Kurz Instruments, Inc.

Series 452
Insertion Flow Element User Guide
360195 Rev. B

covers
Models 452, 452T, 452P & 452PT

March 1998

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LIMITED WARRANTY-PRODUCT

(Liability for Repair or Replacement Only)

The Company's products are warranted to be free from defects in material and workmanship for one year from date of shipment from the factory. The Company's obligation is limited to repairing, or at their option, replacing products and components which, on verification, prove to be defective, at the Factory in Monterey, CA. The Customer is responsible for the construction materials' selection and for the materials' suitability with the intended use of Kurz equipment. The Company shall not be liable for installation charges, for expenses of the Buyer for repairs or replacement, for damages for delay of or loss of use, or other indirect or consequential damages of any kind. The Company extends this warranty only upon proper use and/or installation of the product in the application for which intended and does not cover products which have been modified without the Company's approval or which have been subjected to unusual physical or electrical stress, or upon which the original identification marks have been removed or altered.

Whenever the design of the equipment to be furnished for the system in which it is to be incorporated originates with the Buyer, the Manufacturer's warranty is limited specifically to matters relating to the furnishing of equipment free of defects in material and workmanship and assumes no responsibility for implied warranties of fitness for purpose or use.

Transportation charges for material shipped to the Factory for warranty repair are to be paid by the Shipper. The Company will return items repaired or replaced under warranty prepaid. No items shall be returned for warranty repair without prior authorization from the Company.

TABLE OF CONTENTS

INTRODUCTION

The Kurz Instruments 452 series of insertion mass flow elements are point velocity sensing devices. The flow element is a constant temperature thermal anemometer which intrinsically measures the process fluid Reynolds number. The net meter response is mass rate per unit area. The flow element is half of a two part flow transmitter. The other half is the series 155 mass flow computer. The engineering output of the series 155 may be scaled to represent standard velocity, standard volumetric flow or mass rate. Density changes are automatically accounted for negating the need for pressure and temperature compensation. A complete description of how and what the thermal anemometer measures can be found in Appendix A. The flow element must be calibrated in the fluid type to be measured or may be correlated from Air calibrations if available.

The 452x is a 2-wire current source device whose 100 to 600 mA output is exponentially (about the 1/4 power) proportional to the flow rate. The x can be blank, T, P or PT depending on the model, see brochure. The unit is 24 VDC powered from the 155 series. The 452T version also includes a 4-20 mA output to measure the ambient temperature from an RTD so it is a 4-wire device. The 452T is used for systems which have large temperature changes and use multiple calibration curves with temperature to interpolate the flow element output. The process of using multiple calibration curves at temperature to reduce the temperature coefficient is known as VTM (velocity temperature mapping). The 452P or 452PT have a purge port in the sensor window for automatic cleaning.

The typical flow element configuration has all the electronics in one enclosure, known as the TA configuration. If the sensor and a terminal wiring board are in a separate enclosure from the electronics, this is the TS configuration. All four cases, 452/452T and TA/TS are shown in the field wiring diagram. The TS configuration is used where the sensor enclosure ambient temperature is expected to exceed 60 °C, allowing the electronics to be mounted separately in a cooler place.

Additional product description, specifications, outline drawings and explanation of part numbers can be found in the product brochure at the end of this section. The CE EMI compliance can be found in Appendix B along with descriptions of the Hazardous Area product approvals.

Important Issues for Accurate Flow Measurements

C Duct Velocity Profile Correction:
- Does velocity profile change with dampers, fans, valves, etc. where the sensor is measuring?

C Sensor Insertion Location:
- What part of the profile is to be measured?

C Duct Area:
- Sensor blockage, reducing the effective area.

C Field Calibration:
- Zero, Span, Area and specific gravity adjustments are made in the 155 mass flow computer. Correction factors as a function of velocity to account for velocity profiles or sensor blockage are also possible with the 155 mass flow computer.

C Sensor Pitch or Orientation to the Flow:
- Is the flow arrow pointing in the same direction as the flow?

C Fluid to be Measured:
- Was the unit calibrated in the fluid to be measured?
- Is the fluid composition highly variable?
- Does the fluid change phase?
- Can material build up on the sensor?

Answers to many of these question can be found in this manual or its appendices. Kurz customer service may also be contacted for assistance 408 (831 after July 98)-646-5911 or FAX 408 (831 after July 98)-646-1033. This user’s manual covers installation, operation, calibration and maintenance information.

INSTALLATION

WARNING: Your warranty will be voided if your unit is not installed in accordance with this user guide. Make sure you read and thoroughly understand the installation portion of this guide before you attempt to install your unit. If you have any questions, contact your Kurz customer service representative before attempting installation.

Mounting

The 452 insertion flow element is generally mounted with a compression fitting into a duct or on a flange (See Figure 1). See the product brochure (DCN 367027) for Kurz mounting accessories and a general outline drawing. Model specific outline drawings are available via request to the customer service department. It is important for the mounting design to consider the force that will be exerted on the probe support or flange when the process fluid is under pressure. The insertion depth depends on the duct size and sensor size. Our recommended placement criteria are also in the brochure. The sensor blockage, used to establish the duct area where the measurement is made is specified in DCN 364002 included in Appendix D.

For transmitter separate versions (TS) there are two enclosures. The one with the sensor mounts as described above and contains just a sensor wire terminal board. The second enclosure contains the bridge electronics and is mounted via its conduit ports or a mounting bracket. This bracket has four 1/4" holes with 2.50" square spacing (see the brochure). It is important to know that the sensor serial number must be matched with the bridge board and its linearizer. These three parts are not interchangeable unless recalibrated.

Things to watch out for:

- If the process being monitored has moving valves or other flow profile disturbances you should keep your distance from them to obtain the best performance. About 30 duct diameters are needed to have the profile within about 1% of a long run velocity profile.

- When the dew point is close to your operation temperature, and/or you have a saturated gas in un-insulated ducting and condensation occurs on the walls, do not mount the sensor pointing in a downward angle. Pointing the sensor up or at the least horizontal will prevent condensation from reaching the sensor element and causing false high flow readings as the heated element evaporates the condensate.

- For purge versions, the temperature of the purge gas and the due point of the process must be considered to prevent forming condensation on the sensor during the purge which will make the cleaning even more difficult. With water vapor, this means the purge gas needs to be heated above the ambient, 80 °C for example.

Field Wiring

There are up to three issues for the proper wiring installation of the Kurz 452x:

- Safety Grounding and Explosion Proof enclosure connections.
- Signal/power wiring and of the optional 4-20 mA temperature signal.
- Sensor wiring for transmitter remote (TS) units.

Please read the complete text of the sections and study the wiring diagrams which are relevant to your model before performing the installation.

Safety

To ensure compliance with General Safety requirements the metal enclosures must be grounded to minimize the chance of electrical shock. For Explosive Atmospheres, proper grounding minimizes the chance of sparks occurring (ignition sources) outside an enclosure at its mechanical interfaces if a fault current was to flow. Both internal and external grounds are available, see the wiring diagrams at the end of this section.

For hazardous gas areas, wiring going into and out of the explosion proof enclosures must be done through a conduit seal or cable gland rated for explosion proof applications (Class 1 Div. 1 or Zone 1) attached directly to the enclosure. These seals are not needed for nonincendive designs (Class 1 Div. 2 or Zone 2).

For hazardous areas it is important to not connect or disconnect any wiring when the circuit is energized, the resulting spark could cause ignition.

24 VDC Powered Flow Element

The 24 VDC power is a nominal voltage since all circuits have a regulated supply and will work between 15 and 28 VDC. The exact voltage depends on the maximum temperature the unit is designed for. The series 155 will provide over 23 VDC to the bridge and its 5 Ω current sense resistor. You may also use an unregulated power supply with 50 to 60 Hz ripple as long as the instantaneous voltage is above the minimum and less than 28 VDC. Surge currents during sensor warm up could require up to 660 mA and will fall off after it warms up in about 30 seconds. At no flow the current will be about 0.2 A and about 0.5 A for high flow rates (12,000 SFPM). The power is protected against reverse polarity so if no current flows or there is no output signal you may want to check the polarity against the wiring diagram, DCN 342003.

The flow element is isolated from ground to avoid ground loop currents. However, the 24 VDC power and 4-20 mA signal have MOVs (metal oxide varistors) to clamp voltage spikes going into the unit. These are 39 V nominal (voltage level at 1 mA) and do not conduct significant current below about +/- 30 VDC relative to ground. Consequently, it is a good idea to have the 24 VDC power grounded to prevent leakage currents on the MOVs, which can cause an error in the flow measurement if occurring on the 4-20 mA signal.

Transmitter Separate (TS) Configurations

The wiring of the TS configuration has a few more constraints since you must wire up the 5 sensor wires too. The most important thing about the TS wiring configurations is keeping the 5 wires going to the proper terminals. When connecting the 5 wires to the bridge board for the sensor, the terminals must be tight. Over torquing the connectors can damage them or components' surface mounted on the bridge board.

The 5-wire sensor connection must use quality wire whose resistance per lead is less than 1 Ω. Each wire must match the resistance of the other wires within 0.01 Ω so the lead length correction will work properly. This procedure is needed to ensure that factory calibration and temperature compensation holds up in the field. If the individual wires do not meet the matching specification, their length must be trimmed or extended until they match. The terminal strips for the bridge board are limited to 14 AWG wire which limits the TS configuration to about 400 ft between sensor and electronics (see wiring diagram). Longer lengths would need a wire splice from the larger wire size to 14 AWG to fit the bridge terminals.

To maintain the CE compliance of the product when in the TS configuration one must maintain a good shield around the 5 wires. This can be done with ridged conduit between the sensor junction box and the sensor electronics enclosure. Conduits that seal directly to the enclosure are still needed to meet the explosion proof ratings. Alternately, a braided shield multiconductor cable between the two enclosures can be used. Peripherally bonded shielded cable glands are required for cable connections. Hawk, makes a whole line of cable glands for shielded cable, some have explosion proof ratings too. Please contact Kurz Instruments, Inc. Customer Service if you need information in this area or other aspects of the installation.

Peripherally bonded shield, cable glands and explosion proof versions:

Hawke America

600 Kenrick Suite C-10
Houston Texas 77060
United States of America
Tel: +1 281 445 7400
Fax: +1 281 445 7404
E-mail: hawke@hawkeusa.com
http://www.offshore-technology.com/contractors/cables/hawke/index.html

Optional Power-On Surge Check

Once the mechanical and electrical installation is complete and checked you may safely apply power. By monitoring the 100 to 600 mA signal during power on you can get a rough idea if the unit is working properly. A fast chart recorder, scroll mode digital storage scope or fast milliampere meter should be connected to the 100 to 600 mA signal (measure the current sense voltage, CSV, across a 5 Ω resistor). When power is first applied, you will typically see the signal go to a very high value, hold for up to a few seconds then exponentially decay to the present flow value in about 20 seconds. This occurs because the heated velocity sensing element is initially cold and is warming up. After it warms up, momentarily cycling the power will not produce a turn on surge as large as when it has been off for 5 minutes or longer.

INSERTION FLOW ELEMENT CALIBRATION

Factory Calibration Method

Two methods of velocity calibration are used depending on the gas type to be calibrated. For air calibrations and gas correlations a transfer standard is used where the unit under calibration and the standard are in the same plane perpendicular to the flow. The wind tunnel has a relatively flat velocity profile and locating them in the same sensing plane automatically accounts for sensor blockage. For other gases, a special ducted section on a mass flow calibration system is used. Here the sensor blockage and effective area of the calibration section are used to convert the mass flow to mass flow per unit area or Standard Velocity. These mass flow calibrations are generally performed at room temperature and pressure but can be performed at elevated pressures to account for pressure dependent viscosity induced errors. Figures 2 and 3 show a typical calibration data sheet and graph of the sensor response versus standard velocity.

The series 155 mass flow computer converts this signal to a linearly proportional one. The data from Figure 2 is entered under the input channel the flow element is connected to. Remember, once this data is loaded into a channel, it is now matched to that sensor.

Field Calibration

If Field Calibration data are available on the process, this can be entered into the series 155 as a correction factor at flow xx, for up to 7 flow rates. Alternately, “Flow Perfect” can be used were the observed flow rate on the element and the reference rate are entered for up to four rates and the series 155 will calculate the correction factor. Flow Perfect has the advantage for multipoint arrays of re-computing the proper correction factor even if a sensor becomes defective. It re-computes the CF based on the reading of the remaining good signals. Many of the issues for obtaining accurate flow or mass rate readings from an insertion unit are covered in Appendix A and B.

Velocity Traverse

Another method of field calibration using the factory calibrated standard velocity signal can be used to help establish the volumetric or mass flow calibration. You can use the point velocity measurement to traverse the duct with equal area measurements and average the readings. The ratio between the indicated reading where the sensor sits and the average you computed is the CF you use.

Tracer Dilution
Kurz Instruments offers insitu flow calibrations which account for all the profile issues etc. Here the tracer injection flow rate is measured at a know injection concentration, the diluted concentration is then measured with an analyzer and the unknown flow is then calculated. This method is described under Kurz Doc Number 364011. Both flow profile traversing and tracer gas calibrations are available through the customer service department.

CALIBRATION DATA AND CERTIFICATION DOCUMENT
KURZ INSTRUMENTS, INC.
2411 GARDEN ROAD
MONTEREY, CALIFORNIA. 93940
1-(800)-424-7356 (408)-646-5911 FAX (408)-646-8901
Web Site: www.kurz-instruments.com

---> Sensor Calibration Data <---

Serial no/Filename : FD9999A/FD9999A.WTC
Date : 11/1/97
Customer Code/Name : 999999/XYZ_CO.
Purchase Order No :
Model No : 452-08-MT
PART No : 752731-03-23-16-01-88-01-01-0000-21
MAPICS Item NO :
Flow Units : SFPM
Reference Fluid : AIR
Standard Conditions : 77 °F and 29.92 inHg.

Point No.	CSV VDC	Velocity SFPM	Velocity SMPS
1	0.789	0.0	0.000
2	1.275	306.2	1.555
3	1.415	603.6	3.066
4	1.548	1039.7	5.281
5	1.737	2062.5	10.477
6	1.862	3061.4	15.551
7	1.955	4037.8	20.511
8	2.096	6015.8	30.559
9	2.265	9033.8	45.889

Note: CSV is a voltage measured from signal source

Kurz Model 400D Wind Tunnel Calibration System

FLOW ELEMENT CALIBRATION REFERENCE
Model no: 450-08-AT-12, Serial no: DLI7383F
NIST Calibration Due Date: 02-03-1998

DATA ACQUISITION SYSTEM
Model no: LSDAS-16
Serial no: 9513-0017

This instrument was calibrated with NIST traceable equipment having a rated total system uncertainty of ±1.03% at 12000 SFPM, ±1.17% at 6000 SFPM, ±.85% at 1000 SFPM and ±1.37% at 100 SFPM. Refer to Kurz 400D Calibration System Error Analysis, Kurz Doc. No. 28019, for details. This calibration is traceable to National Institute of Standards and Technology Test No.836/256043-95 Purchase Order No. P16641 and meets the requirements of ISO 10012-1 and ANSI/NCSL Z540-1. This calibration was performed per Kurz Doc. No. 760017.

WIND TUNNEL OPERATOR: **John Doe** DATE : **11-1-96**

QUALITY CONTROL: **Jane Doe** DATE : **11-12-96**

Form Number 180117 REV. D Sheet 1 of 1

Figure 2 Typical input calibration sheet

MAINTENANCE AND TROUBLESHOOTING

Maintenance

The thermal anemometer has no moving parts so there is not too much to the maintenance except cleaning and inspection for corrosion and environmental damage. When an application is first started or changes the sensor should be inspected for dirt build up and a cleaning schedule established as required. There are two approaches to sensor dirt which is used will depend on the type of dirt.

For dry powdered dirt, the sensor will reach a steady state dust load and should be field calibrated with this level of dirt on the sensor. For sticky dirt that just builds up over time, periodic cleaning is needed for the best results. Calibration strategies vary depending on the cleaning schedule of the sensor (ie: is the sensor clean? does it have a typical or maximum dirt load just prior to cleaning?). This establishes the bounds on the calibration errors and/or provides the data to compensate for the dirt over time. The addition of most dirt to a thermal anemometer is to reduce the reading for the same flow rate. The best way to know the impact of the dirt is to check the calibration against some known reference (second unit or method). Despite the above, it is the tolerance for dirt, in contrast to turbines or pitot tubes which is one of the significant reasons the thermal anemometer is a great industrial product.

When cleaning, a stiff hair brush with soap is recommended to clean the sensor. More aggressive cleaners are used at your own risk. Be careful not to bend the sensor elements as this can change the calibration or damage the unit. Corrosion of the sensor probe or probe support will eventually cause contamination to get into the sensor or electronics and the unit will fail shortly thereafter.

The purge versions are blasted on a periodic rate which is determined by experiment to give consistent calibration results. One must remember that the sensor takes about 30 seconds (could be more if the purge temp is different from the process) to recover from a purge

Flow issues

The most common problem with an insertion flow element is that it measures the point mass rate at the sensor, not the duct average. Ignoring this issue can cause a 40% error at low flow that diminishes at higher flow rates. Unless you have invested the time in field calibrations, only relative measurements can be made. Accuracy requires field calibration. To avoid this field calibration issue, the Kurz 502 line will provide an accurate "out of the box" calibration. You must follow the guidelines to avoid flow disruptions from being too close to the element.

For either in-line or insertion flow elements, locating a sensor close to a valve (up or down stream) will give different readings (up to 20% for in line and much more for insertion) depending on the position of the valve even at the same average flow rate. Uninsulated pipe/duct can have a temperature profile which will make the sensor reading too high or low depending on the sensor location and the duct's radial temperature gradient. A unit inserted with the velocity element in the center or on the insertion side of center will read lower for ducts with a hot core and colder walls than the same duct with no thermal gradient. Conversely, It will read high if the duct core is cold and the walls hot. A unit inserted beyond center or the far side of the duct will have the opposite drift from that described above for the same thermal gradient.

Sensor Element

There are 5 sensor wires for the two RTDs. The two white leads connect to a 300 Ω ± 1% @ 0 °C platinum element. The two red leads connect to one side of a 9 Ω ± 3%@ 0 °C element whose other side is the yellow lead. The two red leads should measure below 2 Ω measured between them including any extra wire from a transmitter separate configuration.

Sensor leakage resistance between elements or to ground should be 1 MΩ or higher as measured with a 10 V or larger test voltage. Do not use a standard DVM because its ohm meter test voltage is too low to work with the electrochemical cell voltage from contamination. We typically use the 24 VDC supply applied between the elements (one white lead to the yellow) an make sure the leakage current is less than 24 µA. Next we check the white to sensor case then the yellow to sensor case to ensure its leakage is less than 24 µA. The leakage and resistance test should be made at normal process operation temperatures.

TABLE 2	
TROUBLESHOOTING CHART	
Symptom	Possible Reasons
No CSV signal	- Loss of power - Reversed polarity leads - Bridge Board Defective. See Note 1.
Output Signal “motor boating”	- Sensor has too much leakage current, corrosion or water damage - Defective Bridge Board
CSV does not change with flow	- Defective Sensor or Bridge - Is sensor cover removed?
Unit does not read zero at zero flow	- The gas type or pressure may be different than when calibrated. - Defective series 155, Bridge or Sensor.
Unit saturates before reaching full scale.	- Unit calibrated for a lower flow rate at the factory - Unit calibrated for the wrong gas. - Defective bridge board or series 155.
Calibration is too low.	- Is the sensor orientated to the flow correctly? - Was the unit calibrated for the gas type in use - Has the unit been set up for the ducts velocity profile? (See appendices A & C) - Is there a temperature profile near the sensor? (e.g. hot duct center, cold outside) - Dirt will generally cause the reading to fall off from proper calibration. - Is the flow element connected to the proper channel of the series 155. Check the series 155 setup sheet.

Calibration is too high.	- Have sensor blockage & flow profile effects been accounted for? This is a significant factor in ducts measuring less than 1ft². - Is the sensor oriented to the flow correctly? - Was the unit calibrated for the gas type in use? Is there a temperature profile near the sensor? (e.g. hot duct center, cold outside) - Is there condensation on the sensor? - Is there pulsating flow noise ? (e.g. from a pump inlet or exhaust) Is the flow element connected to the proper channel of the series 155. Check the series 155 setup sheet.
Calibration does not track with temperature.	- Unit measures (density x velocity) or mass rate per unit area. (See appendices A & C for info on converting to actual velocity). - Is there a temperature profile near the sensor? (e.g. hot duct center, cold outside) - If you think it still is not tracking it may be a defective sensor or bridge board.
CSV output is “noisy”.	- Poor electrical contact. Make sure all electrical connections are clean and tight. - Look for foreign objects on the sensor or blocking the sensor in the duct.
No 4-20 mA temperature signal (452T)	- Check for proper polarity on wiring - Defective 604 board

Temperature Calibration off (452T)	- Check that the three RTD wires are connected properly - Check that the calibration data in the series 155 matches the 604 board calibration - The linearization table for the temperature channel can be changed in the series 155 or use the CF features. You can also change the Zero/Span for the meter output used for temp in the series 155.

Note 1.
The bridge board fuse, F1 on assembly 420242, may blow due to shorts between the power semiconductors and the chassis, conducting water on the electronics or just a week fuse. This is a 3/4 A fast blow fuse which is surface mounted. It is removed by heating with a soldering iron one end and lifting it up from that end at the same time. Then the other side is unsoldered. This fuse is Pico part number R459.750 or Kurz stock number 630051.

Major Subassemblies used in the 452 series flow elements.

Description	Part Number
465R8 bridge board for HHT sensors	420242-02
465R8 bridge board for FD sensors (MT versions)	420242-05
185-1-02, Lightning suppression board, 4 wire	420251-02
185-1-04, Lightning suppression board, 2 wire	420251-04
185-1-03, Remote Junction box terminal board	420251-03
604, 4-20 mA temperature transmitter	420046

RETURN SHIPMENT

RMA # (Return Material Authorization #)

If you believe your unit is not working properly, contact the Kurz Customer Service Department at phone # 408 (831 after July 98)-646-5911. Please have the following information ready to give to the Kurz Customer Service Representative:

Defective unit's model #, item # and serial #

Detailed description of application and type of environment unit is being used in

Detailed description of perceived problem

Type of gas, Flow range, and standard conditions unit is to be recalibrated to

Any special QA requirements (nuclear or military application, oxygen service, special calibration or certification etc).

Technical contact's name and phone #

Billing contact's name and phone #

Complete shipping address

Complete billing address

You will then be issued an RMA #. **Kurz personnel will refuse to accept return material shipments if an RMA # is not visible on the outside surface of the shipping container.**

Cleaning of Material to be Returned

Thoroughly clean all material to be returned to Kurz. Because we serve a diverse customer base, there is a risk of receiving contaminated returned material from our customers. **When uncleaned material is received at Kurz, the customer will be contacted to arrange at their expense for the material to be picked up from Kurz and cleaned before Kurz personnel handle the equipment.**

Shipping Material to be Returned

Securely package cleaned material **(When uncleaned material is received at Kurz, the customer will be contacted to arrange at their expense for the material to be picked up from Kurz and cleaned before Kurz personnel handle the equipment)** along with a packing slip referencing the RMA #, model # and serial # in a sturdy container with the return address and RMA # clearly marked on the outside surface of the container. **Kurz personnel will refuse to accept return material shipments if an RMA # is not visible on the outside surface of the shipping container.**

Ship pre-paid to the following address:

KURZ INSTRUMENTS INC
CUSTOMER SERVICE DEPT
2411 GARDEN RD
MONTEREY CA 93940-5394
USA

APPENDIX A
THERMAL ANEMOMETER MEASUREMENTS

The KURZ thermal anemometers use two RTDs, one heated 50 to 100 °C above the ambient, the other monitors the ambient. The current required to keep the velocity element heated is the parameter calibrated in our wind tunnels.

Mass Rate

What does a thermal flow sensor measure? Because of the equations of forced convective heat transfer, the output of any thermal anemometer is proportional to the sensor's Reynolds number (Re). Looking at the Reynolds number we can see how it measures **mass rate** per unit area**,** NOT volumetric flow rate. Therefore, the thermal anemometer automatically compensates for density.

Because a thermal anemometer measures the unit-area mass flow, it can be said to measure **mass rate.** In other words, it measures the true velocity, weighted by the **density** of the flowing gas. If the mass rate is normalized by a known density, it has velocity units, a term know as **standard velocity**. The next section helps explain where these ideas come from.

Mass Flow Equations

Reynolds Number

Lets look at the Reynolds number since it is proportional to the sensor's power or current when heated X degrees above the ambient:

$$Re = \rho v d / \mu$$

where

- ρ = actual density
- v= actual velocity
- d = sensor's diameter
- μ = gas viscosity

t is the density and velocity (ρv) product that makes the thermal anemometer a mass flow meter. Density (ρ) has units of mass/volume and velocity (v) has units of length/time. So the ρv product has units of (mass/time)/area or mass rate per unit area.

For example:

ρ is kg/m^3, v is m/s

so ρv is (kg/s)/m^2

The sensor is sensitive to the energy that the gas molecules hitting it take away in the form of heat. This energy is proportional to the size and number of molecules that hit the sensor. It does not know about density and velocity. Small light gas molecules like hydrogen (H_2) having a large surface area to mass ratio, are more efficient at transferring the vibrational heat energy of the sensor surface than large heavy molecules like Argon (Ar) having a small surface area to mass ratio.

Standard Velocity is the ρv product normalized to a standard density

Standard Velocity = $\rho v/\rho_s$

where ρ_s is the standard gas density. For air this is 0.07387 lb/ft^3 at 25 °C and 29.92 in Hg.

Note the density units cancel and you are left with velocity (m/s). Typical units are: Standard Feet Per Minute (SFPM) or Standard Meters Per Second (SMPS). If the gas density doubled (you went from 15 PSIA to 30 PSIA) at the same actual velocity, the standard velocity would double. This also means that if the process gas is at the same temperature and pressure as the standard condition or the same density, the standard velocity and actual velocity are identical.

Standard Volumetric Flow is the ρv product multiplied by an area (like a pipe cross section), normalized to a standard density

Standard Volumetric Flow = Area x (Standard Velocity)
= $A\rho v/\rho_s$

where A is the area

The units here are volume/time (m^3/s)
Typical Displayed units are:

SCFM, Standard Cubic Feet per Minute
SCMM, Standard Cubic Meters per Minute
SCFH, Standard Cubic Feet per Hour
SCMH, Standard Cubic Meters per Hour

Mass Flow is obtained by simply multiplying the Standard Volumetric Flow by the Standard Density.

MASS Flow = (Standard Volumetric Flow) x ρ_s
= $A\rho v$

The units here are mass/time (kg/s)
Typical units are:
PPH, Pounds per Hour
KGH, Kilograms per Hour

Different gases have different standard densities. This is often described as a reference density (air) multiplied by a specific gravity (sg).

$$\rho_s = \rho_{air} sg$$

Then
Mass Flow = (Standard Volumetric Flow) x $\rho_{air} sg$
= $A(v\rho/\rho_s)\ \rho_{air} sg$

Conversion of Standard Velocity or Standard Volumetric Flow to actual requires only scaling the result for the gas density according to the ideal gas law.

$$V_a = V_s\ (P_s/P_a)(T_a/T_s)$$

or

$$F_a = F_s\ (P_s/P_a)(T_a/T_s)$$

where V_a is actual velocity, V_s is standard velocity
F_a is actual volumetric flow, F_s is standard volumetric flow
P_s is the standard pressure in absolute units
P_a is the actual pressure in absolute units
T_a is the actual temperature in absolute units (Kelvin or Rankin)
T_s is the standard temperature in absolute units (Kelvin or Rankin)
Note °K = °C + 273.16, °R = °F + 459.67

Gas Property Induced Errors

There are secondary effects which cause mistracking of the ideal thermal anemometer.

- **Pressure changes** will affect the calibration for some gasses. For example, N_2 has a large 2.5% /100 psi shift in its viscosity which changes its mass flow reading the same amount. By contrast He has nearly no viscosity change with pressure. These errors are largest at low flow were the free convection term becomes significant. At 7 atmosphere pressure (about 100 psi) and 750 SFPM, this error is about 4% reading. It would be larger at lower velocities and higher pressures.

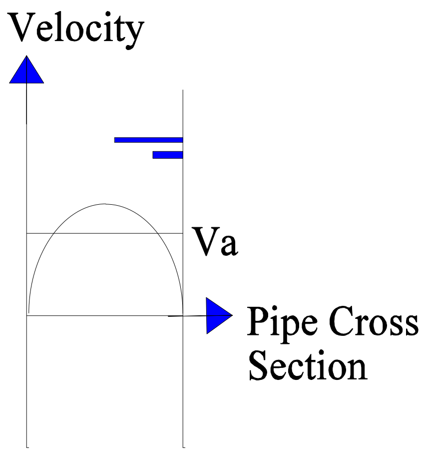
- **Temperature changes** will affect the gas thermal conductivity and viscosity so the calibration will drift. This is typically 2.5% /100 °C. The minimum drift occurs near 3000 SFPM where the dynamic temperature compensation is performed.

- **Temperature profiles** in the pipe will produce flow errors. This is caused by using uninsulated pipe upstream of the sensor where the gas is above or below the ambient temperature.

- **Low flow free convective** heat transfer forces compete with forced convective and conductive heat transfer forces for power. This causes measurable errors (depending on gas type, temperature, pressure, and orientation of sensor to both flow and gravity) starting at about 300 SFPM and becomes significant down at about 100 SFPM.

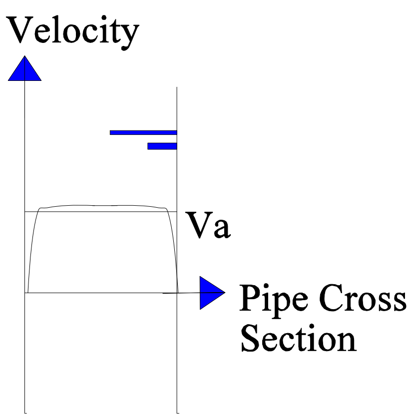
The best solution for all these error sources is to do an in-situ calibration so their contribution is included thus eliminating this error.

Flow Profiles And Correction Factors.



Low Velocity (Reynolds Number) Laminar Profile

At low velocity, a laminar velocity profile develops across the pipe cross section as shown in the figure. Note that the peak velocity is about 30% higher than the velocity average (Va).



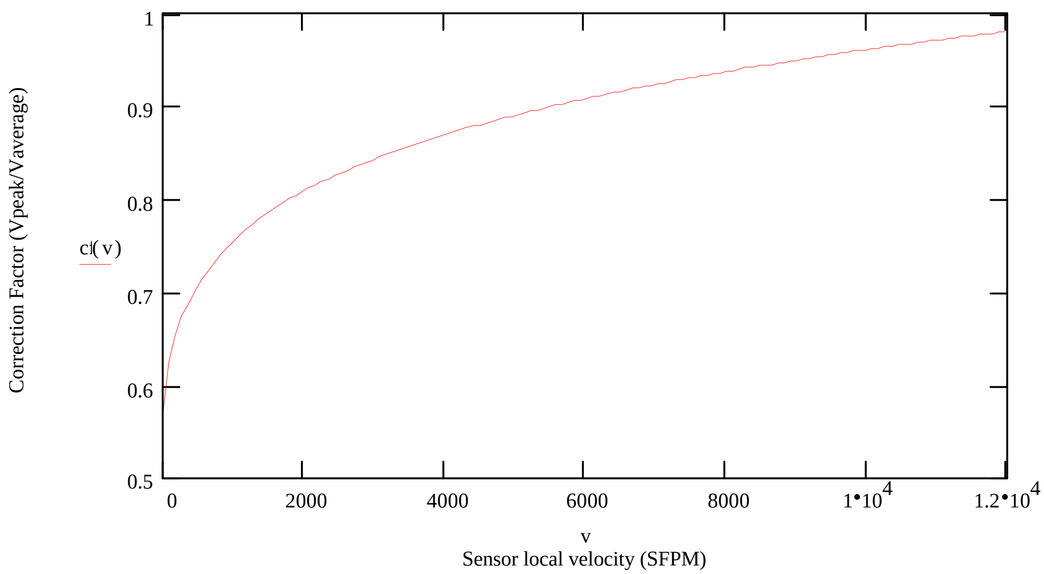
High Velocity (Reynolds Number) Turbulent Profile

At higher flow rates, a flatter velocity profile develops where the peak velocity is closer to the average. So depending on where the sensor is located, it will read a different fraction of the average velocity. It is the average velocity multiplied by the cross sectional area that will obtain the total flow.

Correction Factors

The use of a velocity dependent correction factor can convert the local velocity measurement to average velocity.

$$Flow = V_{local} * Area * CF(V_{local})$$



The above correction factor curve was measured from a 4" ID pipe with a ½" welded support, triple sting CD sensor. For other sized ducts, the data can be scaled by the Reynolds Number.

Use Of The Flow Equations In The KURZ Mass Flow Computer

Single Point Insertion Flow Elements like the 410, 450, 452 are calibrated as velocity devices in gas X. You can display standard velocity or with application specific information you can display standard volumetric flow and mass flow:

Area,
Sensor and probe support blockage
Correction factor (velocity profile)
Gas specific gravity when reading mass flow

Multi point Insertion Flow Elements (K-BAR) are also calibrated as velocity devices in gas X. You can display standard velocity or with application specific information you can display standard volumetric flow and mass flow:

Area,
Sensor and probe support blockage
Correction factor (velocity profile). This tends to be automatic since the velocity is measured across the duct at equal area locations.
Gas specific gravity, when reading mass flow.

In-line Flow Elements (510, 502, 522UHP, 532) are calibrated as standard volumetric flow devices in gas X. You can display standard volumetric flow or with application specific information it will display standard velocity or mass flow:

Area,
Sensor and probe support blockage
Correction factor (velocity profile)
Gas specific gravity when reading mass flow

To maintain the factory calibration on in-line units requires adherence to the recommended L/D upstream and downstream criteria. This ensures the long pipe run velocity profile when used in the field.

Example L/D criteria: Model 502-16, 1996 version

L/D is from the heated sensor to the disturbance	90 ° Elbow at x L/D	Calibration Error
	10	11 %
	20	2.5 %
	30	< 0.5 %

Problems:

Air flow of 100,000 lb/hr through a 3' x 3' square duct, 90ºF, 20 PSIG

What is mass flow in SCFM ______________________________________

What is velocity in SFPM ____

The actual velocity is ____

What range does Kurz calibrate to _________________________________

Nitrogen flow of 10 ACFM through a 3" Schedule 40 pipe, 110ºF, 50 PSIG

What is the area ____

What is the flow rate in SCFM ____________________________________

The velocity in SFPM is ____

The calibration max. range is _____________________________________

Major Points to Remember

APPENDIX B

THEORY AND APPLICATION OF KURZ THERMAL CONVECTION MASS FLOW METERS, DCN 364003

APPENDIX C
PRODUCT APPROVALS

The CE declaration of EMI compliance for this product and hazardous area approvals are found in this appendix.

Declaration of CE Compliance,
File 430007b.wpd printed on Kurz letter head signed by Jerry.

Hazardous Area Product Approvals

Explosion Proof: Series 452 and 452T
CSA File LR 87908-5
300 PSI Maximum Process Pressure.
Explosion Proof For Class I, Zone 1, Group IIB +H_2, T3 or Class I, Division 1, Groups B, C &D, Temperature Rating T3. -40 to 60 °C Ambient Temperature, Rated Input 24 VDC, 660 mA. Indoor & Outdoor Enclosure: Type 4

FMRC File J.I. 0Z7A0.AE
300 PSI Maximum Process Pressure.
Explosion Proof For Class I, Division 1, Groups B, C & D. Dust Ignition Proof For Class II, Division 1, Groups E, F & G Sutable for Class III Hazardious Locations. Temperature Rating T1. -40 to 60 °C Ambient Temperature. Rated Input 24 VDC, 660 mA. Indoor & Outdoor Enclosure: NEMA 4

CENELEC, KEMA No. Ex-96.D.1608
300 PSI Maximum Process Pressure.
Flameproof: EExd IIC T3. -40 to 60 °C Ambient Temperature. Rated Input 24 VDC, 660 mA. Indoor & Outdoor Enclosure: IP66. Do Not Open While Flammable Gases are Present.

Nonincendive: Series 452, 452T, 452P and 452PT
CSA File LR 87908-5
300 PSI Maximum Process Pressure.
Nonincendive For Class I, Division 2, Groups A, B, C and D. Class II, Division 2, Groups F and G. Class III, Division 2. Class I, Zone 2, Group IIC. Temperature Rating T5. -40 to 60 °C Ambient Temperature. Input Rating 24 VDC, 660 mA. Indoor & Outdoor Enclosure: Type 4.

FMRC File J.I. 0Z7A0.AE
300 PSI Maximum Process Pressure.
Nonincendivie For Class I, Division 2, Groups A, B, C and D. Suitable For Class II, Division 2 Hazardous Locations. Temperature Rating T5. -40 to 60 °C Ambient Temperature, Nonhazardious Processes Only. Rated Input 24 VDC, 660 mA. Indoor and Outdoor Enclosure: NEMA 4.

APPENDIX D
RECOMMENDED SENSOR PLACEMENT CRITERIA AND SENSOR FLOW BLOCKAGE CORRECTION FACTORS FOR SERIES 450 SINGLE-POINT MASS FLOW ELEMENTS

DR. JERRY KURZ
PRESIDENT
KURZ INSTRUMENTS, INC.
12-12-95

DCN 364002 REV.B

I. INTRODUCTION

The purpose of this technical note is to assist our customers to use our products in the most advantageous manner in the interests of accuracy, cost, maintenance and reliability.

For several years most suppliers, including Kurz, have recommended placing the centerline of the thermal sensor at the center of circular pipes. However, the velocity profile of a pipe is never flat, and generally has the highest velocity at the center of the pipe, such that the output of the mass flow element usually reads high! A truly laminar velocity profile could have a centerline velocity of about 30% higher than the average velocity; even a fully developed turbulent velocity profile can be 10-12% higher than the average velocity. Somewhere between the wall and the pipe centerline is the location of the average velocity. We have concluded that it is much better to place the sensor centerline at the equal area radial location such as is used for velocity traverses in ducts and pipes. Since this location is only about 15% of the pipe diameter from the inner wall of the pipe, the sensor support need not be very long for even large pipes. For example, if a Series 450 were used in a 60" pipe, the insertion dimension needs to only be about 9", instead of 30" if it were placed at the pipe centerline. This means that:

A) The flow element is less costly,

B) There is less flow blockage,

C) The stress on the sensor support is less,

D) The sensor support has a higher natural frequency so that it can be used in higher vibration, shock environments,

E) Less space is needed to insert the probe into the pipe,

F) A far smaller and more convenient ball valve retractor/restraint system may be used.

Since most user’s don’t know what the actual velocity profile is before installing a Series 450, and field tests are normally made to “dial” in the system accuracy, the sensor location is usually not critical. In addition, the correction for flow blockage is usually much smaller, especially in 2 ½ to 6" pipe because the sensor shield with its open slot (window) has a much lower flow blockage area than the sensor support. Therefore, we think that our new sensor placement criteria is a “win-win” situation.

II. RECOMMENDED SENSOR PLACEMENT CRITERIA:

A) For small pipes use the 0.5-inch diameter sensor support to reduce flow blockage and installation costs. Use the 1-inch diameter sensor support for larger pipes, or in which strength or very dirty air is encountered. For small pipes, or when higher accuracy is required, a Kurz In-Line Mass Flow Element is recommended.

B) For pipes having an inside diameter of 2.50 inches to 3.0 inches, place the centerline of the sensor at 1.50 inches from the inner wall of the pipe.

C) For pipes having an inside diameter of 3.0 inches to 12 inches, place the centerline of the sensor at 1.80 inches from the inner wall of the pipe.

D) For pipes having an inside diameter greater than 12 inches, position the centerline of the sensor at a distance equal to 15% of the pipe inside diameter from the inner wall of the pipe. This is the equal area location for a single sensor, which follows standard velocity traverse procedures.

E) The sensor support must also extend outward from the pipe to allow convenient mounting and to ensure that the surface temperature of the attached electronics enclosure does not exceed 60°C. If the pipe is properly insulated, this can generally be accomplished by ordering a longer support so that the enclosure is 12 inches or more from the pipe. If this is not possible, then a remote sensor electronics enclosure configuration (TS) should be used. (See Feature 4 of the Brochure).

F) If a welded flange connection is used, see the directions following Feature 8 of the Brochure to determine the appropriate “L” dimension. The temperature considerations above also apply to the flanged connections. See the drawings on the Series 450 Brochures.

G) If a Ball Valve Retractor/Restraint assembly is used, see the drawings to determine the proper sensor support length and mounting information.

H) If stress, natural frequency or vortex shedding calculations are required, consult Kurz.

III. SENSOR BLOCKAGE CORRECTION FACTORS:

This section provides equations to enable the user to calculate a **S**ensor **B**lockage **C**orrection **F**actor (SBCF) that may easily be entered into the Series 155 Mass Flow Computer. The effect of the frontal area of the sensor on the indicated velocity in a small pipe is to increase the average velocity within the pipe. Our experiments indicate that using the pipe flow area minus the frontal area of the sensor shield, sensor sting and sensor support gives a very good correction. It needs to be mentioned that this correction only is useful to correct for the reduced area and does not correct for an unusual velocity profile. This must be done using a field test using a reliable **R**eference **M**ethod (RM) such as EPA Method II or a Tracer Gas Method. When using the Series 155 Mass Flow Computer, select the VCF Correction Factor and enter the sensor blockage correction factor. Since the SBCF, is the same for all velocities, only one data point is necessary and any corresponding velocity may be used. If experimental mass flow data is obtained, the SBCF data should be removed (or VCF set to 1.00) during the test. The new VCF data will account for all effects, including flow blockage. The table below gives the appropriate coefficients for the SBCF equation for the three sensor/sensor support geometries of the Series 450. It should be noted that these corrections apply only when using the recommended sensor placement criteria described in Section II, above.

$$SBCF = \frac{D^2 + A \times D + B}{D^2}$$

Corrected Flow Rate = (SBCF) x Indicated Flow Rate

Where: D = Inside diameter of pipe (inches)
And: A, B are listed in the accompanying Table I

TABLE I, SERIES 450 SENSOR BLOCKAGE CORRECTION FACTORS						
Pipe I.D. D	450-08, 452-08, etc. (½" support, FD Sensor)		450-16, 452-16, etc. (1" support, FD Sensor)		450T-16, 450PT-16, etc. (1" support, FDT Sensor)	
	A	B	A	B	A	B
2.5-3"	0	-.894	0	-1.356	0	-1.414
3" - 12"	0	-.944	0	-1.587	0	-1.688
12"-up	-.096	+.202	-.191	+.704	-.191	+.604

Example I:

The application is for a Model 452-16-MT in a 6" Sch. 40 pipe. The I.D. of the pipe D = 6.065 inches. From the table:

A = 0
B = -1.587

$$SBCF = \frac{D^2 - 1.587}{D^2} = \frac{36.784 - 1.587}{36.784} = 0.957$$

Example II:

Assume that a ½" sensor support is used, Model 452-08-MT, instead of the 1" sensor support of Example I:

D = 6.065
A = 0
B = -.944
SBCF = 0.974