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GE330
3/17/03

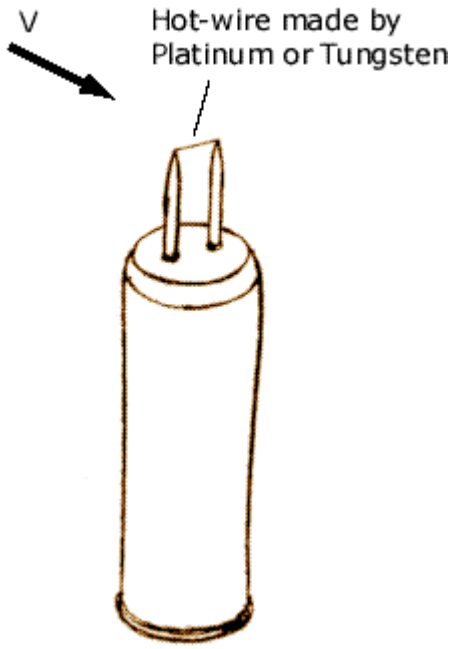
Sensor Report: Hot Wire Anemometers

Introduction

Anemometry is the measurement of gas speeds, and a variety of different sensors have been developed to accurately provide these readings. Some common anemometer devices included the rotating cup type seen for meteorological measurements and the pitot tube that indirectly measures speed from the reading of stagnation pressure. However, a common sensor in industrial processes for measuring air flow in space or through a duct is the hot wire anemometer. It uses principles from electrical circuits, heat transfer, and fluid dynamics to compute an air speed or mass flow based on geometric constraints. For this reason, hot wire anemometers are also called thermal mass flow sensors.

Theory of Operation

A hot wire anemometer operates by using known fluid dynamic and heat transfer relationships to calculate the air velocity based on the amount of power dissipated in the wire. The wire is either supplied constant current or controlled to operate at a constant temperature. The amount of energy lost can be calculated from the temperature change in the constant current case, or the current change in the constant temperature change. The amount of heat dissipated by convection from the wire is a known function of velocity of the surrounding air.



The wire material is typically platinum or tungsten that is 4-10μm in diameter and about 1 mm in length. Performance of typical commercially available hot-wire anemometers can be characterized by their frequency response. Usually, they have a flat frequency response (< 3 dB) up to 17 kHz at the average velocity of 9.1 m/s (30 ft/s), 30 kHz at 30.5 m/s (100 ft/s), or 50 kHz at 91 m/s (300 ft/s). Because of the small size of these devices, they are fragile and typically only suitable for clean gas flows.

When to use

The main reasons to select a hot wire anemometer versus other anemometers and gas flow measurement devices include a relatively flat frequency response and good spatial resolution due to the probe's small size. The limitations for these devices include the need for clean operating conditions due to their delicate nature, and frequent calibration if contaminant and dust buildup occurs over time. In addition, relative to other pressure sensing or mechanical anemometers, hot wires have significantly higher cost.

Sources

Because of their wide usage for testing and industrial applications, hot wire anemometers are available from many different vendors. Some sources found using a quick internet search include:

- Kurz Instruments
- Dantec Dynamics
- Cambridge Accusense
- Extech Instruments
- Elridge products

Because of the complexity of the control, sensing, and analysis required to obtain accurate data from a hot wire anemometer, the devices are typically sold as complete packages that include the probe and a local analyzer/transmitter. The cost for a simple probe and handheld readout begins between $300-400. Kurz seems to be the largest supplier offering a wide range of sensors for both handheld testing and industrial use.

Interfacing

There are several different interfacing options when using a hot wire anemometer because of the variety of different handheld readout and transmitters available. Nearly all common interfacing options can be found among the vendors listed above. The typical complete systems contain a microprocessor in a local handheld or field device to connect to the probe, control its operation, perform calculations, and read out the measurements. These systems typically use an external serial RS232 or RS485 communication protocol. The channel can be used to control the microprocessor and probe remotely. More commonly, the communication channel is used to output sampled sensor readings to a PC, PLC, DSP, etc. Other common options include a 4-20mA or 0-10V output signal. This analog output would need to be connected to an A/D converter to be read by an external processor. Finally, some other proprietary bus communication options also exist including Modbus and Profibus for interfacing with industrial PLCs. In all cases, one would need to consult the detailed information that comes with the particular sensor system to determine the maximum data transfer rate, required conversions and scaling,

and what information is available for the chosen interface option. Although single probes are available, it is probably not practical to attempt to interface with them directly due to their complexity. The probe must be controlled to either a constant wire temperature or constant wire current. Appropriate reading of the sensor current and temperature must be taken. Then the energy balance calculations based on the probe specifications and calibration conditions must be performed to find the velocity.

Typical specifications

	Handheld/Economy	**Industrial Grade**
Measurable velocities	0.2-20 m/s	0.2-90 m/s
Operating temperature ranges	0-50 °C	-40-200 °C
Accuracy	± 3%	± 1%
Time constant	200 ms	100 ms
Interfacing options	Handheld reader, RS232	RS232, RS485, 0-10V, 4-20 mA, Modbus, Profibus, etc.

References and Useful websites:

Summary and theory of operation:

http://www.efunda.com/designstandards/sensors/hot_wires/hot_wires_intro.cfm

Vendors and technical documentation:

http://www.kurz-instruments.com

http://www.dantecmt.com/Literature/Index.html

http://www.extech.com/Products/ExtechProdset.html

http://www.trirep.com/cambrdg.htm

http://www.sksato.co.jp/english/text/7673-00.html

http://www.epiflow.com/9000.html

Attached is a specification package for one of the Kurz instrument devices.

SERIES

410

INSERTION MASS FLOW ELEMENTS

CERTIFIED ISO 9001 QUALITY

KURZ INSTRUMENTS INC.™

SERIES 410 INSERTION MASS FLOW ELEMENTS

DESCRIPTION

Series 410 represents the Kurz family of clean gas, industrial single-point Insertion Mass Flow Elements for air and other non-combustible gases. It uses the new "CD" Fast Dual-Sting Ceramic Duraflo™ sensor. The "CD" sensor has the fastest response to velocity and temperature changes available. The sensor support is 316L Stainless Steel, 0.25" diameter and may be ordered in 3", 6", 12", 18", and 24" lengths. The Series 410 may be inserted into pipes and ducts having an I.D. of 1.5" or larger. A painted NEMA 4 aluminum enclosure is directly attached to the end of the sensor support. The sensor electronics operates as a two-wire loop-powered device.

The 410 uses our latest sensor electronics which includes sensor lead resistance compensation and sensor power and temperature limiting circuitry. It is normally powered with 24VDC by one of the Series 155 Mass Flow Computers.

The Series 410 with a Series 155 Mass Flow Computer provides the most versatile, reliable, accurate and easy-to-use Thermal Mass Flow Meter available today.

Get the "Smart" solution - get Kurz!

PRINCIPLE OF OPERATION

The Series 410 uses the well-known Kurz thermal convective mass flow measurement technology, using constant temperature anemometry with the new "CD" Fast Dual-Sting Ceramic Duraflo™ Sensor. The "CD" sensor has the fastest response to velocity and temperature changes of any commercially available industrial thermal mass flow sensor.

APPLICATIONS

- Clean Industrial and Process Gas Mass Flow
- Combustion Air Flow Rate
- HVAC Air Flow Measurement
- Research and Development
- NIST Traceable Air Velocity Calibration Standard
- Air Sampling and Industrial Hygiene Studies
- Stack Mass Flow Monitoring

KEY FEATURES

- Exceptional accuracy
- 0 to 18,000 SFPM
- Process temperature rating of 200°C
- Pressure and temperature compensated
- Simple, low cost installation
- Fast response to velocity (100 ms)
- Fast response to temperature (500 ms)
- Outstanding repeatability (.25%)
- Two-wire, loop-powered
- Attitude insensitive
- Lead length independent sensor electronics
- Specified accuracy over a 200°C temperature range
- NEMA 4 (IP66) electronics enclosure
- Meets NASA shock and vibration criteria
- Demonstrated 700:1 velocity turn-down ratio
- Laboratory or correlation velocity calibration
- 150 PSIG process pressure rating

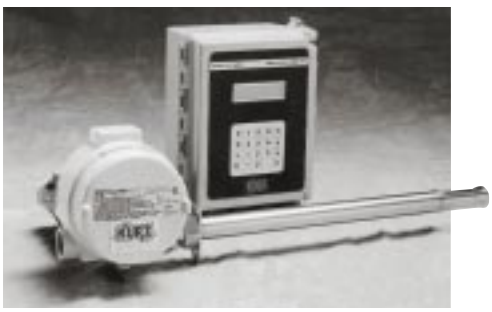
OUR MISSION

To manufacture and market the best thermal mass flow meters available and to support our customers in their efforts to improve their business.

"CD" Fast Dual Ceramic Duraflo™ Mass Flow Sensor

OUTPUT CHARACTERISTICS

The current output is normally converted to a voltage by means of a precision resistor. The resulting signal is about 1-3 VDC. NIST traceable calibration data is provided. Over a large range the output follows an exponential curve. As an option, Kurz will provide an equation such that the user may linearize the data with his own data acquisition system.



Shown above is a Series 452 Insertion Mass Flow Element with an Alloy C276 "MetalClad" sensor for tough, heavy-duty applications, and the "Smart" 155Jr Mass Flow Computer.

SENSOR PLACEMENT CRITERIA

- For pipes having an I. D. of 1.5" to 3.5", place the center line of the sensor at 0.5" from the inner wall of the pipe.
- For pipes having an I. D. greater than 3.5", place the center line of the sensor 15% of the pipe I. D. from the inner wall of the pipe.
- Use a sufficiently long sensor support to ensure that the surface of the Sensor Electronics Enclosure does not exceed 60° C.
- Refer to Kurz technical note DCN 364002 to obtain the appropriate sensor blockage correction factor (SBCF), if required.

Kurz Instruments, Inc. ■ 2411 Garden Road, Monterey, CA 93940 ■ Tel 800-424-7356
Fax 831-646-8901 ■ www.kurz-instruments.com ■ e-mail: sales@kurz-instruments.com

SPECIFICATIONS

Process Velocity Range:
0-18,000 SFPM

Process Temperature Rating:
MT: -40°C to 200°C

Sensor Material:
Glass coated platinum wire over ceramic, epoxy sealant

Sensor Support Material:
316L Stainless Steel

Pressure Rating: 150 PSIG

Repeatability: 0.25%

Response Time (One TC):
Velocity: 100 ms
Temperature: 500 ms

Accuracy: See Feature 4 for overall accuracy to 200°C

Power: 24 VDC

Output: 250mA max.

Field Wiring: Cable with 1 pair of shielded twisted wires, 4 Ohm max. loop resistance

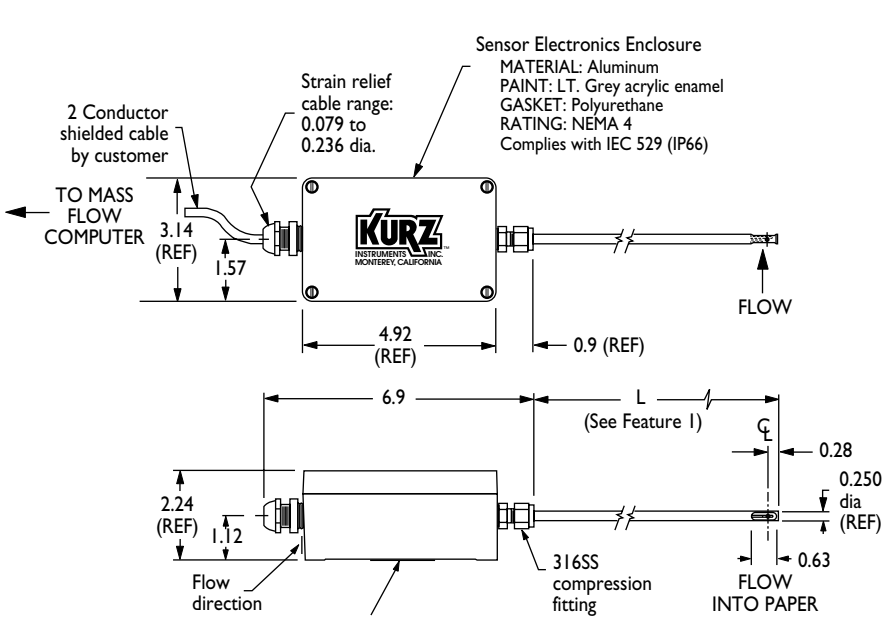
Electrical Enclosure Rating:
NEMA 4 (IP66)
Painted aluminum

Process Connection:
0.25" compression fitting

Environment:
-40°C to 60°C, non-condensing

Weight Net/Shipping:
1.5 lbs/2 lbs. (Typical)

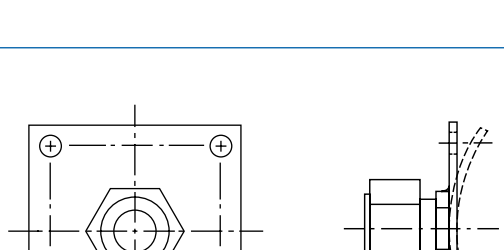
SERIES 410 OUTLINE DRAWINGS



SERIES 410 ACCESSORIES

DUCT MOUNTING BRACKETS

These convenient brackets are used to mount the ¼" sensor support on flat or curved ducts. 316 Stainless Steel bracket and compression fitting, Teflon, Nylon or 316 SS ferrules. Refer to Drawing No. 759030.



MALE COMPRESSION FITTINGS

Bored-thru ¼" diameter fittings, ¼", ⅜", ½", ¾" male IPS threads, 316 SS body, 316 SS, Nylon or Teflon ferrules. Refer to drawing No. 759031.

HOOK-UP CABLE

Part Number	Cable Length (FT)	Description
260036-01	25	Two conductor cables, 1 pair twisted 18 gauge wire with shield, vinyl jacket, .190" diameter.
260036-02	50	
260036-03	100	
260036-04	200	
260036-05	300	

ORDERING INFORMATION

Table A3-1 lists the Series 410 Insertion Mass Flow Element major features and Parent Number. Table A3-2 lists the maximum recommended velocity for various gases.

TABLE A3-1: SERIES 410 INSERTION MASS FLOW ELEMENTS

Model Number	Parent Number	Sensor Support Diameter	Process Temperature Rating	Process Pressure Rating	Sensor Type
410-04-MT	755053	0.250"	MT	150 PSIG	CD

TABLE A3-2: RECOMMENDED MAXIMUM GAS VELOCITY

Gas Type	Velocity	
	SFPM	SMPS
Air, Argon, Carbon Dioxide, Nitrogen, Oxygen	18,000	90
Helium	7,000	35

NOMENCLATURE

PROCESS TEMPERATURE RATING

Identifier	Description	Range
MT	Medium Temperature	-40°F to 392°F
		-40°C to 200°C

SENSOR TYPE

Identifier	Description	Time Response[1]
CD	Fast Dual-Sting Ceramic Duraflo™ Mass Velocity Sensor, Glass-coated Platinum wire over ceramic, epoxy sealant. Maximum of 250 mA. Requires one Series 155 Mass Flow Computer input channel.	Velocity: 100 ms Temperature: 500 ms

Note 1: *Time response is the time required to attain 63% (1 time constant) of the original reading after a step change in process temperature at constant velocity, or a step change in velocity at constant process temperature, at an initial mass velocity of 6000 SFPM.*

PART NUMBER GENERATION PROCEDURE

With the selected Parent Number, specify the entire Part Number by selecting an Option for each Feature as shown in the example below:

755053	2	3	1	8	0	1	0	1
Parent Number	F1		F2		F3		F4	

SUMMARY OF FEATURES

Feature	Description
1	Sensor Material/Length
2	Gas Velocity Calibration Data Range
3	Specialty Gas Velocity Calibration
4	Process Temperature Compensation

FIRST DIGIT OF FEATURE 1: SENSOR SUPPORT MATERIAL

Option	Description
2	316L Stainless Steel
9	Special, consult Kurz

SECOND DIGIT OF FEATURE 1: SENSOR SUPPORT LENGTH

Option	Length	Option	Length
0	18"	3	12"
1	3"	4	24"
2	6"	9	Special

FEATURE 2: GAS VELOCITY CALIBRATION DATA RANGE

Option	SFPM	Option	SMPS
02	300	52	1.5
04	600	54	3
06	1,000	56	5
08	2,000	58	10
10	3,000	60	15
12	4,000	62	20
14	6,000	64	30
16	9,000	66	40
18	12,000	68	60
20	15,000	70	75
22	18,000	72	90
99	Special	99	Special

FEATURE 3: SPECIALTY GAS CALIBRATION

Laboratory Calibration Option	Gas Type	Correlation Calibration Option
01	Air	–
08	Argon	58
14	Carbon Dioxide	64
26	Helium	76
40	Nitrogen	90
44	Oxygen	94
99	Special, mixed gases, consult Kurz	

Note 1: *All calibrations are NIST traceable and taken at room pressure. This procedure is valid because the pressure effect is small up to 150 PSIG. For maximum accuracy the user should obtain the zero flow output data at pressure and enter it into the Series 155 Mass Flow Computer. The customer is responsible for cleaning hydrocarbons from oxygen mass flow elements. The mass flow reference standard is 25°C and 760 mm Hg. Data for velocities above 12,000 SFPM is obtained using the Kurz correlation method. Add [5% reading + 30 SFPM] to the accuracy specification when using a gas correlation calibration.*

FEATURE 4: PROCESS TEMPERATURE COMPENSATION

Option	Description
01	Standard Temperature Compensation (STC) over process temperature range of -40°C to +125°C, all gases. Accuracy: ± [(1% + .025%/°C) reading +(20SFPM + .25 SFPM/°C)] Above or below 25°C.
13	Standard Temperature Compensation (STC) over process temperature range of 0°C to 200°C, air, nitrogen and oxygen only. Accuracy: ± [(2% + .025%/°C) reading +(20SFPM + .25 SFPM/°C)] Above or below 100°C.

ORDERING INFORMATION

Using the Single-Point Insertion Mass Flow Elements Part Number/Order Sheet:

- **A** Complete the application information section.
- **B** Enter the complete Series 410 Part Number.
- **C** Enter the Series 410 mounting hardware and accessory Part Numbers.
- **D** Contact the Kurz Representative or the Kurz factory to place the order or to obtain additional information.

Note: Specifications are subject to change without notice.

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