Experimental Analysis on Multi Hole Nozzle Jet Pump

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ABSTRACT: *Water is central to survival, without water human, plant and animal life would be impossible. Therefore supply of water has become one of the fundamental requirements of any society and the need to transfer water has generated the design of various forms of mechanical devices, which can be categorized as pumps. Jet pump is a device that performs its pumping action by the transfer of energy from a high velocity supply jet to one of low velocity suction flow. These two flows mix in the mixing tube and the kinetic energy of the combined flow is converted partially into the pressure energy in the diffuser. The optimization of the design of multi hole nozzle jet pump with various pitch circle diameter (PCD) and five different diameter mixing tubes.*

The area ratios chosen have been modified and the final area ratios used were R = 0.20, 0.28, 0.36, 0.43 & 0.50. From the graphs, head ratio at zero discharge ratios (N_o), discharge ratio at zero head ratio (M_o) and slope of M-N (m) curve were noted along with the extrapolated values of maximum efficiency (η_{bep}), optimum discharge ratio (M_{opt}), and optimum head ratio (N_{opt}) and tabulated. In order to distinguish these nozzle plates from these charts one can conclude that efficiency is higher at lower pitch circle diameter, lower mixing tube diameter and higher area ratios. In the range of experiments conducted highest maximum efficiency was obtained for an area ratio of 0.43 with 2 holes on 13 PCD with 25.9 mm mixing tube.

Keywords: *Area ratios, Mixing tube, Multi hole nozzle, Nozzle plates, Pitch circle diameter (PCD)*

I. INTRODUCTION

Pumps are hydraulic machinery that converts mechanical energy to fluid energy to increase the hydraulic energy in the flow. Pumps are devices that transfer energy from an external source to liquid in order to move the liquid from one location to another. This process will increase the energy of the liquid as it leaves the pump. In other words “Pumping is the addition of energy to liquid, which is normally used for the purpose of moving the liquid from one place to other or to do any other work”. Jet pump is a device, Layout and Measuring Arrangement of Test Setup as shown in Fig.1, which performs its pumping action by the transfer of energy from a high velocity supply jet to one of low velocity suction flow. These two flows mix in the mixing tube and the kinetic energy of the combined flow is converted into the pressure energy in the diffuser

The applications of jet pump are Deep well pumping, Booster pumping, Dredging, Sediment transportation, Priming of large sumps and Siphons. They are also useful in Reactor coolant circulation, Aircraft fuel pumping, Condensate pumping in space power systems, Recirculation and mixing in process industries, Steam jet refrigeration and Tunnel ventilation. The main advantage of the jet pump compared to the Rotodynamic pumps is offset installation. Possibility of the offset installation is a unique feature of jet pump. It can be installed away from the source of water up to a distance of 90 meters or even more. The only limitation of the jet pump is its comparatively lower efficiency.

The following processes take place in a jet pump

a. Pressure energy of the fluid from supply pipe is converted into kinetic energy in the driving nozzle.
b. Suction fluid induces through suction pipe as the pressure falls in the driving nozzle.
c. The flow from driving nozzle and suction stream combines by turbulent mixing in the mixing tube of jet pump.
d. Kinetic energy of the combined fluid in mixing tube is converted into pressure energy in the diffuser and
e. The resultant fluid is then delivered in the delivery pipe.

II. EXPERIMENTAL SETUP

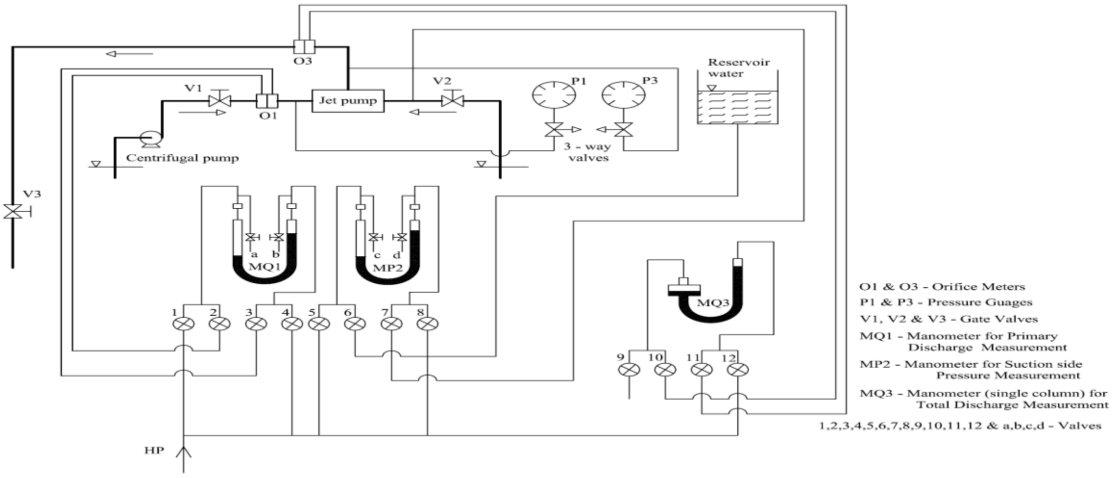

Fig.1 Layout and Measuring Arrangement of Test Setup

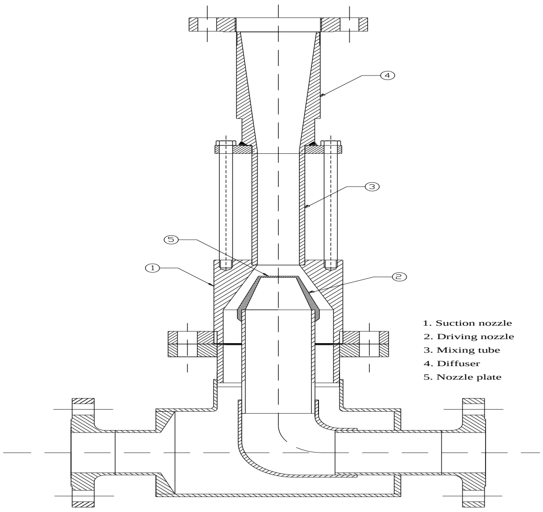

Fig.2 Cross Sectional view of View of The Jet Pump

The performance of a jet pump is graphically represented by Head ratio (N) as a function of Discharge ratio (M) and Efficiency (η) as a function of Discharge ratio (M).The graph indicates that as the discharge ratio increases the head ratio decreases. The slope of the M-N curve depends on the area ratio of the jet pump. In case of discharge ratio versus efficiency, the curve increases till the maximum efficiency then it drops. If the pump is running with cavitation its performance drops drastically at one discharge ratio. The Cross Sectional view of View of The Jet Pump as shown in Fig.2 and Arrangement of holes on various multi holes nozzle plates are shown in Fig.3.

The main objective of this project work is to conduct an experimental study on the performance characteristics of the multi hole nozzle jet pump with number of holes ranging from two to six. This project work includes the optimization of the design of multi hole nozzle jet pump with various pitch circle diameters and mixing tubes.

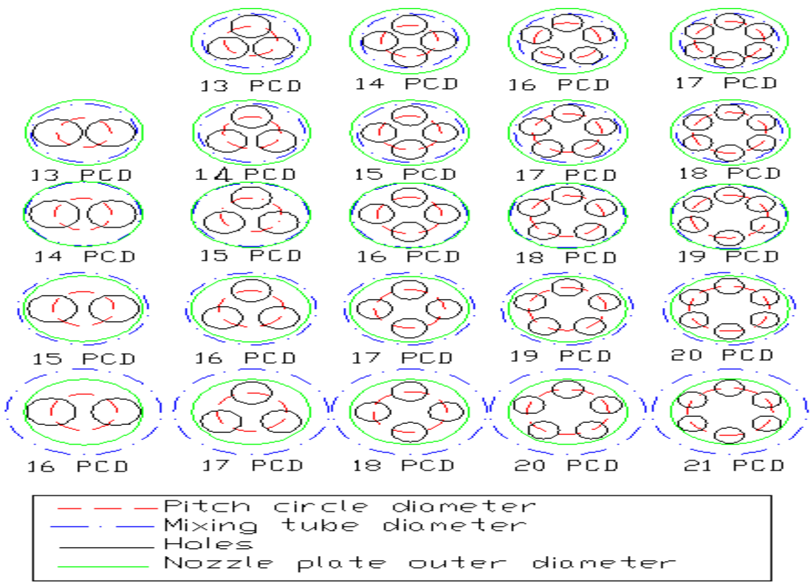

Fig.3 Arrangement of holes on various multi holes

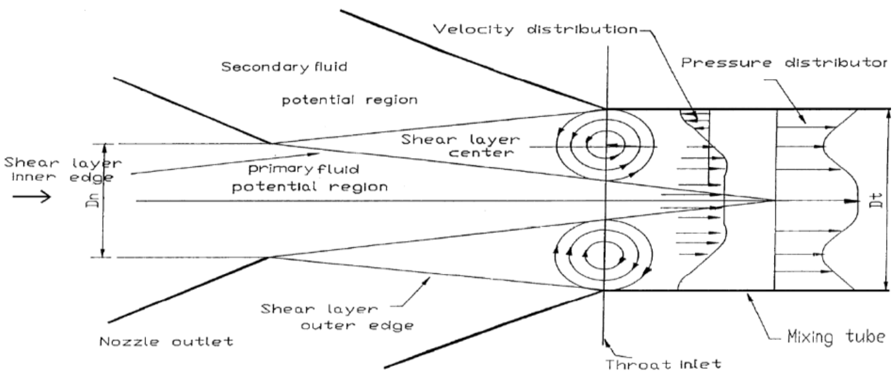

Fig.4 Schematic representation of the flow pattern between the nozzle outlet and the throat inlet

III. EQUATIONS

Area Ratio (R): It is the ratio of driving nozzle area and mixing tube throat area and is given by

$$R = \frac{A_n}{A_t} = \left(\frac{d_n}{d_t}\right)^2 \qquad (1)$$

Discharge Ratio (M): It is the ratio between suction flow rate and primary flow rate of jet pump.

$$M = \frac{Q_2}{Q_1} \qquad (2)$$

Head Ratio (N)

It is the ratio between net jet pump head and net driving head of the jet pump.

Jet pump supply head H_1 is given by

$$H_1 = \frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 \quad (3), \qquad H_2 = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 \quad (4)$$

Jet pump delivery head H_3 is given by

$$H_3 = \frac{p_3}{\gamma} + \frac{v_3^2}{2g} + z_3 \quad (5), \qquad N = \frac{H_3 - H_2}{H_1 - H_3} \quad (6)$$

Efficiency of Jet Pump (η)

It is defined as the ratio of energy increase of suction stream (output energy) to the energy decrease of driving stream (input energy).

$$\eta = \left(\frac{Q_2}{Q_1}\right) \times \left(\frac{H_3 - H_2}{H_1 - H_3}\right) = M \times N \qquad (7)$$

IV. RESULTS

Plots of head ratio (N) Vs discharge ratio (M) are shown in Fig.5a to Fig 9a for various No. of holes. The legend of the Figures refer to No. of holes-PCD-mixing tube diameter. In all the plots M-N curves are fitted as a straight line by the method of least squares.

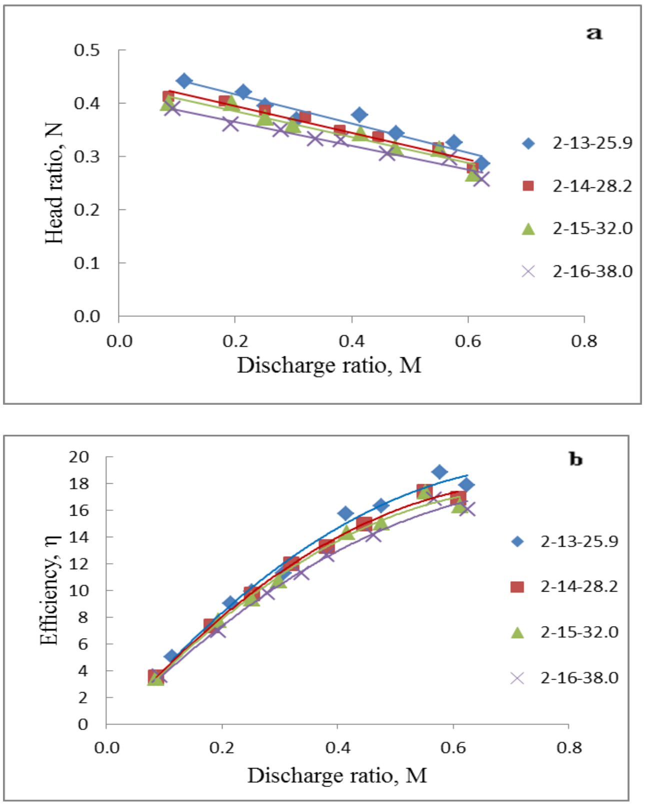

Fig.5 Performance characteristics of Jet Pump with 2 holes

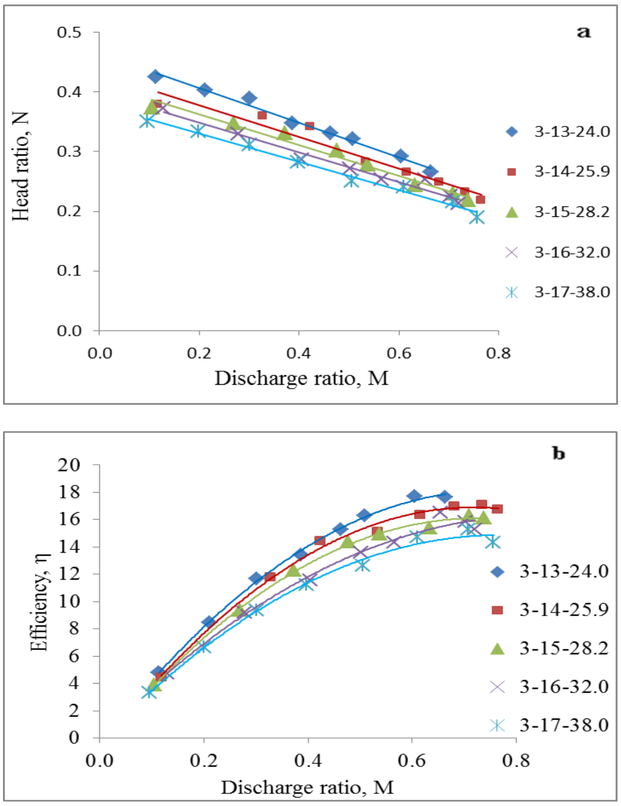

Fig.6 Performance characteristics of Jet Pump with 3 holes

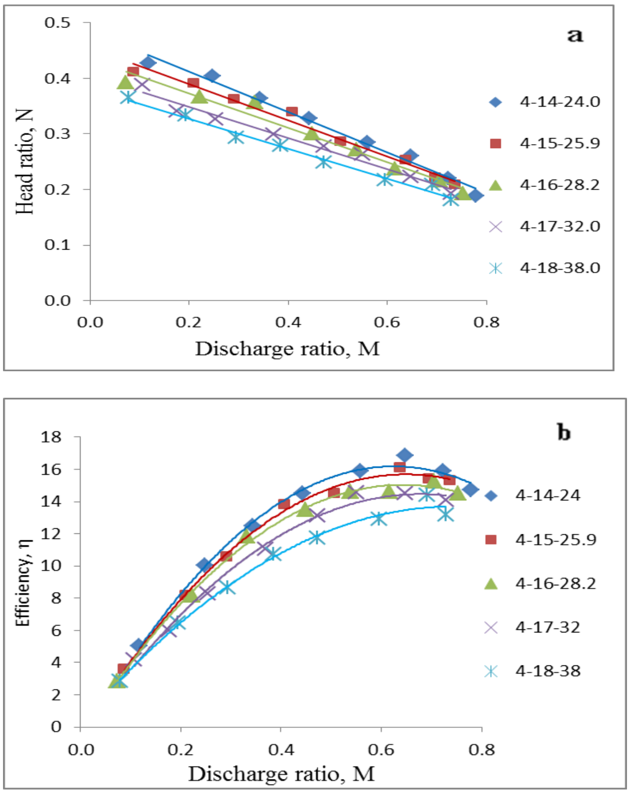

Fig.7 Performance characteristics of Jet Pump with 4 holes

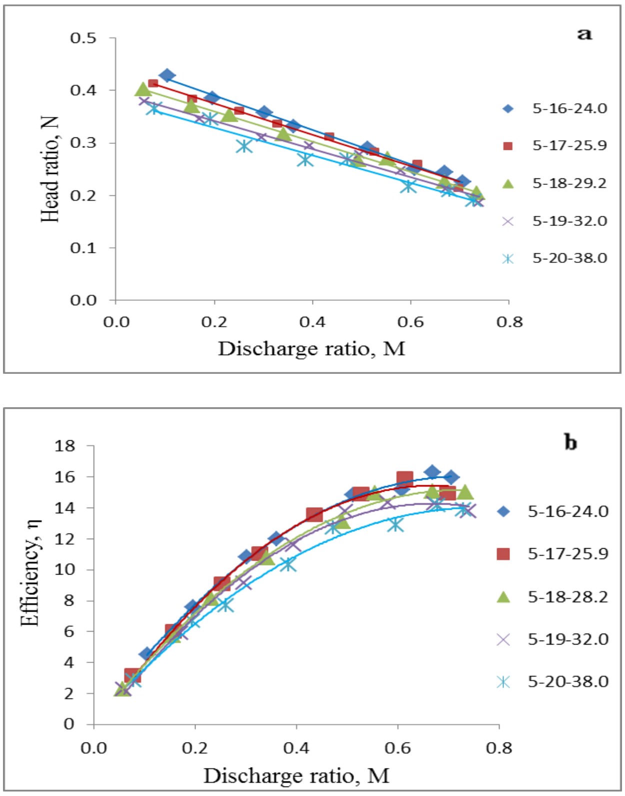

Fig.8 Performance characteristics Of Jet pump with 5 holes

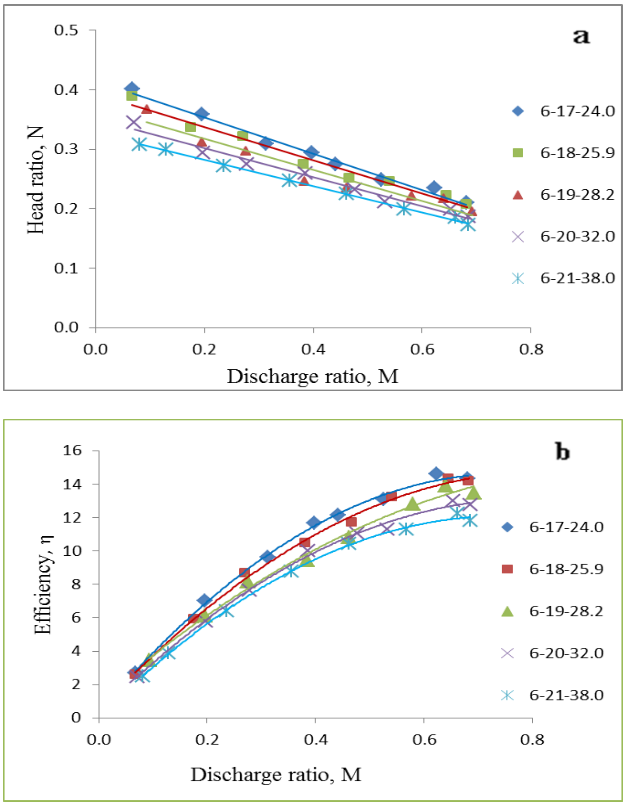

Fig.9 Performance characteristics of Jet pump with 6 holes

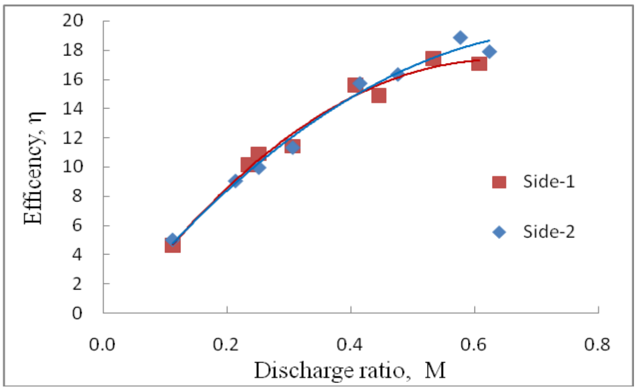

Fig.10 Effect of manufacturing inaccuracy

Shown Fig.10 each time after taking the readings of one nozzle plate, the nozzle plate was reversed and the experiment was repeated. This was because of the considerable variation noticed of the jet pump performance for two cases which might be due to manufacturing inaccuracy in drilling holes on the plates. So after taking the readings on both sides, jet pump performance was determined and the side of the nozzle plate which exhibited higher efficiency was chosen as the right one.

Table.1 Performance parameters for all the Nozzle Plates

S.NO	Dh(mm)	Z	Dp	Dm(mm)	M0	N0	m	Mbep	Nbep	ημαξ %
1	12	2	13	25.9	1.738	0.471	-0.271	0.85	0.24	20.46
2	12	2	14	28.2	1.777	0.446	-0.251	0.9	0.22	19.81
3	12	2	15	32	1.797	0.433	-0.241	0.95	0.2	19.38
4	12	2	16	38	1.839	0.41	-0.223	0.9	0.21	18.84
5	9.8	3	13	24	1.611	0.464	-0.288	0.8	0.234	18.69
6	9.8	3	14	25.9	1.623	0.43	-0.265	0.8	0.218	17.44
7	9.8	3	15	28.2	1.611	0.414	-0.257	0.8	0.208	16.67
8	9.8	3	16	32	1.611	0.398	-0.247	0.8	0.2	15.97
9	9.8	3	17	38	1.595	0.378	-0.237	0.8	0.188	15.07
10	8.5	4	14	24	1.337	0.484	-0.362	0.65	0.249	16.17
11	8.5	4	15	25.9	1.401	0.454	-0.324	0.7	0.227	15.9
12	8.5	4	16	28.2	1.409	0.434	-0.308	0.7	0.218	15.29
13	8.5	4	17	32	1.414	0.41	-0.29	0.7	0.209	14.61
14	8.5	4	18	38	1.448	0.404	-0.279	0.7	0.191	13.35
15	7.6	5	16	24	1.397	0.454	-0.325	0.7	0.227	15.86
16	7.6	5	17	25.9	1.455	0.435	-0.299	0.75	0.211	15.81
17	7.6	5	18	28.2	1.455	0.416	-0.286	0.7	0.216	15.11
18	7.6	5	19	32	1.479	0.395	-0.267	0.75	0.195	14.61
19	7.6	5	20	38	1.443	0.381	-0.264	0.7	0.196	13.73
20	6.9	6	17	24	1.361	0.415	-0.305	0.7	0.202	14.11
21	6.9	6	18	25.9	1.409	0.393	-0.279	0.7	0.198	13.84
22	6.9	6	19	28.2	1.418	0.37	-0.261	0.7	0.187	13.11
23	6.9	6	20	32	1.44	0.35	-0.243	0.7	0.18	12.59
24	6.9	6	21	38	1.482	0.326	-0.22	0.65	0.18	11.68

In all plots of M Vs N shown in Fig. 5a to Fig.9a head ratio (N) and discharge ratio (M) are related as a straight line and an equation of first order of the following form is obtained.

$$\mathbf{N = (m \times M) + N_0} \tag{9}$$

Where, m is the slope of the M-N curve,N_0 is the head ratio at discharge ratio = 0, From this equation, M values at N = 0 is calculated and indicated as M_0

$$\mathbf{M_{bep} = (-No/2m)} \tag{10}$$

Where, M_{bep} = Discharge ratio at best efficiency point

$$\mathbf{N_{bep} = (No/2)} \tag{11}$$

Where, N_{bep} = Head ratio at best efficiency point

Product of M and N is nothing but efficiency. Values of M and N corresponding to best efficiency point ware used to determine maximum efficiency.

$$\boldsymbol{\eta_{max} = M_{bep} \times N_{bep}} \tag{12}$$

It may be observed from this table that maximum efficiency decreases as PCD increases for a given No. of holes. Further, for a given No. of holes maximum efficiency decreases as the No. of holes increases as the PCD increases, there is an increase in maximum efficiency, slope (m), M_{bep}, N_{bep}, N_0 and M_0.In the range of experiments conducted highest maximum efficiency was obtained for 2 holes on 13 PCD with 25.9 mm mixing tube.

V. CONCLUSIONS

- A small manufacturing error in the nozzle plate holes results in a considerable change in performance of the jet pump.
- Jet pump with multihole nozzle having smaller No. of holes with smaller PCD and smaller mixing tube diameter gives higher efficiency
- In the range of experiments conducted highest maximum efficiency was obtained for an area ratio of 0.43 with 2 holes on 13 PCD with 25.9 mm mixing tube.

VI. SCOPE FOR FURTHER WORK

- The performance of jet pump for various area ratios can be done by changing the mixing tube design.

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