PERFORMANCE STUDY OF HYDRAULIC RAM BY VARYING LENGTH AND INCLINATION OF SUPPLY PIPE

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "PERFORMANCE STUDY OF HYDRAULIC RAM BY VARYING LENGTH AND INCLINATION OF SUPPLY PIPE " is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, or any other university or society.

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CERTIFICATE

Certified that this thesis, entitled "Performance study of hydraulic ram by varying length and inclination of supply pipe" is a record of research work done independently by Shri. Ratna Kumar. V.K. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowsphip, or associateship to him.

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SYMBOLS AND ABBREVIATIONS

a	–	area of supply pipe
a_v	–	effective discharge area of waste valve
Agric	–	Agriculture
beats/min	–	beats per minutes
Cv	–	coefficient of velocity
Co	–	Company
cm	–	centimetre
D	–	diameter of supply pipe
Dept	–	department
d	–	diameter of opening of waste valve
d	–	diameter of waste water pipe
d	–	diameter of valve plate in the delivery valve
ed	–	edited
Ed	–	edission
f	–	friction factor
Fig.	–	Figure
gm	–	gram
g	–	acceleration due to gravity
GI	–	galvanized iron
ha	–	hectare
Hd	–	delivery head
Hs	–	supply head
Hd/Hs	–	magnification factor
HDP	–	high density polythene

IS	-	Indian Standard
ISI	-	Indian Standard Institute
Inst	-	Institute
kg	-	kilogram
kg/cm^2	-	kilogram per square centimetre
l	-	litre
l/min	-	litre per minute
l/s	-	litre per second
L	-	length of supply pipe
Ltd.	-	limited
m	-	metre
mm	-	millimetre
m/s	-	metre per second
m^3/s	-	cubic metre per second
mfg	-	manufacturing
MS	-	mild steel
n	-	hydraulic mean radius
η (aub)	-	D' Aubuisson's efficiency
η (ran)	-	Rankine's efficiency
η (trd)	-	Trade expression of efficiency
PVC	-	Poly vinyl chloride
Pvt.	-	private
%	-	percentage
q	-	pumping rate
Qd	-	delivery discharge
Qs	-	supply discharge

Qw	-	waste water discharge
Res.	-	research
s	-	second
t	-	time since start of operation
Td	-	time to collect 5 litres delivery water
Tw	-	time to collect 10 litres waste water
V	-	velocity of waste water through waste valve
Va	-	volume of Air chamber
Vc	-	maximum velocity of water at waste valve closure
Vd	-	volume of delivery water
Vs	-	supply velocity
Vw	-	volume of waste water
W	-	weight of delivery valve
w	-	density of water

INTRODUCTION

The importance of irrigation in increasing yield from Agricultural lands has been widely recoganised for many years. It has been reported that the utilisation of water resources in the country for various purposes is less than 10 percent of the total available water resources. The progressive developement of irrigated area in India is being adversely affected by the non availability of adequate power. The minor irrigation projects did not receive the attention it deserves in five year plans, though they have the inherent advantages such as they are most suited for small group of farmers and the supply of water can be regulated according to the wishes of the farmer depending upon the needs of the crop and the area to be irrigated. The shortage of energy often affects the lift irrigation projects. The increasing exploitation of conventional energy sources for meeting the increasing power demands is also becoming expensive. Under such circumstances, devices like hudraulic rams are to be efficiently designed for lifting water in regions where adequate supply of water and favourable conditions for installation of hydraulic rams exist.

The hydraulic ram, the ingenous, automated pumping machine in the present form was first developed by Montgoller(1796). In developing countries the difficulty in conveying electrical energy to remote hilly areas and the shortage of petroleum fuels have focussed the importance of hydraulic ram for small scale lift irigation and rural water supply. In the mountainous regions of india and other devoloping countries, there are numerous sites where hydraulic ram could be installed. This will to large extent reduce the human drudgery involved in carrying head-loads of drinking water along steep hills, and also facilitates conversion of unproductive and unused lands to efficient farming units. The simplicity of construction and the automatic operation make it especially adaptable to remote areas, which have problems of nonavailability of commercial energy sources.

Hydraulic ram is a simple automatic device, which uses the kinetic energy of a large quantity of flowing water available at lower elevation to lift a portion of it to a higher elevation. The practical merits of this device are its trouble free operation, low operation and maintanence costs and pollution free operation and that it does not require external energy.

Though this device has been in use for a centuary, there is a lack of intensive research work to understand the interaction of different parameters affecting its performance and to improve the device. This is probably because of its site specific applicability, the availability of conventional cheap fuels in abudance till recently. It is expected that a systematic research may help in bringing improvement in the performance of this device as well as reducing its costs.

The important parameters which affect the performance of hydraulic ram are

1. Supply head
2. Quantity of water supplied
3. Length and diameter of the supply pipe
4. Weight and stroke length of the waste valve and delivery valve
5. Number of cycles per minute
6. Delivery head and delivery discharge
7. Volume of Air chamber.

There is no standard method to determine the appropriate combinations of differnt parameters to achieve maximum efficiency of operation. In this study an attempt is made to find out the effect of some important parameters on the performance characteristics of the hydraulic ram.

REVIEW OF LITERATURE

In this chapter an attempt is made to give a brief review of literature relevant to the topic of the study undertaken in the past.

A manually operated machine was first installed by John white Hurst of Derby (England) in 1775 (Tacke, 1988), and he evaluated its operation and practical application.

An automatically operated machine based on same fundamental principle was invented by Joseph (1776), who is the co-inventer of the hot air balloon. He named his machine better hydraulique from which the term hydraulic ram was derived (Tacke,1988).

The hydraulic ram, the ingenious,automated water-pumping machine in the present from was first developed by Montgolfier (1796).

A few hydraulic ram installations in India are:

Blake hydram manufactured by John Blake Ltd:, England was installed at Tajmahal, Agra in 1900 for raising water at the rate of 3.15 L/ sec working satisfactarily with a very low maintenance cost (Lal, 1979).

In U.P. a number of hydraulic rams were installed in garhwal hills. In the five districts of Garhwal division there are 368 intallations. Hydrams were installed at

Komaun hills (U.P.), Himachal Pradesh and in north eastern states and in Nepal also. In Garhwal division 2208ha of land is irrigated by hydraulic ram installations.

Considerable scope for installations exists in other parts of the country also. The scope exists in Jammu and Kashmir, Sikkim, West Bengal, Ootty Hills in Tamil Nadu, western ghats in Kerala, Konkan areas in Maharashtra, southern part of Karnataka and Panchmarhi hills in Madhya Pradesh. (Technical information service 1982).

Comparison of a few of commercially avilable hydraulic ram is given below (tacke ; 1988)

Type of hydraulic ram	Drive pipe(mm)	Efficiency (trd) %	Price for ram alone (Approx) (US -1982)
Vulcan 2.5	65	68	1200
Blake hydram 3.5	65	67	1000
Sano No 5/65 mm	65	77	1000
Rife 20 H DV	50	60	1100
Schlumpf 5 A 23	50	61	2700
AHOCH 66-110-18	65	60	2100
Briaru D4	50	60	3200
Ce Co Co H 50	50	77	3500
WAMA No.6	65	50	1500
B 2H- Ram W6	65	30	1200

The efficiency was computed in all the cases for the following conditions.

Supply discharge Qs = 90 l/mts.

Supply head Hs = 7.5 m

Delivery head Hd = 75 m

Rife hudraulic .Engineering Mfg. Co: U.S.A, Schlumpf A.G. maschinenfabrik; Switzerland, John Blake Ltd., England, J.M. Descland; France, Green and Carter; England are some of the hydraulic ram manufactures.

Attempts were made to understand the complex relationship involved in hydraulic behaviour of water moving through the hydraulic ram (Wanger, 1898 and Simon, 1904) as reported by Herza (1908) and Calvert (1957). Raveendra and Sheshadri (1981) said that no standard method exist to determine the appropriate combination of the parameters to achieve maximum discharge for the required head conditions. Comercially available hydraulic rams are designed through field experience (Watt,1975).

Hydraulic ram works by the water hammer effect which is generated by the automatic and intermittent stopping of the flow of water.

2.1. Water Hammer Effect

The simplest case of water hammer is caused by an instantaneous valve closure and can be explained as follows: (Calvin, 1952).

Upon closure of the valve, a wave of positive pressure travels upstream with a velocity of sound, compressing the water and streching the conduit shell. Upon reaching the reservoir, the pressure wave obtains relief and drops down in intensity to reservoir pressure. This in turn allows the compressed water stored in the streched pipe to drop down to reservoir pressure. Again by means of the passage of a negative pressure wave travelling downstream with the velocity of sound and converting the conduit velocity from zero to minus V_1 in the reverse direction. When the negative wave has reached the closed valve at the downstream end of the conduit,all the water in the conduit is at that instant travelling upstream with a velocity minus v1. Owing to the inertia of the water, this negative pressure wave travelling downstream will next be reflected at the valve so as to travel upstream with the same negative sign. Behind the downstream of the negative wave so reflected, the conduit velocity will again drop to zero, and the conduit shell will shrink a propotionate amount below the original size. so as to furnish the volume of water necessary to maintain the velocity minus V_1 ahead of the travelling wave until the wave reaches the reservoir. When the reflected negative wave reaches the reservoir, the pressure will rise to reservior level, and a positive wave elevating the conduit pressure to the normal reservoir head will be propagated downstream. The velocity upstream from and behind the wave will next be converted to positive V_1. This completes one cycle of wave motion, the same process will be repeated indefinetly.

Streeter; V.L and Wylie; E.B (1967) reported that the speed of propagation of pressure wave is given by

$$C = \sqrt{\frac{1}{\rho\left(1/K + \frac{C_1 D}{TE}\right)}}$$

where K = Bulk modulus of liquid,

ρ = Density of liquid,

E = Elastic modulus of pipe material,

T = Pipe wall thickness,

D = Pipe diameter

Streeter; V.L and Wylie; E.B.(1967) also reported that the friction of the pipe damps out the oscillation in waterhammer effect. Then the net head available for water hammer is givenby $H_n = H_s - KQ^2$.

where 'Hs' is the actual head available

$$K = \left(\frac{\lambda L}{D} + Km\right)\frac{1}{Ap^2}$$

where 'Km' is the minor loss coefficient for the pipe line and 'λ' is the friction factor.

2.2. Input of hydram

Lal (1979) reported that the lowest head at which ram can work is 60 cm. The pumping rate can increase by increasing the supply head (Tacke, 1988). Indian standard (I.S 10808, 1984) recommend that the depth of tank should be minimum of 1 m and 0.5 to 0.7 m head of water should be maintained in the intake tank above the mouth of intake pipe to avoid sucking of air in intake pipe during operation.

More water is required to operate larger size ram and more water can be delivered to a higher level (Tacke, 1988). Indian standard (I.S. 10808, 1984) specified out the capcity of intake tank corresponding to the size of the ram.

Size of ram (mm)	Capacity (litre)
50 x 25	200
75 x 38	1000
100 x 50	2000
150 x 75	6000
200 x 100	10000
300 x 150	25000

2.3. Supply pipe

The delivery head and the ratio of length of supply pipe and supply head (L / Hs) should be small for efficient working of ram (Gibson, 1930). He recommend that it is advisible wherever possible that this ratio should not exceed 2.5. However, where necessary, this may be largely exceeded and supply pipe length of 305 m with a ratio L / Hs = 25 is well within the limits of everyday practice.

Ananthaswamy (1967) observed that a longer length of supply pipe provides larger momentum of water. But then frictional losses are also increased. He said that the ratio L/Hs shold be between 2.5 and 3. He also said that the ratio L/Hs as high as 25 to 30 can be used in some cases.

Smaller supply pipe length will reduce the impulse and subsequently delivery head. Hence in order to develop maximum impulse, the supply pipe should be as long as possible (Lal,1979).

Lal(1979) developed an equation for the size of the pipe on the basis that the size of supply pipe should be such that the amount of liquid pumped by the ram per second is equal to 1/3 times the average quantity of liquid consumed by the ram.

The expression is given by $D = \sqrt{0.5(Qw+Qd)}$ metres, where D is the diameter of the supply pipe.

where Qw = waste water discharge in cumecs

Qd = delivery discharge in cumecs

The material of the supply pipe also affects ram performance. Hydraulic ram is operated with sucessive water hammer pressure waves. The velocity of water hammer pressure wave in the supply pipe is depends on the modulus of elasticity of the pipe material. Hence the pipe wall must be thick enough to prevent bursting or flexing excessively. Steel is commonly used as pipe material(Willardson,1984).

A mathematical formulae is developed by Herza (1908) to determine velocity in the supply pipe before and after the closure of the waste valve. the period during which the valve is fully opens depends entirely on the time necessary to produce the required velocity of flow along the supply pipe,and will increase with weight of valve,and with ratio of length of supply pipe to supply head.

The velocity of flow in the supply pipe after 't' seconds is given by

$$V = C \cdot \frac{a}{a_v} \frac{1 - e^{-\frac{2c}{k}t}}{1 + e^{-\frac{2c}{k}t}}$$

where $c = \sqrt{\dfrac{2gH_s}{1 + \frac{fl}{n} \cdot \frac{a_v^2}{a^2}}}$

and $K = 2l \frac{a_v}{a} \cdot \frac{1}{1 + \frac{fl}{n} \cdot \frac{a_v^2}{a^2}}$

where f = friction factor

n = Hydraulic mean radius = D/4 for pipe running full.

2.4. Delivery pipe

The delivery pipe is usually made of any material like poly vinyl chloride (PVC) or high density polyethene(HDP). If the delivery head exceeds the pipe pressure specification, then the lower portion of the delivery pipe must be galvanised iron pipe.(Tacke,1988).

The discharge of the hydraulic ram is inversaly propotional to the delivery head.The discharge pipe may have a uniform size if the water is tapped at highest point only.

If however the water is to be taken out at intermediate points, a variable size delivery pipe line may be used. Alarger pipe is used in the lower section to reduce the head loss by friction and to get a higher rate of discharge. The pipe size may be reduced at each point the flow is tapped.

The size of delivery pipe line in relation to the supply pipe should be selected according magnification factor is given below

Magnificationfactor. (Hd\Hs)	Ratio of diameter of delivery pipe to supply pipe
Up to 10	1:2
10 to 20	1:4
20 to 30	1:6

The delivery pipe should be laid in shortest route to achieve high efficiency. In delivery pipe line sharp bend should be avoided to reduce frictional resistance to the flow of water for achieving higher efficiency(Indian standards;IS;10808).

2.5. Waste valve

Gibson (1930) recommended a waste valve weight between 0.021 kg/cm^2 to 0.0315 kg/cm^2, so that a static pressure corresponding to 0.315m head would be sufficient to prevent any opening.He found that time of opening of waste valve increases as the weight increases, since the acceleration of the valve will diminish as its weight increases.He also found that the time during which it remains off its seat increases with the length of supply pipe and delivery head, and will decrease with increase in (Hs/L) ratio.Gibson got the following results from the experiment conducted with the ram having a supply pipe of 26m long with a supply head of 2.48m.

Delivery head(Hd) m	Proportion of cycle during which valve is open.		
	Wide open	closing	closed
3.14	0.58	0.11	0.31
5.88	0.78	0.09	0.13
15.39	0.88	0.07	0.05

Anantha Swamy(1967) found out that the increase in stroke length of delivery valve reduce the delivery head.This is due to the fact that when the stroke length increases the pressure devoloped in the valve box is not high. The increase in stroke length of valve increases the time of opening, which in turn increases the wastage of water. Hence the ram works at lower efficiency when the stroke length is high.For a given stroke length of waste valve,increase in delivery head increases the wastage of water.Hence the ram efficiency will be higher at some what moderately low delivery heads.

As per Indian standards (IS 10809,1984)the cross section of supply pipe should be less than the area of waste water opening.

Suseela (1989) observed that the weight of waste valve have no significant effect on the operating range of hydraulic ram. For an increase in the stroke length of waste valve, there is a large reduction in the beat frequency.

2.6. Air chamber

Silver (1978) recommended an air chamber volume of 100 Qd for efficient working of ram, where Qd is the desired discharge for one cycle of operation.

Selvarajan (1985) conducted experiments with a hydraulic ram having an air chamber volume of 7.86 litres in order to study the rate of air depletion from the air chamber.He observed that the volume of air in the air chamber decreases as the time increases.this is due to air dissolving in water and escaping with the delivery discharge. He developed an equation from a linear correlation analysis.

$$Va = 5.222 - 0.163t$$

where Va is the volume of air in the air chamber in litres and 't' is the time since start of operation in hours. He said that this type of relation can be used to compute the duration of uninterrupted opertion of hydraulic ram provided that there is no other mechanical failure of the system.

Suseela (1989) conducted experiments with Air chamber volumes of 4.99, 7.39, 9.52 litres. She found that there is a steep increase in delivery discharge with the increase in volume of Air chamber.

2.7. Delivery valve

The time during which delivery valve remains closed increases as the delivery head increases, which in turn decreases delivery discharge (Gibson,1930).

box and the ratios L/Hs and Hd/Hs. He observed that for optimum performance the ratio Hd/Hs should be about 5 and under these conditions as high as 75% can be obtained.

Lal (1979) reported that the maximum efficiency of ram is obtained if the ratio Hd/Hs is less. With Hd/Hs = 4, he got an efficiency of 72% .He observed that when the delivery head is 6 to 12 times the fall, quantity of water delivered by the ram is 1/12 to 1/24 of amount supplied.

Modi, and Seth (1980) reported equations for the delivery discharge and waste water discharge as follows.

$$q = [(\pi/4)d^2)] \times \frac{V_0}{2} \times t_2$$

$$Q = [(\pi/4)d^2)] \times \frac{V_0}{2} \times t_1$$

where 'q' is the delivery discharge.

Q = waste water discharge

t_2 is the time during which waste valve is opened.

t_1 is the time during which waste valve is closed.

V_0 is the maximum velocity of flow in supply pipe.

The efficiency of hydram for various lift magnification as given by Indian Standards (IS; 10809; 1984) is given below.

Sadaphal (1986) conducted regression analysis to determine the relationship between delivery discharge, weight of delivery valve and stroke length of delivery valve and the multiple regression equation obtained was

$$Qd = 4.48 + 8.34\,w - 0.36s$$

where Qd = delivery discharge (l/min.)

w = weight of delivery valve (kg)

s = stroke length of delivery valve (cm)

He got a coefficient of determination 0.75.

As the weight of delivery valve increases, the effect of stroke length on delivery head gradually decreases (Suseela, 1989).

2.8. Output of the ram

Anantha Swamy (1967) observed that a longer length of supply pipe provides a larger momentum of water. But then the frictional losses are also increased. He recommended an L/Hs ratio of 2.5 to 3. But ratios as high as 25 to 30 are used in some cases. The ratio(Hd/Hs) affects the efficiency of the pump.When the ratio Hd/Hs is upto 4 an efficiency as high as 75% can be achieved. If this ratio is increased further the efficiency falls rapidly.

Nagaratnam (1971) observed that the efficiency of hydraulic ram depends upon the losses in the pipe and valve

Lift magnification.	Efficiency %
Up to 3	85
4	80
5 and 6	75
7	70
8 and 9	65
10 and 12	60
14 and 15	55
16 and 18	45
20 and 25	40
30	35

An increase in the velocity of wate in the supply pipe at waste valve closure normally increases the pumping rate, but more water (Qs) is needed to operate the ram.

Kitani and Willardson (1984) conducted experiments on a 24.3 ha farm near Cornville. The farm was used as a pasture land and a side roll sprinkler system was used for irrigation. Four hydraulic rams were used in parrallel since 1976 to obtain water heads and flow volumes large enough for the sprinkler irrigation system. They found that the hydraulic ram can effectively used to provide water used adequate pressure and to operate agricultural sprinkler irrigation systems. They also emphasized that if a physically suitable installation site is available, use of hydraulic ram may be the most economical pumping system.

Indian standards (Is. 10809; 1984) specifies that a hydraulic ram of suitable size can be added in a battery to increase the discharge instead of going for bigger hydram at a very high cost. Size of the delivery pipe may be increased initially to accomodate discharge of additional hydram or separate delivery line may be connected to existing line. The hydraulic rams may be installed in a battery when discharge of available water from a stream varies significantly over the season.

MATERIALS AND METHODS

3.1. Objective

The objective in general of this research work is to evaluate the performance of a hydraulic ram by varying different parameters namely len'.gth and inclination of supply pipe and L/D ratio of Air chamber.

The specic objectives are

1. Study performance of hydraulic ram by varying length of supply pipe.
2. Study the effect of L/D ratio of air chamber in. the delivery discharge for a given volume.
3. Study the effect of volume of air chamber on delivery discharge.
4. Study the effect of continous operation of ram on disharge.
5. Study the effect of inclination of supply pipe.

3.2. General description

Hydraulic ram is a simple automatic device, which uses the kinetic energy of the large quantity of flowing water available at lower elevation to lift a portiion of it to a higher elevation.

Ram consists of a supply pipe, fixed at an inclination. The upper end of supply pipe is connected to the supply reservoir atits lower end to a valve box.The supply pipe is the essential part of the installationin which the potential energy of the supply water is converted into kinetic energy. The supply pipe should have a sdlope of about one vertical to eight horizontal.The valve box has two automatic valves, waste valve and delivery valve.Waste valve falls open downwards by gravity. The delivery valve is a nonreturn valve and is usually is a simple rubber disc covering a grid shaped seat. It opens upwards.Air chamber is prioivided above .the delivery valve assembly.When the ram operates,air vessel is partly fiiled with water and partly with air. The delivery pipe is connected to the air chamber.The minimum pressure in the air chamber is the delivery pressure. A pressure gauge is connected to the delivery pipe just before the gate valve, to measure the delivery head. All the hydraulic rams are equiped with an air valve which is a small brass plug with a pin hole drilled through it. The air valve is used for the replenishment of air in the air chamber.

The operation of hydraulic ram is briefly discribed below.

3.2.1. Action of the ram

The ram operates on a flow of water falling under a head Hs from the supply resorvoir down through the supply pipe to the valve box. Initially both waste valve and delivery valve are closed. When waste valve remains closed, the hydraulic ram dose not function at all, and the delivery valve also remains closed by its own weight. When the waste valve is opened manually, the water in the supply pipe begins to run through the waste valve and the flow is set up. The velocity of water in the supply pipe increases due to the hydraulic gradient provided. During this perid, the dynamic pressure of the water on the underside of the waste valve become greater than the dead weight of the waste valve. Then the waste valve will close. Owing to this closure, momentum of moving column of water in the supply pipe is destroyed. This creates a high positive water pressure. if this pressure exceeds the pressure on the top of the delivery valve in the air chamber the delivery valve opens. The water will rush in to the air vessel through the delivery pipe line. When pressure inside the valve box decreases and is less than the pressure in the air chamber, the delivery valve closes preventing the return flow of delivered water.In the water hammer cycle after the positive wave , a negative wave will genarate. This in turn will create a negative pressure in the valve chamber. The waste valve will open due to this negative pressure and due to its own weight and allows water to flow through the waste water outlet.The waste valve opens because the pressure inside the valve box goes below at atmospheric pressure due to water hammer effect. As the velocity of water in the supply pipe increases the waste valve again closes suddenly and the cycle is repeated. The continous operation of the ram will increase the pressure inside the air chamber, which in turn force the water in the air chamber to an elevation many times higher than the supply head.

The air in the air chamber is gradually carried away by the water. So an air valve is provided through which air is admitted to the air chamber at the begining of the ram operation.

Cycle of operation of hydraulic ram can be summed as follows:

1. Both the delivery and waste valves are closed.
2. Initially to start with, the waste valve is opened and water starts flowing through the valve.
3. Waste valve closes suddenly causing water hammer.
4. Momentary high pressure resulting from water hammer, forces open the delivery valve.
5. Water enters the air vessel through the delevery valve.
6. Pressure rises in the air chamber slowly bringing the incoming water to rest. This closes the delivery valve, thus completing the cycle.

The operation of the hydraulic ram depends upon the successful creation and destruction of velocity in the supply pipe.

The hydraulic ram at the KCAET, Tavanur has the provisions for varying various parameters like weight and stroke length of the delivery and waste valves. By varying the stroke length of waste valve, number of strokes per minute was varied. Since weight of waste valve is an important parameter, provision was also given to vary the weight of waste valve.

The supply and delivery pipe size were 50 mm and 25 mm respectively. This is commercially specified as 50 mm x 25 mm hydraulic ram. A centrifugal pump was utilised to supply water from a sump to a supply tank of the hydraulic ram. Supply tank is of size 101cm x 91 cm x 70cm.

The major parts of a hydraulic ram are waste valve, delivery valve and air chamber. Both valves are made of brass. The air chamber is fabricated with 76 mm G.I pipe of length 210 cm. Commercially available standard G.I pipe fittings are used as the principal components of hydraulic ram.

3.3. The Experimental Set up

The general lay out of the experimental set up is presented schematically in fig(1). The detailed drawings

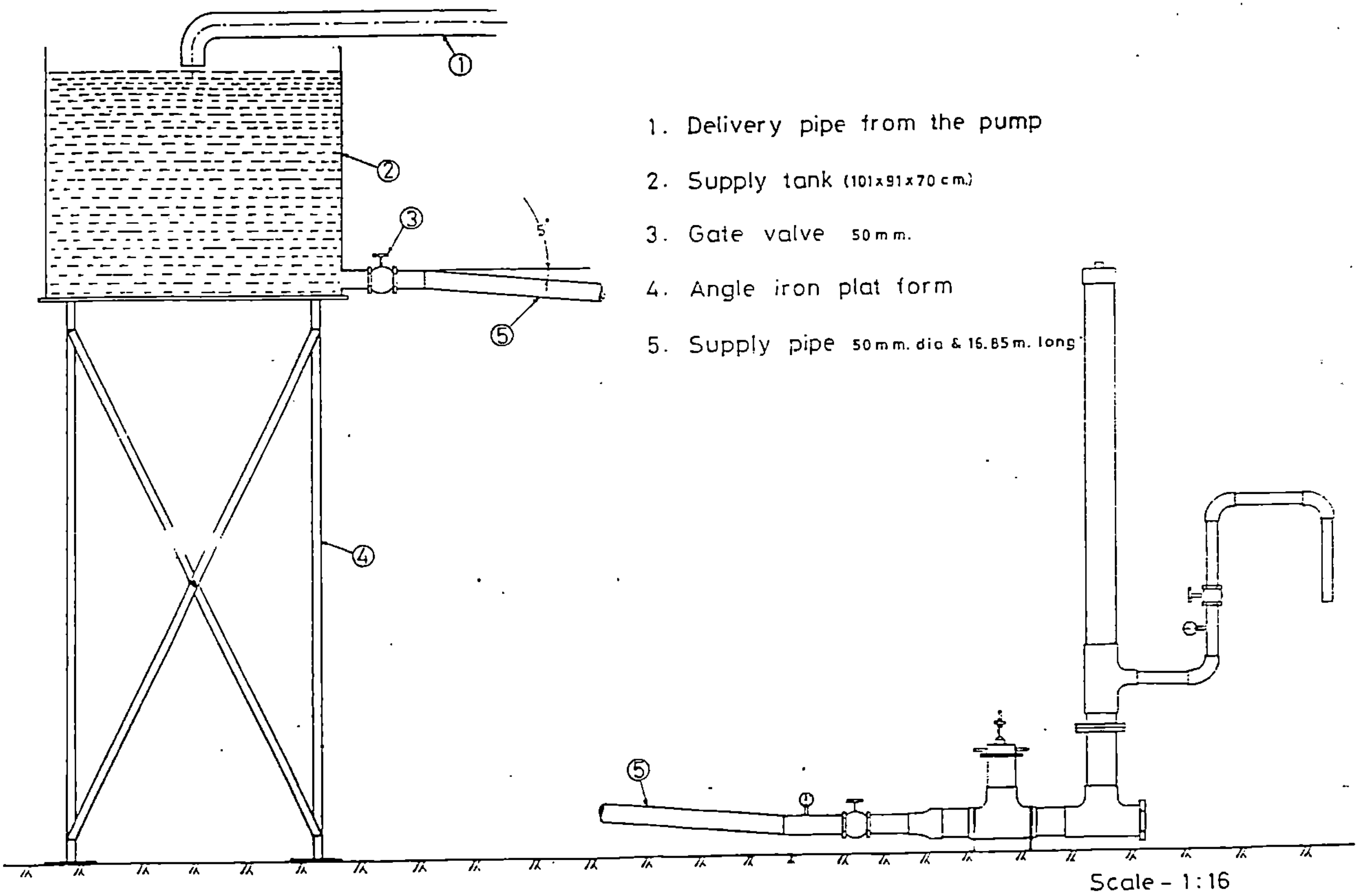
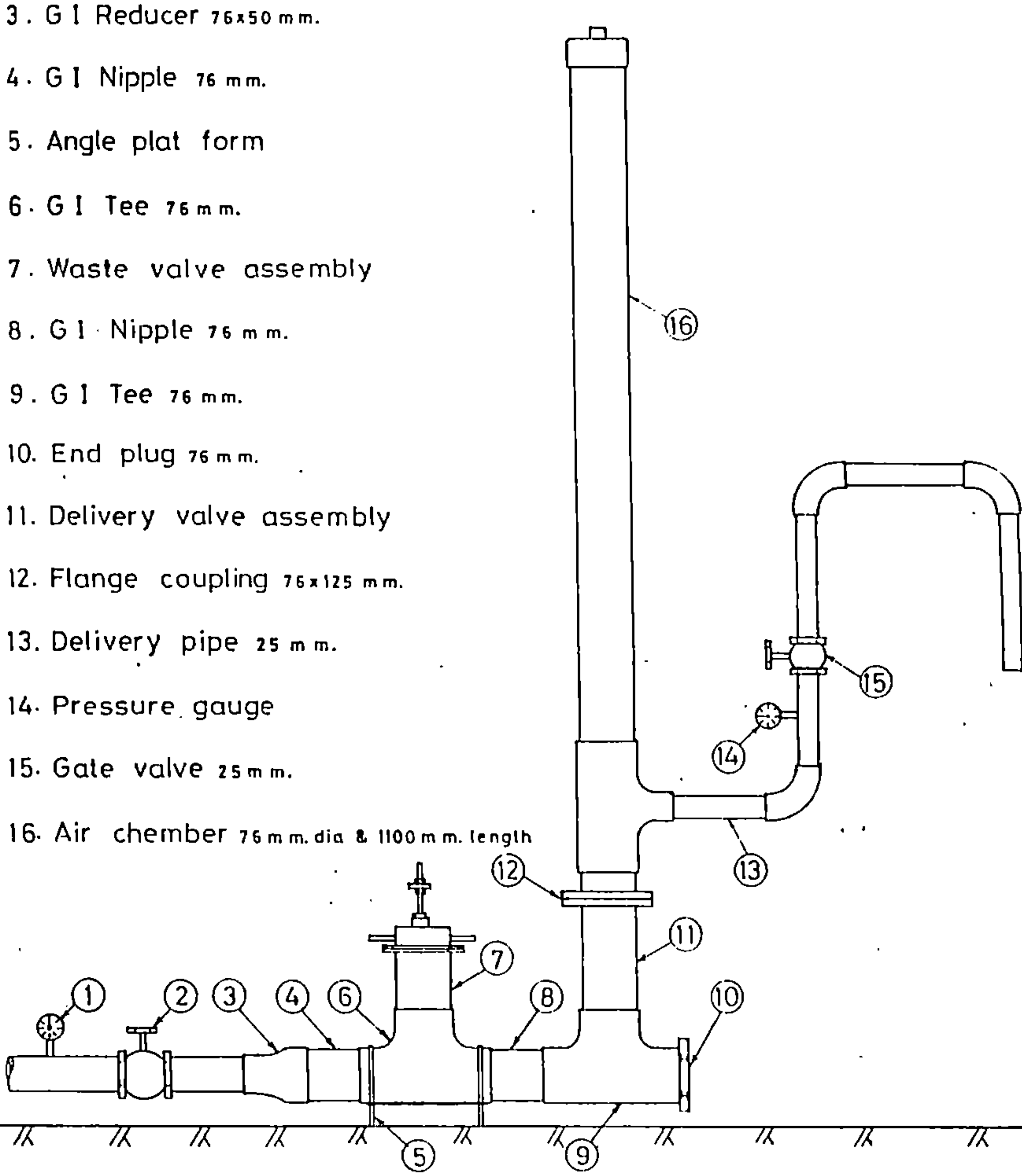


Fig. 1a. Schematic diagram of the general layout of hydraulic ram.

1. Pressure gauge
2. Gate valve 50 mm.
3. G I Reducer 76x50 mm.
4. G I Nipple 76 mm.
5. Angle plat form
6. G I Tee 76 mm.
7. Waste valve assembly
8. G I Nipple 76 mm.
9. G I Tee 76 mm.
10. End plug 76 mm.
11. Delivery valve assembly
12. Flange coupling 76x125 mm.
13. Delivery pipe 25 mm.
14. Pressure gauge
15. Gate valve 25 mm.
16. Air chember 76 mm. dia & 1100 mm. length



Scale - 1:10

Fig. 1b. Arrangement of various parts of hydraulic ram

Plate 1 & 2. Hydraulic ram installed in the hydraulic laboratory..

of waste valve and delivery valve are also given in the figures (2) & (3). The different parts of hydraulic ram are given below.

3.3.1. Constant head supply system

A centrifugal pump was used to supply water to the supply tank of the hydrualic ram. The supply tank was of size 101 cm x 91cm x 70cm. One 50mm outlet was provided at the bottom of the tank, which in turn was connected to the supply pipe. The height of water in the supply tank was maintained at a constant head of 1.955m from the centre of the waste valve by the over flow arrangement. The over flowing water returned to the sump through a 25mm pipe.

3.3.2. Supply pipe

The Supply Pipe was of 50 mm in size. The observations were taken with a supply pipe having length 14m.

3.3.3. Waste valve assembly

The sectional view of the waste valve is given in fig (2). The Waste Valve Assembly was connected to a 76mm G.I.Tee.The length of valve stem was so designed to vary the stroke length.There was provision to vary the weight of the waste valve.A suitable gun metal bush was provided to the valve stem, to avoid excessive friction and uneven movements of the valve during the operation.

29

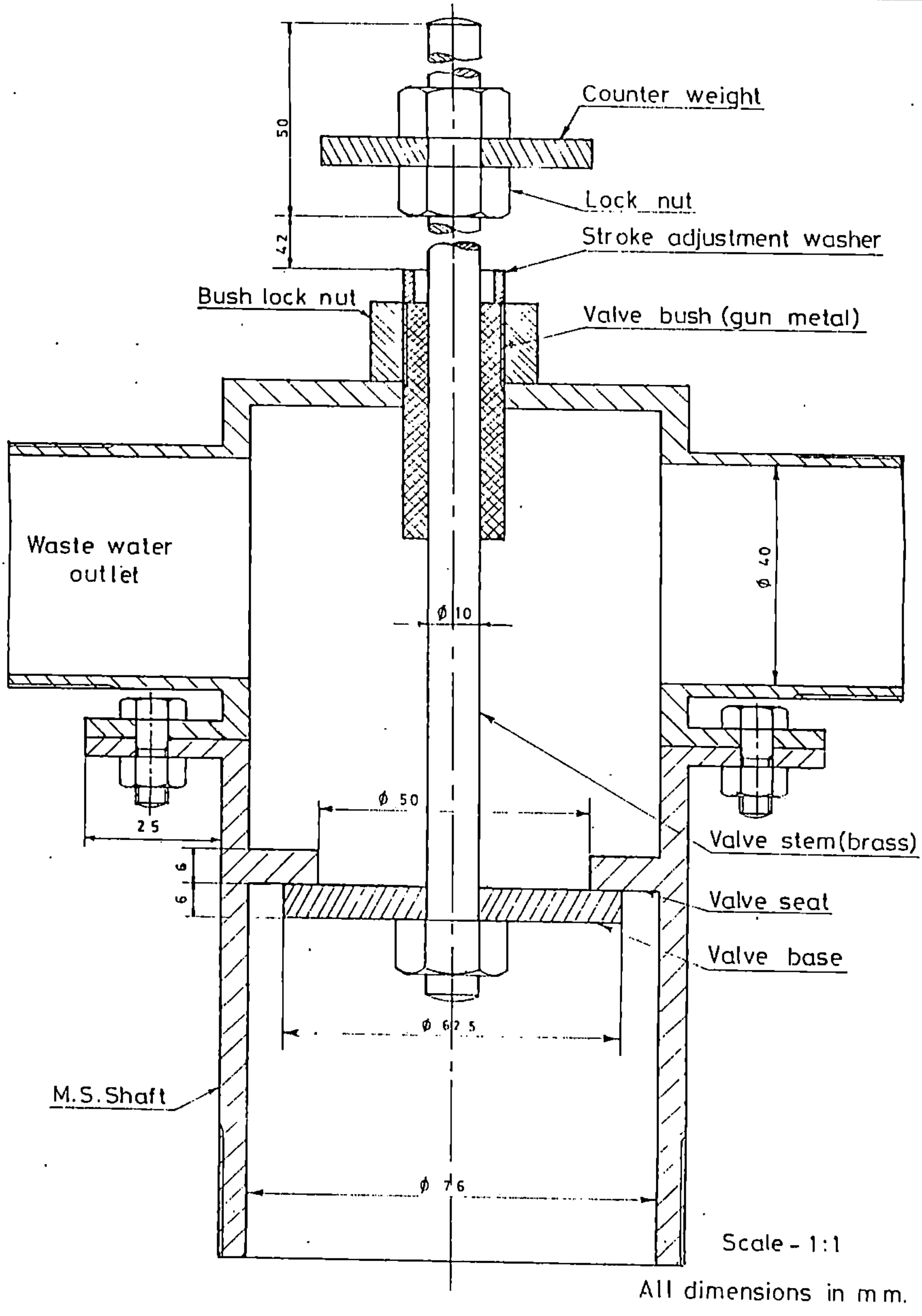


Fig. 2. Sectional view of waste valve

Stroke length of the waste valve was varied by adjusting the length of the valve stem using a washer.The maximum length of the stroke taken was 42mm. Stroke length was measured by using vernier caliper. The weight of the waste valve was varied by placing steel discs of 100gm and 200gm in between the lock nuts. Thus totally three waste valve weights namely 400gm, 500gm, 600gm were used in the present study.

3.3.4. Delivery valve assembly

Sectional view of the delivery valve is given in fig (3). The stroke length of delivery valve was varied by inserting the spacers of varying lengths. The spacers were of P.V.C pipes of 15mm diameter and 2mm thickness.Check nuts were used at the top of the valve stem to restrict the movement of the spacer.Provision was also given to vary the weight of the delivery valve. The weight of the delivery valve was varied by placing steel discs of different weights on the steel plate reinforcing the leather flap.

3.3.5. Air chamber

The air chamber smoothens the fluctuations of pressure of water flow through the delivery pipe of ram. The waste valve as well as delivery valve will be operating intermittenly due to the water hammer effect.Accordingly the discharge through the delivery pipe also will be

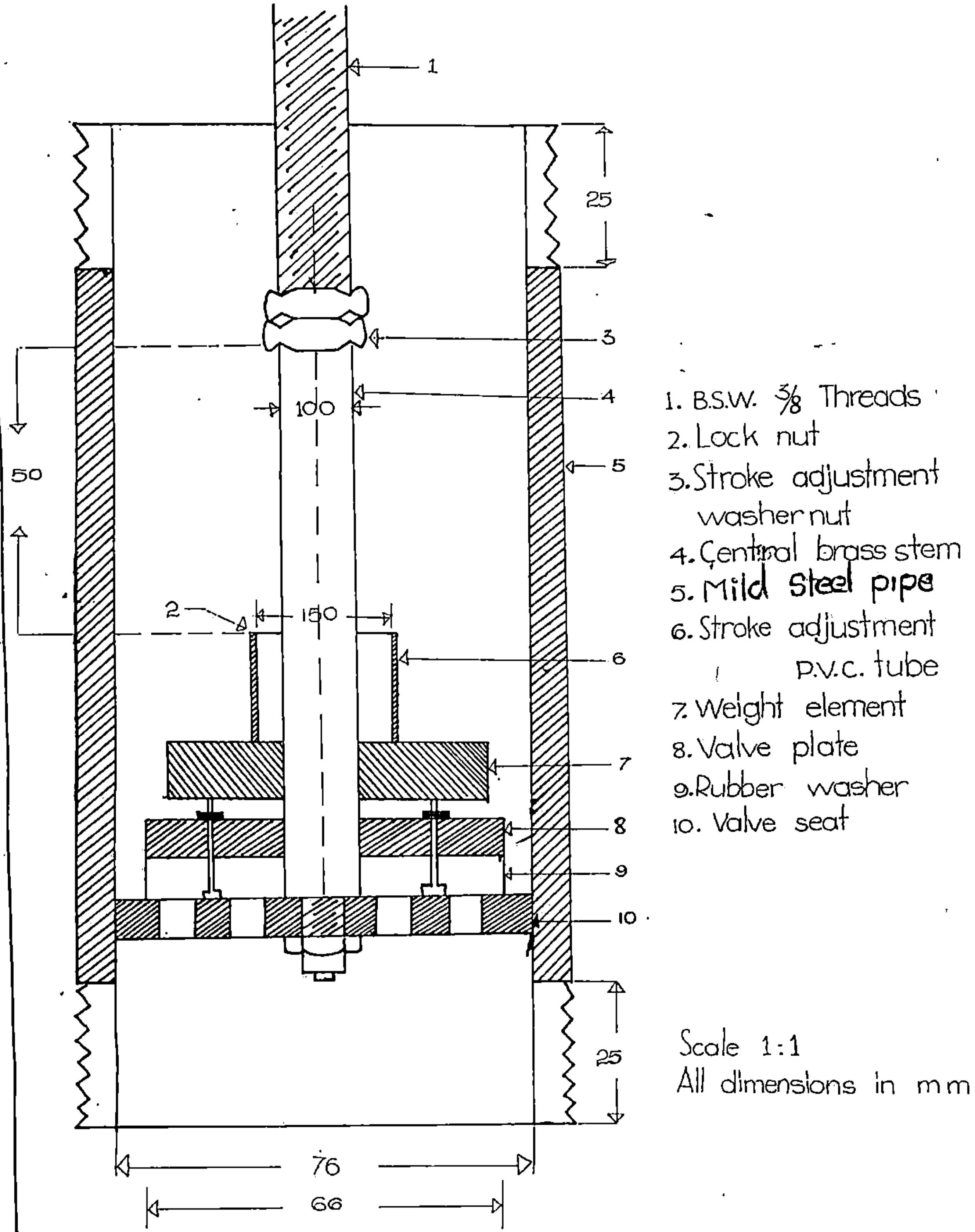
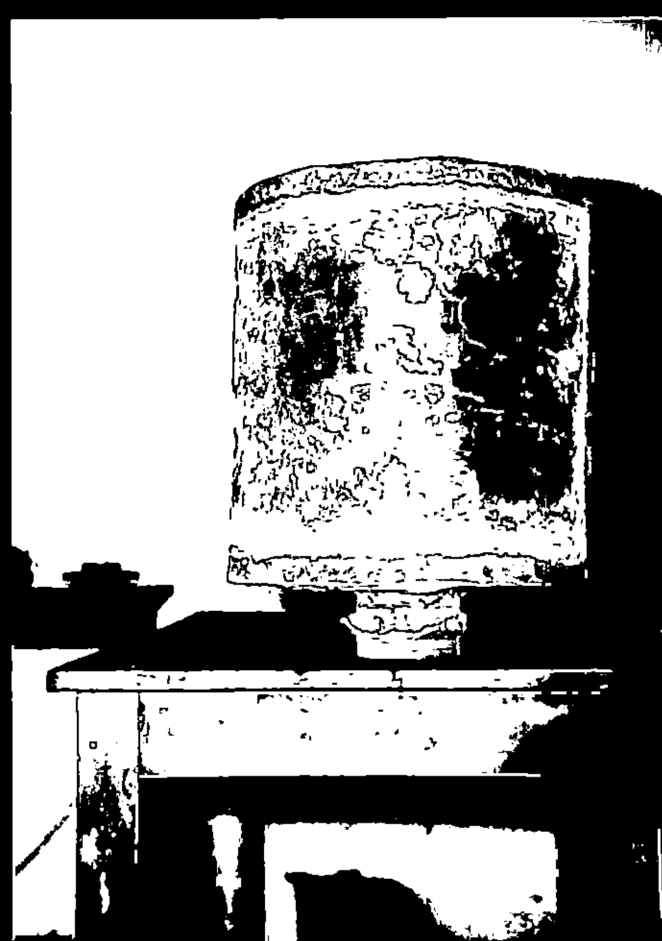


Figure. 3 Sectional view of delivery valve

te 3.Air chamber of 100 mm
diameter G.I.pipe

e 4.Cylindrical air chamber
of 20 litres.



intermittent which is not desirable in places where continuous flow of water is required. The flow of water into the air vessel compresses the air column above the water in the air vessel. The compressed air column acts on the water in the air vessel to maintain a nearly constant delivery discharge.

The commercially available 76mm G.I. pipe was fitted as the air chamber. It was fitted above the delivery valve. The length of air chamber used for most of the observations was 210cm.

3.4. Efficiency of Ram

The efficiency of the ram may be considered from three points of view.

3.4.1. 'D' Aubuissons's efficiency

In this concept tail water level was taken as datum. 'Qd' is the volume of water delivered by the ram, and 'Qw' is the volume of water through the waste valve, 'Hs' the effective supply head and 'Hd' the effective delivery head measured from the level of waste valve, the total input energy to the ram is (Qw + Qd)Hs, and total output energy is Qd Hd.

Therefore 'D' Aubuisson's efficiency

$$\eta_{(aub)} = \frac{Qd.Hd}{(Qd+Qw)\ Hs}$$

This method of calculation of the efficiency considers the ram as a machine.

3.4.2. In product information of hydraulic ram manufactures as well as in some other publications on hydraulic rams efficiency is often simply defined as

$$\eta_{(trd)} = \frac{Qd\ (Hd - Hs)}{QW.Hs}$$

where η_{trd} = trade expression of efficiency.

3.4.3. Rankine's efficiency

In this concept supply head level is taken as the datum and the hydram is considered as a hydrualically operated pump which actuated by a volume of water Qw under the supply head Hs and utilising this energy to lift a volume Qd. As this volume Qd is initially at a height Hs, the additional height to which it is lifted is (Hd - Hs).

Then Rankine's efficiency $= \dfrac{Qd\ (Hd - Hs)}{Qw.Hs.}$

This method will give efficiency of the plant as a whole.

Although it is difficult to justify the idea of entire separation of the water pumped from the operating water, yet for the sake of comparison with other types of pump, this formula can be used.

Most of the earlier workers like watt (1975) Inversion (1978) and Ravendra and seshadri (1981) considered the 'D' Aubuisson's efficiency as standard and used for the performance testing. So in this study also 'D'Aubuisson's formula is used to compute the efficiency of the hydraulic ram.

3.5. Effect of different parameters on the performance of hydraulic ram

3.5.1. Effect of the length of supply pipe

The length of supply pipe was kept 16m initially. Delivery valve was adjusted for a weight of 185.37gm and a stroke length of 50mm.Waste valve was adjusted for 600gm and a stroke length of 42mm which was the maximum possible stroke length in this set up. A supply head of 1.955m was maintained.Then gate valve was opened allowing the water to flow into the ram body from the supply reservoir. Initially the waste valve was operated manually for a few times until it worked automatically.The delivery discharge, waste discharge and beat frequency were measured. The delivery head is measured directly from the pressure gauge fitted at the delivery pipe line. Details of measurements are given separately. The readings were also taken for a waste valve stroke length of 20 mm. The whole procedure was repeated for a waste valve weight of 500gm.

The length of supply pipe was changed to 15m keeping other parameters constant.Then the delivery discharge(Qd)waste discharge(Qw) and beat frequency per minute for different delivery head (Hd) values were recorded. Same test procedure was repeated for lengths of supply pipe 14m and 13m.

3.5.2. Effect of L/D ratio of Air chamber

Initially an air chamber having an L/D ratio of 14.5 was connected to the ram,using G.I.pipe of 76mm diameter.Waste valve was adjusted for a weight of 600 gm and a stroke length of 20mm. Delivery valve was adjusted for a weight of 185.37gm and a stroke length of 50mm. The procedure was repeated for a stroke length of delivery valve 35 mm, for delivery valve weights of 185.37 gm and 285.37 gms. Then Qd,Qw and beat-frequency per minute were measured for different delivery head values. Then the experiment was repeated for the L/D ratios 6.2 and 24.7 using 100mm and 62.5mm G.I.pipes as air chamber.

3.5.3. Effect of Volume of Air chamber

Initially an air chamber volume of 20 litre was connected to the ram using a 30cm diameter cylinder. Delivery valve was adjusted for a weight of 185.37gm and a stroke length of 50mm. Waste valve was adjusted for a weight of 500 gm and a stroke length of 20mm. Then Qd, Qw and beat-frequency per minute were measured for different delivery head values. This was repeated for a waste valve weight of 600gm.After completing the observation the air chamber volume was changed to 25 l and all observations were taken.Same procedure was repeated for the air chamber volumes of 30 l and 35 l.

3.5.4. Effect of continous operation of the ram

The hydraulic ram was continuously operated for 12 hours and discharge measurements were taken at hourly intervals.

3.5.5. Effect of inclination of supply pipe

Inclination of supply pipe was kept 8.5 degree with horizontal initially. Delivery valve was adjusted for a weight of 185.37 gm and a stroke length of 50mm.The waste valve valve was maintained for a wieght of 600gm and stroke length 20mm.Then Qd,Qw and N/min were measured for different values of delivery head. The experiment was repeated for different waste valve weights and stroke lengths. Same procedure was repeated for the inclinations of supply pipe 7 and 6 degrees.

3.6. Observations

3.6.1. Measurement of delivery head and discharge

The delivery head was varied with the help of gate valve connected to the delivery pipe. Delivery head was measured from the Bourdon pressure gauge which was connected just before the gate valve in the delivery pipe line. It was seen that the pressure readings were fluctuating during each cycle of operation. The highest value observed was taken as the delivery head.

For each variation of delivery head the corresponding delivery discharge was measured. The delivery discharge was measured using a measuring bucket and stop watch, volumetrically.Some fluctuations in the delivery discharge measurements were observed. So average of five independent discharge observation were taken as the delivery discharge, Qd.

3.6.2. Waste Water Discharge

For each delivery head measurement, the waste discharge Qw was also taken. This was also made by collecting the water wasted through the waste valve for a particular time in the measuring bucket. Average of five independent discharge observations were taken as the waste discharge, (Qw). Then the quantity of water supplied to the hydraulic ram, Qs = Qw + Qd.

3.6.3. The number of beats per minute (Beat frequency)

For each set of observation, the beat frequency was noted. This was done by direct counting and line measured using a stop watch.

RESULTS AND DISCUSSION

The results of the study on the performance characteristics of the hydraulic ram are discussed in this chapter.

4.1. Effect of length of supply pipe

In order to study the effect of length of supply pipe on the performance of ram, all other parameters like weight and stroke lengths of delivery valve and waste valve, volume of air chamber were kept constant and delivery head and delivery discharge were measured for different lengths of supply pipe.

The results are given in Table 1.a, b, c, d, ; 2.a, b, c, d, 3.a, b, c, d, 4.a, b, c, d, 5 and 6. The corresponding curves are shown in Figures 4, 5, 6, 7, 8 and 9. These curves show the effect of the length of supply pipe on the performance of ram for specific values of weight and stroke length of waste valve, weight and stroke length of delivery valve and delivery head.

It is observed from the curves that there is an increase in delivery discharge with increase in length of supply pipe up to a point and then shows a reduction in delivery discharge with further increase in length of supply pipe. This may be due to the following reasons. The increase in length of supply pipe will increase the water hammer pressure, which in turn will increase the delivery discharge. But at the same time, the time during which the delivery valve remains off its seat will increase with increase in length of supply pipe and diminish with increase in (Hs/L) ratio (Gibson, 1930). Besides that the increase in length of supply pipe will reduce the reservoir head available for water hammer by an amount 'KQ^2', where 'K' is a constant, and Q is the discharge, due to increased friction. So the increase in delivery discharge with increase in length of supply pipe upto a certain limit may be due to the gain resulting from increased water hammer pressure. The decrease in delivery discharge with further increase in length may be due to, the loss resulting from increased friction and increase in time of opening of the waste valve. The effect of length of supply pipe on delivery discharge is shown in figure (4) and figure (5).

Curves for same weight and stroke lengths of waste valve and delivery valve show that, at lower delivery head the change in delivery discharge is more, per unit change in length of supply pipe.

The figure (6) and figure (7) shows the relationship between efficiency of ram and delivery head, keeping other parameters constant. From the curves it is

TABLE 1. EFFECT OF LENGTH OF SUPPLY PIPE ON THE PERFORMANCE OF HYDRAULIC RAM

(a) Length of supply pipe = 13m

Sl. No	Volume of delivery water, Vd(l)	Time (s) Td	Delivery discharge Qd (l/min)	Volume of waste water Vw(l)	Time (s) Tw	Waste water discharge (l/min)	Supply discharge Qs=Qd+Qw (l/min)	Delivery head, Hd (m)	Beat frequency per minute	Efficiency = Qd.Hdx100 / Qs.Hs(%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	5	136.4	2.20	10	23.0	26.1	28.3	12.1	46	48.1
2	5	73.54	4.08	10	22.50	26.7	30.78	7.5	46	50.8
3	5	47.2	6.35	10	22.0	27.3	33.65	4.5	45	40.3
4	5	42.8	7.00	10	21.60	27.8	34.80	4.0	44	39.8
5	5	38.0	7.90	10	21.40	28.0	35.90	3.6	44	38.0

Weight of waste valve = 500gm, stroke length = 42mm

Weight of delivery valve = 185.37gm, stroke length = 50mm

(b) Length of supply pipe = 14m

1	2	3	4	5	6	7	8	9	10	11
1	5	146.3	2.05	10	23.8	25.2	27.25	13.2	47	50.8
2	5	70	4.28	10	22.4	26.8	31.08	7.5	48	52.6
3	5	44.4	6.75	10	22.2	27.0	33.75	4.5	47	44.3
4	5	39.7	7.55	10	22.0	27.2	34.75	4.0	46	42.3
5	5	36.8	8.15	10	21.4	28.0	36.15	3.15	46	40.0

(c) Length of supply pipe = 15m

1	2	3	4	5	6	7	8	9	10	11
1	5	162.5	1.85	10	25	24	25.85	14	48	51.2
2	5	140	2.14	10	23	26	28.14	13	48	52.6
3	5	68	4.41	10	22	27.3	31.71	7.5	47	53.85
4	5	42.5	7.05	10	20.5	29.3	36.35	4.5	47	44.6
5	5	38	7.9	10	20.6	29.12	37.02	4.0	46	43.7

(d) Length of supply pipe = 16m

1	2	3	4	5	6	7	8	9	10	11
1	5	150	2.0	10	23.5	25.5	27.5	13.5	46	50.2
2	5	69.6	4.31	10	23	26	30.31	7.5	46	53.15
3	5	44.1	6.8	10	22.8	26.3	33.1	4.5	45	46.73
4	5	39.2	7.65	10	22.2	27.0	34.65	4.0	45	44.0
5	5	31.6	9.5	10	22.0	27.3	36.8	3.20	44	42.0

Table 2. EFFECT OF LENGTH OF SUPPLY PIPE ON THE PERFORMANCE OF HYDRAULIC RAM

(a) Length of supply pipe = 13m

1	2	3	4	5	6	7	8	9	10	11
1	5	130	2.3	10	23	26.0	28.3	12	54	50
2	5	120	2.5	10	22.3	26.8	29.3	11	53	48
3	5	73.2	4.1	10	21.9	27.4	31.5	7	52	46.6
4	5	55.5	5.4	10	21.6	27.8	33.2	5	52	38.8
5	5	32.6	9.2	10	21.4	28.0	37.2	3	51	38.0

Weight of waste valve = 600gm, stroke length = 20mm

Weight of delivery valve = 185.37 gm, stroke length = 50mm

(b) Length of supply pipe = 14m

1	2	3	4	5	6	7	8	9	10	11
1	5	130.0	2.30	10	23.8	25.2	27.5	12.2	55	52.0
2	5	110.0	2.73	10	22.7	26.4	29.13	11.0	55	52.7
3	5	68.2	4.40	10	22.2	27.0	31.50	7	54	51.15
4	5	51.7	5.80	10	22.1	27.1	32.90	5.0	54	43.2
5	5	29.1	10.3	10	21.9	27.4	37.70	3.0	54	42.0

Table (c) Length of supply pipe = 15m

1	2	3	4	5	6	7	8	9	10	11
1	5	139.5	2.15	10	23.9	25.1	27.25	12.75	56	51.4
2	5	126.0	2.38	10	23.2	25.86	28.24	12.00	55	52.0
3	5	65.2	4.60	10	23.0	26.09	30.69	7.00	55	53.76
4	5	49.2	6.1	10	22.7	26.43	32.53	5.00	54	48.0
5	5	26.0	11.5	10	22.4	26.78	38.29	3.00	54	46.0

Table (d). Length of supply pipe = 16m

1	2	3	4	5	6	7	8	9	10	11
1	5	133.3	2.25	10	23.6	25.4	27.65	12.5	55	52
2	5	106	2.83	10	23.2	25.9	28.73	11.0	55	54
3	5	67.4	4.45	10	23.1	26.0	30.45	7.0	54	52.3
4	5	50.85	5.9	10	22.7	26.4	32.30	5.0	53	45.0
5	5	28.6	10.5	10	22.4	26.8	37.3	3.0	53	43.2

3(a). EFFECT OF LENGTH OF SUPPLY PIPE ON PERFORMANCE OF HYDRAULIC RAM

Length of supply pipe = 13m

1	2 (Vd)	3 (Td)	4 (Qd)	5 (Vw)	6 (Tw)	7 (QW)	8 (Qs)	9 (Hd)	10 (B)	11
1	5	93.75	3.2	10	19.05	31.5	34.7	10.5	61	49.8
2	5	74.25	4.04	10	21.2	28.3	32.35	8	60	50.1
3	5	44.1	6.8	10	22.2	27	33.8	3.7	59	38.1
4	5	35.7	8.4	10	19.4	30.9	39.30	3.2	58	35.2

Weight of waste value = 500gm, Stroke length = 20mm
Weight of delivery valve = 185.37gm, Stroke length = 50mm

3(b). EFFECT OF LENGTH OF SUPPLY PIPE ON PERFORMANCE OF HYDRAULIC RAM

Length of supply pipe = 14m

1	2 (Vd)	3 (Td)	4 (Qd)	5 (Vw)	6 (Tw)	7 (QW)	8 (Qs)	9 (Hd)	10 (B)	11
1	5	114.1	2.63	10	16.5	36.4	39.03	13	63	44.8
2	5	89.8	3,34	10	21.5	27.88	31.22	9.5	62	52.0
3	5	71.4	4.2	10	21.4	28.0	32.2	8	61	53.4
4	5	42	7.15	10	21.33	28.13	35.28	3.7	60	39.5

Weight of waste value = 500gm, Stroke length = 20mm
Weight of delivery valve = 185.37gm, Stroke length = 50mm

3(c). EFFECT OF LENGTH OF SUPPLY PIPE ON PERFORMANCE OF HYDRAULIC RAM

Length of supply pipe = 15m

1	2 (Vd)	3 (Td)	4 (Qd)	5 (Vw)	6 (Tw)	7 (QW)	8 (Qs)	9 (Hd)	10 (B)	11
1	5	120	2.5	10	16.75	35.8	38.3	13.5	65	45.1
2	5	90.1	3.3	10	20.8	28.85	32.15	10	63	52.5
3	5	68	4.41	10	21.6	27.8	32.2	8	63	56
4	5	39.6	7.58	10	22.0	27.25	34.83	3.7	62	41.8

Table 3(d). Length of supply pipe = 15m

1	2	3	4	5	6	7	8	9	10	11
1	5	95.2	3.15	10	20.75	28.9	32.05	11	66	55.3
2	5	66.4	4.52	10	20.9	28.7	33.24	8	65	57.1
3	5	38.7	7.75	10	23	26.06	33.9	3.7	65	44.2
4	5	36.8	8.15	10	24.7	24.25	32.4	3.4	63	42.1

Table (4). EFFECT OF LENGTH OF SUPPLY PIPE ON PERFORMANCE OF RAM

(a) Length of supply pipe = 13m

1	2 (Vd)	3 (Td)	4 (Qd)	5 (Vw)	6 (Tw)	7 (QW)	8 (Qs)	9 (Hd)	10 (B)	11
1	5	146.3	2.05	10	22.65	26.48	28.53	12	52	44.1
2	5	78.9	3.8	10	20.9	28.7	32.5	8	51	47.8
3	5	58.25	5.15	10	19.1	31.45	36.6	6	50	43.2
4	5	36.6	8.2	10	18.2	32.9	41.1	3.9	49	39.8

Weight of waste valve = 600gm, stroke length = 42mm

Weight of delivery valve = 185.37gm, stroke length = 50mm

Table (4). EFFECT OF LENGTH OF SUPPLY PIPE ON PERFORMANCE OF RAM
(b) Length of supply pipe = 14m

1	2 (Vd)	3 (Td)	4 (Qd)	5 (Vw)	6 (Tw)	7 (QW)	8 (Qs)	9 (Hd)	10 (B)	11
1	5	42.9	2.1	10	21.7	27.6	29.71	13	53	47.1
2	5	74.1	4.05	10	21.2	28.35	32.41	8	52	51.2
3	5	54.5	5.5	10	19.4	30.93	36.43	6	52	46.3
4	5	35.3	8.5	10	18.7	31.9	40.4	4	51	43

Table (4). EFFECT OF LENGTH OF SUPPLY PIPE ON PERFORMANCE OF RAM

(c) Length of supply pipe = 15m

1	2 (Vd)	3 (Td)	4 (Qd)	5 (Vw)	6 (Tw)	7 (QW)	8 (Qs)	9 (Hd)	10 (B)	11
1	5	150	2.0	10	23.4	25.6	27.6	13	53	47.1
2	5	75	4.0	10	21.8	27.54	31.54	8	53	51.9
3	5	55.2	5.43	10	19.2	31.27	36.7	6	52	45.4
4	5	37	8.1	10	18.9	31.8	39.9	4.2	51	43.6

Table 4(d). Length of supply pipe = 16m

1	2 (Vd)	3 (Td)	4 (Qd)	5 (Vw)	6 (Tw)	7 (QW)	8 (Qs)	9 (Hd)	10 (B)	11
1	5	157.9	1.9	10	23.25	25.8	27.7	12.5	52	43.8
2	5	80.0	3.75	10	21.4	28.05	31.8	8	51	48.2
3	5	58.8	5.1	10	19.7	30.15	35.15	6	51	44.5
4	5	36.4	8.25	10	17.9	33.55	41.75	4.1	50	41.2

Table 5. EFFECT OF LENGTH OF SUPPLY PIPE ON DELIVERY DISCHARGE.

Length of supply pipe (m)	delivery head (m)	Delivery discharge l/min.
13	7.5	4.08
14	7.5	4.28
15	7.5	4.41
16	7.5	4.31
13	4.5	6.35
14	4.5	6.75
15	4.5	7.05
16	4.5	6.8
13	4.0	7.0
14	4.0	7.55
15	4.0	7.9
16	4.0	7.65

Weight of waste valve = 500gm, stroke length = 42m

Weight of delivery valve = 185.3gm, stroke length = 50mm

Volume of air chamber = 9.5 litres.

Table 6. EFFECT OF LENGTH OF SUPPLY PIPE ON DELIVERY DISCHARGE.

Length of supply pipe (m)	delivery head (m)	Delivery discharge l/min.
13	11	2.5
14	11	2.73
15	11	2.85
16	11	2.83
13	7.0	4.10
14	7.0	4.40
15	7.0	4.60
16	7.0	4.45
13	5.0	5.4
14	5.0	5.8
15	5.0	6.1
16	5.0	5.9

Weight of waste valve = 600gm, stroke length = 20mm

Weight of delivery valve = 185.3gm, stroke length = 50mm

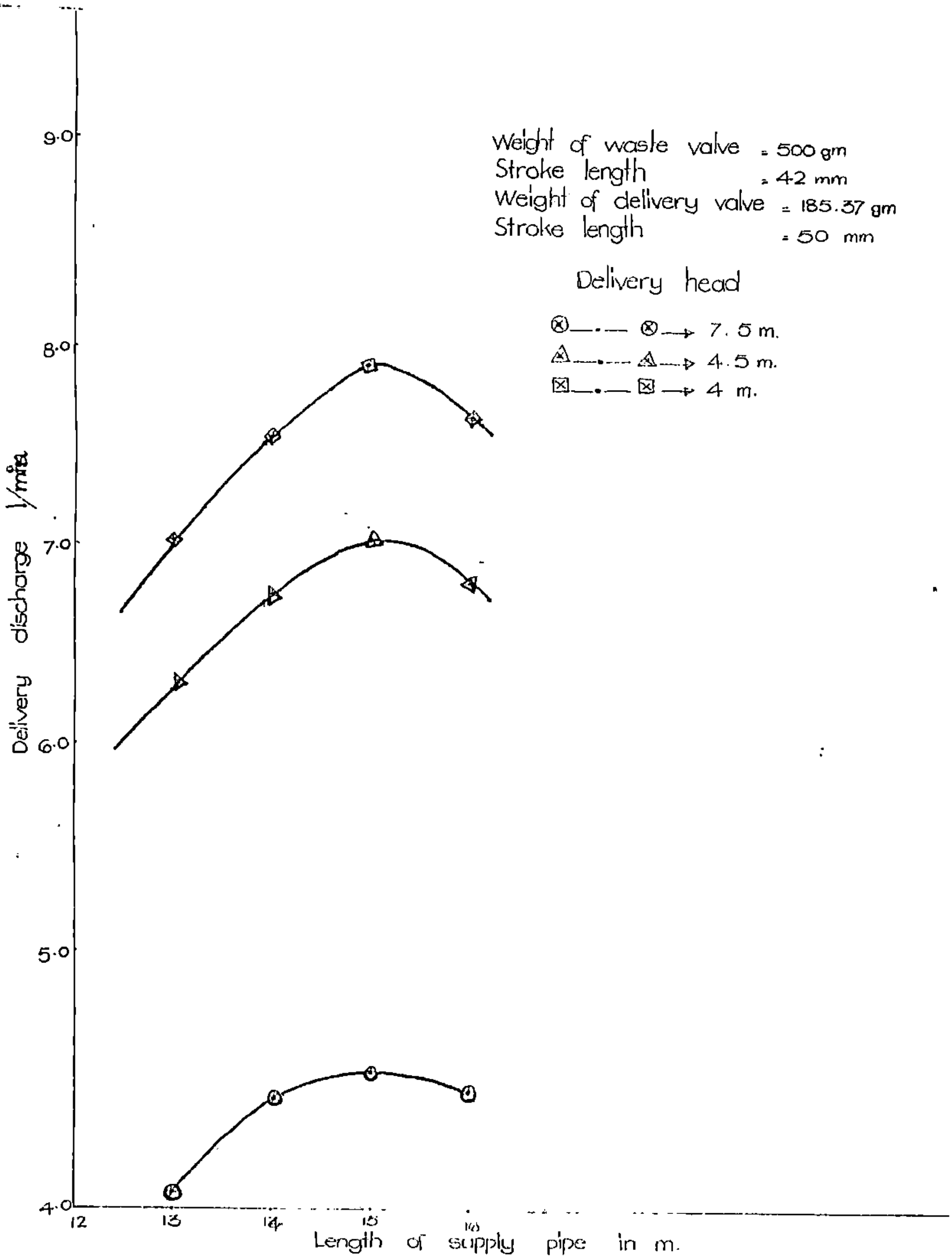


Figure. 4 Effect of length of supply pipe on delivery discharge

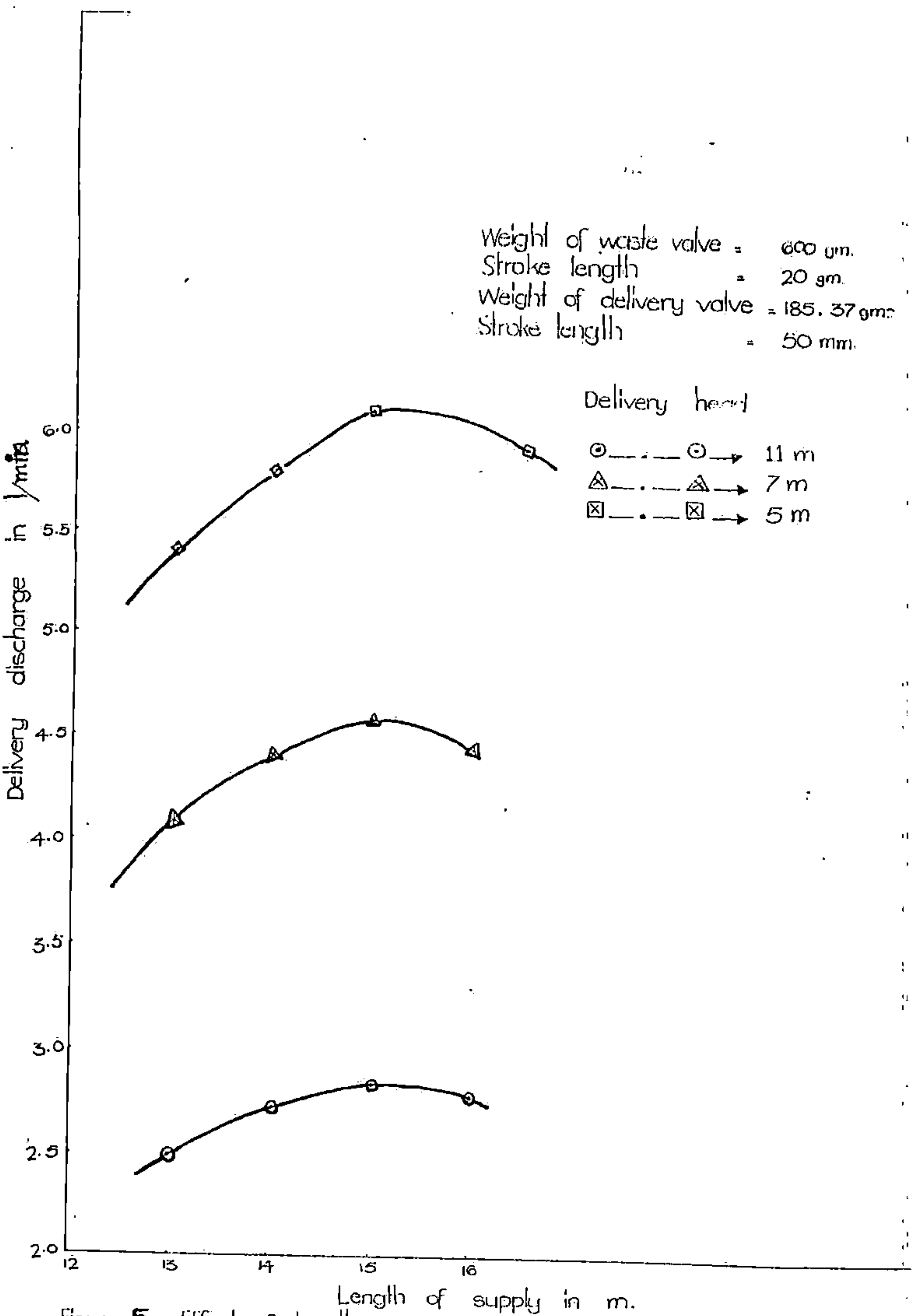


Figure. 5. Effect of length of supply pipe on delivery discharge

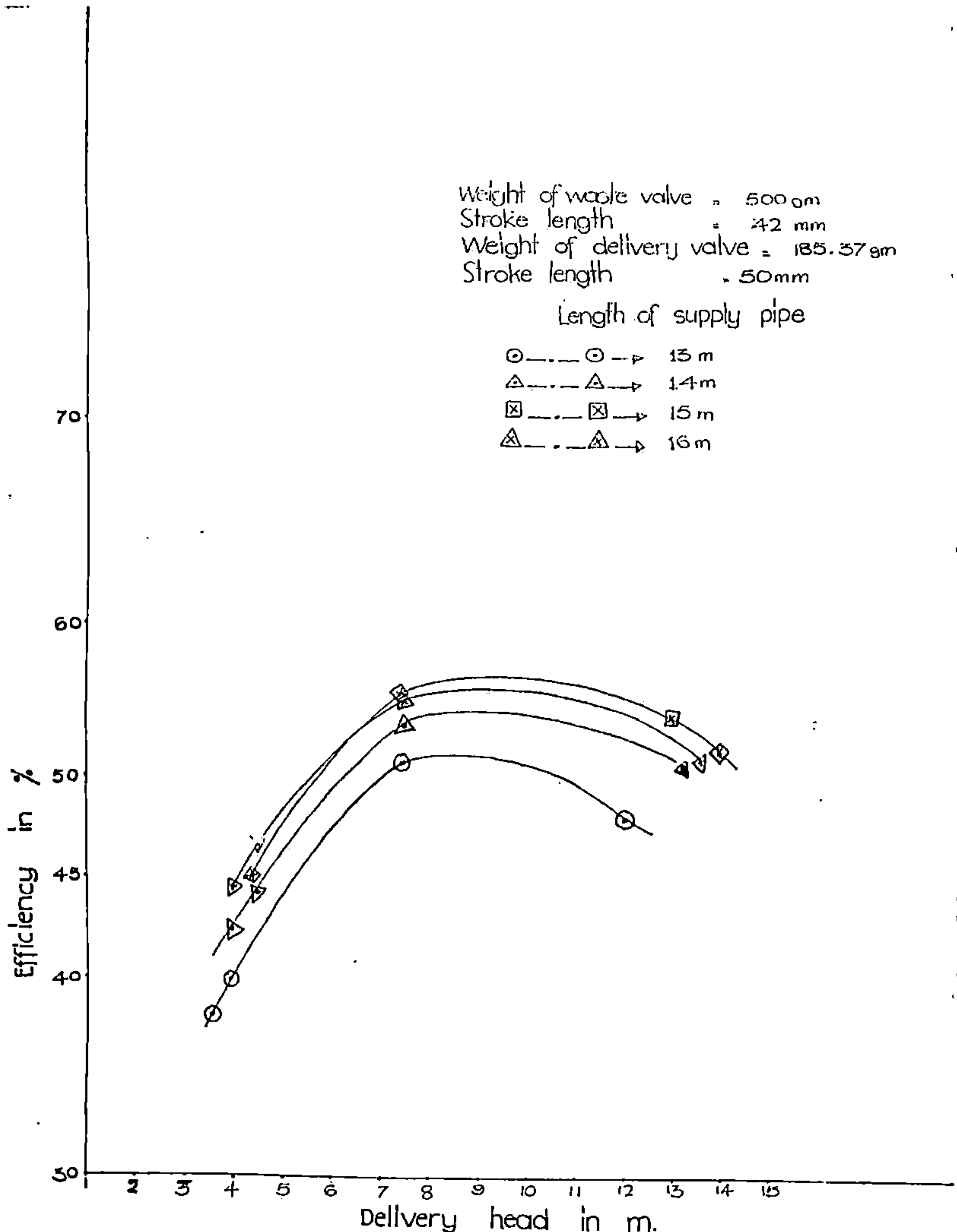


Figure. 6. Effect of length of supply pipe on the performance of hydraulic ram.

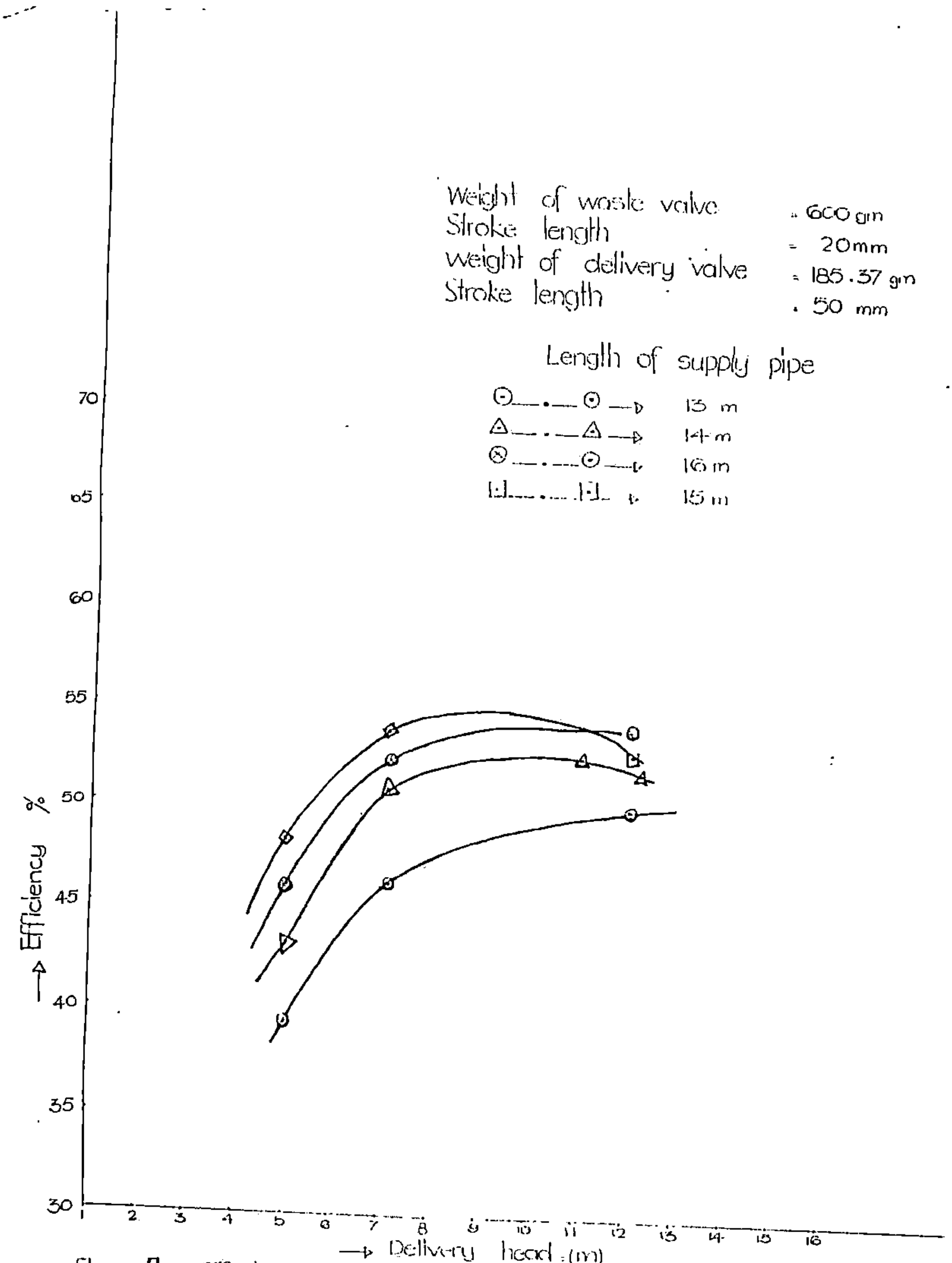


Figure 7. Effect of length of supply pipe on the performance of hydraulic ram.

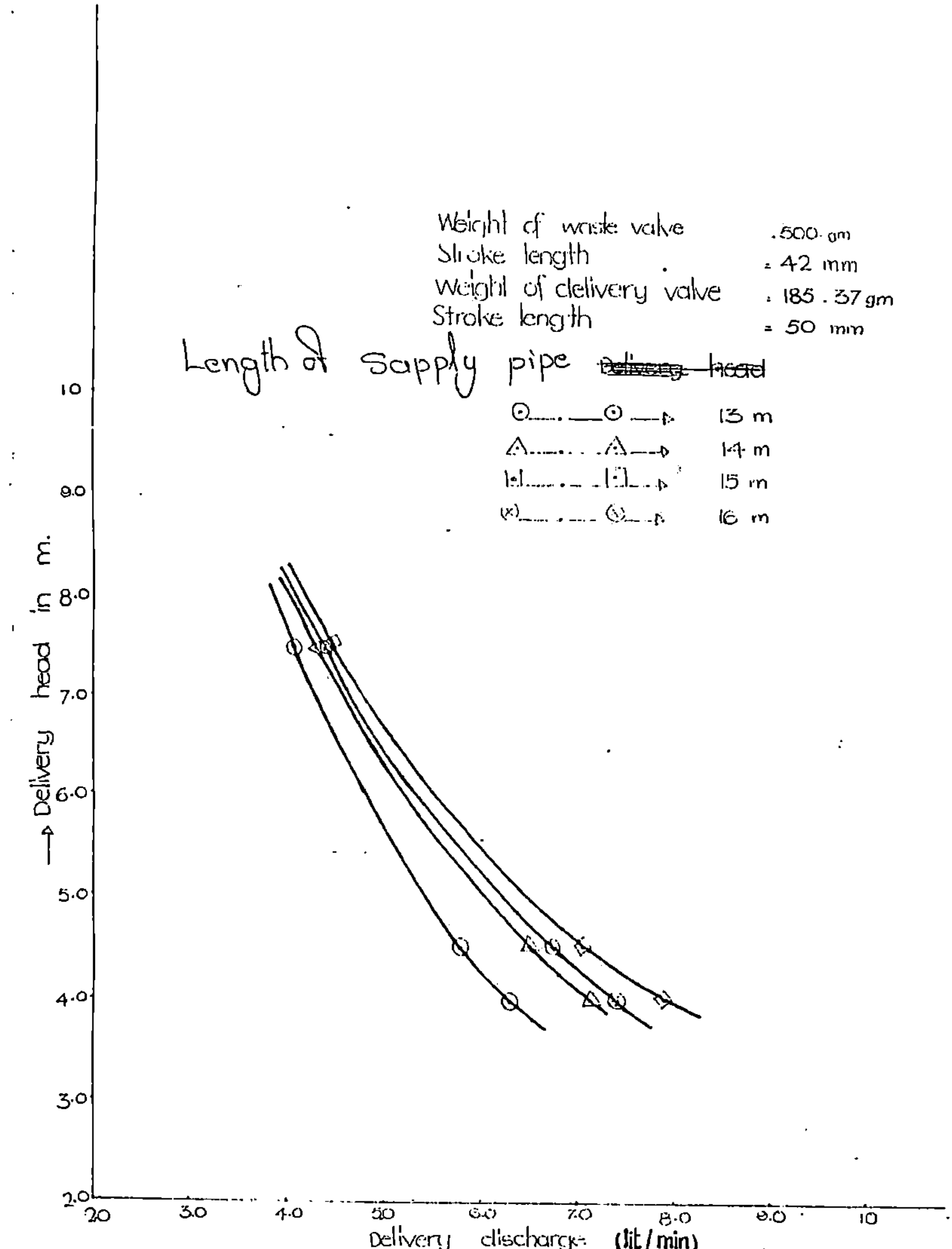


Figure. 8· Effect of length of supply pipe on the performance of hydraulic ram

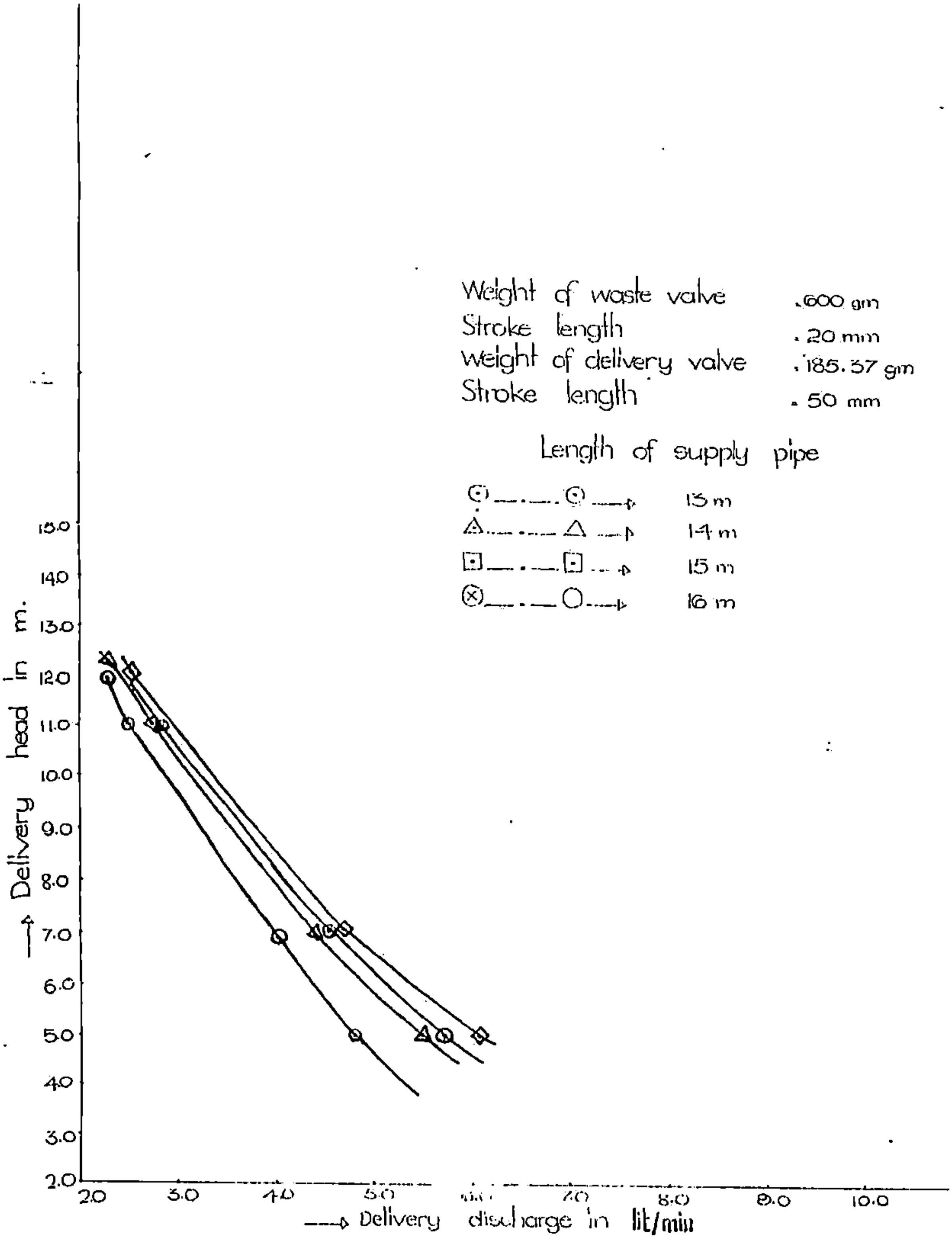


Figure. 9. Effect of length of supply pipe on the performance of hydraulic ram.

observed that the efficiency increases with increase in length of supply pipe up to a level, which may be due to the increase in delivery discharge. In most of the cases the eficiency of the hydraulic ram increases with increase in delivery head up to a certain value of delivery head, at which it attains maximum value of efficiency. After attaining the maximum efficiency, the efficiency decreases with the increase of delivery head. As the delivery head increases, the time during which waste valve remains off its seat increases and so the waste discharge increases and increased wastage decreases the efficiency (Gibson, 1930). At one stage, when delivery head further increases, the efficiency decreases which may be due to the increase in waste water discharge. Frictional losses in the supply pipe and delivery pipe increases with increase in delivery head. Hence it is found that at moderate delivery head ram efficiency will be higher. In the present study, the maximum efficiency is observed for delivery head between 7 m to 8 m. From Table 1(a), it is observed that the maximum efficiency is corresponding to a delivery head of 7.5 m and is 50.8 % and the efficiency corresponding to the delivery head 12 m and 3.6 m are 48.1 % and 38 % respectively.

Figure (8) and Figure (9) are curves plotted with delivery discharge along horizontal axis and delivery head along vertical axis for different lengths of supply pipe for a specific value of weight and stroke lengths of waste valve and delivery valve. From the curves it is observed that the difference in delivery discharge for a given delivery head, due to the effect of change in length of supply pipe is more for low values of delivery head. From the figure (8), it is observed that the change in delivery discharge, due to the effect of change in length of supply pipe is more for 4 m delivery head than the 4.5 m and 7.5 m delivery head.

The results of this study indicates that the length of supply pipe have a definite effect in influencing the the performance of hydraulic ram. In this study supply pipe lengths between 14 and 16 m show best range of efficiency of operation.

4.2. Effect of L/D ratio of Air Chamber

The performance of hydraulic ram was evaluated primarily by interpreting the delivery head, delivery discharge, and efficiency of values with respect of varying ratios of length and diameter of Air chamber for different weight and stroke length of delivery valve. The results of the study are presented in the tables 7. a, b, c, d. 8. a, b, c, d. 9. a, b, c, d.

Figure (10), shows the delivery head discharge relationship for differnt values of L/D ratios. Curve is plotted for three L/D ratios of Air chamber, they overlap.

From the curve it is clear that the delivery discharge values for a given head is more or less same for all L/D ratio values of Air chamber. Which indicates that L/D ratio of Air chamber have no effect on delivery discharge when the volume of Air chamber is constant. Hence the volume of Air chamber, not the shape of Air chamber determines the delivery discharge.

Figure (11) shows the relationship between efficiency and delivery discharge for different values of L/D ratio. They are also in overlaping in nature. The efficiency variation shows more or less the same pattern for differnt L/D ratios keeping all other parameters constant.

Table (10) gives the range of efficiency and maximum efficiency for different values of weight and stroke length of delivery valve. It is observed that the efficiency corresponding to the L/D ratios 6.2, 14.5, 24.7 are 44, 43 and 44.6 percentages and range of efficiency are 31.4 to 44, 30.5 to 43 and 30.9 to 44.6 percentages respectively. From the table it is clear that the range of efficiency and maximum efficiency are same in nature for differnt L/D ratios for a given stroke length and weight of delivery valve.

Figure (12), (13), (14) and (15) shows the characteristics curves of the hydraulic ram. From the curve

TABLE 7. EFFECT OF L/D RATIO OF AIR CHAMBER ON THE PERFORMANCE OF HYDRAULIC RAM
L/D Ratio of Air chamber = 14.5

TABLE (a). Weight of delivery valve = 185.37gm; stroke length = 50mm

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency = Qd.Hdx100 / Qs.Hs (%) (11)
1	5	225	1.2	10	24.9	24.09	25.3	10	53	24.39
2	5	140	2.14	10	26.1	23	25.13	7	52	30.00
3	5	105.2	2.86	10	26.0	22.56	25.42	6	52	33.75
4	5	54.3	5.56	10	26.8	22.39	27.94	3.5	51	35.8
5	5	34.9	8.57	10	27.2	22.05	30.62	2.15	51	29.38

TABLE (b). Weight of delivery valve = 285.37 gm; stroke length = 50mm

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency $= \frac{Qd.Hd \times 100}{Qs.Hs}$ (%) (11)
1	5	259.8	1.15	10	20	30	31.15	15.5	56	28.6
2	5	192.2	1.56	10	20.5	29.3	30.83	12.5	55	31.68
3	5	90.0	3.34	10	20.3	29.56	32.9	8	55	40.6
4	5	59.2	4.35	10	20.6	29.12	33.48	6	54	38.9
5	5	50.1	6.0	10	21.0	28.57	34.57	3.2	54	27.8

TABLE 7(c). Weight of delivery valve = 185.37 gm; stroke length = 35mm

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency = Qd.Hdx100 / Qs.Hs (%) (11)
1	5	225.2	1.33	10	27	22.22	23.56	11.5	56	30.45
2	5	140.1	2.14	10	26.7	22.47	24.61	7	57	30.5
3	5	81	3.7	10	27.1	22.14	25.84	6	56	43
4	5	63.2	4.76	10	27.5	21.82	26.6	4.5	56	40.2
5	5	34.8	8.57	10	28.2	21.3	29.85	2.2	55	30.58

TABLE 7(d). Weight of delivery valve = 285.37gm; stroke length = 35mm

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency = Qd.Hdx100 / Qs.Hs (%) (11)
1	5	240	1.25	10	19.9	30.15	31.4	15.2	58	30.25
2	5	174.8	1.72	10	20.1	29.85	31.56	13	58	35.30
3	5	91.2	3.3	10	20.3	29.56	32.86	8.2	57	42.50
4	5	34.9	8.57	10	20.8	28.84	37.42	3	56	33.25
5	5	62	4.84	10	20.5	29.3	34.1	6	58	41.20

TABLE 8. L/D Ratio of air chamber = 6.2

(a) Weight of delivery valve = 185.37 gm; stroke length = 50mm

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency $= \frac{Qd.Hd \times 100}{Qs.Hs}$ (%) (11)
1	5	209.8	1.43	10	25.1	23.9	25.33	10	54	26.73
2	5	143.5	2.09	10	28	21.42	23.51	7	53	30.43
3	5	85.7	3.5	10	26.4	22.73	26.23	5.5	52	39.5
4	5	31.9	9.4	10	23.7	25.3	34.7	2	50	28.0
5	5	45	6.67	10	24.1	24.9	31.57	3	51	32.69

TABLE 8(b). Weight of delivery valve = 285.37 gm; stroke length = 50 mm

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency = Qd.Hdx100 / Qs.Hs (%) (11)
1	5	250	1.2	10	19.5	30.9	32.1	15	56	28.6
2	5	187.5	1.6	10	19.75	30.4	32	12.5	57	31.9
3	5	92.0	3.26	10	20.25	29.63	32.89	8	57	40.5
4	5	63.8	4.7	10	20.5	29.3	34	5.5	56	39.0
5	5	46.15	6.5	10	20.7	29.0	35.5	3.0	56	28.5

Table 8(c). Weight of delivery valve = 185.37 gm; stroke length = 35mm

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency = Qd.Hdx100 / Qs.Hs (%) (11)
1	5	250	1.2	10	27	22.2	23.4	12	56	31.5
2	5	137.6	2.18	10	27.3	22.0	24.18	7	55	32.20
3	5	82.2	3.65	10	27.6	21.75	25.4	6	55	44.1
4	5	41.6	7.21	10	28.0	21.5	28.71	3	54	38.5
5	5	32.3	9.3	10	29.0	21.0	30.3	2	54	31.4

TABLE 8(d). Weight of delivery valve = 285.37 gm; stroke length = 35 mm

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency $= \frac{Qd.Hd \times 100}{Qs.Hs}$ (%) (11)
1	5	250	1.2	10	21	29	30.2	16	58	32.5
2	5	177.5	1.69	10	20.8	28.8	30.49	13	57	36.35
3	5	85.7	3.5	10	21	28.4	31.9	8	58	44.6
4	5	55.35	5.42	10	21.4	28	33.42	5.5	56	43.59
5	5	34.9	8.6	10	21.7	27.75	36.35	3.0	56	34.50

TABLE 9. EFFECT OF L/D RATIO OF AIR CHAMBER ON PERFORMANCE OF RAM
L/D Ratio of Air chamber = 24.7

(a) Weight of delivery valve = 185.37 gm; stroke length = 50mm

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency = Qd.Hdx100 / Qs.Hs(%) (11)
1	5	211.2	1.42	10	25	24	25.42	10	52	27.9
2	5	145	2.07	10	26	23	25.07	7	51	29.5
3	5	102.7	2.92	10	26.2	22.9	25.82	6	51	34.7
4	5	44.1	6.8	10	24.3	24.7	31.5	3	50	33.12
5	5	32.6	9.2	10	24.5	24.5	33.7	2	50	28.0

TABLE 9(b). Weight of delivery valve = 285.37 gm; stroke length = 50mm

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency $= \frac{Qd.Hd \times 100}{Qs.Hs}$ (%) (11)
1	5	240	1.25	10	19.7	30.45	31.7	15	54	30.25
2	5	194	1.55	10	20	30	31.55	12.5	54	31.4
3	5	89	3.37	10	20	30	33.37	8	53	41.32
4	5	63.8	4.7	10	20.3	29.55	34.25	5.5	54	38.6
5	5	45.5	6.6	10	20.5	29.26	35.86	3	53	28.3

TABLE 9(c). Weight of delivery valve = 185.37gm; stroke length = 35mm

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency = Qd.Hdx100 / Qs.Hs (%) (11)
1	5	240	1.25	10	27.3	22	23.25	12	56	33.0
2	5	142.8	2.1	10	26.8	22.4	24.50	7	56	30.6
3	5	79.4	3.78	10	27.0	22.2	25.98	6	55	44.6
4	5	54.75	5.48	10	27.6	21.75	27.23	4	55	41.16
5	5	31.6	9.5	10	28.6	21	30.5	2	54	30.86

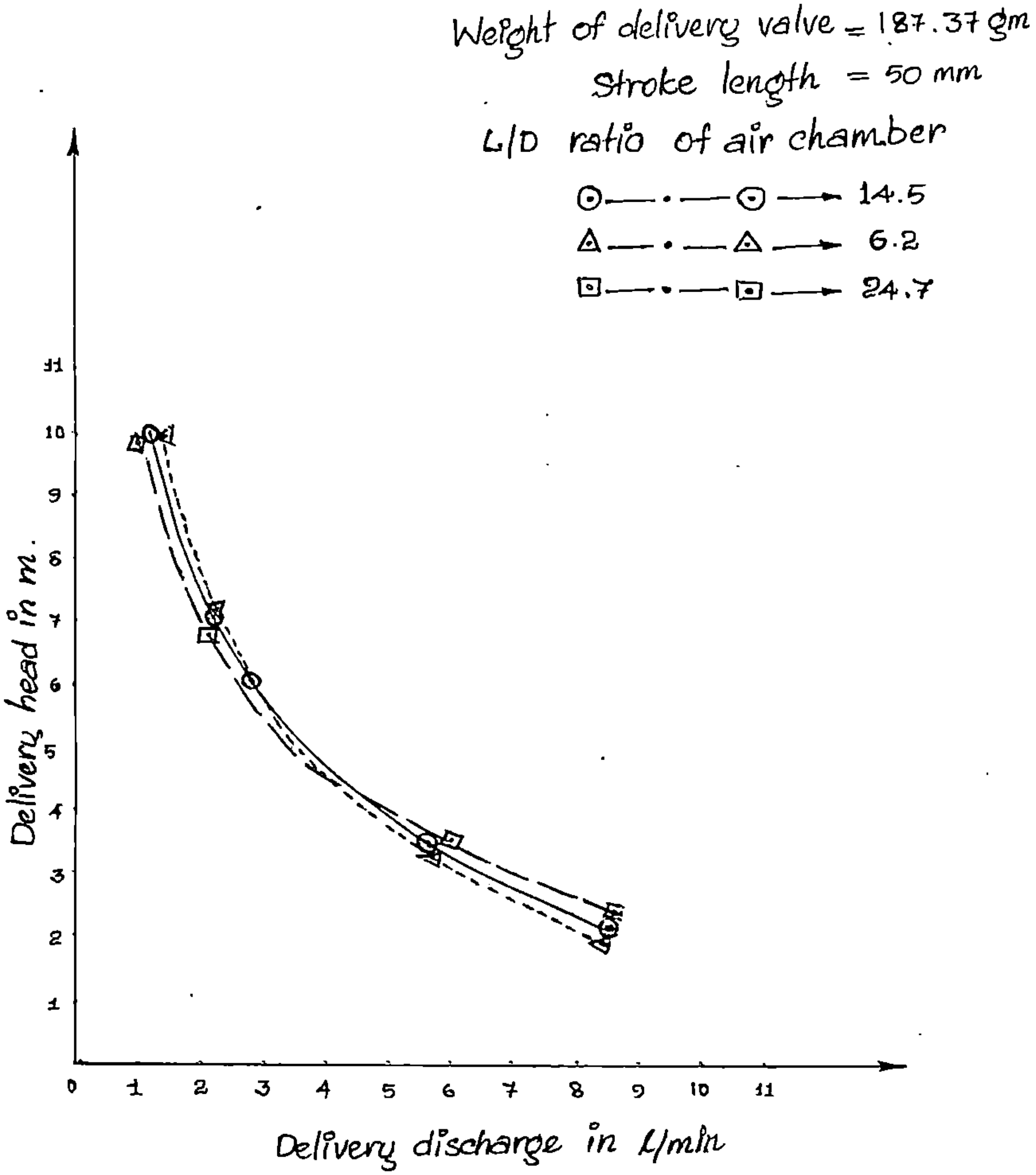
TABLE 9(d). Weight of delivery valve = 285.37 gm, stroke length = 35mm

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) Td (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency = Qd.Hdx100 / Qs.Hs (%) (11)
1	5	259	1.16	10	20	30	31.16	16	58	30.46
2	5	179.6	1.67	10	20.2	29.75	31.42	13	59	35.34
3	5	86.2	3.48	10	20.3	29.6	33.08	8	58	43.00
4	5	60.9	4.93	10	20.5	29.2	34.13	6	57	44.33
5	5	37.5	8.0	10	20.7	29.0	37.00	3.1	57	34.28

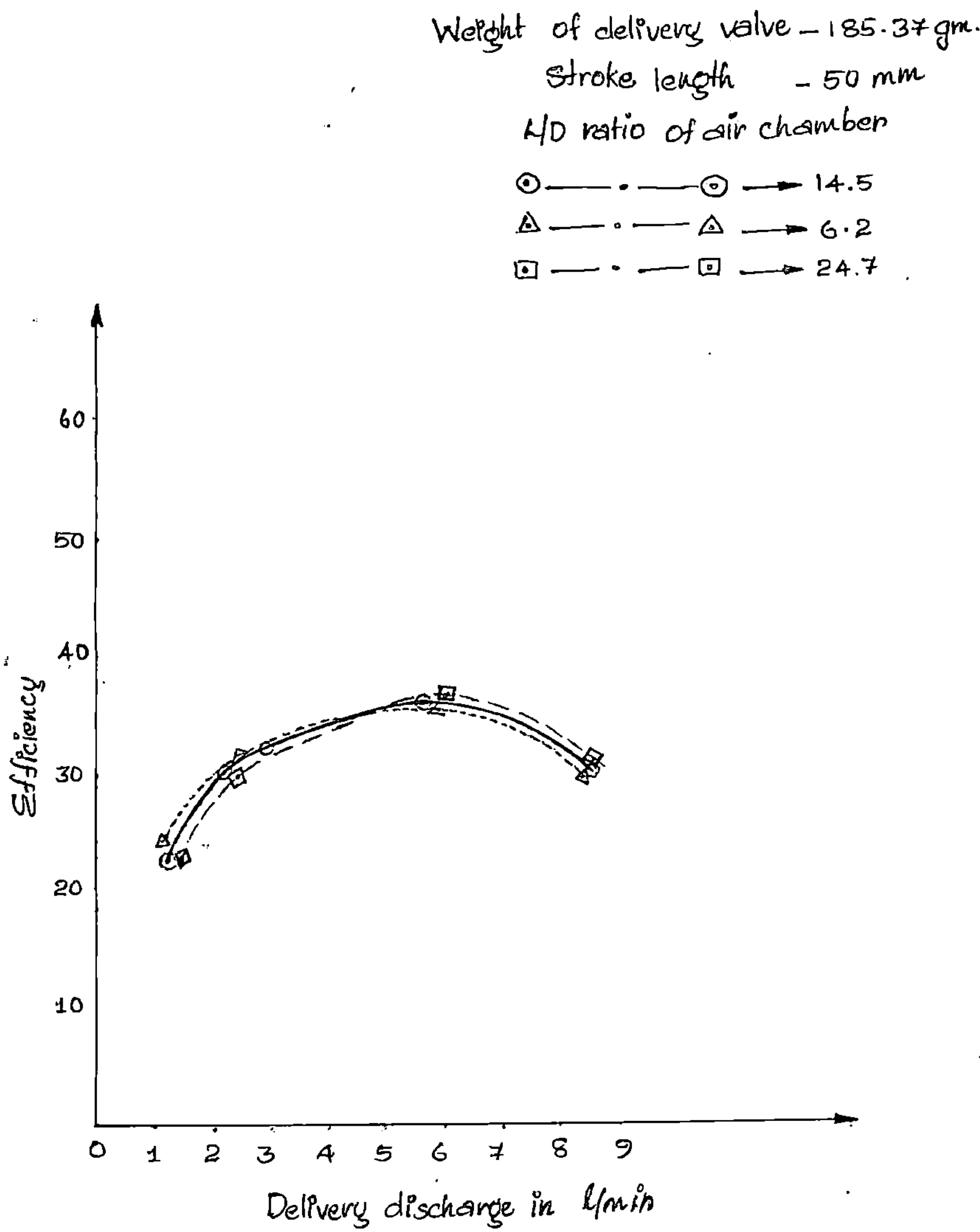
TABLE 10. EFFECT OF L/D RATIO OF AIR CHAMBER ON EFFICIENCY OF RAM

L/D RATIO	RANGE OF OBTAINED (%)	OFEFFICIENCY	MAX.EFFICIENCY (%)	DELIVERY Wt(gm)	VALVE S.L.(mm)
14.5	24.4	36	36.0	185.37	50
6.2	26.0	39.5	39.5	185.37	50
24.7	25.2	35.0	35.0	185.37	50
14.5	27.8	40.6	40.6	285.37	50
6.2	28.5	40.5	40.5	285.37	50
24.7	28.30	41.32	41.3	285.37	50
14.5	30.5	43	43.0	185.37	35
6.2	31.40	44	44.0	185.37	35
24.7	30.90	44.6	44.6	185.37	35

Weight of waste valve = 600 gm, stroke length = 20 mm.



Fig(10) - Effect of L/D ratio of air chamber on performance of hydraulic ram.



Fig(II) – Effect of L/D ratio of air chamber on performance of hydraulic ram.

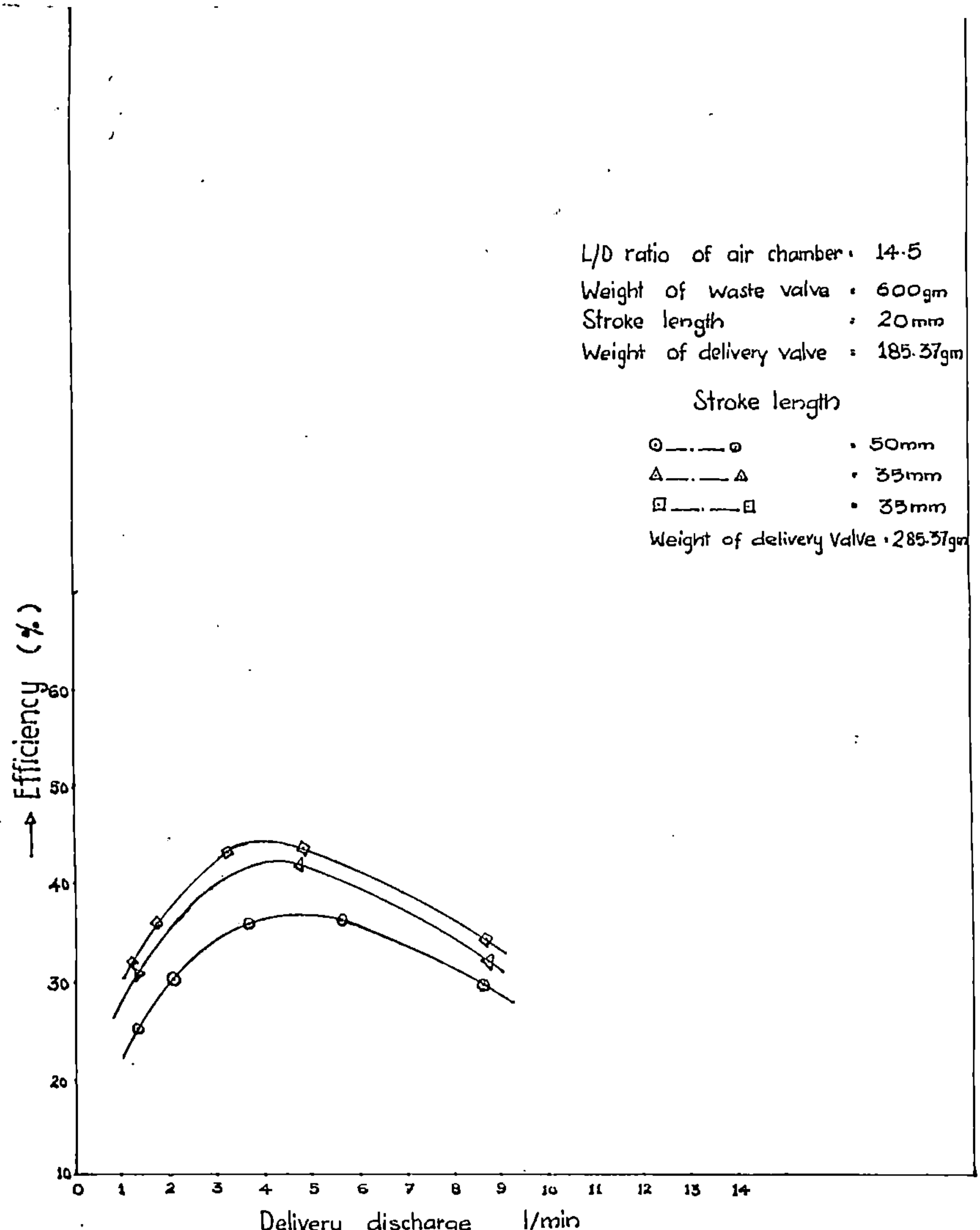


Figure.12. Effect of L/D ratio of air chamber on performance of hydraulic ram.

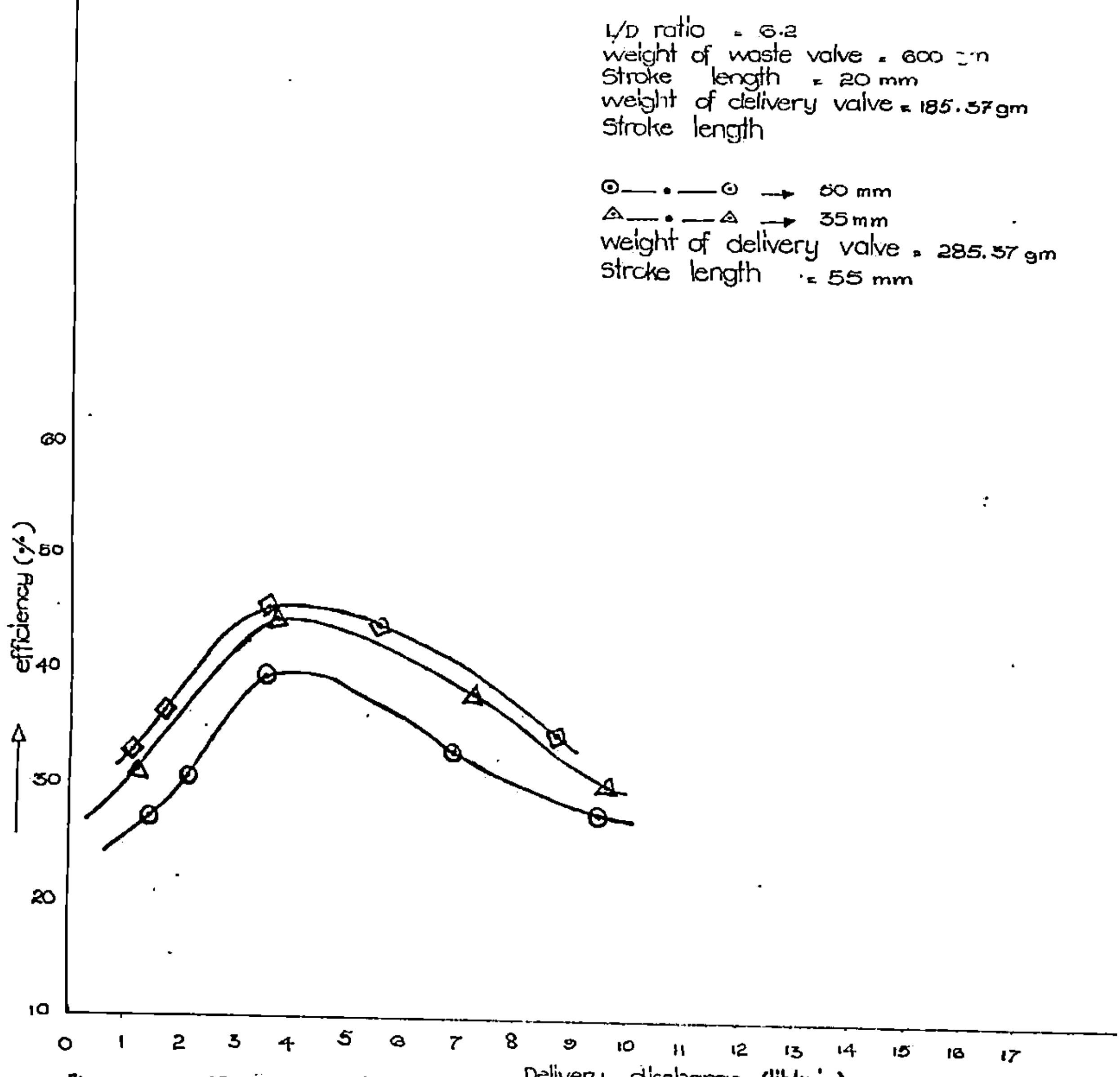


Figure 13. Effect of L/D ratio of air chamber on performance of hydraulic ram.

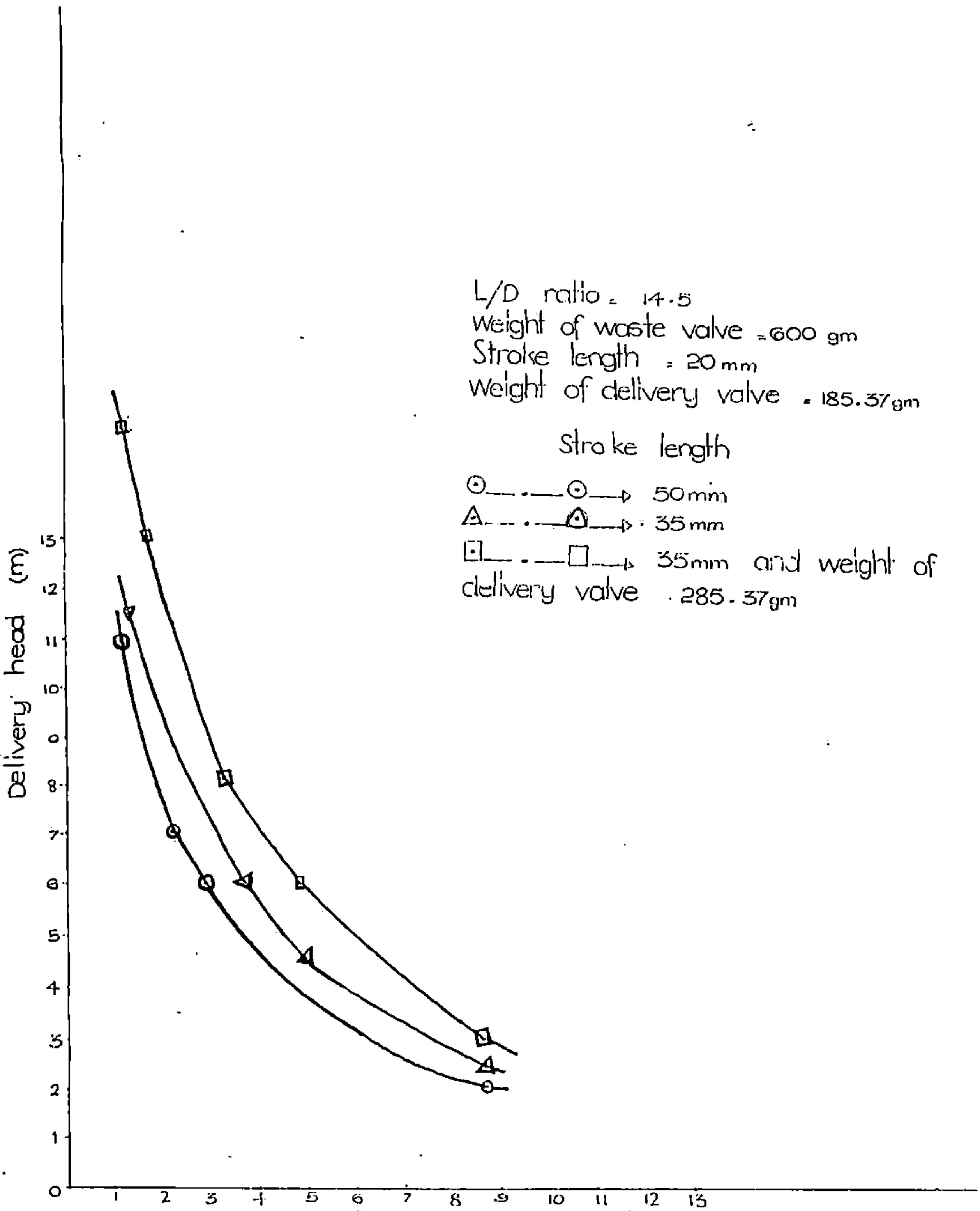


Figure.14. Effect of L/D ratio of airchamber on performance of hydraulic ram.

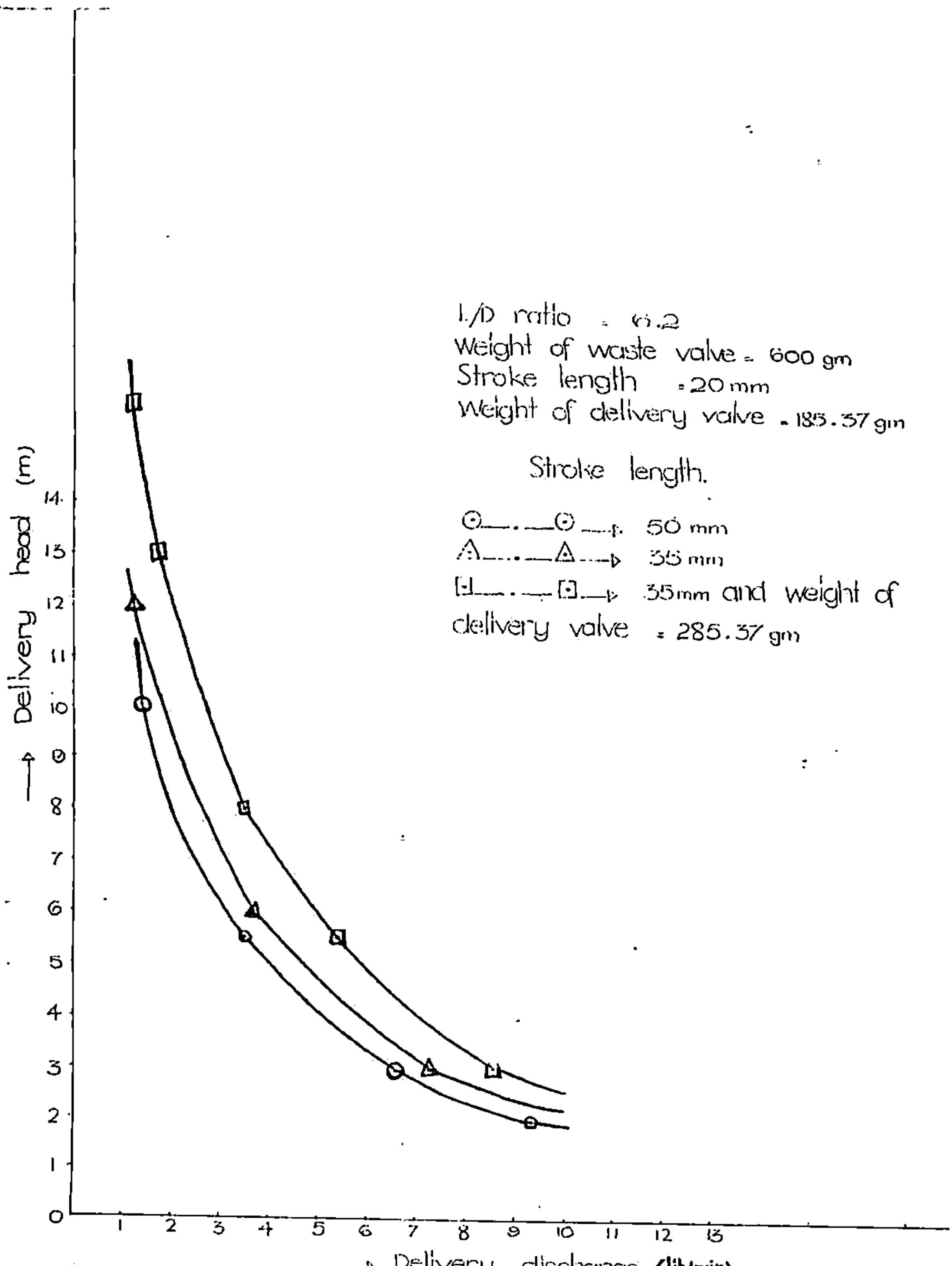


Figure.15. Effect of L/D ratio of air chamber on performance of hydraulic ram.

it is found that the delivery discharge increases with decrease in strokelength of delivery valve for a given L/D ratio of Air chamber. It is due to the fact that as the stroke length of delivery valve decreases, the number of strokes per minute increases, that is number of times the water forced into the Air chamber increases. So the delivery discharge increases. Besides that it is found that as the stroke length of delivery valve decreases the delivery valve closes quickly, then the return flow of water through the delivery valve into the supply pipe decreases. This results in higher discharge at a given head. From Table 7(a) and (c), it is observed that for a delivery head of 6 m and for a stroke lenghts of delivery valve 35 mm and 50 mm, the delivery discharge are 3.7 litre per minute and 2.86 litre per minute respectively keeping all other parameters constant.

Figure (12) and (13) shows that the variation of efficiency with respect to the delivery discharge. From the curves it is clear that there is an increase in efficiency per unit increase in delivery discharge upto a point after that efficiency decreases with increase in delivery discharge. It is also seen that the efficiency increases with decrease in stroke lenght of delivery valve.

From the results, it is clear that the change in L/D ratio of Air chamber, keeping volume constant, have no significant effect on the performance of hydraulic ram. The results obtained from three differnt L/D ratios show that the variation in L/D ratio have not affected the values of delivery discharges, efficiency and delivery head. It is concluded that the shape of the Air chamber has no effect on the delivery discharge when the volume of Air chamber is constant.

4.3. Effect of Volume of Air chamber

The effect of volume of Air chamber on performance of hydraulic ram was studied using 30 cm, diameter cylinder as Air chamber, for the volumes of 20 litre, 25 litre, 30 litre, 35 litre keeping all other parameters like weight and stroke length of delivery valve and waste valve constant. The results are shown in Tables 11.a, b, c, d. 12.a, b, c, d. and Table 13 and corresponding curves in Figures (16), (17), (18), (19), (20) and (21).

Curves showing the variation of delivery discharge with respect to volume of Air chamber are presented in figures 14 and 15. These curves depicts the effect of volume of Air chamber on delivery discharge for specific values of weight and stroke length of waste valve, weight and stroke length of delivery valve and delivery head. It is observed from the curve that there is an increase in delivery discharge with increase in the volume of Air chamber, but the rate of increase in delivery discharge decreases with increase in volume of Air chamber. In the present study, the increase in discharge between 30 litre to 35 litre is small compared to the increase in discharge between 20 litre to 25 litre. In general the ram shows very steep increase in discharge at lower volumes and the rate of increase is decreases with further increase in volume. Curves for same weight and stroke length of weight valve and delivery valve show that the variation in delivery discharge per unit change in volume of air chamber is more at lower delivery head.

Curves showing the relationship between the delivery head and the efficiency of the ram for different volumes of Air chamber keeping other parameters constant are shown in figures (20) and (21). It is seen that the efficiency of hydraulic ram increases with increase in delivery head upto a certain value of delivery head at which it attains maximum value of efficiency. After attaining the maximum efficiency, the efficiency decreases with increase in value of delivery head. In this study maximum efficiency is obtained between 8 to 10 metres of delivery head. From figure (20), it is observed that the maximum efficiency is corresponding to a delivery head of 9 metre and it increases from 55 percentage to 61 percentage with increase in volume of Air chamber from 20 litre to 35 litre. From the curves

Table 11. EFFECT OF VOLUME OF AIR CHAMBER ON PERFORMANCE OF RAM

(a) Volume of air chamber = 20 litres

Sl. No	Volume of delivery water, Vd(l)	Time (s) Td	Delivery discharge Qd(l/min)	Volume of waste water, Vw(l)	Time (s) Tw	Waste water discharge (l/min)	Supply discharge Qs=Qd+Qw (l/min)	Delivery head, Hd (m)	Beat frequency per minute	Efficiency = Qd.Hdx100 / Qs.Hs(%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	5	130	2.3	10	16.4	36.5	39.8	15	58	44.4
2	5	107.1	2.8	10	18.0	33.2	39.0	13	57	47.74
3	5	79	3.8	10	21.4	28.0	31.8	9	57	55.0
4	5	56.6	5.3	10	17.8	33.8	39.1	6.5	56	45.1
5	5	34.5	8.7	10	17.7	34.0	42.7	4.2	56	41.7

Weight of the waste valve = 500gm, Stroke length = 20mm
Weight of delivery valve = 185.37gm, Stroke length = 50mm.

TABLE 11(b) VOLUME OF AIR CHAMBER = 25 litre.

1	2	3	4	5	6	7	8	9	10	11
1	5	133.3	2.25	10	15.2	39.50	41.75	17	60	46.9
2	5	98.4	3.05	10	17.02	35.25	38.3	13	60	53
3	5	69.0	4.35	10	19.9	30.15	34.5	9	59	58
4	5	50.4	5.95	10	17.7	33.90	39.9	6.5	59	50
5	5	40.5	7.4	10	17.1	35.10	42.5	5.5	58	48.2

TABLE (C). Volume of Air chamber = 30 litres

1	2	3	4	5	6	7	8	9	10	11
1	5	130.4	2.3	10	14.85	40.4	42.7	18.0	61	49.6
2	5	95.25	3.25	10	17.25	34.8	37.95	13	61	55.2
3	5	66.1	4.54	10	19.4	30.92	35.46	9	60	58.9
4	5	48	6.35	10	17.8	33.66	39.9	6.5	60	52
5	5	40	7.50	10	16.9	35.48	42.9	5.75	59	51.2

TABLE (D). VOLUME OF AIR CHAMBER = 35 litres

1	2	3	4	5	6	7	8	9	10	11
1	5	127.7	2.35	10	14.85	40.4	42.75	18.5	63	52.0
2	5	92.3	3.25	10	17.4	35.6	38.13	13	63	56.5
3	5	63.4	4.73	10	19.4	30.97	35.70	9	62	61.0
4	5	45.8	6.55	10	17.8	33.70	40.25	6.5	61	54.1
5	5	41.7	7.2	10	16.6	36.23	43.43	6.0	60	51.0

TABLE 12. EFFECT OF VOLUME OF AIR CHAMBER ON THE PERFORMANCE OF HYDRAULIC RAM

(a) Volume of air chamber = 20 litres

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) Td (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency = Qd.Hdx100 / Qs.Hs (%) (11)
1	5	130	2.3	10	18.4	32.6	34.9	14.75	54	48.5
2	5	94.3	3.18	10	19	31.6	34.8	12	53	54.2
3	5	70.9	4.23	10	21.4	28	32.23	8.5	53	56.2
4	5	48.9	6.13	10	20.6	29.07	35.2	6.0	52	52.16
5	5	30	10	10	19.8	30.3	40.3	4.3	52	48.5

Weight of waste valve = 600gm, stroke length = 20mm

Weight of delivery valve = 185.37gm, stroke length = 50mm

TABLE 12(b). Volume of air chamber = 25 litres

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency = Qd.Hdx100 / Qs.Hs (%) (11)
1	5	136.4	2.2	10	18.6	32.24	34.44	17.2	56	51.7
2	5	86	3.45	10	18.15	33.06	36.51	12	56	58
3	5	62.75	4.78	10	19.9	30.14	34.92	8.5	55	59.5
4	5	43.4	6.9	10	18.4	32.66	39.57	6.0	54	56
5	5	37.5	8.0	10	17.5	34.28	42.28	5.5	53	53.1

TABLE 12(c). Volume of Air chamber = 30 litres

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency $= \frac{Qd.Hd \times 100}{Qs.Hs}$ (%) (11)
1	5	125	2.4	10	15.6	38.4	40.8	18	56	54.1
2	5	85	3.53	10	18.3	32.8	36.33	12	56	59.7
3	5	58.8	5.1	10	19.8	30.3	35.4	8.5	55	62.7
4	5	41	7.3	10	16.85	35.6	42.9	6	55	52.2

TABLE 12(d). Volume of air chamber = 35 litres

Sl. No (1)	Volume of delivery water, Vd (l) (2)	Time (s) (3)	Delivery discharge Qd (l/min) (4)	Volume of waste water, Vw (l) (5)	Time (s) Tw (6)	Waste water discharge (l/min) (7)	Supply discharge Qs=Qd+Qw (l/min) (8)	Delivery head, Hd (m) (9)	Beat frequency per minute (10)	Efficiency = Qd.Hdx100 / Qs.Hs (%) (11)
1	5	124.5	2.41	10	15.5	38.75	41.16	18.5	56	55.4
2	5	82.4	3.64	10	18.2	33	36.64	12	57	61
3	5	57.7	5.2	10	20	30	35.2	8.5	56	64.1
4	5	40	7.5	10	18.2	33	40.4	6.0	56	57.6

Table 13. EFFECT OF VOLUME OF AIR CHAMBER ON DELIVERY DISCHARGE

Weight of Valve (gm)	Stroke length (mm)	Delivery head (m)	Volume of air (l)	Delivery discharge (l/min.)
			20	3.8
500	20	9	25	4.35
			30	4.54
			35	4.73
			20	5.3
500	20	6.5	25	5.95
			30	6.35
			35	6.55
			20	4.23
600	20	8.5	25	4.78
			30	5.1
			35	5.2
			20	6.13
600	20	6.0	25	6.9
			30	7.3
			35	7.5

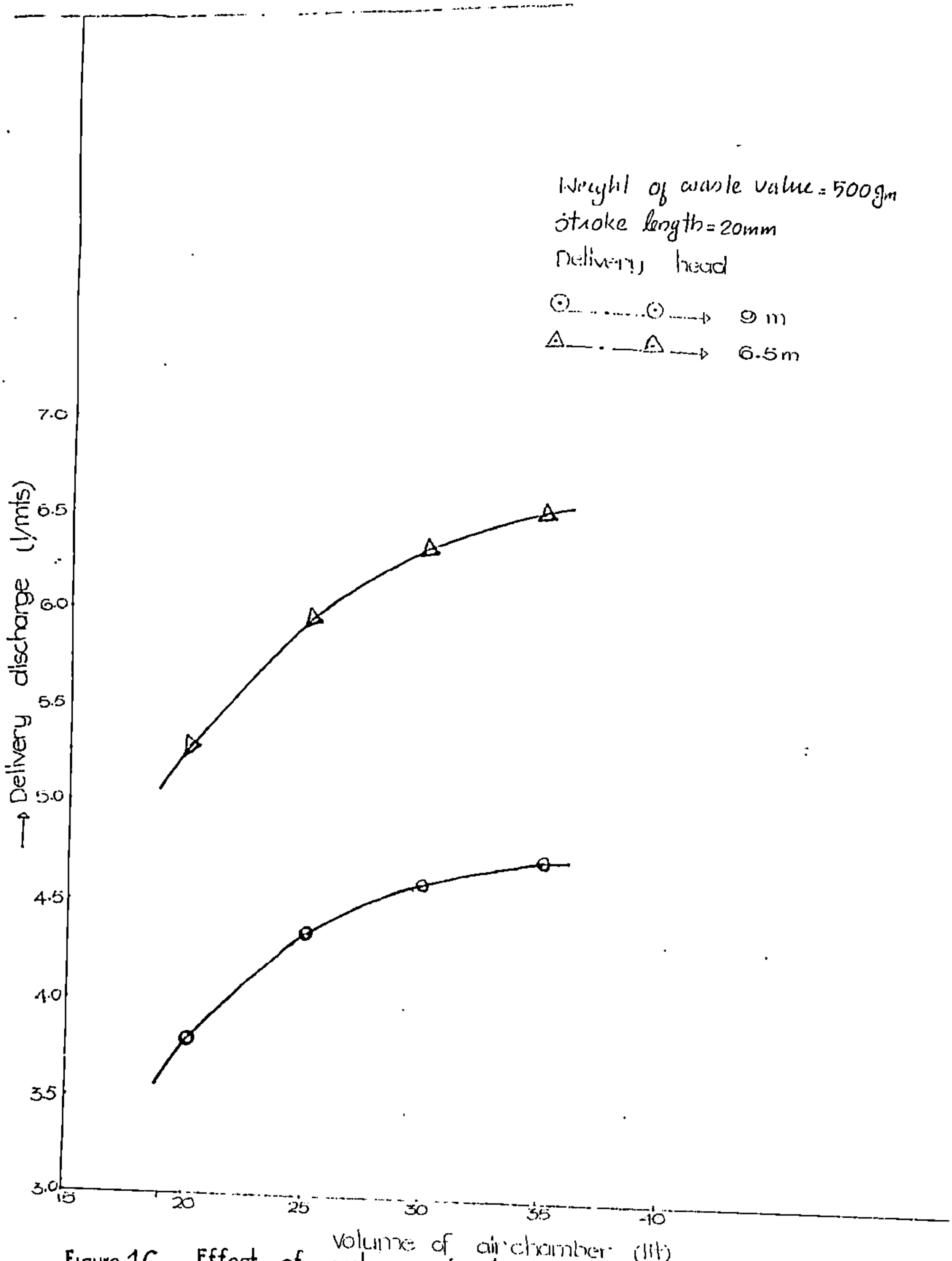


Figure.16. Effect of volume of air chamber on delivery discharge

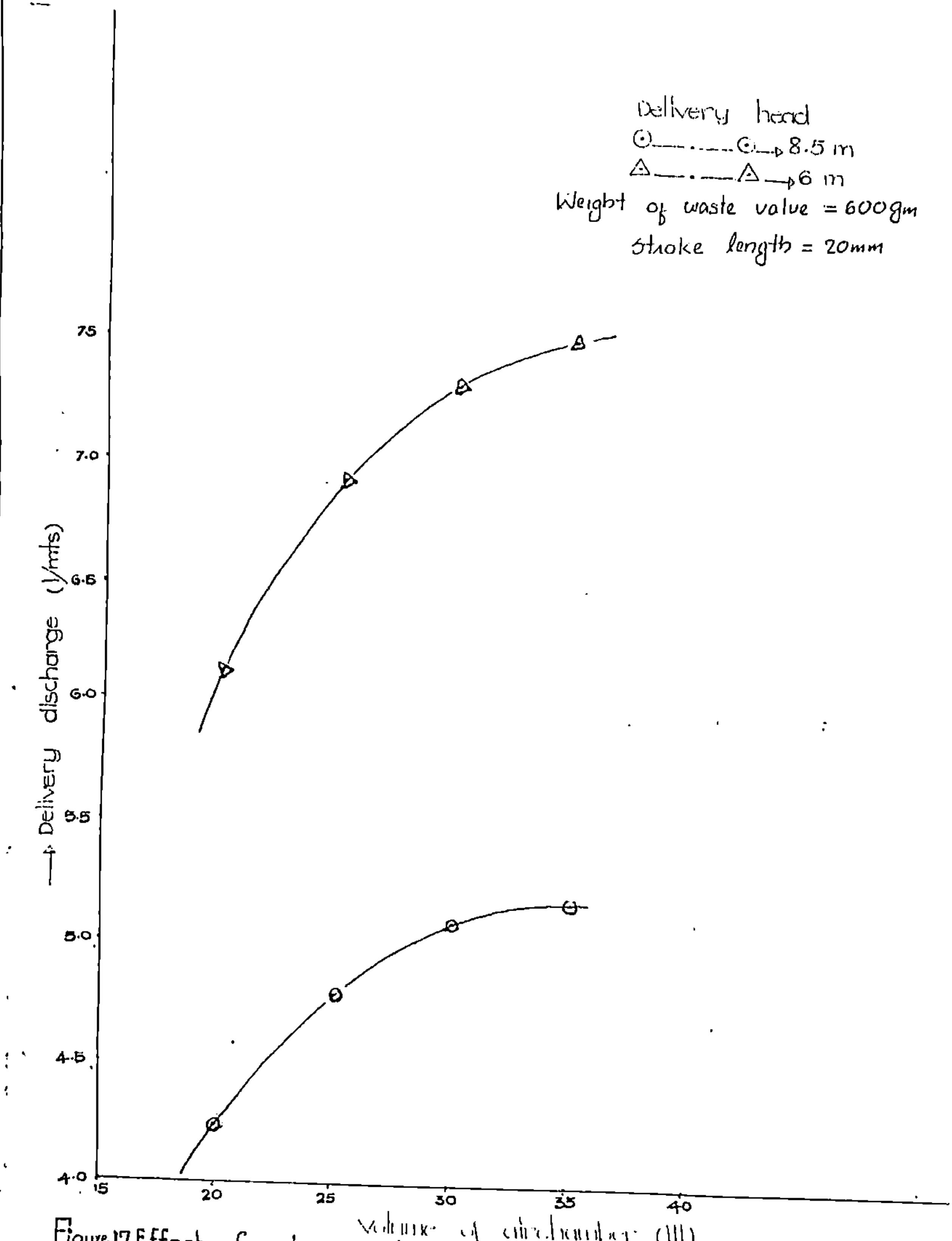


Figure 17. Effect of volume of air chamber on delivery discharge.

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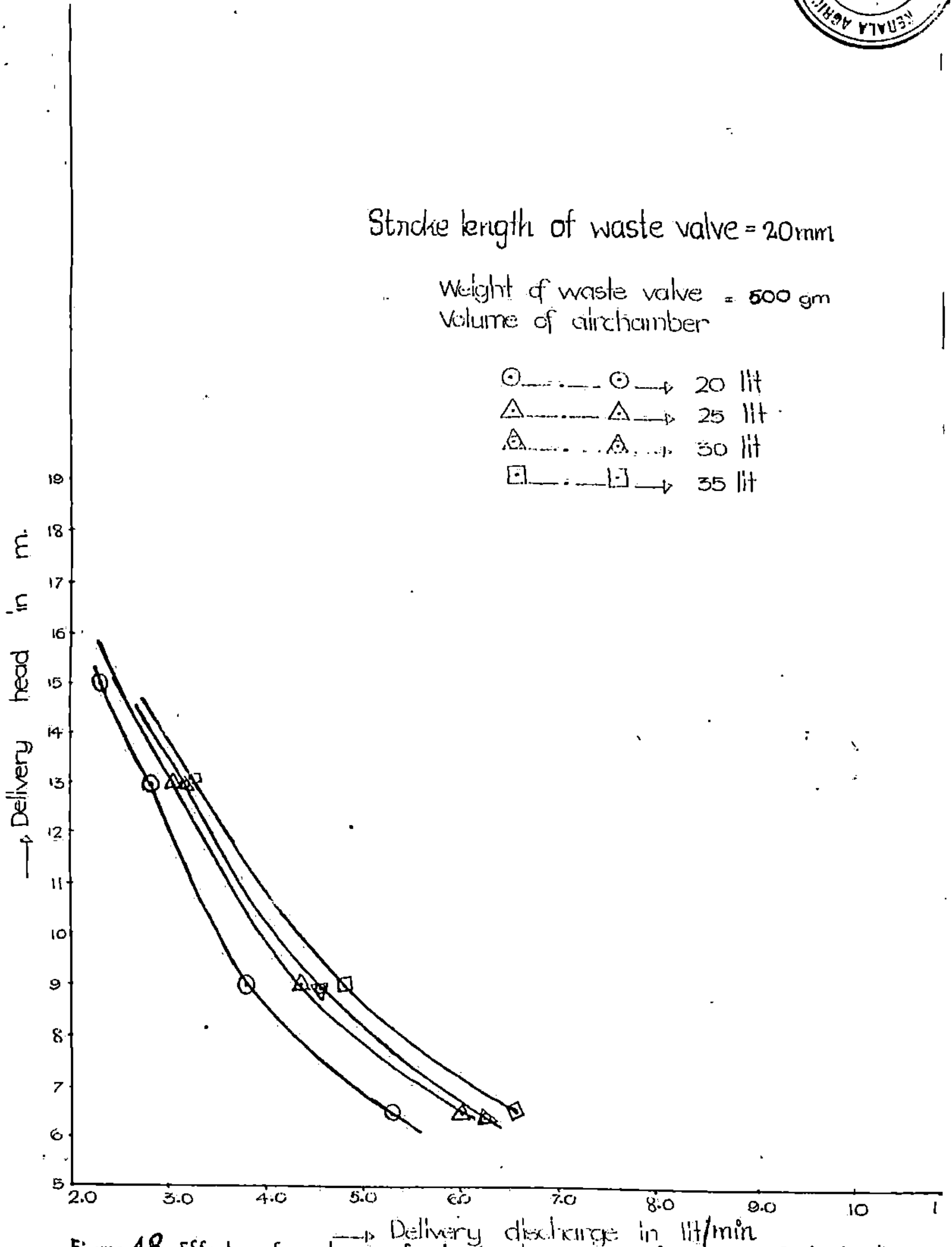

Figure 18. Effect of volume of air chamber on performance of hydraulic ram.

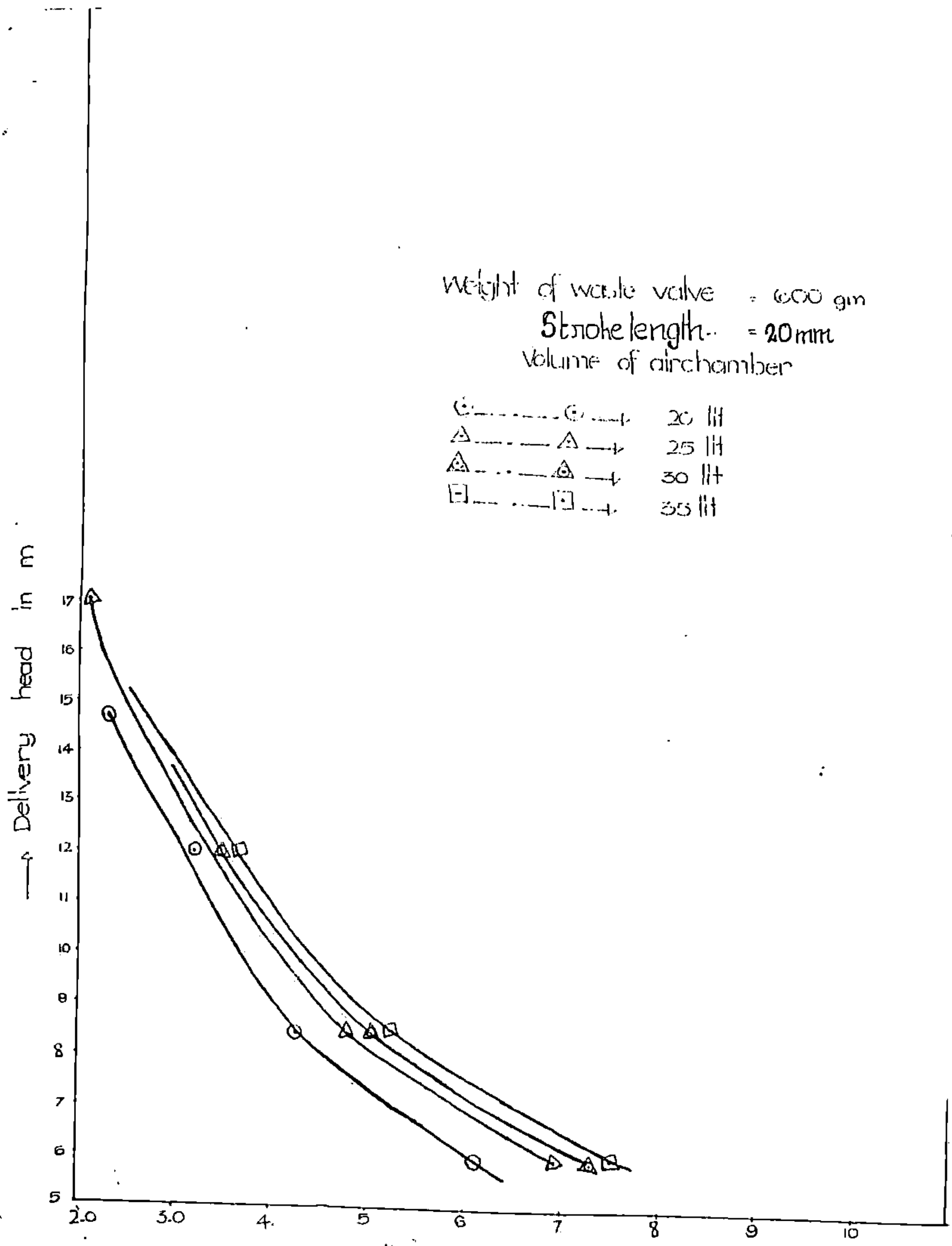

Figure 19. Effect of volume of air chamber on performance of hydraulic ram.

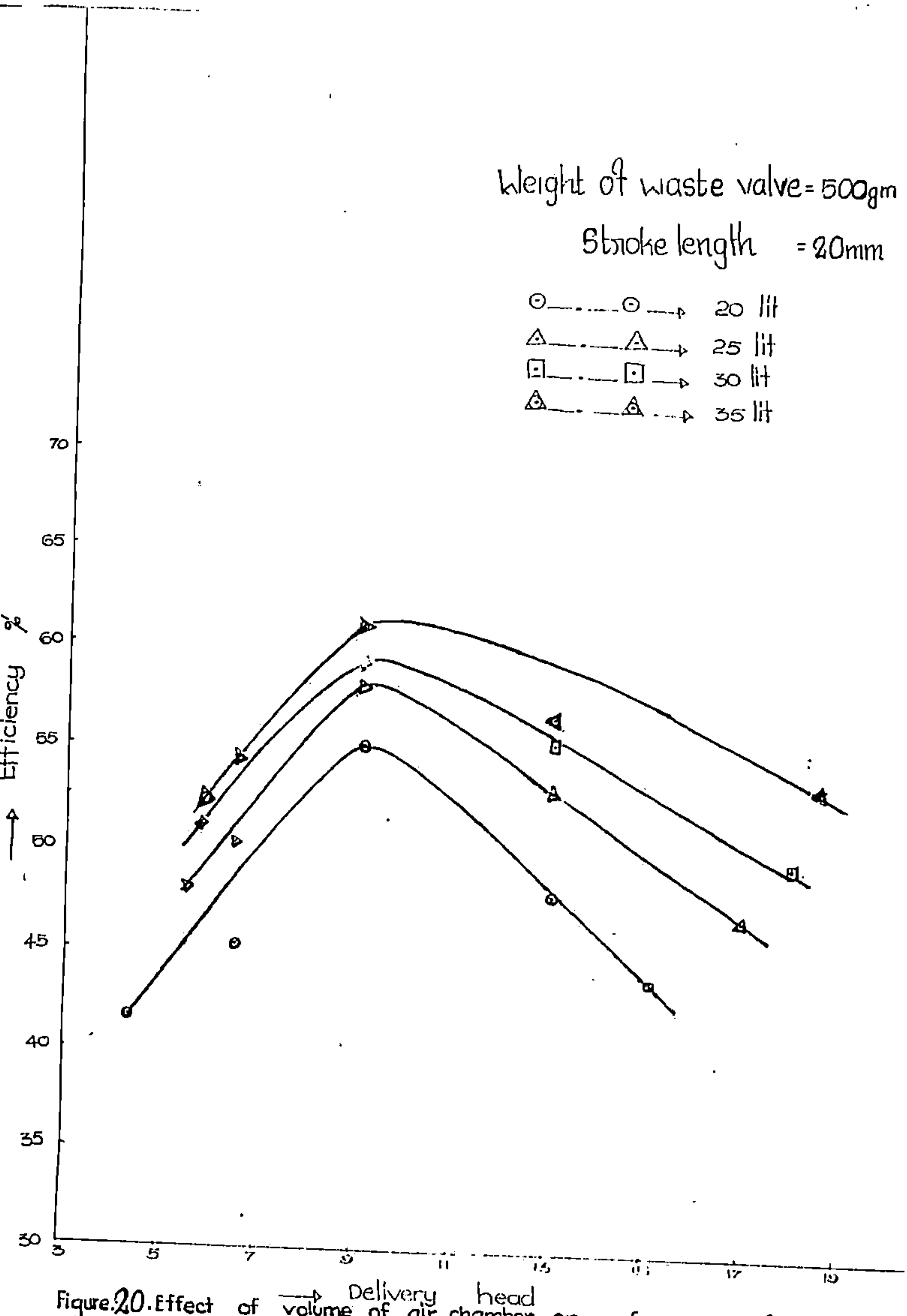

Figure.20. Effect of volume of air chamber on performance of hydraulic ram.

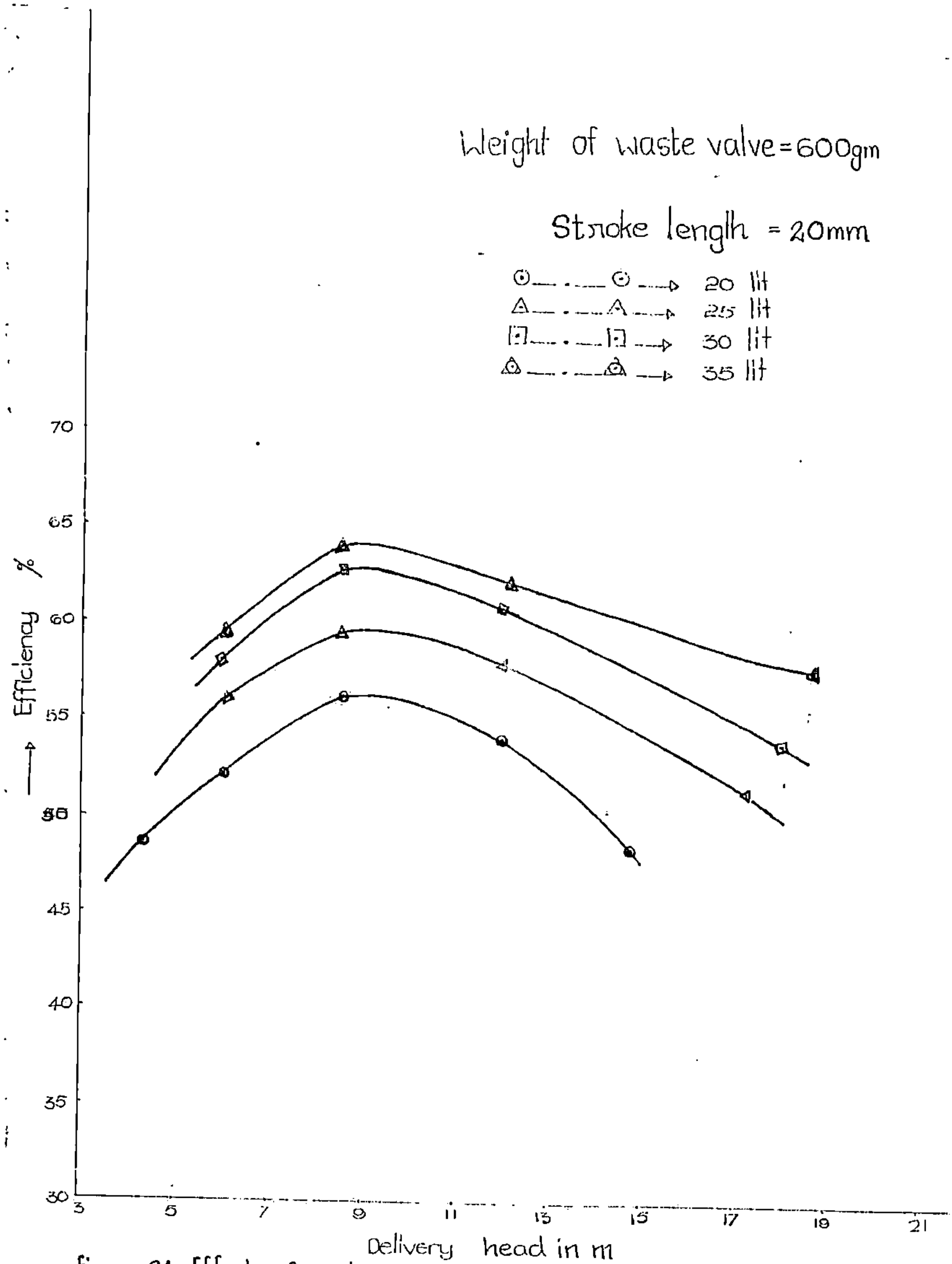

Figure.21. Effect of volume of air chamber on performance of hydraulic ram.

it is also observed that the efficiency of ram increases with increase in Air chamber volume for a given value of delivery head keeping other parameters constant, which may be due to the corresponding increase in delivery discharge with increase in Air chamber volume. It is also observed from the curves that the delivery head corresponding to the maximum efficiency at different volumes of Air chamber for a particular weight and stroke length of waste valve and delivery valve is more or less same. It is found that the difference is efficiency due to the increase in volume of Air chamber is less for low values of delivery head. After attaining the maximum efficiency, the difference in efficiency with increase in volume of Air chamber tends to increase as the delivery head increases.

Figure (18) and (19) shows that the relationship between delivery discharge and delivery head at different volumes of Air chamber. From this it is seen that the change in delivery discharge is more pronounced at lower delivery heads with change in volume of Air chamber. In the present study the increase in delivery discharge between 5 m to 8 m delivery head is high compared to the increase in delivery discharge between 10 m to 13 m delivery head. In general, the ram shows steep increase in delivery discharge at lower delivery heads and the rate of increase is decreases with increase in delivery head.

From the observed values it is clear that the operating range of hydraulic ram for different volume of Air chamber are differnt. The operating range under different volumes are given in Table 14.

Table 14. Operating range of hydraulic ram at different volumes of Air chamber

Volume of Air chamber		Operating range
20 litre	:	4.20 - 15
25 litre	:	5.50 - 17
30 litre	:	5.75 - 18
35 litre	:	6.00 - 18.5

From the Table, it is clear that operating range and minimum delivery head for which the hydraulic ram operates increases with increase in volume of Air chamber.

Hence from all these it reveals that the volume of Air chamber plays a significant role in the efficiency of operation of hydraulic ram, especially at lower volume of Air chamber.

4.4. Effect of continous operation of ram on discharge

To study whether continous operation of the ram for a long time has any effect on its output, the ram was operated continously for 12 hours and its delivery discharge

TABLE 15 EFFECT OF CONTINOUS OPERATION

OF RAM ON DISCHARGE

Time hrs	Discharge l/min
0	6.1
1	6.1
2	6.05
3	5.98
4	5.95
5	5.95
6	5.90
7	5.87
8	5.8
9	5.8
10	5.73
11	5.7
12	5.7

were monitored at one hour interval. The data is presented in Table 15. It shows a slight decrease in delivery discharge with time which is found to be insignificant. The slight decrease in delivery discharge may be due to the decrease in volume of air in the Air chamber, which dissolved and escaped through the delivery discharge.

Selvarajan (1985) had found an effect of the air volume in the Air chamber on the continous operation of hydraulic ram. The reduction in air volume had brought about a reduction in delivery discharge. The reduction in delivery discharge in this study was found to be very low or insignificant which implies that the reduction in air volume is insignificant compared to the volume of Air chamber. This may be due to fact that in the present study an Air chamber volume of 20 litres was used which was about thrice the Air chamber volume used by Selvarajan.

4.5. Effect of Inclination of supply pipe

In order to study the effect of inclination of supply pipe on the performance of hydraulic ram, all other parameters like weight and stroke length of delivery valve and waste valve, volume of Air chamber were kept constant and delivery head and delivery discharge were measured for different inclination of supply pipe. The results of the study are presented in Tables 16. a, b, c, d. 17.a, b, c, d.

TABLE 16. EFFECT OF INCLINATION OF SUPPLY PIPE ON THE PERFORMANCE OF HYDRAULIC RAM

(a) Angle of inclination of supply pipe = 8.5

Serial . No.	Delivery discharge l/min.	supply discharge l/min.	Delivery head Hd (m)	Ratio of suppl plied water to delivered water	Ratio of deli vered head to supply head	Beat freq uency per minute.	Efficency %
1	2	3	4	5	6	7	8
1	2.2	29	11.9	13.2	6.1	45	46
2	4.2	31.2	7.0	7.4	3.6	45	48.5
3	5.5	34.5	4.5	6.3	2.3	44	36.7
4	7.0	36.2	3.5	5.2	1.8	43	35.0

Weight of waste valve = 500gm, stroke length = 42mm
Weight of delivery valve = 185.37gm, stroke length = 50mm

TABLE 16. EFFECT OF INCLINATION OF SUPPLY PIPE ON THE PERFORMANCE OF HYDRAULIC RAM

(b) Angle of inclination of supply pipe = 7

Serial No.	Delivery discharge l/min.	supply discharge l/min.	Delivery head Hd (m)	Ratio of suppl plied water to delivered water	Ratio of deli vered head to supply head	Beat freq uency per minute	Efficency %
1	2	3	4	5	6	7	8
1	1.75	18.2	9.0	10.4	5.17	43	50
2	2.9	22.4	7.0	7.72	4.0	42	52.
3	4.0	27.7	4.5	6.2	2.6	42	36.7
4	6.2	27.8	3.2	4.4	1.84	42	35.0

Weight of waste valve = 500gm, stroke length = 42mm

Weight of delivery valve = 185.37gm, stroke length = 50mm

TABLE 16. EFFECT OF INCLINATION OF SUPPLY PIPE ON THE PERFORMANCE OF HYDRAULIC RAM

(c) Angle of inclination of supply pipe = 6.

Serial No.	Delivery discharge l/min.	supply discharge l/min.	Delivery head Hd (m)	Ratio of supplied water to delivered water	Ratio of delivered head to supply head	Beat frequency per minute	Efficency %
1	2	3	4	5	6	7	8
1	1.8	18.0	7.0	10.	4.42	40.0	45
2	2.75	19.7	5.0	7.18	3.15	41.0	45.4
3	3.7	24.5	4.0	6.62	2.52	41.0	38.0
4	5.6	39.4	3.0	5.26	1.9	40 .0	36.0

Weight of waste valve = 500gm, stroke length = 42mm

Weight of delivery valve = 185.37gm, stroke length = 50mm

TABLE 17. EFFECT OF INCLINATION OF SUPPLY PIPE ON THE PERFORMANCE OF HYDRAULIC RAM
(a) Angle of inclination of supply pipe = 8.5

Serial No.	Delivery discharge l/min.	supply discharge l/min.	Delivery head Hd(m)	Ratio of supplied water to delivered water	Ratio of delivered head to supply head.	Beat frequency per minute	Efficency %
1	2	3	4	5	6	7	8
1	2.25	26.5	12.0	10.65	6.13	55	52.8
2	4.3	28.30	7.0	8.18	3.58	55	54.4
3	5.3	29.4	5.0	4.62	2.55	54	46.20
4	9.9	34.5	3.0	3.48	1.54	53	44.6

Weight of waste valve = 600gm, stroke length = 20mm

Weight of delivery valve = 185.37gm, stroke length = 50mm.

TABLE 17. EFFECT OF INCLINATION OF SUPPLY PIPE ON THE PERFORMANCE OF HYDRAULIC RAM
(b) Angle of inclination of supply pipe = 7

Serial No.	Delivery discharge l/min.	supply discharge l/min.	Delivery head Hd (m)	Ratio of supplied water to delivered water	Ratio of delivered head to supply head	Beat frequency per minute	Efficency %
1	2	3	4	5	6	7	8
1	1.8	19	10.	10.56	5.76	52	54.6
2	2.5	20.9	8.0	8.36	4.6	52	55.6
3	4.0	24.0	5.0	6.0	2.9	51	49.2
4	8.0	29.0	3.0	3.62	1.73	50	47.6

Weight of waste valve = 600gm, stroke length = 20mm

Weight of delivery valve = 185.37gm, stroke length = 50mm

TABLE 17. EFFECT OF INCLINATION OF SUPPLY PIPE ON THE PERFORMANCE OF HYDRAULIC RAM

(c) Angle of inclination of supply pipe = 6

Serial No.	Delivery discharge l/min.	supply discharge l/min.	Delivery head Hd (m)	Ratio of supplied water to delivered water	Ratio of delivered head to supply head	Beat frequency per minute	Efficency %
1	2	3	4	5	6	7	8
1	1.82	16.4	7.5	6.88	4.73	49	52.24
2	2.75	18.0	6.0	6.54	4.56	49	53.0
3	3.2	19.0	5.0	5.90	3.15	48	54.1
4	6.2	22.2	3.0	3.58	1.90	47	51.0

Weight of waste valve = 500gm, stroke length = 42mm

Weight of delivery valve = 185.37gm, stroke length = 50mm

TABLE 18. EFFECT OF INCLINATION OF SUPPLY PIPE ON PERFORMANCE OF HYDRAULIC RAM

Sl. No	Angle of inclination	Delivery discharge (l/min)	Ratio of supplied water to delivered water	Magnification factor	Beat frequency per minute	Maximum Efficiency %
		4.2	7.4	3.6	45	48.5
1	8.5	4.3	8.18	3.58	55	54.4
		2.9	11.4	6.9	61	59.0
		2.9	7.72	4	42	52.0
2	7	2.5	8.36	4.6	52	55.6
		2.05	9.15	7.1	59	62.0
		2.75	7.19	3.15	41	45.4
3	6	3.20	5.9	3.15	48	54.1
		2.5	10.2	6.0	57	57.2

and 18.

From the table, it is observed that the efficiency for different range of magnification factor was generally high for 7 degree inclination of supply pipe than the 8.5 and 6 degree inclination of supply pipe. The efficiency range at 7 degree inclination of supply pipe for a magnification factor range of 1.84 to 5.17 is observed as 40 to 52 percentage. The maximum efficiency is corresponding to a magnification factor of 4. The efficiency range for 8.5 degree inclination is found to be 35 to 45 percentage and 6 degree inclination is 36 to 45.5 percentage.

From the Table it is also observed that the ratio of supplied water to delivered water is increased with increase in magnification factor. At magnification factor of 1.8 to 5.2 in case of 7 degree inclination of supply pipe the ratio of supplied water delivered water ranged from 4.4 to 10.4.

It is also observed from the Table the same number of beat frequency for all ranges of magnification factor at a particular angle did not give the highest efficiency. For low magnification factor, the delivered discharge as well as efficiency was generally higher for higher beat frequency.

From the results, it can be concluded that in the present study, the hydraulic ram shows best range of efficiency of operation at 7 degree inclination of supply pipe than the 8.5 and 6 degree inclinations.

SUGGESTIONS FOR FURTHER WORK

As a result of the present study conducted on the hydraulic ram, the following areas are considered important for further investigation.

1. An exhaustive study is necessary to standardise the volume of Air chamber for different sizes of hydraulic ram for different supply head and delivery head conditions.

2. In the present study the impulse valve is fitted prior to the Air chamber, it has to move up and down during the operation of hydraulic ram causing some loss of energy dur to 90 degree deviation in the direction of flow from the supply pipe. If however, the impulse valve is fitted along the supply pipe and with a spring mechanism so that the direction of flow through the valve does not change and the opening of the valve is ensured due to spring action. This aspects needs intensive study.

3. A detailed study is necessary to standardise the length of supply pipe for different size of the hydraulic ram under different supply head conditions.

SUMMARY AND CONCLUSION

The importance of irrigation in increasing yield from agricultural land has been widely recognised for many years. In India the Agricultural production in many years is hampered by the non-availability of adequate power for irrigation. The shortage of power often affects the lift irrigation projects. The hydraulic ram is the simple device, which uses the kinetic energy of a large quantity of flowing water available at a lower elevation to lift a portion of it to a higher elevation. This is achieved by the successive water hammer pressure generated by the automatic and intermittent stopping of the flow of water. In the mountainous regions of India and other developing countries, there are numerous sites where hydraulic ram can be installed. Realizing this vast potential of hydralic ram in hilly regions, manufacturing and use of hydraulic rams have been intensified.

A number of manufactures in the country and outside have started the manufacture of hydraulic rams. The design of such hydraulic rams are based on experience rather than the basis of understanding of the behaviour of the different parameters influencing the performance of the hydraulic ram. Though this device has been in use for a century, only limited information is available to the designers on the effects of differnt parameters on the performance of hydraulic ram. No serious attention has been given to hydraulic ram for a long term since its advantages have not been realized due to its site specific applicability and cheap availability of fuels in abudance till recently. The rapid depletion of conventional sources of energy and increasing demands have now focussed the attension on a high efficiency hydraulic ram.

The present study was done with the hydraulic ram installed in the Hydraulic Laboratory at K.C.A.E.T., Tavanur, fabrication of which was done with commonly available pipes and fittings and with some easily fabricable components. Provisions were given to the hydraulic ram to change the weight and stroke lengths of waste and delivery valves. An Air chamber was separately fabricated above the delivery valve. Air chamber was fabricated with provisions to alter its volume.

The performance of hydraulic ram was evaluated mainly by observing the delivery head and delivery discharge relationships. In each case, the efficiency was evaluated. Typical performance characteristics were plotted for each of the changes in the condition of operations.

The performance of the ram was evaluated for the following conditions.

The effect of length of supply pipe, by changing the length of supply pipe. Studies were conducted for supply pipe lengths of 13, 14, 15 and 16 metres.

The effect of L/D ratio of air chamber on the performance of ram for a given volume for the L/D ratios of 6.2, 14.5 and 24.7.

The variation in delivery discharge and efficiency were evaluated for volumes of air chamber 20 litres, 25 litres, 30 litres and 35 litres.

The effect of continous operation on delivery discharge was also studied. The ram was worked for 12 hours continously.

The performance of ram was evaluated for inclinations of supply pipes 8.5, 7.0 and 6.0 degrees.

The findings of the present study are as follows:

1. The delivery discharge increases with increase in length of supply pipe upto a point and then gave a decrease in delivery discharge with further increase in length of supply pipe. Supply pipe lengths of 14 and 15 metre show best range of efficiency of operation.

2. The change in delivery discharge for a given delivery head due to the effect of change in length of supply pipe is more for low values of delivery head.

3. There is a general trend that the efficiency of the hydraulic ram increases with the increase in delivery discharge until it attains a maximum value. After attaining the maximum value, efficiency decreases with increase in delivery discharge.

4. The L/D ratio of air chamber have no significant effect on the values of delivery discharge, efficiency and delivery head for a given volume of air chamber.

5. For a given L/D ratio of air chamber, the delivery discharge increases with decrease in stroke length of delivery valve.

6. There is an increase in delivery discharge with increase in volume of air chamber, but the rate of increase in delivery discharge decreases with increase in volume of air chamber.

7. The efficiency of ram increases with increase in air chamber volume for a given value of delivery head keeping other parameters constant. The delivery head corresponding to the maximum efficiency at different volumes is more or less same. In the present study maximum efficiency was observed in the range of 8 to 10m delivery head.

8. The ram shows steep increase in delivery discharge at lower delivery heads with increase in Air chamber volume and the rate of increase is decreases with increase in delivery heads.

9. The minimum delivery head for which the hydraulic ram operates increases with increase in volume of Air chamber.

10. The operating range of hydraulic ram increases with increase in volume of Air chamber.

11. The continous operation of hydraulic ram have no significant effect on delivery discharge when the Air chamber volume is more than 20 litres.

12. The hydraulic ram shows best range of efficiency of operations at 7 degree inclination of supply pipe than the 8.5 and 6 degree inclinations.

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PERFORMANCE STUDY OF HYDRAULIC RAM BY VARYING LENGTH AND INCLINATION OF SUPPLY PIPE

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ABSTRACT OF A THESIS

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ABSTRACT

In India, the agricultural production in many years is hampered by the non availability of the adequate power for irrigation. The shortage of power often affects the lift irrigation project. Main problems in enhancing irrigation facilities in hilly regions are their highly uneven topography and non availability of conventional sources of power. The increasing exploitation of conventional energy sources for meeting the increasing power demands is becoming expensive. Under such circumstances, devices like hydraulic rams are to be efficiently designed for lifting water in regions where adequate supply of water and favourable conditions for installations for hydraulic rams exists. Hydraulic ram is a simple automatic device, which uses the kinetic energy of a large quantity of flowing water available at lower elevation to lift a portion of it to a higher elevation. The simplicity of construction and the automatic operation make it especially adaptable to remote areas.

The performance study of hydraulic ram was evaluated mainly by observing the delivery head and delivery discharge relationships. In each case, the efficiency was evaluated. Typical performance characteristics were plotted

for the changes in conditions of operations. Effect of the performance of the hydraulic ram was studied by changing length of supply pipe, L/D ratio of Air chamber, volume of Air chamber and inclination of supply pipe.

The major findings of the research work are:

1. The ram shows best range of efficiency of operation for 14 and 15 metre lengths of supply pipe.

2. The L/D ratio of Air chamber have no significant effect on the values of delivery discharge, efficiency and delivery head for a given volume.

3. The delivery discharge increases with increase in volume of Air chamber, but the rate of increase in delivery discharge decreases with increase in volume of Air chamber.

4. The continous operation of hydraulic ram have no significant effect in higher volumes of Air chamber.

5. The hydraulic ram shows best range of efficiency of operation at 7 degree inclination of supply pipe than the 8.5 and 6 degree inclinations.