FPP3 Experiment 2

3-hole probe calibration

The aim of this lab session is to use the *Bingo Machine* calibration tunnel to calibrate a 3-hole probe. Calibration of the probe is required to determine the relationship between the probe-head pressures and the local properties of the flow. The result of your calibration will be a number of relationships (calibration curves), each describing a single flow property as a function of the angularity of the flow.

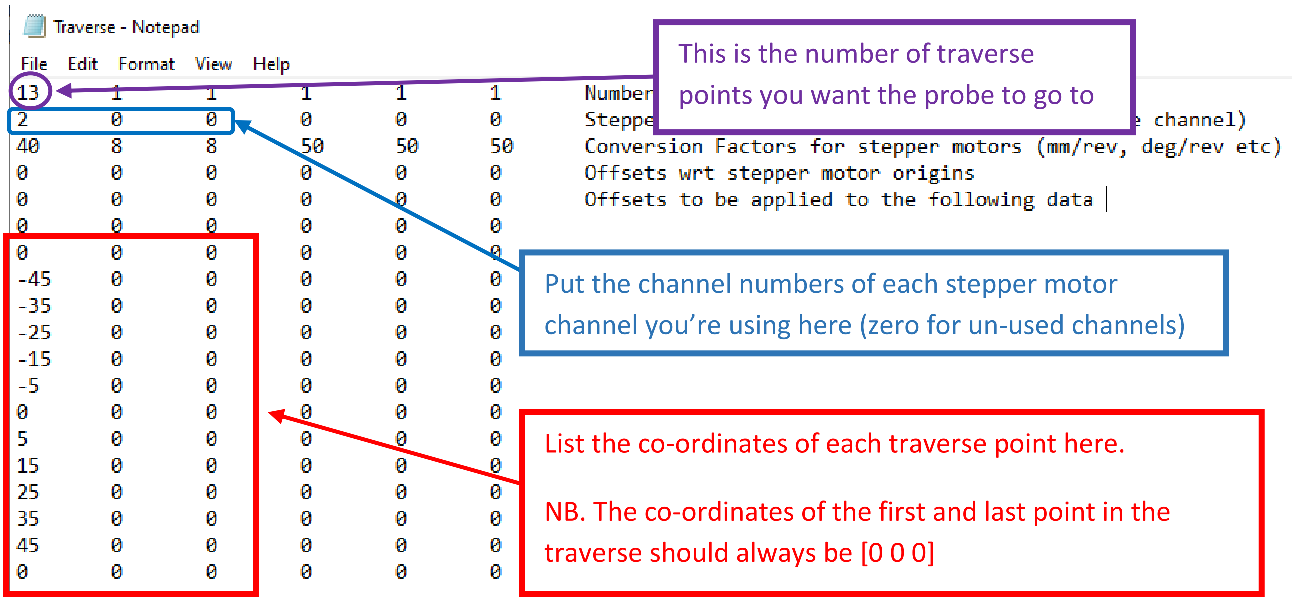
To determine the calibration curves you will need to measure the three probe-head pressures and the reference pressures in the calibration tunnel environment. To record the pressure data you will use the DSA as in experiment 1. In the calibration tunnel the relative incoming angularity of the flow is set by rotating the probe about its axis. This is done using a rotary traverse gear. A LabVIEW script will record the pressures and angular position of the probe-head. It is important to know the Reynolds' number at which the probe has been calibrated.

Part 1: LabVIEW Setup

The LabVIEW script will record the pressures measured by the DSA and the thermocouples readings. It also controls the traverse gear. The LabVIEW script requires two input files to run, the stepper file and traverse file. You will not need to edit the stepper file. It contains the information required for the LabVIEW script to drive the stepper motor. For example, the drive current to the stepper motor are set here. It looks like this:

```
0    0    0    0    0    0    Motor Resolution MR (0=400,1=800,2=2000,3=4000)
3    3    3    3    3    3    Limits Disable Code/Mask (0=+/-,1=-,2=+,3=off)
1    1    1    1    1    1    Mode M (1=Absolute MA,0=Incremental MI) (Continuous MC?)
1    1    1    1    1    1    Reset on start-up Z (1=ON,0=OFF)
3    3    3    3    3    3    Motor Current MC (0=50,1=60,2=70,3=80,4=90,5=100%)
0.1  0.02 1.0  0.1  0.1  0.1  Motor Acceleration/Deceleration A (revs/s^2)
2.0  0.2  2.0  2.0  2.0  2.0  Start/Stop Velocity Threshold VS
2    0.8  6    2    2    2    Velocity V
2    2    2    2    2    2    Encoder Resolution ER (0=200,1=400,2=1000,3=2000)
0    0    0    0    0    0    Deadband Range (encoder counts)
0    0    0    0    0    0    Distance Units DU (0=Motor steps,1=Encoder steps)
0    0    0    0    0    0    Position Maintenance POSMAIN (1=ON,0=OFF)
1    1    1    1    1    1    Stop on stall (1=STOP,0=CONTINUE)
0    0    0    0    0    0    Stall detect STALL (1=ON,0=OFF)
1    1    1    1    1    1    Com Port
```

The traverse file contains information about which motors to drive and the desired co-ordinates to move to, as well as the calibration of each motor, i.e. the number of steps per degree (or millimetre). You should save your own copy of this file before editing it. The origin is reset every time the LabVIEW script is run - it is therefore not a fixed location, but simply the position that the probe is at when the script is started. The traverse file looks like this:



Set the DSA AVG to your chosen value from Experiment 1. Set these based on your results where you determined the number of samples required to give an appropriate standard deviation in your data. The output file is similar to that from experiment 1 but with six additional columns: three position columns followed by three columns of zeros. The exit file will have the following columns:

- Atmospheric pressure (input)
- Number of point in the traverse
- Position (x6 – only one column will be non-zero and indicates the position of the probe from the reference starting point)
- Pressures (x16 – corresponding to the 16 channels of the DSA)
- Temperatures (x2 – the first one is the thermocouple cold junction, the second one is the tunnel inlet temperature)

You will need to set the location of the input and output files on the script.

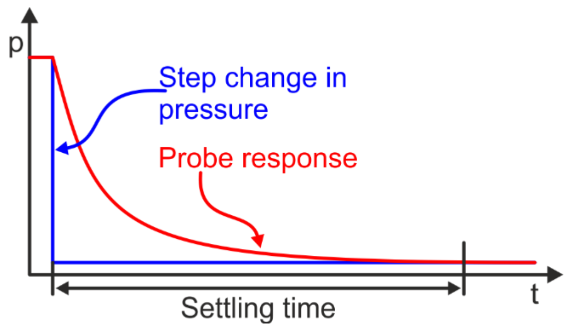
Part 2: Setup of the 3-hole probe in the Bingo Machine

A schematic of the Bingo Machine is attached at the end of this handout. The 3-hole is mounted on a rotary traverse gear which is fixed to the side of the Bingo Machine. The rotary traverse gear rotates the probe about its axis and is controlled by the LabVIEW script.

The reference total and static, from the Bingo Machine, as well as the three probe pressures need to be connected to the DSA. The thermocouple reader should be carefully placed on the ledge of the Bingo Machine so that the thermocouple can be used to measure the temperature of the reference flow. Ensure the stepper motor cable is connected from channel 2 of the stepper motor driver box to the rotary traverse gear.

Part 3: Calibration

Before you perform a full calibration investigate the settling time of the probe. The volume of air in the pneumatic tubing (which connects the probe pressure ports to the DSA pressure ports) and volume of air inside the DSA itself cannot respond instantaneously to changes in pressure. There is a finite settling time over which the pressure must equalise between successive traverse steps, illustrated in the sketch below. You can make a sudden change in pressure by rotating the probe from -45° to +45° and back again. If the time taken is greater than the probe settling time, the two readings taken at -45° will be identical (+/- error). If the time taken is less than the settling time, there will be a difference between the measurements at -45°. If you allow the probe to settle at each traverse point for a period of time much greater than the settling time of the probe, you will waste time (this really adds up on a traverse with several hundred data points).



Produce a new *traverse.txt* file with the co-ordinates 0, -45, +45, -45, 0 (and the number of points set to 5). Switch the Bingo Machine on and run a few traverses with the *settle time* set to different values (e.g. 0.1 s, 1 s, 10 s) and see whether there is a difference in the answers given by the probe. (You may find that the inherent time delay in the LabVIEW program is sufficient to allow the probe to settle).

Once you have decided on a settling time you can now calibrate the probe. Write two traverse files to perform a 'coarse' calibration and a 'fine' calibration (i.e. one with only a few points in it and one with much higher spatial resolution). In the fine calibration concentrate the points near 0° yaw as most of your measurements in the wind tunnel will be close to 0°. Perform both of these calibrations with the Bingo Machine running at the maximum speed. Finally, perform a fine calibration with the Bingo Machine running at the minimum speed to see if there are any Reynolds' number effects.

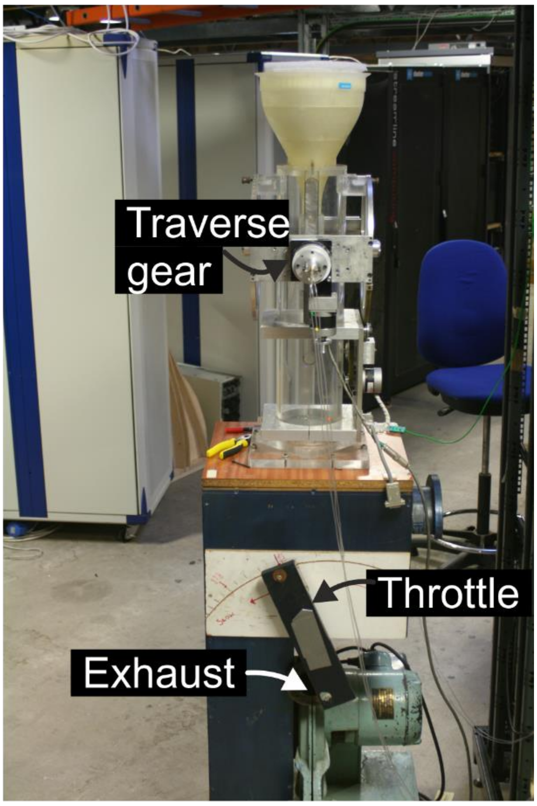
Use the coarse calibration to test your MATLAB script for applying your fine calibration to the raw data. Compare the calibrations at different Reynolds' numbers. How do these Reynolds' numbers compare to those that the probe will experience in the wind tunnel environment? Does this have any implications on using this probe in the wind tunnel?

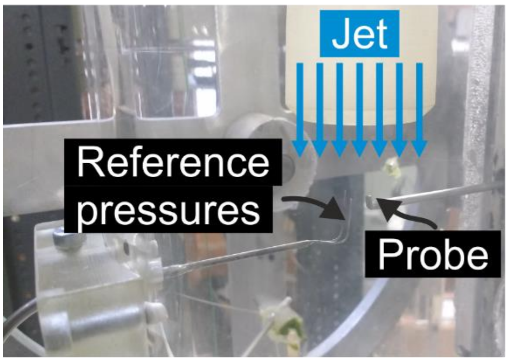
Bingo Machine

Produces a clean, straight jet of flow for calibrating probes

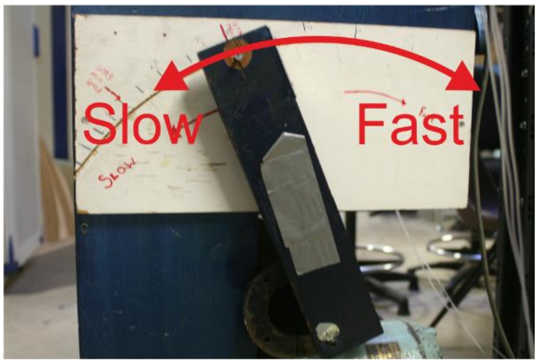
Front view

Rear view





The reference pressures (static on left, total on right) enable the outputs of the probe under calibration to be compared to the actual tunnel pressures
NB. Please try not to rotate the reference probe or it'll give inaccurate readings!



The throttle restricts the flow rate through the working section, and so enables the speed to be varied. I've marked the maximum and minimum speeds you should run at (any faster and pressures are too large for the DSA's range, any slower and the fan may stall). Do a calibration at the maximum speed and a slower speed of your choice.