# Air Jet Laboratory Report

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Word Count:2070

**Abstract**

This report highlights the velocity distribution of a circular air jet at several stations along the length to reveal how a uniform jet interacts with its surroundings. The experience is conducted thanks to a pitot-static probe linked to a manometer. The local velocity was measured, and the height of the fluid moving along an inclined manometer allows us to have the velocity values at different position of the pitot-static tube positioned either in an x or y-axis. The volumetric flow rate is computed by increasing the downstream of the jet. We can conclude that the experimental and theoretical results put forward that when h decreases, the local velocity decreases as well.

# Contents



# Nomenclature

| | | |
|---|---|---|
| $\dot{Q}$ | Altitude | m |
| $\rho$ | Fluid Density | Kg.m$^{-3}$ |
| $g$ | Gravitational constant | 9.81m.s$^{-2}$ |
| $p$ | Pressure | Pa |
| $v$ | Velocity | m.s$^{-1}$ |
| $z$ | Altitude | m |

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REVOIR LA VIDEO ET VOIR SI ON A TOUT

# 1 Introduction

Flow measurements in aviation or racing cars as F1 are essential for the sake of improving and checking certain aerodynamic conditions of the engine [4]. It is most often used in aviation to determine an aircraft's airspeed, Mach number, altitude, and altitude trend [10].

In our experiment, we are using a pitot-static tube also called Prandtl tubes [3] which measures air and liquid flow in ducts, pipes and weirs. It is not expensive, exceptionally reliable and suits a wide range of conditions in temperature and pressure. The airflow is emitted by an air jet which is a nozzle with a pressurised jet of air directed in a particular direction. A manometer is also used to hold a liquid and measure the pressure of liquids or gases [6].

This experiment explores the interaction of a free air jet with its surroundings. The goal is to make velocity and flow rate measurements using the tools described above and look at the structure of a free jet and its interactions with the surroundings.


Figure 1: Real life applications for the pitot probe

# 2 Theory

Before moving to the result section, the theory is critical to master as the experiment directly links with the theory.

In this laboratory, we are using a pitot-static tube (Figure 1) which measures two pressures, $p_0$ and p, the TOTAL and STATIC pressures, respectively as well as the pressure transducer which measures the difference in total and static pressure by estimating the strain in a thin element using an electronic strain gauge [3].

## 2.1 Bernoulli's equation

The figure below shows streamlines from the same source (in blue), representing the airflow and a manometer where water line inside it.

To understand the physics behind the pitot-static tube and the computation of velocity, Bernoulli's equation is essential to master. It states that the sum of the pressure, the kinetic and potential energy will remain constant; i.e.:

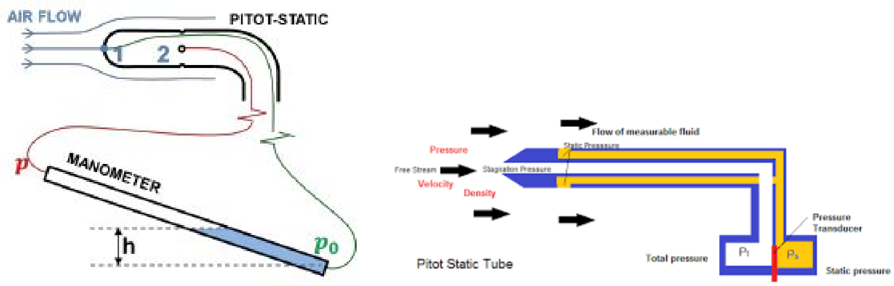


Figure 2: Pitot-static tube [8]

$$p + \frac{1}{2}V^2\rho + gh\rho = constant \tag{1}$$

In Bernoulli's equation, the assumptions are the following:

The total pressure will remain constant, the flow is steady, the fluid is incomparable, the density does not change, fluid is inviscid, and the flow is friction-less but, if it is mixing, it is due to turbulence. [7]. As you can see in Figure 1, we need to use the equation below across point 1 and 2:

$$p_1 + \frac{1}{2}V_1^2\rho + gh_1\rho = p_2 + \frac{1}{2}V_2^2\rho + gh_2\rho \tag{2}$$

Thanks to the assumptions made before, we can therefore put forward that $p_1$ is equal to the total pressure $p_0$ and it is also situated at the stagnation point; by definition, $V_1 = 0$ m/s. Furthermore, the variation in height is negligible for the sake of the experiment. We can re-arrange Bernoulli's equation as follow:

$$(p_0 - p) = \frac{1}{2}V_2^2\rho_{air} \tag{3}$$

Equation 2 demonstrates p, which is the pressure at point 2 of the diagram in figure 1. It is equivalent to static air pressure. The velocity $V_2$ represents an undisturbed air streamline.

In this experiment, we will have to re-arrange Bernoulli's equation as the variation in height matters, and as a consequence, we can neglect the velocity values. If this pressure difference is applied to a manometer to produce a vertical level change of h meters, equilibrium is established when[2]:

$$(p_0 - p) = gh\rho_{water} \tag{4}$$

As the manometer is not perpendicular to the surface, it creates an angle $\alpha$. The water travels along the edge of the manometer, and it is represented by the distance $h_r$, which allow us to calculate the value of h:

$$h = h_r \sin\alpha \tag{5}$$

We can show by integrating equations 3 and 4, that if h is measured in millimeters and $\rho_{air} = 1.225\ kgm^{-3}$ and $\rho_{water} = 1000\ kgm^{-3}$:

$$
\begin{aligned}
gh\rho_{water} &= \frac{1}{2}V^2\rho_{air} \\
V &= (\frac{2gh\rho_{water}}{\rho_{air}})^{0.5}
\end{aligned}
\tag{6}
$$

$$
V = 4.00\sqrt{h} \tag{7}
$$

## 2.2 Flow rate

The flow rate leaving the nozzle of a circular air jet, $Q_0$ can be considered equal to exit velocity, $v_0$ , multiplied by nozzle surface area, A [1]. The following equations highlight the flow rate where the area is $r^2\pi$:

$$
Q = vA \tag{8}
$$

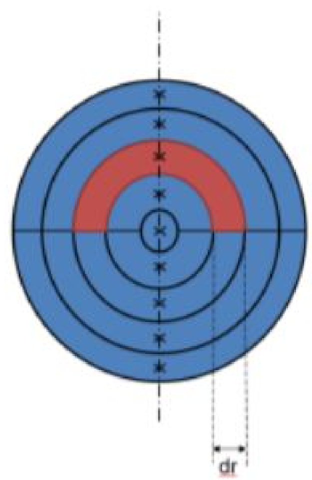


Figure 3: Jet profile with divided annulus

The next one relies on equation 8 to compute the volumetric flow rate for the discs by integrating the velocity as it can not be considered constant at all vertical points of the nozzle exit, the radial position and dR, which is the length of the annulus:

$$
\begin{aligned}
\dot{Q} &= \int_0^R v_r 2r\pi \, dr \\
\dot{Q} &= \frac{v_r 2R^2\pi}{2}
\end{aligned}
\tag{9}
$$

In the same way, we can find the volumetric flow rate with a summation formula for an annulus by multiplying the velocity, the radial position and the change in radius $\Delta_r$:

$$\dot{Q} = \sum_{n=1}^{N} v_n r_n \Delta r \tag{10}$$

# 3 Methodology

## 3.1 Image and description of the setup

In this section, pictures of the experiment are shown with a description of each component used as well as their specifications[1].

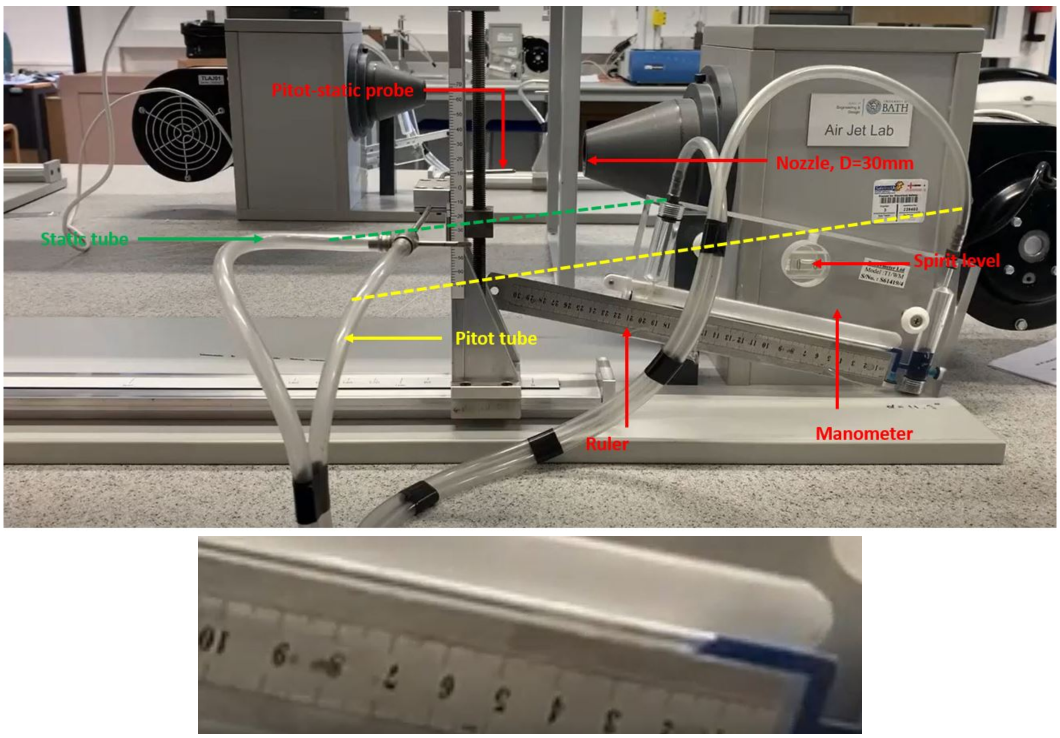


Figure 4: Experiment apparatus

Figure 3 shows the experiment apparatus where you can find:

- A fan supplies air inside the nozzle.
- Nozzle diameter of 30mm, which creates a perfect jet of air.
- Pitot-static probe: flow measurement device used to measure fluid flow velocity. It measures the air jet coming at the nozzle's exit the difference between the total and static pressure.[5]

[1]Due to the current pandemic, the images provided come from the video and the PowerPoint.

- An inclined manometer which contains water that will move regarding the pressure applied around the Pitot-static tube.
- A ruler to measure the displacement $h_r$ of the water along the edge.
- A zero to track down the starting point of the measurements.
- The static tube is connected to the top of the manometer and the pitot tube to its bottom.

### 3.2 Description of the experience

To complete this experiment and get future data, we need to follow a set of instructions. As soon as the air jet is turned on, we can start the experiment.

Firstly, the height $h_r$ is measured by the ruler and recorded when the pitot-static tube moves along the x-axis at coordinates (0,0) of the middle of the nozzle. The pitot-static tube moves along a predefined series of distance from 0 to 500mm.

Secondly, the height $h_r$ is measured by the ruler and recorded each step when the pitot-static tube is at:

- 60mm from the nozzle and moves along the y-axis from -28mm to 28mm with an increment of 4mm.
- 180mm from the nozzle and moves along the y-axis from -50mm to 50mm with an increment of 5mm.
- 300mm from the nozzle and moves along the y-axis from -60mm to 60mm with an increment of 5mm.

## 4 Results

### 4.1 Results of the measurements

In this section, tables show the recorded values and the value of h and the centerline velocity computed thanks to equations 5 and 7. The value of $\alpha = 11.3$ degrees $= 0.917$ rad and r is the radial distance from the centerline.

| Axial Distance, x (mm) | 0 | 40 | 80 | 120 | 160 | 200 | 300 | 400 | 500 |
|---|---|---|---|---|---|---|---|---|---|
| Manometer Reading, hr (mm) | 90 | 90 | 90 | 83 | 74 | 61 | 32 | 18 | 12 |
| Value of h (mm) | 17.6352 | 17.635 | 17.6352 | 16.2635 | 14.5 | 11.9527 | 6.27028 | 3.52703 | 2.35135 |
| Velocity, v (m/s) | 16.7977 | 16.798 | 16.7977 | 16.1312 | 15.2316 | 13.8291 | 10.0162 | 7.51216 | 6.13365 |

Figure 5: Data centerline velocity

| X=2D (60mm) | | | |
|---|---|---|---|
| r (mm) | hr (mm) | h (mm) | v (m/s) |
| -28 | 0 | 0 | 0 |
| -24 | 0 | 0 | 0 |
| -20 | 8 | 1.56757 | 5.0081 |
| -16 | 31 | 6.07433 | 9.85846 |
| -12 | 66 | 12.9324 | 14.3847 |
| -8 | 86 | 16.8514 | 16.4202 |
| -4 | 90 | 17.6352 | 16.7977 |
| 0 | 90 | 17.6352 | 16.7977 |
| 4 | 90 | 17.6352 | 16.7977 |
| 8 | 90 | 17.6352 | 16.7977 |
| 12 | 75 | 14.696 | 15.3341 |
| 16 | 36 | 7.05406 | 10.6238 |
| 20 | 8 | 1.56757 | 5.0081 |
| 24 | 0 | 0 | 0 |
| 28 | 0 | 0 | 0 |

| X=6D (180mm) | | | |
|---|---|---|---|
| r (mm) | hr (mm) | h (mm) | v (m/s) |
| -50 | 0 | 0 | 0 |
| -45 | 0 | 0 | 0 |
| -40 | 0 | 0 | 0 |
| -35 | 1 | 0.195946 | 1.770632 |
| -30 | 4 | 0.783785 | 3.541264 |
| -25 | 8 | 1.567569 | 5.008104 |
| -20 | 17 | 3.331084 | 7.300503 |
| -15 | 30 | 5.878384 | 9.698152 |
| -10 | 46 | 9.013523 | 12.00901 |
| -5 | 58 | 11.36488 | 13.48473 |
| 0 | 67 | 13.12839 | 14.49325 |
| 5 | 64 | 12.54055 | 14.16506 |
| 10 | 48 | 9.405415 | 12.2673 |
| 15 | 32 | 6.270277 | 10.01621 |
| 20 | 19 | 3.722977 | 7.718007 |
| 25 | 9 | 1.763515 | 5.311897 |
| 30 | 4 | 0.783785 | 3.541264 |
| 35 | 1 | 0.195946 | 1.770632 |
| 40 | 0 | 0 | 0 |
| 45 | 0 | 0 | 0 |
| 50 | 0 | 0 | 0 |

| X=10D (300mm) | | | |
|---|---|---|---|
| r (mm) | hr (mm) | h (mm) | v (m/s) |
| -60 | 0 | 0 | 0 |
| -55 | 0 | 0 | 0 |
| -50 | 0 | 0 | 0 |
| -45 | 1 | 0.195946 | 1.770632 |
| -40 | 3 | 0.587838 | 3.066825 |
| -35 | 5 | 0.979731 | 3.959254 |
| -30 | 7 | 1.371623 | 4.684652 |
| -25 | 10 | 1.959461 | 5.599231 |
| -20 | 14 | 2.743246 | 6.625099 |
| -15 | 20 | 3.918923 | 7.918508 |
| -10 | 25 | 4.898654 | 8.853161 |
| -5 | 30 | 5.878384 | 9.698152 |
| 0 | 31 | 6.07433 | 9.858463 |
| 5 | 29 | 5.682438 | 9.535146 |
| 10 | 26 | 5.0946 | 9.028488 |
| 15 | 21 | 4.114869 | 8.114056 |
| 20 | 16 | 3.135138 | 7.082529 |
| 25 | 11 | 2.155408 | 5.872523 |
| 30 | 7 | 1.371623 | 4.684652 |
| 35 | 5 | 0.979731 | 3.959254 |
| 40 | 3 | 0.587838 | 3.066825 |
| 45 | 1 | 0.195946 | 1.770632 |
| 50 | 0 | 0 | 0 |
| 55 | 0 | 0 | 0 |
| 60 | 0 | 0 | 0 |

Figure 6: Data radial velocity at a distance of 2D, 6D, 10D

Tables in figure 5 and 6 were used to plot the MATLAB graphs (see appendix for the scripts).

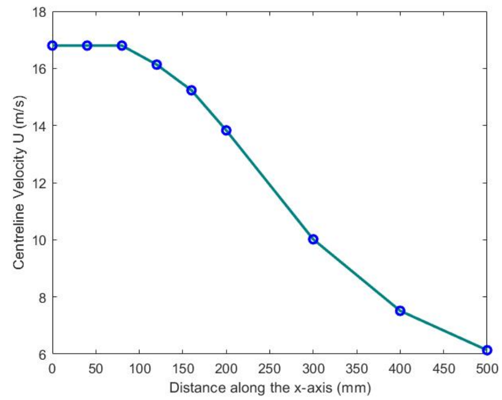


Figure 7: Centerline velocity along the x-axis

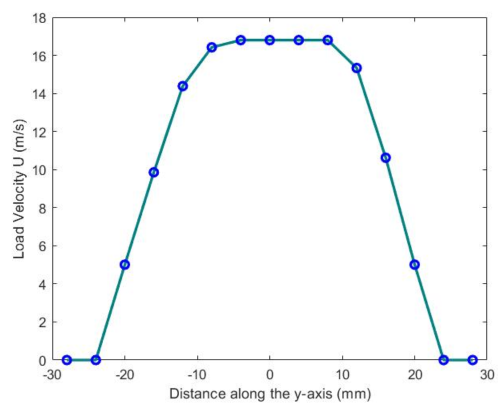


Figure 8: Load radial velocity 2D

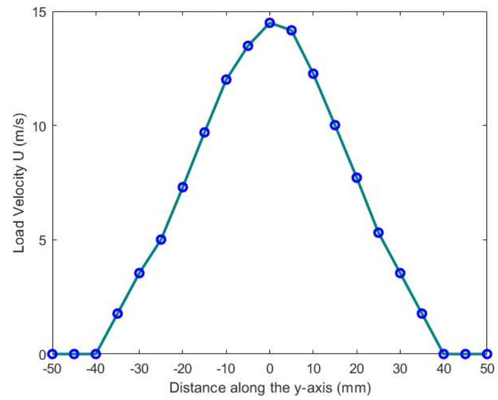


Figure 9: Load radial velocity 6D

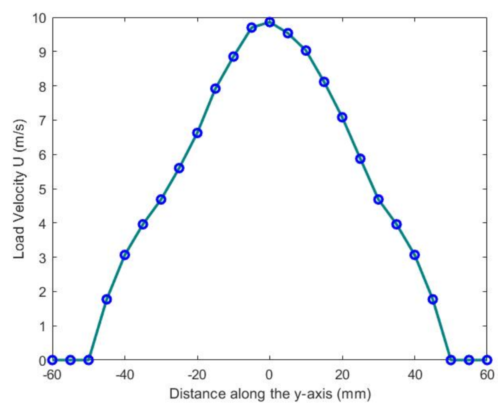


Figure 10: Load radial velocity 10D

The last plot was combined on the same graph where the edge is the straight blue line; the core is the red triangle where V = $V_0$ and the mixing region is between the green and red curve where V ¡ $V_0$. The divergence angle was calculated thanks to a program written on Matlab that i invite you to check in the appendix. The program computed a divergence angle of 6.65 degrees, representing the angle at the intersection of the edge and x -50/50.

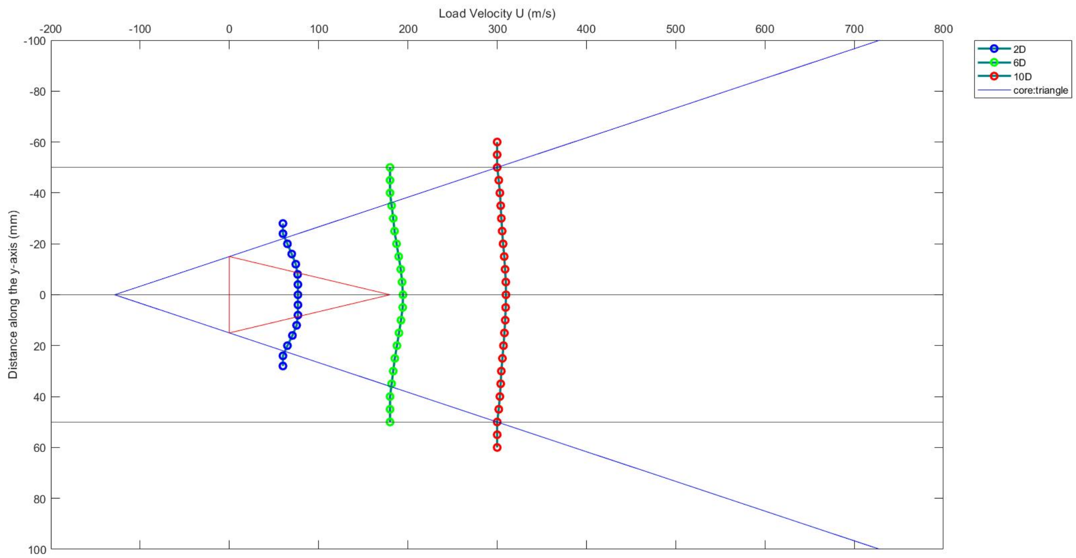


Figure 11: Plan view for jet velocity profiles

Figure 12 shows the plot of the flow rate at remaining downstream planes as function of x/D.

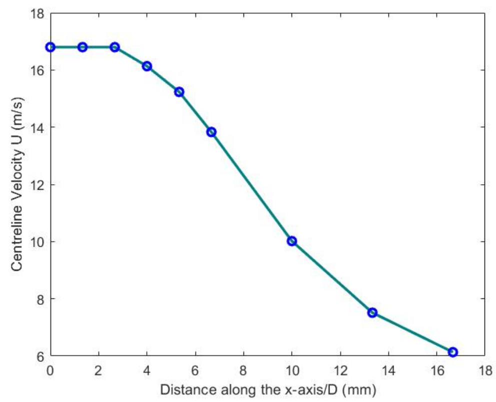


Figure 12: Centerline velocity distribution

Using equation 9, we can calculate different volumetric flow rates:

$$Q_0 = pi * (0.5D)^2 * v_0 = 0.0119 m^3/s \tag{11}$$

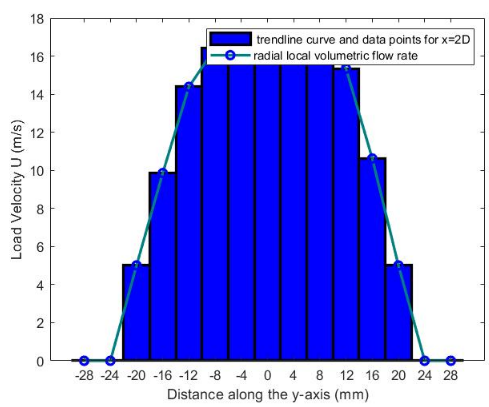


Figure 13: Radial local volumetric flow rate

| Total Area for | Area mass flow rare in m^3/s |
|---|---|
| 0D | 0.0119 |
| 2D | 0.0164 |
| 6D | 0.0249 |
| 10D | 0.322 |

Figure 14: Volumetric flow rate at different instances (data)

The table above allow us to build the graph that you can see below.

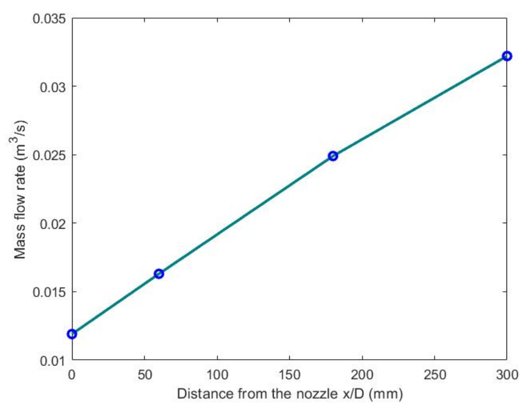


Figure 15: trendline of volumetric flow rate downstream of the air jet

# 5 Analysis

## 5.1 The air jet

This lab allows us to study the importance of three regions that describes the main characteristics of the air jet: the edge, the core and the mixing region; all these regions are illustrated in **figure 11**.

The edge of the jet constantly increases as soon as the air leaves the jet. Thanks to our calculation of the divergence angle, we found that these lines increase with a rate of 6.65degrees of the centerline. In real-life applications, the divergence angle is independent of nozzle diameter.

The core shows us that the velocity v = $v_0$ and therefore, the velocity remains more or less constant up to 120-180mm along the centerline as shown on **figure 7 and 12**.

The mixing region is represented by the fact that v¡$v_0$. In other words, the local velocity is less than the rate at the exit of the nozzle due to the surrounding ambient air; this phenomenon is applied after the green graph as shown on **figure 11**.

To finish, **figure 7 to 10** illustrates the radial load velocity where high velocity is encountered at the centerline and slightly decreases when moving the pitot-static tube in the y-direction.

## 5.2 Air distribution along the centreline

The air distribution velocity along the centerline remains constant with a slight change in the velocity value with an absence of external forces acting. As soon as we left the core zone, the surroundings affect the velocity and the density impacted by the ambient fluid. The resultant of this is traduced by a drop of the velocity and significant velocity fluctuations at the jet's edge.

## 5.3 Radial volume distribution: volume flow rate

The graph highlighted on **figure 15**, demonstrates the volumetric flow rate downstream of the air jet that gradually increases from 0.0119 meter cube per sec to 0.332 on an axial distance of 300mm. Concerning **figure 13**, we can see that the area goes up when the velocity is high, representing the conservation of momentum. Moving downstream in the y-direction, we can conclude, thanks to our results, that the volumetric flow rate that the area of a disc is proportional to the disc's squared radius. That is why you can see the $x^2$ shape of the graphs previously. The area increases faster than the velocity.

As the jet goes downstream, the flow will mix with the stationary air in the lab. Once you get far enough downstream, you won't be able to feel the jet at all. By plotting the centreline velocity and the velocity distribution, we can see how the jet spreads out and slows down as it goes downstream.

## 5.4 Errors and variability

This lab demonstrated the characteristics of an air jet, as discussed in the previous subsection. However, there is a wide range of errors and uncertainties that can affect our results. In this part, we will discuss the potential source of errors that can happen in this lab and real-life applications.

The error can come from the pitot-static tube involving the malfunctioning of the instrument, the surroundings that can affect it and limitations affecting it:

Regarding the velocity, if it low, the pressure difference is small and hard to measure, and therefore it does not very work well for low velocities applications. On the other hand, if the velocity is high (supersonic), Bernoulli's equation does not work as our assumptions are biased, and a shock wave will change the total pressure around the pitot-static tube[3]. Simultaneously, in actual life application, the pitot tube can be blocked, affecting airspeed indicators. Several factors may occur as ice, water or insects (ice which was the main reason why the flight Paris-Rio in 2009 involved the altimeter that froze at a constant altitude). To prevent icing, pitot tube is armed with a heating element that minimises the risks. Inherent errors affect instruments. Density errors affect the airspeed and altitude mechanisms as the pressure and temperature variations in the atmosphere and compress the tube.

Regarding the experiment, human error is the most common source of inaccuracy in this experiment. The ruler used to measure the distance of the fluid and the manometer, the approximation of the zero position, the location of the centerline position, and radial.

Finally, the manometer can have some bubbles in its fluid, affecting the distance measured and changing all the parameters of the equations used to plot graphs [9].

# 6 Conclusion

To conclude, the air jet study allows us to see the interaction of free air coming from the air jet and the effects occurring on the pitot-static tube when moving along the centerline and mixing region.

We identified three central regions: the core, the mixing region and the edge. The core shows that the pressure and velocity are the highest. In the mixing area, the pressure and the velocity decrease as the pitot tube moves further from the nozzle. The edge

We also found out the different sources of errors that will make our experiment less accurate than the theoretical application of the problems. However, they are small enough to highlight a certain amount of precision to outline the air jet streamlines' trend and the behaviour of the air in the surroundings.

We will need to operate this lab on a computational fluid dynamics (CFD) system to understand the problem better for further applications.

# A Appendix

**- Radial Local Volumetric flow 2D**:

[Module: ME10019
Lecturer: Doctor Anna Young
Author: Alexandre BENOIT
This code will run a plot showing the local radial velumetric flow at a distance of x = 2D (60mm).]

q = [-28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28];
w = [0 0 5.008104079 9.858462737 14.38468381 16.42016731 16.79769174 16.79769174 16.79769174 16.79769174 15.33412446 10.62379306 5.008104079 0 0];

[ha1 is the first halh annulus and ha2 is the second half annulus. equation ... in the report allows us to calculate the mass flow rate of half annulus]
wha1 = w(1:8);
dR = 0.005;
Rha1 = [-28:4:0];
dQha1 = pi * Rha1 * wha1 * dR;
Qha1 = sum(dQha1);

wha2 = w(8:end);
Rha2 = [-28:4:0];
dQha2 = pi * Rha2 * wha2 * dR;
Qha2 = sum(dQha2);

[equation ... in the report allows us to calculate the mass flow rate of the central disc]

w1 = max(w);
r = 0.0025;
Qcdisc = w1 * pi * ($r^2$);

Q2D = Qha1 +Qha2 + Qcdisc;

b= plot(q,w,'g');

camroll(-90)

b.LineWidth = 2;
b.Color = [0 0.5 0.5];
b.Marker = 'o';
b.MarkerEdgeColor = 'b';

xlabel('Distance along the y-axis (mm)')
ylabel('Load Velocity U (m/s)')

**- Q calculation 2/6/10D**:

[Module: ME10019
Lecturer: Doctor Anna Young
Author: Alexandre BENOIT]

[mass flow rate of 2Q
ha1 is the first halh annulus and ha2 is the second half annulus.
equation ... in the report allows us to calculate the mass flow rate of half annulus.]

wha1 = w(1:8);
dR = 0.004;
Rha1 = [28 24 20 16 12 8 4 0]*10$^-$3;
dQha1 = pi .* dR .* Rha1 .* wha1;
Qha1 = sum(dQha1);

wha2 = w(8:end);
Rha2 = [0:4:28]*10$^-$3;
dQha2 = pi .* Rha2 .* wha2 .* dR;
Qha2 = sum(dQha2);

[equation ... in the report allows us to calculate the mass flow rate of the central disc]

Vr = max(w);
r = 2*10$^-$3;
Qcdisc = Vr .* pi .* ($r^2$);

Q2D = Qha1 + Qha2 + Qcdisc;

disp(Q2D)

[Module: ME10019
Lecturer: Doctor Anna Young
Author: Alexandre BENOIT]

[mass flow rate of 2Q
ha1 is the first halh annulus and ha2 is the second half annulus.
equation ... in the report allows us to calculate the mass flow rate of half annulus.]

wha1 = w(1:11);
dR = 0.005;
Rha1 = [50 45 40 35 30 25 20 15 10 5 0]*10$^-$3;
dQha1 = pi .* dR .* Rha1 .* wha1;
Qha1 = sum(dQha1);

wha2 = w(11:end)

Rha2 = [0:5:50]*$10^{-}3$;
dQha2 = pi .* Rha2 .* wha2 .* dR;
Qha2 = sum(dQha2);

[equation ... in the report allows us to calculate the mass flow rate of the central disc]

Vr = max(w);
r = 2*$10^{-}3$;
Qcdisc = Vr .* pi .* ($r^2$);

Q2D = Qha1 + Qha2 + Qcdisc;

disp(Q2D)

[Module: ME10019
Lecturer: Doctor Anna Young
Author: Alexandre BENOIT]

[mass flow rate of 2Q
ha1 is the first halh annulus and ha2 is the second half annulus.
equation ... in the report allows us to calculate the mass flow rate of half annulus.]

wha1 = w(1:13);
dR = 0.005;
Rha1 = [60 55 50 45 40 35 30 25 20 15 10 5 0]*$10^{-}3$;
dQha1 = pi .* dR .* Rha1 .* wha1;
Qha1 = sum(dQha1);

wha2 = w(13:end)
Rha2 = [0:5:60]*$10^{-}3$;
dQha2 = pi .* Rha2 .* wha2 .* dR;
Qha2 = sum(dQha2);

[equation ... in the report allows us to calculate the mass flow rate of the central disc]

Vr = max(w);
r = 2*$10^{-}3$;
Qcdisc = Vr .* pi .* ($r^2$);

Q2D = Qha1 + Qha2 + Qcdisc;

disp(Q2D)

**- centerline velocity distribution**:

[Module: ME10019

Lecturer: Doctor Anna Young
Author: Alexandre BENOIT
This code will run a plot showing the centerline velocity distribution as a function of the disance x divided by the diameter of the nozel D (30mm).

x = [0 40 80 120 160 200 300 400 500]./ 30;
y = [16.79769174 16.79769174 16.79769174 16.13122685 15.23155392 13.82907939 10.01620816 7.512156118 6.133649786];

a = plot(x,y,'g');
a.LineWidth = 2;
a.Color = [0 0.5 0.5];
a.Marker = 'o';
a.MarkerEdgeColor = 'b';

xlabel('Distance along the x-axis/D (mm)')
ylabel('Centerline Velocity U (m/s)')

**- centerline velocity**:

[Module: ME10019
Lecturer: Doctor Anna Young
Author: Alexandre BENOIT
This code will run a plot showing the centerline velocity in function of the disance x from the nozel exit.

x = [0 40 80 120 160 200 300 400 500];
y = [16.79769174 16.79769174 16.79769174 16.13122685 15.23155392 13.82907939 10.01620816 7.512156118 6.133649786];

a = plot(x,y,'g');
a.LineWidth = 2;
a.Color = [0 0.5 0.5];
a.Marker = 'o';
a.MarkerEdgeColor = 'b';

xlabel('Distance along the x-axis (mm)')
ylabel('Centerline Velocity U (m/s)')

**- load radial velocity 2/6/10D**:

[Module: ME10019
Lecturer: Doctor Anna Young
Author: Alexandre BENOIT]

[allow us to re-run the code without manually writting 'clear all' every time.]

```
clear all

[load radial velocity 2D data to a simple variable.]
a = [-28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28];
b = 60+ [0 0 5.008104079 9.858462737 14.38468381 16.42016731 16.79769174 16.79769174 16.79769174
16.79769174 15.33412446 10.62379306 5.008104079 0 0];

[load radial velocity 6D data to a simple variable.]
c = [-50:5:50];
d = 180 + [0 0 0 1.770632177 3.541264355 5.008104079 7.300503492 9.698151846 12.00901171
13.48473292 14.493249 14.16505742 12.26729957 10.01620816 7.718006728 5.311896532 3.541264355
1.770632177 0 0 0];

[load radial velocity 10D data to a simple variable.]
e = [-60:5:60];
f = 300 + [0 0 0 01.770632177 3.066824893 3.959253912 4.684652405 5.599230579 6.625098966
7.918507824 8.853160887 9.698151846 9.858462737 9.535146088 9.028488024 8.114055981 7.08252871
5.872522574 4.684652405 3.959253912 3.066824893 1.770632177 0 0 0];

figure(1)

[plot load radial velocity 2D data]
g = plot(a,b,’g’);
hold on

[plot load radial velocity 6D data]
h= plot(c,d,’g’);

[plot load radial velocity 10D data]
i= plot(e,f,’g’);

x = -100:0.1:0;
y = -(60/7)*x - 4500/35;

v = 0:0.1:100;
w = (60/7)*v - 4500/35;

plot(x,y,’b’)
plot(v,w,’b’)

hold off

camroll(-90)

xline(-50)
xline(0)
```

xline(50)

[A, B and C are three points that will allows us to get the the divergence angle where A and C are two points of the curve y.]

A = [-50 300];
B = [-50 400];
C = [-70 3300/7];

[calculation of the angle]

[vector form]
AB = [B(1)-A(1) B(2)-A(2)];
AC = [C(1)-A(1) C(2)-A(2)];

[norm form]
ABn = norm(AB);
ACn = norm(AC);

norm = ABn .* ACn;

[scalar product]
scalarABAC = dot(AB,AC);

theta = scalarABAC ./ norm;

[Display the angle between the horizontal plane and the edge of the jet is called the divergence angle.]

divergenceAngle = ['The divergence angle is: ', num2str(acosd(theta)), ' degrees'];
disp(divergenceAngle)

line([-15,15], [0, 0], 'Color', 'r');
hold on;
line([15,0], [0, 180], 'Color', 'r');
line([0,-15], [180, 0], 'Color', 'r');

g.LineWidth = 2;
g.Color = [0 0.5 0.5];
g.Marker = 'o';
g.MarkerEdgeColor = 'b';

h.LineWidth = 2;
h.Color = [0 0.5 0.5];
h.Marker = 'o';
h.MarkerEdgeColor = 'g';

i.LineWidth = 2;
i.Color = [0 0.5 0.5];
i.Marker = 'o';
i.MarkerEdgeColor = 'r';

xlabel('Distance along the y-axis (mm)')
ylabel('Load Velocity U (m/s)')
legend('2D','6D','10D','core:triangle')

**- trendline of volumetric flow rate downstream of the air jet**:

[Module: ME10019
Lecturer: Doctor Anna Young
Author: Alexandre BENOIT
This code will run a plot showing trendline of volumetric flow rate downstream of the air jet.]

p = [0 60 180 300];
s = [0.0119 0.0163 0.0249 0.0322];

d = plot(p,s,'g');

d.LineWidth = 2;
d.Color = [0 0.5 0.5];
d.Marker = 'o';
d.MarkerEdgeColor = 'b';

xlabel('Distance from the nozzle x/D (mm)')
ylabel('Mass flow rate ($m^3/s$)')

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