

AE305 LAB-2 Round Turbulent Jet (Radial Traverse)



Fig. 1: Round Jet Apparatus

PRINCIPLE AND TASK

Engineers learning about aerodynamics and fluid mechanics need to understand how fluid behaves as it emerges from different apertures or holes. They can then use this knowledge to predict the behaviour of air and fluids when passing through or around the parts of their own designs.

The apparatus explains the difference between a 'submerged' and 'free' jet and how the submerged turbulent jet of air mixes with the surrounding air.

AIMS

To produce charts of velocity distribution along the vertical centreline and radial axis of the jet.

To use experiment results to determine the length of the centreline of the jet core at a given velocity, both as a defined length and as a ratio of its distance to jet radius.

SETUP AND PROCEDURE

1. Connect the pressure tapplings from the Air Box and Pitot probe as shown in Fig. 2.

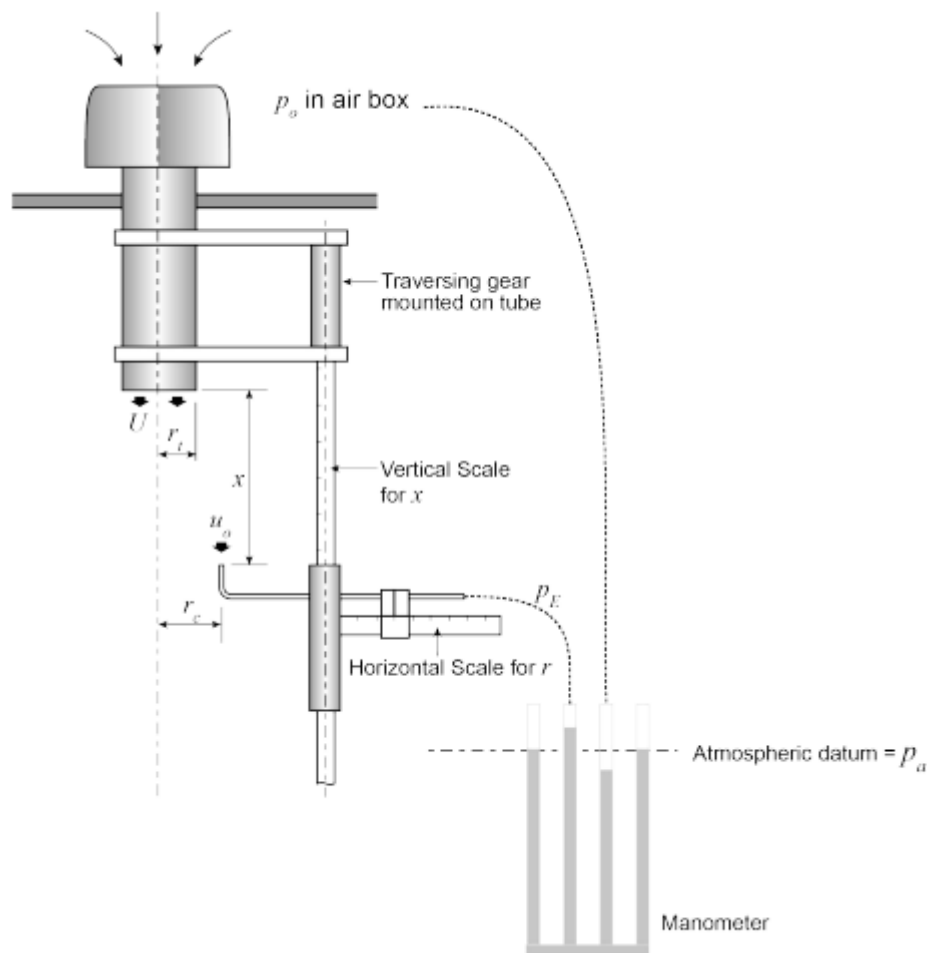


Fig. 2: Arrangement of the apparatus.

- Proceed exactly as experiment 1 but using three fixed vertical positions as shown in the table, traverse the probe radially outwards from the centreline.

NOTE



This experiment assumes that the radial pressure profile is identical each side of centreline, so it is only necessary to do one side.

Note that as the jet becomes wider (large values of x), then it is not necessary to record pressure at every radial position.

The table recommends a maximum distance x of 300 mm for radial traverses because the results start to become very similar as this distance is exceeded.

- Move the Pitot assembly around to repeat the radial traverse at roughly 90, 180 and 270 degrees to the original position, to confirm that the jet gives a uniform radial velocity profile.

DATA SHEET

r_c	$x = 75 \text{ mm}$				$x = 150 \text{ mm}$				$x = 300 \text{ mm}$			
mm	p_E		u	u/u_o	p_E		u	u/u_o	p_E		u	u/u_o
	mmH ₂ O	N.m ⁻²	m.s ⁻¹		mmH ₂ O	N.m ⁻²	m.s ⁻¹		mmH ₂ O	N.m ⁻²	m.s ⁻¹	
0				1.00				1.00				1.00
5												
10												
15												
17.5												
20												
22.5												
25												
27.5												
30												
32.5												
35												
40												
45												
50												
55												
60												
65												
70												
75												
80												
85												
90												
	u_o at $r_c = 0 \text{ mm}$:				u_o at $r_c = 0 \text{ mm}$:				u_o at $r_c = 0 \text{ mm}$:			
	$x/r_t =$				$x/r_t =$				$x/r_t =$			

RESULTS ANALYSIS

- For each radial position, use the local pressure with the density calculated earlier to calculate the local velocity u .
- Where u_o is the velocity where $r_c = 0$, calculate u/u_o for each radial position, which should start at 1 for $r_c = 0$.
- Create three charts - one for each distance x . On each chart plot u/u_o (vertical axis) against distance r_c .
- Compare the shape of the radial profiles with those shown in (Figure 3) in the theory.
- From the internal radius of the tube (r_t) calculate the value x/r_t for each of the three centreline positions (75 mm, 150 mm and 300 mm).

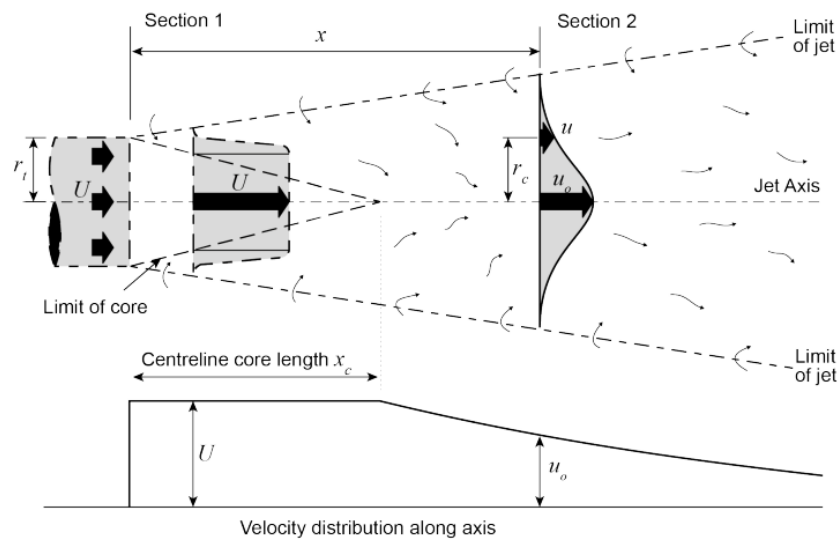


Fig. 3: Round turbulent jet.

APPENDIX

Theory

Notation

Symbol	Term	Units
D	Diameter of tube	m
ν	Kinematic viscosity of air	$\text{m}^2 \cdot \text{s}^{-1}$
p, p_a, p_o and p_E	Pressure, ambient pressure, pressure in the Air Box and exit (jet) pressure	Pa or $\text{N} \cdot \text{m}^{-2}$
r_c	Radial position with respect to centreline	m
r_t	Radius of tube	m
R	Gas Constant	$287 \text{ J} \cdot \text{kg}^{-1} \cdot \text{K}$ for air
T and T_a	Temperature and ambient temperature	K or $^{\circ}\text{C}$ where shown
U, u and u_o	Air velocity	$\text{m} \cdot \text{s}^{-1}$
x	Vertical position with respect to tube exit	m
ρ	Density	$\text{kg} \cdot \text{m}^{-3}$
μ	Dynamic viscosity of air (at 20°C)	$1.82 \times 10^{-5} \text{ Pas}$

Table 1 Notation

Velocity Distribution

Consider the jet of (Figure 5). If we assume that Reynolds number has no effect on flow pattern, then we can expect the velocity on the jet axis to depend on position in the dimensionless form:

$$\frac{u_o}{U} = f\left(\frac{x}{r_t}\right)$$

In the core of the jet:

$$\frac{u_o}{U} = 1$$

Far downstream, the core of the jet has dissipated and the centreline velocity should be expected to decay inversely to distance x , so:

$$\frac{u_o}{U} = \frac{c}{x}$$

Where c is a constant.

The velocity u at any position (r, x) in the jet may also be written in the dimensionless form:

$$\frac{u}{u_o} = g\left(\frac{x}{r_t}, \frac{r_c}{x}\right)$$

Consider now the velocity distribution over a section far downstream, ie where x/r_t is large. We might reasonably expect that the velocity distribution across the section would not depend appreciably on the precise detail of the flow near the tube exit, so we might ignore the dependence upon x/r_t and simply write that, far downstream:

$$\frac{u}{u_o} = g\left(\frac{r_c}{x}\right) \quad (2)$$

Velocity profiles of this type, in which the velocity ratio depends on a parameter, are frequently called 'similar', in the sense that a single expression is used to characterise the velocity distribution at any number of chosen sections. Using certain assumptions about the nature of the turbulent processes, it is possible to show that Equation 2 should take the form:

$$\frac{u}{u_o} = \frac{1}{\left\{ 1 + 0.25 \left(\frac{\lambda r_c}{x} \right)^2 \right\}^2} \quad (3)$$

where λ is a constant to be found during experiment.

Values of u/u_o computed from this expression are presented in (Table 2). The value $\lambda r_c/x = 1.287$ is included, as this makes $u/u_o = 0.5$. When comparing with experimental results it is useful to have this value, since the radius at which $u/u_o = 0.5$ is easily identified on the velocity profile.

u/u_o	1.000	0.980	0.925	0.842	0.743	0.640	0.500	0.405	0.307	0.205	0.109	0.052	0.019	0.004	0.000
$\lambda r_c/x$	0	0.20	0.40	0.60	0.80	1.00	1.287	1.40	1.60	1.80	2.00	2.25	2.50	3.00	4.00

Table 2 Calculated Velocity Profile of Round Jet