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Probes for Hot-wire Anemometry

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Introduction

General information

This catalog describes the complete line of Dantec Dynamics' standard hot-wire and hot-film probes for use with Constant Temperature Anemometers (CTA).

The CTA anemometer is today's most widely used instrument for measurement and analysis of the micro-structures in turbulent gas and liquid flows. The output of the anemometer represents the instantaneous velocity at a point and forms the basis of a statistical analysis describing the flow conditions in that point, for example mean velocity, turbulence intensity etc.

Its main features are:

- Fast response. Fluctuations up to 400 kHz or more can be measured.
- High spatial resolution. small eddies down to some tenths of a mm can be resolved.
- High dynamic range. Velocities from a few cm/s up to several hundred m/s can be measured with almost constant sensitivity.
- Continuous signal.
- Little disturbance of the flow due to small sensor size.

The basic working principle makes it possible to determine fluctuations in any parameter that, in addition to the velocity, influences the heat transfer from the sensor, for example density, pressure, temperature and composition, provided proper means are taken.

Manufacturer's responsibility

Dantec Dynamics is responsible for the safety, reliability and performance of the items described in this catalog only if:

- The specific environmental conditions correspond to the requirements stated for the specific item in this catalog or on the probe or probe support container.
- Modifications or repairs are carried out by persons authorized by Dantec Dynamics.
- The items are used in accordance with the recommendations given herein or on the probe or probe support container.

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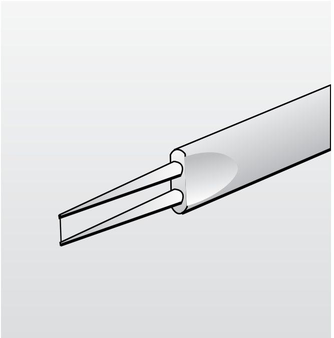


Fig. 1. 5 µm dia. plated tungsten wire, welded to the prongs.

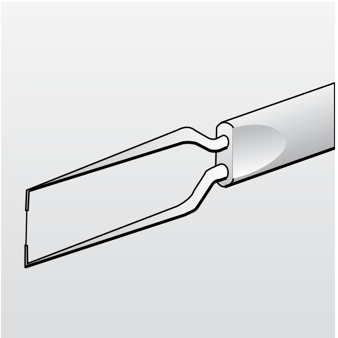


Fig. 2. 5 µm dia. plated tungsten wire, gold-plated at the ends to provide active sensor length of 1.25 mm.

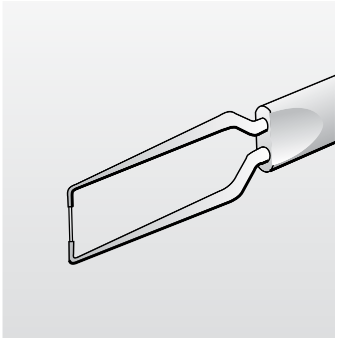


Fig. 3. 70 µm dia. fiber-film, welded to the prongs.

The Dantec Probe System

Dantec provides a complete probe system with a variety of probe types and configurations that cover most applications in fluid dynamics. The probe system includes probes, probe supports and shorting probes.

Probe construction

In general, a probe consists of the following:

- Sensor, forming the heating element.
- Sensor supports (prongs or substrate), carrying the sensor and leading current to it.
- Probe body, carrying the sensor supports.
- Connector, providing electrical connection to the probe support or probe cable.

Probes may have one, two or three sensors for use in one-, two- or three-dimensional flows. Each sensor requires its own anemometer bridge.

The sensor may either be a thin wire suspended between two prongs or a thin metal film deposited on an electrically insulating substrate. Film sensors can be cylindrical (fiber-film probes) or non-cylindrical (film probes). Wire sensors are used in gases and in non-conducting liquids, while film sensors are primarily designed for use in water and other conducting liquids.

The sensor materials are selected to provide maximum flow sensitivity and highest possible mechanical strength with a minimum of thermal inertia. The size of the sensor and its mounting are selected to give minimal disturbance of the flow.

Most probe types are available with different prong or substrate configurations covering a wide variety applications.

Wire probes

Wires are used as sensors in probes for measurements in air and other gases at velocities from a few cm/s up to supersonic velocities. In addition, they may be used in non-conducting liquids at low velocities.

Wire sensors have high flow sensitivity and the highest frequency response. On the other hand, the mechanical strength is limited and they are quite sensitive to particle contamination.

The sensor supports, or prongs, are made of stainless steel and tapered, providing an end surface of around 0.1 mm in diameter to which the wires are spot-welded.

Miniature wire probes

Miniature wire probes have 5 µm diameter, 1.25 mm long plated tungsten wire sensors (Fig. 1). The wires are welded directly to the prongs and the entire wire length acts as a sensor. They are general purpose probes recommended for most measurements in one- or two-dimensional flows of low turbulence intensity. The accuracy of turbulence measurements may be reduced because of interference from the prongs. On the other hand, the more rigid construction makes them more suitable for high speed applications without the risk of self-oscillation.

The probes are the cheapest in the Dantec program and are straightforward to repair. Miniature wire probes are available with one or two sensors (single, X- and parallel arrays) in five different configurations.

Gold-plated wire probes

Gold-plated probes have 5 µm diameter, 3 mm long plated tungsten wire sensors. The wire ends are copper- and gold-plated to a thickness of 15 to 20 µm, leaving an active sensor, 1.25 mm, in the middle of the wire (Fig. 2). They are designed for measurements in high turbulence flows of one-, two- and three-dimensions.

The plating of the ends serves the dual purpose of accurately defining the sensing length and reducing the amount of heat dissipated by the prongs. This results in a much more uniform temperature along the wire than is the case for miniature wires.

Another advantage is less flow interference from the prongs at the point of measurement due to the wider prong spacing. Both increase the accuracy at high turbulence levels.

Gold-plated wires probes are available with one, two and three sensors (single, X- and tri-axial arrays) in six different configurations.

For measurements of quickly fluctuating temperatures, a wire probe with a 1 µm diameter, 0.4 mm long platinum sensor is available. The wire is spot welded to stainless steel prongs. It is used with a special constant current anemometer bridge and operated as a cold-wire probe with a measuring current a fraction of a mA. The temperature probe is available in one straight probe configuration.

Film probes

Film probes are used for measurements in liquids at low and medium velocities and in gases. They are considerably more rugged than wire probes and less sensitive to contamination. Sensors are nickel films placed on quartz substrates of different shapes.

They are deposited by cathode sputtering, which is a technique where the film forms in a continuous process and results in a homogenous thin film of high purity and good adherence to the substrate.

The films have high temperature coefficients of resistance and possess high mechanical and electrical stability.

The films are protected by a sputtered quartz coating, 0.5 µm or 2 µm in thickness for air and water applications respectively. This layer prevents against electrolysis, when used in liquids, and protects against wear and oxidization in gas applications.

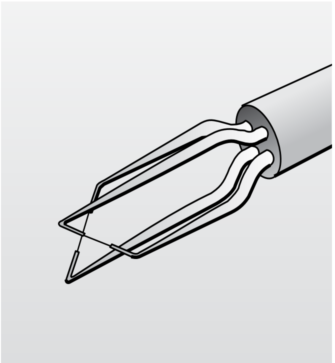


Fig. 4. Sensor arrangement of X-probe.

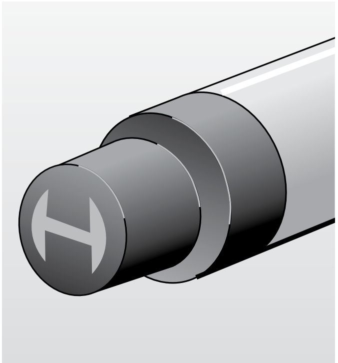


Fig. 5. Tip of flush-mounting probe.

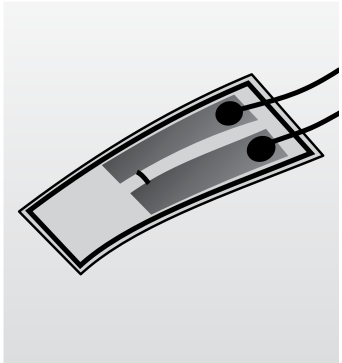


Fig. 6. Glue-on probe.

Film probes with cylindrical sensors
Fiber-film probes

Fiber-film probes have cylindrical thin film sensors and may be used as a substitute for wire probes in liquids or in gas applications where more robust probes are needed. Fiber sensors are 70 µm diameter quartz fibers, 3 mm long, covered by a nickel thin film approx. 0.1 µm in thickness (Fig. 3). The ends are copper- and gold-plated.

The fiber is soldered onto the prong ends. Fiber probes for water applications have lacquer-coated soldering joints and prongs insulating them electrically from the surroundings. Fiber probes are available with one, two and three sensors (single, X- (Fig. 4) and tri-axial arrays) in six different prong configurations.

Split-fiber probes

Split-fiber probes have two parallel nickel films deposited on the same quartz fiber, 200 µm diameter and 3 mm long (Fig. 7). The ends are copper- and gold-plated, leaving a 1.2 mm sensing length. The film is protected with a 0.5 µm quartz coating.

Split-fibers are intended for measurement of instantaneous velocity and direction in two-dimensional gas flows. They may replace dual-sensor fiber probes (X-probes) in slowly fluctuating flows, when a high spatial resolution is required, or when the angle of attack exceeds the ±45° acceptance angle for conventional X-array probes. Split-fiber probes are available in three configurations for work in free-stream flows, pipe flows and boundary layers. The standard versions are only for gas applications.

Film probes with non-cylindrical sensors

Film probes with non-cylindrical sensors have the nickel film deposited on quartz substrates of different aerodynamic shapes: flat surfaces and spheres.

The sensor is defined as a line or a ring. Two sputtered silver leads carry the current from the cable, normally attached to the probe body, forward to the sensor. The sensor is protected by a quartz coating (0.5 µm in gases and 2 µm in liquids), while the leads are insulated by means of a lacquer coating.

Flush-mounting probes

These probes have the sensor (0.8x0.2 mm) placed on the flat end of a quartz cylinder (Fig. 5). They are intended for measurement of wall shear stress in both laminar and turbulent boundary layers. They may also be used for determination of points of transition and separation.

The working principle is based on the similarity between temperature and velocity profiles in the viscous sub-layer, and the probe is used in practice like any other film probe. It mounts in a hole in the wall of the body under investigation. It is available in one straight configuration in versions for liquid and gas applications.

Glue-on probe

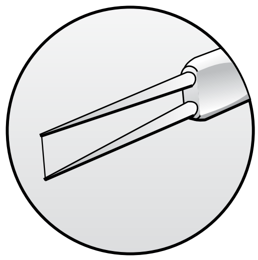
This is a special version of the flush-mounting probe, where the sensor is deposited on a KaptonTM foil, 50 µm thick. The sensor is 0.9x0.1 mm and connected to gold-plated lead areas (Fig. 6). It is primarily intended for qualitative measurements of points of transition and separation. It is glued directly onto the wall in the points of interest. Copper wires soldered to the leads constitute the electrical connection between probe cable and probe. If the probe is used for quantitative measurements it must be calibrated in situ, as it normally cannot be removed when first glued in place.

Sensor configurations

The Dantec Dynamics probe system comprises probes with one, two or three sensors for measurements in one-, two- or three-dimensional flows. Normally, each probe type is available in a number of configurations with different prong or substrate bends. In this way it is possible to select the correct probe for almost any measurement situation.

Single-sensor probes
Wire and fiber probes with cylindrical sensors

Probes with cylindrical sensors (wires and fiber films) are available in the following configurations:



(a) Straight prongs, sensor perpendicular to probe axis.

Measures mean and fluctuating velocities in free-stream one-dimensional flows. Mounts with the probe axis parallel to the direction of the flow.

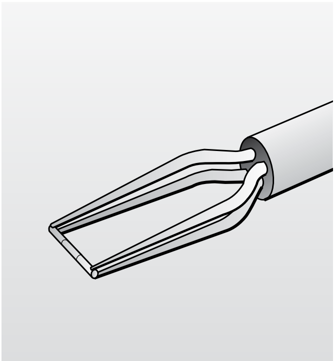


Fig. 7. Tip of split-fiber probe

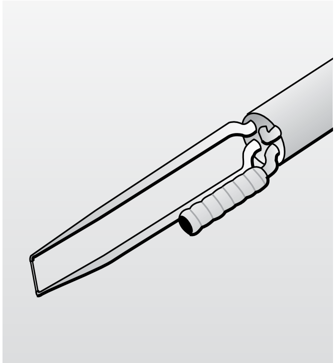
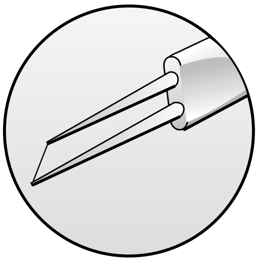
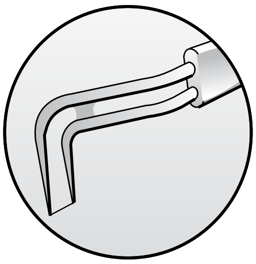


Fig. 8. Temperature-compensated wire probe for slow temperature fluctuations.



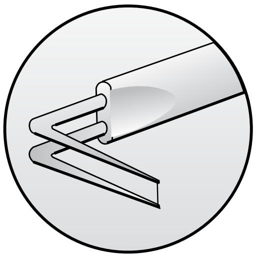
(b) Straight prongs, sensor at angle of 45° to probe axis.

Measures mean flow velocities, flow fluctuations and Reynolds shear stress in stationary two- and three-dimensional flows.
Mounts with the probe axis parallel to the direction of the mean flow. The probe is rotated to get the velocity components.



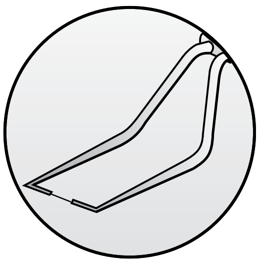
(c) Right-angled prongs, sensor parallel to probe axis.

Measures mean flow velocities and flow fluctuations in places that are not readily accessible, e.g. in pipes. Mounts with the probe axis perpendicular to the direction of the flow.



(d) Right-angled prongs, sensor perpendicular to probe axis.

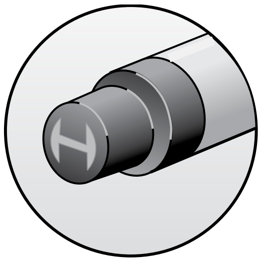
Used in the same applications as (c), except that the sensor is turned 90°. This makes these probes suitable for boundary layer measurements, e.g. in pipes, as well. Mounts with the probe axis perpendicular to the direction of the flow.



(e) Offset prongs, sensor perpendicular to probe axis.

Designed for use in boundary layers. The shape of the prongs permits measurements close to a solid wall without disturbance from the probe body, which is out of the boundary layer. Mounts with the probe axis parallel to the direction of flow.

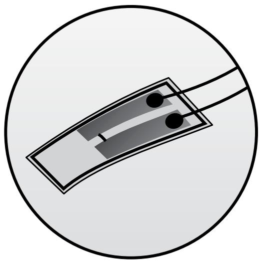
Film probes with non-cylindrical sensors



g) Flush-mounting probes.

Measures skin friction (wall shear stress) in both laminar and turbulent boundary layers. Determines the points of transition and separation. Mounts in a hole in the wall confining the flow to be measured with the substrate end plane flush with the wall.

The sensor is oriented perpendicular to the flow direction.



(h) Glue-on probe.

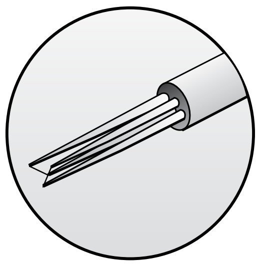
Determines the points of transition and separation and may measure skin friction and heat transfer numbers. It is glued directly onto the wall. The sensor is oriented perpendicular to the flow direction.

Dual-sensor probes

Dual-sensor probes are designed for use in two-dimensional flows. The sensors are arranged in X-arrays or V-arrays, where they form an angle of 90° with one another, or they are placed opposite each other on a cylinder surface (split-fibers).

X-array wire and fiber probes

All X-probes measure two velocity components simultaneously in turbulent, instationary two-dimensional flow fields. They provide information for calculation of Reynolds shear stress. The flow vector may not exceed ±45°.



(i) X-probe, straight prongs.

Used in free-stream applications. Mounts with the probe axis parallel to the direction of main flow, so that the predominant flow vector attacks the two wires under 45°.

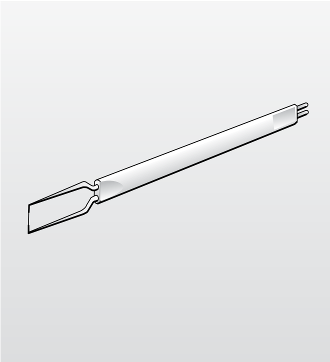


Fig. 9. Plug-in probe design.

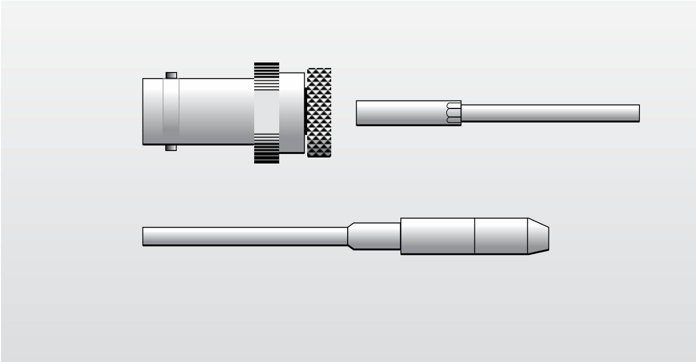
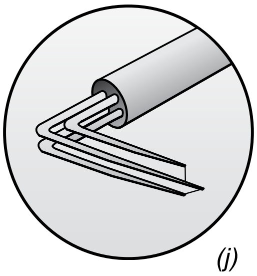
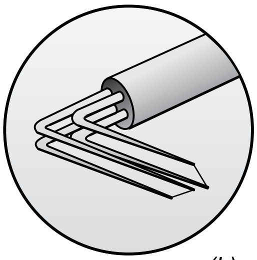


Fig. 10. Probe support for single-sensor probes.



(j)



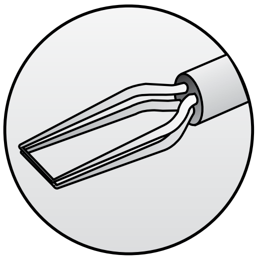
(k)

(j) and (k) X-probe, right-angled prongs, radial operation.

Two different versions are available, both of which are intended for radial operation in pipes or ducts. One version has the sensor plane parallel with the probe axis (j), while the other (k) has the sensor plane perpendicular to the probe axis. The two versions thus measure the U-V and U-W components respectively. Mounts with the probe axis perpendicular to the main flow and rotated, so that the predominant flow vector attacks the two wires under 45°.

Split-fiber probes

Split-fiber probes may substitute for X-array probes in cases where optimum spatial resolution is required, or when the flow vector varies between ±90°. They are available in three different configurations.

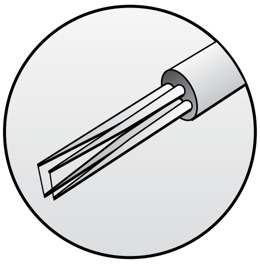


(l) Split-fiber probe, straight prongs.

Used in free-stream applications. Mounts with the probe axis parallel to the direction of main flow, so that the predominant flow vector attacks in the prong plane and perpendicular to the fiber.

Two different versions are available, both of which are intended for radial operation for example between compressor guide vanes. One version has the sensor perpendicular to the probe axis, (Fig. 7) while the other has the sensor parallel with the probe axis. The two versions thus measure the U-V and U-W components respectively. Mounts with the probe axis perpendicular to the main flow and rotated, so that the predominant flow vector is in the prong plane and attacks the fiber under 90°.

Parallel-array probe



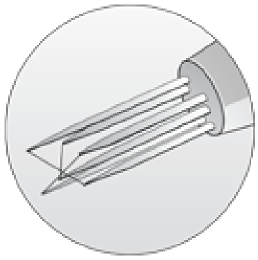
(m) Parallel-array probe, straight prongs.

This probe is specially designed for measurement of extremely small turbulence in one-dimensional flows. The two wires are supposed to measure simultaneously the same turbulence, whereafter the electronic noise is filtered away using a correlation technique on the two signals. Mounts with the probe body parallel to the flow direction.

Triple-sensor probes

Triple-sensor probes have three sensors and are normally used in three-dimensional flows.

Tri-axial wire and fiber probes



(n) Tri-axial sensor probes.

Tri-axial sensor probes have three mutually perpendicular sensors, consisting of gold-plated wires or fiber films. The sensors form an orthogonal system with an acceptance cone of 70.4°. This gives minimum prong interference and increases the accuracy, when the three probe signals are decomposed into velocity components.

Used for measurement of the U, V and W velocity components in an instationary three-dimensional flow field. Provides information for calculation of the full Reynolds shear stress tensor. Mounts with the probe axis in the main flow direction. The resulting velocity vector must be within the acceptance cone.

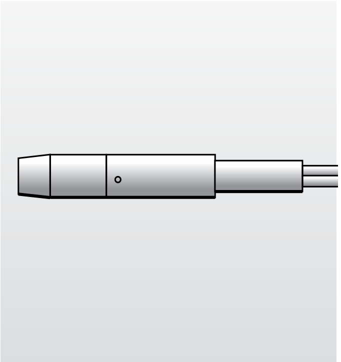


Fig. 11. Probe support for dual-sensor probes.

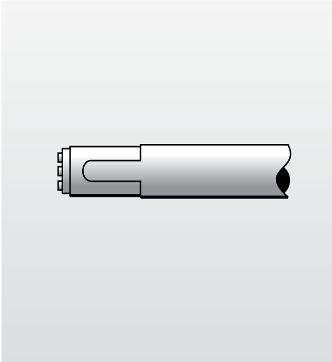


Fig. 12. Probe support for triple-sensor probes.

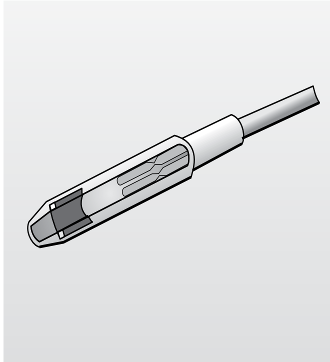


Fig. 13. Probe support for single-sensor probes. Sectional view.

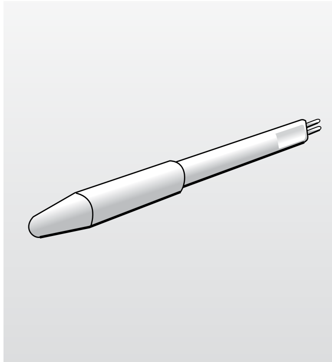


Fig. 14. Shorting probe for single-sensor probes.

Miscellaneous dual-sensor probes

Temperature-compensated probe

Temperature changes in the medium under investigation can affect velocity measurements. In this dual-sensor probe, one sensor operates as a velocity sensor while the other operates as a temperature sensor (Fig. 8).

Probe body design

The probe bodies are designed to provide a rigid, aerodynamic mounting of the sensors and sensor supports with a reliable electrical contact further on to the probe support or the probe cable.

Single- and dual-sensor wire and fiber-film probes

Wire and fiber-film sensors are all mounted on probe bodies, normally made of ceramic tubes, equipped with connector pins that connect to the probe supports by means of plug-and-socket arrangements (Fig. 9).

Dual-sensor probes have marks (one and two dots) that indicate the sensor number. Fiber probes are also marked with symbols indicating applications in gas or liquids (red dot = air, blue dot = water).

Triple-sensor probes

Triple-sensor probes are mounted on probe bodies of stainless steel, 6 mm outside diameter, ending in six gold-plated connector pins. Tri-axial probes have straight prongs embeded in a ceramic substrate in a stainless steel tube that mounts axially in the 6 mm body.

Film probes

Film probes (flush-mounting etc.) have cable equipped probe bodies and connect directly to the probe cable without the need for a probe support. The probe bodies are made of chromium-plated brass and the quartz rods carrying the sensors are glued directly into the probe bodies by means of epoxy resin. The cable extending from the probe body is terminated in a detachable BNC connector.

Probe supports

All plug-in probes are mounted using probe supports. Probe supports serve as the electrical connection between probe and probe cable and provide a mechanical mount for the probe at the same time.

Probe supports for single- and dual-sensor probes

There are three probe support types available for single-sensor (Fig. 10) and dual-sensor (Fig. 11) probes: short, long straight and long right-angled.

The supports consist of a coupling ring with an internal rubber ring that provides a water- and pressure-tight sealing, and one or two sets of contacts embedded in a cylindrical body that ends in one or two PTFE-coated cables with detachable BNC connectors (Fig. 13).

Outside diameters for probe supports are 4 mm and 6 mm for single- and dual-sensor probes, respectively. The cables on dual-sensor supports are marked with one and two rings indicating the connector number corresponding to the sensor number on the probe.

Probe supports for triple-sensor probes

There is one long straight probe support available for triple-sensor probes. It consists of a stainless steel tube, 6 mm outside diameter, with six connector sockets in the front. The connector is coded, so that the probe will always be properly oriented in the support (Fig. 12).

The support is not watertight. It has three PTFE-coated cables with detachable BNC connectors marked with one, two and three rings indicating the connector number, which again corresponds to the sensor number on the probe.

Shorting probes

Shorting probes are used to short-circuit the probe support or the probe cable. This is done in order to cancel the influence of the cable and support resistances, when probe resistance is measured in connection with the setup of the anemometer bridge. Three versions are available for single (Fig. 14), dual and triple probe supports, respectively.

In addition a BNC shorting probe is available for direct short-circuiting of the probe cable.

Probe selection chart

- Recommended (R)
- Applicable (A)
- Inapplicable (blank)

		WIRE PROBES								FILM PROBES				
		Gold-plated wire probes	Miniature wire probes	Resistance thermometer	Temperature-compensated probes	Gold-plated X-probes	Miniature X-probes	Parallel-sensor probes	Triple-sensor probes	Fiber-film probes	Flush-mounting probes	Glue-on probes	Fiber-film X-probes and Split-fiber probes	Fiber-film Triple-sensor probes
MEDIUM	Gases and non-conducting liquids	R	R	R	R	R	R	R	R	R	R	R	R	R
	Conducting liquids									R	R		R	A
STATE OF MEDIUM	Low and medium temp. up to 150°C	R	R	R	R	R	R	R	R	R	R	R	R	R
	Contaminated flow													
FLOW CONDITIONS	Extremely low velocities			R										
	Low and medium velocities	R	R	R	R	R	R	R	R	R	R	R	R	R
	High velocities	A	A		A	A	A	A	A	R	R	R	R	R
	Large velocity gradients	R	A		A	R	A		R	R			R	R
	Varying temperature	A	A	R	R	A	A	A	A	A	A	A	A	A
SPACE CONDITIONS	Sufficient space	R	R	R	R	R	R	R	R	R	R	R	R	R
	Little space		R	R			R	R			R			
	Very little space													
QUANTITY TO BE MEASURED	Mean velocity	R	R		R	R	R		R	R			R	R
	Instanteneous flow direction					R	R		R				R	R
	Velocity fluctuations	R	R		R	R	R	R	R	R	R		R	R
	Extremely low turbulence intensities							R						
	Low and medium turbulence intensities	R	R		R	R	R		R	R			R	R
	High turbulence intensities	R	A		A	R	A		R	R			R	
	Extremely high-frequency fluctuations													
	Turbulent shear stress	A	A		R	R			R	A			R	R
	Spatial turbulence components	A	A		R	R			R	A			R	R
	Wall shear stress										R	R		
	Temperatures and temp. fluctuations	A	A	R						A	A	A		
TYPE OF ANEMOMETER	MiniCTA	R	R			R	R	R	R	R	A *	A *	A *	A *
	MultiChannel CTA	R	R			R	R	R	R	R	A *	A *	A *	A *
	StreamLine & StreamLine Pro	R	R	R	R	R	R	R	R	R	R	R	R	R
TYPE OF CALIBRATOR	Hot-wire calibrator	R	R	R	R	R	R	R	R					
	StreamLine - & StreamLine Pro calibrator	R	R	R	R	R	R	R	R	R			R	R

*) 54T42 MiniCTA and 9054N0802/0812/0822 Multichannel versions only!

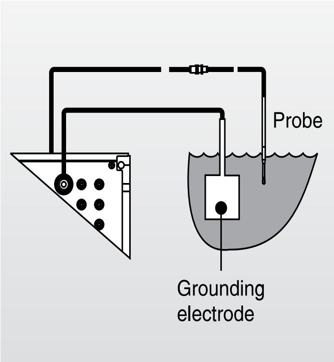


Fig. 15. Grounding in liquids.

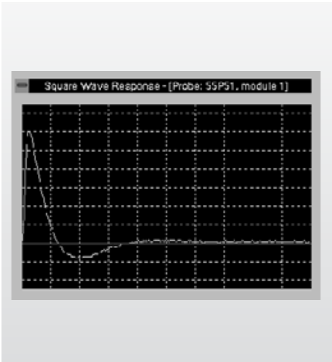


Fig. 16. Typical square wawe test for 0.5 μm wire probe.

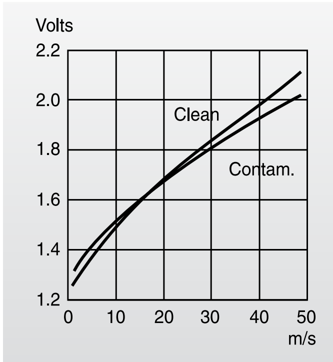


Fig. 17. Calibration curves for clean and contaminated (dust) hot-wire probe.

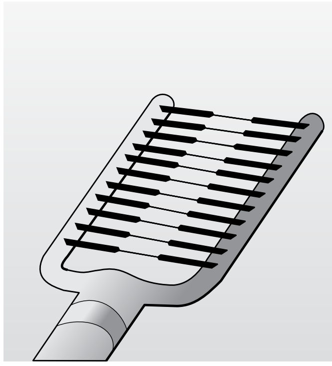


Fig. 18. Wire magazine with 10 wires for gold-plated wire probes.

Recommendations for use

Mounting and adjustment

Avoiding ground loops and noise pickup

BNC connectors on probes, probe supports and probe cables must not be in contact with any metallic part of test rigs or mounting systems. BNC connectors on dual- and triple-sensor supports must not touch each other, as this will disturb the operation of the individual CTA servo-loops in the anemometer electronics.

Grounding in liquids

The liquid must be grounded as close to the probe as possible by means of e.g. an electrode plate connected to the signal ground of the anemometer (see CTA manuals for further information). If no grounding is made, the thin protective quartz coating may break down due to voltage differences caused by electric charges building up in the liquid - or direct conduction if the liquid is somewhat conductive. Such a grounding will also reduce the amount of electrical noise that can be coupled dielectrically from the liquid to the CTA circuits (Fig. 15).

Probe orientation

The probes must be placed in the flow with the same sensor orientation as during calibration.

It is recommended that the wire and fiber probes are mounted with the prongs parallel with the flow whenever possible in order to avoid vibrations in the prongs during measurement.

Overheat adjustment

Recommended overheat ratio for wires and fiber probes in air is 0.8, giving an over-temperature between 200 and 300°C, and for film probes in water 0.1, corresponding to about 30°C.

Modern computer controlled anemometers, like the StreamLine, have a facility for automatic adjustment of overheat resistance.

Square wave test

It is important to perform the square wave test to make sure that the system will not oscillate during measurement and cause the sensor to burn out. The square wave test must be made at the highest velocity encountered in the flow (Fig. 16).

Disturbing effects

Varying fluid temperature

If the ambient temperature changes, it will introduce systematic errors in the calculation of the velocity. As the heat transfer is proportional to the temperature difference between sensor and fluid, a change in ambient temperature will result in a change in probe voltage. If not accounted for it will be misinterpreted as a change in velocity.

Sensor contamination

Contaminants, like dust in air and chemicals in water, may adhere to the sensor and change the heat transfer drastically. The influence of dirt increases with decreasing diameter; this means wires are generally more sensitive than fibers.

In liquids, particle contamination may be a serious problem, especially for fiber probes, and it may often be necessary to filter the liquid for particles down to the size of a few micrometers. Even then, cleaning both fiber and film probes used in liquids is recommended at regular intervals. Film probes used for a long time may accumulate calcium carbonate deposits that reduce sensitivity. The deposition increases with sensor operating temperature (Fig 17).

Chemical reactions

Chemical reaction in the form of electrolysis may occur with fiber and film probes used in water if the liquid is not properly grounded, or if the quartz coating has been damaged. Electrolysis eats away the sensor film in the vicinity of the damage. This results in an increase in sensor resistance and decrease in sensitivity. If electrolysis is allowed to continue, the sensor will eventually disappear.

Bubbles

In liquids, absorbed gases may form bubbles on the heated sensor. In this case, the anemometer should be switched to Standby and the bubbles removed by means of a soft marten hair brush. Bubbles can be avoided by keeping the liquid still for some time, so that the air can escape from it. Also the sensor temperature should be kept as low as possible to avoid formation of bubbles. At atmospheric conditions the sensor temperature in the water should be kept below 60°C. If the sensor element is partly covered with bubbles temperature gradients may actually damage the thin protective quartz coating.

Vortex shedding and vibrations

Vibrations in the probe mounting or even in the supports can occur at high velocities, introducing noise to the probe signal. Care should be taken to take proper means against them or even better to avoid them, for example by mounting the probe with the prongs in the flow direction.

Maintenance and repairs

Control and testing at Dantec Dynamics

Each probe is thoroughly controlled and tested at Dantec Dynamics before it is shipped to the customer. The control includes a visual inspection of sensor dimensions and check of mechanical strength and electrical properties. Finally the probes are tested in a CTA anemometer under normal operating conditions. Film probes for use in conducting liquids are operated in running water for several hours. The insulation of the protective quartz coating is tested in a sodium chloride solution (3%) by applying a voltage across it.

All probes have their technical data (sensor resistances, leads resistance, temperature coefficient of resistance and maximum operating temperature) written on a probe label on the probe container.

Cleaning the sensor

Cleaning of wire probes is best performed by a soft marten hair brush dipped in 2-propanol alcohol or acetone. Fiber and film probes should preferably be cleaned using distilled water. 2-propanol alcohol should be used in a limited amount as the lacquer coating may soften if exposed to alcohol for a longer time. Acetone should never be used on film probes. Probes used in water may get a deposit of calcium carbon ate. This can be removed by using a 15% acetic acid solution. After washing in the acid the deposits may be removed by a soft marten hair brush or a folded piece of lense tissue. It is important to use a microscope when cleaning sensors in order to avoid mechanical damage.

Wire probe repair

All wire probes can be repaired in case of wire breakage. The damaged wire should be removed and the prong ends polished with fine-grade wet-grinding paper and cleaned with acetone, so that they are absolutely free from any traces of grease. The new wire is then fastened by spot-welding. It is important that the wire is not tightened between the prongs so that any slight vibrations in the prongs will not break it. Wires for miniature wires are available in spools for repair purposes. Gold-plated wires are available in wire magazines with 10 wires in each (Fig. 18).

Fiber probe repair

Fiber probes can be repaired by soldering on a new fiber. This involves a rather complicated procedure including lacquer coating of the soldering joints followed by a burn-in to stabilize the resistance of the sensor. It is therefore recommended that fiber probes are returned to Dantec Dynamics for repair.

Film probe repair

Film probes (cones, etc.) cannot normally be repaired. If only a small hole has appeared in the quartz coating on probes used in liquids, it may be possible to cover the damage with a dot of lacquer. This kind of repair should be considered a temporary solution, as it will reduce the sensitivity and frequency response. Replacement of the probe is to be preferred.

Technical reference

Summary of technical data

Sensor material

The standard sensor materials are selected on the basis of the most common applications. The following property values are of importance when selecting sensor material:

As appears from the Table A, tungsten is a superior sensor material in most applications mainly due to its high mechanical strength.

To provide high flow sensitivity:

- High specific resistivity σ ($\Omega \cdot$ m)
- High temperature coefficient of resistance α (%/K)

To provide small time constant:

- Small density ρ (kg/m^3)
- Small heat capacity c (J/kg/K)

To reduce heat transfer to the prongs:

- Small thermal conductivity λ (W/m/K)

To withstand the flow:

- High tensile strength γ (N/m^2)
- High resistance against chemical attacks (oxidisation)

Sensor resistance

The sensor resistance figures given in the technical data are typical values. The actual values vary from probe to probe due to manufacturing tolerances. Wire probes have much closer tolerances, normally around ±10%, than film probes, which can vary more than ±50% around the typical value. The film probe resistance is determined not only by the sensor geometry but also by thickness and the metallic structure of the thin film resulting from the sputtering process.

Actual sensor resistance is written on the label on the probe container for each individual probe. Sensor resistances are always given at 20°C.

Temperature coefficient of resistance

The relation between resistance and temperature for a metallic conductor can be expressed by means of the temperature coefficient of resistance α_0(TCR):

$$R_T = R_0 \cdot (1 + \alpha_0 \cdot (T - T_0))$$

Higher order terms are negligible for the normally used sensor materials in a temperature range of a few hundred degrees. The TCR value α_0 refers to 20°C. The TCR at another temperature T1 may be calculated as:

$$\alpha_1 = \alpha_{20}/(1 + \alpha_{20} \cdot (T_1 - 20))$$

The TCR figure stated for a wire probes is a typical value common for all probes with that wire type.

For film probes it may vary with the metal structure and degree of annealing.

The TCR is therefore measured for each individual film probe and written on the probe label.

Lead resistance

The lead resistance R_L is the internal probe resistance defined as the resistance between the sensor and the connector pins (or BNC connector) on the probe. All values given in the technical data are typical values for the probe type. Deviations in actual lead resistance will influence the over-temperature but will only have a second order effect on the overall measuring accuracy.

Sensor temperature

The maximum sensor temperature indicates the level up to which the sensor will operate stably. For wire probes the limit is determined by the onset of oxidization, which is most pronounced for small wires. Film probes with thin quartz coating are annealed at Dantec Dynamics for stable operation up to the stated limit. If the films are operated above that, the cold resistance will start to drop and, if the temperature is further increased, the film will burn off. Film probes with thick quartz coating are only annealed up to 150°C. If used at higher sensor temperatures, the resistance will drop, and the lacquer coating may start to detoriate.

When the sensor temperature is used for calculation of the overheat ratio, use of a sensor temperature somewhat below the maximum in the technical data is advised. This prevents the center portion of the sensor, which is normally the hottest, exceeding the maximum allowable temperature.

Ambient temperature

The maximum ambient temperature states the limit up to which the probe can be used without damage. It is determined by the materials and assembly methods (for example glue) used.

Max. ambient pressure

CTA probes are normally used around atmospheric pressure. The stated maximum pressure is determined primarily by the mounting and tightening method (O-rings, plane seals etc.). A minimum pressure is not given as it depends primarily on the application and the acceptance of slip-flow conditions.

	Unit	Tungsten	Pure platinum	PtRh 10% Rh	Pt Ir 20% Ir	Nickel
Resistivity	$\Omega \cdot m \cdot 10^8$	7.0	10.2	18.9	32.0	6.6
Temp. coeff. of res.	%/°C	0.36	0.38	0.16	0.07	0.64*
Density	kg/m^3 · 10^3	19.3	21.45	19.95	21.61	8.9
Heat capacity	J/kg · K	33.0	31.4	35.4	32.0	105.0
Heat conductivity	W/m · K	178	69.0	50.1	25.5	90.5
Tensile strength	N/m^2 10^{10}	2.50	0.30	0.60	1.32	0.65
Max. operating temp.	°C	300	1200	800	700	400
Available as wollaston wire		no	yes	yes	yes	no
Can be welded		if plated	yes	yes	yes	-
Can be soldered		if plated	yes	yes	yes	yes
Figure of merit	$\Omega \cdot W \cdot 10^9$	4.1	5.7	4.4	3.6	4.5

*Table A. *) This value is for nickel in its bulk condition. When sputtered, the temperature coefficient of resistance is typically reduced to between 0.4 and 0.5%/K.*

Fluid velocity
Minimum velocity

The lower velocity limit is defined by the onset of natural convection. If a probe is calibrated and used under the same orientation with respect to the gravity field, it may be used at even lower velocities.

The limit will then be reached when the natural convection overrules the forced convection. This happens when the Reynolds number Re becomes smaller than two times the Grashoff number to the power 1/3:

$$Re < 2 \cdot Gr^{1/3}$$

where Re = U·D/n and $Gr = g \cdot D^3 \cdot \beta \cdot (T_w - T_0)/\nu^2$. U is fluid velocity, D is sensor diameter, ν is kinematic viscosity of fluid, g is acceleration of gravity, β is coefficient of thermal expansion (equal to 1/T for a perfect gas) and $(T_w - T_0)$ is sensor over temperature. The limit may be reduced if the sensor over-temperature is lowered, as this will lower the Grashoff number.

Maximum velocity

Normally, wires and fiber film sensors are designed to withstand the aerodynamic loads occurring in practice, even at supersonic speeds. The upper velocity limit in the data sheet for wire and film probes is defined as the velocity that creates a stagnation temperature of 220°C on the sensor. Special probe designs may work up to considerably higher velocities.

Frequency limit in CTA mode

The frequency limit fc_{max} represents what may be expected when the probe is exposed to a velocity (normally 100 m/s in air) and operated in an optimally adjusted CTA anemometer (closed loop). For wire probes the bandwidth may be calculated directly from the square wave test as $(1.3 \cdot \tau)^{-1}$, where τ is the time between start and first zero crossing of the response curve.

The bandwidth of film probes is in theory limited only by the servo loop, as the thermal inertia of the thin-film sensor is neglectible. In practice, however, the bandwidth is determined by the damping effect of the backing substrate, the protecting quartz coating and the boundary layer flow.

The maximum bandwidths stated in the technical data for fiber and film probes in air are calculated from the square wave test as $(1.3 \cdot \tau)^{-1}$. The stated bandwidths serve as an indication of optimium adjustment of the servoloop rather than a measure of the real bandwidth.

In water the boundary layer over the sensor plays a predominant role, and in practice fiber and film probes never exceed bandwidths of more than 0.5 to 1 kHz in liquids. This is normally fully adequate because of the low frequency content of most liquid flows.

Secondary heat transfer through the substrate makes the amplitude characteristic of films probes non-linear at low frequencies (below 100 Hz).

Summary of Technical data

SENSOR TYPE	Sensor material	Sensor dimensions	Thichness of quartz coating	Sensor resistance R_{20} (approx.)	Temperature coefficient of resistance (TCR) α_{20} (approx.)	Max. sensor temperature	Max. ambient temperature	Max. ambient pressure	Min. velocity	Max. velocity	Frequency limit fmax (63% response)	Medium
Gold-plated wire sensors	Plated tungsten	5 µm dia. 1.25 mm long 1)	–	3.5 Ω	0.36%/K	300°C	150°C	– 2)	0.20 m/	200 m/s	90 kHz 5)	Air
Miniature wire sensors	Plated tungsten	5 µm dia. 1.25 mm long	–	3.5 Ω	0.36%/K	300°C	150°C	– 2)	0.20 m/s	500 m/s	150 kHz 5)	Air
Wire sensors for temperature measurements 3)	Platinum	1 µm dia. 0.4 mm long	–	50 Ω	0.35%/K	–	150°C	– 2)	–	60 m/s	2 kHz 6)	Air
Fiber-film sensors	Nickel	70 µm dia. 1.25 mm long 3)	0.5 µm	6 Ω	0.40%/K	300°C	100°C	–	0.20 m/s	350 m/s	90 kHz	Air
			2 µm	6 Ω	0.40%/K	60°C 7)8)	100°C	–	0.01 m/s	10 m/s	30 kHz	Water
Split-fiber sensors	Nickel	200 µm dia. 1.25 mm long	0.5 µm	6 Ω	0.40%/K	300°C	100°C	–	0.20 m/s	350 m/s	40 kHz	Air
Flush-mounting film sensors	Nickel	0.75 mm × 0.2 mm	0.5 µm	15 Ω	0.35%/K	200°C	100°C	70 bar	–	–	–	Air
			2 µm	15 Ω	0.35%/K	60°C 7)8)	100°C	70 bar 4)	–	–	–	Water
Glue-on film sensors	Nickel	0.9 mm × 0.1 mm	0.5 µm	15 Ω	0.40%/°C	200°C	120°C	–	–	–	–	Air

NOTES

1) Overall tungsten wire length is 3 mm. Wire ends are gold-plated to 25-30 µm dia., limiting sensor length.
2) Depending on type of mounting.
3) Overall fiber length is 3 mm. Fiber ends are gold-plated, limiting sensor length.
4) At 20°C, decreasing with increasing temperature, 1 bar at 80° (applies to probe design listed).
5) At 100 m/s.
6) Constant current mode.
7) At 1 bar atmosphere pressure
8) Max. 150°C at elevated pressure. Avoid bubble formation.

Quick guide to probe selection

Type of flow	Medium	Recommended probes
One-dimensional		
Uni-directional	Gas	Single-sensor wire Single-sensor fiber, thin coating
	Liquid	Single-sensor fiber, heavy coating
Bi-directional	Gas Liquid	Split-fibers, thin coating Split-fibers, heavy coating
Two-dimensional		
One quadrant	Gas	X-array wires X-array fibers, thin coating
	Liquids	X-array fibers, heavy coatings
Half plane	Gas	Split-fibers, thin coating
	Liquids	Split-fibers, heavy coating
Full plane	Gas	X-array, flying hot wire
Three-dimensional		
One octant 70° cone	Gas	Tri-axial wire Tri-axial fiber, thin coating
	Liquids	Tri-axial fiber, Special
90° cone	Gas	Slanted wire, rotated probe
	Liquids	Slanted fiber, heavy coating

Wall flows (shear stress)

One-dimensional

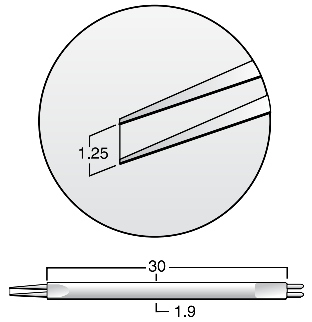
Uni-directional	Gas	Flush-mounting film, thin coating Glue-on film, thin coating
	Liquids	Flush-mounting film, heavy coating

Probes and probe supports

SINGLE-SENSOR PROBES WITH CYLINDRICAL SENSORS

Miniature wire probes

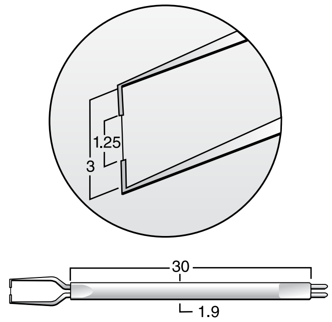
Plated tungsten wire, diameter 5 µm, length 1.25 mm.



MOUNTING: 4 mm dia. probe supports

Gold-plated wire probes

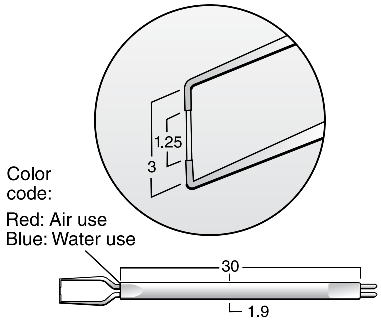
Plated tungsten wire, diameter 5 µm, overall length 3 mm, sensitive wire length 1.25 mm. Copper and gold plated at the ends to a diameter of approx. 15 µm.



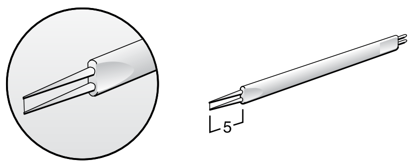
MOUNTING: 4 mm dia. probe supports

Fiber-film probes

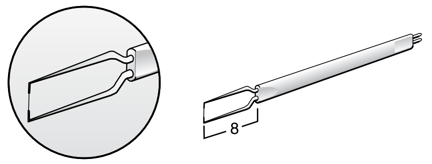
Nickel film deposited on 70 µm diameter quartz fiber. Overall length 3 mm, sensitive film length 1.25 mm. Copper and gold plated at the ends. Film is protected by a quartz coating approx. 0.5 µm or 2 µm in thickness.



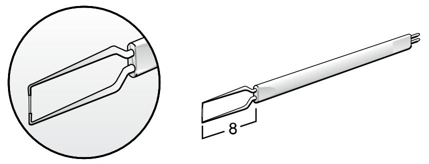
MOUNTING: 4 mm dia. probe supports



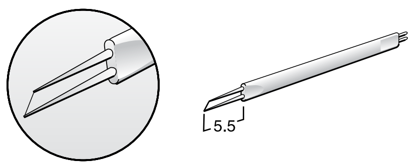
55P11 Straight general-purpose type



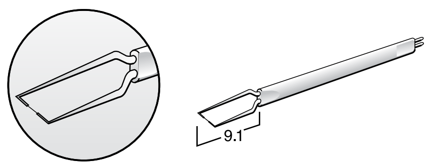
55P01 Straight general-purpose type



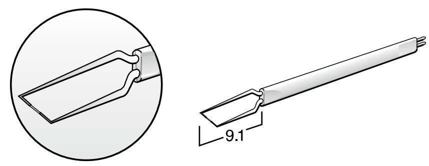
55R01 (0,5 µm coating) 55R11 (2 µm coating) Straight general-purpose type



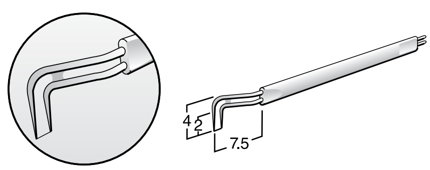
55P12 45° slanting sensor type



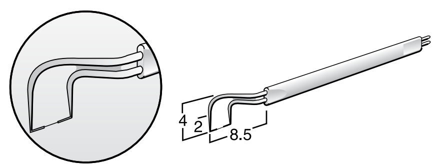
55P02 45° slanting sensor type



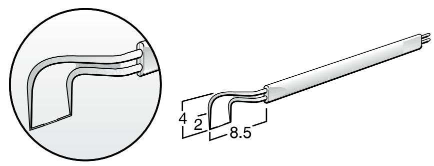
55R02 (0,5 µm coating) 55R12 (2 µm coating) 45° slanting sensor type



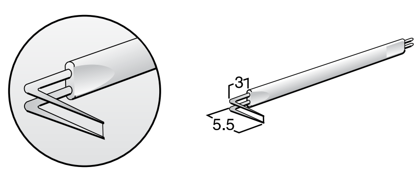
55P13 90° sensor parallel to probe axis



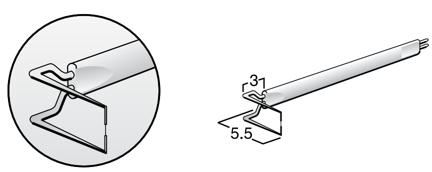
55P03 90° sensor parallel to probe axis



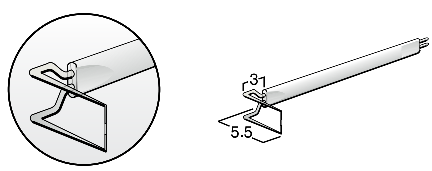
55R03 (0,5 µm coating) 55R13 (2 µm coating) 90° sensor parallel to probe axis



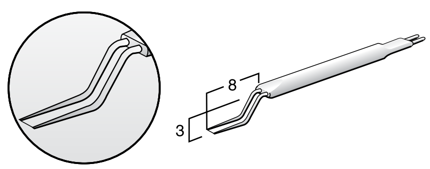
55P14 90° sensor perpendicular to probe axis



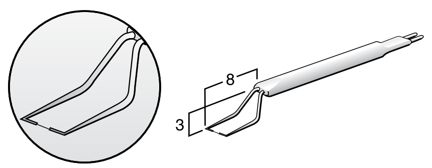
55P04 90° sensor perpendicular to probe axis



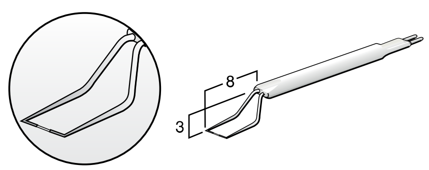
55R04 (0,5 µm coating) 55R14 (2 µm coating) 90° sensor perpendicular to probe axis



55P15 Boundary layer type



55P05 Boundary layer type

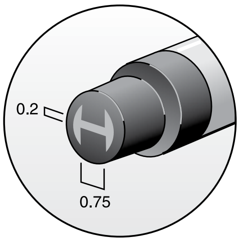


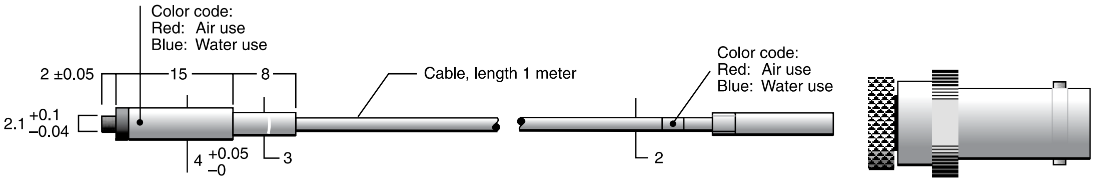
55R05 (0,5 µm coating) 55R15 (2 µm coating) Boundary layer type

All dimensions in millimeters.

SINGLE-SENSOR PROBES WITH NON-CYLINDRICAL SENSORS

Flush-mounting probes



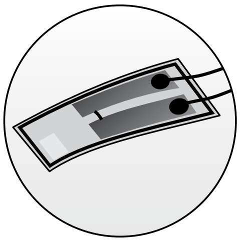


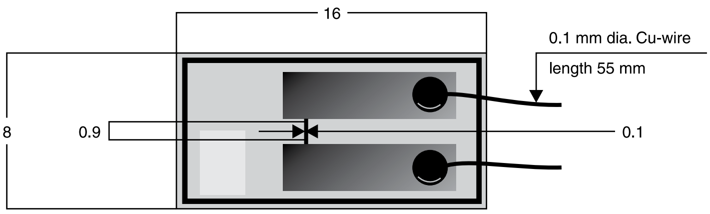
55R45 (0.5 µm coating)
55R46 (2 µm coating)

Nickel film deposited on the front edge of a cylindrical quartz rod. Approximate dimensions of film 0.2 x 0.75 mm. Film is protected by quartz coating approx. 0.5 µm or 2 µm in thickness.

MOUNTING: No probe support. Probe mounts in hole in wall confining flow to be investigated, with sensor flush with wall surface.

Glue-on probes





55R47 Glue-on Probe

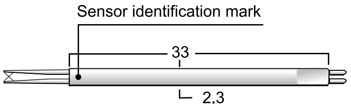
Sensor 0.1 x 0.9 mm nickel film deposited on a 0.05 mm thick polyimid foil carrying a 0.5 µm quartz coating. Probe is glued onto the wall, and cable leading to the anemometer is soldred onto the copper leads.

All dimensions in millimeters.

DUAL-SENSOR PROBES WITH CYLINDRICAL SENSORS

Miniature wire probes

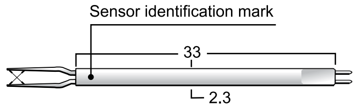
Pt-plated tungsten wire, diameter 5 µm, length 1.25 mm. Wire separation 1 mm.



MOUNTING: 6 mm-dia. probe supports

Gold-plated wire probes

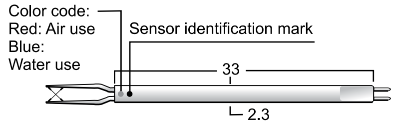
Pt-plated tungsten wire, diameter 5 µm, overall length 3 mm, sensitive wire length 1.25 mm. Copper and gold plated at the ends to a diameter of approx. 30 µm. Wire separation 1 mm.



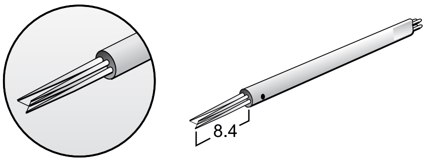
MOUNTING: 6 mm-dia. probe supports

Fiber-film probes

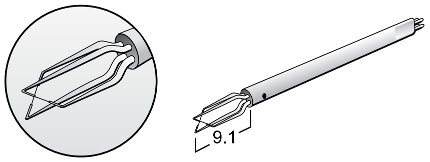
1.25 mm. Copper and gold plated at the ends. Film is protected by a quartz coating approx. 0.5 µm or 2 µm in thickness. Wire separation 1 mm.



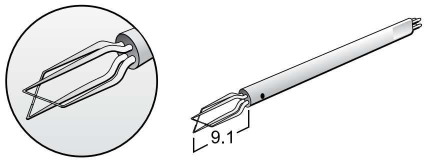
MOUNTING: 6 mm-dia. probe supports



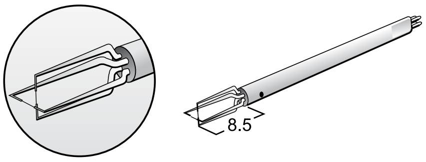
55P61 — X-array probe, sensor plane parallel to probe axis



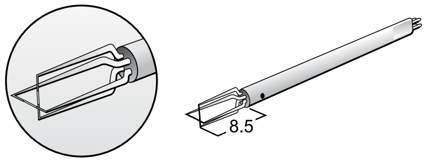
55P51 — X-array probe, sensor plane parallel to probe axis



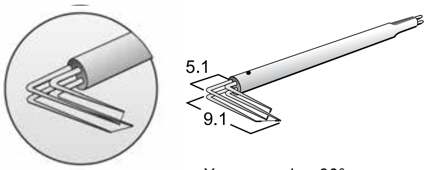
55R51 (0.5 µm coating)
55R61 (2 µm coating) — X-array probe, sensor plane parallel to probe axis



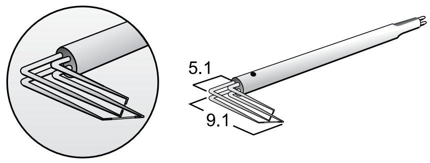
55P52 — X-array probe, sensor plane perpendicular to probe axis



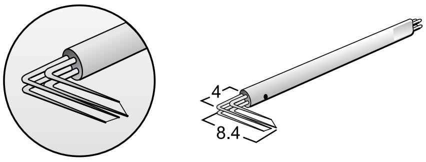
55R52 (0.5 µm coating)
55R62 (2 µm coating) — X-array probe, sensor plane perpendicular to probe axis



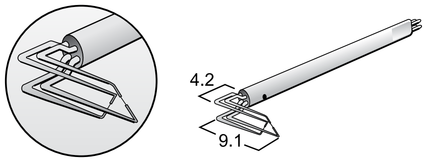
55P53 — X-array probe, 90°, sensor plane parallel to probe axis



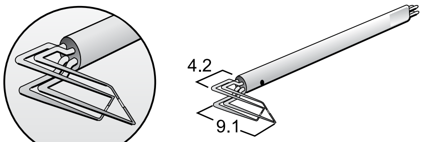
55R53 (0.5 µm coating)
55R63 (2 µm coating) — X-array probe, 90°, sensor plane parallel to probe axis



55P64 — X-array probe, 90°, sensor plane perpendicular to probe axis



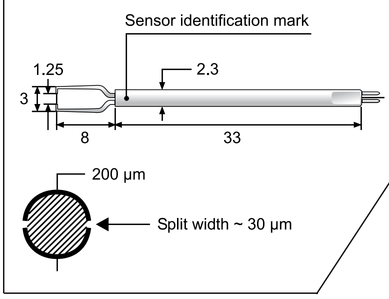
55P54 — X-array probe, 90°, sensor plane perpendicular to probe axis

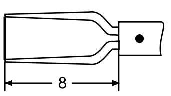


55R54 (0.5 µm coating)
55R64 (2 µm coating) — X-array probe, 90°, sensor plane perpendicular to probe axis

Split-fiber probes

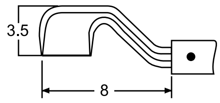
Nickel film is deposited on 200 µm dia. quartz fiber. Overall length 3 mm. Active sensor length 1.25 mm. The film is protected by a quartz coating approx. 0.5 µm.

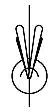




Split

55R55
Straight probe 0.5 µm coating

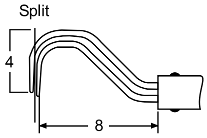


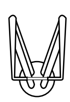


Split

55R57 90° probe
Sensor parallel to probe axis

Split



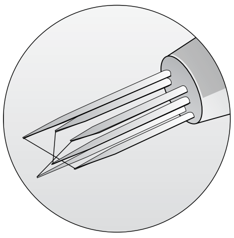


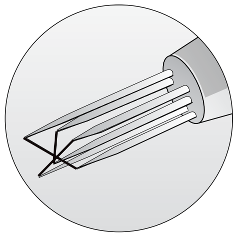
55R56 90° probe
Sensor perpendicular to probe axis

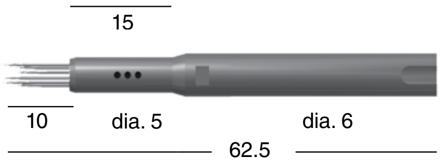
All dimensions in millimeters.

TRIPLE-SENSOR PROBES WITH CYLINDRICAL SENSORS

Triaxial Parallel-flow probe



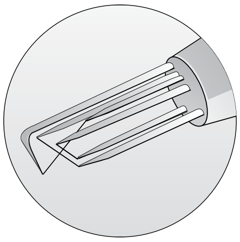


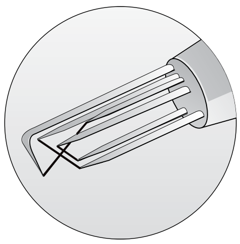


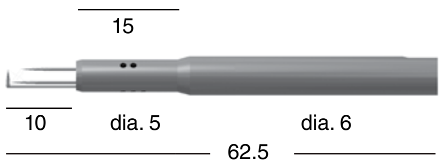
55P95 Gold-plated wire probe

55R94 water (2 µm coating)
55R95 air (0.5 µm coating)
Fiber-film probe

Triaxial Cross-flow probe





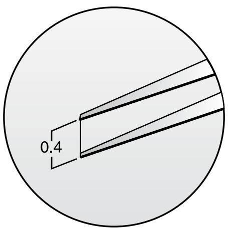


55R96 Fiber-film probe
55R97 Fiber-film probe

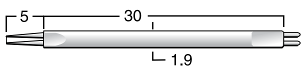
water (2 µm coating)
air (0.5 µm coating)

MISCELLANEOUS PROBES

Resistance thermometer



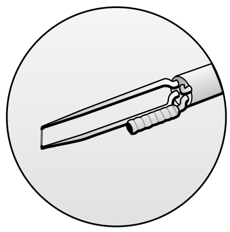
55P31 Straight probe



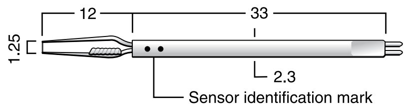
Sensor is 0.4 mm long 1 µm dia. platinum wire.

MOUNTING: 4 mm dia. probe supports.

Temperature-compensated minature wire probes



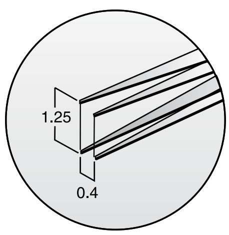
55P81



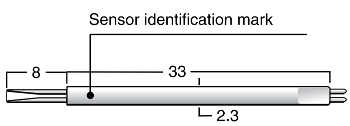
Straight type, velocity sensor perpendicular to probe axis; for velocity measurements at slowly varying medium temperatures. (Adjust automatically overheating ratio: approx. 0.8).

MOUNTING: 6 mm dia. probe supports.

Parallel-array probe



55P71 Straight probe



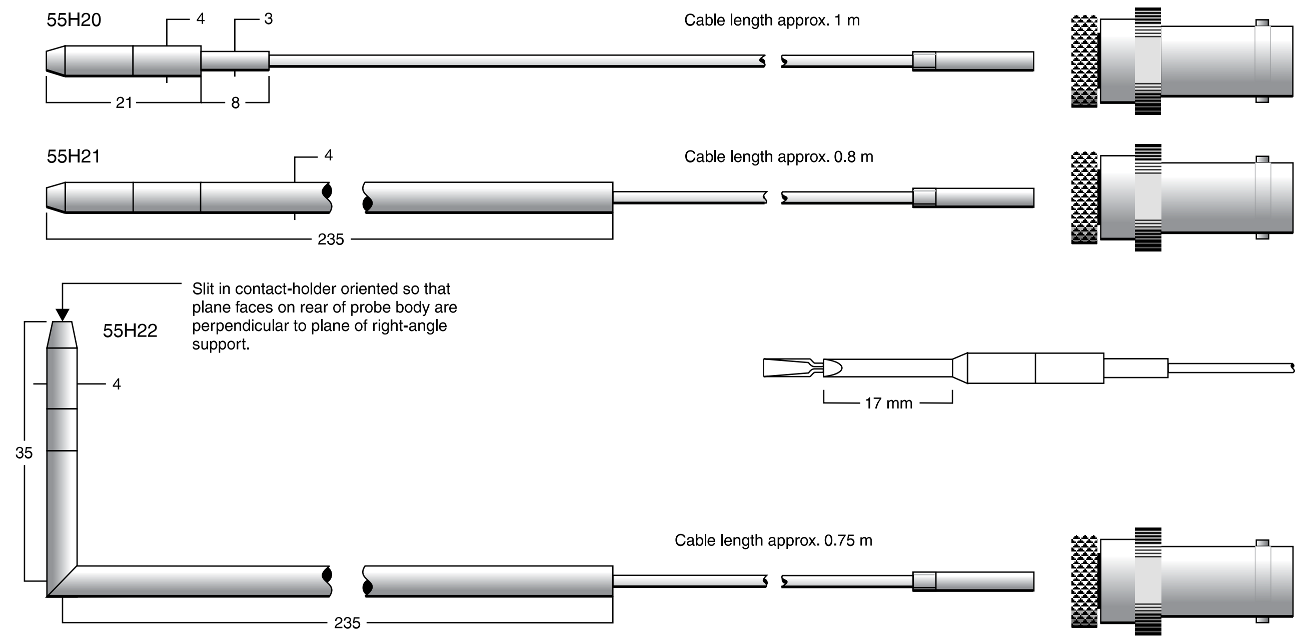
Sensors are 1.25 mm long 5 µm dia. Pt-plated tungsten wires.

MOUNTING: 6 mm dia. probe supports

All dimensions in millimeters.

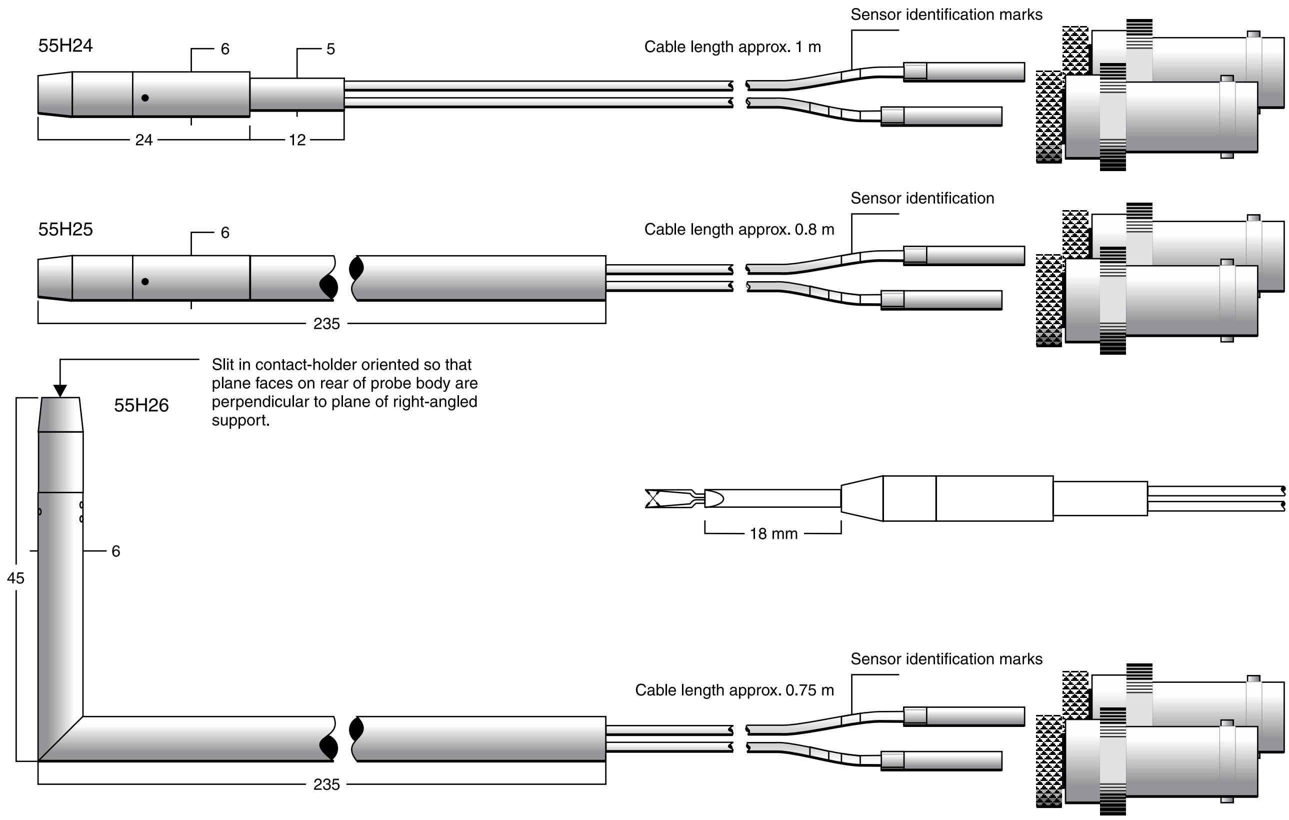
PROBE SUPPORTS

4mm dia. probe supports for single-sensor probes



The short 4 mm support (type 55H20) fits into both the 4 mm chuck and the 4 mm mounting tubes shown below.

6mm dia. probe supports for dual-sensor probes

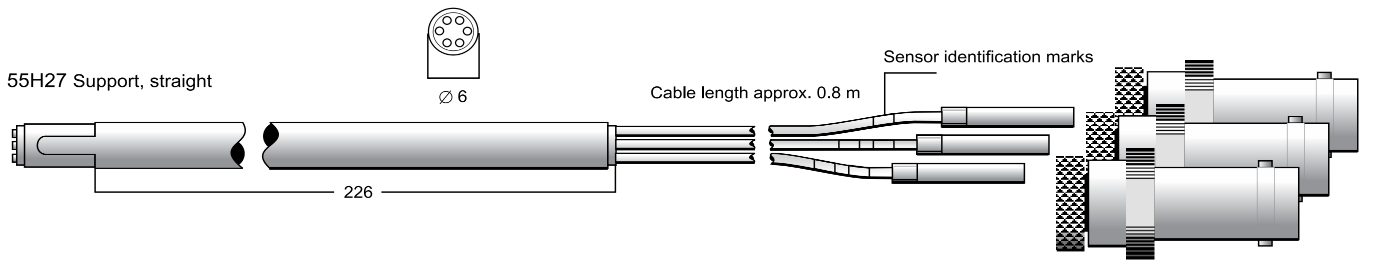


The short 6 mm support (type 55H24) fits into both the 6 mm chuck and the 6 mm mounting tubes shown below.

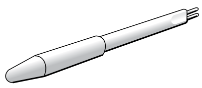
All dimensions in millimeters.

PROBE SUPPORTS

Probe supports for triple-sensors probes

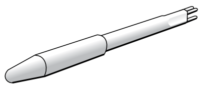


SHORTING PROBES



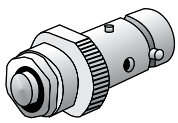
55H30

The 55H30 shorting probe is used for short-circuiting the 4 mm dia. supports in connection with measurements with single-sensor probes. Short-circuit resistance: R < 0.01 Ω.



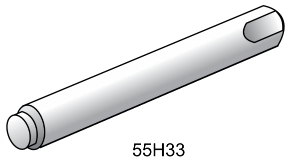
55H31

The 55H31 shorting probe is used for short-circuiting the 6 mm dia. supports in connection with measurements with dual-sensor probes. It contains two separate shorting loops. Short-circuit resistance: R < 0.01 Ω.



55H32

The 55H32 shorting probe is used for short-circuiting probe cables in connection with measurements with cable-equipped probes.
It is constructed as a modified BNC plug. Short-circuit resistance: R < 0.01 Ω.



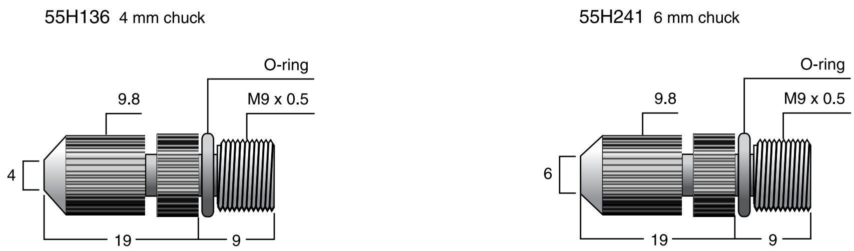
55H33

The 55H33 shorting probe is used for short-circuiting the triple-sensor probe support. Short-circuit resistance: R < 0.01 Ω.

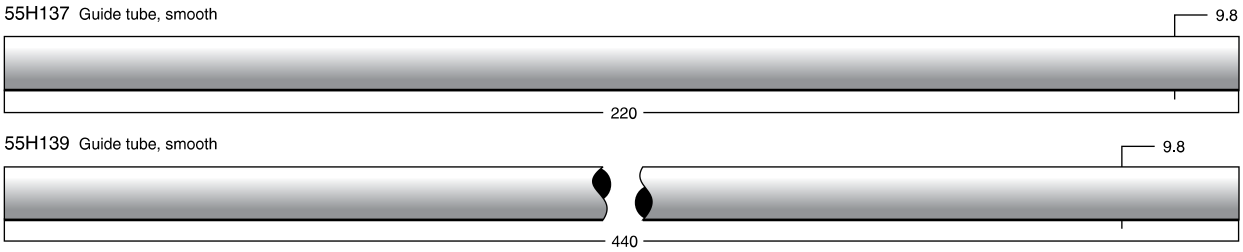
All dimensions in millimeters.

MOUNTING TUBES AND GUIDE TUBES

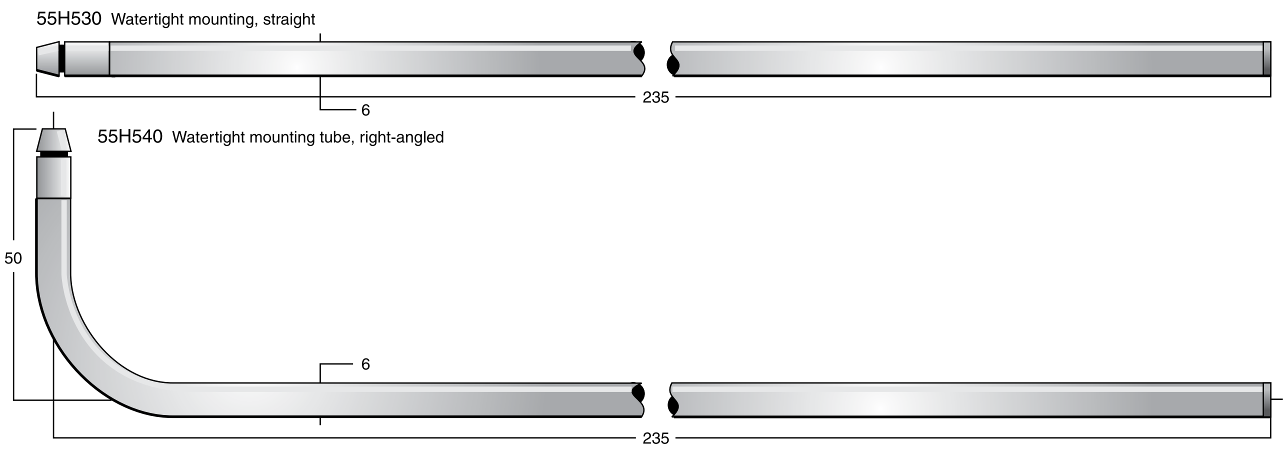
Chucks



Guide tubes



Watertight mounting tubes



All dimensions in millimeters.

Wires for probe repair

Spools of replacement wire of different materials and diameters and magazines with gold-plated wires are available, but must be ordered separately:

2 m of plated tungsten wire, 5 μm dia.	55A40
Wire magazine with 10 gold-plated wires, 5 μm dia.	55P157

Special probes

In addition to the extensive range of standard probes Dantec Dynamics offers probes and supports for special applications, specially designed to meet customers' requirements.

If you do not find the probe you need in the standard program, do not hesitate to contact your local Dantec Dynamics representative, who will help you to find a technical solution for your measuring problem.

In order to make a quotation for a special probe, Dantec Dynamics requires an outline indicating the critical dimensions and a short description of the application:

- parameter to be measured
- medium
- velocity range
- temperature range
- pressure range
- physical restrictions and constraints

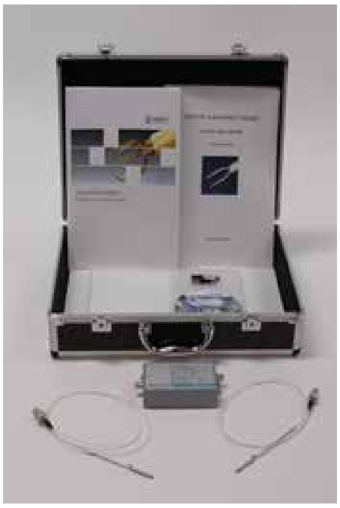
Hot-wire Anemometry systems

Dantec Dynamics has nearly 50 years of experience in making Constant Temperature Anemometers. The probes and anemometers have been designed for perfect matching.

The product programme comprises three lines of anemometers:

MiniCTA

- Cost effective miniature Constant Temperature Anemometer system for basic flow studies



The MiniCTA system is a versatile anemometer that can be used with Dantec Dynamics wire and fibre-film probes in airflows. It is especially suitable for basic flow diagnostics and its small size facilitates mounting close to the probe or even for it to be built into flow models. Quick calibration of probes is possible with an optional hot-wire calibrator.

Multichannel CTA System

- Efficient and affordable solution for mapping of velocity and turbulence fields in most air flows

The Multichannel CTA offers an efficient and affordable solution for mapping of velocity and turbulence fields in most air flows. Up to 16 points can be monitored simultaneously, reducing the need for traversing. A version with reference velocity transducer allows for simultaneous calibration of all probes in a wind tunnel. This means reduced experimental time and lower costs.

StreamLine Pro Research CTA system

- For high-precision CTA measurements

The StreamLine Pro system offers a complete concept of hot-wire anemometry for efficient, reliable and cost-effective flow analysis in air (or other gases) and liquids.

StreamLine is computer-controlled and is integrated with a fully automatic probe calibrator.

The system is designed for high-precision measurements and is Dantec Dynamics' top-of-the-line CTA anemometer.

CTA Calibration systems

StreamLine Pro Calibrator

- Automatic calibration of hot-wire probes

The StreamLine calibration system is intended for computer- automated calibration of probes in air from a few cm/sec up to Mach 1. The flow unit creates a free jet and requires air from a pressurized air supply.
The probe to be calibrated is placed at the jet exit. The optional pitch-yaw manipulator allows 2D and 3D probes to be rotated for calibration of directional sensitivity.

Hot-wire Calibrator

- Time-saving 2-point calibration of hot-wire probes

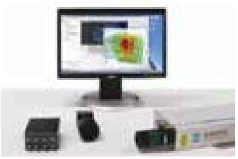
The Dantec Dynamics Hot-wire Calibrator is accurate, device for calibration of hot-wire probes in air from 0,5 m/s to 60 m/s. By combining calibration at just two velocities with a generic transfer function, a calibration function valid for the entire velocity range can be created.

The calibrator produces a free jet, where the probe is placed during calibration. It requires a normal pressurized air supply.

In addition to two-point mode, velocities in the entire range can be set manually.

About Dantec Dynamics

Dantec Dynamics is the leading provider of laser optical measurement systems and sensors. Since 1947 we have provided solutions for customers to optimize their component testing and products. Our large number of customers benefit from our quality solutions within:



Fluid Mechanics

Spray and Particle Characterization

Combustion Diagnostics

Microfluidics

3D Shape Deformation, Strain and Vibration Measurement

Strain and Stress Measurement

Non Destructive Testing

DISATAC Tachometers

Thermal Comfort

Worldwide representation

From our six offices and more than 30 representatives worldwide we approach our customers individually. We examine the specific needs and find the best solution for you. For us you are a long-term partner in improving efficiency, safety and quality of life. A list of representatives is available at our website.

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