

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



Figure 1 Multi-hole Probes

The multi-hole probes from Vectoflow range from 3-hole over 5-hole up to 7-hole probes for larger flow angles up to $\pm 60^\circ$. 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 tubing or welding, avoiding any internal leakage and assuring a long lifetime.

The Vectoflow concept offers a high level of customization. The probes can therefore be 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.

Multi-hole Probe	
Geometry	Straight, L-shaped, Cobra, Drilled elbow
Number of holes	3, 5, 7 plus static ring
Max. length	< 280 mm (one part) >280 mm multipart designs
Min. tip diameter	≥ 3 mm (micro: $>1,6$)
Tip geometry	Conical, spherical, or custom
Material	Stainless steel, Titanium, Inconel, Plastic
Connections	Standard 1mm or 1,6mm pressure tubes
Fastening	Square, hexagonal, one-sided flattened cylinder, or custom
Reference	Reference surface normal to Z axis
Temperature range	Max. 800°C (higher on request)
Angular range	$\pm 60^\circ$
Angular accuracy	$< \pm 1^\circ$
Velocity range	3 m/s to supersonic speeds (depends on calibration)
Velocity accuracy	$< \pm 1$ m/s
Optional	Frequency calibration dependent on geometry. Temperature measurements (Thermocouple or PT100)

Table 1 General Data

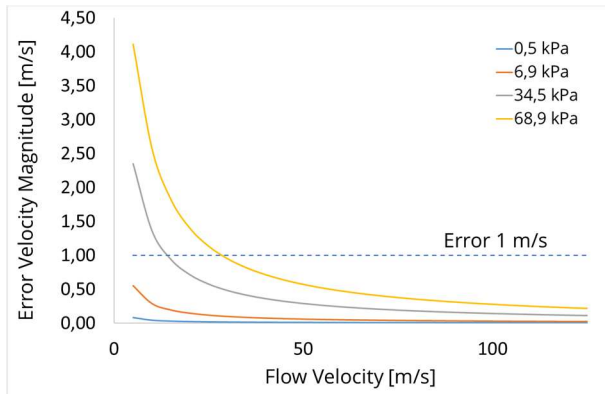


Figure 2 Dependency of velocity measurement error on pressure scanner range (0.05% FS accuracy)

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 (higher Mach numbers upon request). Vectoflow has a very rigid quality assurance, which ultimately leads to the highest possible measurement accuracy of the flow probes.

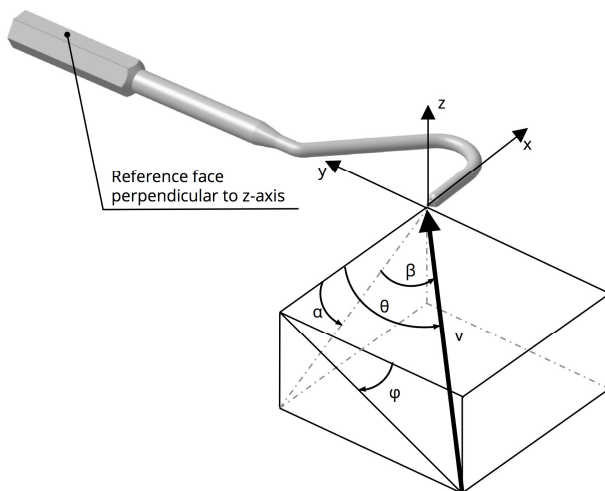


Figure 3 Flow angle definitions

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 3 Flow angle definitions Figure 3.

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

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

Table 2 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

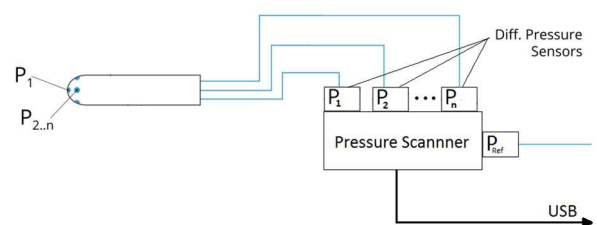


Figure 4 Multi-hole probe pressure tube connection

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