Institute for Aerospace Studies
UNIVERSITY OF TORONTO

AER303F
Aerospace Laboratory I

Supersonic Flow

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Fall 2017

1 Objectives

The teaching objectives of this laboratory are two folds:

- allow students to gain hands-on experience with a supersonic flow
- apply knowledge gained in this course on the gathering, analysis and reporting of experimental data to a real experiment

The practical objectives of the laboratory are to:

- measure the pressure distribution inside a supersonic tunnel and compare to theoretical predictions
- measure the Mach number and speed inside the tunnel with total and static pressure ports
- install and tune an optical measurement apparatus - a Schlieren system
- visualise the shock waves produce inside a supersonic wind tunnel using a Schlieren system

2 Preparation

The following questions need to be considered and answered before arriving at the laboratory. The answer are to be submitted to the lab instructor.

1. Given the specifications of the optical elements for the Schlieren system, is the distance between the following elements important and if so what should they be? (Give an answer for each pair of elements.)
   (a) light source and first mirror
   (b) first and second mirrors
   (c) second mirror and knife edge
2. Assuming the inlet pressure to the tunnel is atmospheric and that the flow is isentropic through the whole tunnel, what is the maximum exit pressure to the tunnel that will give sonic flow condition at the nozzle throat?

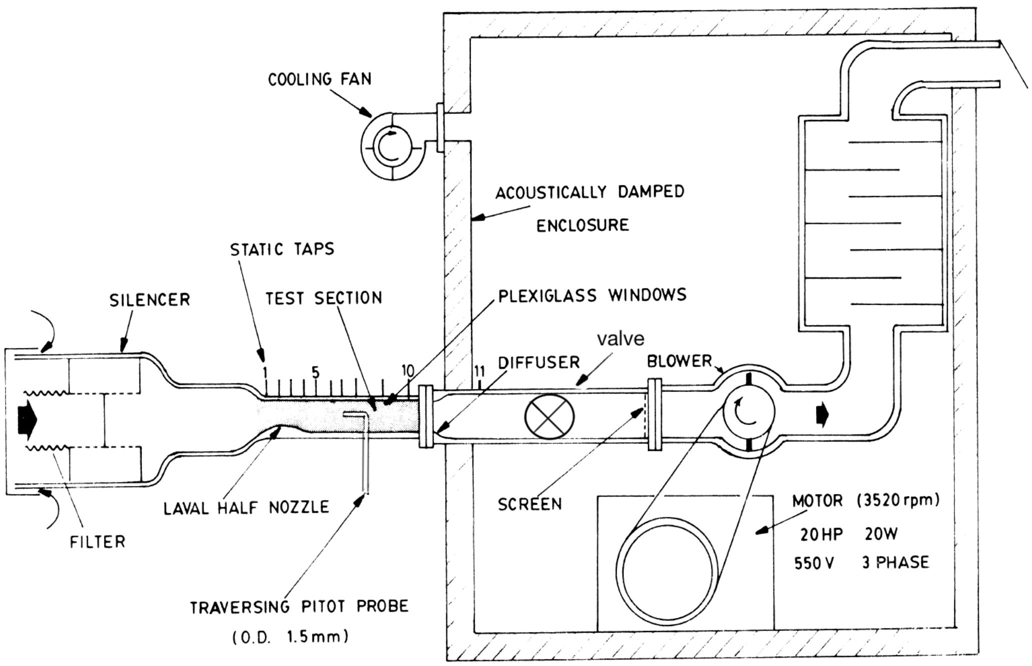

Figure 1: Sketch of the aerospace laboratory supersonic facility.

3 Apparatus

The experiment will be performed in a suction wind tunnel equipped with a de Laval half nozzle capable of accelerating the flow to approximately Mach 1.3. A sketch of the facility is provided in Figure 2. The section downstream of the nozzle is 25.4 mm wide by 21.82 mm high and approximately 110 mm long. The tunnel is powered by a 20 HP motor and a silencer and muffler are located at the inlet and outlet respectively to mitigate the noise from the apparatus. A manual valve between the working section and the pump can be used to change the speed of the tunnel.

A total of 11 static pressure taps are located at different locations along the de Laval nozzle and test section length. The floor of the test section is also slotted to allow a static (or impact) tube to be located at different locations in the tunnel. The pressure from these various pressure ports can be measured using 12 Honeywell pressure transducers (model 142PC15A) with a range of 0 psi to 15 psi. The signal from the pressure sensor can be sampled using a data acquisition board connected to a PC computer.

The locations of the static pressure tap and geometry of the nozzle are given in Table 1. The nozzle was designed to account for the viscous effects due to the presence of a boundary layer at the surface and assuming the top surface is the symmetric plane of a tunnel with twice the height

Table 1: Static pressure tap location

Tap number	x (mm)	y (mm)	h (mm)	A/A^*
	0.0	3.45	26.55	1.58
	11.6	8.86	21.14	1.26
1	24.7	12.17	17.83	1.06
2	36.6	13.21	16.79	1.00
3	48.3	12.37	17.63	1.05
4	61.0	10.69	19.31	1.15
5	73.7	9.40	20.60	1.23
6	86.4	8.64	21.36	1.27
7	99.1	8.33	21.67	1.28
8	118.0	8.18	21.82	1.30
9	209.5	8.18	21.82	1.30
10	300.1	8.18	21.82	1.30
11	diffuser			

of the present one.

Two 76.2 mm diameter spherical concave mirrors with a focal length of 762 mm will be provided with adjustable mirror mounts. A light source, knife edge and camera mount will be provided to complete the Schlieren system along with T-slot components on which to install each components of the Schlieren system.

4 Procedure

1. Determine the sampling frequency and sampling time required to obtain accurate measurements from the pressure transducers. To do so, take some representative samples of the pressure transducer output. Using the MatLab routines provided, determine the frequency content and time constant of the signal. Set the sampling time to provide $\pm 1\%$ accuracy on the transducer signal (in units of pressure).

2. Measure the pressure distribution inside the wind tunnel from the first 10 static pressure ports for two different valve settings - one leading to subsonic flow and one yielding supersonic speeds.

3. Using the total pressure tube inside the tunnel, measure the total pressure at different locations along the wind tunnel, from the throat of the nozzle to the constant area of the test section.

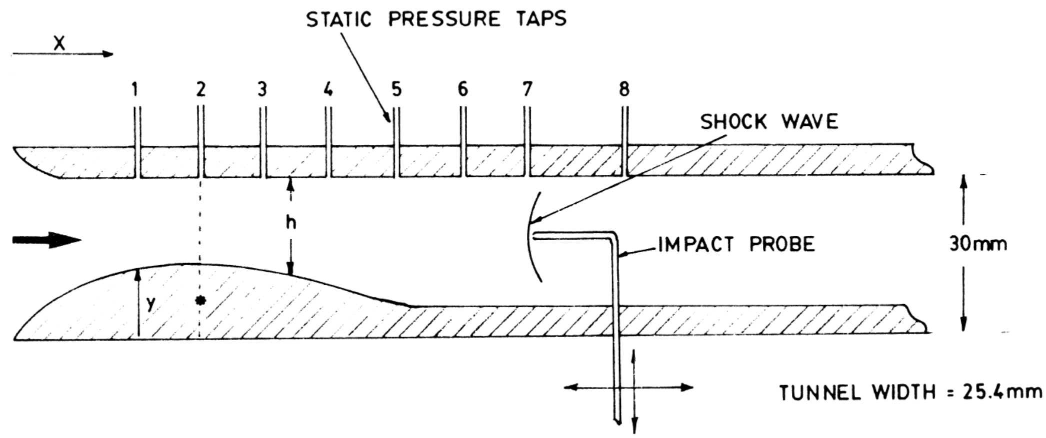

Figure 2: Schematic of nozzle and tunnel geometry.

Locate the probe approximately 5 mm away from the ceiling of the tunnel, which is roughly equivalent to the centerline of the tunnel if a full de Laval nozzle was used.

4. Using the Schlieren system, take images of the different types of shocks present in the tunnel at different valve settings.

5 Presentation of Results

In your lab report, compare your measurements with predictions from isentropic relationships. Consider both the pressure distribution and Mach number distribution. Produce appropriate plots for your discussion. Also, discuss the different types of shock waves present in the tunnel and under what conditions they appear. Use the images you took to support your discussion.

In your conclusion, include a “recommendation for future experiment” subsection of paragraph. This can discuss suggestion for improving this laboratory and/or suggestions for answering questions that have arisen during your analysis.