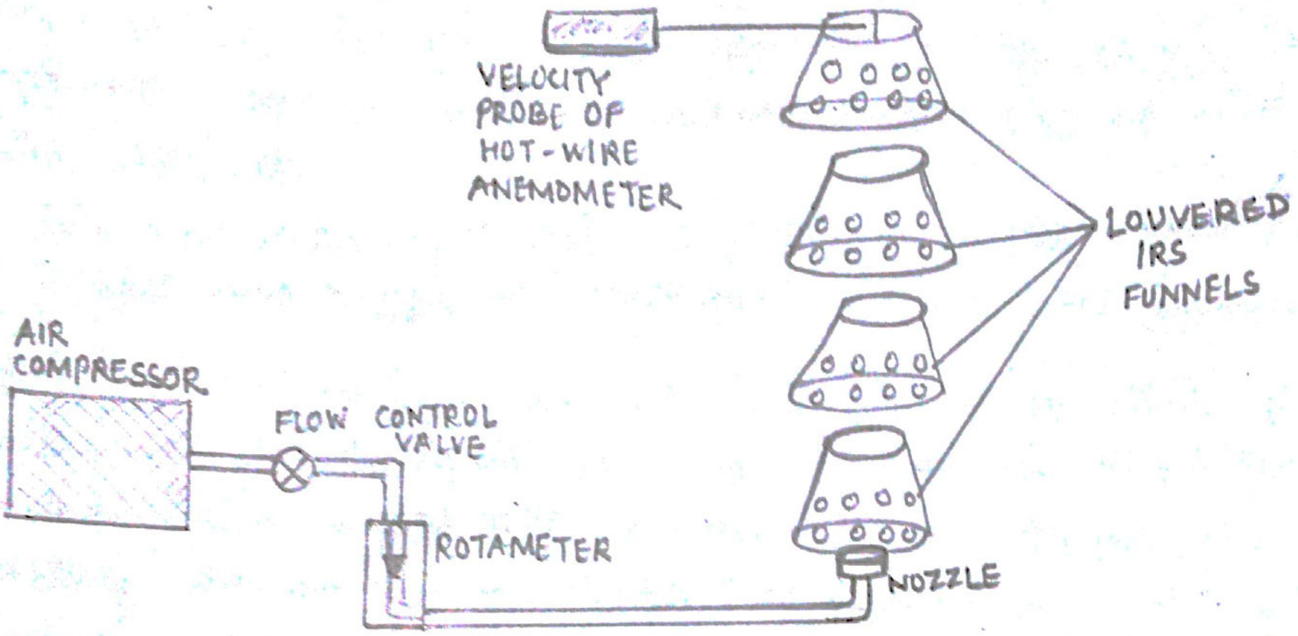
EXPERIMENT No. : 3

AIR ENTRAINMENT INTO AN IRS DEVICE

◎ **Objective:** To investigate air entrainment into a louvered infrared suppression (IRS) device experimentally on a laboratory scale set up for cold air.

◎ **Experimental set up:** The diagram of experimental setup is shown.



From the setup, it can be observed that the IRS device consists of funnels, made up of thin mild steel sheet which are stacked one up on another. The shape of each funnel is just like a frustum cone. All the four funnels are similar in dimensions; each having a height of 20.7 cm, top diameter of 14.4 cm and bottom diameter of 20.4 cm. Each funnel is having two rows of louvers located at a distance of about 5.15 cm and 10.15 cm respectively from the bottom of each funnel. Each funnel is having eight number of louvers per row each having diameter of 2.5 cm, thus there are a total of 16 louvers in each of the funnel. These louvers are arranged in a circumferential manner around the surface of each funnel. This device is held vertically with the help of an iron stand. All the funnels and nozzles are attached to this iron stand by means of nuts and bolts. By sliding funnels through the groove provided in the iron stand the parameters like funnel overlap and nozzle protrusion can be varied easily. A nozzle diameter of 1.25 cm is used for the present experiment. The nozzle receives high speed cold (as well as hot) air. Heaters may be used to obtain hot air.

The exit velocities at different locations on top-most surface of funnel and nozzle are measured by a hot wire anemometer.

● **Experimental Procedure:** The air from the storage tank of a compressor is allowed to enter the duct heater via a flow control valve. Experiments on hot air are carried out by heating air in a duct heater (we carried out our experiment using cold air only). The air is thrown vertically up into the IRS device from a metal nozzle (diameter: 1.25cm length: 7.5cm). Uniform velocity at the exit of the nozzle is assumed (l/d ratio is very small). The mass flow rate at the nozzle exit is varied using the flow control valve

The velocity is measured on the nozzle exit plane and at nine locations on the exit plane of the IRS device using a single probe hot-wire anemometer under isothermal conditions of ambient temperature. The probe is kept perpendicular to the air flow.

Calculation procedure:

$$a_{nozzle} = \frac{\pi D^2_{nozzle}}{4}$$

$$\dot{q}_{in} = V_{nozzle} \times a_{nozzle}$$

$$\dot{m}_{in} = \dot{q}_{in} \times \rho$$

$$\dot{q}_{out} = 2 \times \pi \times \int (r \times v)\, dr \leftarrow \text{NUMERICAL INTEGRATION}$$

$$\dot{m}_{out} = \dot{q}_{out} \times \rho$$

$$\text{Entrainment Ratio} = \dot{m}_{suc} / \dot{m}_{in}$$

$$= \frac{\dot{m}_{out} - \dot{m}_{in}}{\dot{m}_{in}}$$

$$= \frac{\dot{m}_{out}}{\dot{m}_{in}} - 1$$

$a_{nozzle} \rightarrow$ area of nozzle

$D_{nozzle} \rightarrow$ diameter of nozzle

$\dot{q}_{in} \rightarrow$ Volume flow rate at nozzle inlet

$\dot{q}_{out} \rightarrow$ Volume flow rate at nozzle outlet

$\rho \rightarrow$ density of working fluid

$\dot{m}_{in} \rightarrow$ Mass flow rate at nozzle inlet

$\dot{m}_{out} \rightarrow$ Mass flow rate at nozzle outlet.

$\dot{m}_{suc} \rightarrow \dot{m}_{out} - \dot{m}_{in}$

TABLE:1

Flow Rate= 60 lpm
Nozzle Exit Velocity=12.56 m/s
Air Density=1.225 kg/m^3

Sensor Location	Velocity,v(m/s)	Radial Distance,r(m)	r*v(m^2/s)	0.5*Sum of Parallel Sides(k)	Area of Trapezium(k*0.008)
1	1.13	0	0	0.00376	0.00003008
2	0.94	0.008	0.00752	0.00992	0.00007936
3	0.77	0.016	0.01232	0.01396	0.00011168
4	0.65	0.024	0.0156	0.0166	0.0001328
5	0.55	0.032	0.0176	0.0188	0.0001504
6	0.5	0.04	0.02	0.02272	0.00018176
7	0.53	0.048	0.02544	0.02672	0.00021376
8	0.5	0.056	0.028	0.02872	0.00022976
9	0.46	0.064	0.02944	0.02944	0.00023552
				Sum of Areas (∫(r*v)dr)	0.00136512
q_out(2π ∫(r*v)dr)	m_out(kg/s)	area_nozzle(m^2)	m_in(kg/s)	m_suc(kg/s)	m_suc/m_in
0.008578414	0.010508557	0.000122734	0.001888391	0.008620166	4.564820382

TABLE:2

Flow Rate= 80 lpm
Nozzle Exit Velocity=16.70 m/s
Air Density=1.225 kg/m^3

Sensor Location	Velocity,v(m/s)	Radial Distance,r(m)	r*v(m^2/s)	0.5*Sum of Parallel Sides(k)	Area of Trapezium(k*.008)
1	1.35	0	0	0.005	0.00004
2	1.25	0.008	0.01	0.0142	0.0001136
3	1.15	0.016	0.0184	0.02048	0.00016384
4	0.94	0.024	0.02256	0.02536	0.00020288
5	0.88	0.032	0.02816	0.02928	0.00023424
6	0.76	0.04	0.0304	0.03272	0.00026176
7	0.73	0.048	0.03504	0.03656	0.00029248
8	0.68	0.056	0.03808	0.04624	0.00036992
9	0.85	0.064	0.0544	0.0544	0.0004352
				Sum of Areas (∫(r*v)dr)	0.00211392
q_out(2π ∫(r*v)dr)	m_out(kg/s)	area_nozzle(m^2)	m_in(kg/s)	m_suc(kg/s)	m_suc/m_in
0.013283873	0.016272745	0.000122734	0.002510838	0.013761906	5.48100024

⊙ Observations and Calculations:

TABLE:3

Flow Rate= 100 lpm
Nozzle Exit Velocity=22.7 m/s
Air Density=1.225 kg/m^3

Sensor Location	Velocity,v(m/s)	Radial Distance,r(m)	r*v(m^2/s)	0.5*Sum of Parallel Sides(k)	Area of Trapezium(k*.008)
1	1.72	0	0	0.0062	0.0000496
2	1.55	0.008	0.0124	0.01596	0.00012768
3	1.22	0.016	0.01952	0.02428	0.00019424
4	1.21	0.024	0.02904	0.03324	0.00026592
5	1.17	0.032	0.03744	0.04072	0.00032576
6	1.1	0.04	0.044	0.0424	0.0003392
7	0.85	0.048	0.0408	0.04364	0.00034912
8	0.83	0.056	0.04648	0.05236	0.00041888
9	0.91	0.064	0.05824	0.05824	0.00046592
				Sum of Areas (∫(r*v)dr)	0.00253632

q_out(2π ∫(r*v)dr)	m_out(kg/s)	area_nozzle(m^2)	m_in(kg/s)	m_suc(kg/s)	m_suc/m_in
0.015938235	0.019524338	0.000122734	0.003412936	0.016111402	4.72068652

TABLE : 4

m_in(kg/s)	m_suc(kg/s)	Entrainment Ratio
0.001888	0.008620166	4.56482
0.002511	0.013761906	5.481
0.003413	0.016111402	4.7207

Plot:

PLOT : ENTRAINMENT RATIO Vs MASS INPUT