PERFORMANCE STUDY OF CENTRIFUGAL PUMP USING DIFFERENT FOOT-VALVES AND PIPES

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PROJECT REPORT

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1996

DECLARATION

We hereby declare that this project report entitled **"PERFORMANCE STUDY OF CENTRIFUGAL PUMP USING DIFFERENT FOOT-VALVES AND PIPES"** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, associateship, fellowship, or other similar title of any other University or Society.

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29th May, 1996

CERTIFICATE

Certified that this project report, entitled **"PERFORMANCE STUDY OF CENTRIFUGAL PUMP USING DIFFERENT FOOT-VALVES AND PIPES"** is a record of project work done jointly by JYOTHY PADMAKUMAR, KAILAS, K.P. AND LITHA, S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

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SYMBOLS AND ABBREVIATIONS USED

BIS	-	Bureau of Indian Standards
CBIP	-	Central Board of Irrigation and Power
cm	-	centimetre
cm^2	-	square centimetres
Fig.	-	figure
GI	-	Galvanised iron
HDPE	-	High density polyethylene
hp	-	horse power
"	-	inch
IS	-	Indian Standard
kg/cm^2	-	kilogram per square centimetres
kw	-	kilowatt
kwh	-	kilowatt hour
lps	-	litres per second
m	-	metre
m kwh	-	million kilowatt hour
ml	-	millilitre
mm	-	millimetre
Mw	-	megawatt
No.	-	number
%	-	per cent
PVC	-	Poly venyl chloride
RPM	-	revolutions per minute
RPVC	-	rigid polyvenyl chloride
Rs.	-	Rupees

INTRODUCTION

India is an agricultural based nation. It is estimated that the geographical area of India is 328.8 m ha out of which 113.5 m ha can be brought under irrigation. Lift irrigation from major rivers and streams plays a vital role in development of rural economy and generation of opportunities for gainful employment where canal irrigation facilities are inadequate or absent. Creating canal irrigation facilities requires large capital and longer gestation periods whereas lift irrigation schemes yield quick returns and capital required is very much less and also they can be completed in one or two working seasons. Hence wherever lift schemes are possible the same will have to be preferred and executed. Amongst modern pumps, centrifugal pumps are most widely used in lift irrigation practice.

In India, agricultural production in many areas is seriously hampered due to non-availability of adequate power to lift water for irrigation. During last two decades, there has been rapid development in the field of agriculture which has considerably increased the demand for power. Estimates have been made on energy requirements during the period 1973-74 to 1998-99 (Michael, 1978). According to these estimates, at the end of the century the human and animal power will reduce from 2366 m kwh per year to 893 m kwh per year. At the same time diesel power requirement will increase from about 1813 m kwh to 3621 m kwh. The electrical power demand will increase from 4242 m kwh to 14208 m kwh. These figures indicate that the energy requirements will be approximately trippled by the end of the century.

What is really needed is a great deal of effort to conserve or save energy in pumping. 'Engery saved is energy produced'. Conservation in this context does not mean a restriction in demand. It means an efficient use of energy. Efficiency of energy use also means a reduction in the production cost of agriculture for the farmer.

Diesel oil is the other energy source for irrigation pumping. We have a large number of diesel pumpsets about 45 lakhs (1995) already working. Besides over a lakh of pumpsets are being added every year. Requirement of diesel oil is consequently mounting steadily adding to the burden of imports using scarce foreign exchange resources. Diesel pumpsets are also more expensive to the farmer. Both the investment and the operating costs are higher than electric pumpsets. Hence diesel is not a practical solution to the growing problem of energy supplies to agriculture and more specifically the problem of electricity shortage.

We have today (1996), 13.5 million pumpsets installed in agricultural farms across the length and breadth of our country. Nearly half a million more pumpsets are added every year. It is known that a great majority of the pumpsets are grossly inefficient from the view point of energy consumption. However, field trials have shown that these pumpsets can be rectified through some minor modifications which can give upto 30 per cent savings in energy required. The modifications may cost only Rs.1500 to Rs.2000 per pumpset, but the savings that they bring about are of immense value.

For instance, if 80 per cent of the 57 lakh pumpsets operating in 1984-85 had been rectified, the energy savings would have accrued at the global level could displace a 1870 MW generation capacity (estimate given in the 7th Five Year Plan Document, p. 127) creation a new capacity of this order would call for an investment of almost Rs.3000 crores, while the cost involved in rectification would be less than one fourth of this amount. Hence the importance and urgency involved in the programme of energy conservation in agricultural pumpsets.

The system efficiency of a properly selected efficient pumping system is 40-55 per cent. However in field conditions, it is observed as low as 13-27 per cent. This decrease in efficiency is due to the following reasons.

(i) Use of poor designed foot-valves.

(ii) Use of high friction non-smooth pipes.

(iii) Use of high resistance foot valves and reflux valves.

(iv) Use of undersized pipes in suction and delivery lines.

(v) Unnecessary height of delivery pipe.

(vi) Use of belt-drive instead of monoset pumps.

(vii) Use of shallow elbows instead of long radius bends.

(viii) Poor match of pump with irrigation.

(ix) Pump wear due to cavitation.

(x) Poor maintenance practices.

(xi) The Q (rate of water discharge) and H (the otal head over which the water is to be lifted) do not match with actual Q and H of the well from which water has to be lifted.

(xii) Loss of RPM (revolutions per minute) because of the faulty power transmission system or lower than the expected RPM of the prime mover, especially in an oil engine.

Among all pipe fittings in the suction line responsible for increasing the suction head through their frictional losses, the foot valve contributes to the maximum. Hence the selection of low resistance foot-valve for satisfactory operation of pump is of prime importance. The specifications of foot-valves used for agricultural pumping system is given in IS-10805-1986 (BIS, 1986). The following are the basic requirements of an efficient foot valve.

1. The total area of opening in strainer should be more than cross-sectional area of the suction pipe. An optimum value of the ratio of the cross-section of the suction pipe and the total open area of perforations in the strainer is 1:3.

2. The strainer should have smooth slotted perforations which are properly streamlined to reduce turbulance of flow into it.

3. The area of opening of the base plate on which the valve rests should be equal to or more than the area of the suction pipe.

4. Valve should be hinged that it opens easily and fully.
5. Valve should be leak proof when closed.

The rectification efforts needed are broadly on two fronts namely,

a. Reduction of the friction losses in the foot valve and the piping system.

b. Improving the efficiency of the pump, prime mover and the power transmission system.

Objective of this study are:

(i) To find out more efficient foot valves which are commonly available in Kerala.

(ii) To find out low resistance and suitable piping system on suction and delivery sides of the pumpset.

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.

Patel (1981) reported that depending on the type of foot valve used, the energy consumption due to foot valve in running a pump may be as high as 15 per cent of the total input power.

Pandya (1981) reported that there are about 40 lakhs electric and about 36 lakhs diesel pumpsets operating in India and the excess operational cost due to a cheap but improper quality foot valves, would be of very high magnitude.

Parikh *et al.* (1981) studied the performance of lister type low horse power stationary diesel engines and noticed that the improper foot valve was one of the key factors responsible for excessive fuel consumption.

Thaman *et al.* (1982) reported an improvement of 3.8 to 7.6 per cent in pumpset efficiency as a result of proper design, selection, maintenance and operation of pumpset.

Sewa Ram *et al.* (1982) studied the relationship between velocity head and frictional loss due to foot valve for different ratios of area of opening of strainer and the area of suction pipe. The ratio (strainer opening area to suction pipe area) with less than 3 resulted in heavy loss of head due to friction. However, optimum ratio was found to be in the range 3 to 3.5.

Sewa Ram *et al.* (1982) developed Pantnagar foot valve and claimed that the pantnagar foot valve is 8 times more efficient than local foot valves. The design criteria for this low resistance foot valve are given below.

1. The perforation area of the strainer of the foot valve should be 3 times the cross-sectional area of the suction pipe of the pump.

2. The diameter of opening below the valve seat through which water enters in the casing of the foot valve should be equal to diameter of suction pipe of the pump so that the flow is not restricted.

3. The valve should be connected in such a way that it opens vertically at about 90° when the pump is in operation.

Patel (1982) observed that 95 per cent of the Gujarat farmers use inefficient foot valves with their pumpsets which leads to wastage of energy in the pumpsets. He suggested that by introducing low resistance foot valves, atleast 10 per cent of the energy used in agricultural pumps can be saved.

He also conducted experiments on frictional losses in locally manufactured foot valves and found that a head loss of 10-50 cms was experienced in flap type foot valves. Strainer opening, valve opening and shape of dome are the important factors affecting the frictional loss.

Patel (1982) conducted experiments on foot valves for head loss characteristics at the department of Soil and Water Engineering, Gujarat and reported that the percentage head loss due to foot valves ranged from 14.5 per cent to 35.8 per cent of the total head depending on the discharge. In other words, the seriousness of the foot valve loss can be so great as to cause a loss equal to 1/3 of the total pumping head.

Chauhan *et al* (1982) conducted experiments on foot valves with strainers having circular holes and strainers with continuous slots having total areas of perforation three times the area of suction pipe for comparision. The relationship between velocity head and head loss due to foot valve was studied. The foot valve with slotted strainer performed better.

Bhattacharya *et al.* (1982) estimated the loss of money due to improper foot valve. The cost estimate was calculated for 1000 hours of operation on the basis of current market prices of diesel and electricity rate such annual cost for overcoming the frictional losses due to foot valve with an electric motor driven pump ranged from Rs.5.36 to Rs.30.84 depending on the discharge, whereas the cost with a diesel pump varied from Rs.16.16 to Rs.373.18 for the same discharge condition.

Patel (1984) correctly diagonised the causes of pressure loss in the foot valve. The principal factor for the loss is the flap opening area. When the flap opening area is larger than the suction pipe area there would be covergence of flow and for the reverse there would be divergent flow. As known from the hydraulics the loss in the divergent flow would be more than in the convergent flow. The values of head loss as observed by Patel where 0.1 to 0.13 m in the convergent flow and 0.2 to 0.23 m in the divergent flow.

He reported that foot valve is a major energy consumer component of pumpset. It consumes upto 10 per cent of the total input energy worth Rs.1.50 to 200 crores is consumed by foot valve every year through 40 lakhs electrified and 36 lakhs dieselised pumpsets working at present in India. His study revealed that low resistance foot valve about 8 per cent energy could be saved in pumpsets such saving in 70 lakh pumpsets in the country would be worth around a 50 crore rupees every year.

Patel (1985) analysed that the total head loss in a foot valve would be of loss at the strainer, loss due to sudden contraction of flow at the valve, loss due to sudden enlargement of flow just after the valve, loss due to sudden contraction of flow at the foot valve throat.

Patel *et al.* (1985) found that the foot valve loss by comparing the friction loss in suction pipe with and without foot valves. They noted that the increment in discharge due to absence of foot valve increased the frictional losses in the pipe due to increased velocity. They have conducted test on 10 number of foot valves in the Department of Soil and Water Engineering, Navsari and reported that coefficient of resistance had a value of about 3.1.

Patel (1985) reported that the actual velocity of flow through strainers, the valve opening and in the body of the foot valve, is entirely different from the suction line velocity. The true representative velocity existing at the above points in a foot valve is difficult to assess due to sudden change of flow direction, partial or incomplete opening of the flap and varying flow areas at these three points.

The Petroleum Conservation Research Association (1986) conducted a study of 1724 dieselised pumpsets in Gujarat and revealed that it was possible to save an average of 30 per cent of fuel in these pumpsets by implementing various fuel efficiency measures like adoption of improved foot valves etc. Fifty seven pumpsets were modified and a saving of 16 per cent to 41 per cent were noticed in diesel utilisation.

On the basis of various field studies carried out over the last few years, including the two pilot projects sponsored by the Rural Electrification Corporation covering 24000 pumpsets during 1986-87, the following four types of cost effective rectification measures have been identified in the case of centrifugal pumpsets; as given in Table 1.

In Karnataka state, in a pilot study sponsored by CBIP 100 pumpsets were rectified in 1992 by replacing old foot valves with frictionless and also delivery pipes with PVC/HDPE pipes. The details of investment and savings of the rectification measures are given in Table 2.

It may be observed from table that the scope for saving conforms with the results obtained in the studies conducted elsewhere in India. What is liable to change is the cost of power and investment needed for rectification which are crucial in determining the feasibility of rectification. Agricultural tariffs being the lowest, or as in many states

Table 1. Cost effective types of rectification measures

Type of rectification	Code	Energy saving per cent
1. Use of low resistance foot-valve	R_1	10-15
2. Use of proper sized RPVC pipe for suction line + R_1	R_2	20-25
3. Use of proper sized RPVC pipe for delivery line + R_2	R_3	30-35
4. Use of monoblock pumpset + R_3	R_4	40-60

KARNATAKA CASE STUDY

Table 2. Summary of cost and benefit per pumpset

Sl. No.	Item	Investment	Saving	Cost of power
1.	Foot valve	Rs.175/-	8.6%	(i) Lowest L.T. tariff is 0.25 paise kWh (ii) Average 0.39 paise tariff
2.	Suction and delivery by HDPE/RPVC pipes	Rs.1400/-	29%	"
3.	Foot valve + piping systems	Rs.1525/-	33.16%	"

Source: CBIP, Tech. Report No.81 "Energy in irrigation pumpsets in Karnataka" 1992.

determined on horse power basis which turns out to be lowest in terms of realisation of money per unit of power consumed the economics of rectification is heavily in favour of replacing old foot valves with frictionless foot valves and in selected cases piping system too can be rectified. It and when there is scope for evaluating the rectification benefits with market prices of power, the scope for total rectification tremendously improves. The phases plan for rectification of pumpsets has to take the prevailing tariffs into serious consideration to determine the feasibility.

The existing pumping systems were replaced by new energy, pumping systems at 300 sites 1995 at Gujarat state. In such cases efficient monoblocks of low horse power and improved piping systems were used. The consumption of electricity was reduced by more than 50 per cent and connected load was also reduced by 50 per cent. Summary results are presented in Table 3.

It may be seen from table that even with substantial increase or the investment needed for rectification, alongside reducing the value of electricity of 0.5 paise per KWh as recommended by the power ministers conference, the results are still positive. It also may be noted that out of three types of rectifications, changing foot valve and suction line is most best effective and it is simple too.

Table 3. Summary results of different types of rectifications carried in the Gujarat state with current market prices (1995)

Sl. No.	Item	Foot-valves suction line R_1	Total piping with FV R_2	Complete rectification R_3
1.	No. of pumpsets under rectification	500	127	300
2.	Annual consumption of electricity in kWh per pump			
	A. Before	6892	8157	20198
	B. After	5379	5787	9582
	C. Difference	1513 (21.9%)	2370 (29%)	10616 (52.5%)
3.	Investment needed for rectification goods (in Rs.)	500	1500	10000
4.	Annual cost @ 30% of investment (Rs.)	150	450	3000
5.	Value of electricity saved per pump per year (Rs.)			
	(i) @ Re.1/- per unit	1513	2370	10616
	(ii) @ Re.0.5 per unit	756	1185	5308
6.	Pay back period			
	(i)	4 months	7.5 months	11 months
	(ii)	8 months	15 months	22 months
7.	Incremental cost benefit ratio			
	(i)	1:10	1:5.2	1:3.5
	(ii)	1:5	1:2.6	1:1.7

Hence the criteria for different types of rectification can be as follows.

1. Foot valve + suction line	:	Recommended on all inefficient pumping systems
2. Piping systems + foot valve	:	Recommended on these inefficient pumpsets where the annual consumption is around 10,000 KWh
3. Complete rectification	:	Recommended on these pumping systems where annual consumption is above 10,000 operating hours

The principle is that higher horse power pumpset with more running if inefficient is fit for making investment for complete rectification and vice versa.

MATERIALS AND METHODS

Objective in general of this research work is to evaluate the performance of centrifugal pump with different types of foot-valves and suction and delivery pipes.

The specific objectives are:

(i) Collection of details regarding the availability of different types of foot-valves

(ii) Selection of different types of foot-valves suitable for this study.

(iii) Study the performance characteristics of centrifugal pump by using different foot-valves and select most efficient foot-valve that is available in the market.

(iv) Study the performance characteristics of centifugal pump using GI pipe and PVC pipe on both suction and delivery sides and also to note the power that can be saved by using efficient foot-valve and pipe.

The centrifugal pump consists of an impeller enclosed in a casing. Water enters the pump through pump inlet and is rotated by the impeller of pump. Rotation causes a flow from the centre of the impeller to its rim. The water is then thrown up passing through the gap between casing and impeller and escapes through the discharge pipe. As a result of the vacuum created at inlet, water continues to enter through the suction side due to atmospheric pressure.

Proper installation of a centrifugal pump ensures its prolonged trouble free service. The pump is installed as close to the water surface as possible. It is located at an easily accessible place in clean, dry, well ventilated surroundings. To ensure maximum capacity, the site selected should permit the use of the shortest and most direct suction and discharge pipes.

The centrifugal pumps will not lift water until and unless they are primed before starting. Foot-valve keeps the pump in primed position by retaining water in the pump and in the suction pipe and thereby eleminating the need of repeat priming during the next starting operation. The following are the basic requirements of an efficient foot-valve.

1. The total area of the openings in a strainer should be such that the velocity head is minimum. An optimum value of the ratio of the cross section of the suction pipe and the total open area of perforations in the strainer is 1:3.

2. The strainer should have smooth slotted perforations which are properly streamlined to reduce turbulence of flow into it.

3. The area of opening of the base plate on which the valve rests should be equal to or more than the area of the suction pipe.

4. The valve should be so hinged that it opens nearly full.

5. The valve should be leak-proof when closed.

The trade names of foot-valves selected for the study are:

1. Kirloskar
2. Meccano
3. Prashant
4. Vinu
5. Buno
6. Raj

3.1 Details of various foot valves

3.1.1 Prashant foot valve (Fig.1, Plate 1, Plate 3)

Material of construction	:	Plastic
Strainer area	:	65.42 cm^2
Base opening area	:	18.24 cm^2

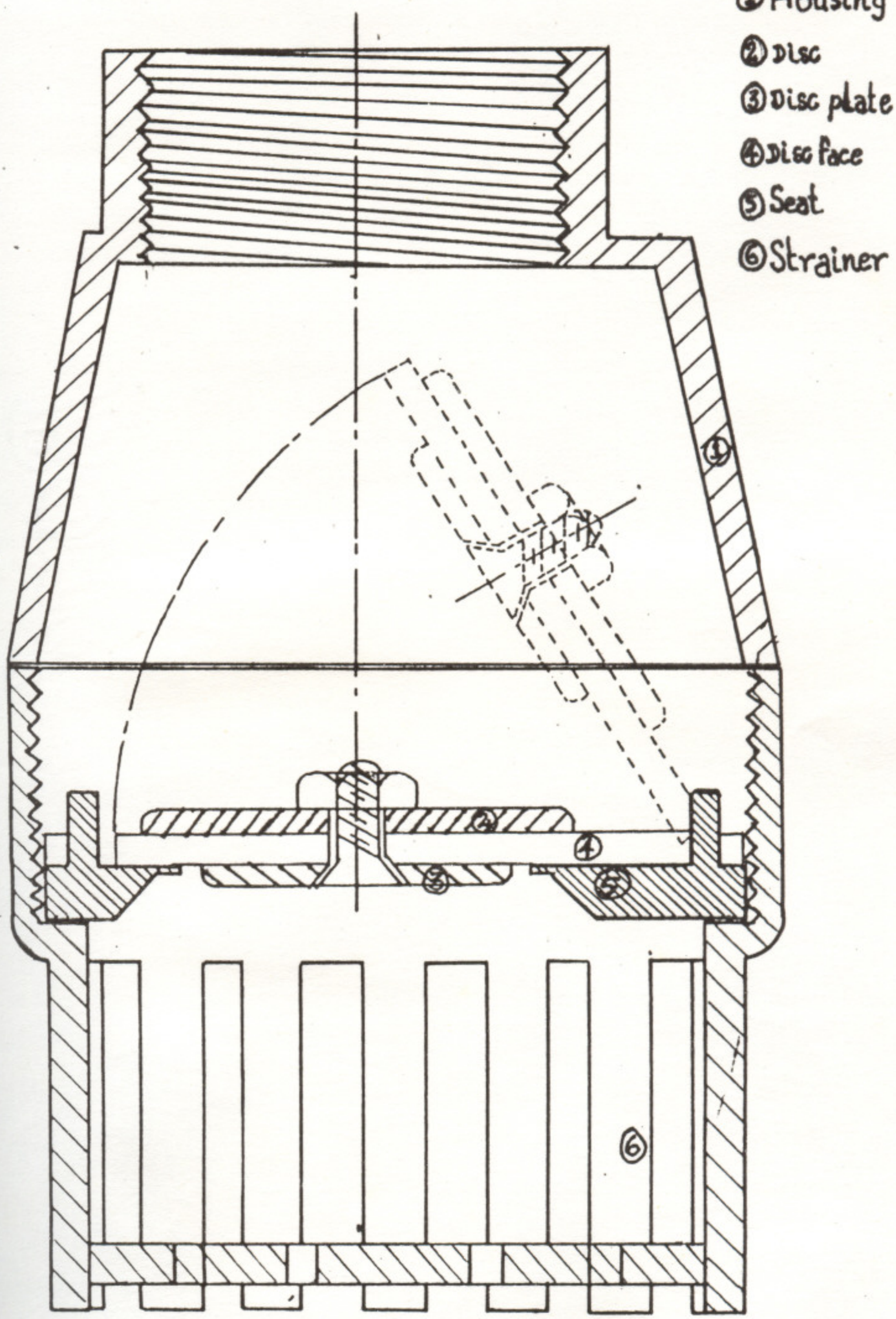


Fig. 1 Sectional view of Prashant foot-valve

Strainer area:suction pipe area	:	3.23:1
Base opening area:suction pipe area	:	0.9:1
Surface smoothness	:	Smooth
Shape of strainer opening		
(i) at the bottom	:	circular at the centre with triangles surrounding it
(ii) at the side	:	rectangular shaped

3.1.2 Kirloskar foot-valve (Fig.2, Plate 2 and Plate 4)

Material of construction	:	Cast iron
Strainer area	:	48.28 cm^2
Base opening area	:	23.26 cm^2
Strainer area:suction pipe area	:	2.383:1
Base opening area:suction pipe area	:	1.15:1
Surface smoothness	:	Rough
Shape of strainer opening		
(i) at the bottom	:	circular at the centre
(ii) at the side	:	oval shaped

3.1.3 Meccano foot valve (Fig.3, Plate 1, Plate 3)

Material of construction	:	Plastic
Strainer area	:	48.26 cm^2
Base opening area	:	18.97 cm^2
Strainer area:suction pipe area	:	0.85:1

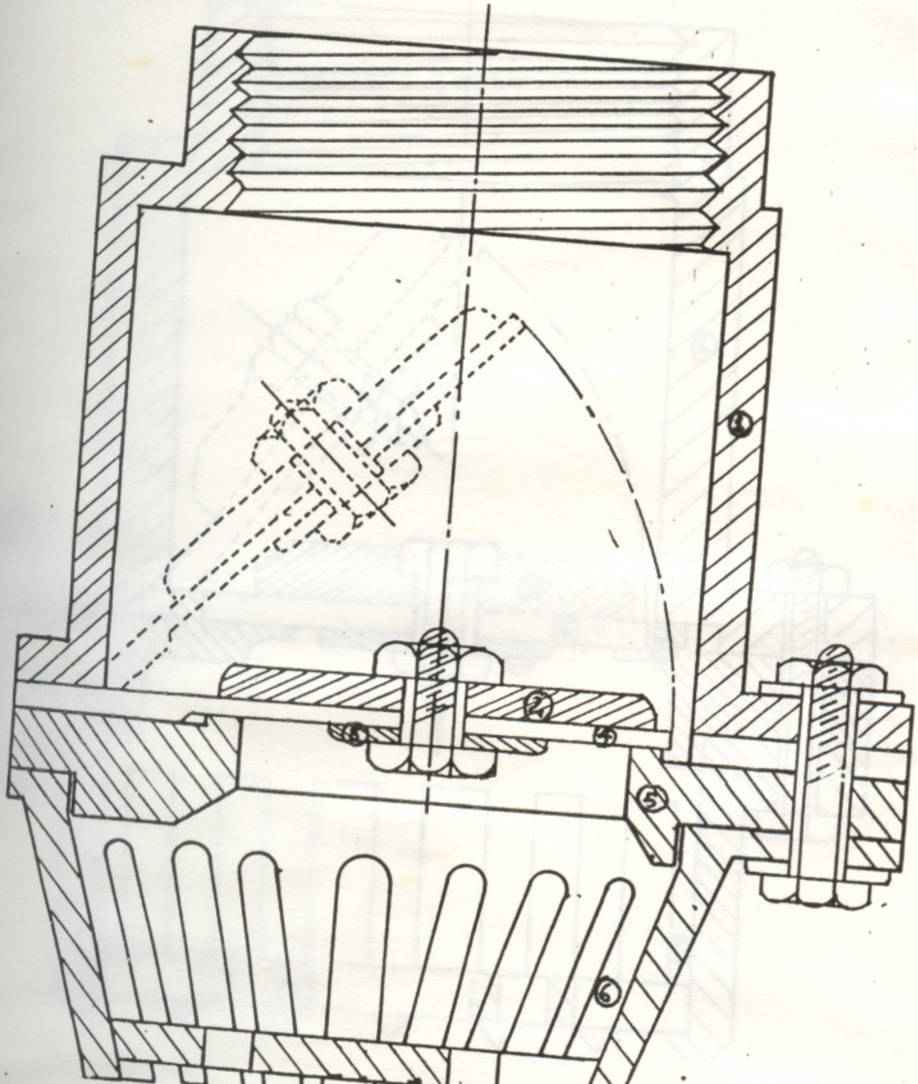


Fig.2. Sectional view of Kirloskar foot-valve

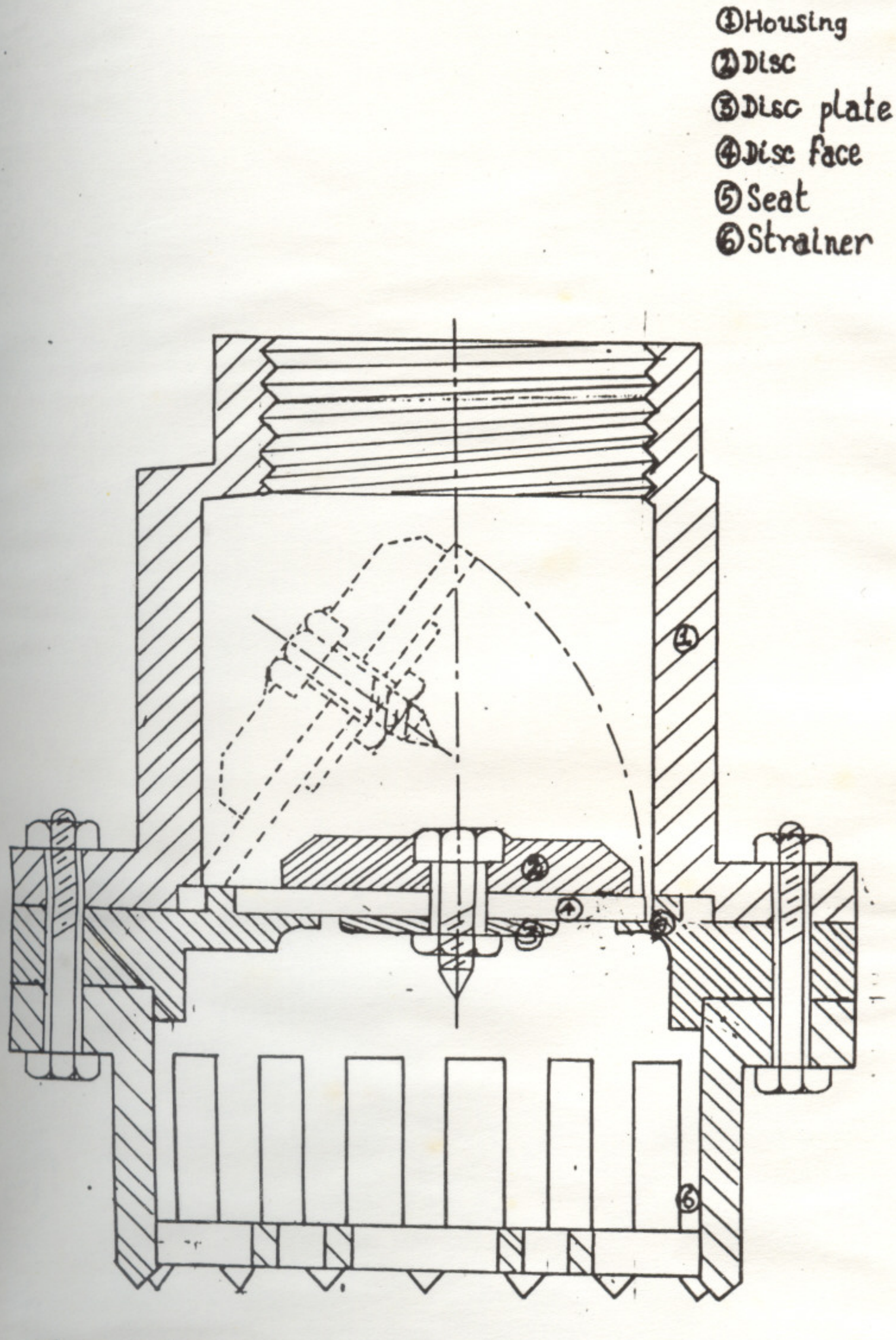


Fig.3. Sectional view of Meccano foot-valve

Base opening area:suction pipe area	:	0.94:1
Surface smoothness	:	Smooth

Shape of strainer opening

(i) at the bottom	:	three concentric circles equally divided into eight sections
(ii) at the side	:	rectangular shaped

3.1.4 Vinu foot-valve (Fig.4, Plate 1, Plate 3)

Material of construction	:	Plastic
Strainer area	:	35.52 cm^2
Base opening area	:	15.42 cm^2
Strainer area:suction pipe area	:	1.753:1
Base opening area:suction pipe area	:	0.76:1
Surface smoothness	:	Smooth

Shape of strainer opening

(i) at the bottom	:	no opening
(ii) at the side	:	dome shaped side with oval opening with an additional wire mesh inside it

3.1.5 Buno foot-valve (Fig.5, Plate 2, Plate 4)

Material of construction	:	Cast iron
Strainer area	:	18.36 cm^2
Base opening area	:	15.93 cm^2
Strainer area:suction pipe area	:	0.91:1
Base opening area:suction pipe area	:	0.79:1

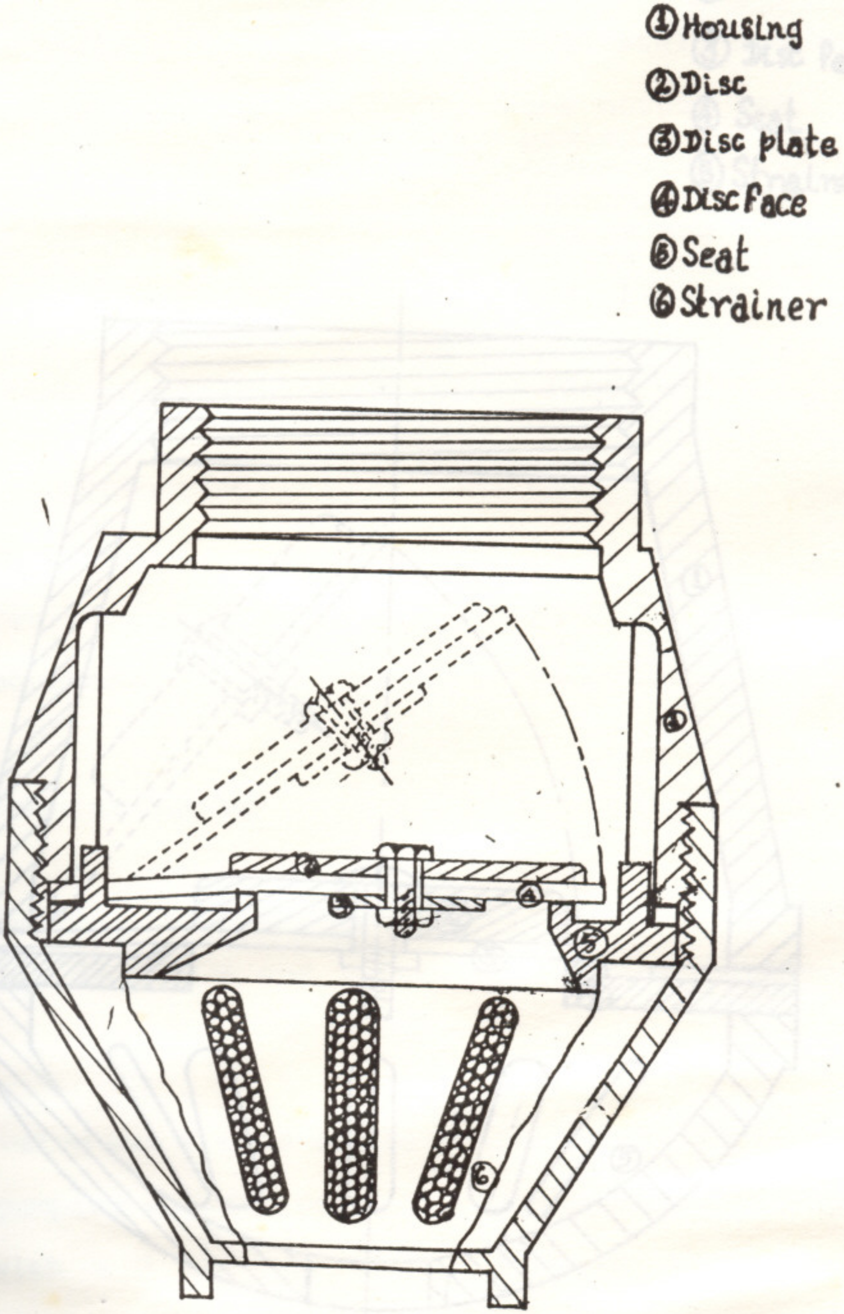


Fig.4. Sectional view of Vinu foot-valve

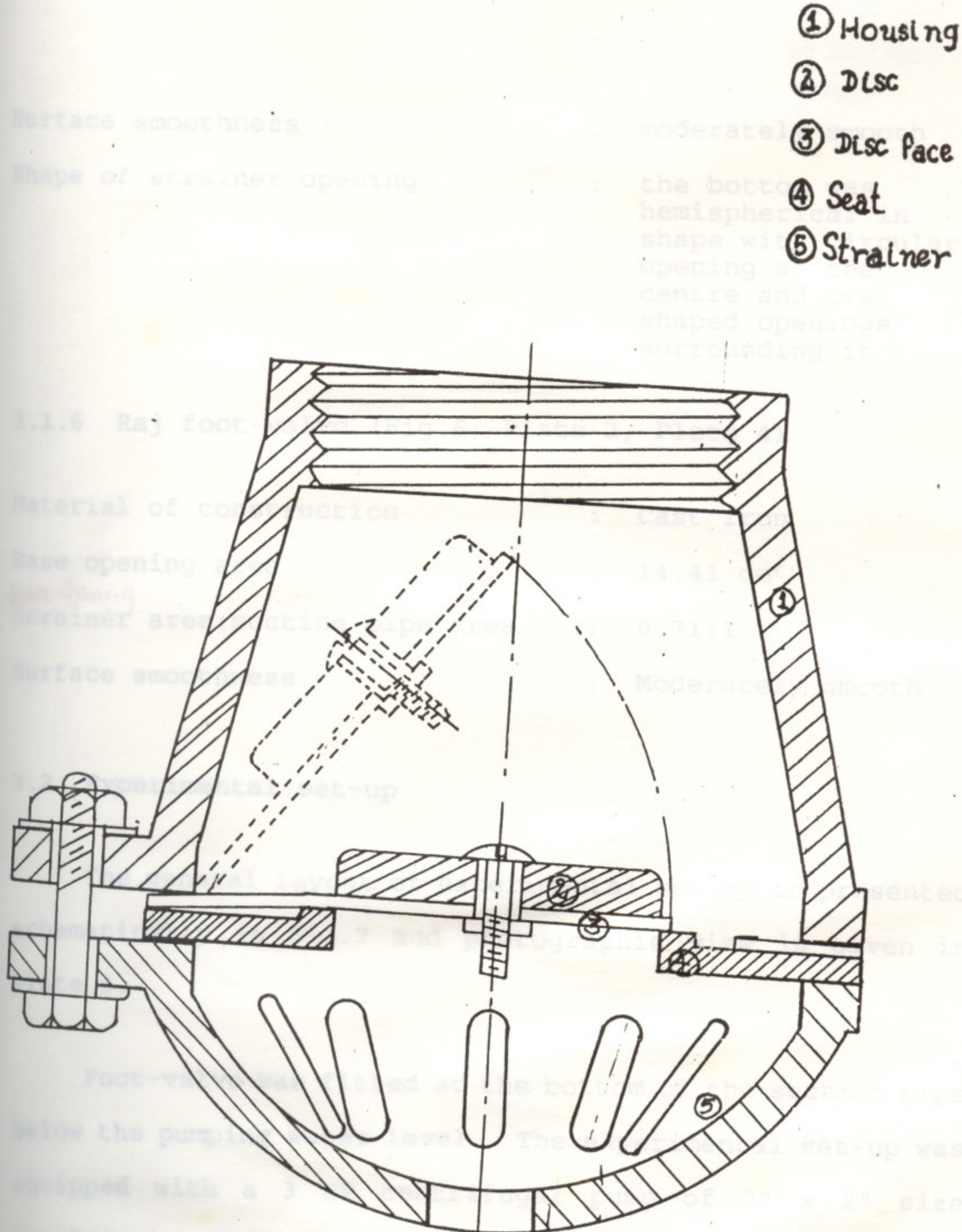


Fig.5. Sectional view of Buno foot-valve

Surface smoothness	:	moderately smooth
Shape of strainer opening	:	the bottom was hemispherical in shape with circular opening at the centre and oval shaped openings surrounding it

3.1.6 Raj foot-valve (Fig.6, Plate 2, Plate 4)

Material of construction	:	Cast iron
Base opening area	:	14.41 cm^2
Base opening ~~Strainer~~ area:suction pipe area	:	0.71:1
Surface smoothness	:	Moderately smooth

3.2 Experimental set-up

The general layout of experimental set-up is presented schematically in Fig.7 and photographic view is given in Plate 5.

Foot-valve was fitted at the bottom of the suction pipe below the pumping water level. The experimental set-up was equipped with a 3 HP centrifugal pump of 2" x 2" size coupled with 3 HP motor having a speed of 1440 rpm.

Performance study was conducted at the hydraulic laboratory of Kelappaji College of Agricultural Engineering and Technology. A sump having a dimension of 5.4 x 1.25 x 1.35 m was utilized for the study. The discharge pipe was

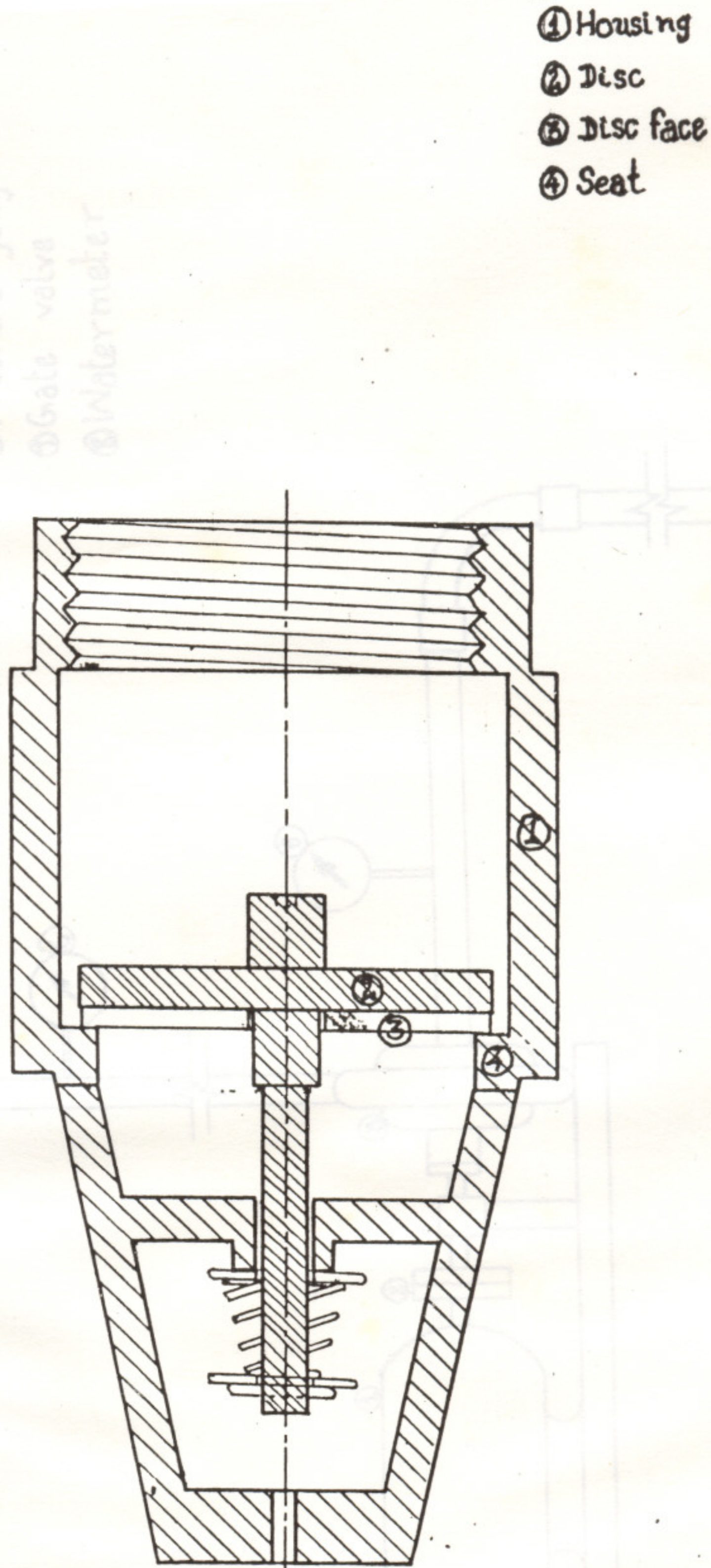
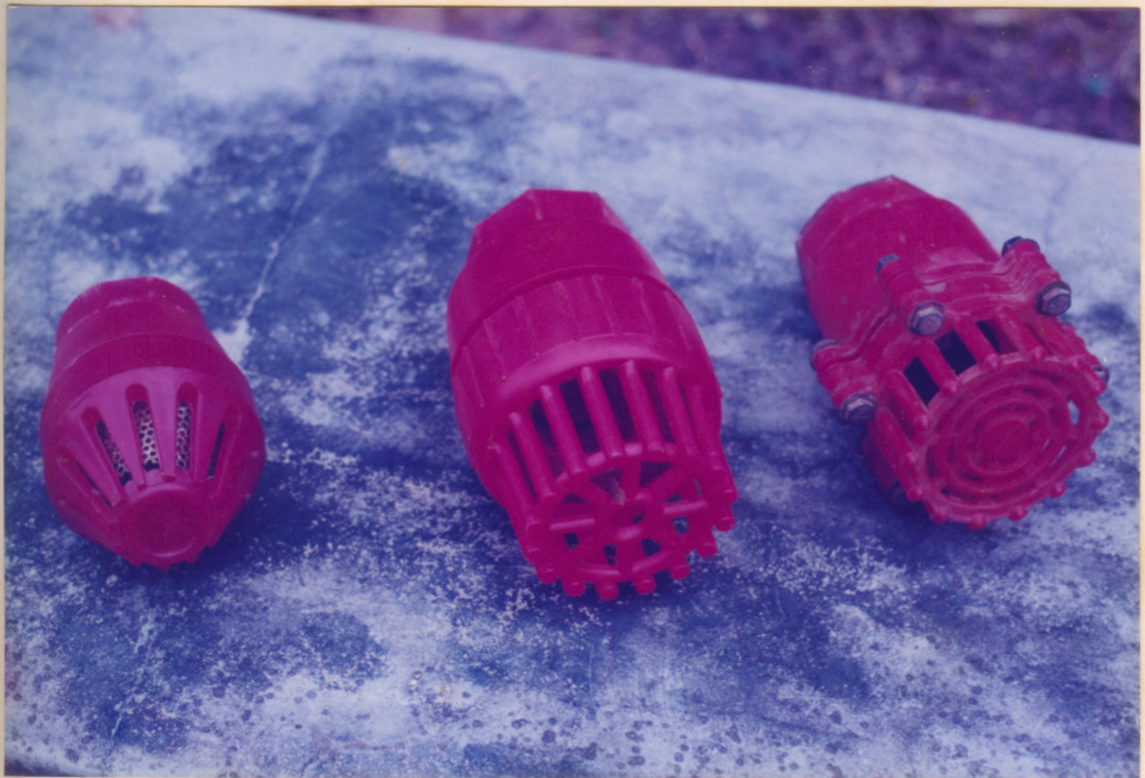
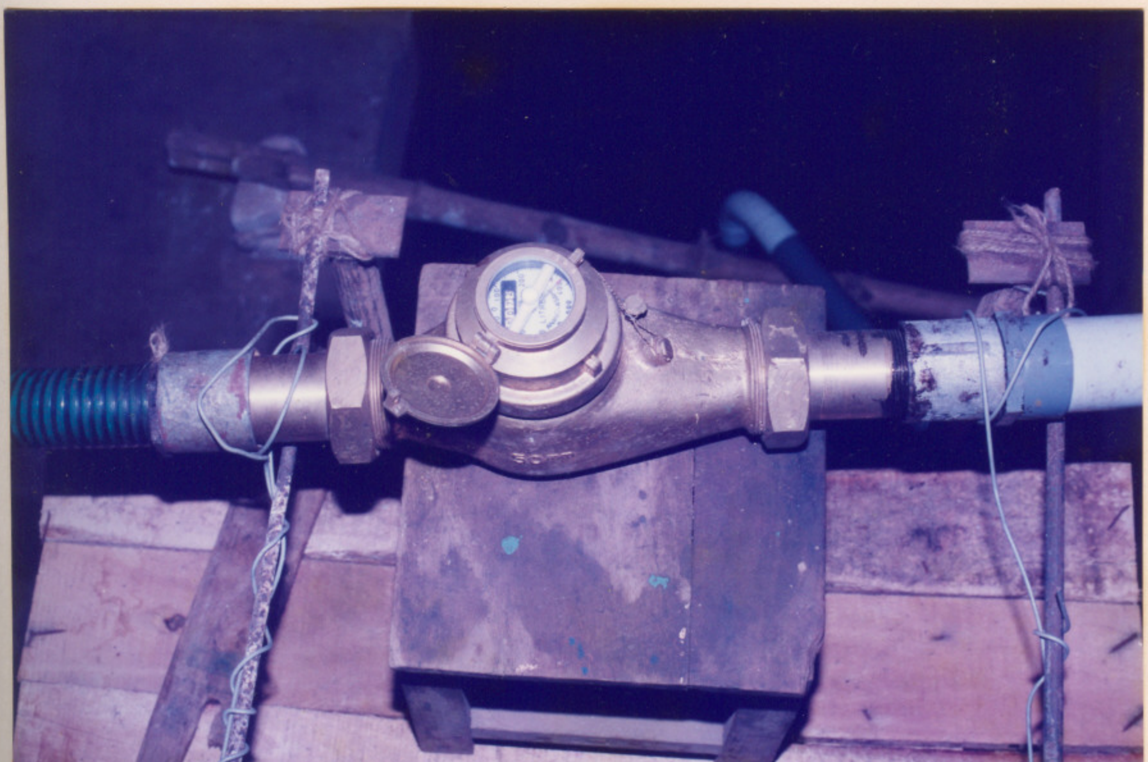


Fig. 6. Sectional view of Raj foot-valve





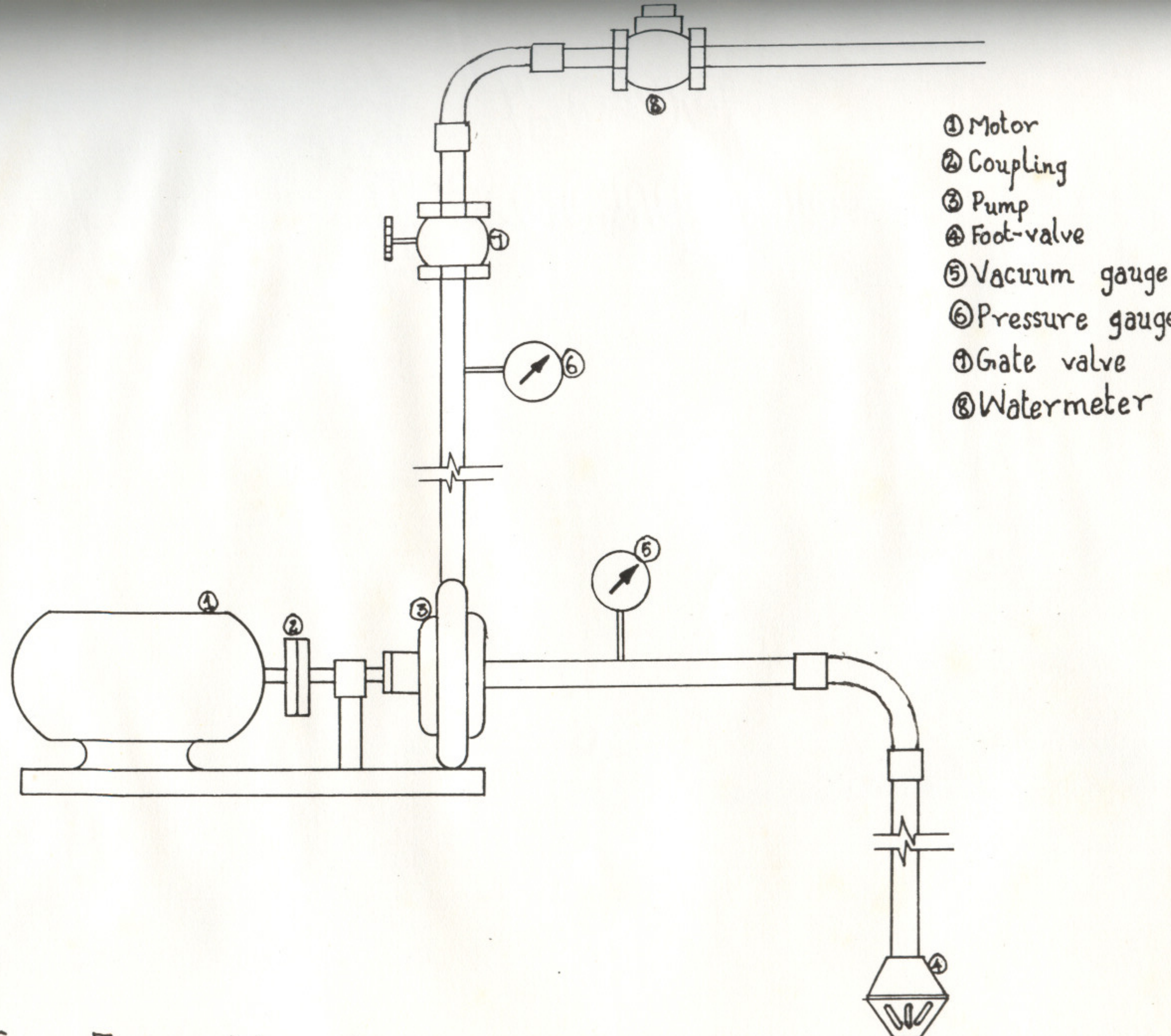


Fig.7. Experimental set-up

set up in such a manner that it deliver water back into the sump itself. In this manner suction head in the sump was maintained at a constant level. Starter used is of push butten type.

3.3 Test procedure

The experiment was conducted using GI pipes on the suction and delivery sides. Initially Meccano foot-valve was fitted on the bottom end of the suction pipe of centrifugal pump. The pump was started after priming. Gate valve was shut off at first. After sometime it was opened slowly when the motor attains its speed. Necessary measurements of suction head delivery head, energy meter reading and delivery discharge were noted. At least six sets of readings were taken by varying the head. Readings at the shut off were also noted. After completing the measurements, Meccano foot-valve was removed from bottom of the suction pipe. The experiment was repeated for every foot-valve in the order Vinu, Prashant, Buno, Kirloskar and Raj.

The experiment was repeated using PVC pipes instead of GI pipes.

To conduct the performance study of centrifugal pump using different foot valves and pipes the following parameters were measured.

3.3.1 Measurement of head

Arrangements for measuring the suction head and delivery head were made with the help of vacuum gauge and pressure gauge respectively attached in the suction and delivery lines connected to the pump. Suction head was determined from the readings directly obtained from the vacuum gauge in mm of Hg. Similarly discharge head was determined from the readings shown in the pressure gauge in kg/cm^2. The distance between pump centre line and pressure gauge was 1 m. Total head was calculated as follows.

Total head (m) =

$$\text{Reading from vacuum gauge} \times \frac{13.6}{1000}\,(m) + 1\,(m) +$$

$$\text{Reading from pressure gauge} \times 10\,(m)$$

For varying the head, a gate valve was attached at the delivery side just before the pressure gauge.

3.3.2 Measurement of discharge

Discharge of pump was measured with the help of a water meter (2") (Plate 6) at the delivery side. For varying the discharge a gate-valve was attached at the delivery side. Discharge was directly obtained from the readings in litres shown in water meter. Time taken for a delivery discharge of 200 litres is noted. Delivery discharge = $\frac{200}{t}$ lps.

3.3.3 Power measurement

With the help of an energy meter, power required to deliver a discharge of 200 litres was noted. Initial and final readings were directly taken during the delivery discharge of 200 litres. Readings were given in kWh.

$$\text{Energy consumption(kW)} = \frac{(\text{Final reading-initial reading})\ \text{kWh}}{\text{Time in hours}}$$

Efficiency of the pump is calculated using the formula,

$$= \frac{Qh}{E(101.85)}$$

Where,

Q is the delivery discharge in lps

h is the total head in m

E is the energy consumption in kW

RESULTS AND DISCUSSION

The results of the experimental study conducted are discussed in detail in this chapter.

4.1 Variation of head with discharge

The study was conducted using various foot-valves. In this study GI pipe was used in suction and delivery. Observations are shown in Tables 4, 5, 6, 7 8 and 9. The curves showing variation of head with discharge is shown in Fig.8. The figure reveals that for all foot-valves as the discharge increases, head decreases gradually. At higher heads the rate of increase of discharge with decrease in head is very high compared to that of lower heads. For a particular discharge, the pump gives maximum head using Prashant foot-valve. The head corresponding to maximum efficiency is about 20.5 m while using Prashant foot-valve. Head corresponding to maximum efficiency with other foot-valves is lesser (Fig.24) than that of Prashant foot-valve. the slopes of head-capacity curves corresponding to Prashant, Kirloskar and Meccano is almost uniform. Eventhough the pump operates in lower heads using other three foot-valves, the incremental increase in discharge is negligible in lower heads. The operating head is maximum for the pump using Prashant foot-valve becuse it had created

Table 4. Observations to calculate pump efficiency using GI pipe (Prashant foot-valve)

Energy consumption E(kW)	Total head, h (m)	Delivery discharge, Q (lps)	Pump efficiency $\eta = \frac{Q.hx100}{E(101.85)}$ (%)
4.27	18.84	11.77	51.00
4.00	19.45	11.10	53.00
3.70	19.73	10.53	55.00
3.34	20.07	9.76	57.50
2.70	20.50	8.16	60.05
2.46	20.60	7.24	59.50
2.25	21.00	5.50	50.20
1.80	21.80	0.00	0.00

Table 5. Observations to calculate pump efficiency using GI pipe (Kirloskar foot-valve)

Energy consumption E(kW)	Total head, h (m)	Delivery discharge, Q (lps)	Pump efficiency $\eta = \frac{Q.hx100}{E(101.85)}$ (%)
4.27	18.40	11.77	50.60
4.00	19.00	11.10	51.70
3.55	20.07	10.00	55.50
3.35	20.61	9.52	57.50
2.70	20.32	8.00	59.10
2.45	20.60	6.90	57.01
2.32	20.70	5.70	49.85
1.80	21.70	0.00	0.00

Table 6. Observations to calculate pump efficiency using GI pipe (Meccano foot-valve)

Energy consumption E(kW)	Total head, h (m)	Delivery discharge, Q (lps)	Pump efficiency $\eta = \frac{Q.hx100}{E(101.85)}$ (%)
3.90	19.00	10.53	49.80
3.50	19.65	9.52	52.50
3.00	20.17	8.30	54.80
2.60	20.40	6.50	50.07
2.46	20.58	5.10	41.90
2.40	20.70	4.93	41.70
2.20	21.00	2.90	24.00
1.93	21.50	0.00	0.00

Table 7. Observations to calculate pump efficiency using GI pipe (Vinu foot-valve)

Energy consumption E(kW)	Total head, h (m)	Delivery discharge, Q (lps)	Pump efficiency $\eta = \frac{Q.hx100}{E(101.85)}$ (%)
4.25	17.04	10.00	39.38
4.10	18.49	9.52	42.17
3.80	20.00	8.70	44.95
3.40	20.20	7.84	45.70
3.20	20.25	7.14	44.36
2.90	20.32	6.15	42.30
2.74	20.52	5.10	37.50
2.20	21.20	0.00	0.00

Table 8. Observations to calculate pump efficiency using GI pipe (Buno foot-valve)

Energy consumption E(kW)	Total head, h (m)	Delivery discharge, Q (lps)	Pump efficiency $\eta = \frac{Q.hx100}{E(101.85)}$ (%)
4.65	14.90	10.81	34.00
4.00	17.43	9.00	42.50
3.89	18.90	8.89	42.40
3.30	19.94	7.40	43.90
3.04	20.08	6.67	43.25
2.88	20.20	5.26	36.96
2.67	20.52	3.20	24.00
2.53	20.90	0.00	0.00

Table 9. Observations to calculate pump efficiency using GI pipe (Raj foot-valve)

Energy consumption E(kW)	Total head, h (m)	Delivery discharge, Q (lps)	Pump efficiency $\eta = \frac{Q.hx100}{E(101.85)}$ (%)
3.56	18.13	7.40	37.00
3.50	19.60	7.00	38.62
3.40	19.80	6.50	37.16
3.10	19.90	5.13	32.33
2.88	20.03	3.85	26.28
2.80	20.18	2.96	20.90
2.60	20.50	0.00	0.00

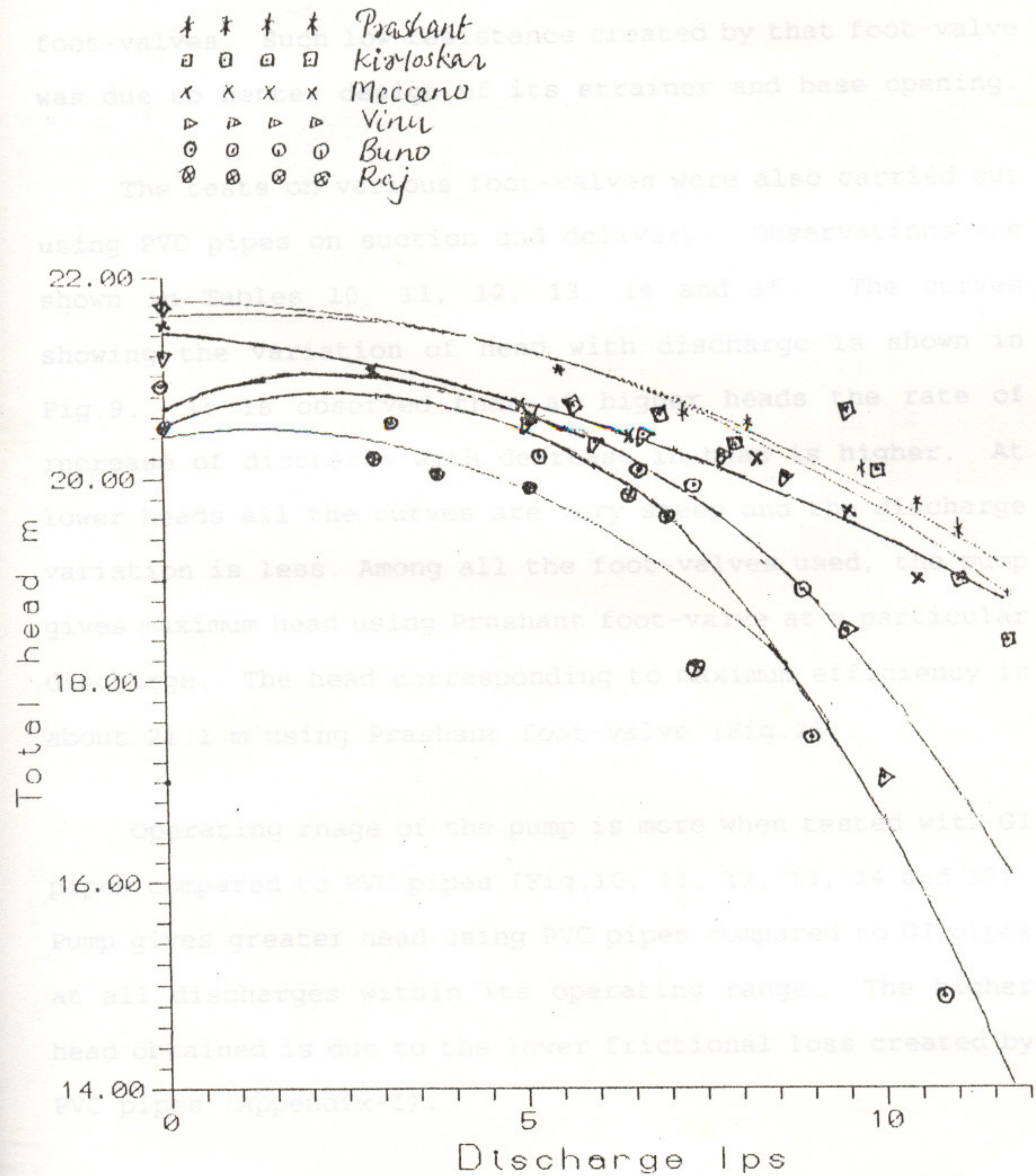


Fig.8 Variation of head with discharge using G.I pipe

less head loss due to friction as compared to that of other foot-valves. Such low resistance created by that foot-valve was due to better design of its strainer and base opening.

The tests on various foot-valves were also carried out using PVC pipes on suction and delivery. Observations are shown in Tables 10, 11, 12, 13, 14 and 15. The curves showing the variation of head with discharge is shown in Fig.9. It is observed that at higher heads the rate of increase of discharge with decrease in head is higher. At lower heads all the curves are very steep and the discharge variation is less. Among all the foot-valves used, the pump gives maximum head using Prashant foot-valve at a particular discharge. The head corresponding to maximum efficiency is about 21.1 m using Prashant foot-valve (Fig.25).

Operating rnage of the pump is more when tested with GI pipes compared to PVC pipes (Fig.10, 11, 12, 13, 14 and 15). Pump gives greater head using PVC pipes compared to GI pipes at all discharges within its operating range. The higher head obtained is due to the lower frictional loss created by PVC pipes (Appendix-I).

4.2 Variation of efficiency with discharge

Readings of performance study using GI pipes are shown in Tables 4, 5, 6, 7, 8 and 9. The curves showing variation of efficiency with discharge is shown in Fig.16. Among

Table 10. Observations to calculate pump efficiency using PVC pipe (Prashant foot-valve)

Energy consumption E(kW)	Total head, h (m)	Delivery discharge, Q (lps)	Pump efficiency $\eta = \frac{Q.hx100}{E(101.85)}$ (%)
2.13	20.50	6.25	59.26
1.97	21.10	5.80	60.89
1.90	21.36	4.82	53.20
1.82	21.74	2.86	33.54
1.68	21.90	0.00	0.00

Table 11. Observations to calculate pump efficiency using PVC pipe (Kirloskar foot-valve)

Energy consumption E(kW)	Total head, h (m)	Delivery discharge, Q (lps)	Pump efficiency $\eta = \frac{Q.hx100}{E(101.85)}$ (%)
2.03	20.60	6.00	58.62
2.00	21.00	5.88	60.62
1.96	21.34	5.40	57.73
1.88	21.30	4.65	51.80
1.81	21.70	2.50	29.43
1.70	21.88	0.00	0.00

Table 12. Observations to calculate pump efficiency using PVC pipe (Meccano foot-valve)

Energy consumption E(kW)	Total head, h (m)	Delivery discharge, Q (lps)	Pump efficiency $\eta = \frac{Q.hx100}{E(101.85)}$ (%)
2.25	20.40	6.45	57.20
2.07	20.44	6.15	59.44
2.06	20.64	5.88	57.70
1.98	21.34	4.44	47.08
1.97	21.68	2.67	28.70
1.80	21.86	0.00	0.00

Table 13. Observations to calculate pump efficiency using PVC pipe (Vinu foot-valve)

Energy consumption E(kW)	Total head, h (m)	Delivery discharge, Q (lps)	Pump efficiency $\eta = \frac{Q.hx100}{E(101.85)}$ (%)
2.60	20.86	5.90	46.47
2.53	20.87	5.80	46.89
2.33	21.00	5.13	44.12
2.30	21.19	4.82	43.60
2.11	21.23	4.00	39.69
2.10	21.50	2.74	27.50
1.90	21.78	0.00	0.00

Table 14. Observations to calculate pump efficiency using PVC pipe (Buno foot-valve)

Energy consumption E(kW)	Total head, h (m)	Delivery discharge, Q (lps)	Pump efficiency $\eta = \frac{Q.hx100}{E(101.85)}$ (%)
2.83	20.15	6.06	42.36
2.60	21.00	5.70	45.20
2.45	21.30	5.00	42.59
2.42	21.36	4.44	38.50
2.39	21.40	3.64	32.00
2.33	21.43	2.50	22.50
2.25	21.50	0.00	0.00

Table 15. Observations to calculate pump efficiency using PVC pipe (Raj foot-valve)

Energy consumption E(kW)	Total head, h (m)	Delivery discharge, Q (lps)	Pump efficiency $\eta = \frac{Q.hx100}{E(101.85)}$ (%)
2.70	20.20	5.26	38.64
2.55	21.05	4.89	39.63
2.45	21.06	4.44	35.20
2.40	21.08	3.77	32.50
2.35	21.10	2.86	22.50
2.20	21.13	0.00	0.00

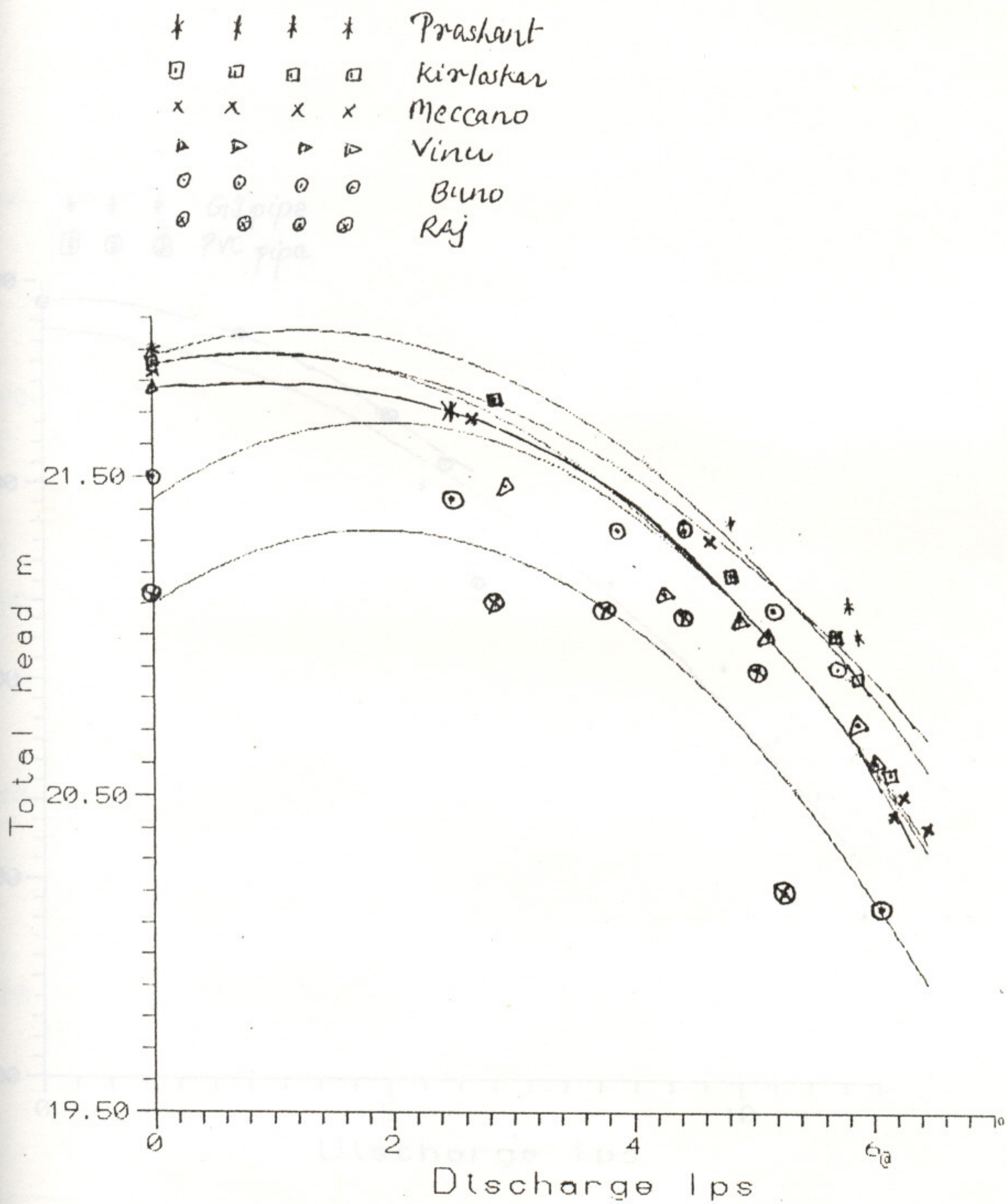
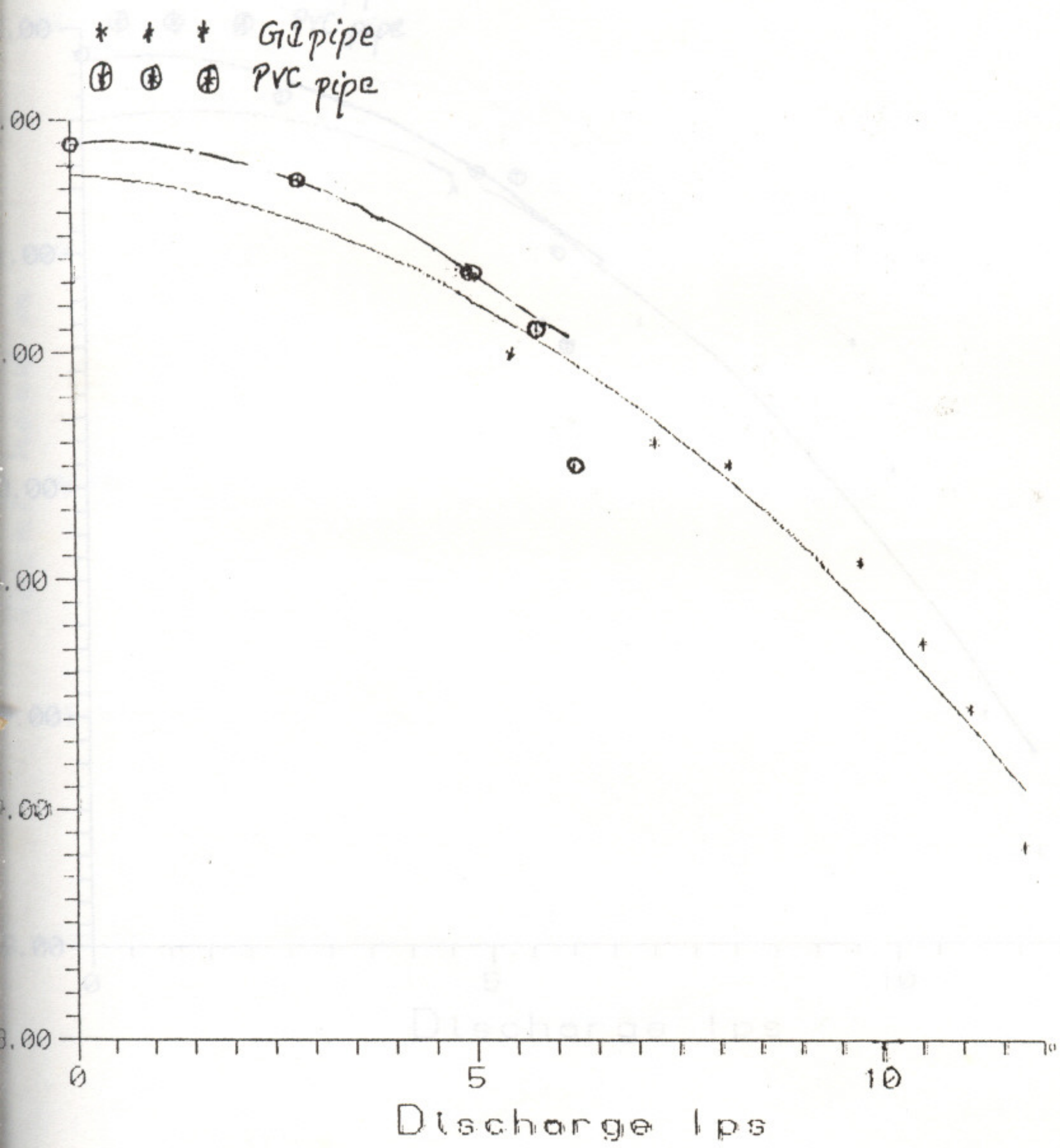


Fig. 9 Variation of head with discharge using PVC pipe



Variation of head with discharge using Prashant foot-valve

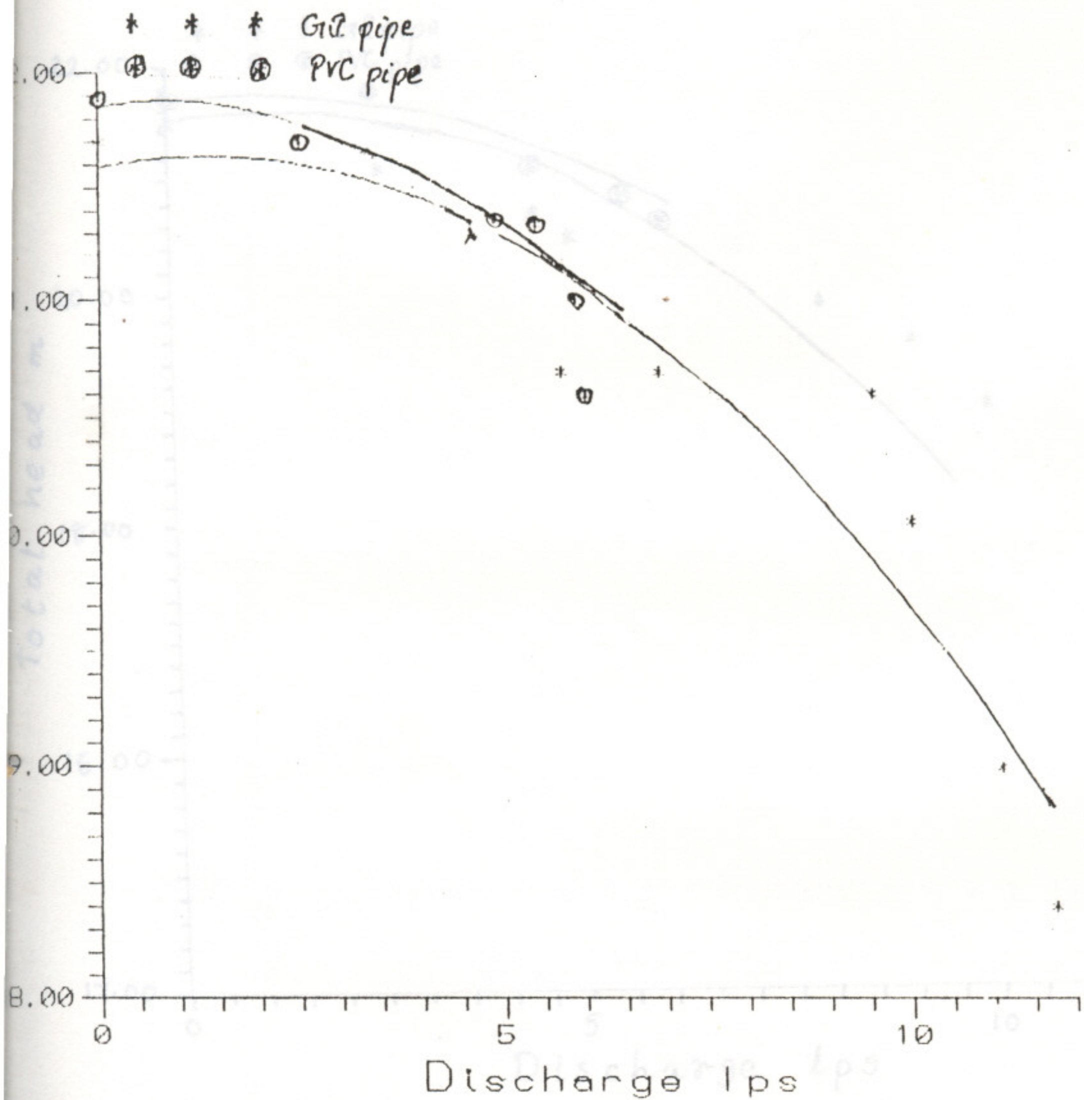


Fig.11 Variation of head with discharge using Kirloskar foot-valve

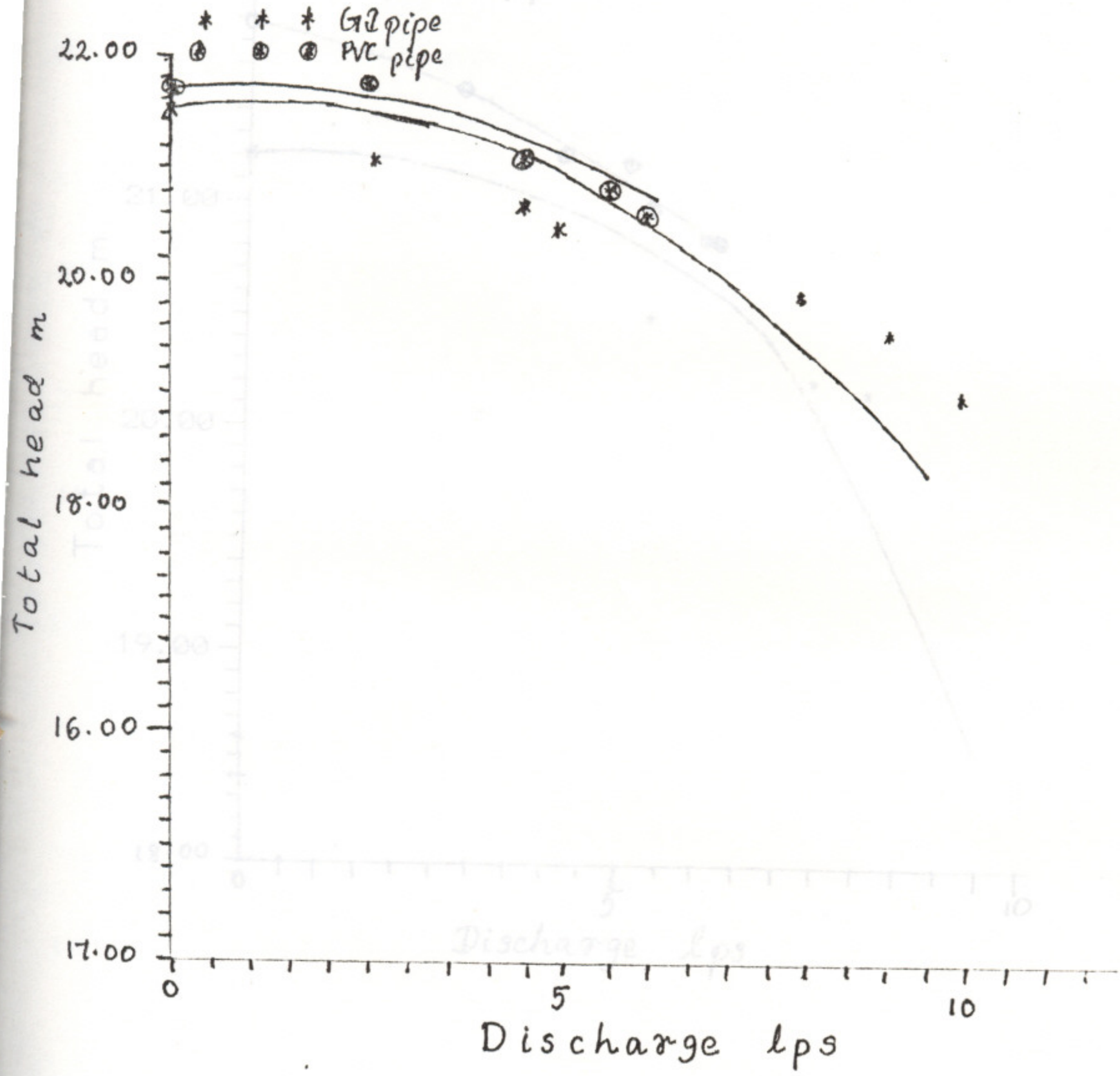


Fig. 12 Variation of head with discharge using Meccano foot valve

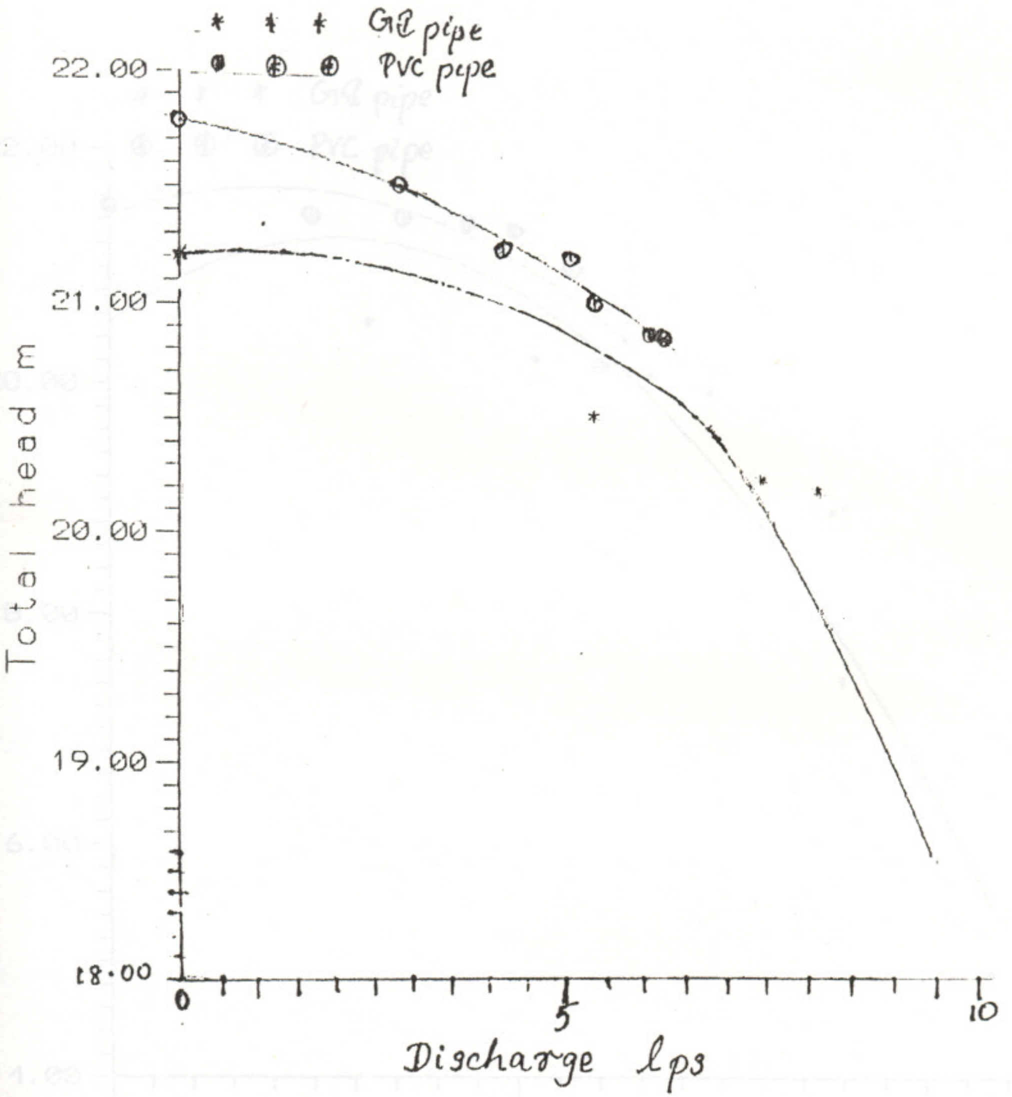


Fig.13 Variation of head with discharge using Vinu foot-valve

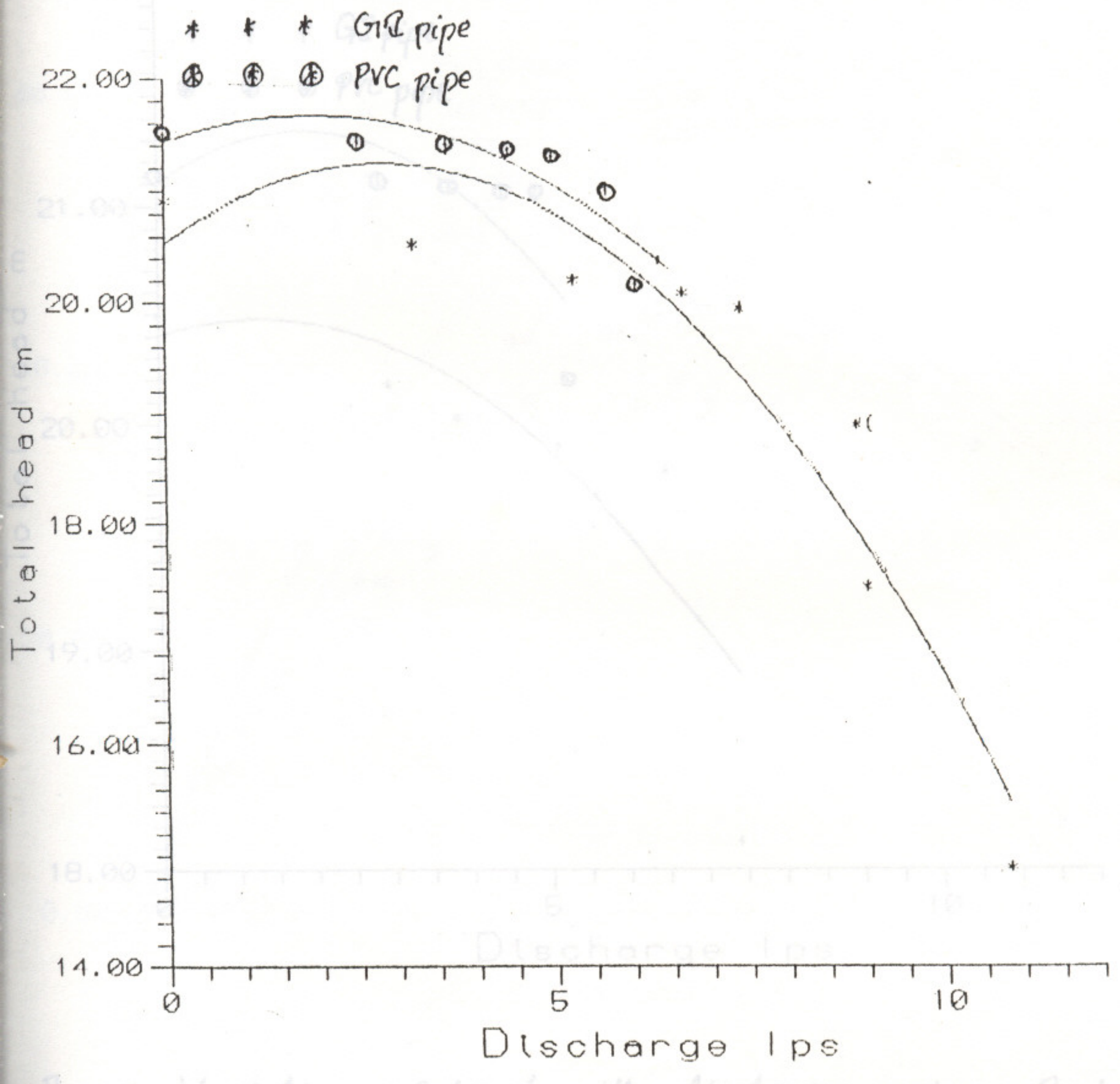


Fig. 14 Variation of head with discharge using Buno foot-valve

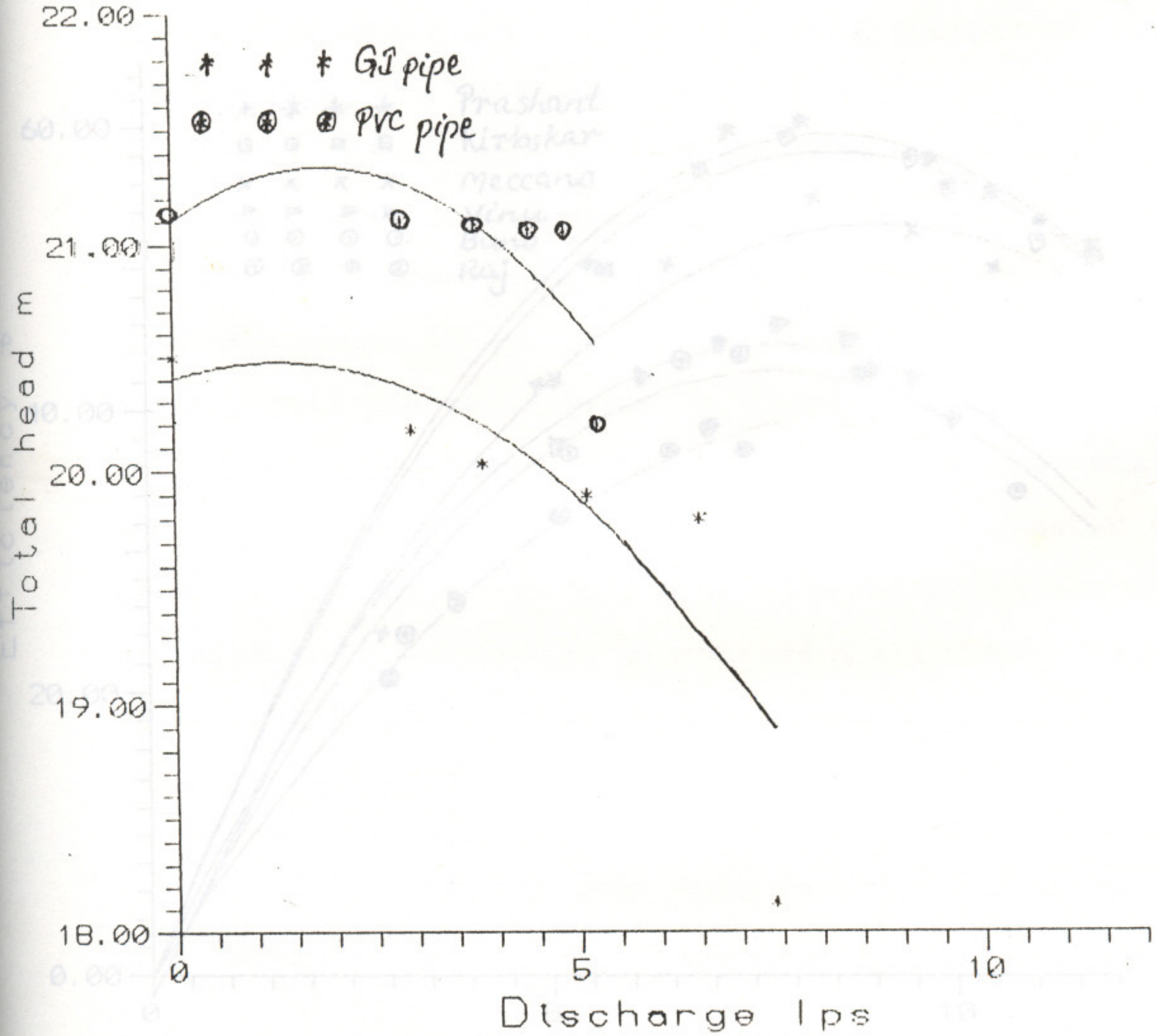


Fig. 15 Variation of head with discharge using Raj foot-valve

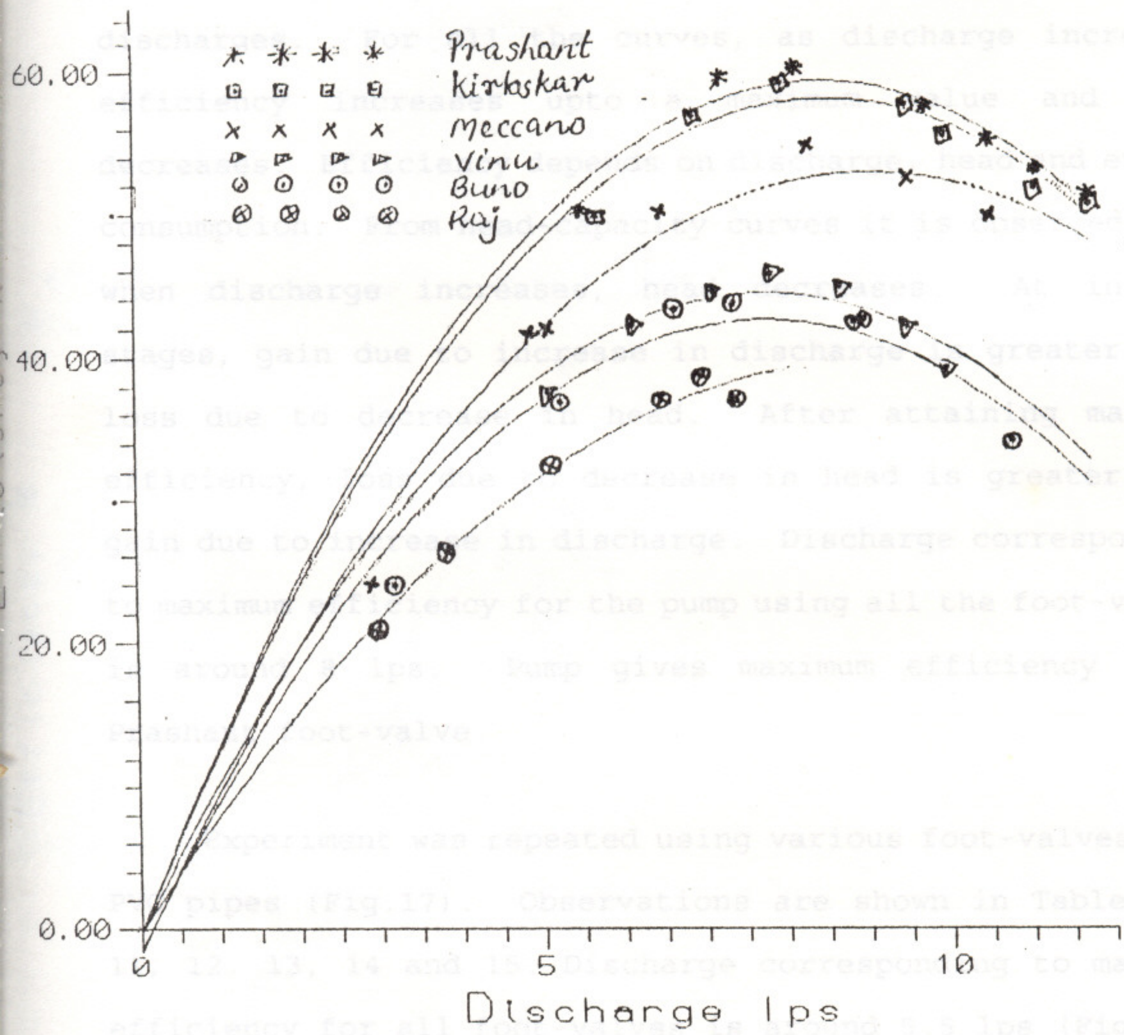


Fig. 16 Variation of Efficiency with discharge using GI pipe

different curves, the variation of efficiency is very less at low discharges and this variation, increases at higher discharges. For all the curves, as discharge increases efficiency increases upto a maximum value and then decreases. Efficiency depends on discharge, head and energy consumption. From head-capacity curves it is observed that when discharge increases, head decreases. At initial stages, gain due to increase in discharge is greater than loss due to decrease in head. After attaining maximum efficiency, loss due to decrease in head is greater than gain due to increase in discharge. Discharge corresponding to maximum efficiency for the pump using all the foot-valves is around 8 lps. Pump gives maximum efficiency using Prashant foot-valve.

Experiment was repeated using various foot-valves with PVC pipes (Fig.17). Observations are shown in Tables 10, 11, 12, 13, 14 and 15. Discharge corresponding to maximum efficiency for all foot-valves is around 5.5 lps (Fig.29). Efficiency of the pump is found to be higher when tested with PVC pipes compared to GI pipes (Fig.18, 19, 20, 21, 22 and 23).

4.3 Variation or energy consumption with discharge

Pump was tested using various foot-valves with GI pipe on both suction and delivery sides and reading are given in

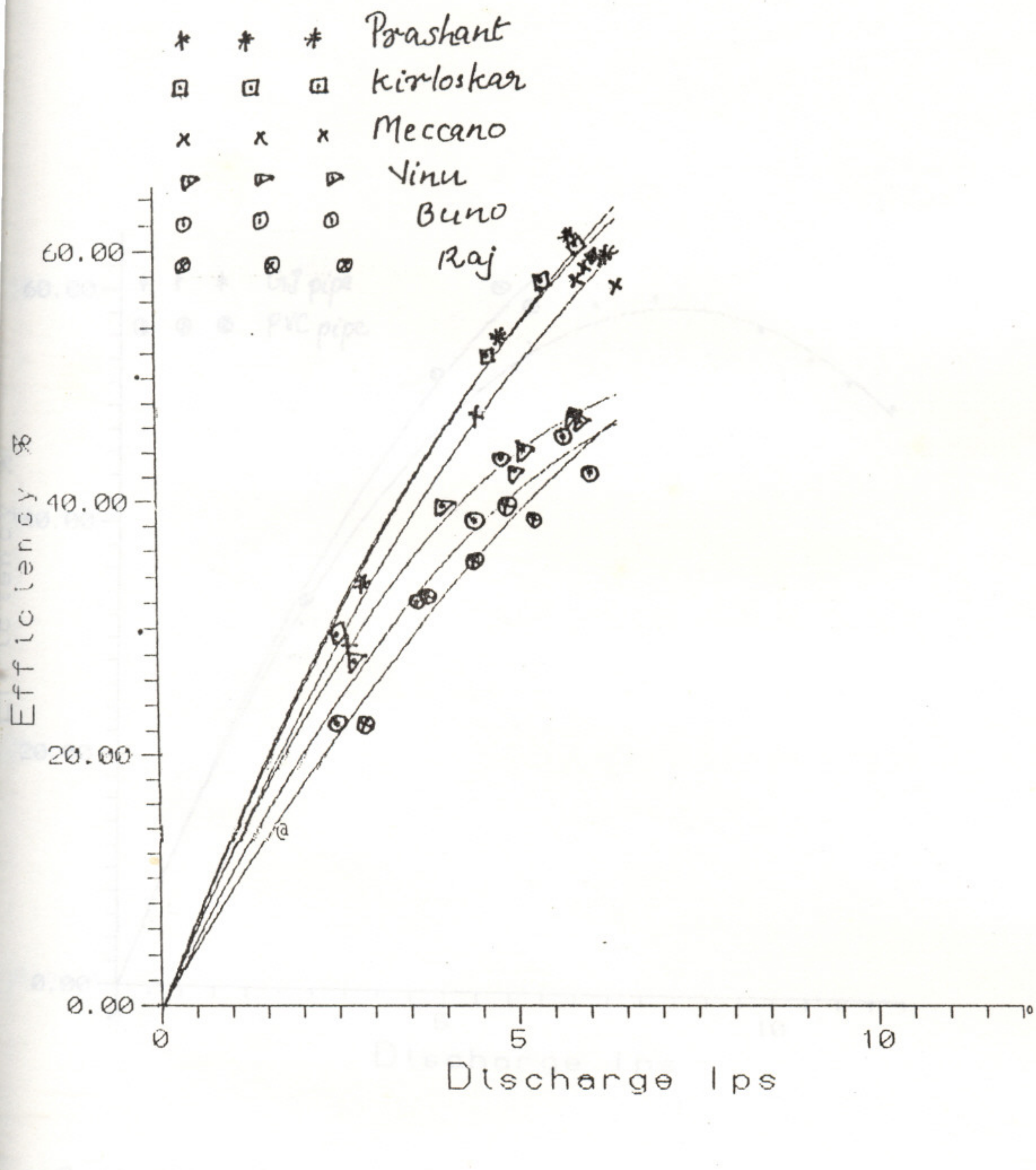


Fig.17 Variation of efficiency with discharge using PVC pipe

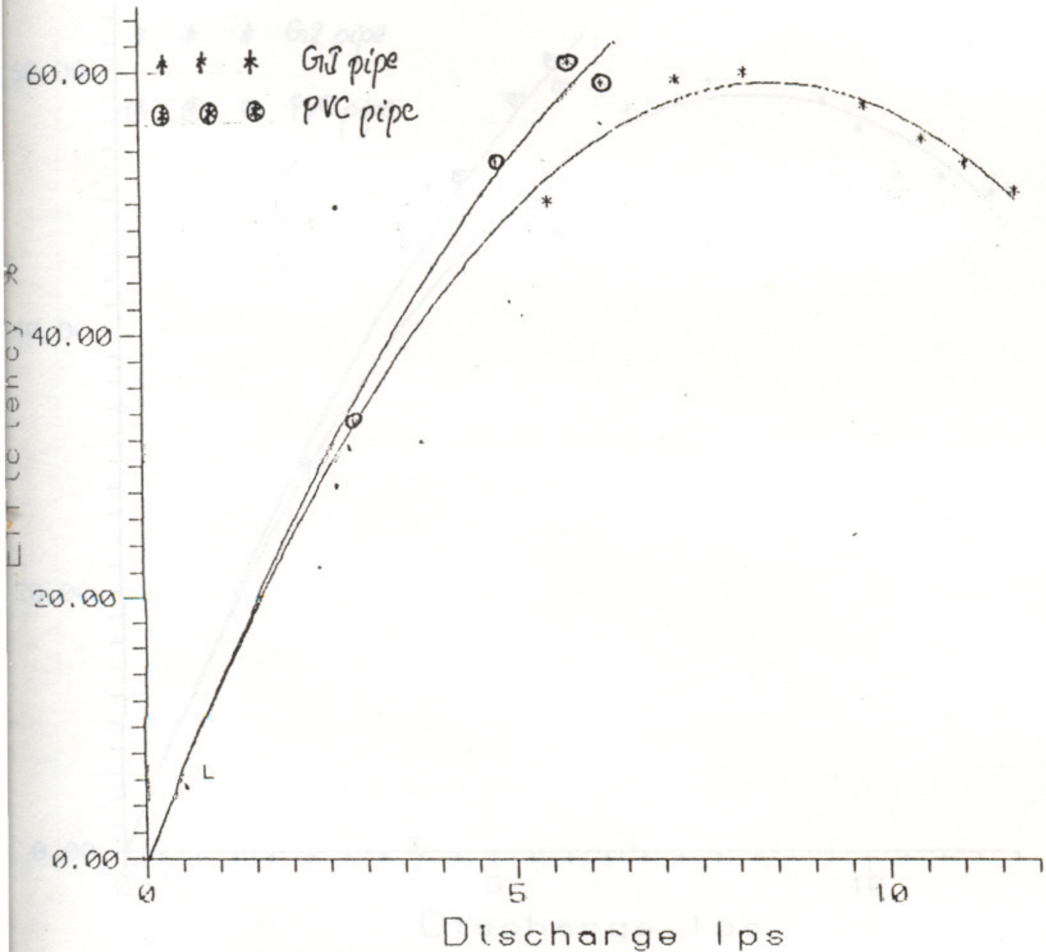


Fig. 18 Variation of efficiency with discharge using Prashant foot-valve

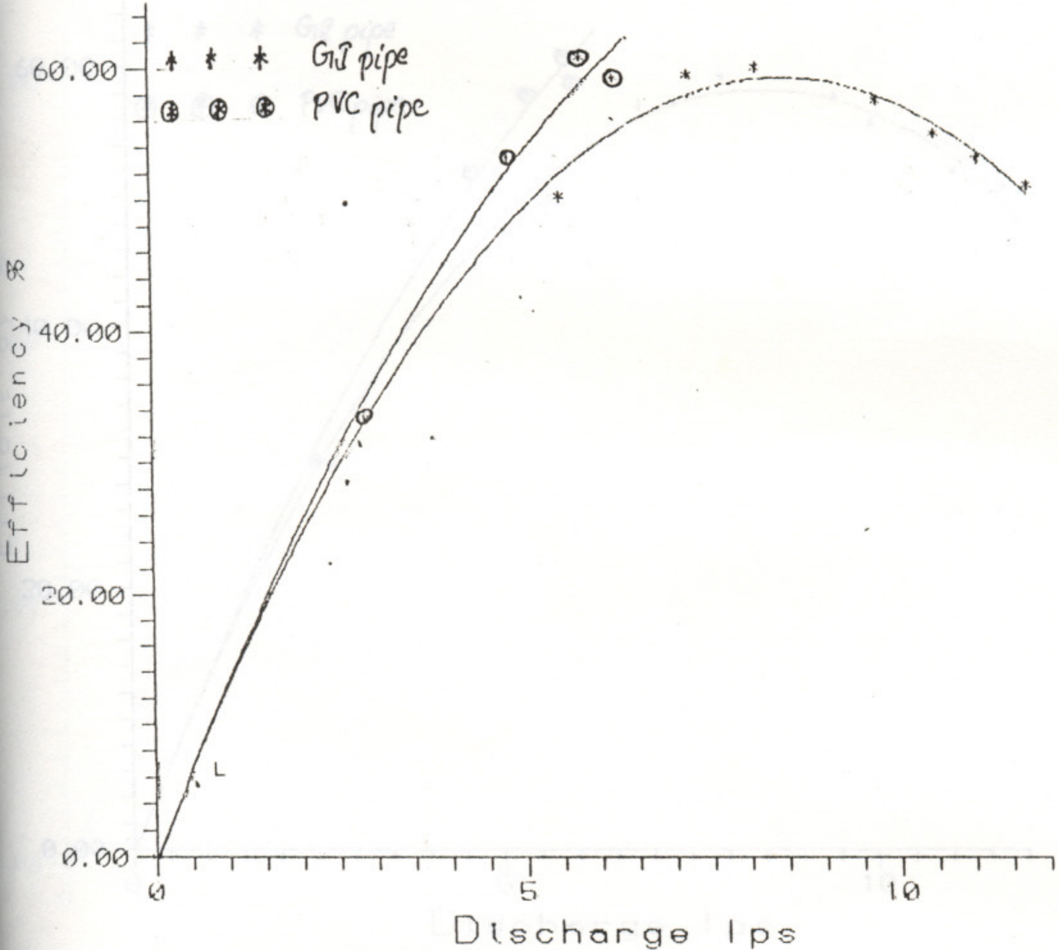


Fig. 18 Variation of efficiency with discharge using Prashant foot-valve

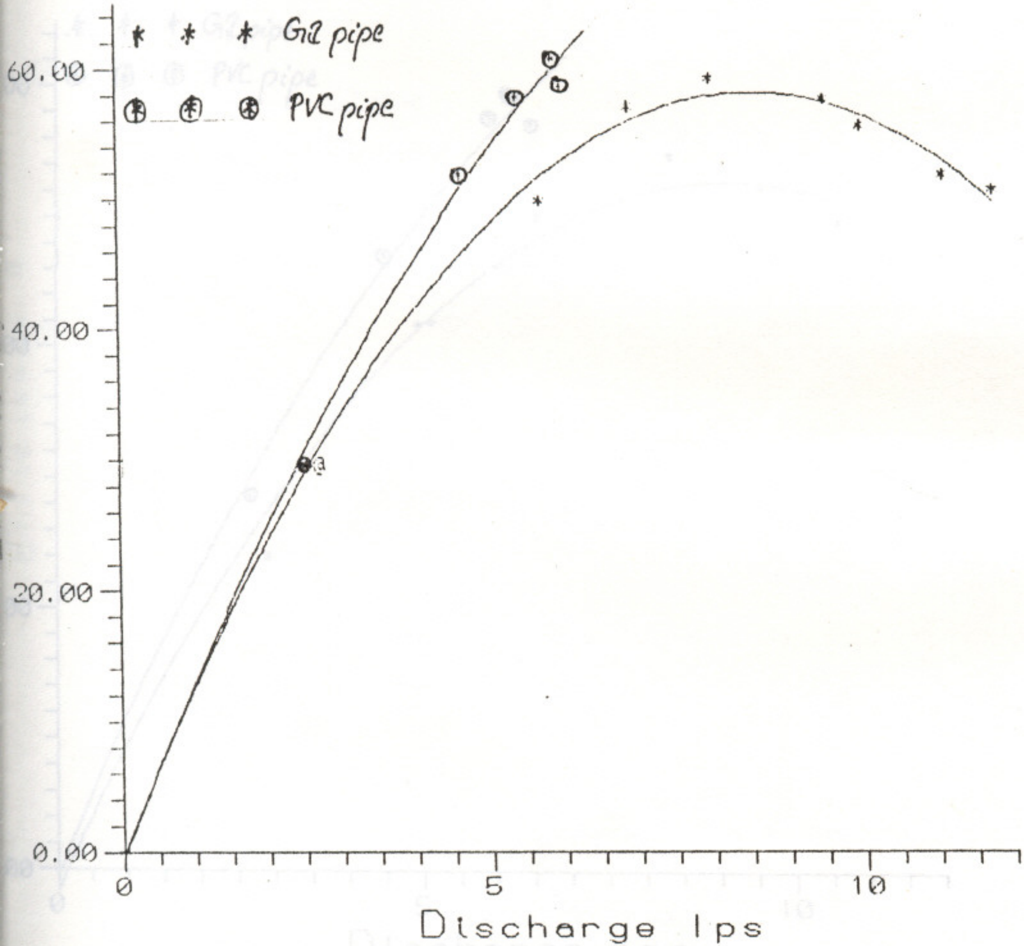


Fig. 19 Variation of efficiency with discharge using Kirloskar foot valve

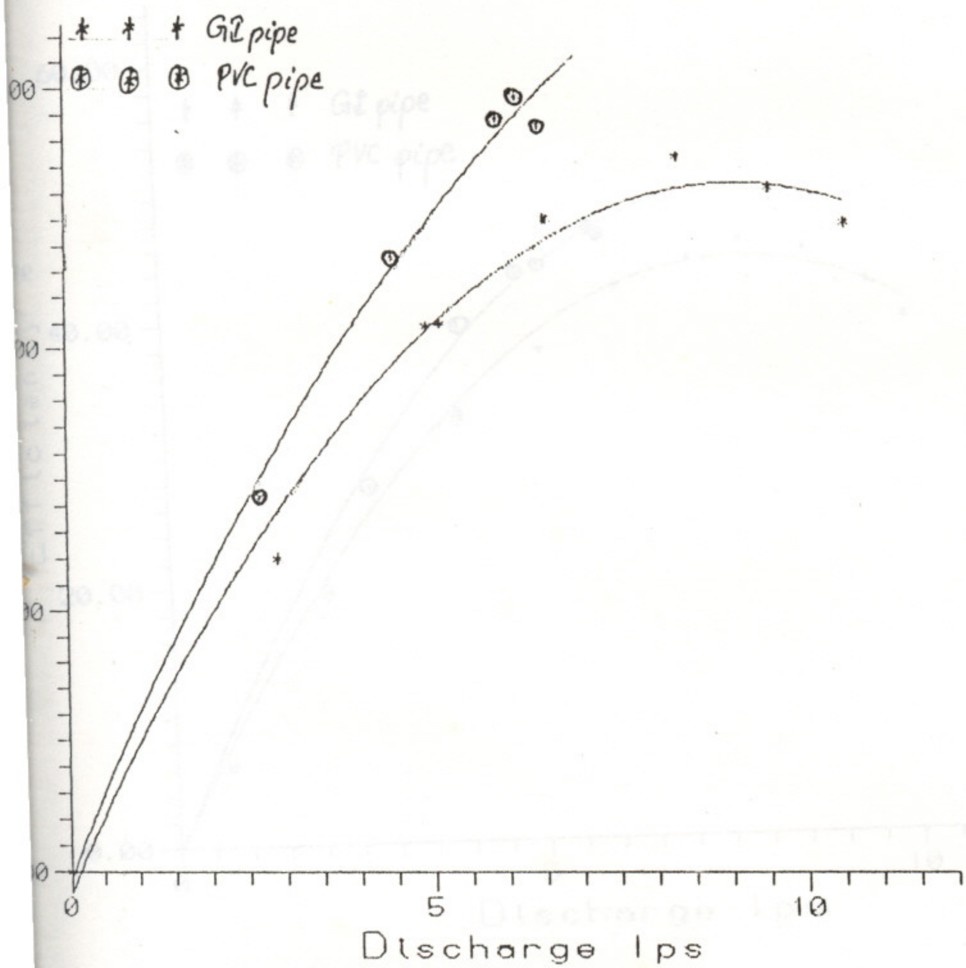
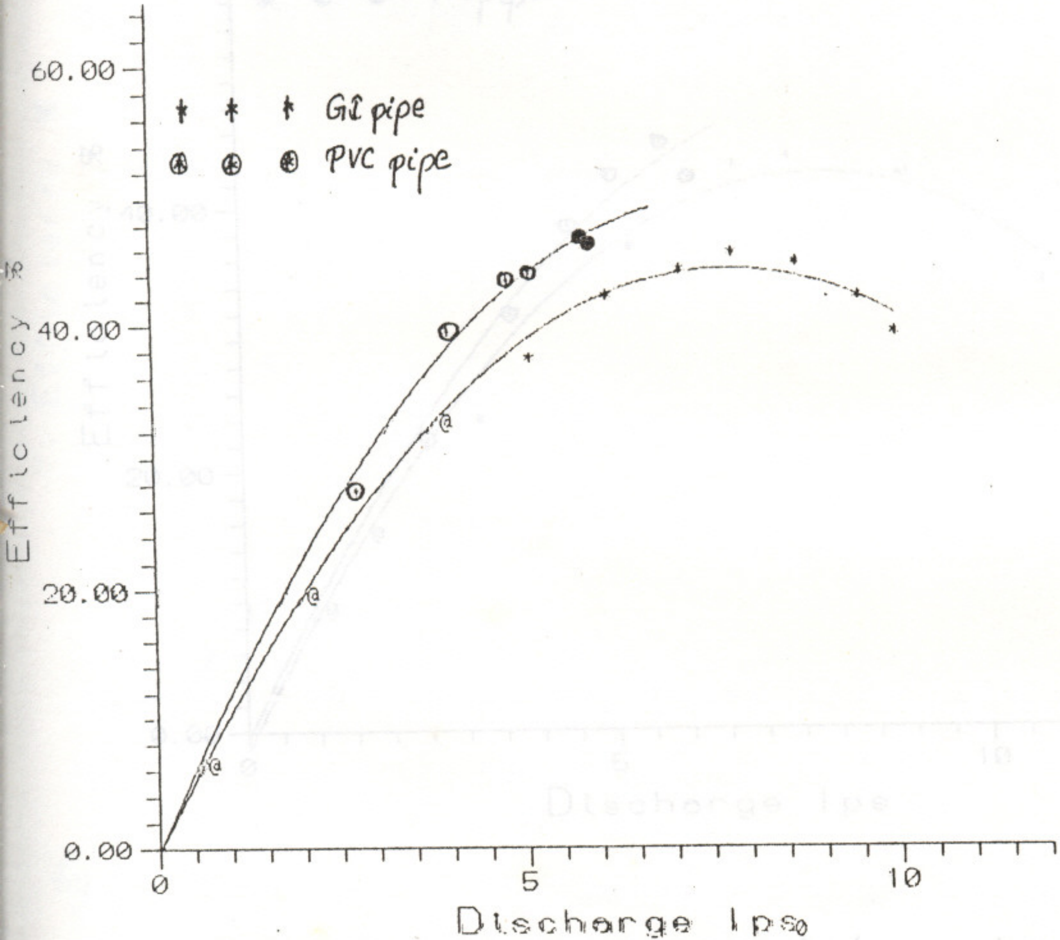


Fig. 20 Variation of efficiency with discharge using Meccano foot-valve



Fig·21 Variation of efficiency with discharge using Vinu foot-valve

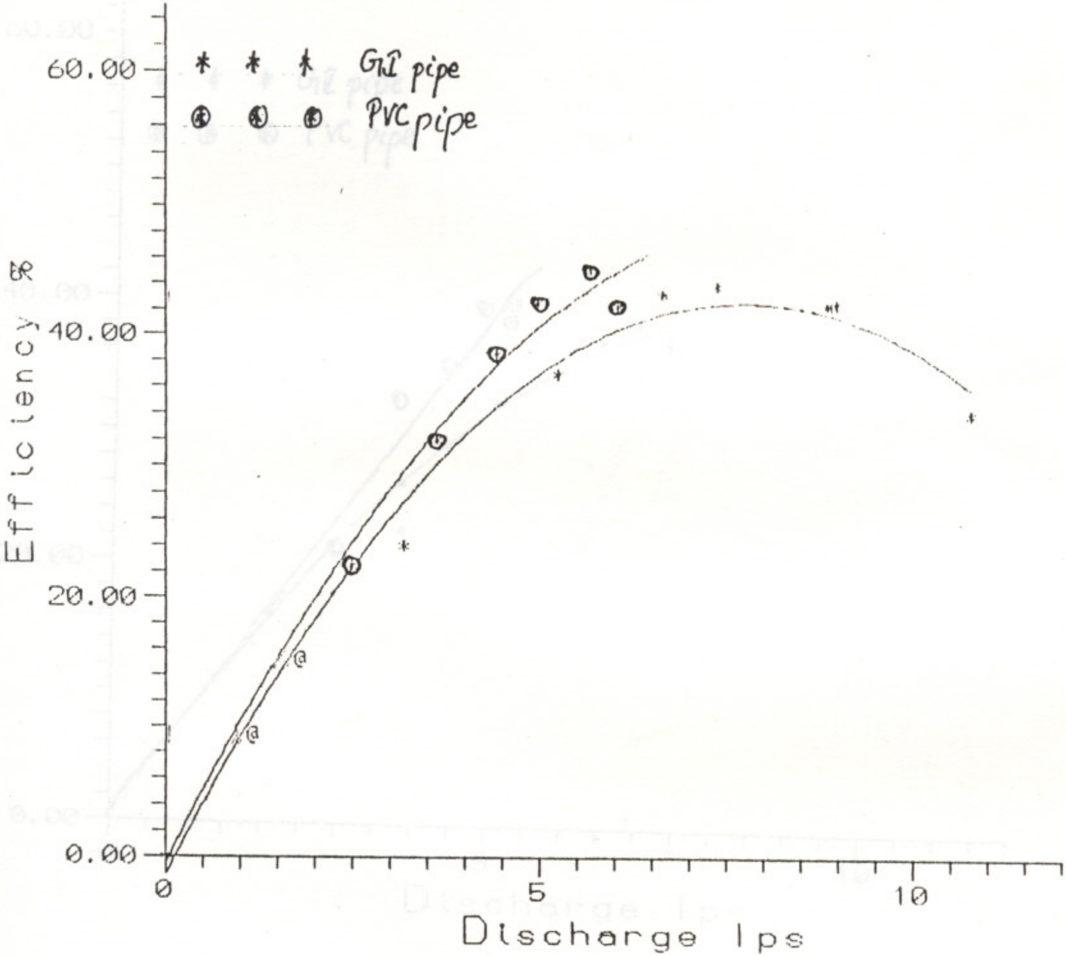


Fig. 22 Variation of efficiency with discharge using Buno foot-valve

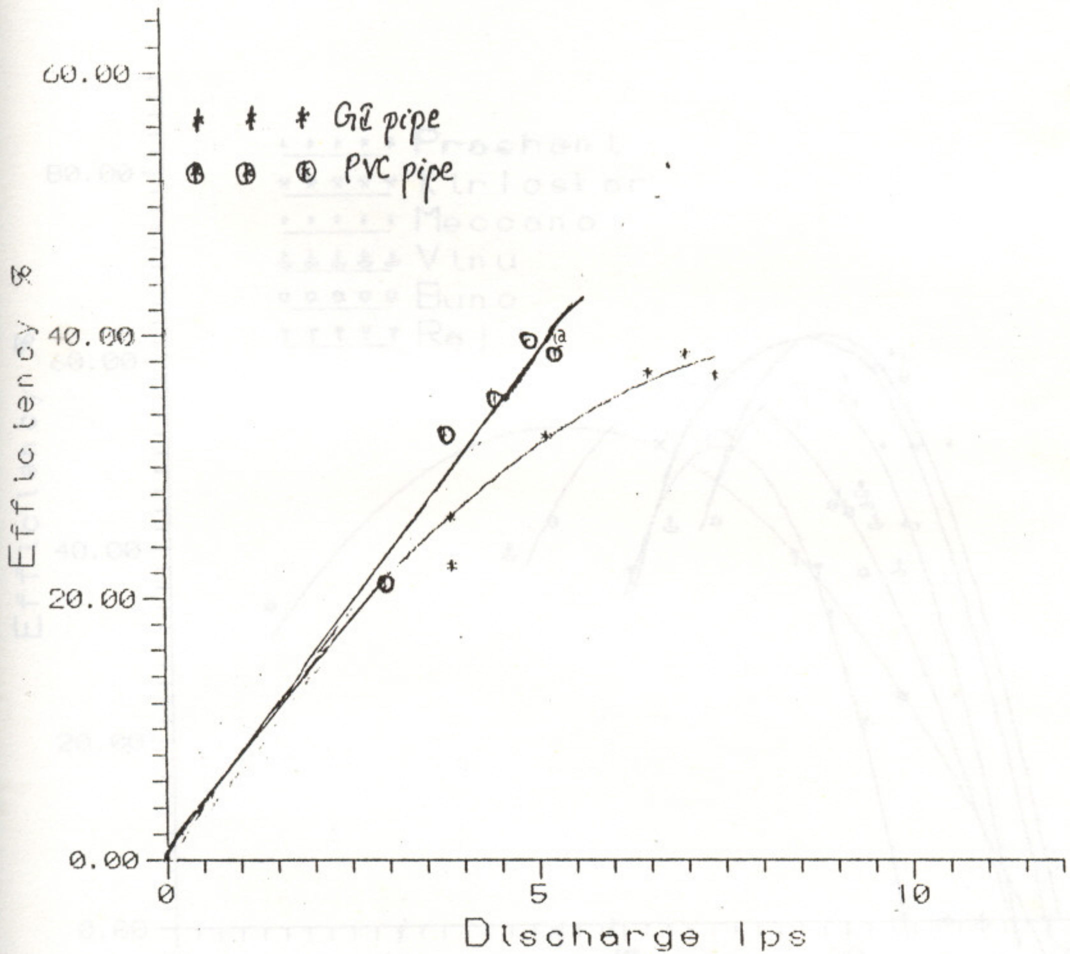


Fig. 23 Variation of efficiency with discharge using Raj foot-valve

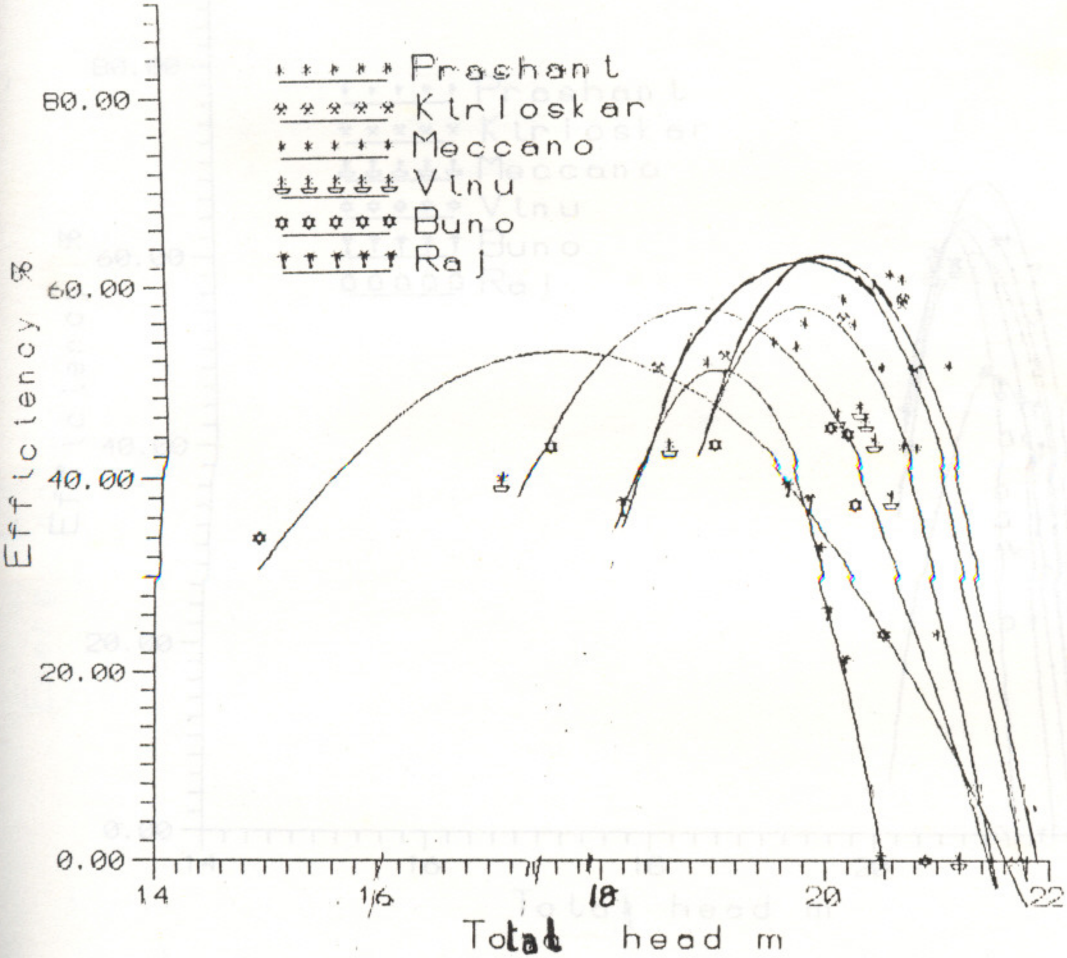


Fig. 24 Variation of efficiency with total head using GI pipe

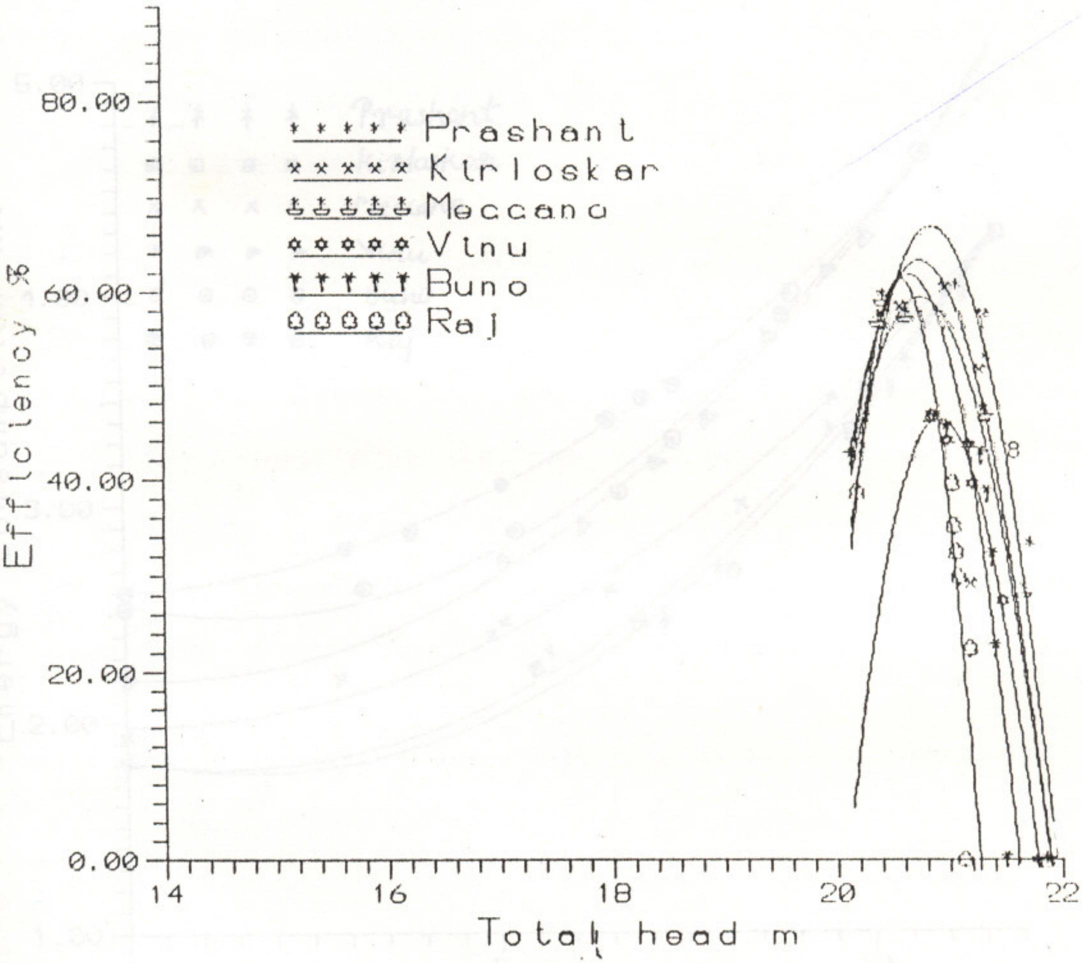


Fig. 25 Variation of efficiency with head using PVC pipe

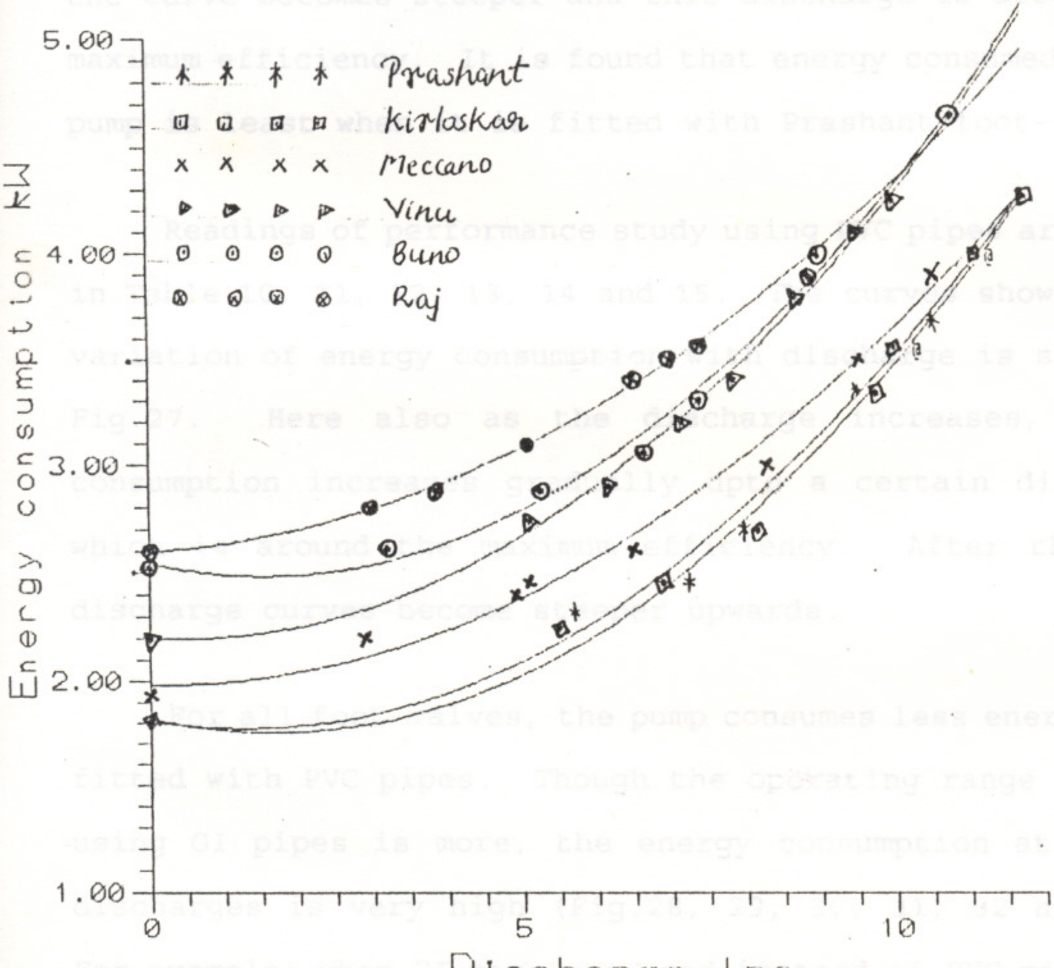


Fig. 26 Variation of energy consumption with discharge using GI pipe

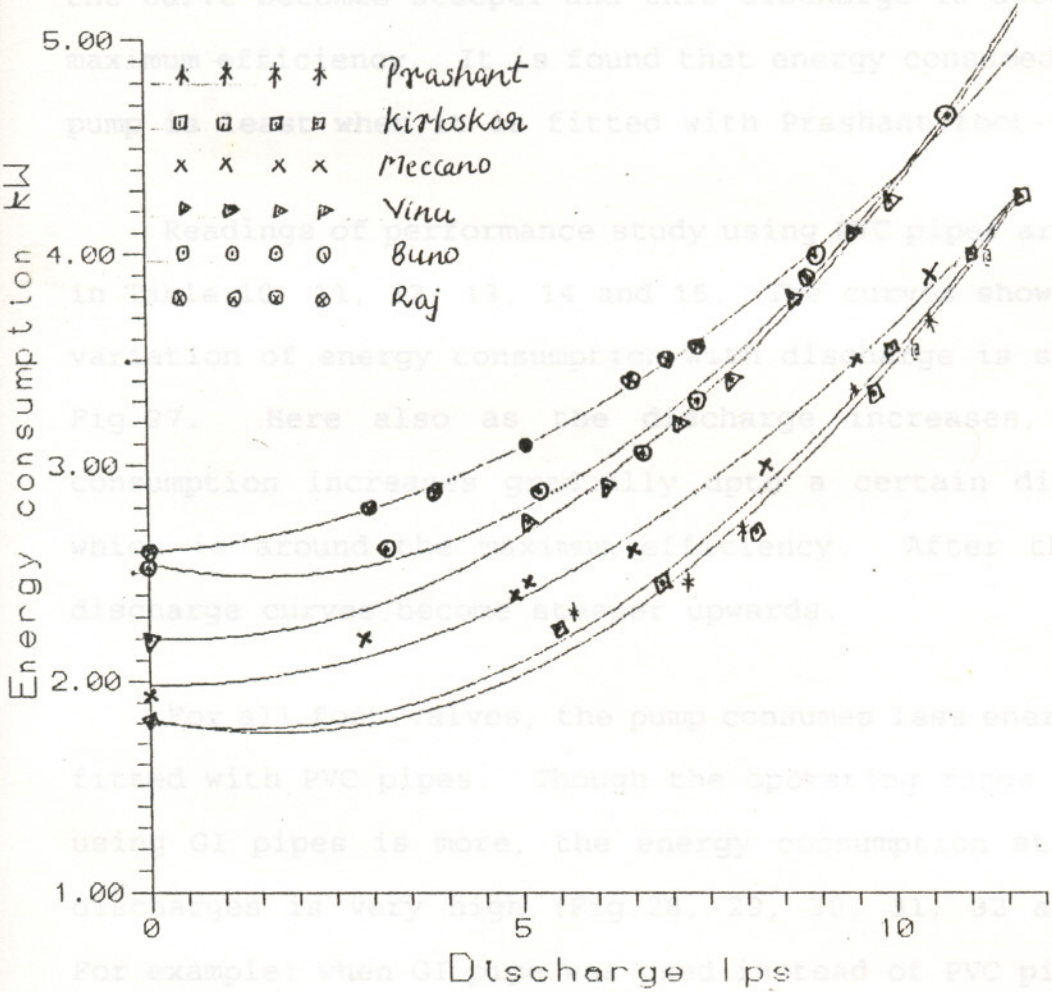


Fig. 26 Variation of energy consumption with discharge using GI pipe

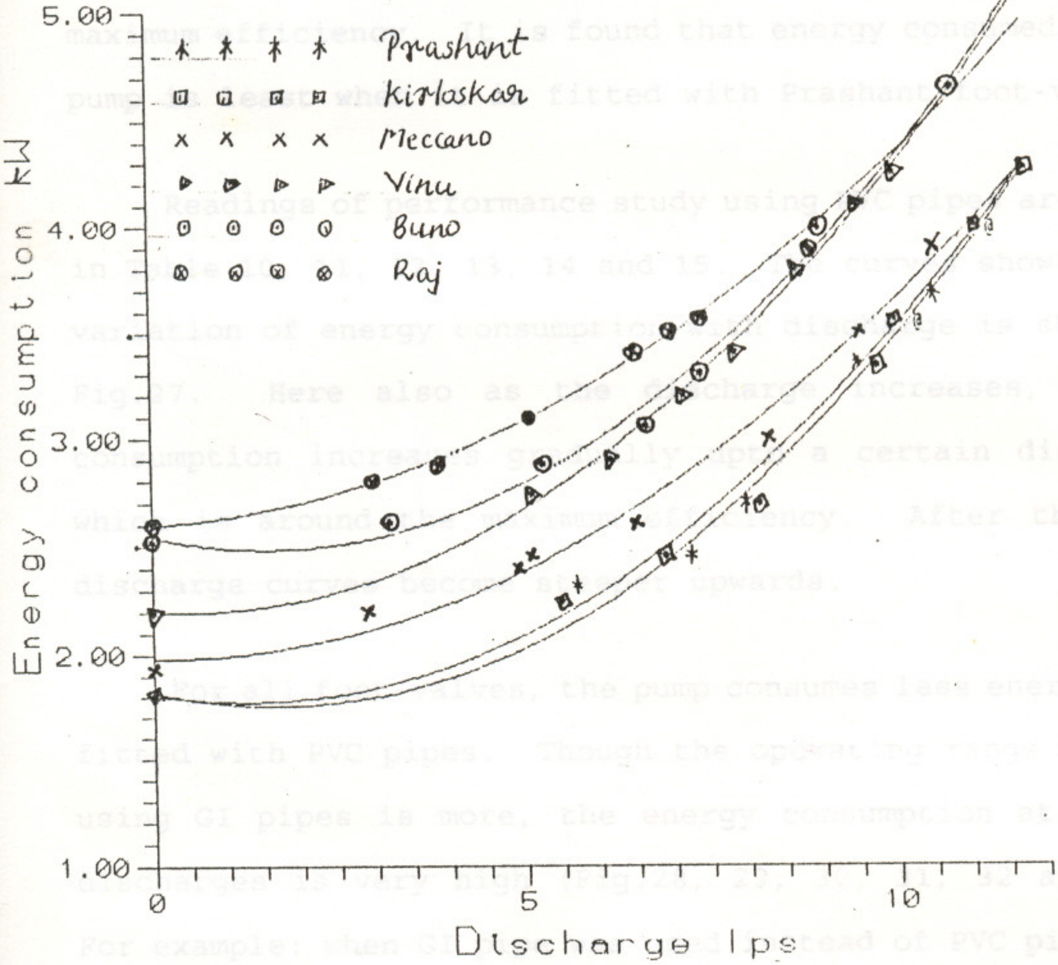


Fig. 26 Variation of energy consumption with discharge using GI pipe

Tables 4, 5, 6, 7, 8 and 9. The corresponding curves showing the variation of energy consumption with discharge is shown in Fig.26. As the discharge increases, energy consumption also increases. After a particular discharge, the curve becomes steeper and this discharge is around the maximum efficiency. It is found that energy consumed by the pump is least when it is fitted with Prashant foot-valve.

Readings of performance study using PVC pipes are shown in Table 10, 11, 12, 13, 14 and 15. The curves showing the variation of energy consumption with discharge is shown in Fig.27. Here also as the discharge increases, energy consumption increases gradually upto a certain discharge which is around the maximum efficiency. After that the discharge curves become steeper upwards.

For all foot-valves, the pump consumes less energy when fitted with PVC pipes. Though the operating range of pump using GI pipes is more, the energy consumption at higher discharges is very high (Fig.28, 29, 30, 31, 32 and 33). For example: when GI pipe was used instead of PVC pipe, the increase in energy consumption using Prashant foot-valve at 6 lps is about 0.3 kW. Let the pump works 8 hours in a day.

Power loss in a day	=	0.3 x 8
	=	2.4 kWh

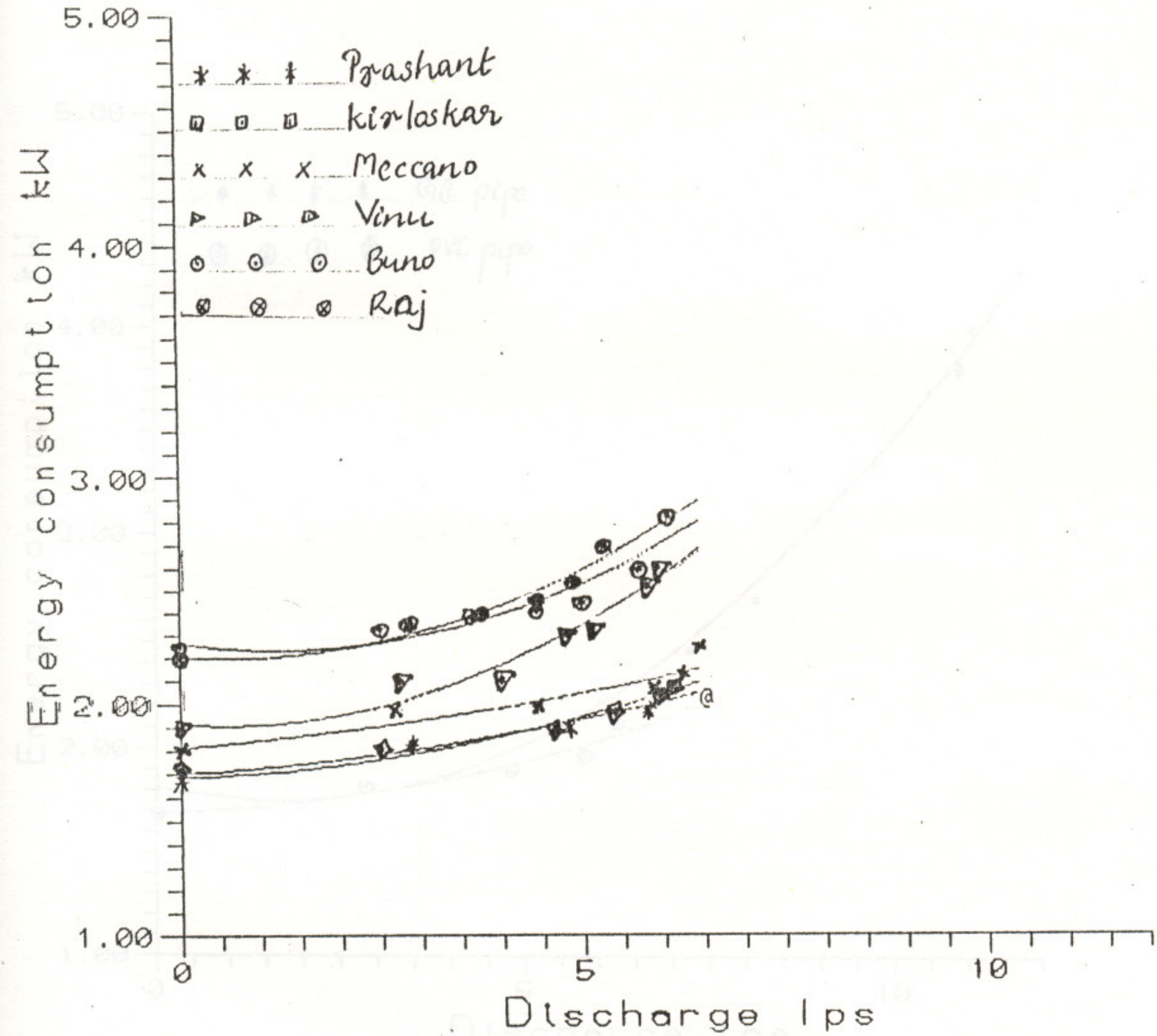


Fig. 27 Variation of energy consumption with discharge using PVC pipe

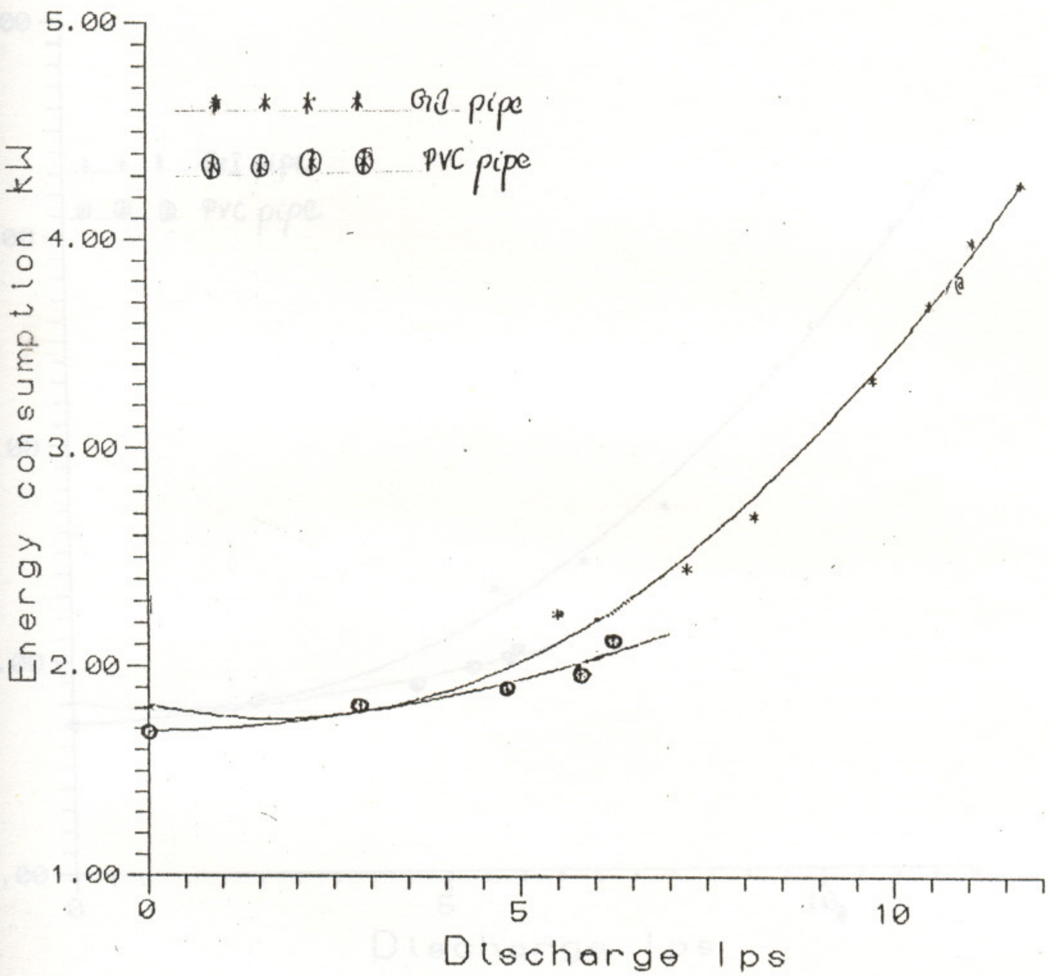
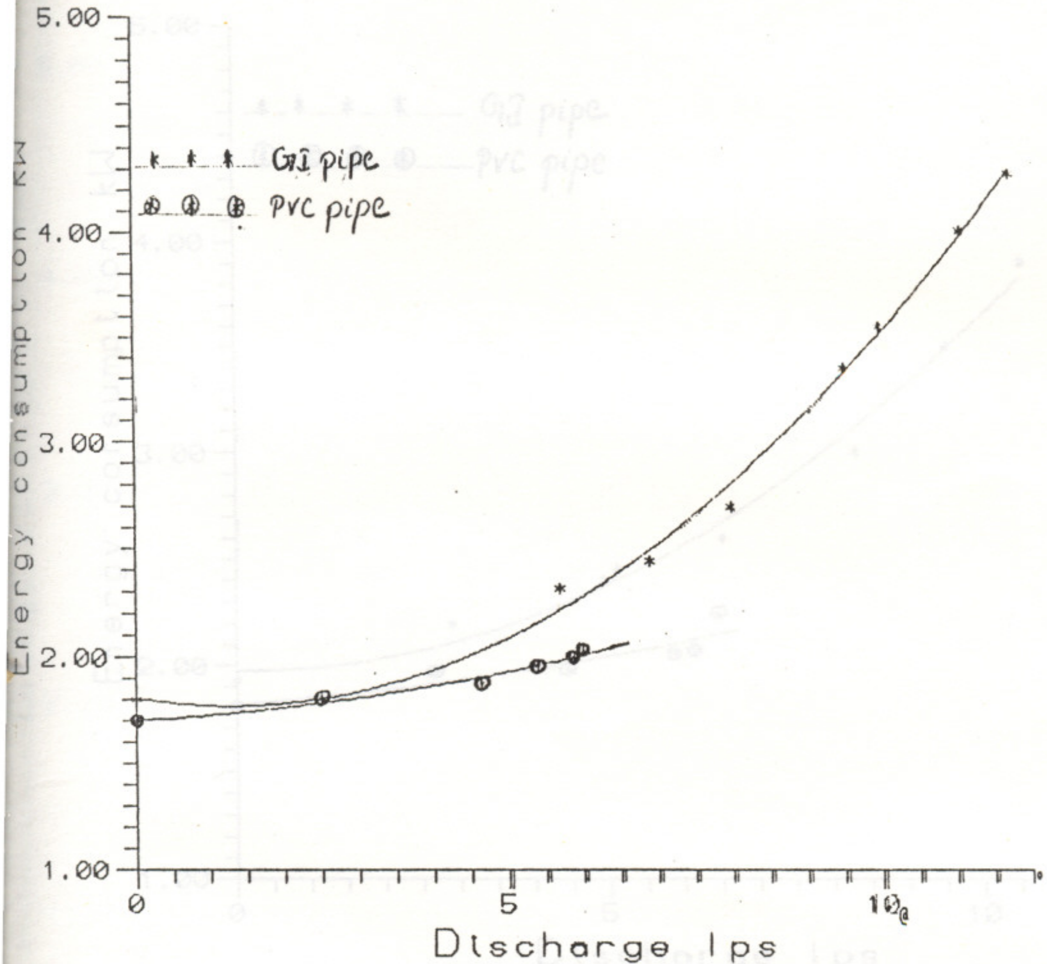


Fig. 28 Variation of energy consumption with discharge using Prashant foot-valve



29 Variation of energy consumption with discharge using Kirloskar foot-valve

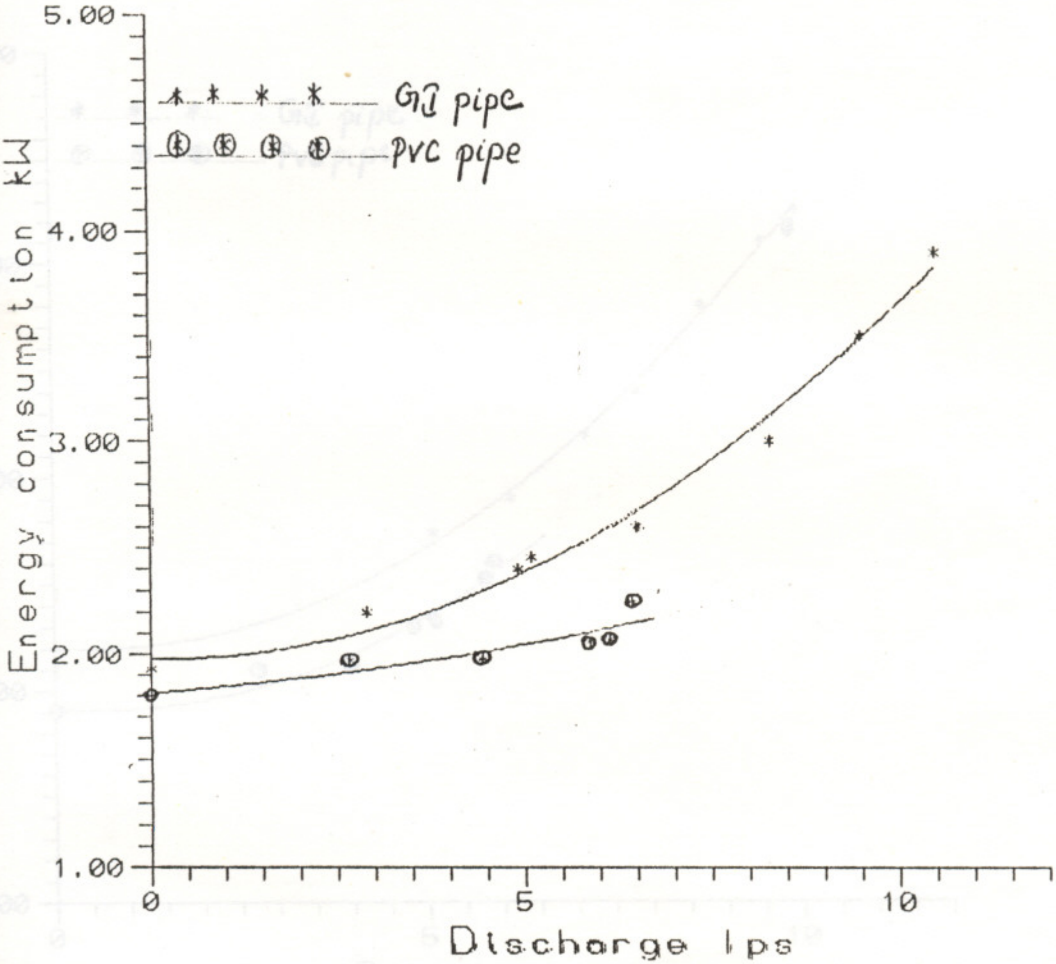


Fig.30 Variation of energy consumption with discharge using Meccano foot valve

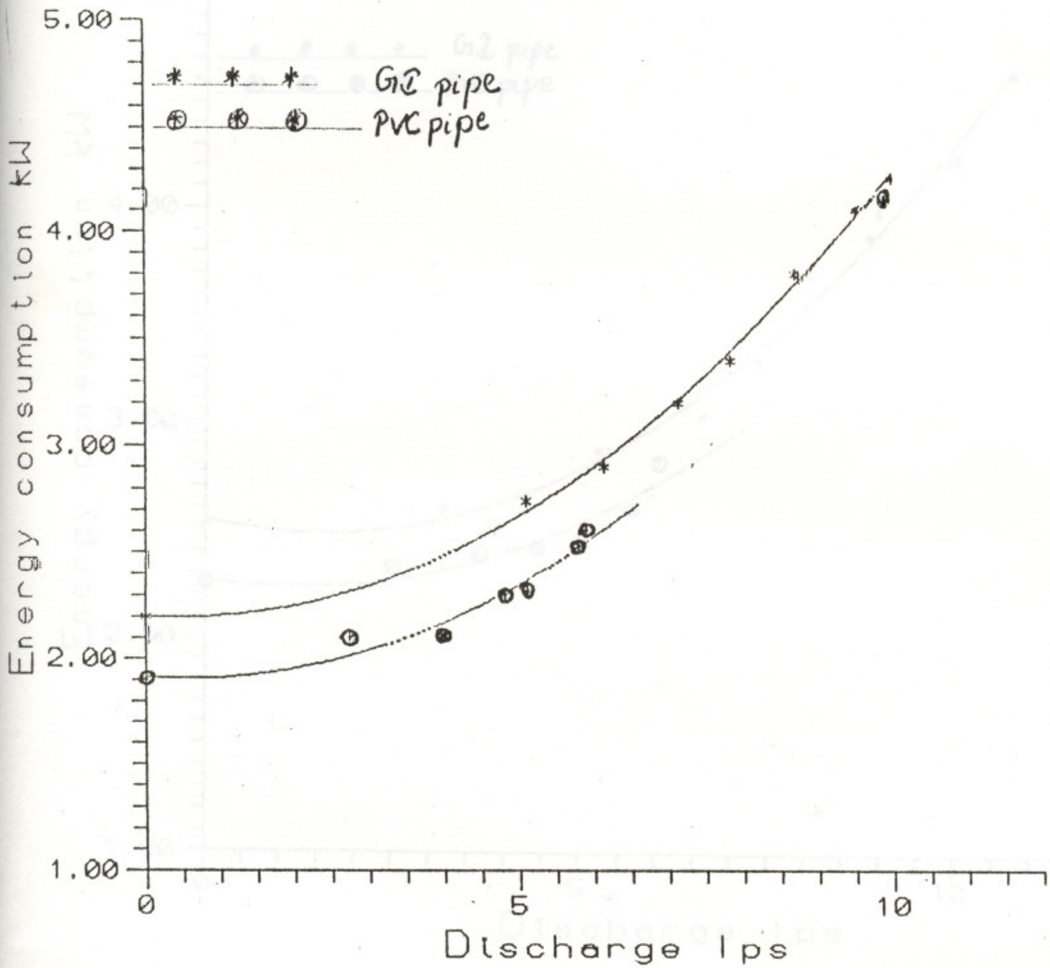
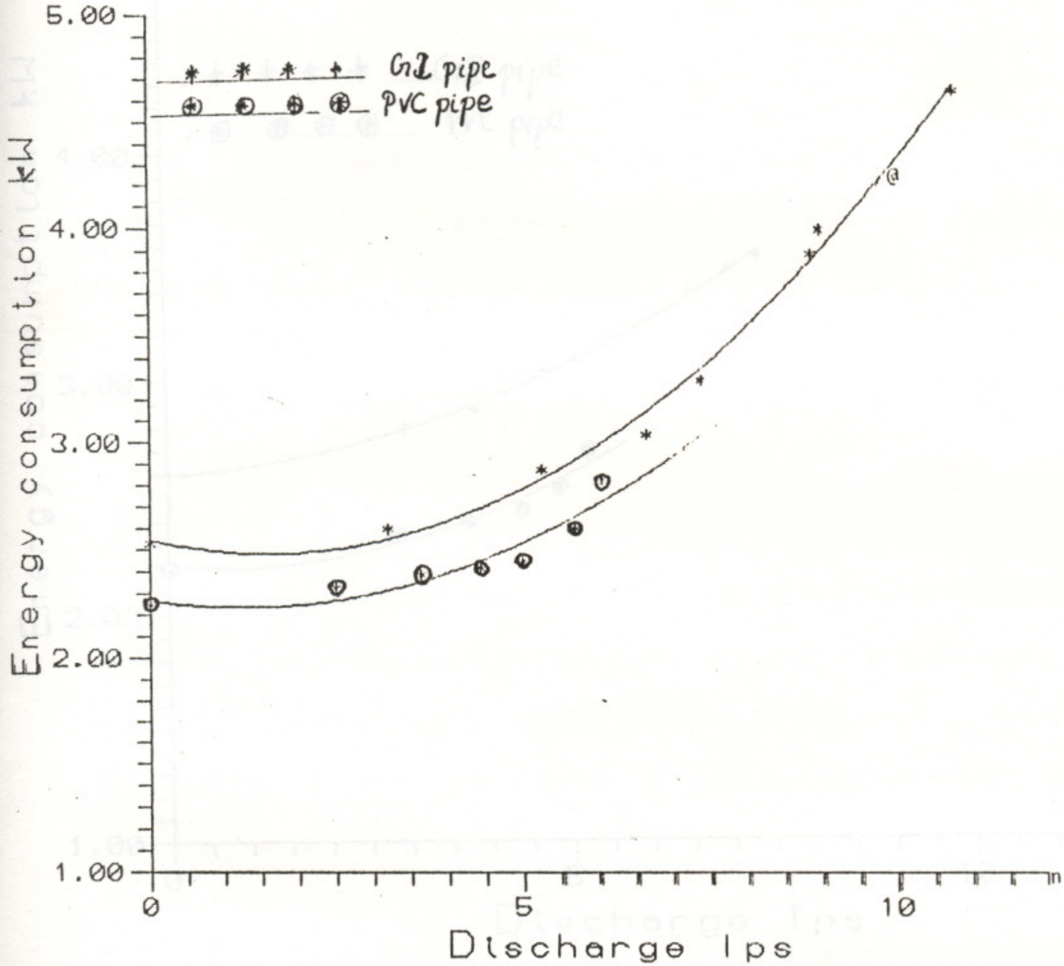


Fig. 31 Variation of energy consumption with discharge using Vinu foot-valve



Fig·32 Variation of energy consumption with discharge using Buno foot-valve

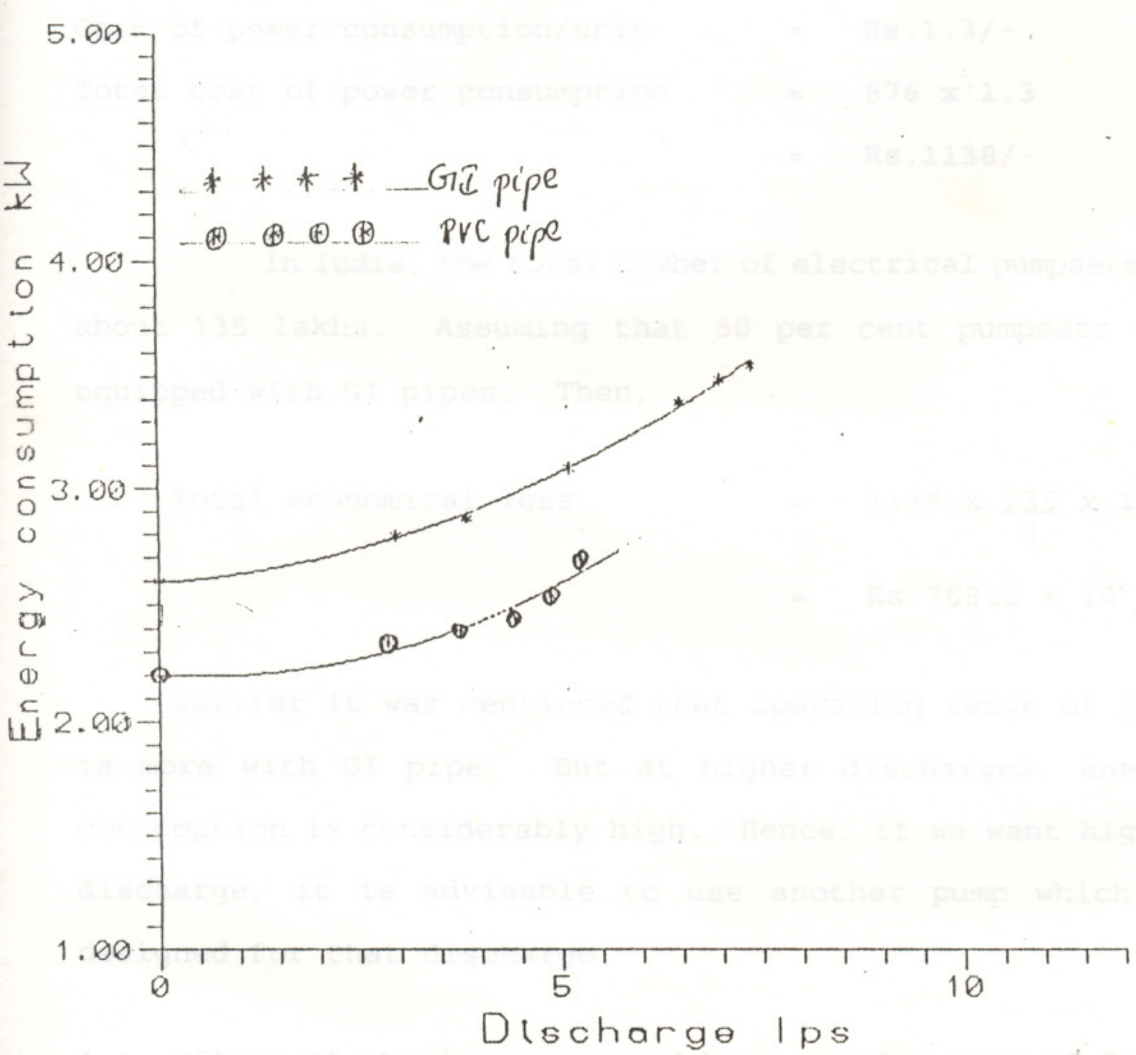


Fig. 33 Variation of energy consumption with discharge using Raj foot-valve

Power loss in a year = 2.4 x 365

= 876 kWh

Cost of power consumption/unit = Rs.1.3/-

Total cost of power consumption = 876 x 1.3

= Rs.1138/-

In India, the total number of electrical pumpsets is about 135 lakhs. Assuming that 50 per cent pumpsets are equipped with GI pipes. Then,

$$\text{Total economical loss} = 1138 \times \frac{135}{2} \times 10^5$$

$$= \text{Rs.}76815 \times 10^5$$

Earlier it was mentioned that operating range of pump is more with GI pipe. But at higher discharges, energy consumption is considerably high. Hence, if we want higher discharge, it is advisable to use another pump which is designed for that discharge.

4.4 Effect of strainer area and base opening area of foot-valve on the performance of pump

The total strainer area and base opening area of all the foot-valves tested are shown in Table 16. The pump gives maximum efficiency when tested with Prashant foot-valve. This is because only Prashant foot-valve satisfies the specifications of strainer area as per IS recommendations. According to IS:10805-1986 (BIS, 1986)

Table 16. Variation of pump efficiency with strainer area and hase opening area

Trade name	Area of suction pipe (cm^2)	Total area of opening of strainer (cm^2)	Area of opening of base (cm^2)	Maximum efficiency using GI (%)	Maximum efficiency using PVC (%)
1. Prashant	20.26	65.42	18.24	60.05	60.89
2. Kirloskar	20.26	48.28	23.26	59.10	60.62
3. Meccano	20.26	48.26	19.97	54.80	59.44
4. Vinu	20.26	35.52	15.42	45.70	46.89
5. Buno	20.26	18.36	15.93	43.95	45.20
6. Raj	20.26	-	14.41	38.62	39.63

optimum value of the ratio of cross section of the suction pipe and total open area of perforations in the strainer is 1:3. For Prashant foot-valve this ratio is 1:3.23. Its base opening area is nearly equal to the suction pipe area. Kirloskar is having higher base opening area than the Prashant foot-valve. The efficiency of Kirloskar is still less compared to Prashant. This is because its strainer area is lower than the Prashant foot-valve. The total strainer area of Meccano foot-valve is almost equal to that of Kirloskar. But its efficiency is lower than Kirloskar. The reason my be due to lesser base opening area of Meccano.

Among all the foot-valves tested Buno, Raj and Vinu has created very high frictional losses. Such a high frictional resistance is due to their poor design of strainer as well as base opening. Such foot-valves are very common in the market. Foot-valves which cause considerable head loss due to friction should be rejected. In such foot-valves the total strainer opening area and base opening area are very less. It is, therefore, recommended to avoid the foot-valves with high frictional head. All the manufacturers of foot-valves carry out the hydraulic tests of their foot-valves so as to reject the foot-valves which leak or fail at high pressure. All the manufacturers including some of the reputed manufacturers of foot-valve do not test their foot-valves for frictional losses. They feel that leak proof operation of the foot-valve is the main and only function of the foot-valve. However, good foot-valves with low resistance or low head loss due to friction would turn out to be energy-savers. The farmers may adopt foot-valves like Prashant and Kirloskar in which the total area of opening of strainer equal to about three times the cross-sectional area of the pipe to which it is connected.

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 areas is hampered by the non-availability of adequate power for irrigation. The shortage of power often affects the lift irrigation projects. Amongst modern pumps centrifugal pumps are most widely used in lift irrigation. It is known that a great majority of pumpsets grossly inefficient from the view point of energy consumption. However, field trials have shown that these pumpsets can be rectified through some minor modifications.

Present study included the rectification of centrifugal pump using different foot-valves and pipes. The performance study was conducted at the hydraulic laboratory of KCAET, Tavanur. The various foot-valves used in this study were Prashant, Kirloskar, Meccano, Vinu, Buno and Raj. The pipes used in this study were GI pipes and PVC pipes. A sump having a dimension of 5.4 x 1.25 x 1.35 m was utilised for the study. The discharge pipe was set up in such a manner that it deliver water back into the sump itself. In this manner, suction head in the pump was maintained at a constant level. Arrangements for measuring the head in the suction and delivery pipes were made with the help of vacuum gauge and pressure gauge respectively attached in the suction and delivery lines. total head was calculated as the sum of suction head, delivery head and the distance between pump centre line and pressure gauge (1 m). For varying the head a gate valve was attached at the delivery side. Discharge of pump was measured directly with the help of water meter provided at the delivery side. Energy consumption was directly obtained from the energy meter. Time taken for a delivery discharge of 200 litres was carefully noted with the help of a stop watch.

Initially Meccano foot-valve was fitted at the bottom end of the suction pipe. GI pipe was used both in the suction and delivery lines. The pump was started after priming. Necessary measurements of suction head, delivery head, energy consumption, delivery discharge were taken. At least six sets of readings were taken by varying the head. After completing the measurements, Meccano foot-valve was removed from bottom of the suction pipe. The experiment was repeated for every foot-valve in the order Vinu, Prashant, Buno, Kirloskar and Raj.

The experiment was repeated using PVC pipes instead of GI pipes.

The findings and recommendations of the present study are as follows:

(i) PVC pipes give greater head at all discharges within its operating range. the higher head obtained is due to the lower frictional losses created by PVC pipes.

(ii) Efficiency of the pump is found to be higher when tested with PVC pipes compared to that of GI pipes.

(iii) The pump consumes less energy when fitted with PVC pipes.

(iv) Though the operating range of pump using GI pipes is more, energy consumption at higher discharges is very high. This greater energy consumption is a huge loss for the nation.

(v) Foot-valves which cause considerable head loss due to friction should be rejected. Among all the foot-valves tested Buno, Raj and Vinu had created very high loss of head due to friction. In such foot-valves total strainer opening area and base opening area are comparatively low.

(vi) Farmers ~~may~~ can adopt low resistant foot-valves like Prashant and Kirloskar. The low resistance created by these foot-valves is due to better design of their strainer and base opening.

Appendix I

Frictional head losses in metres per 100 metres length of PVC pipeline at pressur rating r kg/cm²

Discharge (lps)	Pipe diamter (mm)		
	50	63	75
1.0	0.80	0.26	0.12
1.5	1.60	0.52	0.25
2.0	2.63	0.87	0.40
2.5	3.89	1.26	0.59
3.0	5.37	1.74	0.81
3.5	6.92	2.30	1.05
4.0	8.91	2.88	1.35
4.5	10.72	3.47	1.62
5.0	-	4.17	1.95
5.5	-	5.01	2.29
6.0	-	5.62	2.69
6.5	-	6.61	3.09
7.0	-	7.59	3.55
7.5	-	8.71	3.98
8.0	-	9.55	4.47
8.5	-	-	5.01
9.0	-	-	5.50
9.5	-	-	6.03
10	-	-	6.60
11	-	-	7.76
12	-	-	8.91
13	-	-	10.23
14	-	-	-
15	-	-	-

Appendix II

Head loss due to friction in galvanized iron pipes per 100 metres of pipe length, m

Discharge (lps)	Pipe diamter (mm)			
	40	50	60	70
1.0	3.7	1.1	0.43	0.27
1.2	5.0	1.6	0.58	0.27
1.4	7.3	2.2	0.83	0.37
1.6	9.2	2.8	1.10	0.50
1.8	11.8	3.7	1.40	0.62
2.0	15.5	4.5	1.70	0.73
2.2	16.2	5.2	2.15	0.90
2.4	20.5	6.4	2.50	1.07
2.6	23.5	7.5	2.90	1.27
2.8	27.5	8.7	3.30	1.47
3.0	32.0	10.0	3.80	1.68
3.5	42.5	13.5	5.30	2.30
4.0	56.0	17.5	7.30	3.00
4.5	71.5	22.5	8.80	3.80
5.0	87.0	28.0	10.80	4.70
5.5	-	33.0	12.40	5.70
6.0	-	40.0	15.50	6.80
6.5	-	47.0	18.30	8.00
7.0	-	54.0	21.50	9.30
7.5	-	62.0	24.00	10.60
8.0	-	70.0	28.00	11.60
8.5	-	80.0	31.00	13.30
9.0	-	90.0	36.00	15.00
10.0	-	100.0	38.00	17.00
12.0	-	-	43.00	19.00
14.0	-	-	63.00	27.00
16.0	-	-	86.00	37.00
18.0	-	-	-	47.00
20.0	-	-	-	60.00
22.0	-	-	-	72.00
24.0	-	-	-	86.00
26.0	-	-	-	-

Appendix III

Instrumentation

a. Specifications of the stop watch

Make	-	Dolmy, Switzerland
Least count	-	1/10

b. Specifications of vacuum gauge

Make	-	Bourdon's Patent, Germany
Range	-	0 to 760 mm of Hg

c. Specifications of pressure gauge

Make	-	Bourdon's Patent, Germany
Range	-	0 to 7 kg/cm^2

d. Specifications of energy meter

Make	-	General Electric Corporation of India Pvt. Ltd., Calcutta
Phase	-	3
Volts	-	3 x 400 112.5 Rev.s/kWh
Range	-	0 to 10,000 kWh
Cycles	-	50

e. Specifications of pump

Make	-	Suguna Pumps, Coimbatore
Size	-	2 x 2
RPM	-	1440

f. Specifications of water meter

Make	-	Anand Ashi, India
Size	-	50 mm
Range	-	0 to 1000 litres

g. Specifications of starter

Make	-	Escol Electromech Ltd., Bombay
Type	-	Push button

h. Specifications of motor

Make	-	Suguna Motors, Coimbatore
HP	-	3
Amps	-	4.5
RPM	-	1440
Phase	-	3
Volts	-	415
Cycles	-	50
Class of insulation	-	A

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PERFORMANCE STUDY OF CENTRIFUGAL PUMP USING DIFFERENT FOOT-VALVES AND PIPES

By

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ABSTRACT OF THE PROJECT REPORT

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ABSTRACT

In India, the agricultural production in many areas is hampered by the non-availability of adequate power for irrigation. The shortage of power often affects the lift irrigation projects. Amongst modern pumps, centrifugal pumps are most widely used in lift irrigation. It is known that a great majority of pumpsets grossly inefficient from the view point of energy consumption. These pumpsets can be rectified through some minor modifications.

Present study included the rectification of centrifugal pump using different foot-valves and pipes. The various foot-valves used in this study were Prashant, Kirloskar, Meccano, Vinu, Buno and Raj. The pipes used in this study were GI pipes and PVC pipes. Necessary arrangements for measuring the total head, delivery discharge and energy consumption were made.

The major findings of the study are as follows:

1. PVC pipes give greater head at all discharges within its operating range. The higher head obtained is due to the lower frictional losses created by PVC pipes.

2. Efficiency of the pump is found to be higher when tested with PVC pipes compared to that of GI pipes.

3. Pump consumes less energy when fitted with PVC pipes.

4. Though the operating range of pump using GI pipes is more, energy consumption at higher discharges is very high.

5. Foot-valves which cause considerable head loss due to friction should be rejected. Among all the foot-valves tested, Buno, Raj and Vinu had created very high loss of head due to friction. In such foot-valves total strainer opening area and base opening area are comparatively low.