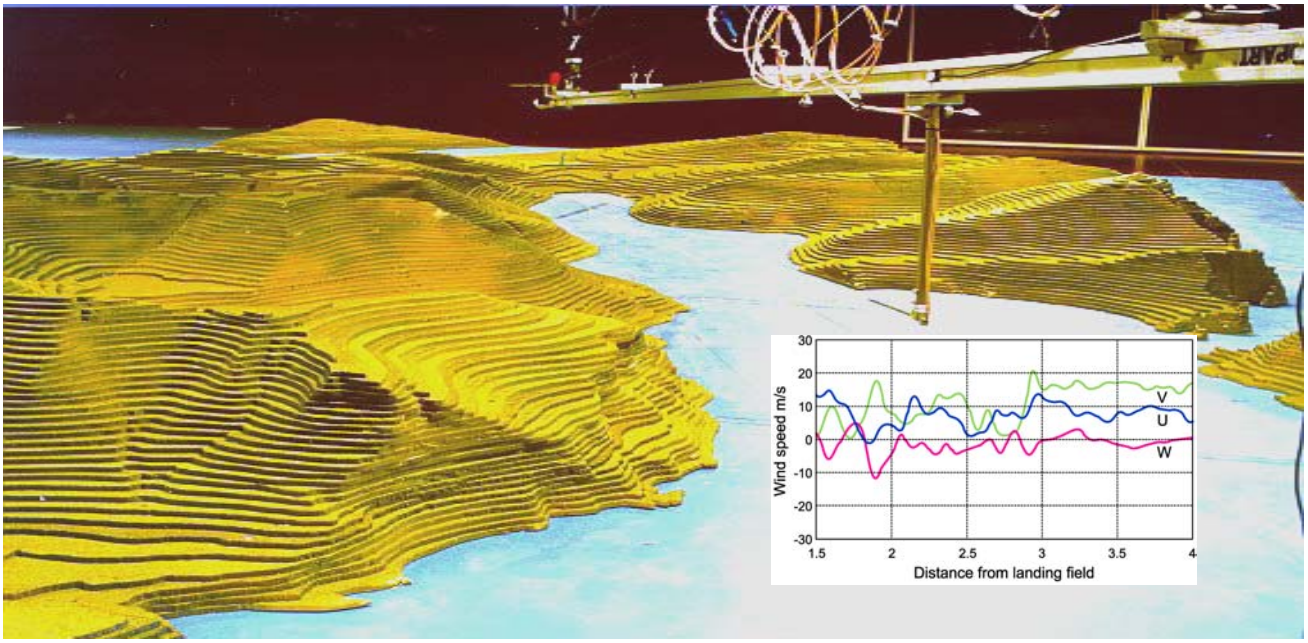
StreamLine CTA Anemometer System

Computer-controlled CTA anemometer with calibrator for advanced turbulence studies with hot-wire and hot-film probes



Investigation of wind conditions along the landing path on a model of Vagar Airport on the Faroe Islands using a flying Tri-axial hot-wire probe. Courtesy of the Danish Maritime Institute.

Applications

- Single- or multi-point measurements of velocity and turbulence.
- Measurement of fluctuating temperatures.
- Gas and liquid flows.
- Transient and cyclic flow phenomena.
- 1-, 2- and 3-velocity components.
- Both free-field and near-wall measurements.
- Internal flows.
- Boundary layer transition.
- Wall shear stress.

Features

- High temporal resolution. Fluctuations up to 450 kHz can be measured.
- High spatial resolution. Eddies down to fractions of a mm can be resolved.
- High dynamic range. Covers velocities from a few cm/s to supersonic.
- Real-time continuous output signal. Provides full information in the entire frequency range.
- Application software supports set-up, calibration, data acquisition and data reduction.
- Turbulence statistics in both amplitude and frequency domain based on velocity time series.

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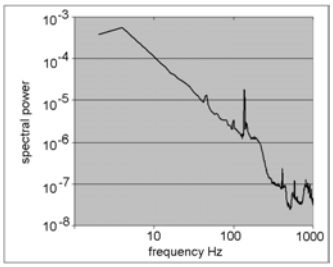
Introduction

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



Typical power spectrum measured with a hot-wire probe.

The hot-wire anemometer provides a continuous output signal, which is directly related to the instantaneous velocity acting on the heated sensor, normally a thin wire, placed in the flow. Conversion of the output voltage into velocity components is done on the basis of a velocity calibration and a directional calibration (in the case of two- or three-dimensional sensor arrays). Statistics in both the amplitude domain: *mean velocity, standard deviation of velocity fluctuations, Reynolds shear stresses etc.* and in the frequency domain: *power spectra etc*. are readily made in a computer on the basis of time series acquired via an A/D board.

The StreamLine system concept

StreamLine is an analogue anemometer system with computerised set-up supported by a data acquisition and data analysis software package. StreamLine combines the advantages of the classical high-quality hot-wire anemometer and the power of the PC and Windows graphical user interface. The system comprises:

- Frame with controller and temperature monitor
- CTA anemometer modules
- Automatic probe calibrator
- Temperature module (for fast fluctuations)
- StreamWare application software

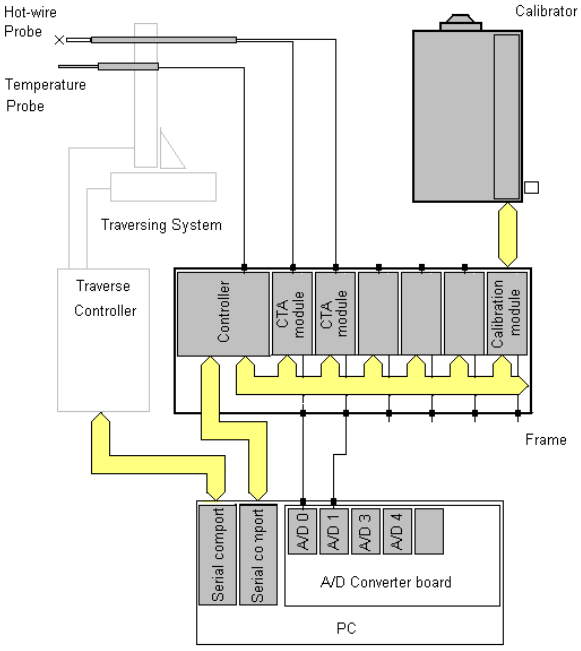
The automatic calibrator is an important part of the system as it facilitates fast and accurate probe calibrations prior to experiments. The calibrator also allows directional calibration of multi-sensor probes.

An optional temperature module is available for measurement of fast temperature fluctuations.

The complete system is operated by the StreamWare application software, which performs module set-up, automatic probe calibration, acquisition of data, data conversion and data reduction. Raw and reduced data can be presented in StreamWare or they can be exported to other applications (e.g. Excel and TecPlot®) for further manipulations.

The StreamWare software also controls a traverse system moving one or more probes through the area or volume under investigation.

StreamLine hardware

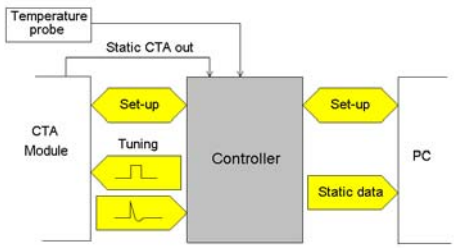


StreamLine system layout.

Frame with controller

The StreamLine frame contains 6 power supplies, a controller and slots for 6 modules (CTA, temperature or calibration modules).

Module set-up and temperature monitoring:



Controller functionality.

The controller manages communications between the hardware modules and the PC via a serial comport. A built-in microprocessor checks system functions and optimises set-up parameters. The processor has a high precision voltmeter function for measurement of output voltages from the modules via the serial comport.

The controller also includes a temperature circuit for a system temperature probe. It is used to monitor the ambient temperature during overheat set-up and data acquisition. The ambient temperature is then used by the application software to correct the anemometer voltages before conversion.

A software-based square-wave generator makes it possible to optimise the bandwidth of the CTA modules by applying a voltage perturbation to the CTA bridge and analyse the overall system response. It also allows a check of the dynamic behaviour of the system under different set-up and flow conditions.

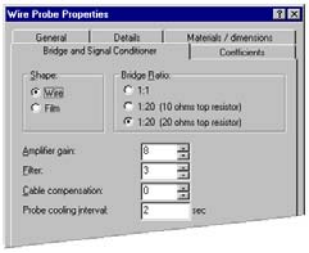
Separated low-noise power supplies:

The quality of the power supplies determines to a great extent the quality of the output signal from the CTA with respect to electronic noise. The power supplies in the frame are galvanically separated in order to minimise the noise and prevent cross-talk between modules, which is especially important in low-turbulent flows.

CTA anemometer module with signal conditioner

The anemometer module contains a high-performance constant temperature anemometer circuit with three bridge configurations and a signal conditioner for signal filtering and amplification. The module is designed to operate all Dantec Dynamics probes with cable lengths up to 100 m. All adjustments are done from the software.

CTA bridges for general-purpose, high-frequency and high-power applications:



Bridge selection via StreamWare dialogue

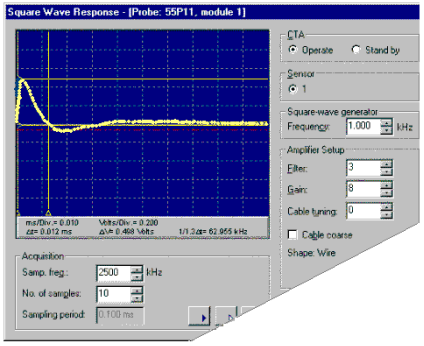
The CTA module contains three bridge configurations, all selectable from StreamWare.

The general-purpose bridge (ratio 1:20) has a 20 ohms top resistor and is designed for wire and film probes in almost all applications. It can be used with 5 and 20 m cables respectively, with cable compensation circuits tuneable from the software.

The general-purpose bridge can be switched into high-power mode by selecting a 10 ohms top resistor instead of the default 20 ohms. In this way e.g. film probes in water at high velocities are supported.

The 1:1 symmetrical bridge gives highest system bandwidth and lowest electronic noise. It is also intended for applications with slowly varying temperatures in combination with temperature-compensated probes. It is also needed when the set-up includes long cables (up to 100 m) or high-resistance probes.

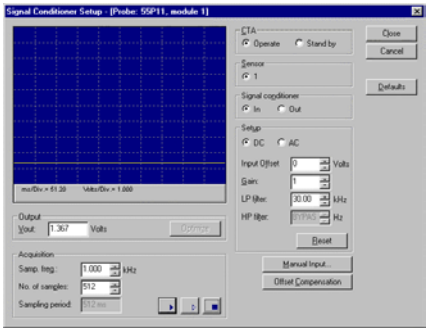
Computerised CTA set-up with transparent fine tuning:



Optimisation of bandwidth by means of voltage perturbation (square-wave test)

The CTA set-up is automatically done by StreamWare on the basis of default values for the actual probe stored in the probe library in StreamWare. Fine tuning of bridge, servo-amplifier and cable compensation can all be performed by the user, who has full access to all functions via software dialogue boxes.

Programmable signal conditioner:

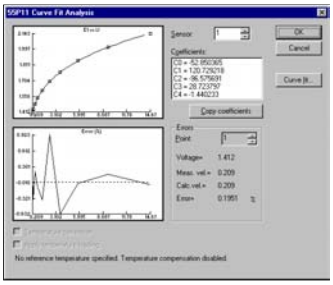


Optimisation of offset and gain in a low-turbulent flow.

Each anemometer module incorporates a programmable signal conditioner with offset and gain and high-pass/low-pass filters. With an offset resolution off less than 1 mV and a gain up to 1024, signals from even very low turbulence may be adapted to the A/D converter input range. The low-pass filter ensures proper anti-aliasing filtering in order to prevent folding back of high-frequency noise in power spectra.

Calibration system

StreamLine's automatic calibration system is designed for calibration of wire and film probes in air at velocities from a few cm/s up to Mach 1. The probe is placed in a free jet with a flat, low-turbulent velocity profile during calibration. The velocities are controlled from StreamWare.



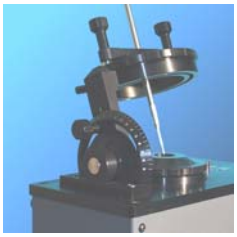
StreamLine calibration system.

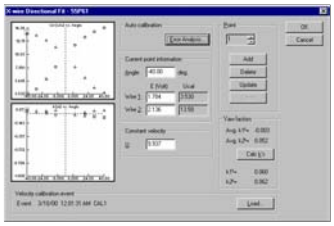
The system consists of a calibration control module placed in the StreamLine frame and a separate flow unit, which creates the free air jet used as the velocity reference. The flow unit contains a set of control valves, pressure and temperature transducers and a settling chamber with an exchangeable exit nozzle. Four nozzles cover the entire velocity range. It operates on compressed air, but it can be programmed to work with other gases too.

Traceable velocity calibration via built-in transducers:

The velocity calculation is based on the equation of a polytropic expanded gas. The necessary input parameters are measured with high-precision transducers for absolute pressure, differential pressure and temperature respectively. These transducers all have individual calibrations traceable to accredited laboratories.

Pitch-yaw manipulator for directional calibrations:





Pitch-yaw manipulator allows probe rotation around 2 axes.

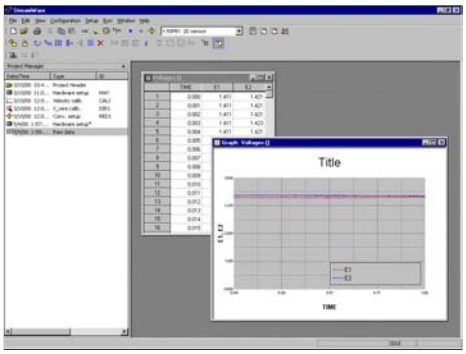
The pitch-yaw manipulator is intended for directional calibration of X-array and Tri-axial probes. By rotating the probe, while it is exposed to a constant velocity, and comparing its response with the actual velocity components, StreamWare calculates the yaw and pitch correction factors. Individual directional calibration improves the accuracy when probe voltages are decomposed into velocity components.

Temperature module for fast-fluctuating temperatures

The temperature module is intended for measurement of fast temperature fluctuations with wire probes of diameters down to 1 µm. It delivers a constant current adjustable between 0.1 and 5 mA through the wire and offsets, amplifies and filters the output voltage, which is a linear function of the flow temperature. The output is acquired by StreamLine and can be analysed individually or correlated with velocity fluctuations measured with an ordinary hot-wire.

StreamWare application software

StreamWare offers a complete software platform in Windows environment that helps you design, organise and document your measurements and results.



StreamWare graphical user interface with Project Manager.

Database organised measurements and results:

With StreamWare the measurement situation is described in a dedicated database. StreamWare performs the complete task from configuration and experiment layout to acquiring, reducing and storing data.

Default set-up parameters related to the actual probe are stored in dedicated libraries, as are drivers for a number of A/D boards and a traverse system. StreamWare communicates with StreamLine and a possible traverse system via serial comports, while analogue data are acquired via an A/D board.

All set-ups, calibrations, experiment layouts and raw and reduced data are stamped into a project manager, which puts you into full control and ensures traceability of results.

Expandability:

StreamWare contains drivers for the most commonly used A/D boards and for an external data analysis package delivered together with StreamWare. If you want to use non-supported boards, a programmer's toolkit is available, which can be used as a template for writing your own drivers for A/D boards, traverse systems or data analysis.

Graphical hardware configuration and set-up:

The hardware configuration is created graphically on the computer screen. The probe library delivers default set-up parameters for the CTA module inclusive signal conditioner, which may optimised individually if need be.

Velocity and directional calibrations:

It is normal routine to calibrate the probe before and after an experiment. StreamWare supports automatic velocity calibration and curve-fitting used for converting CTA output voltages into velocities.

X-probes and Tri-axial probes can be calibrated for directional sensitivity, i.e. individual yaw and pitch constants are measured on the basis of a direct calibration over a specified angular range.

On-line data acquisition and data analysis:

An on-line facility working as an oscilloscope helps to determine the proper set-up of data acquisition sequences.

Default experiment set-up:

A default experiment loop makes it easy to get started. It contains set-up of anemometer and signal conditioner, movement of the probe and acquisition of data. Finally, data are reduced in accordance with a predefined scheme utilising the actual probe calibration. When the default set-up is defined, it is saved into the project manager, from which it can be started and re-used as need be. Data are then stored with headers pointing to the default experiment set-up.

Advanced experiment set-up:

It is also possible to design more advanced experiments with conditional sampling, waiting loops, exchange of data with other equipment etc.

Data conversion and reduction:

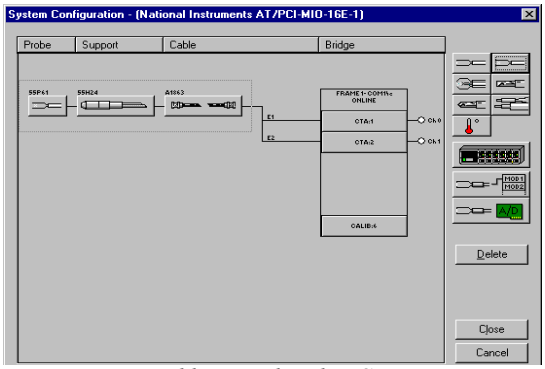
Raw data are converted into velocity samples and further decomposed into velocity components in the case of multi-sensor probes. Data reduction comprises analysis in both the amplitude and the time (spectral) domain selected in a data reduction dialogue box. Reduced data are stored separately and are always available for graphical presentation.

Correction for ambient temperature changes:

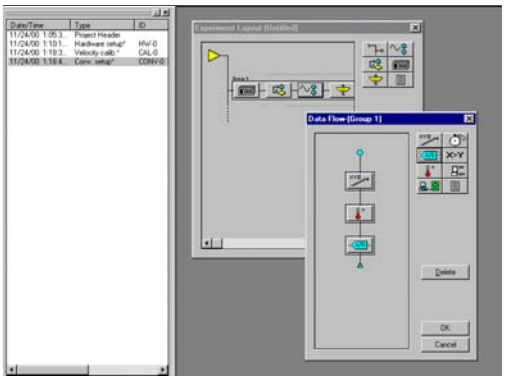
StreamWare contains routines for temperature correction of raw data, prior to linearisation, based on temperature input from the system temperature probe. As the ambient temperature often varies during an experiment, this is an important feature that improves the overall measurement accuracy significantly.

Data export and data presentation:

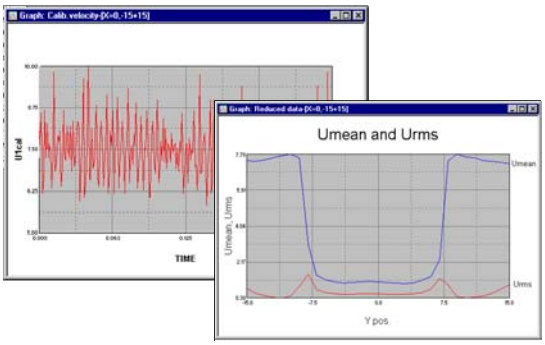
Data can be exported to other applications for further analysis or for advanced graphical presentation (TecPlot®).



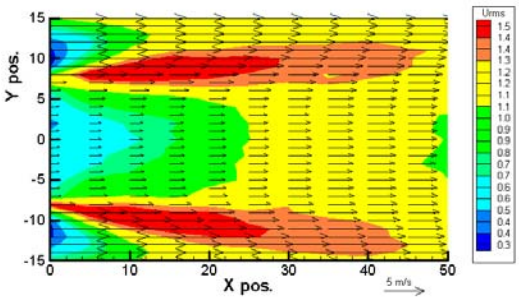
Hardware set-up is quickly completed in StreamWare's environment.



Experimental set-up is designed on-screen before execution



Time series are reduced into mean velocity and rms of velocity fluctuations (flow behind circular cylinder).



Same data exported to TecPlot for 2-D presentation.

Completing the measuring chain

Precision-engineered probes, probe supports and traversing systems will enhance measurement quality.

Thin-film probes are produced in Dantec Dynamics' own clean room facilities.

Probes

Dantec Dynamics' standard programme of wire and film probes covers most applications in flow measurements.

Hot-wire probes, ideal at high frequencies:

Dantec Dynamics' hot-wire probes are very compact. Small sensor size ensures high spatial resolution, low flow interference and fast response. The wire, typically made of tungsten, 5 µm in diameter and 1.2 mm long, is mounted on needle shaped prongs embedded in ceramic tubes with gold-plated connector pins. Tungsten combines high sensitivity with electrical stability and superior mechanical strength. It can be used for flows from a few cm/s up to supersonic and withstand ambient temperatures up to 150 °C. Wires with gold-plated ends are available for high-turbulence applications. Wire probes all require a support in order to be electrically connected to the anemometer.

Film and fibre-film probes for gases and liquids:

Film and fibre-film probes are used in gas flows containing some contamination or in liquid flows. The sensors are nickel thin films protected by a thin quartz coating against wear, oxidation and analysis. The frequency response of thin-film probes is below that of wires. Fibre-film probes require supports, while film probes have fixed cables with BNC connectors.

Multi-array probes for 2- and 3-dimensional flows:

Hot-wire and fibre-film probes are also available with X-arrays or Tri-axial (orthogonal) arrays for measurement of velocity components in 2- and 3-dimensional flows.

Probe supports, mounting tubes and cables:

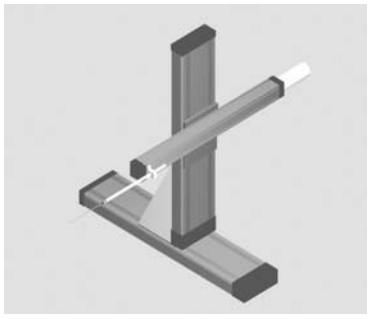
Probe supports connect the probe electrically with the CTA module while supporting them mechanically. They are available for 1D, 2D and 3D probes in straight and right-angle bent versions. The can be extended by means of mounting-tubes made of stainless-steel.

It is important to select the proper cable for connecting the support with the CTA module as it has to match the servo-loop set-up with respect to impedance and inductance. It is therefore strongly recommended to use standard probe cables from Dantec Dynamics.

Special probe service:

Dantec Dynamics can also offer special probes and supports for unique flow situations in accordance with customers' specifications. Contact your Dantec Dynamics representative for more details on special probes or consult our home page: www.dantecdynamics.com.

Traversing systems



3D traverse with support for a hot-wire probe.

Dantec Dynamics offers traversing systems that can move the probe in one, two or three directions in a predefined traverse grid with fraction-of-a-millimetre accuracy. The traverse may be equipped with a probe rotation unit that also allows probes to be rotated. The rotation may be needed in order to obtain proper alignment of the probe with respect to the flow.

Main specifications:

StreamLine hardware:

Frame		
No. of modules	6 per frame. Up to 3 frames are supported by StreamWare	
No. of channels	Depends on selected A/D converter	
Range of temp. probe	0 to 150 °C ±0.5°C	
Response of temp. probe	Approx. 1 s, depending on velocity	
Square-wave test generator	0.15 to 50 kHz. 20 MHz samples/s digitizer.	
Resolution of voltmeter function	0.08 mV	
Communications protocol	RS232, 9600 baud	
CTA module		
Anemometer		
Output voltage	0 to 10 V	
Equivalent input amplifier noise	1.8 nV/√Hz typical	
Equivalent amplifier input drift	0.5 µV/°C typical	
Accuracy of resistance measurement	0.1%±0.01 Ω	
Frequency response shaping	Wire and film probes	
Bridge	**1:20**	**1:1**
Probe current	830 mA max. (at 10 Ω top res.)	450 mA max.
Max. bandwidth	250 kHz typical	450 kHz typical
Operating resistance	2 to 64 Ω	-
Bridge top resistance	10 or 20 Ω	20 Ω
Probe cable length	5 or 20 m	100 m maximum
Accuracy of overheat resistor	0.1%	-
Signal conditioner		
Gain	1 to 1024 with 0.15% accuracy	
Input offset	0 to 10 V ±0.15%, <1 mV resolution	
Upper frequency limits	>1.2 MHz at Gain 1 >500 Hz at Gain 128 >250 kHz at Gain 1024	
Low-pass filter settings	0.3, 1, 3, 10, 30, 100, 300 kHz ±5%, -60 dB/decade	
High-pass filter settings	10, 100 Hz ±10%, -20 dB/decade	
Equiv. input noise	35 nV/√Hz, typical for all gains	
Equiv. input drift	20 µV/°C – eliminated by automatic offset adjust function	
Output voltage (load >10 kΩ)	-10 to +10 Volts, 50 Ω input impedance	
Output offset adjustment	0 to 5 V ±0.1%, <0.5 mV resolution (input AC coupled)	

StreamLine hardware:

Temperature module	
Probes	55P31 Temperature probe with 1 µm Pt
Probe current	0.1, 0.2, 0.5, 1.0, 2.0 and 5.0 mA
DC offset	10 V adjustable with 10 turns
Gain	1 to 8000 in 16 steps
High-pass filter	0.1 and 1 Hz
Low-pass filter	1 and 3 kHz

Calibration system	
Velocity range	0.02 m/s to Mach 1 using 4 nozzles
Accuracy (2 sigma)	<±1% o.r. ±0.02 m/s, typically <±0.5%
Reproducibility	<±0.2% o.r. ±0.02 m/s
Turbulence intensity	<0.3% in entire range, typically <±0.2%
Test section	Free jet
Nozzle diameters	0.02 to 0.5 m/s: 63 mm 0.5 to 60 m/s: 12 mm 5 to 120 m/s: 8.7 mm 5 to 300 m/s: 5 mm
Air supply	Compressed air at 0.7 to 0.9 MPa
Air consumption	0.2 to 26 m^3/h

StreamWare software

Processor	PC with Pentium II/III. Minimum 233 MHz for Win 95/98 Minimum 300 MHz for WIN NT/2000
Bus structure	Must match the selected A/D board
Free space required	40 Mb for StreamWare software and data
RAM	64 Mb minimum, 128 Mb recommended
Interface	One RS232 serial comport for each Frame and for each 3-DTraverse (if a traverse system is used). Probe rotation in addition to 3-D traverse requires separate comport.
A/D converter boards supported	Contact Dantec Dynamics or visit our website for further information

Ordering information

StreamLine hardware

Model	Description
90N10	StreamLine main frame incl. serial controller, comprising: 90P10 Temperature probe, 90B10 Null modem cable and practical guide: "How to measure turbulence with hot-wire anemometers"
90C10	StreamLine CTA module with signal conditioner and two 06A1863 coaxial 4 m BNC/BNC cables.
90C20	Temperature module for StreamLine with two 06A1863 coaxial 4 m BNC/BNC cables.
90H10	StreamLine calibration system, comprising 90H01 calibration module, with 5 m calibrator inter-connecting cable, 90H02 StreamLine flow unit with 4 nozzles
90H03	StreamLine pitch/yaw/roll manipulator
5278S01	Motorised pitch-yaw manipulator for 90H10 StreamLine calibration system. Please add 41T71 or 41T68 2D controller
90H04	Air purifier filter unit for StreamLine calibration system, incl. 10 m air hose.

StreamWare software:

Model	Description
90S10	StreamWare 3.0 software incl. two dongles, manual and installation CD-ROM.
46S26	Programmer's Toolkit for StreamWare, version 3.0. Requires C++ programming tools.
80S49	Data loader for TecPlot. Requires TecPlot 7.5 or higher (not included)

Probes and supports:

Please refer to the on-line probe catalogue on www.dantecdynamics.com.

Traverse systems:

Please contact your local Dantec Dynamics representative for more details.

Dantec Dynamics undertakes a continuous and intensive product development programme to ensure that its instruments perform to the highest technical standards. As a result, the specifications in this document are subject to change without notice.

Complete 3-channel StreamLine system with calibrator and StreamWare application software.

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