





## Standard Multi-hole Probes

-  Additive manufacturing allows almost any geometry
-  Titanium, Inconel, stainless steel, plastics and more
-  One-piece, robust design
-  Adjustable reference surfaces, connections and software



Multi-hole Probe	
<b>Geometry</b>	Straight, L-shaped, Cobra, Drilled elbow
<b>Number of holes</b>	3, 5, 7 plus static ring
<b>Max. length</b>	Up to 280 mm (one part) (>280 mm for multipart designs)
<b>Min. tip diameter</b>	1 mm (Standard 3 mm)
<b>Tip geometry</b>	Conical, spherical or custom
<b>Material</b>	Stainless steel, Titanium, Inconel, plastic
<b>Fastening</b>	Square, hexagonal, one-sided flattened cylinder or custom
<b>Connections</b>	Standard 1 mm pressure tubes
<b>Reference</b>	Reference surface normal to Z axis
<b>Temperature range</b>	950°C
<b>Angular range</b>	±60°(3-hole and 5-hole), ±70° (7-hole)
<b>Angular accuracy</b>	< ±1°
<b>Velocity range</b>	3 m/s to > Mach 1.4
<b>Velocity accuracy</b>	< ±1 m/s
<b>Optional</b>	-Frequency calibration dependent on geometry -Temperature measurements (Thermocouple)

The multi-hole probes from Vectoflow range from 3-hole over 5-hole up to 7-hole probes for larger flow angles up to  $\pm 70^\circ$ . They are used in a large variety of applications like motor sports, turbomachinery and drones.

Like all probes from Vectoflow, they are made by additive manufacturing, giving a high geometrical flexibility and a very high robustness at the same time. The probes are generally built out of one piece, with no internal tubings or weldings, avoiding any internal leakage and assuring a long lifetime.

The Vectoflow concept offers a high level of customization, which is why there are no real standard geometries. The probes are adapted to every specific use case.

### Measurement error

The measurement error of a multi-hole probe depends on the pressure scanner used for the calibration and data acquisition.

We recommend the use of a scanner whose pressure range just covers the expected dynamic pressure, and whose accuracy is 0.1 % full scale or better.

The lower the velocity, the higher becomes the impact of the pressure measurement error onto the determination of the flow velocity, as shown in figure 1 (for a scanner accuracy of  $\pm 0.05$  % FS).

Generally, an error of 1 m/s or 1% of the measured velocity —whichever is higher— is expected at higher speeds. For lower speeds, the error depends on the pressure scanner and increases the lower the speed.

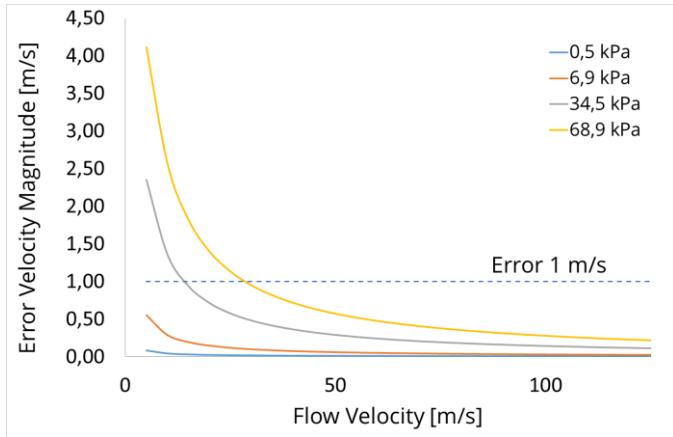


Figure 1: Dependence of velocity measurement error on pressure scanner range (0.05% FS accuracy)

### Calibration process

The calibration process is always necessary for each manufactured multi-hole probe. Vectoflow has its own calibration wind tunnel, delivering flow speeds from 1 m/s up to Mach 1.4. Vectoflow has a very rigid quality assurance, which ultimately leads to the highest possible measurement accuracy of the flow probes.

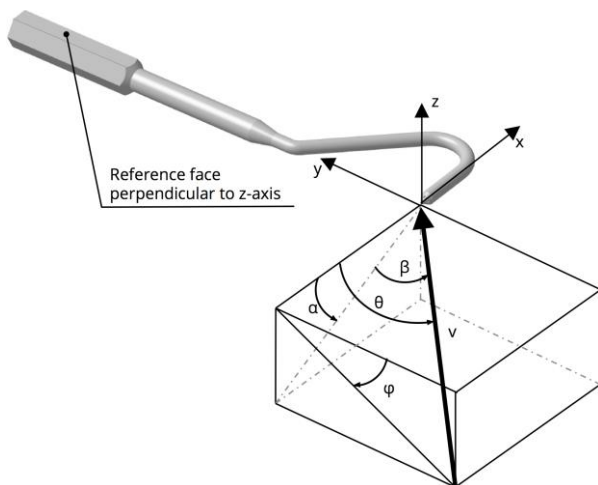


Figure 2: Flow angle definitions

During the calibration process, the probe is exposed to a steady flow with known conditions,

while pitch and yaw angles change through thousands of positions. The definition of the flow angles is shown in figure 2.

The following table shows the main characteristics of the Vectoflow calibration wind tunnel:

Calibration wind tunnel	
<b>Angular range</b>	$\pm 165^\circ$ (yaw axis), $180^\circ$ (roll axis)
<b>Max. Power</b>	90 kW
<b>Velocity range</b>	From 1 m/s to Mach 1.4
<b>Control parameters</b>	Mach number, velocity (m/s)
<b>Long-term velocity stability</b>	$\pm 0.25\%$ (at M 0.1)

Table 1: Calibration wind tunnel characteristics

### System solutions

Vectoflow provides not only flow probes, but complete measurement systems.

These solutions include:

- Probe
- Tubing connections
- Pressure scanner
- Software

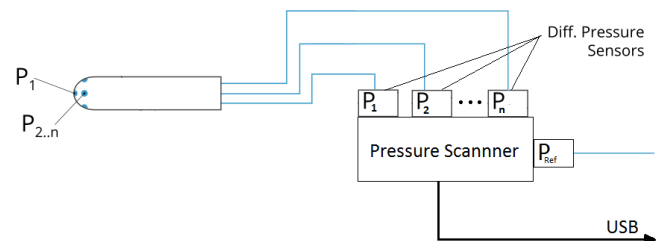


Figure 3: Multi-hole probe pressure tube connection

There is a variety of pressure scanners available, which integrate perfectly into the VectoAcquire Pro Software.

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