DATE | EXPERIMENT No. : 4 | SHEET NO.

PERFORMANCE OF A CENTRIFUGAL FAN

OBJECTIVES: ▷ To determine the Pressure rise (ΔP) vs. Discharge characteristics of a centrifugal fan.

EXPERIMENTAL SETUP:

▷ Thermofluids Tutor Setup

THEORY: A large number of fans and blowers for relatively high pressure applications are of centrifugal type.

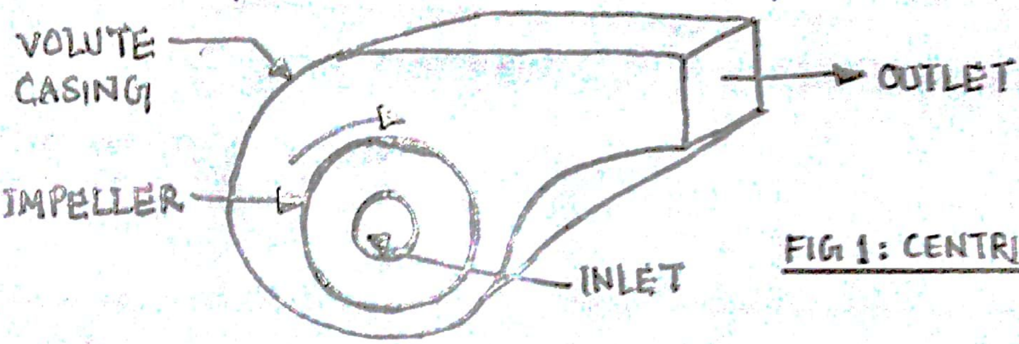


FIG 1: CENTRIFUGAL FAN

The main components of a centrifugal fan are shown in Fig 2. A fan consists of an impellar which has blades fixed between the inner and outer diameters. The impellar can be mounted directly on the shaft extension of the prime mover or separately on a shaft supported between two additional bearings. Air or gas enters the impellar axially through the inlet nozzle which provides slight acceleration to the air before its entry to the impellar. The action of the impellar swings the gas from a smaller to a larger radius and delivers the gas at a high pressure and velocity to the casing. The flow from the impellar blades is collected by a spiral-shaped casing known as the volute casing or spiral casing. The casing can further increase the static pressure of the air and it finally delivers the air to the exit of the blower.

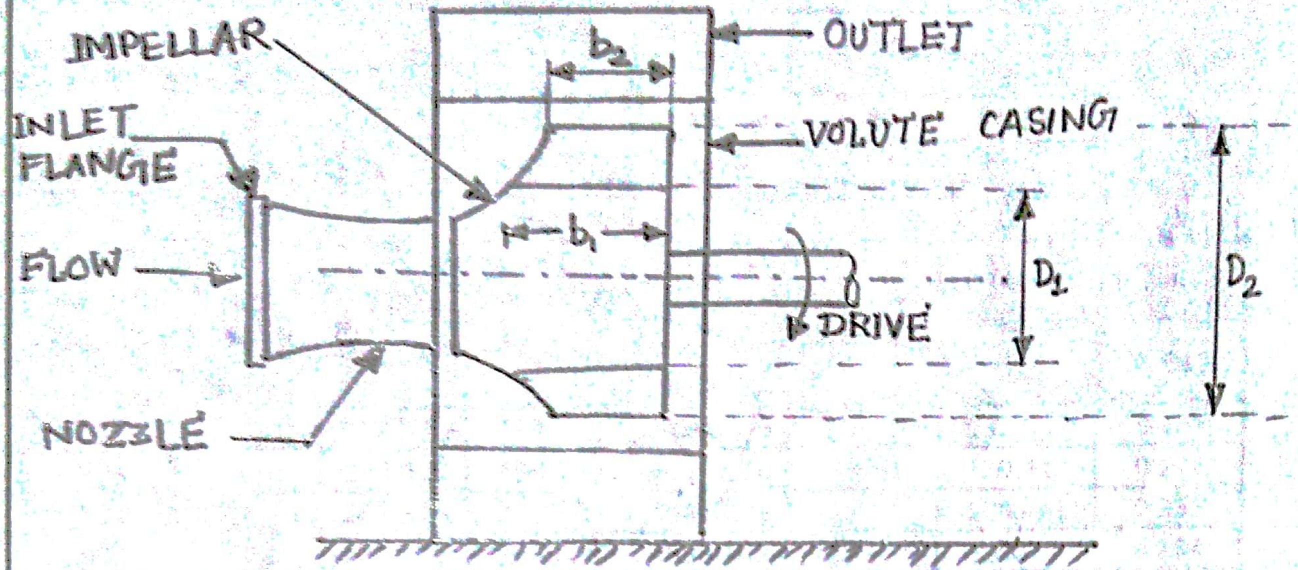
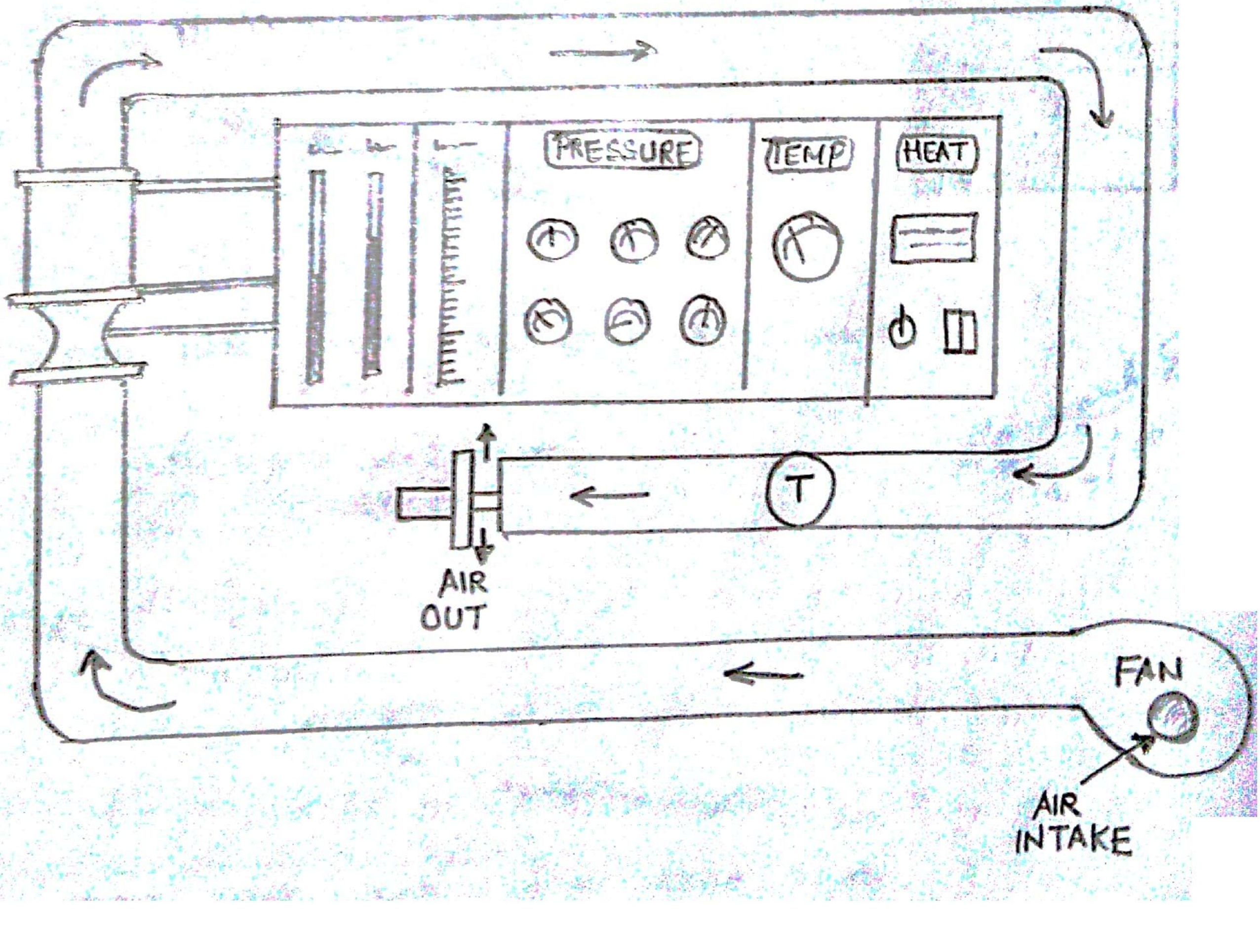


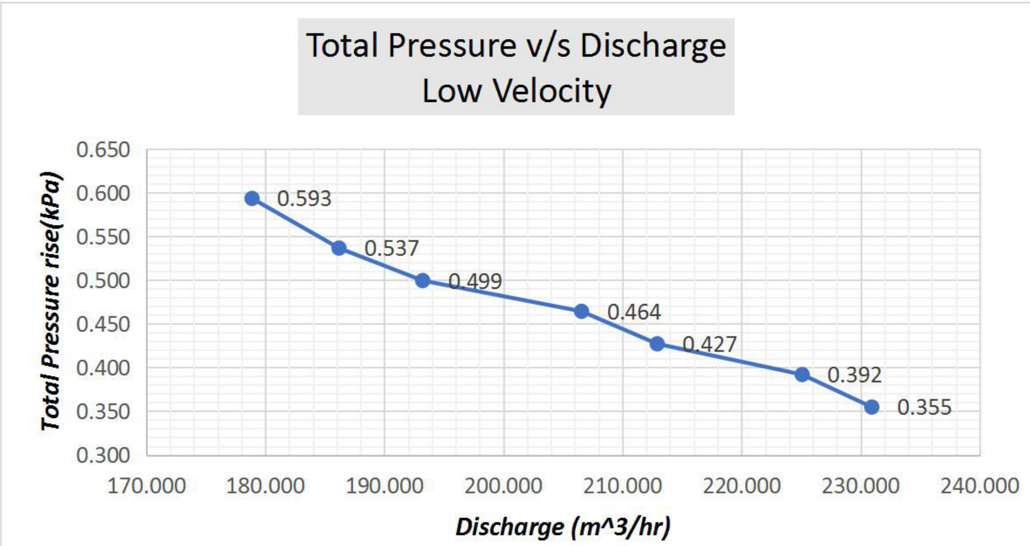
FIG 2: MAIN COMPONENTS OF A CENTRIFUGAL FAN

- SCHEMATIC OF THE SETUP:

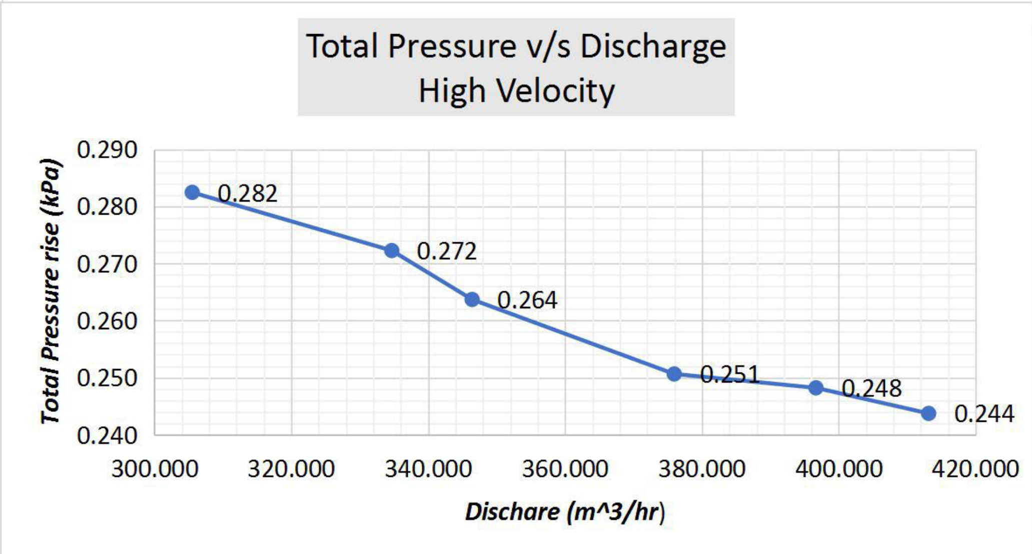


Low Velocity								
S. No	Venturi (mbar)	Static Pressure (mm of water)	Static Pressure (Pa)	Discharge (m^3/hr)	Velocity (m/hr)	Velocity (m/s)	Dynamic Pressure (Pa)	Total Pressure (kPa)
1	2	32	313.813	230.941	30383.75	8.44	40.912	0.355
2	1.9	36	353.039	225.094	29614.41	8.23	38.867	0.392
3	1.7	40	392.266	212.917	28012.43	7.78	34.775	0.427
4	1.6	44	431.493	206.560	27176.05	7.55	32.730	0.464
5	1.4	48	470.719	193.219	25420.87	7.06	28.639	0.499
6	1.3	52	509.946	186.191	24496.16	6.80	26.593	0.537
7	1.2	58	568.786	178.886	23535.15	6.54	24.547	0.593

High Velocity								
S. No	Venturi (mbar)	Static Pressure (mm of water)	Static Pressure (Pa)	Discharge (m^3/hr)	Velocity (m/hr)	Velocity (m/s)	Dynamic Pressure (Pa)	Total Pressure (kPa)
1	6.4	11.5	112.776	413.120	54357.89	15.10	130.947	0.244
2	5.9	13	127.486	396.654	52191.36	14.50	120.717	0.248
3	5.3	14.5	142.196	375.945	49466.43	13.74	108.441	0.251
5	4.5	17.5	171.616	346.412	45580.48	12.66	92.072	0.264
6	4.2	19	186.326	334.665	44034.92	12.23	85.934	0.272
7	3.5	21.5	210.843	305.506	40198.20	11.17	71.612	0.282



P_atm (mbar)	999
d (m)	0.0984
A (m^2)	0.0076
Density of air (kg/m^3)	1.1487



CALCULATIONS:

Pipeline inner diameter = 0.0984 m

Flow rate = $Q = 163.3\sqrt{h}\ \frac{m^3}{hr}$ where $h \rightarrow$ pressure reading in mbar

From $Q = VA$

$\Rightarrow Q = V\frac{\pi D^2}{4}$

$\Rightarrow \boxed{V = 131.498\,Q\ m/s}$

Sample calculation

for high speed, 1st Reading

Venturi reading, $\boxed{h = 6.4\ mbar}$

$\therefore Q = 163.3\sqrt{h} = 163.3\sqrt{6.4}\ m^3/hr = 413.12\ \frac{m^3}{hr}$

$\Rightarrow \boxed{Q = 0.11476\ m^3/s}$

$\therefore$ Velocity, $V = 131.498 \times 0.11476\ m/s$

$\Rightarrow \boxed{V = 15.10\ m/s}$

$P_{static} = 11.5$ mm of Water

$\Rightarrow \boxed{P_{static} = 112.776\ Pa}$

$\Rightarrow P_{Dynamic} = \frac{1}{2}\rho V^2 = \frac{1}{2} \times 1.1487 \times 15.1^2$

$\Rightarrow \boxed{P_{Dynamic} = 130.947\ Pa}$

$P_{Total} = P_{Static} + P_{Dynamic}$

$\Rightarrow \boxed{P_{Total} = 0.244\ KPa}$ ~~Gauge Pressure~~

DISCUSSIONS

Q1. Discuss the fan laws and their limitations.

Ans. The fan laws (also known as the 'affinity laws' or 'pump laws') are used in hydraulics, hydronics and/or HVAC to express the relationship between variables involved in pump or fan performance (such as head, volumetric flow rate, shaft speed) and power.

These laws are derived using the Buckingham π theorem.

Law 1: With impeller diameter (D) held constant

Law 1a: Flow is proportional to shaft speed ($Q \propto N$)

Law 1b: Pressure or Head is proportional to the square of shaft speed ($H \propto N^2$)

Law 1c: Power is proportional to the cube of shaft speed ($P \propto N^3$)

Law 2: With shaft speed (N) held constant

Law 2a: Flow is proportional to the impeller diameter ($Q \propto D$)

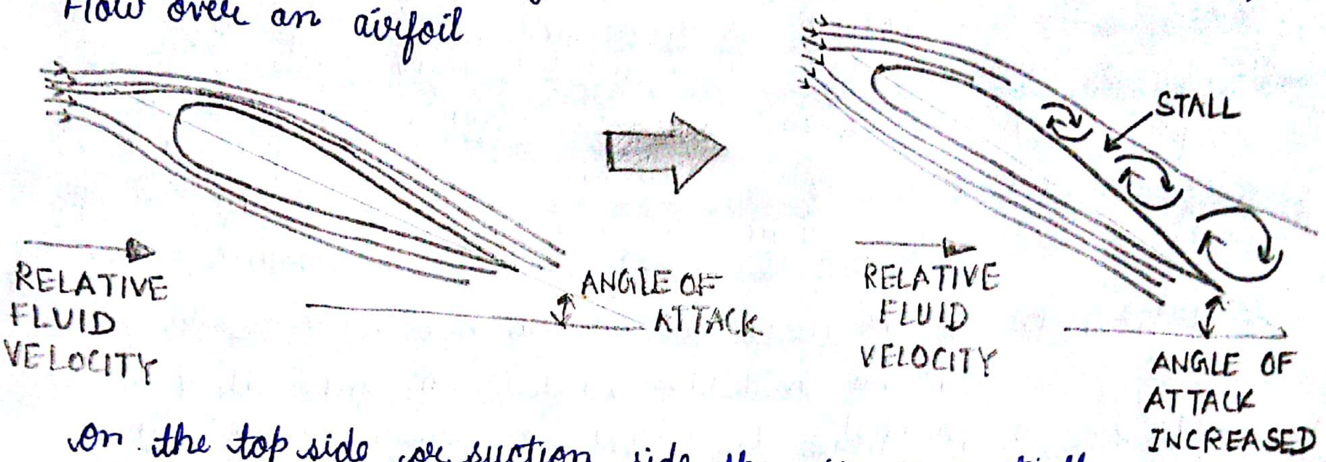
Law 2b: Pressure or Head is proportional to the square of the impeller diameter ($H \propto D^2$)

Law 2c: Power is proportional to the cube of impeller diameter ($P \propto D^3$)

The limitations of the fan laws are that these laws assume that the fan efficiency remains constant i.e., $\eta_1 = \eta_2$, which is rarely exactly true. Also, they aren't strictly followed due to design considerations and manufacturing alterations. So, these laws are obeyed closely but not strictly.

Q2. What do you mean by surging and stalling.

Ans Surging and stalling both lead to unstable flow in fans.
Flow over an airfoil



On the top side or suction side the air is initially accelerated from the leading edge (LE), causing a reducing pressure gradient. As the flow reaches the maximum thickness of the airfoil, it starts to slow down, causing the pressure to increase, or a +ve pressure gradient starts to occur. This pressure gradient is unstable as the airflow is still +ve. This airflow condition forces a flow separation — there is a reverse flow over the airfoil surface past the separation point. If the angle of attack of the airfoil increases, this separation point will move forward towards the LE, making the flow separation area bigger. It will come to a point that the whole flow over the airfoil separates, starting from LE. This condition is called stall. It is a local phenom-enon.

Surging is the complete breakdown of steady flow, affecting the whole machine, in other words, when stalling takes place on all the blades simultaenously. This leads to choking of the flow. Sometimes even reversal of the flow may take place. Heavy vibrations also occur.

Q3. Discuss different methods of fan capacity control.

Ans The different methods of fan capacity control are :-

(i) <u>Modulating fan speed</u>: The speed of the fan can be adjusted using a frequency controller or changing the configuration of fan or the motor drive.

(ii) <u>Adjusting the blades</u>: One can adjust the pitch of the blades, possible with axial flow fan and propeller.

(iii) <u>Throttling the air volume</u>: One can control the discharge using discharge dampers to reduce the volume of flow.

(iv) <u>Inlet vane damper</u>: Provide inlet swirl in the direction of fan rotation reducing power consumption.

<u>Q4. Give the fan classification according to the blade curvature. Discuss their respective application.</u>

Ans According to the blade curvature, fans are classified as

1. Forward curved: High flow, low pressure, low speeds.
2. Backward curved: High pressure, medium flow
3. Straight / radial: High speed, low flow, low pressure.