence 4:

The “shock wave” reaches the holding tank causing a “gasp” for water in the Drive Pipe (A). The Waste Valve (B) falls open and the water in the Drive Pipe (A) begins to flow into the pump and out the Waste Valve (B). The Check Valve (C) remains closed. The air volume in the Pressure Tank (D) has stabilized and water has stopped flowing out the Delivery Pipe (E). At this point Sequence 1 begins all over again.

3.4 Nature of hydram operation

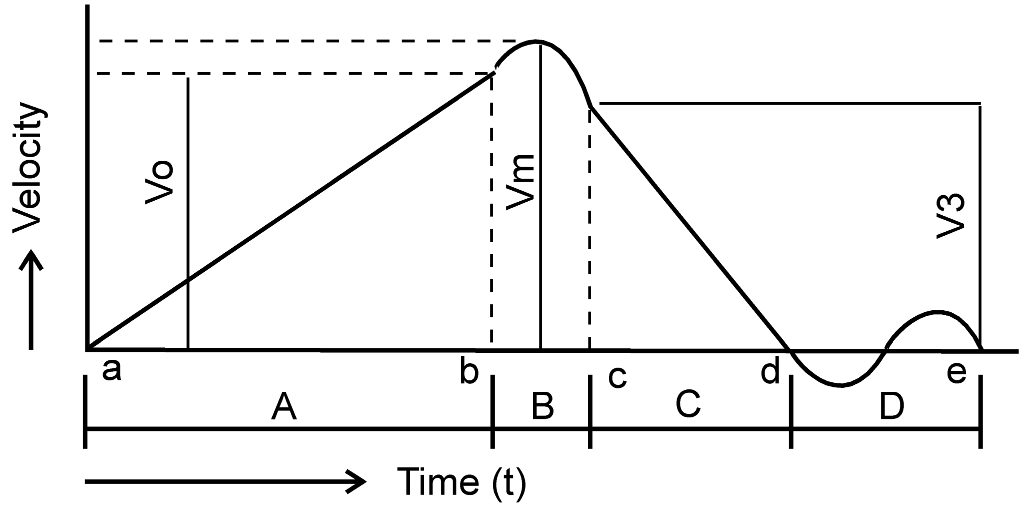


Fig 34: Time-Velocity Variation in Drive Pipe

For analysis, the pumping cycle of a hydram is divided into four main periods, based on the position of the waste valve and the average time-velocity variation in the drive pipe.

A. The waste valve is open and water starts to flow from the source and escapes through the waste valve. The flow accelerates under the effect of the supply head (H), until a velocity V_0 is attained in the drive pipe;

B. The waste valve continues to close and finally closes fully. For a good hydram design, the valve closure is rapid or instantaneous;

C. The waste valve is fully closed and remains closed. The sudden closure creates a high pressure in the hydram and on the check valve that is in excess of the static delivery pressure. The check valve is forced open and pumping takes place until the velocity becomes zero and pumping stops, under the retarding effect of the delivery pressure head; and

D. The delivery valve closes. The pressure near the check valve is much higher than the static supply pressure and the flow is reversed towards the supply source. This action is termed recoil. The recoil action creates a vacuum in the hydram, temporarily forcing a small amount of air to be sucked into the hydram through the air valve. The pressure on the underside of the waste valve is also reduced and together with the effect of its own weight, the waste valve opens automatically. The water in the drive pipe returns to the static supply pressure as before and the next cycle begins. The action is repeated automatically at a frequency of a few beats to more than 300 beats per minute [1].

3.5 Applications and limitations of hydraulic ram pumps

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

- Use of a renewable energy source ensuring low running cost
- Pumping only a small proportion of the available flow has little environmental impact
- Simplicity and reliability give a low maintenance requirement
- There is good potential for local manufacture in the rural villages
- Automatic, continuous operation requires no supervision or human input.

The main limitations are:

- They are limited in hilly areas with a year-round water sources
- They pump only a small fraction of the available flow and therefore require source flows larger than actual water delivered
- Can have a high capital cost in relation to other technologies

- Are limited to small-scale applications, usually up to 1KW, but this requires economical and other considerations.

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

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

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

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

CHAPTER 4:
DESIGN METHODOLOGY FOR HYDRAM PUMP

4.1 Considerations in hydraulic ram pump system design

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

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

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

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

4.1.3 General considerations

- Shape of hydram has little effect on performance
- Valve design considerations. The correct design of valves is a critical factor in the overall performance of ram pumps. Hence, this needs special consideration.
- Strength considerations. This determines thickness of hydram body and air chamber.

4.2 A] Theoretical Pressure Rise in a Hydram

As indicated earlier, a hydram makes use of the sudden stoppage of flow in a pipe to create a high pressure surge. If the flow in an inelastic pipe is stopped instantaneously, the theoretical pressure rise that can be obtained is given by **equation 1.**

$$DH = V * C / g \qquad (1)$$

Where

DH is the pressure rise [m]

V is the velocity of the fluid in the pipe [m/s]

C is the speed of an acoustic wave in the fluid [m/s]

g is the acceleration due to gravity = 9.81 m/s^2

According to David and Edward, the speed of an acoustic wave in a fluid is given by **equation 2.**

$$C = (E_v / rho)^{1/2} \qquad (2)$$

Where

$\mathbf{E_V}$ is the bulk modulus of elasticity, which expresses the compressibility of a fluid. It is the ratio of the change in unit pressure to the corresponding volume change per unit volume. For water, a typical value of E_V is 2.07 x 109 N/m^2, and thus the velocity of a pressure wave in water is C = 1440 m/s.

rho is the density of the fluid [kg/m^3]

Equation 1 represents the maximum rise possible. The actual rise will be lower than that given by equation 1, since all pipes have some elasticity and it is impossible to instantaneously stop the flow in a pipe.

Because of the head (H) created, water accelerates in the drive pipe and leaves through the waste valve. This acceleration is given by **equation 3**.

$$H - f * (L / D) * V^2 / (2 * g) - S (K * (V^2) / (2 * g)) = (L / g) * dV/dt \qquad (3)$$

Where

H is the supply head [m]

$f * (L / D) * V^2 / (2 * g)$ is the lost head in the pipe [m]

f is the friction factor (Darcy-Weibach Formula)

$S (K * (V^2) / (2 * g))$ is the sum of other minor head losses [m]

K is a factor for contraction or enlargement

L is the length of the drive pipe [m]

D is the diameter of the drive pipe [m]

V is the velocity of the flow in the pipe [m/s]

t is time [s]

The values of K and f can be found from standard fluid mechanics textbooks.

Eventually this flow will accelerate enough to begin to close the waste valve. This occurs when the drag and pressure forces in the water equal the weight of the waste valve.

The drag force F_d is given by **equation 4**.

$$F_d = C_d * A_V * rho_w * V^2 / (2 * g) \qquad (4)$$

Where

Fd is the drag force on the waste valve [N]

A_V is the cross sectional area of the waste valve [m^2]

rho_w is the density of water = 1000 kg/m^3

C_d is the drag coefficient of the waste valve [-]

The drag coefficient C_d depends on Reynolds number of the flow and the shape of the object. For circular disks, $C_d = 1.12$.

Applying Bernoulli's theorem for points at inlet and outlet of results in **equation -5**

$$(P_0/ rho *g) + V_0 / (2 * g) + Z_0 - H_L = (P_3 / rho *g) + V_3/ (2 * g) + Z_3 \qquad (5)$$

Where

P_0 is the pressure at point 0 equal to zero (atmospheric) [N/m^2]

P3 is the pressure at point 3 [N/m^2]

V_0 is the velocity of the fluid at point 0 equal to zero [m/s]

Z_0 is the height of point 0 = H [m]

V_3 is the velocity of fluid at point 3 equal to zero [m/s] (At the instant the flow is suddenly and fully stopped)

Z_3 is the height of point 3 equal to zero (datum) [m]

H_L is the head loss [m]

With the above values, equation 5 reduces to equation 6.

$$\mathbf{H - H_L = P_3 / rho * g} \quad \mathbf{(6)}$$

The force that accelerates the fluid can be written using Newton's Equation **(equation 7).**

$$F = m * a = rho * A * L * dV/dt \qquad (7)$$

Where

F is the accelerating force [N]

m is the accelerated mass [kg]

a is the acceleration of the mass [m/s^2]

A is the area of the drive pipe [m^2]

L is the length of the drive pipe [m]

The pressure at delivery valve section (p3) is obtained by dividing the force (F) in equation 7 by the area A.

$$P_3 = F / A = rho * L * dV/dt \qquad (8)$$

Therefore,

$$P_3 / rho * g = L / g * dV/dt \qquad (9)$$

From equations 6 & 9:

$$H - H_L = L / g * dV/dt$$

4.3 B] Max velocity in the pipe.

By knowing flow rate and recommended pipe diameter calculate max velocity in the pipe.

Vmax=Q/area of supply pipe.

4.4 C] Length of supply pipe

Using empirical relation determine length of supply pipe ***(ls = 2.5H)***

4.5 D] Operation time for valve

Calculate time during which velocity in supply pipe builds by using following relation

$$t1=ls*vmax/(H-h)g$$

From water hammer equation calculate ***t2***

Then compute total time ***T= t1+t2***

4.6 E] Efficiency of a Hydram

There are two methods commonly used to compute the efficiency of a hydram installation, the Rankine and the D'Aubuisson methods given by equations 11 and 12 respectively.

4.6.1 $E\ (Rankine) = Q * h / ((Q+Q_W) * H) \quad (11)$

4.6.2 $E\ (D'Aubuisson) = Q * H_d / ((Q+Q_W) * H) \quad (12)$

Where

E is the efficiency of the hydram [-] is the pumped flow [l/min]

Q is the pumped flow [l/min]

Q_W is the wasted flow [l/min]

h is the pump head above the source [m]

H is the supply head above the waste valve opening [m]

H_d is the total head above the waste valve opening = (H+h) [m]

Assume “D Abussions efficiency” =***0.4***

And thus calculate flow rate at outlet using relation ***0.4=q*H/q8h***

Now compute diameter of supply pipe using relation

q= (0.785*ds^2)*(Vmax/2)*t2/T

4.7 F] Frictional losses in pipe

Calculate friction loss in supply pipe using relation

hwv =(h-hfs)*0.9

4.8 G] Pressure at waste valve

Now evaluate pressure and velocity acting at waste wall using following relations

hwv= pwv/density * g

hwv= vwv^2/2*g

4.9 H] Weight of waste valve

And finally compute weight of the waste wall using relation

Wwv=0.785*(dwv)^2*Pwv

**** Assume diameter of waste valve****

4.10 Practical aspects of a hydram design

Hydram Parameters: The detailed mechanics of hydram operation are not well understood. Several parameters relating to the operation of the hydram are best obtained experimentally. These parameters include:

- Drive pipe length (L);
- Cross-sectional area of the drive pipe (A);

- Drive pipe diameter (D) and thickness;
- Supply head (H);
- Delivery head (h);
- Friction head loss in the drive pipe;
- Friction head loss through the waste valve;
- Friction head loss at the delivery valve;
- The velocity in the drive pipe when the waste valve begins to close (V_0);
- The steady flow velocity (V_S) through the waste valve when fully open;
- Valve weight (W);
- Valve stroke (S);
- Valve opening orifice area (A_0);
- Valve cross sectional area (A_V); and
- Size of the air chamber.

4.10.1 ***Drive Pipe Length (L)****:* The drive pipe is an important component of a hydram installation. The drive pipe must be able to sustain the high pressure caused by the closing of the waste valve. Empirical relationships to determine the drive pipe length are:

6H< L <12H (Europe & North America)

$L = h + 0.3\ (h/H)$ (Eytelwein)

$L = 900\ H / (N^2 * D)$ (Russian)

Where N is the Number of Beats/min

$L = 150 < L/D < 1000$ (Calvert)

Many researchers have indicated that Calvert's equation gives better guidelines

4.10.2 ***Air chamber:*** It is recommended that the volume of the air chamber be approximately 100 times the volume of water delivered per cycle.

4.10.3 ***Air Valve****:* Experiments with different sizes indicate that the air valve size has negligible effect on a hydram operation. A small hole, less than 1 mm, is sufficient.

4.10.4 ***Waste Valve:*** The flow area (A_0) through the waste valve should equal to or exceed the cross-sectional area of the drive pipe to avoid "chocking" of the flow.

4.10.5 ***Delivery (Check) Valve****:* 1.45 cm^2 of area for every liter of water to be delivered through the valve is recommended.

4.10.6 ***Supply Head (H):*** With simple weighted impulse valves, the supply head should not exceed 4 m, otherwise the valve will be closing so rapidly and frequently that no useful work will be done. In such a case, the valve should be assisted by a spring to regulate its closure.

CHAPTER 5:
RAM PUMP DESIGNING SOFTWARE

When we design a water system using ram pumps, we like to know before we build it how much water it will deliver to how much head and with what efficiency manually manipulating these parameters using design methodology for different input parameters is a very long and tiring process.

Therefore in order to evaluate performance and design parameters for different site conditions its necessary to implement this methodology into a computer code that would readily manipulate the values for you so that manual work load would be offloaded thereby increasing design efficiency and also design time would be reduced

In order to serve the above purpose our project team has developed a hydram pump design software whose platform is visual basic and is much more user friendly same like windows application.

What you have to do is to just feed you resource parameters i.e. your site data and let the software evaluate all the design parameters for you. With help of this software you can compare different results for different input parameters and could select the one specification which is having optimum efficiency. Thus serving both the purpose, designing as well as reducing the calculation time.

5.1 Features of our software

1) User friendly
2) Requires only few input parameters i.e. available flow rate, available head, diameter of waste valve, friction factor, expected lift.
3) Calculates almost all the parameters which are essential in designing a hydram pump.
4) It is handy, can be installed easily on any system and can be used within no time.

Note: it require **.NET** frame work installed on the system for its operation

5.2 Software pictures.

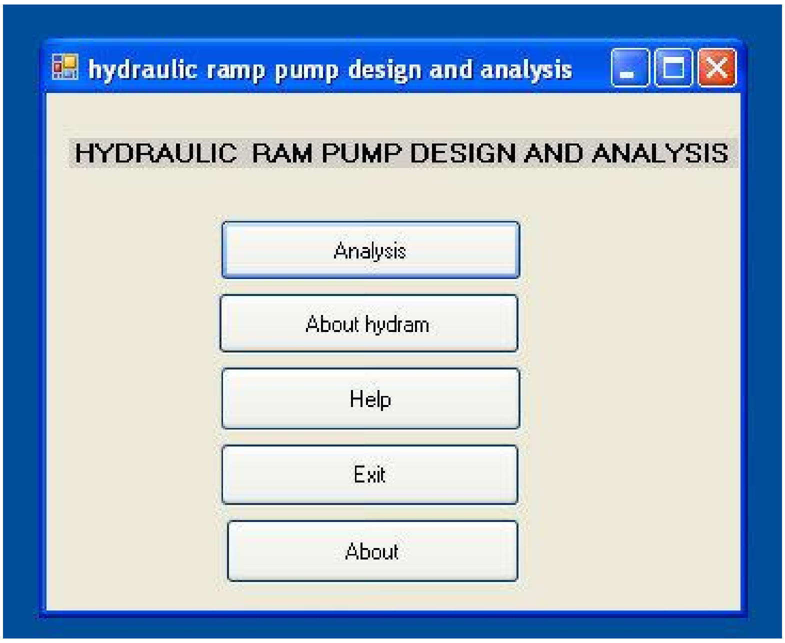


Fig 35: main page

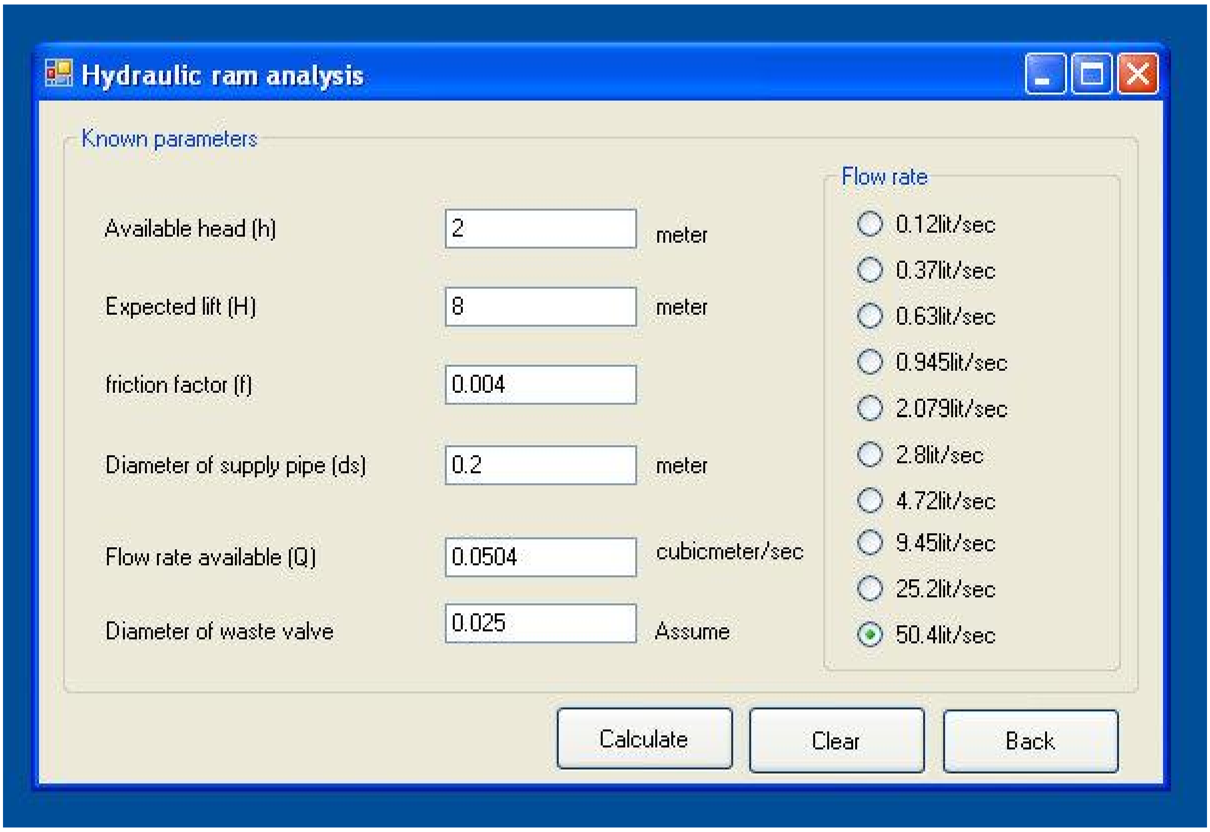


Fig 36: input parameter page

Software pictures.

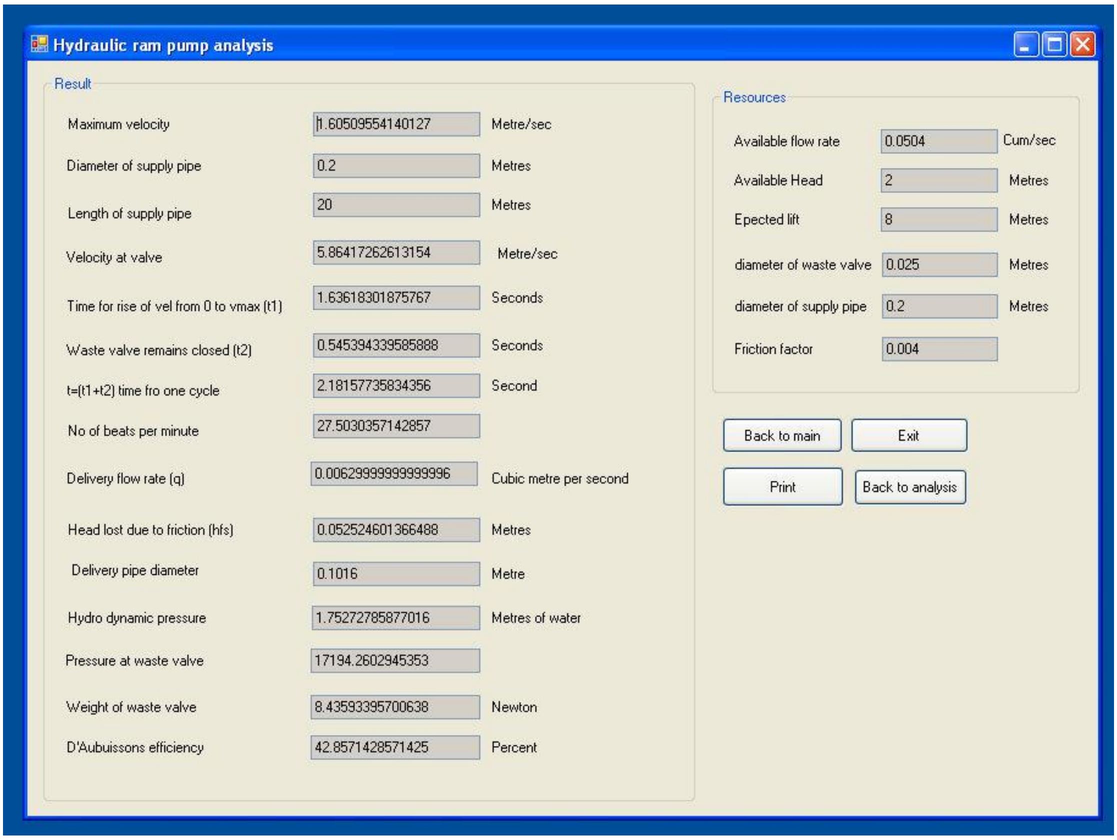
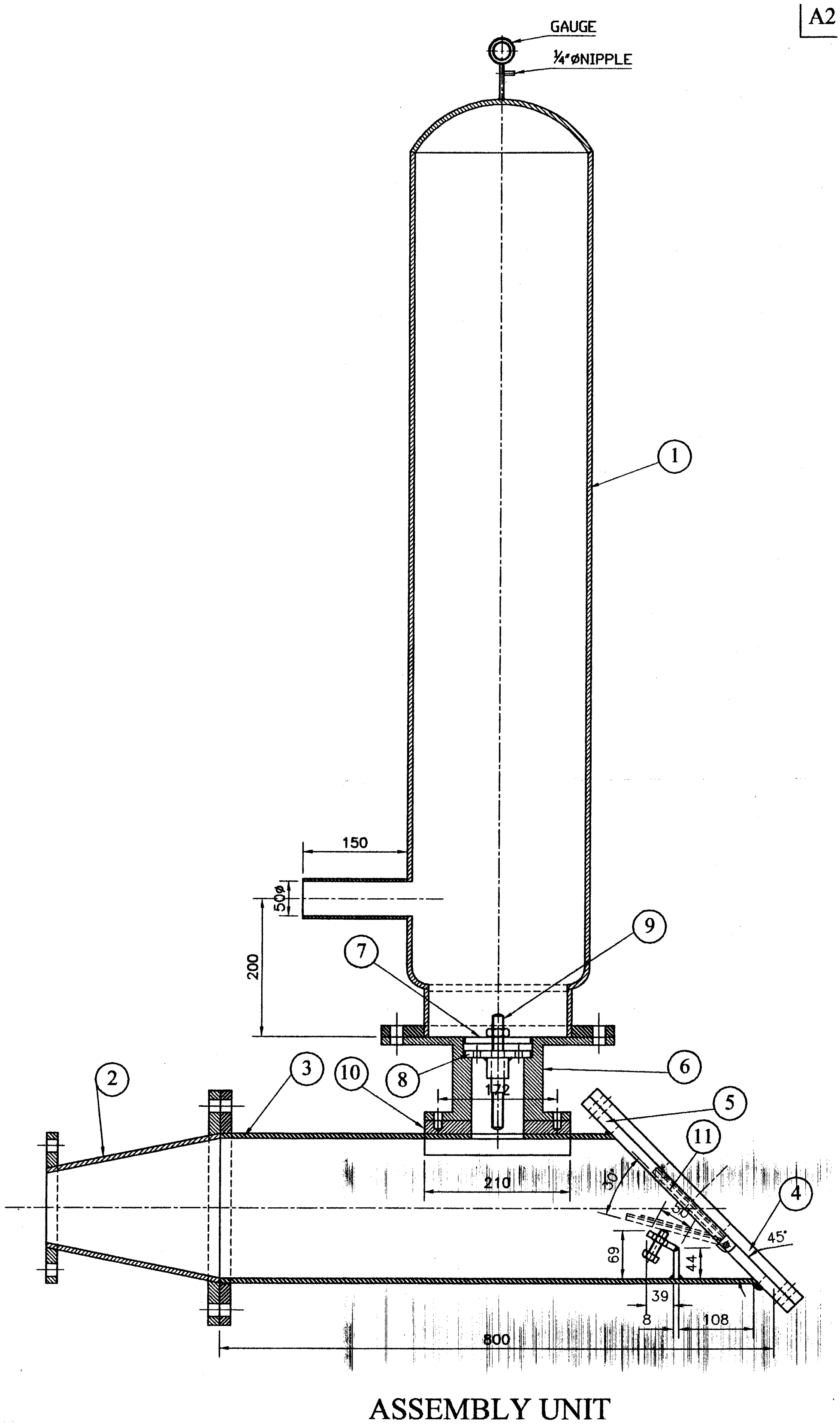


Fig 37: result page

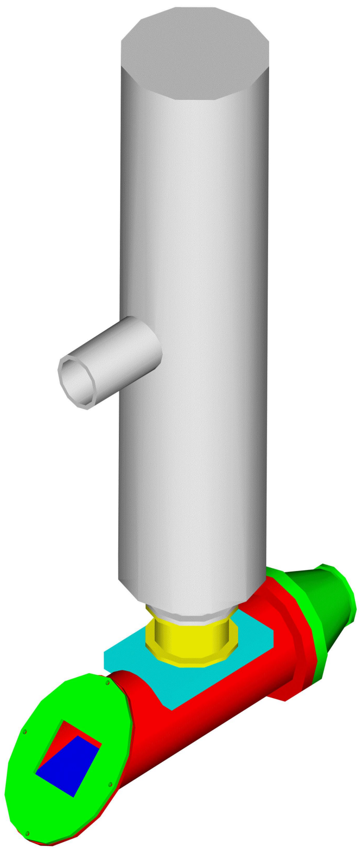
A2



ASSEMBLY UNIT

Fig 54: Assembly of hydram pump, installed at Sameerwadi, Bagalkot

CAD models of hydram pump



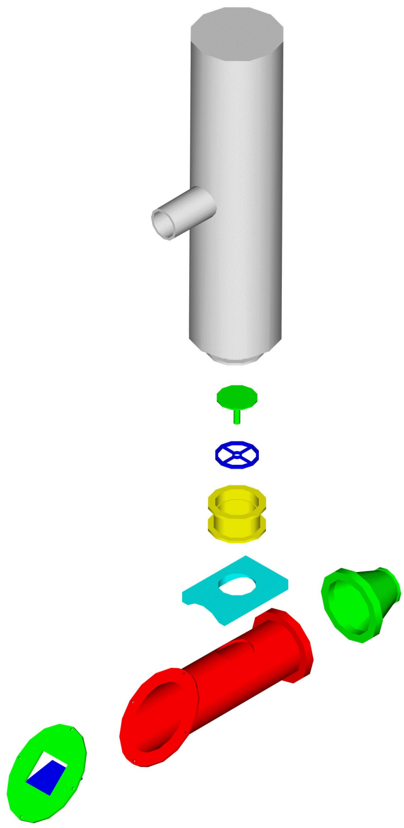


Fig 55: hydram pump final assembly

fig 56: exploded view

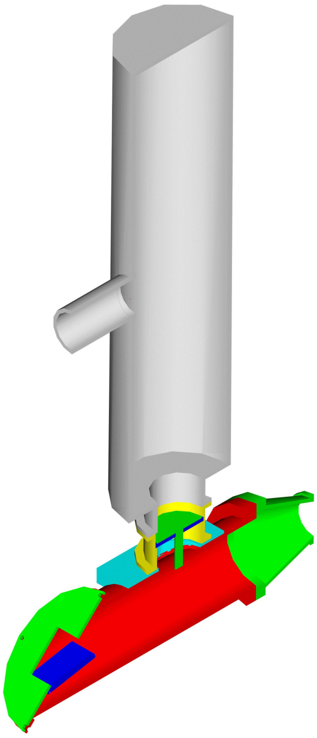


Fig 57: sectional view

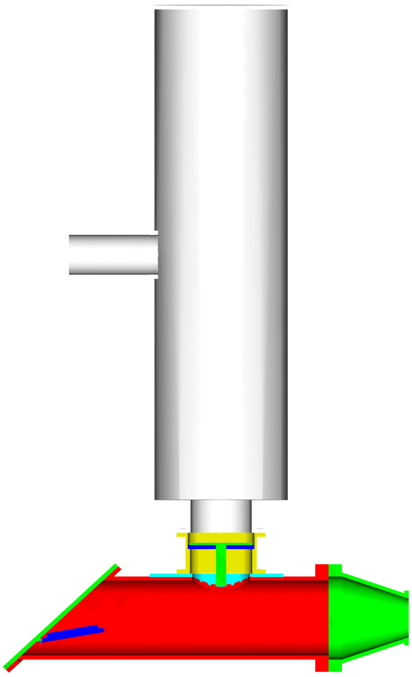


fig 58: sectional side view

6.9 Corrosion protection

To protect the pump against corrosion oil paint must be used and applied.

The waste valve spindles and nuts for the discharge and waste valve which is fully immersed or in contact with water most of the time should be made of brass. The rest of the studs and nuts with aluminum coating should be purchased from hard ware shops. Deep inside the air chamber painting with brush is difficult here spray painting must be used to cover this area.

6.10 Advantages of our hydram design

1) The valve openings are wide and that makes them self cleansing and not easily clogged by sand, grit and debris
2) The waste valve and discharge valve guides can be replaced in case they wear out and enlarge at a very small cost.
3) The snifting or air valve design is easy to unclog and even replace if the hole enlarges.
4) The design is easy to fabricate and fix with minimum workshop facility and can be maintained by unskilled users
5) The pump is low cost as compared with available commercial models.

6.11 Specification of our hydram pump

Description	Details
Available head (h)	2m
Available flow rate (Q)	70 liter per second
Expected lift (H max)	20m
Dia of supply pipe (D)	4”
Dia of deliver pipe (d)	2”
Delivery flow rate (q)	15-20 liter per second. At 4m delivery

Fig 61: Valve seat and flange area **Fig 62: Delivery side of hydram**

CHAPTER 7:

TROUBLE SHOOTING THE HYDRAM PUMP

If the pump starts or stop delivering less water than usual, it may require adjustment or repair.

Look at the pump and if there is no obvious fault start it again if you can. Watch the pump and listen for irregular pumping or unusual noises. A worn waste valve, for example, is usually obvious because water squirts through when the valve is closed. Some parts of your ram may require occasional replacement, the frequency of this depend on how hard the pump is working and on the cleanliness of the drive water.

7.1 Taking the Pump Apart.

Depending upon the fault it may be necessary to disassemble the waste valve and/or the air vessel.

Before attempting to take apart the pump:

1) Make sure that the drive pipe valve is closed and the impulse valve is open.

2) Depressurize the air vessel.

7.2 WARNING: Before attempting to remove the air vessel, always release the pressure in it slowly. An ideal system will have a gate valve or one way valve and a union fitted in between the air vessel and the bottom of the delivery pipe and the optional bleed screw fitted to the air vessel. With the pump stopped, close the gate valve in the delivery pipe to stop it draining back. If a one-way valve is fitted it will close automatically. Then loosen the bleed screw to release the pressure in the air vessel. If none of the above are fitted, the only other way to release the pressure in the air vessel is to loosen each of the air vessel flange bolts one turn at a time until the water and air escapes through the joint at the flange.

7.3 CHECKS

1) Check delivery valve rubber for wear and blockage of the valve holes.

2) Check that the snifter valve is in good condition.

3) Remove the waste valve and the waste valve rubber. Check the nuts on the valve stem. Replace things if necessary.

4) Check the pump body is firmly bolted down, and then reassemble the pump, ensuring that all bolts are greased.

7.4 Putting the Pump Back Together

Assemble the pump as per the drawing detailed, but the following important points need to be kept in mind:

1) Assembly of the Delivery Valve

Put together the delivery valve plate, the rubber and the bolt. Make sure the side of the plate with the chamfered holes is on the opposite side to the rubber, and that the rubber is on top. Screw on the first nut until it is finger tight and then undo it by one turn. Care must be taken not to over tighten the bolt and nuts as this will affect the performance of the valve. Next screw on the other nut and tighten it up against the first.

2) Assembly of the Air Vessel and the Delivery Valve

Align the delivery valve, air vessel, pump body and rubber gasket mounting holes and feed through the bolts. Make sure the delivery valve is the correct way up and then tighten the nuts by hand. Use the spanners to tighten the all nuts and bolts little at time, working around the flange. This will draw the assembly together evenly.

3) Assembly of the waste Valve

The first parts to assemble are the valve stem, discs and rubber. Screw two nuts onto the longer threaded end of the stem up to the end of the thread. Push a steel washer on up to the nuts. Follow this with the valve plug disc, with the chamfered side towards the nut. Slide the valve rubber up against this. Then the weight disc with the chamfered side facing away from the rubber. Follow this with another steel washer. Screw the nut up to them until it is finger tight. Thread on another nut and use the spanners to tighten the nuts together, put rubber sheet in between two plates for water tight joint.

7.5 Installation Notes

The hydram pump should be installed in a properly designed system. To prevent vibrations causing breakages, it should be firmly bolted to a steel frame (called a pump cradle) that is half buried in a concrete base. The cradle is usually made up from a iron angle. All pipes in the system should be supported firmly, and buried where possible. The drive and delivery tanks should be constructed on good foundations by experienced tradesmen. Pipe joints to the drive tank should allow the pipes to move slightly without damaging the tank walls or leaking badly.

7.6 Starting and Stopping of the Ram Pump:

Although ram pumps often start very easily, they can be awkward the first time they are run. **To start pump**:

1) Make sure that any valve fitted on the delivery pipe is open and then open the drive pipe valve. Water will flow out of the open waste valve until it suddenly shuts. If it reopens automatically, the pump should continue to run on its own. If it does not, you must prime the delivery system as described in next step.

2) Push down on the top of the waste valve stem with your foot to reopen it. Again, water will flow out of the open impulse valve until it suddenly shuts, then push down immediately to re-open the valve. Keep helping the valve to re-open until it will do so by itself.

To stop the pump, hold the impulse valve stem up to close it or shut the valve at the bottom of the drive pipe.

7.7 Turning For Best Performance

The ram can be turned to adjust performance. This is done by changing the up and down movement of the waste valve. Tuning is usually done to achieve either the maximum delivery flow or the most efficient use of the drive water available.

1) Maximum Delivery

When there is plenty of drive water available, the pump can be tuned to deliver as much water as possible. To do this, remove or adjust the inclination or the opening angle of the impulse valve so that the valve has as much up and down movement as possible.

2) Low Drive Flow

If the pump uses more drive flow than is available it will soon stop. If this happens it must be tuned to use less. The impulse valve should be tuned down to use 90-95% of the water available from the source. To tune the pump down, add or adjust the impulse valve stem so that the valve has less up and down movement. The shorter the stroke, the smaller the amount of drive flow needed, and the less water is delivered.

7.8 Routine Maintenance

While the pump is running normally, a visit should be made once a week to check that bolts are tight and that there are no leaks. Once a month an inspection of the whole system should be carried out. It is also recommended that a log book is kept to record the checks and repairs that have been made.

Monthly maintenance checks list (without stopping the pump)

1) Inspect all the joints for leaks.
2) Check if there is sufficient air in the air vessel. This can be done by listening carefully to the pump. If there is insufficient air in the air vessel, the pump will be much louder than usual. This means that the snifter valve is probably blocked and will need to be cleared.
3) Clean any filters installed in the system.
4) Remove excess slit or debris from tanks or from behind the intake dam or weir if necessary.
5) Walk along all pipes looking for damage. Also, inspect the tanks for leaks, particularly at pipe joints.

CHAPTER 8:

COMPUTAIONAL FLUID DYNAMICS ANALYSIS OF HYDRAM PUMP

A reliable simulated hydram model is needed to facilitate the development of an optimized hydram design and thereafter to be able to generate an efficient design deign of hydram with good operating characteristics. This calls for a model that simulates the hydram performance with a high degree of accuracy and which is able to identify the effect of the waste valve design on the hydram performance. And the answer to this is computational fluid dynamics (CFD) analysis.

The CFD model is expected to provide a better understanding of the hydram operation to enable on the design and optimize its output.

8.1 CFD Hydram model

To serve the above purpose we used CFD technique to simulate our hydram valve box using FLUENT CFD package.

Our aim was to visualize how exactly the flow in the valve box would behave for different values of opening, inclination and weight of the waste valve.

Thus helping us, in optimizing our valve box design.

8.2 Objective of CFD analysis

1) To simulate flow pattern in valve box
2) To determine pressure acting at waste valve and delivery valve
3) To determine maximum pressure generated in valve box
4) To determine pressure and velocity distribution in valve box
5) To optimize our design by evaluating the above mentioned parameters.

8.3 CFD Analysis stages

8.3.1 Modeling

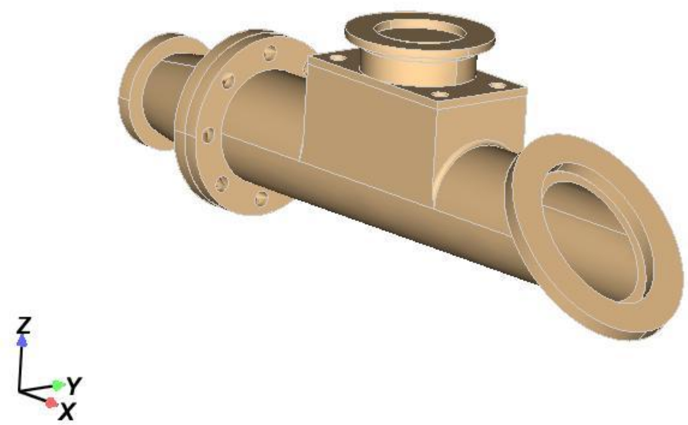


Fig 63: CAD model used for carrying analysis in FLUENT

8.3.2 Meshing of hydram valve box

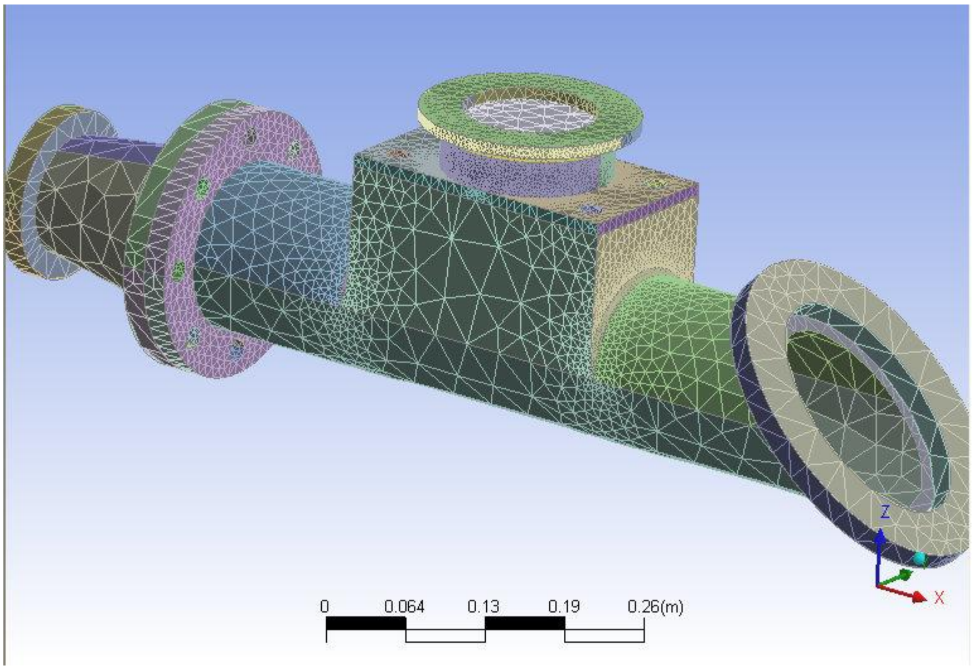


Fig 64: Meshing of hydram valve box

8.3.3 Mesh Information

Volumetric meshing of valve box was done using FLUENT. Following is the mesh information

Variable	Value
Mesh type	Tetrahedral mesh
Total number of cells	11752
Tetrahedral cells	11752
Wedge cells	0
Hexahedral cells	0
Pyramid cells	0

8.3.4 Analysis

Waste valve closed and delivery valve open (condition 1)

Boundary Conditions

Name	Type	Flow Condition	Thermal Condition	Source of Flow
Ram pump inlet	Inlet	Velocity=8.85 m/s		Settling tank
Hydram body	Wall	not applicable		not applicable
Hydram body	Wall	not applicable		not applicable
Delivery outlet	Outlet	To be calculated	not applicable	not applicable

8.3.5 Results

Pressure Differences (Pascal)

From Boundary	To Boundary	Value
Hydram inlet	Delivery valve	9405.7009926

Velocities (m/s)

Boundary or Region	Average	Minimum	Maximum
Hydram inlet	8.85000038147	8.85000038147	8.85000038147
Hydram body	0.0	0.0	0.0
Delivery side	4.97999030836	0.1176417768	8.76269895694
Hydram body	0.0	0.0	0.0
Fluid velocity	2.29600270525	0.0	10.3585455175

Pressures (Total) (Pascal)

Boundary or Region	Average	Minimum	Maximum
Hydram inlet	61449.8059701	57673.1953902	63228.6697039
Hydram body	54975.1183861	-11158.3891021	65264.7781042
Delivery side	30232.3646546	10139.1946372	52140.8925471
Hydram body	59450.3260859	59399.7560624	59474.1919199
Fluid pressure	57319.7481543	-12617.6070864	70944.3041021

Mass Flow Rate (kg/s)

Boundary	Value
Hydram inlet	43.898705
Delivery side	-43.898712
Net	-7.00000000364e-006

Force (N)

Boundary	X-Component	Y-Component	Z-Component
Hydram body	-165.94974	0.1638507	-1088.8053
Hydram body	666.92015	-0.00051216962	666.91988
Net	500.97041	0.16333853038	-421.88542

8.3.6 Analysis pictures for condition 1

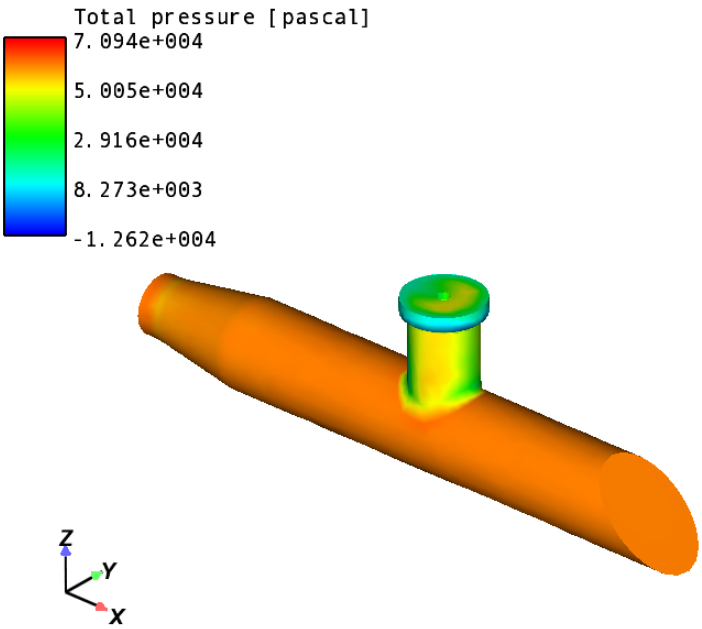


Fig 65: Total pressure distribution in valve box

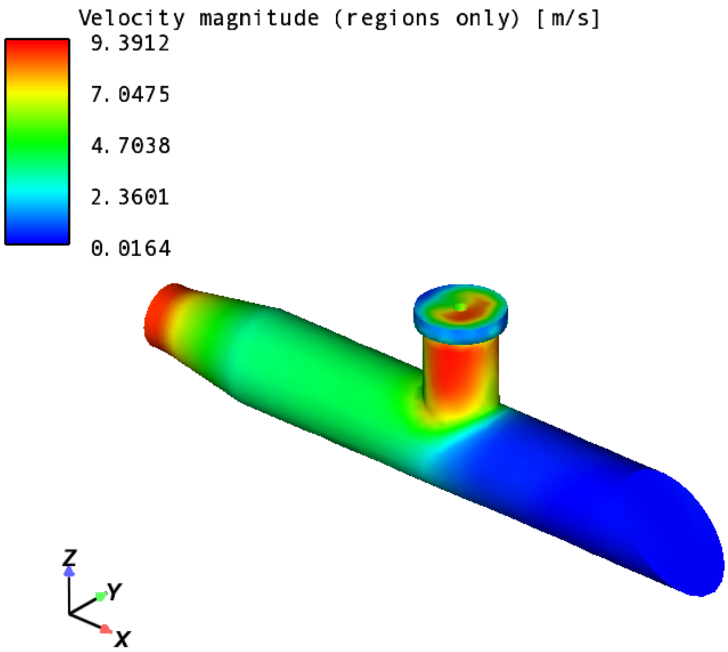


Fig 66: Velocity magnitude in hydram valve box

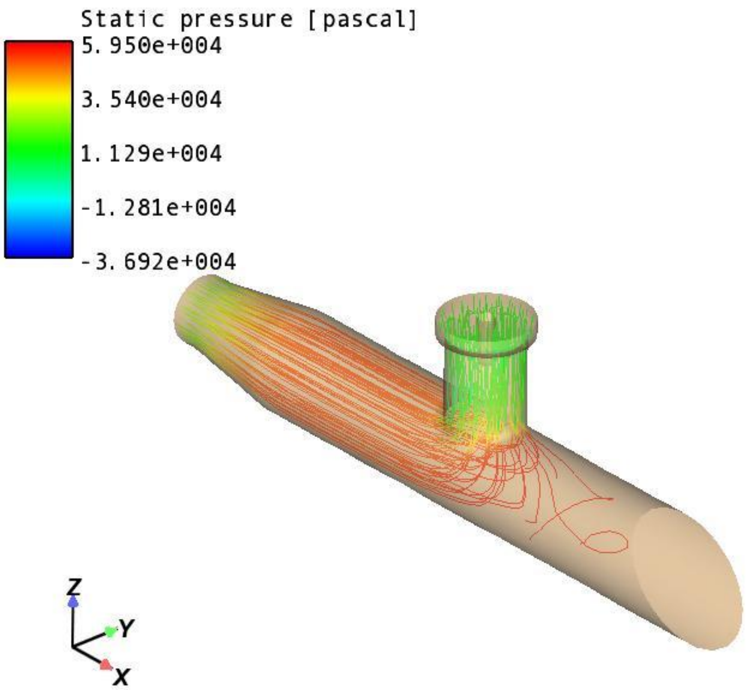


Fig 67: Pressure pattern in fluid

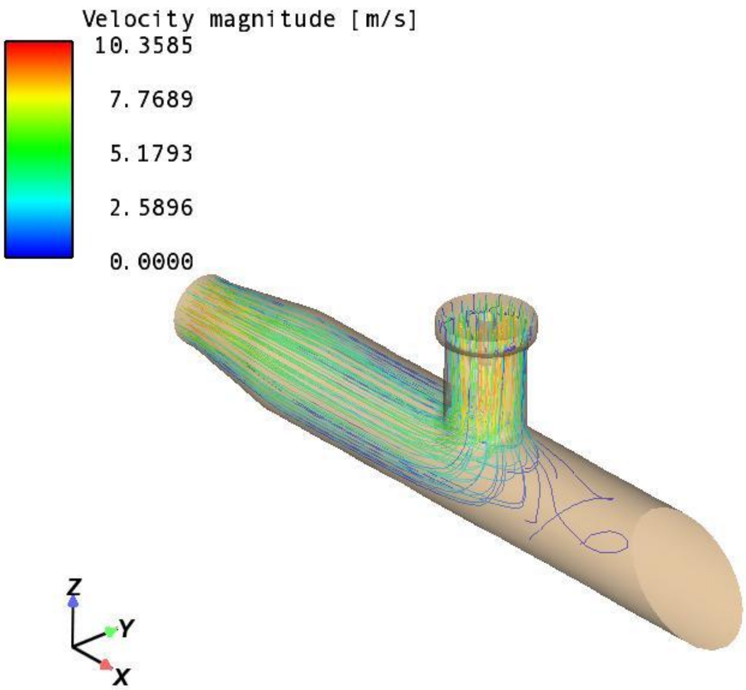


Fig 68: Velocity flow pattern

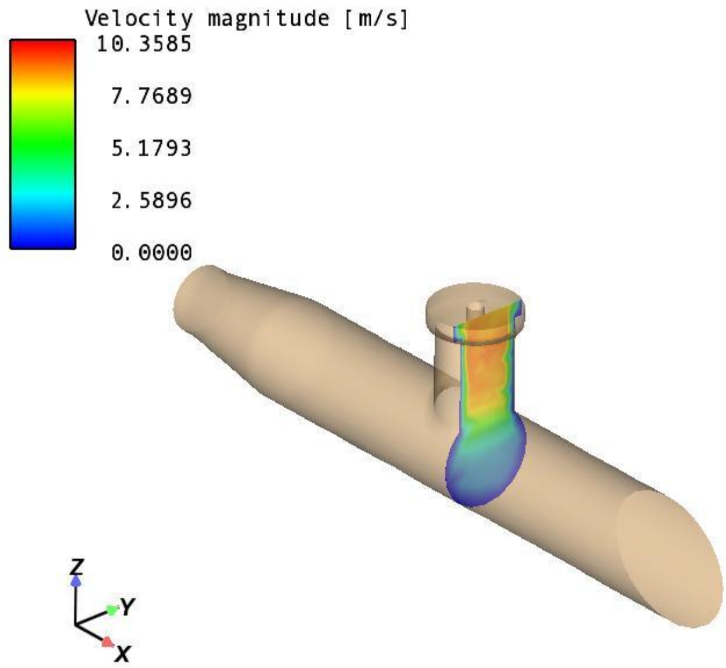


Fig 69: Velocity at section of delivery side

8.3.7 Waste valve open delivery valve closed (condition 2)

Pressure Differences (Total) (Pascal)

From Boundary	To Boundary	Value
Hydram inlet	Delivery side	2408.95431976

Velocities (m/s)

Boundary or Region	Average	Minimum	Maximum
Hydram body	0.0	0.0	0.0
Hydram inlet	8.85000038147	8.85000038147	8.85000038147
Delivery	3.91781078508	3.64172625229	4.04643947002

Fluid	2.84460876114	0.0	9.48572637591

Pressures (Total) (Pascal)

Boundary or Region	Average	Minimum	Maximum
Hydram body	6905.67724753	-159.284196609	11336.7017602
Hydram inlet	10078.242744	7844.69440236	11746.9974924
Delivery side	7669.28842425	6637.00276758	8365.79447258
Fluid	7607.86853884	-159.586262361	12581.0679204

Mass Flow Rate (kg/s)

Boundary	Value
Hydram inlet	43.898643
Delivery side	-43.898487
Net	0.000155999999997

8.3.8 Analysis pictures for condition 2

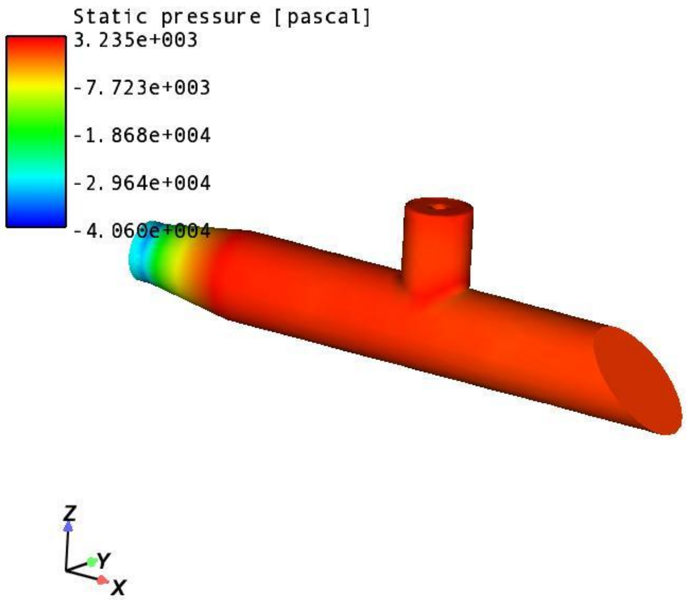


Fig 70: Static pressure distribution

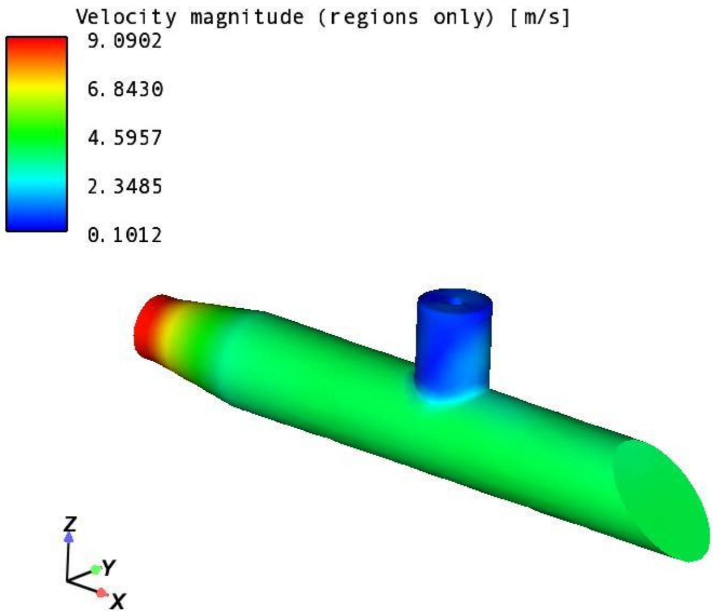


Fig 71: Velocity magnitude distribution

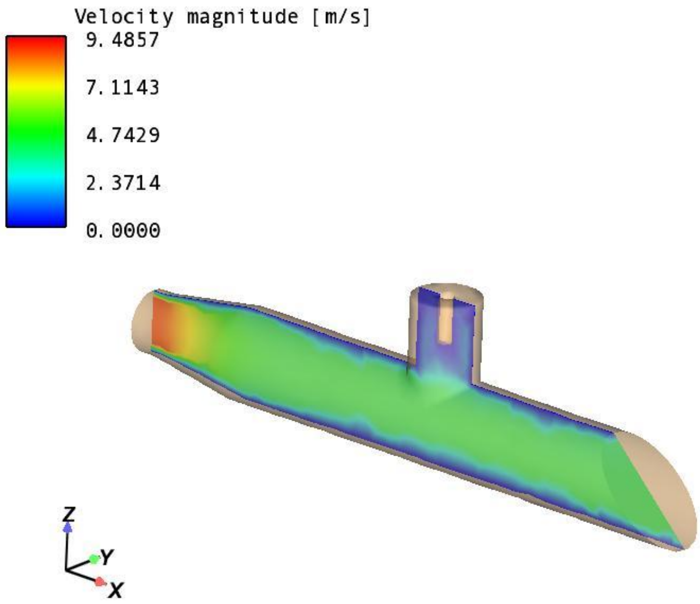


Fig 72: Velocity magnitude at mid section of valve box

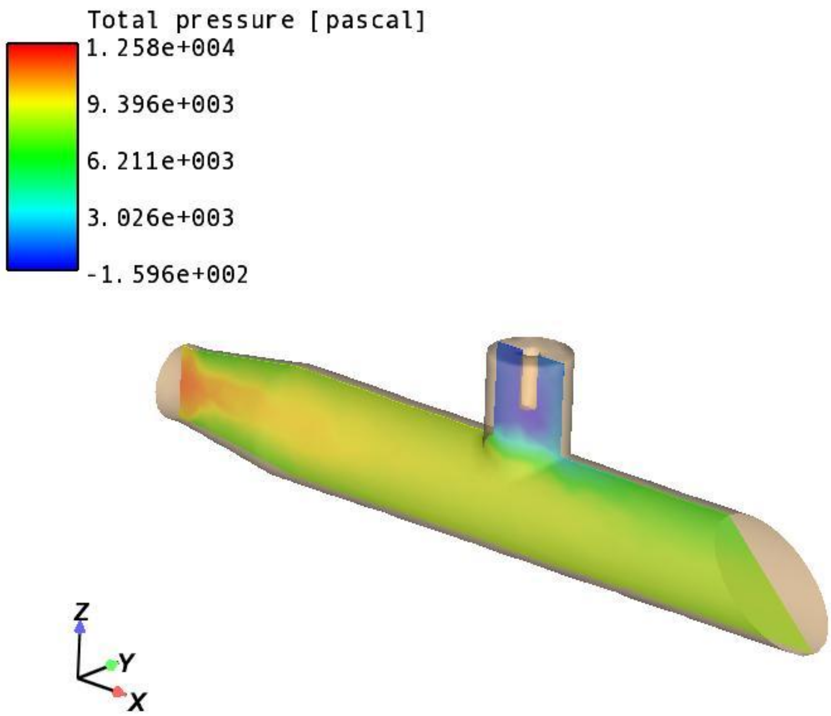


Fig 73: Pressure acting at mid section of valve box

8.4 Conclusion

The model results show that model simulates well. In all case the model prediction are much higher than experimental data.

The required pressure and velocity for good operation of hydram is successfully built to our boundary conditions. So there would not be much difficulty for operation of our designed hydram at these conditions.

CHAPTER 9:

PROTOTYPE MODELLING

We started prototype modeling of the hydram model in order to recognize what practical difficulties we would face during actual fabrication. It also gave us an idea about how exactly it would look and work.

Prototype model was made from components which where readily available in the local hardware shops.

Our prototype model was scaled to size 1:4

9.1 Part list of prototype model

Sr no	Part name	Material	Quantity
1	Valve box	Acrylic sheet 5 mm thick	1
2	Delivery valve	Acrylic sheet 5 mm thick	1
3	Perforated disc	Acrylic sheet 5 mm thick	1
4	Waste valve	Acrylic sheet 5 mm thick	1
5	Air vessel	Plastic	1

Valve box and all other components where cut to required dimensions from acrylic sheet of 1 sq feet having thickness of 5mm and where fastened together, and to ensure leak proof joint where sealed with silicon gel. A simple 1 liter capacity of plastic bottle was taken as air vessel. It was made in such a fashion that it could be easily screwed and unscrewed over the deliver valve top i.e. valve box upper are thus making it easy to assemble and disassemble.

After its fabrication we came to know that delivery valve should be properly constrained in linear position also adjustment for inclination for the waste valve should be made in such a way that it could be achieved in easiest way without removing much of the parts. Leakage problem was detected from waste valve during its closure, which was overcome by making provision of rubber sealing.

9.2 Images of prototype model

Fig 74: Assembly of prototype

fig 75: Prototype waste valve

Fig 76: Prototype delivery valve

CHAPTER:10
EXPERIMENTAL TEST RESULTS

The pump was tested for variable delivery head and for different stroke angles of waste valve. The testing showed that effect of varying stroke angle of waste valve increased and decreased supply as well as delivery head.

The experimental rig limitation didn’t allow experiments at higher head but the test and their results indicate that pump operate normally in the test region.

Below is our experimental observation table and related graphs depicting our ram pumps performance

10.1 Test results for hydram pump

Valve opening (degree)	Total head (H+h) (Hd)	3	4	5	6
15 degree	Qout (lit/min) Efficiency%	23 32.5	17 40	6 28.5	5 20
20 degree	Qout (lit /min) Efficiency	30 40	21 50	9 37.5	6 22.5

The test results can be still improved as the flow rate for which the hydram was designed was not available at the testing rig. Its is sure that the hydram would perform more efficiently at the actual site when installed.

10.2 Characteristics Curves of the Prototype

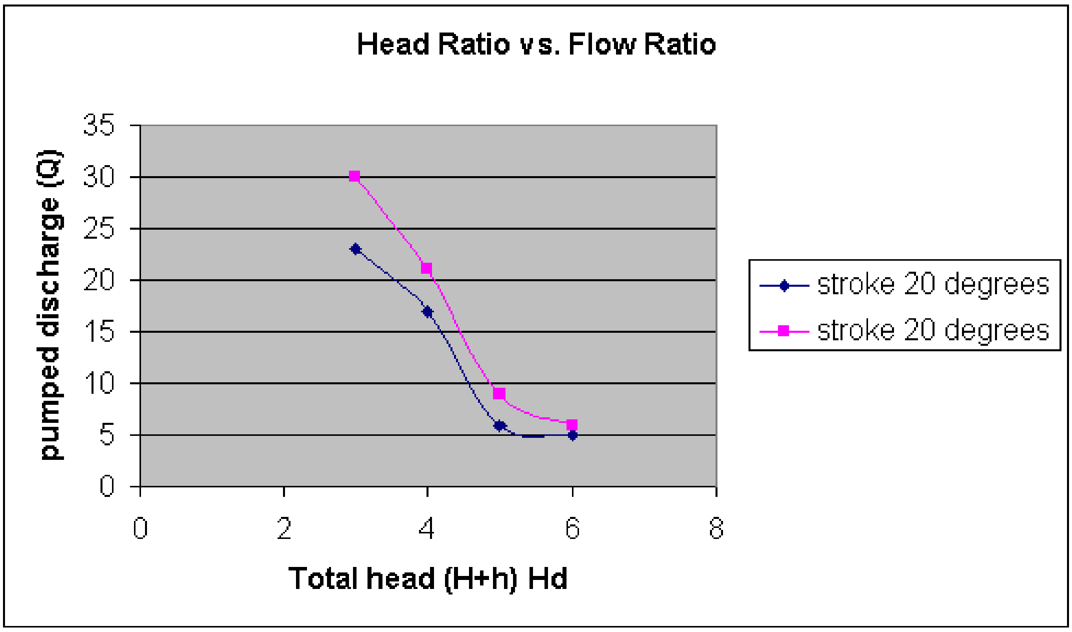


Fig: Head Ratio vs. Flow Ratio

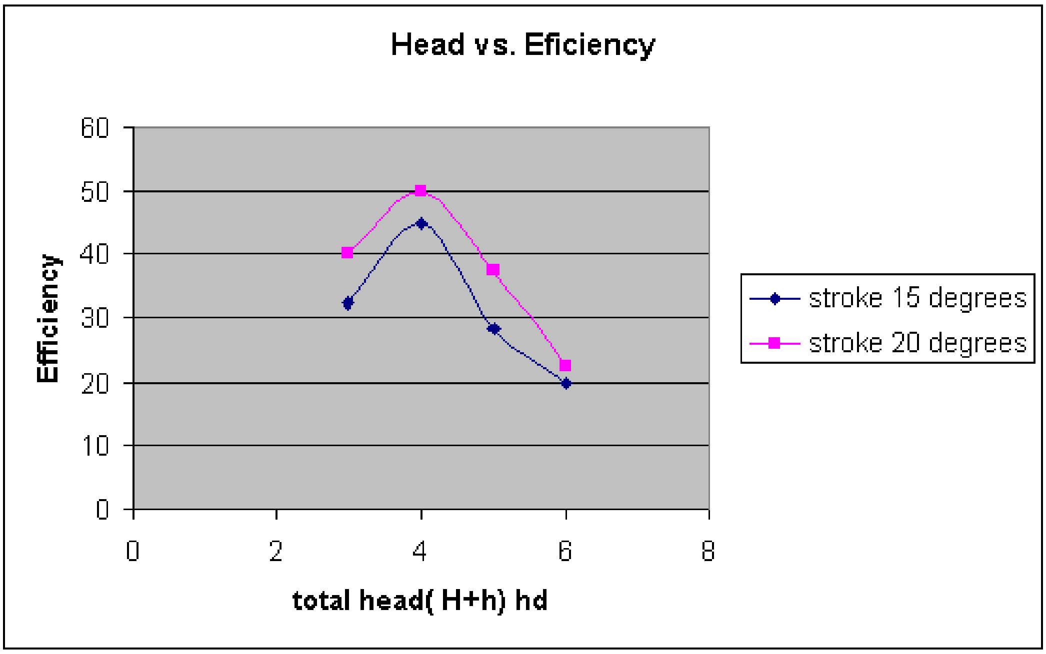


Fig Head vs. Efficiency

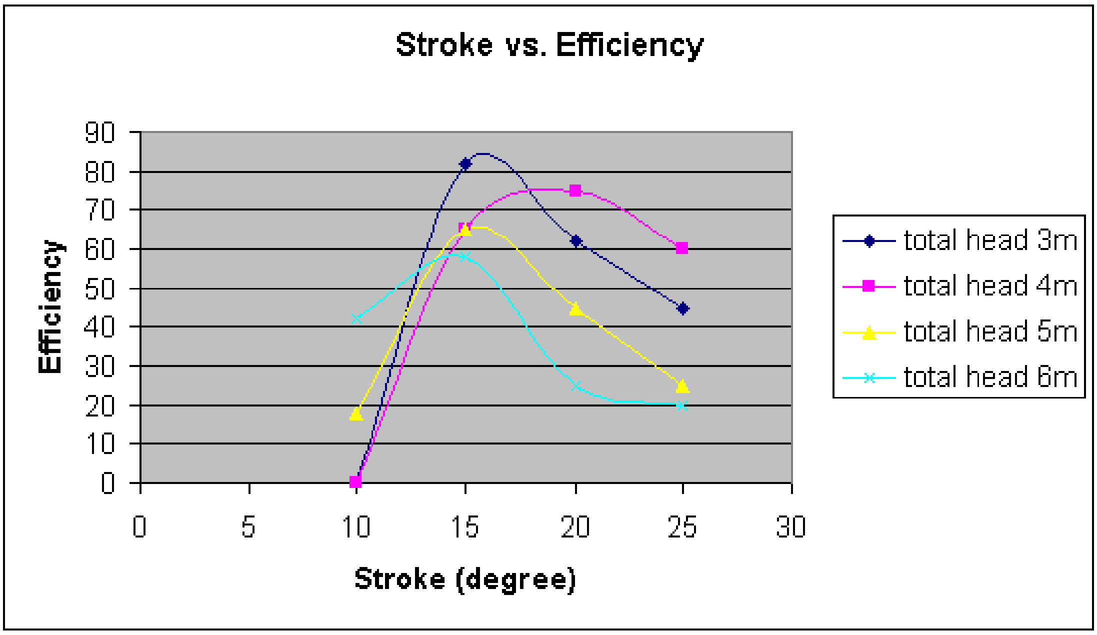


Fig: Stroke vs. Efficiency

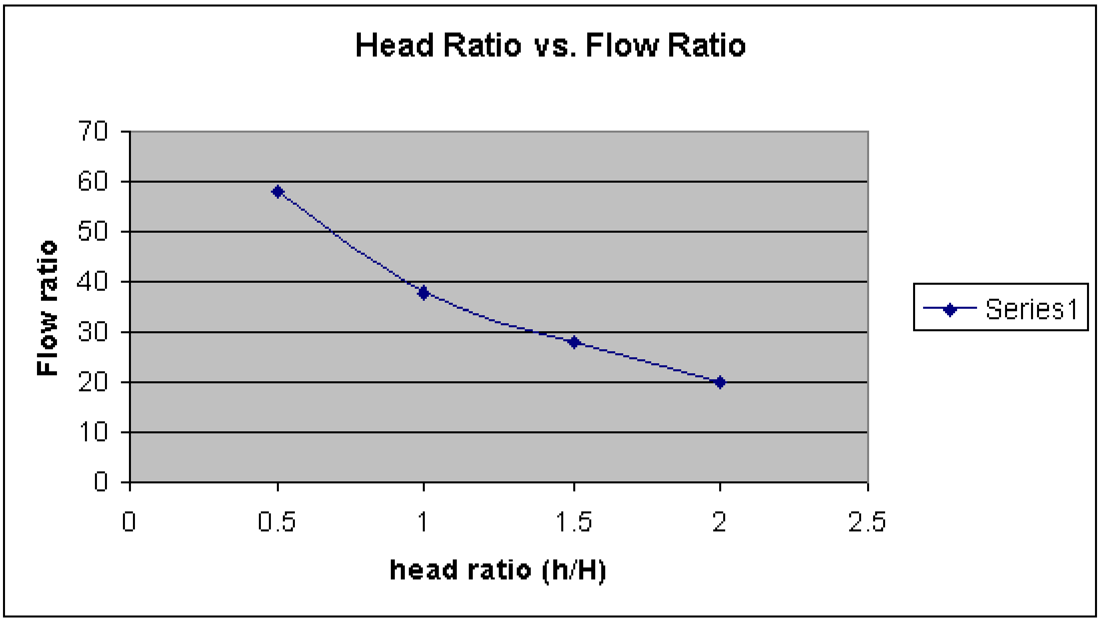


Fig:Head Ratio vs. Flow Ratio

11 CONCLUSION AND RECCOMENDTAIONS

1) The hydraulic ram pump of good quality and high performance was successfully fabricated and tested at Sameerwadi, Bagalkot state Karnataka under this project. The skills gained with this project where fabrication, modification, computer analysis and testing capability.

2) The ram developed is low cost of high performance comparable with commercial models.

3) The use of CFD model to successfully simulate the hydram performance was helpful in optimizing the design constraints

4) A weighted waste valve was designed and operated successfully. It eliminates the need of retainer springs which are not available locally.

5) A proven and effective methodology to identify suitable sites for hydraulic ram use was evolved and tested.

6) A locally made hydram was successfully developed and tested. It is recommended that ministry of water and agriculture department to establish small scale water supply schemes using hydram pumps to utilize the this pump so that it would greatly solve water problems for agricultural as well as domestic purpose.

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