FlowKinetics™ LLC

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Custom Specifications

FKT 3DP1A Series Flow Measurement And Pressure Acquisition System

User's Manual

Date: August 20, 2025

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⚠ **IMPORTANT:** Read all instructions and precautions in this manual before use. Keep this manual for future reference.

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Limitations of Usage and Cautions

The FKT series of instruments are not *intrinsically safe*, and must not be used in dangerous or hazardous areas. Servicing of these instruments incorporating battery changing must only occur in a safe area. Use of the FKT series may require working in a hazardous environment. Necessary safety precautions must be followed.

FlowKinetics™ LLC's products (including the FKT series) are not authorized for use as any component in a life support system or device or as component of an aircraft's on board flight system. Life support systems or devices are defined as any system that can sustain, monitor or support life.

The pressure transducers used by the FKT system are compatible with most clean non-corrosive gases, however toxic gases are not suitable, nor are liquid pressure measurements. Measuring flows with high particulate content requires filtering to prevent damage to the instrument.

Any attempts to service or modify or alter the product in any way, will negate any right of claim against FlowKinetics™ LLC, relating to any liability in respect of the product.

Warranty

All of FlowKinetics™ LLC's instruments have been assembled using strictly defined and controlled procedures and tests, and are warranted against any faults in workmanship and materials for one year from the date of purchase. Liability under this warranty is limited to repair or replacement F.O.B. factory of any parts which prove to be defective within that time or repayment of the purchase price at the Seller's option provided the product has been returned, transportation prepaid, within one year from date of purchase. In no case is the Seller liable beyond replacement of product F.O.B. factory or the full purchase price. This warranty does not apply if the product or equipment is abused, altered, used at ratings above the maximum specified, used with disregard of instructions and specified operating procedures, or otherwise misused in any way. All technical advice, recommendations and services are based on technical data and information which the Seller believes to be reliable and are intended for use by persons having skill and knowledge of the application, on their own judgment. There are no implied warranties of merchantability or of fitness for a particular purpose for goods covered hereunder. In no event will the manufacturer be responsible for consequential, incidental or special damages resulting from the use of this product.

Buyer's Remedies: The buyer's exclusive and sole remedy on account of or in respect to the furnishing of non-conforming or defective material shall be to secure replacement thereof as said above. The seller shall not in any event be liable for the cost of any labor expended on any such material or for any special, direct, indirect, consequential or incidental damages to anyone or any property by reason of the fact that it shall have been non-conforming or defective.

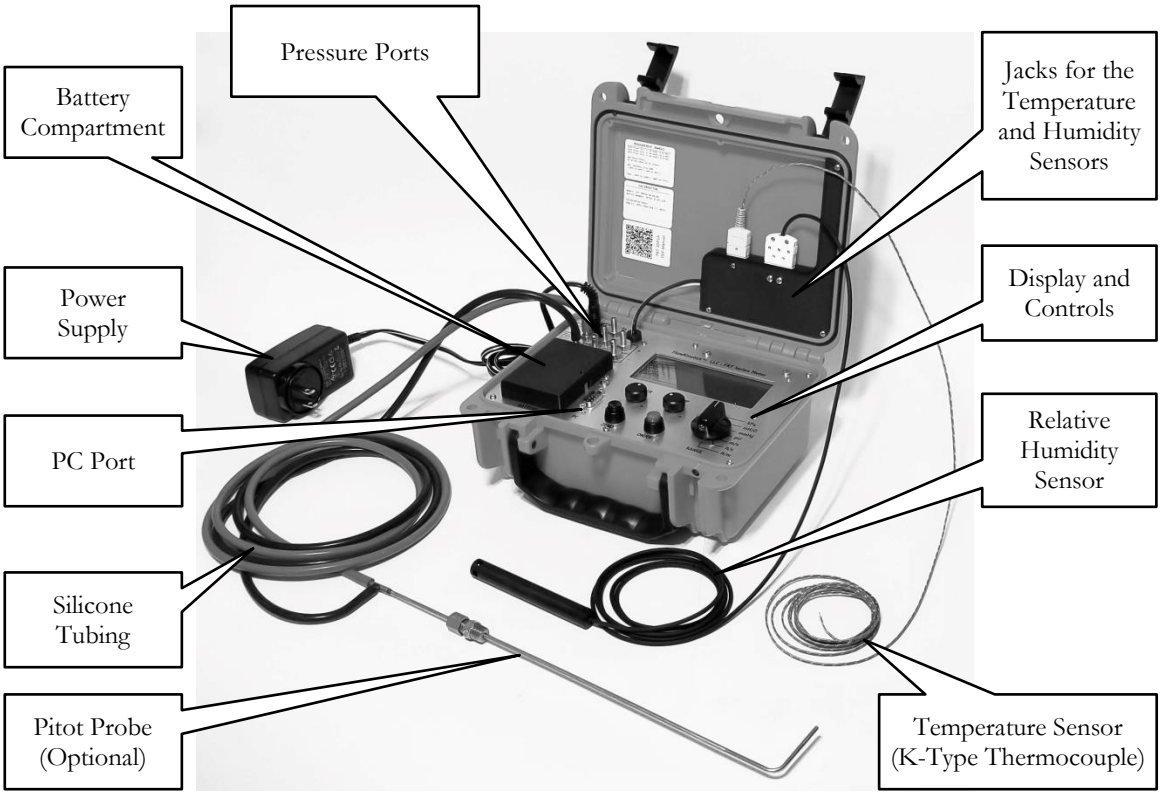
Repairs: Authorization must be obtained before shipping items to FlowKinetics™ LLC for repairs. When requesting a repair please include a detailed description of the problem with the item, date of purchase, your P.O. or reference number and our invoice number if available.

In the interest of product improvement, FlowKinetics™ LLC, reserves the right to change the design features without any prior notice.

INTRODUCTION

Overview

The FKT series of instruments are portable, self-contained micro-processor based process/pressure acquisition systems. The FKT series allow for the simultaneous measurement and display of up to three independent differential pressures as well as concurrent measurement and display of atmospheric pressure, target gas temperature and relative humidity. The last three parameters are used to calculate density, which is also displayed. In conjunction with a Pitot Static tube, the FKT series can display measured speed accounting for true gas density. The instruments can interface with a PC allowing data logging functions and can configure as a component of a data acquisition system.



Sections in this manual marked with a ⚠ refer to information that is critical for the correct operation of this instrument.

Features

- Simultaneous measurement and display of:
    - One to three independent differential pressures. This allows excellent flexibility in that multiple pressures may be measured simultaneously, or the transducer yielding optimum accuracy for a particular application may be selected.
    - Gas temperature.
    - Gas Relative Humidity.
    - Atmospheric pressure (or absolute pressure).
    - Real time true gas density including effects of temperature and water vapor.
- Extreme ease of use. The series was specifically designed to avoid menu driven operation, as this usually proves cumbersome and requires continual reference to the manual. Almost all required information is displayed concurrently through the use of a large 4 line LCD display.
- Four pressure units and three speed units.
- In conjunction with a Pitot Static tube (or multiple tubes), up to three speeds based on true gas density are displayed in three user selectable units. It is not necessary to post-process the measured dynamic pressures, calculate the true gas speed, or estimate the gas density.
- Variable damping for measurements involving pulsating flows.
- Auto-zeroing without disconnecting from the pressure source (through the use of internal solenoids) reduces zero-drift errors in differential pressure sensors and simplifies operation. The auto-zero function can also be implemented on-command by depressing the zero button. This is particularly useful when measuring in conditions with large ambient temperature fluctuations.
- Auto-protection: If the applied differential pressure exceeds the transducer rating, the instrument will automatically enter the auto-zero cycle which will equalize pressure across the differential transducers reducing the possibility of damaging the transducer.
- Data logging with optional FlowScan™ Software Suite.
- Can operate with AC power or AA batteries.

The FKT series are not suitable for use with toxic or corrosive gases or for liquid pressure measurement. The FKT series are not approved for use in any life support application.

If the FKT series instrument is used in a flow with high-particulate content filters must be installed on the tubing between the probe and the instrument. Any unused ports should be covered if the ambient around the instrument is also dirty.

Equipment and Accessories Included

The instrument is supplied complete with all required hardware and accessories for pressure measurement. These include:

- FKT 3DP1A pressure / speed meter
- A carrying bag that accommodates the instrument and most required accessories.
- Several pieces of silicone pressure tubing rated to 20psi. Tubing size: $^1/_4$ inch OD by $^1/_8$ inch ID. Tubing comes in two colors for easy identification of the connected port side.
- T-barb splitters for the rubber tubing. One for each differential pressure port installed.
- Auto-switching AC power supply. Batteries are not included.
- Relative humidity sensor.
- K-type thermocouple.
- Printed manual.

Optional Accessories and options

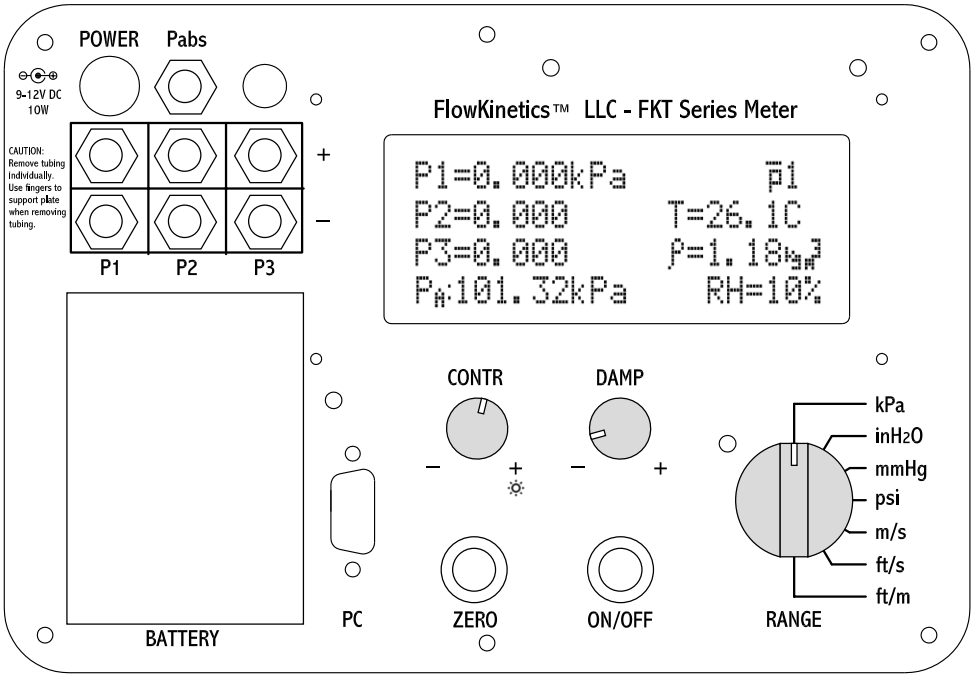
- A speed probe with many options for size and configuration. Pitot-static for general speed measurements, S-type Pitot probes suitable for dirty flows, rapid averaging probes (RAP) to quickly determine flow rates in ducts, and Kiel probes for flow with high angularity.
- FlowScan™ software suite, cable, and USB adapter to access and record the instrument readings using a computer.
- Extra rubber tubing.
- High temperature K-type thermocouple.
- Inline filters for high-particulate flow.
- Absolute pressure upgrade to 30 psi.
- Extra power supplies and cables.
- Customized programming.

OPERATION OF THE FKT SERIES

Overview

In this section, the operation of the instrument will be detailed. It will be evident that a strong emphasis in the design of the FKT series is on simplicity of use. Operation is straightforward and unambiguous.

Controls



ON/OFF — This button turns the instrument on or off through sequential depression. When in the ON position, the button remains semi-depressed.

RANGE — The instrument has four available pressure ranges and three speed ranges. Range selection is accomplished by rotating the switch to the desired position indicated by the indicator mark.

ZERO — Depressing the ZERO button initiates the auto-zero cycle and resets the zero timer. This zero interval can be changed in the setup/calibration menu at startup.

CONTR — This controls the screen contrast and backlight to best suit the ambient light conditions. The backlight will turn on when the control is turned fully clockwise. Please note that turning the backlight on will consume significantly more power and the batteries will be drained faster.

DAMP — Rotating the control varies the damping level from 1 to 8 and it is indicated by $\bar{P}1$ to $\bar{P}8$ on the upper right hand portion of the display.

PC — This serial port allows connection of the instrument to a PC for data logging. If a USB connection is needed the optional USBA2 adapter is available.

P1,P2,P3+ These pressure port barb connections are for the typical positive pressure of the differential transducers, such that a greater pressure at this port then the corresponding P– port will result in an indicated positive pressure.

P1,P2,P3- These pressure port barb connection are for the typical reference pressure of the differential transducers, such that a greater pressure at this port then the corresponding P+ port will result in an indicated negative pressure.

Pabs This barb connection is for the absolute pressure transducer. If the true density in a duct or similar element is desired, a tube should be connected from this port to a static port on the duct or the static port of a Pitot Static tube inserted into the duct, see Section C.

Power

The unit can be powered with AC power or batteries. To power the unit press the ON/OFF button. The screen will indicate the instrument information, followed by a prompt to setup or calibrate the instrument. Without any input the menu will be bypassed and continue with the startup.

Subsequently, the unit will perform an initial auto-zero and be ready for operation. Auto-zeroing will occur every few minutes afterwards, unless initiated with the ZERO button. The zero interval defaults to six minutes and this interval can be modified in the setup / calibration menu at startup.

AC Power Supply

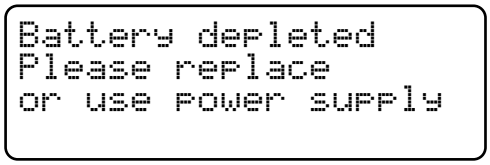
For AC power, plug the included power supply into a suitable AC outlet and connect its plug into the POWER jack on the instrument. The supplied auto switching power supply can operate from 100 to 240V_{AC}, 50-60Hz and provides an output of 9V_{DC}, 2Amps. **Note**: when the power supply is plugged into the unit, there is no need to remove the batteries, they are automatically disconnected.

⚠ Use of any power supply other than that supplied with the instrument will remove any rights of claim against FlowKinetics™ LLC, relating to product liability or consequential damage against a third party. If an alternative power supply is used, its output voltage range must be regulated and within 9 to 12 V_{DC}.

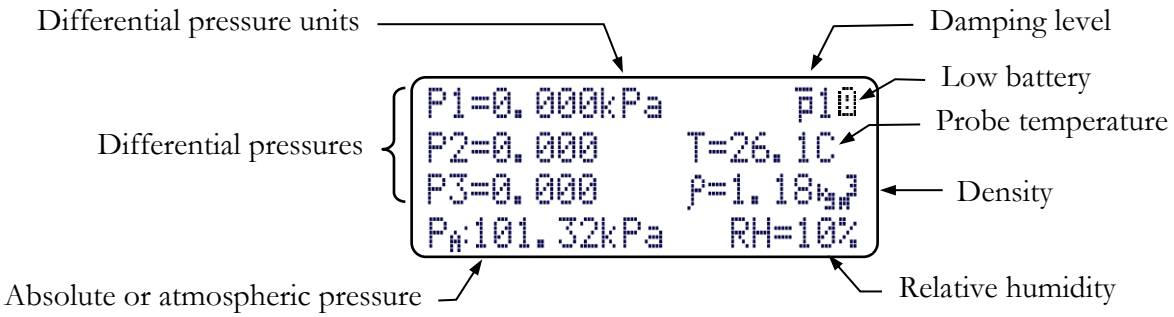
Battery Power

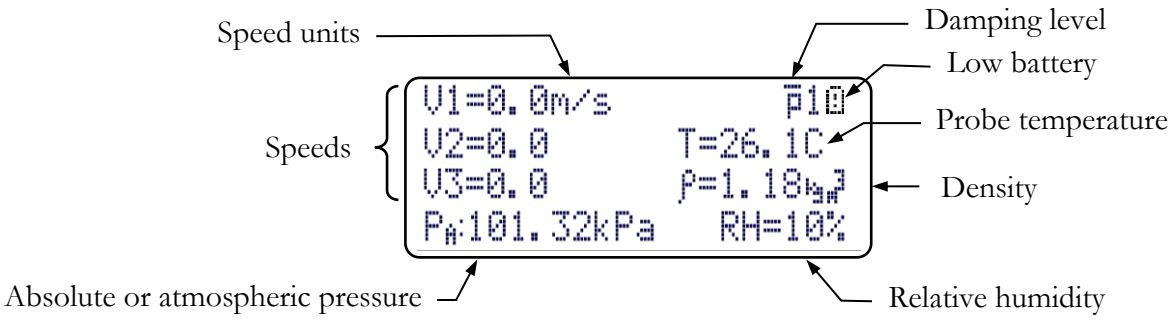
The FKT requires eight AA-sized batteries (1.5V each). Use dry alkaline leak-proof types. If the FKT series is stored, or not used for over a week, the batteries must be removed. For battery connection and maintenance, see Battery Replacement in page 23.

If the batteries are too depleted for proper operation when the meter is powered, the message below will be shown and the meter will not continue until new batteries are installed or the power supply is used.



Display





Pressure / Speed (P1, P2, P3, V1, V2, V3)

Displays up to three differential pressure (P1, P2, P3) or speed (V1, V2, V3) readings. The units for all three sensors are shown on the first row of the display. The units depend on the RANGE knob position.

Temperature and Relative Humidity (T, RH)

The temperature as measured by the thermocouple. Temperature units are displayed so as to be compatible with the pressure/speed range selected. The Relative Humidity percentage as measured by the relative humidity probe.

If the measured temperature is below -200°C (328°F) or exceeds 816°C (1500°F), the display unit of temperature, i.e. C or F, will be replaced by the ! symbol. Relative humidity exceeding 99% will also be indicated by the appearance of the ! symbol instead of %.

Damping (P1 to P8)

The damping level selected with the DAMP knob.

Ambient or Test Point Density. (ρ)

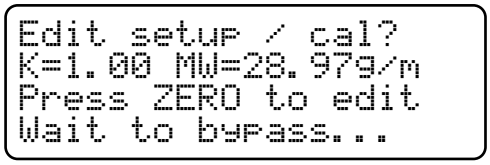
The temperature, ambient pressure, and relative humidity are used to calculate the density. The density is always displayed in kg/m^3.

Battery warning ( )

Low battery will be indicated by the appearance of on the top right hand side of the display, indicating that the supply battery voltage under load has dropped below approximately 8V. At this point the batteries should be replaced or the power supply should be used. Using the FKT with low battery levels for extended periods may lead to unreliable readings after auto-zero.

Setup and Calibration

The meter can be configured and calibrated by pressing ZERO when prompted at startup. Once the menu is started the instrument will run through several options. These settings are saved in the internal non-volatile memory and will stay with the meter even without power.



In the setup and calibration menus the CONTR knob is used to dial the values or select options and ZERO button to set the value. Once the value is set the meter will show the new value on screen for a few seconds as a confirmation before moving on to the next option. Once the menu is finished the values are saved to non-volatile memory. If a previous setup was performed, the saved setting will be displayed in the menu while editing.

The setup / calibration menu sections are listed below.

Reset

This resets all the settings and calibration corrections to the factory defaults. All slope corrections are set to 1.0 and offset corrections to 0.0. Probe coefficient is set to 1.0, molecular weight to air (28.97 g/mol), and zero interval to every six minutes.

Pitot Correction (K)

This value is the correction factor (K) for the speed probe being used. Defaults to 1.0. The correction is applied to speed (V_{gas}) as follows:

$$V_{gas} = K \times \sqrt{\frac{2 \times P_{dynamic}}{\rho}}$$

Typically, the value of the correction factor is provided by the probe manufacturer. The available range is 0.75 to 1.25.

Molecular Weight (MW)

This is the molecular weight of the gas used to determine the density of the flow. It defaults to air (28.97 g/mol). For better coverage of different gas values, this quantity is set in two parts: its integer and fractional parts. The available range is 1.00 to 150.99 g/mol.

Zero interval

Number of minutes between automatic zero of the differential pressures. This setting defaults to six minutes. This interval can be adjusted from 1 to 60 minutes. Shorter intervals will deplete the battery faster as the solenoids work more often. Longer intervals may lead to larger drift in the differential pressure sensors under certain conditions. Note that the FKT series will automatically perform a calibration 2 minutes after it is powered on.

Calibration

This option enters the calibration menu. Here you can adjust the calibration of the instrument. For the differential transducers it will modify the slope only. The offset is automatically adjusted with the solenoids. For all other values the adjustment is as shown below.

$$Value_{adjusted} = Value \times slope + offset$$

All slope corrections default to 1.0 and offsets to 0.0. For temperature and relative humidity, the adjustments are applied only when the sensor is connected to the instrument. Available ranges for slope corrections are 0.99 to 1.01. The range for offset corrections is up to ±2×(sensor uncertainty).

For more details on how to adjust the instrument calibration see User Calibration in page 23.

Pressure/Speed ranges

The FKT series allow for the simultaneous measurement of up to three differential pressures / speeds and one absolute pressure. Detailed ranges, resolutions, and accuracies are listed in the FKT Series Sensor Ranges section in page 28.

The pressure transducers are true differential sensors; positive pressures can be applied to either port. The absolute pressure transducer, when it is unconnected, displays local atmospheric pressure. If the absolute pressure sensor is connected to a Pitot-static probe or duct system then it measures the static pressure in the duct or where the probe is located.

Rotate the RANGE switch to the desired position to display the differential pressures or speeds. The selection of any of the speed ranges (m/s, ft/s and ft/m) will use the Pitot correction factor, K, stored in memory. Speed is calculated as follows:

$$V = K \times \sqrt{\frac{2 \times P_{dynamic}}{\rho}}$$

Where $P_{dynamic}$ is the differential pressure (from P1, P2 or P3), ρ is the density and K is the probe coefficient. Dynamic pressure is measured directly and density is determined from the temperature, ambient pressure, and relative humidity.

If the speed ranges are being used to measure speed of gas exiting a nozzle, then K can be left at the default value of one. If the nozzles discharge coefficient is known, then the square root of this coefficient may be entered as K.

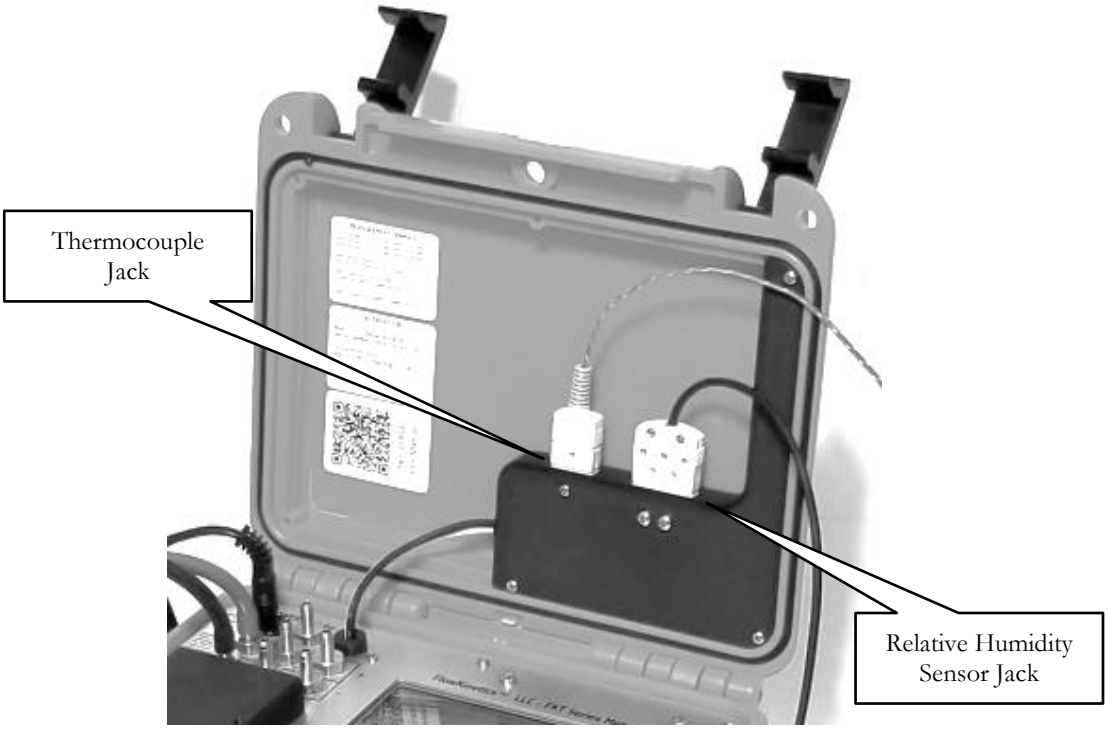
Tubing Connection Recommendations

- Ensure that the tubing sections connecting P+ and P- are of approximately equal length.
- Check that the tubing is un-kinked and non-constricted.
- Use the full length of the supplied tubing when measuring dirty or saturated air streams to avoid any contaminants draining into the pressure ports.
- Do not moisten the tubing to attach to the port barbs. The moisture can block the tubes and interfere with the transmission of pressure.
- Always connect the tubing and probe to the instrument **first** before inserting the probe into the flow or connecting the tubing to the pressure source. This prevents too many contaminants filling the tubing and reaching the sensors. Especially in high-particulate environments.
- When removing tubing from the barbs, ensure that the face of the instrument is supported before pulling on the tubing (i.e. place two fingers on the surface adjacent to the barb). DO NOT PULL ON THE TUBING WITHOUT SUPPORTING THE PLATE. Remove the tubing individually.

⚠ Under no circumstances should pressure differentials greater than 2.5 times the maximum rating be applied to the differential ports (P1, P2, P3).

Temperature and Relative Humidity measurement

The instrument comes with two detachable probes that allow for the measurement of test point temperature and humidity. The temperature and humidity probe jacks are located inside the lid of the FKT instrument. Both sensor plugs are polarized and have one wider pin.



Temperature is measured by the K-type thermocouple that can be inserted into a duct or attached to a speed probe while testing. For accurate measurements the tip of the thermocouple should be exposed to the flow directly so it can measure the stagnation temperature. The exposed tip of the thermocouple is ideal for measuring in gases. Care should be taken to avoid direct contact of the tip with metal or liquids. If the instrument is operated with the thermocouple disconnected then the meter will display a standard temperature of 70°F (21.1°C).

K-type thermocouple

The included temperature probe is a K-type wire thermocouple with a range of 0 to 482°C (32 to 900°F) and a quick disconnect miniature connector. The FKT instrument can work with other K-type thermocouples and can display temperatures from -200 to 816°C (-328 to 1500°F) depending on the thermocouple materials.

The relative humidity is measured by the plastic detachable probe with a three prong copper connector as shown below. If measuring relative humidity in a location such as a duct, the probe tip

is inserted into the duct. For insertion of the relative humidity probe into gas streams, it is necessary that the gas is clean and free of contaminants. If the relative humidity sensor is disconnected, the instrument will default to a value of 0% relative humidity.

The relative humidity probe is designed to operate in a temperature range of -40°F (-40°C) to 185°F (85°C). If the temperature recorded by the meter is outside these limits the humidity reading will default to 0%.

Relative Humidity probe

⚠ The **maximum** immersion temperature of the RH probe is 85°C (185°F). The relative humidity probe must only be inserted into clean, uncontaminated gas streams.

⚠ Turn off the instrument before connecting or disconnecting the temperature or RH probe.

Density

Density is calculated as shown below. The temperature (T) is in Celcius. The ambient pressure is Pabs in Pa, the molecular weight of the gas is MW in g/mol, and R_{univ} is the universal gas constant (8.31446 J mol^{-1} K^{-1}). Pws is the saturation vapor pressure in Pa and it is a function of the temperature. MW_{water} is the molecular weight of water (18.015 g/mol). Relative humidity (RH) is in percent. Note that the RH effect on density is only applied for a temperature range of -10 to 80°C. For other temperatures RH is set to zero.

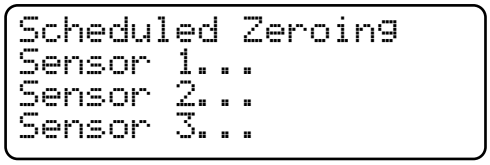
$$\rho = \frac{MW}{R_{univ} \times (T + 273.15)} \left(Pabs + Pws \times \frac{RH}{100} \times \left(\frac{MW_{water}}{MW} - 1 \right) \right)$$

Damping

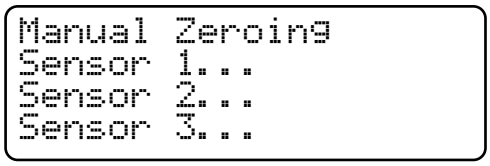
The damping feature, when measuring unsteady or pulsating pressures or flows, is achieved through repeated data averaging. Rotating the DAMP control varies the damping level from P1 to P8 on the upper right hand portion of the display. The meter uses the square of the display number for the number of averages. For example, the P3 level averages 9 readings per sample. P1 is minimum damping with one reading per sample, and P8 is the maximum with 64 readings per sample. Increasing the number of averages will slow down the screen update intervals as the FKT processes the data.

Zeroing

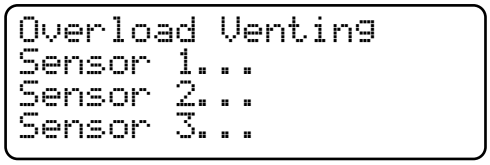
The FKT series has fully autonomous auto-zeroing for the differential pressures without the need to disconnect from the pressure source. This feature activates every 6 minutes by default and can be changed in the setup / calibration menu at startup.



The user can initiate the auto-zero cycle at any instant by depressing the ZERO button. It is necessary to keep this button depressed until the display indicates that the instrument has entered the auto-zero cycle. The display will indicate the sequential venting of each differential pressure transducer (as installed) accompanied by mechanical clicks of the internal valves.



If the range of a differential transducer is exceeded, the FKT series will automatically enter the auto-zero cycle to equalize pressures across the differential pressure transducers, so lessening the possibility of permanent damage to the transducers.



Data Logging

Using the optional FlowScan™ Software Suite logging or recording instrument outputs is fully automated and greatly simplified. FlowScan™ also includes computational features, and can calculate volumetric and mass flow rates for surveyed ducts. The suite includes the FlowScan™ stand-alone application, Excel® Add-In, and the libraries such as the LabVIEW® Virtual Instrument. The data logging facility also allows the instrument to function as a component of an external data acquisition program. Refer to the FlowScan™ manual for more details.

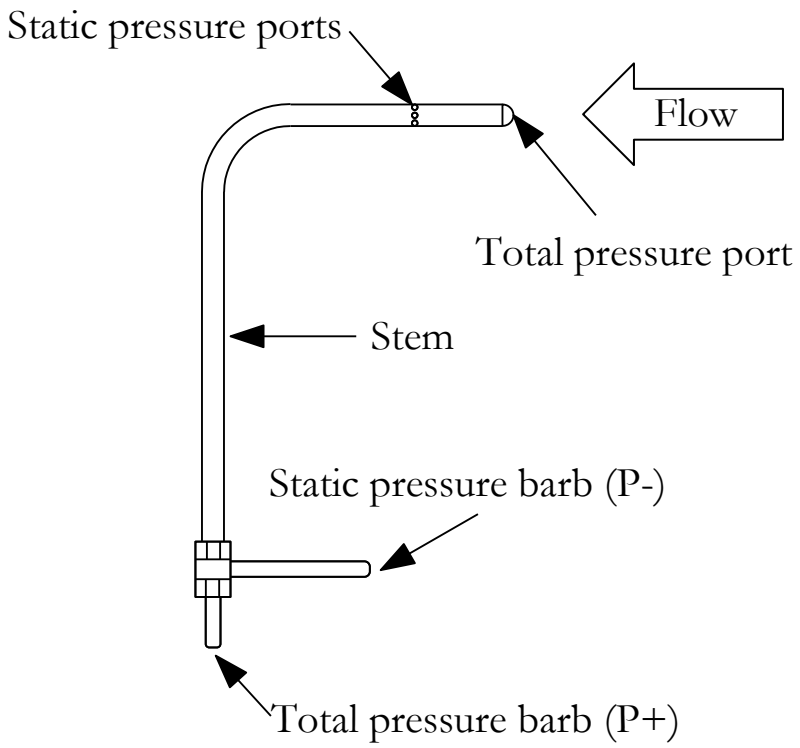
USING A PITOT STATIC TUBE FOR SPEED MEASUREMENT

Overview

In this section, use of a Pitot Static tube, in conjunction with the FKT series instrument will be explained. The Pitot Static tube allows the direct measurement of dynamic pressure allowing calculation of the gas speed in ducts, pipes wind tunnels etc. For other types of probes please refer to the documentation included with the probe.

Pitot Static probes

A Pitot Static tube is shown below



Generic Pitot Static tube configuration.

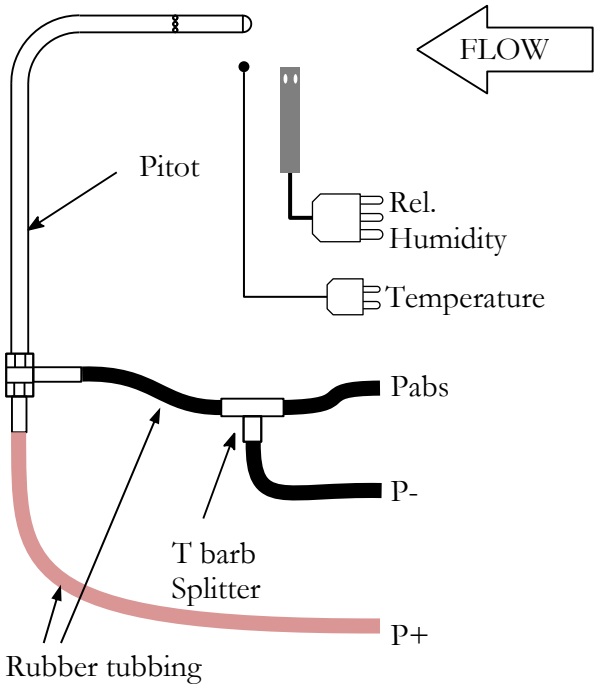
The Pitot Static tube measures the total pressure (or impact pressure) at the nose of the Pitot tube and the static pressure of the gas stream at side ports. The difference of these pressures, i.e. the dynamic or speed pressure ($P_{dynamic}$) varies with the square of the gas speed. Thus the gas speed may be expressed as shown below.

$$V = K \times \sqrt{\frac{2 \times P_{dynamic}}{\rho}}$$

The gas density is ρ and K is a correction factor dependent on the design of the Pitot Static tube.
NOTE: This equation is typically valid for incompressible (constant density) flow. High speeds (V) will lead to increasing errors.

Measurement of Actual Flow Speed

To measure speed with the instrument with the greatest accuracy, it is necessary to measure the absolute pressure, temperature, and relative humidity of the gas being tested. This allows the FKT series to calculate the correct gas density. This is achieved by connecting the probes as shown below. The thermocouple and relative humidity probe should be as close as possible to the Pitot probe tip taking the speed measurements. Alternatively the Pabs port can be connected to a wall static pressure tap in the case of a duct (or averaging ring) at the measurement point location.



⚠ The **maximum** immersion temperature of the RH probe is 85°C (185°F). The relative humidity probe must only be inserted into clean, uncontaminated gas streams.

⚠ The FKT series are not suitable for use with toxic or corrosive gases or for liquid pressure measurement.

⚠ If the FKT series instrument is used in a flow with high-particulate content filters must be installed on the tubing between the probe and the instrument. Any unused ports should be covered if the ambient around the instrument is also dirty. For very dirty flows we recommend using a S-type probe instead.

⚠ Always connect the tubing and probe to the instrument **first** before inserting the probe into the flow. This prevents contaminants from filling the tubing.

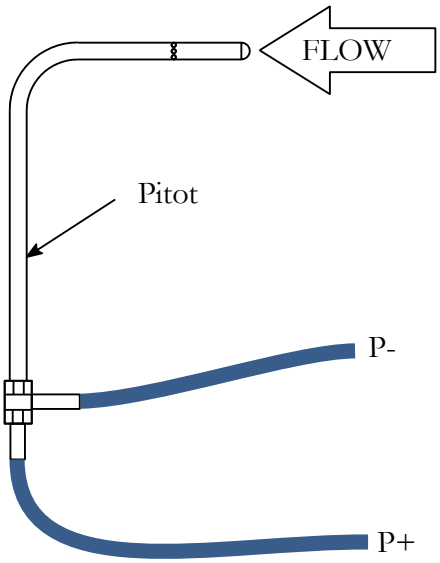
Measurement starts with attachment of rubber tubing to the Pitot Static tube and the pressure transducer of choice. The P+ connection barb of the transducer is connected to the Total pressure port of the Pitot tube, and the Static pressure port of the Pitot tube is connected to the transducers

P- barb connection. The appropriate transducer for the expected speed range should be used for maximum accuracy. However, if in doubt as to the expected speeds, use the largest pressure range available to avoid overloading.

The Pitot Static tube can then be carefully inserted into the gas flow. It may be necessary to drill holes into the ducting for insertion. The absolute pressure, temperature and RH must be measured simultaneously with the differential pressure measured by the Pitot Static tube for best accuracy. The supplied T-barb splitter can be used to connect the static port of the Pitot Static tube to the P- port of the differential pressure transducer as well as the Pabs absolute pressure transducer. A Pitot Static tube with K of approximately unity should be used when this type of connection is employed.

In many applications, the ambient density may be close to the target gas density. This can readily be determined using the FKT series by recording the ambient density (displayed continuously), followed by the target gases density. The density will be calculated and autonomously presented by the FKT series through measurement of absolute pressure, temperature and RH. If the density is comparable, then simultaneous measurement of target flow density is unnecessary, i.e. the thermocouple and RH probe can be left out of the test area.

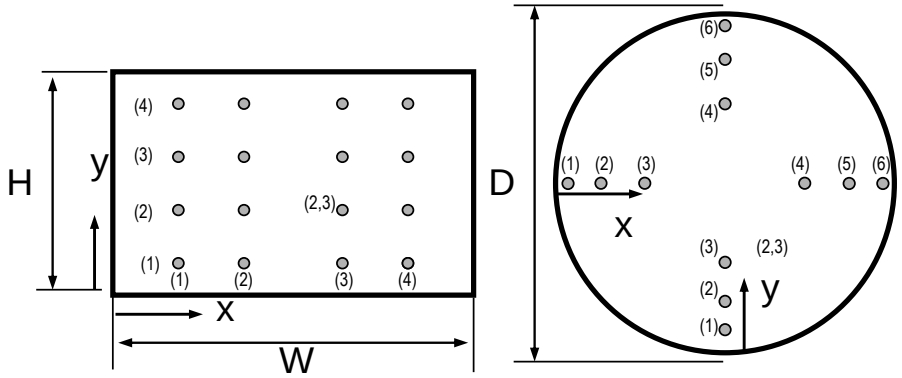
Measuring Standard Speed



If you want to quickly measure the speed assuming air standard conditions you can connect the Pitot probe as shown below. Standard conditions refer in this manual as temperature of 21.1°C, atmospheric pressure of 1 atmosphere, and 0% relative humidity. These conditions result in an air density of 1.2kg/m^3.

*Pitot Static tube duct surveys**

If average duct speeds, or mass or volumetric flow rates are required, it is necessary to perform a Pitot traverse of the duct. This involves taking measurements at various positions across the duct. Before a traverse is conducted, it is necessary to select a suitable location to perform the survey. If possible, avoid traverses close to fans, dampers pipe bends, expansions etc. Try to survey at least 8 duct diameters downstream of the aforementioned elements and 2 duct diameters upstream of these elements. The survey is performed with the aid of the figure and table below. Either the **Centroids of Equal Areas** ***or*** **Log-Tchebycheff** point distribution may be used.



4-Point Example 6-Point Example

Rectangular Ducts – Centroids of Equal Areas							
Points	**Distance from wall, x/W or y/H**						
4	0.125	0.375	0.625	0.875			
5	0.100	0.300	0.500	0.700	0.900		
6	0.083	0.250	0.417	0.583	0.750	0.917	
7	0.071	0.214	0.357	0.500	0.643	0.786	0.929

Circular ducts – Centroids of Equal Areas												
Points	**Distance from wall, x/D or y/D**											
6	0.043	0.147	0.296	0.704	0.853	0.957						
8	0.032	0.105	0.194	0.323	0.677	0.806	0.895	0.968				
10	0.026	0.082	0.146	0.226	0.342	0.658	0.774	0.854	0.918	0.974		
12	0.021	0.067	0.118	0.177	0.250	0.356	0.644	0.750	0.823	0.882	0.933	0.979

Rectangular Ducts – Log-Tchebycheff							
Points	**Distance from wall, x/W o y/H**						
5	0.074	0.288	0.500	0.712	0.926		
6	0.061	0.235	0.437	0.563	0.765	0.939	
7	0.053	0.203	0.366	0.500	0.634	0.797	0.947

Circular ducts – Log-Tchebycheff										
Points	**Distance from wall, x/D o y/D**									
6	0.032	0.138	0.312	0.688	0.862	0.968				
8	0.024	0.100	0.194	0.334	0.666	0.806	0.900	0.976		
10	0.019	0.076	0.155	0.205	0.357	0.643	0.795	0.845	0.924	0.981

* For specifics regarding validation of surveys, etc, the following references are suggested: (1) ASHRAE. 1988. *Practices for measurement, testing, adjusting and balancing of building heating, ventilation, air-conditioning and refrigeration systems*. Standard 111-1988, Atlanta, GA and (2) AABC. 1989. *National standards, 5th ed., volume measurements.* Washington, D.C.

Survey procedure

1. Decide on the number of survey points and then mark these on the Pitot tube using a marker or adjustable spring clips (present on some Pitot Static tubes).
2. At the selected survey location, drill two perpendicular holes in the duct (for a round duct) or the desired number of holes for a rectangular duct, ensuring sufficient hole clearance to safely insert the Pitot Static tube.
3. Partially insert the thermocouple and RH probe in an additional hole located close to the previously drilled holes. You can attach them to the Pitot if desired.
4. Connect Pabs to a static pressure tap/ring close to the survey location, or use a T-barb to connect to the static Pitot tube port.
5. Carefully insert the Pitot Static tube into the duct and position at the first traverse location. Ensure that the Pitot Static tube is aligned with the axis of the duct using the alignment guide on the tube as a reference.
6. Wait for the readout on the display to stabilize. If the readout continues to oscillate increase the damping (DAMP). If the magnitude of the oscillations is greater than 25%, then another measuring point should be considered as the results may not be representative.
7. When stabilized, record the desired reading(s).
8. Move the Pitot Static tube to the next traversing point and repeat 5 and 7 until the traverse is complete.
9. Repeat points 5–8 for the other traverse locations.

Once the traverse has been completed, the volumetric and mass flow rate through the duct can be calculated.

Volumetric flow rate

$$Q = A_{duct} \times \frac{1}{n} \times \sum_{i=1}^{n} V_i$$

where: A_{duct} is the duct cross sectional area.
n is the total number of points surveyed.
V_i is the indicated speed at each measurement point.

Thus, using a **Centroids of Equal Areas** or **Log-Tchebycheff** point distribution allows the speed measurements to simply be summed and averaged.

Mass flow rate

$$\dot{m} = \rho \times Q = A_{duct} \times \frac{1}{n} \times \sum_{i=1}^{n} \rho \times V_i$$

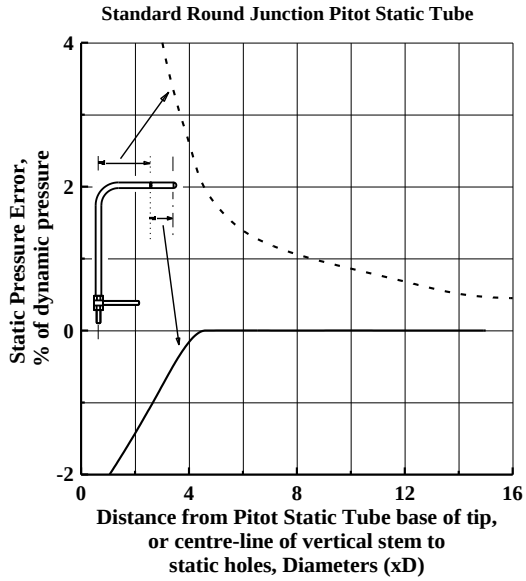
where ρ is the density of the gas in the duct.

Assuming fully developed turbulent flow with low air swirl (rotation), i.e. after a long section of duct, the average duct speed may be estimated using a single Pitot reading at the center of the duct. The average speed is then approximately 0.9 of this reading with an accuracy of ±5%.

ASHRAE (1988) guidelines suggest that for a speed distribution to be acceptable, 75% or more of the speed measurements must be greater than 10% of the maximum measured speed of the survey.

Determining the Coefficient of a Pitot-Static Probe

If the coefficient (K) for a particular Pitot-Static probe tube is not known, it may be estimated. This factor is dependent on the spacing of the Pitot tubes' static pressure ports from the base of the Pitot tube's tip and the stem's center line. Prandtl type Pitot tubes typically have factors K close to 1. Figure below shows the effect and error of the location of the static pressure ports on the static pressure error.



Effect of static pressure hole location from Pitot Static Tube stem or tip

The lower line gives the static pressure error associated with the distance of the static ports from the base of the tip, expressed in diameters. The upper line presents the static pressure error due to the distance of the static ports (expressed in diameters) from the stem center-line.

The probe coefficient can also be determined directly from the table below for a various Pitot tube geometric variations (for a standard round junction tube).

Pitot Static tube correction factor K											
Dist from Tip, ×D / Dist from Stem, ×D	**2**	**2.5**	**3**	**3.5**	**4**	**6**	**8**	**10**	**12**	**14**	**16**
2	1.023	1.025	1.026	1.028	1.029	1.030	1.030	1.030	1.030	1.030	1.030
4	1.006	1.007	1.009	1.010	1.012	1.013	1.013	1.013	1.013	1.013	1.013
6	1.001	1.002	1.004	1.005	1.007	1.008	1.008	1.008	1.008	1.008	1.008
8	0.998	1.000	1.001	1.003	1.005	1.005	1.005	1.005	1.005	1.005	1.005
10	0.997	0.999	1.000	1.002	1.003	1.004	1.004	1.004	1.004	1.004	1.004
12	0.996	0.998	0.999	1.001	1.002	1.003	1.003	1.003	1.003	1.003	1.003
14	0.996	0.997	0.999	1.000	1.002	1.003	1.003	1.003	1.003	1.003	1.003
16	0.995	0.997	0.998	1.000	1.001	1.002	1.002	1.002	1.002	1.002	1.002
18	0.995	0.996	0.998	1.000	1.001	1.002	1.002	1.002	1.002	1.002	1.002
20	0.995	0.996	0.998	0.999	1.001	1.002	1.002	1.002	1.002	1.002	1.002

Example

The coefficient for a standard round nose Pitot Static tube is unknown. This probe has a 5 mm tube diameter (D). It has static orifices located 10 mm from the base of the tip and 50 mm from the stem's center-line.

The distance from the tip in tube diameters is 2D and the distance from the stem in diameters is 10D. From the figure above the tip error is -1.4% and the stem error is +0.8%. The net error is -0.6%. The correct dynamic pressure and speed is then:

$$P_{dynamic\ correct} = \left(1 + \frac{\boxed{-0.6}}{100}\right) \times P_{dynamic} = 0.994 \times P_{dynamic}$$

$$V_{correct} = \sqrt{\frac{2 \times P_{dynamic\ correct}}{\rho}} = \sqrt{\frac{2 \times 0.994 \times P_{dynamic}}{\rho}}$$

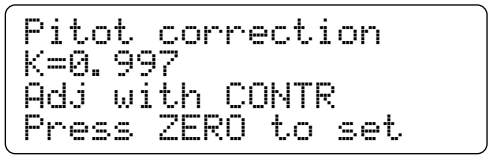
$$V_{correct} = \sqrt{0.994} \times \sqrt{\frac{2 \times P_{dynamic}}{\rho}} = K \times \sqrt{\frac{2 \times P_{dynamic}}{\rho}}$$

$$Probe\ coefficient, \qquad K = \sqrt{0.994} = \boxed{0.997}$$

The K value can also be found directly in the table above for a tip distance of 2D and stem distance of 10D (K= 0.997). If this K value is stored in the settings, the speeds displayed by the meter will be corrected for this probe.

Storing the Pitot tube Correction factor, K

At power up entering the setup /calibration menu allows you to edit the Probe correction. It defaults to K=1.000. Rotate the CONTR control until the desired value is displayed. To store this value, press the ZERO button. Values of from 0.750 to 1.250 can be stored, representative of most Pitot tubes. All speeds displayed by the instrument will incorporate the correction factor K.



MAINTENANCE

Operational maintenance

- Ensure that the FKT series are kept clean, dry and do not come into contact with any corrosive elements.
- Do not spill any liquids onto the instrument when the unit's lid is open.
- Do not use any solvents for cleaning purposes. To clean surfaces, wipe with a clean dry cloth.
- When used in a dusty environment, the unconnected pressure barbs should be covered.
- When the low battery warning appears on the display the battery pack should be replaced.
- If the flow being tested has high particulate content use an inline filter on the tubing to prevent damage to the internals of the unit.
- If tubing becomes clogged or too dirty internally it is best to clean it or replace it.
- The FKT series should be returned to FlowKinetics™ LLC, for calibration annually.

Battery Replacement

1. Check to ensure that the instrument is turned off.
2. Unscrew the two thumb screws and remove the battery compartment cover plate.
3. Carefully lift the battery pack out of the compartment.
4. DO NOT PULL ON THE BATTERY LEADS.
5. Remove the battery snap (connector).
6. Remove the old batteries out of the holder.
7. Replace all the batteries with fresh batteries. Be careful to ensure the correct battery polarity as indicated on the battery holder. **Do not mix batteries of different age, brands or types.**
8. Re-connect the battery snap to the battery pack. Check to ensure a positive connection.
9. Carefully insert the pack into the battery compartment
10. Replace the compartment cover plate. Hand-tighten the lid thumb screws.

User Calibration

If desired, the factory calibration can be easily adjusted. This is achieved by calculating and storing a slope and offset correction for each sensor. The slope corrections can be changed from the factory-determined spans by up to ±1% (0.9900 to 1.0100). The offset correction can be up to ±2×(sensor accuracy).

⚠ Altering the factory calibration may affect the accuracy of the FKT series instruments, and thereby may remove any rights of claim against FlowKinetics™ LLC relating to product liability or to any consequential damage to any third party. If in doubt, return the instrument to FlowKinetics™ LLC for calibration.

⚠ If it is determined that a correction is required larger than allowed in the user calibration, then the instrument must be returned to FlowKinetics™ LLC for factory recalibration and maintenance. Note that a factory recalibration will update the internal calibration of the FKT and will reset all the user corrections to their defaults (unity slopes and zero offsets).

Calibration Procedure

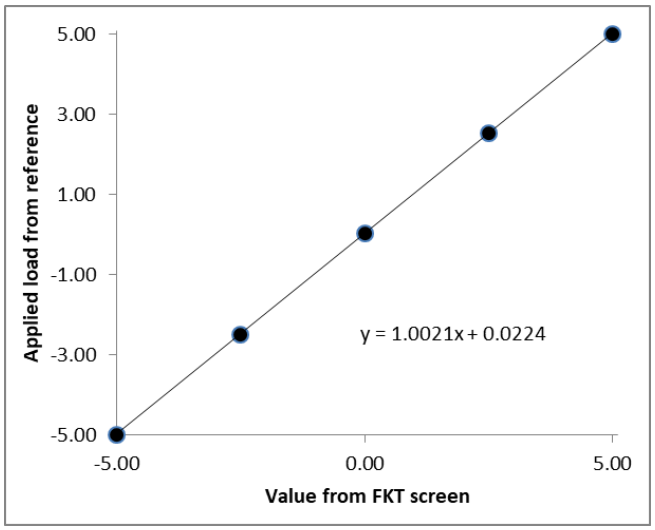
1. Ensure that the FKT instrument has been powered up for at least 10 minutes. Check that there are no corrections applied to the sensors by resetting the slope to 1.0 and offset to 0.0 using the setup / calibration menu at startup.
2. For each sensor you wish to calibrate, break up the sensor range into uniform intervals. Typically a 5 point calibration should suffice. For example, a ±5inH_2O (±1.2kPa) differential pressure sensor you could be calibrated by applying pressures at +5, +2.5, 0, -2.5, -5 inH_2O. These intervals may be limited by the standard that you use such as a dead weight tester that comes with fixed weight sets.
3. Connect your reference to the sensor on the FKT instrument which is to be calibrated.
    a. For pressure just connect the reference source to the port (P1,P2,P3,Pabs)
    b. For temperature either use the thermocouple included with the FKT with a known temperature source, or use a K-type thermocouple calibrator connected directly to the thermocouple jack on the FKT.
    c. For the relative humidity place the included sensor in a known humidity source.
4. Apply loads. For each applied load record the indicated value from the FKT screen.
5. Organize the data into two columns: Applied loads and FKT screen readings.
    a. For differential pressures, store the readings and applied loads using the same units.
    b. For absolute pressure, store the values in kPa.
    c. For temperature, store the values in degrees Celsius.
    d. For humidity store the values in percent.
6. Calculate a linear fit to the data. Set the FKT readings (V_{FKT}) as the x-axis and the reference loads (V_{REF}) as the y-axis. The linear fit would result in the form of $V_{REF} = V_{FKT} \times A + B$ for each sensor calibrated.
    a. For differential pressures, A is the slope correction. Offset is not needed since the FKT calculates it automatically using the solenoid valves.
    b. For absolute pressure, A is the slope correction, B is the offset in kPa.
    c. For temperature, A is the slope correction, B is the offset in degrees Celsius.
    d. For relative humidity, A is the slope correction, B is the offset in percent.
7. Enter the setup / calibration menu in the FKT and enter the values obtained for each transducer.

Example 1 (differential pressure sensor calibration)

1. FKT with a ±5inH_2O (±1.2kPa) differential pressure sensor (P1).
2. Using a deadweight tester as a reference, these loads were applied: -5.0, -2.5, 0.0, +2.5, +5.0 inH_2O. Negative pressures were applied to P1- and positive to P1+.
3. The following data was acquired by reading the FKT screen:

Value read from the FKT screen (inH_2O)	Applied pressure from reference (inH_2O)
-4.99	-5.00
-2.49	-2.50
0.04	0.00
2.55	2.50
5.01	5.00

4. Plotting the data and fitting a line as shown below results in a slope of 1.0021. This is the slope correction that should be entered for P1 in the FKT setup menu available at startup. Note that the offset is not needed since the solenoid venting automatically recalculates the offset for the differential pressure sensors.



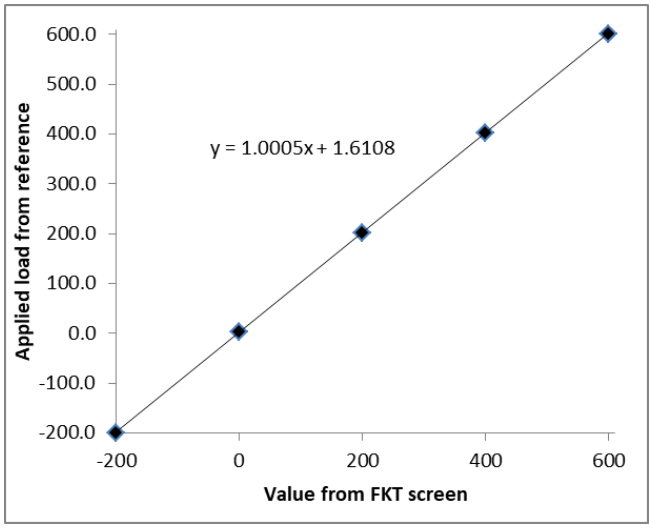

```
P1 Calibration
slope corr=1.0021
Adj with CONTR
Press ZERO to set
```

Example 2 (Temperature reader)

1. FKT with a K-type thermocouple reader range of -200 to 816°C.
2. Using a K-type thermocouple calibrator as a reference, these loads were applied: -200, 0, 200, 400, 600°C. Note that this range is less than the maximum range as the end user will not be using the thermocouple at higher temperatures than 600°C.
3. The following data was acquired by reading the FKT screen:

Value read from the FKT screen (deg C)	Applied temperature from reference (deg C)
-199.5	-200
2.7	0
201.5	200
403.0	400
600.9	600

4. Plotting the data and fitting a line as shown below results in a slope of 1.0005 and an offset of 1.6°C. These are the values that should be entered in the FKT setup / calibration menu for the temperature calibration.




```
Temp Calibration
slope corr=1.0005
Adj with CONTR
Press ZERO to set
```

```
Temp Calibration
offset=1.6C
Adj with CONTR
Press ZERO to set
```

SPECIFICATIONS

General

Enclosure	UV protected, water resistant and virtually unbreakable
Dimensions	Length: 8.7 in (220.9 mm) Width: 7.5 in (190.5 mm) Height: 3.9 in (99.1 mm)
Weight	2.93 lb (1.33 kg)
Working Temperatures	Operating: 32°F to 158°F (0°C to 60°C) Storage: 14°F to 140°F (-10°C to 60°C)
Power Supply	8 x 1.5V AA Alkaline batteries, field replaceable (batteries not included) 100V-240V AC auto-switching power supply (included)
Battery life	30hrs approx. with screen backlight off.
Pressure Connectors	1/8 in barb, 0.41 in (10.45 mm) long by 0.19 in (4.9 mm) diameter. Accepts 1/8 in ID rubber tubing
Differential Pressure	For available ranges see FKT Series Sensor Ranges in page 28. Up to three independent differential pressure sensors. Zero offset and zero temperature shift: eliminated through auto-zero without disconnect. Accuracy at 25°C: Typically within ±0.1% of full scale pressure (±0.22% max) Common mode pressure: Maximum simultaneous pressure on both ports for each sensor: 10 psi for sensors with a range of ±5inH_2O or below. 15 psi for sensors with a range of ±12inH_2O or above. Maximum differential pressure: 2.5 stated range. User recalibration procedure available
Speed	For available ranges see FKT Series Sensor Ranges in page 28. Corrected for gas density and humidity Determined using a speed probe with user selectable flow coefficient Accuracy at 25°C: Typically within ±0.24% of full scale speed (±0.3% max)
Absolute Pressure	For available ranges see FKT Series Sensor Ranges in page 28. Accuracy (0 to 85°C): ±0.5% of Full Scale typical. Includes effects of linearity, temperature and pressure hysteresis, zero temperature shift and span temperature shift. User recalibration procedure available

Temperature	For available temperature reader ranges see FKT Series Sensor Ranges in page 28. The included K-Type wire thermocouple has a range of 32°F to 900°F (0°C to 482°C). Accuracy: ±1.8°F (±1°C) Quick disconnect miniature size connector Cable length: 60 in (150 cm) User recalibration procedure available
Relative Humidity	Range: 0 - 99% Relative Humidity, non-condensing Accuracy: ±2% typical at 25°C, non-condensing Response time (1/e): 15s in slow moving air at 25°C Working temperature: -40°F to 185°F (-40°C to 85°C) Storage: 0 to 90% Relative Humidity, non-condensing Cable length: 60 in (150 cm) Probe size: Cylinder 4 in (100 mm) long with a diameter of 0.5 in (13 mm). User recalibration procedure available
Density	For available range see FKT Series Sensor Ranges in page 28. Calculated using the absolute pressure, temperature and relative humidity readings as well as the molecular weight and, for the FKT 2DP1A-C, the ratio of specific heats set by the user. Accuracy: ±0.8% of reading from -200 to 0°C (average) ±0.5% of reading from 0 to 816°C (average)
Damping	User selectable from 1 to 64 data averages available.
K factor	Probe coefficient set by user. Range: 0.75 to 1.25
Display	4-line large character variable contrast alphanumeric LCD with LED backlight. Viewing area: 4.02 in (102 mm) by 1.63 in (41.5 mm) Pressure units: kPa, inH_2O, mmHg and psi Speed units: m/s, ft/s and ft/min Temperature units: °C and °F Density units: kg/m^3 Humidity units: percent
Compatible Mediums	Clean, dry, non-corrosive, non-flammable gases
Output	RS232 serial port interface, 9-pin connector. USB adapter available as an optional accessory.
Warranty	One year parts and labor.

FKT Series Sensor Ranges

See table below for the ranges, resolutions and accuracies of all the sensors available for the FKT meter. All speeds were calculated with an air density of 1.2kg/m^3 and with a probe of unity coefficient (K=1.0). Units of inH_2O are defined at 16°C (60°F).

0.25 inH_2O Differential Pressure / Speed Sensor		
Range	**Display Resolution**	**Accuracy**
±0.0622 kPa	0.0001 kPa	±0.0001 kPa
±0.2500 inH_2O	0.0001 inH_2O	±0.0006 inH_2O
±0.467 mmHg	0.001 mmHg	±0.001 mmHg
±0.00902 psi	0.00001 psi	±0.00002 psi
±0.01837 inHg	0.00001 inHg	±0.00004 inHg
0.75 to 10.18 m/sec	0.01 m/sec	±0.15 to ±0.03 m/sec
2.46 to 33.4 ft/sec	0.01 ft/sec	±0.5 to ±0.09 ft/sec
148 to 2004 ft/min	1 ft/min	±30 to ±5 ft/min

0.5 inH_2O Differential Pressure / Speed Sensor		
Range	**Display Resolution**	**Accuracy**
±0.1244 kPa	0.0001 kPa	±0.0003 kPa
±0.500 inH_2O	0.001 inH_2O	±0.001 inH_2O
±0.933 mmHg	0.001 mmHg	±0.002 mmHg
±0.01805 psi	0.00001 psi	±0.00004 psi
±0.03674 inHg	0.00001 inHg	±0.00008 inHg
1.06 to 14.4 m/sec	0.01 m/sec	±0.22 to ±0.04 m/sec
3.5 to 47.2 ft/sec	0.1 ft/sec	±0.7 to ±0.1 ft/sec
209 to 2835 ft/min	1 ft/min	±43 to ±7 ft/min

1 inH_2O Differential Pressure / Speed Sensor		
Range	**Display Resolution**	**Accuracy**
±0.2488 kPa	0.0001 kPa	±0.0005 kPa
±1.000 inH_2O	0.001 inH_2O	±0.002 inH_2O
±1.866 mmHg	0.001 mmHg	±0.004 mmHg
±0.03609 psi	0.00001 psi	±0.00008 psi
±0.0735 inHg	0.0001 inHg	±0.0002 inHg
1.49 to 20.37 m/sec	0.01 m/sec	±0.31 to ±0.05 m/sec
4.9 to 66.8 ft/sec	0.1 ft/sec	±1 to ±0.2 ft/sec
290 to 4010 ft/min	10 ft/min	±60 to ±10 ft/min

5 inH_2O Differential Pressure / Speed Sensor		
Range	**Display Resolution**	**Accuracy**
±1.244 kPa	0.001 kPa	±0.003 kPa
±5.00 inH_2O	0.01 inH_2O	±0.01 inH_2O
±9.33 mmHg	0.01 mmHg	±0.02 mmHg
±0.1805 psi	0.0001 psi	±0.0004 psi
±0.3674 inHg	0.0001 inHg	±0.0008 inHg
3.3 to 45.5 m/sec	0.1 m/sec	±0.7 to ±0.1 m/sec
10.8 to 149.3 ft/sec	0.1 ft/sec	±2.2 to ±0.4 ft/sec
650 to 8960 ft/min	10 ft/min	±130 to ±20 ft/min

12 inH_2O Differential Pressure / Speed Sensor		
Range	**Display Resolution**	**Accuracy**
±2.986 kPa	0.001 kPa	±0.007 kPa
±12.00 inH_2O	0.01 inH_2O	±0.03 inH_2O
±22.39 mmHg	0.01 mmHg	±0.05 mmHg
±0.433 psi	0.001 psi	±0.001 psi
±0.882 inHg	0.001 inHg	±0.002 inHg
5.2 to 70.6 m/sec	0.1 m/sec	±1.1 to ±0.2 m/sec
17.1 to 231.6 ft/sec	0.1 ft/sec	±3.5 to ±0.6 ft/sec
1020 to 13900 ft/min	10 ft/min	±210 to ±40 ft/min

20 inH_2O Differential Pressure / Speed Sensor		
Range	**Display Resolution**	**Accuracy**
±4.98 kPa	0.01 kPa	±0.01 kPa
±20.00 inH_2O	0.01 inH_2O	±0.04 inH_2O
±37.32 mmHg	0.01 mmHg	±0.08 mmHg
±0.722 psi	0.001 psi	±0.002 psi
±1.470 inHg	0.001 inHg	±0.003 inHg
6.7 to 91.1 m/sec	0.1 m/sec	±1.4 to ±0.2 m/sec
22 to 298.9 ft/sec	0.1 ft/sec	±4.5 to ±0.8 ft/sec
1320 to 17930 ft/min	10 ft/min	±270 to ±50 ft/min

* Compressible flow with reduced speed accuracy for V > 100m/s (328ft/s).
** Limited range due to supersonic flow forming a shock wave on the nose of the Pitot Static tube.

30 inH_2O Differential Pressure / Speed Sensor		
Range	**Display Resolution**	**Accuracy**
±7.47 kPa	0.01 kPa	±0.02 kPa
±30.00 inH_2O	0.01 inH_2O	±0.07 inH_2O
±56.0 mmHg	0.1 mmHg	±0.1 mmHg
±1.083 psi	0.001 psi	±0.002 psi
±2.204 inHg	0.001 inHg	±0.005 inHg
8.2 to 111.6 m/sec	0.1 m/sec	±1.7 to ±0.3 m/sec
26.9 to 366.1 ft/sec	0.1 ft/sec	±5.5 to ±0.9 ft/sec
1610 to 21970 ft/min	10 ft/min	±330 to ±60 ft/min

40 inH_2O Differential Pressure / Speed Sensor		
Range	**Display Resolution**	**Accuracy**
±9.95 kPa	0.01 kPa	±0.02 kPa
±40.00 inH_2O	0.01 inH_2O	±0.09 inH_2O
±74.6 mmHg	0.1 mmHg	±0.2 mmHg
±1.444 psi	0.001 psi	±0.003 psi
±2.939 inHg	0.001 inHg	±0.006 inHg
9.4 to 128.8 m/sec*	0.1 m/sec	±1.9 to ±0.3 m/sec
31 to 423 ft/sec*	1 ft/sec	±6 to ±1 ft/sec
1850 to 25350 ft/min*	10 ft/min	±380 to ±70 ft/min

60 inH_2O Differential Pressure / Speed Sensor		
Range	**Display Resolution**	**Accuracy**
±14.93 kPa	0.01 kPa	±0.03 kPa
±60.0 inH_2O	0.1 inH_2O	±0.1 inH_2O
±112.0 mmHg	0.1 mmHg	±0.2 mmHg
±2.165 psi	0.001 psi	±0.005 psi
±4.41 inHg	0.01 inHg	±0.01 inHg
11.6 to 157.8 m/sec*	0.1 m/sec	±2.4 to ±0.4 m/sec
38 to 518 ft/sec*	1 ft/sec	±8 to ±1 ft/sec
2280 to 31060 ft/min*	10 ft/min	±470 to ±80 ft/min

* Compressible flow with reduced speed accuracy for V > 100m/s (328ft/s).
** Limited range due to supersonic flow forming a shock wave on the nose of the Pitot Static tube.

130 inH_2O Differential Pressure / Speed Sensor		
Range	**Display Resolution**	**Accuracy**
±32.35 kPa	0.01 kPa	±0.07 kPa
±130.0 inH_2O	0.1 inH_2O	±0.3 inH_2O
±242.6 mmHg	0.1 mmHg	±0.5 mmHg
±4.69 psi	0.01 psi	±0.01 psi
±9.55 inHg	0.01 inHg	±0.02 inHg
17 to 195.3 m/sec**	0.1 m/sec	±3.5 to ±0.6 m/sec
56 to 641 ft/sec**	1 ft/sec	±11 to ±2 ft/sec
3300 to 38400 ft/min**	100 ft/min	±700 to ±100 ft/min

200 inH_2O Differential Pressure / Speed Sensor		
Range	**Display Resolution**	**Accuracy**
±49.8 kPa	0.1 kPa	±0.1 kPa
±200.0 inH_2O	0.1 inH_2O	±0.4 inH_2O
±373.2 mmHg	0.1 mmHg	±0.8 mmHg
±7.22 psi	0.01 psi	±0.02 psi
±14.70 inHg	0.01 inHg	±0.03 inHg
21.1 to 195.3 m/sec**	0.1 m/sec	±4.3 to ±0.7 m/sec
69 to 641 ft/sec**	1 ft/sec	±14 to ±2 ft/sec
4200 to 38400 ft/min**	100 ft/min	±900 to ±100 ft/min

400 inH_2O Differential Pressure / Speed Sensor		
Range	**Display Resolution**	**Accuracy**
±99.5 kPa	0.1 kPa	±0.2 kPa
±400.0 inH_2O	0.1 inH_2O	±0.9 inH_2O
±746 mmHg	1 mmHg	±2 mmHg
±14.44 psi	0.01 psi	±0.03 psi
±29.39 inHg	0.01 inHg	±0.06 inHg
30 to 195 m/sec**	1 m/sec	±6 to ±1 m/sec
98 to 640 ft/sec**	1 ft/sec	±20 to ±3 ft/sec
5900 to 38400 ft/min**	100 ft/min	±1200 to ±200 ft/min

* Compressible flow with reduced speed accuracy for V > 100m/s (328ft/s).
** Limited range due to supersonic flow forming a shock wave on the nose of the Pitot Static tube.

15 psi Absolute Pressure Sensor (Default)		
Range	**Display Resolution**	**Accuracy**
15 to 115 kPa	0.01 kPa	±0.58 kPa
60.3 to 462.1 inH_2O	0.1 inH_2O	±2.3 inH_2O
112.5 to 862.4 mmHg	0.1 mmHg	±4.3 mmHg
2.176 to 16.679 psi	0.001 psi	±0.083 psi
4.43 to 33.96 inHg	0.01 inHg	±0.17 inHg

30 psi Absolute Pressure Sensor (Upgrade)		
Range	**Display Resolution**	**Accuracy**
15 to 207 kPa	0.1 kPa	±1 kPa
60.3 to 831.9 inH_2O	0.1 inH_2O	±4.2 inH_2O
112.5 to 1552.3 mmHg	0.1 mmHg	±7.8 mmHg
2.18 to 30.02 psi	0.01 psi	±0.15 psi
4.43 to 61.13 inHg	0.01 inHg	±0.31 inHg

Temperature Reader		
Range	**Display Resolution**	**Accuracy**
-200 to 816°C	0.1°C	±1°C
-328 to 1500°F	0.1°F	±1.8°F

Relative Humidity		
Range	**Display Resolution**	**Accuracy**
0 to 99%	1 %	±2 %

Density (with 15 psi Absolute Pressure Sensor)		
Range	**Display Resolution**	**Accuracy**
0.05 to 5.48 kg/m³	0.01 kg/m³	±0.04 kg/m³

Density (with 30 psi Absolute Pressure Sensor)		
Range	**Display Resolution**	**Accuracy**
0.05 to 9.86 kg/m³	0.01 kg/m³	±0.07 kg/m³

UNIT CONVERSIONS

Rows*: units converting to* **Columns:** *units converting from*

PRESSURE CONVERSION TABLE							
from \ to	**inH_2O**	**mH_2O**	**psi**	**inHg**	**mmHg**	**mbar**	**Pa**
inH_2O	1	0.025375	0.0361	0.07348	1.866	2.488	248.84
mH_2O	39.409	1	1.42233	2.8959	73.55592	98.0665	9806.65
psi	27.708	0.70307	1	2.03602	51.71493	68.9476	6894.757
inHg	13.609	0.34532	0.49115	1	25.4	33.8639	3386.388
mmHg	0.536	0.01359	0.01934	0.03937	1	1.3332	133.322
mbar	0.402	0.01019	0.0145	0.02953	0.75006	1	100
Pa	0.004019	0.000102	0.00015	0.000295	0.0075	0.01	1

SPEED CONVERSION TABLE						
from \ to	**cm/s**	**ft/s**	**m/s**	**km/hr**	**knots**	**mph**
cm/s	1	0.03281	0.01	0.036	0.01943	0.02237
ft/s	30.48	1	0.3048	1.097	0.5925	0.6818
m/s	100	3.281	1	3.6	1.943	2.237
km/hr	27.78	0.9113	0.2778	1	0.5399	0.6214
knots	51.48	1.688	0.5148	1.852	1	1.151
mph	44.7	1.467	0.447	1.609	0.869	1

FORCE CONVERSION TABLE						
from \ to	**N**	**poundal**	**ozf**	**lbf**	**kip**	**kgf**
N	1	7.233	3.597	0.225	0.00022	0.102
poundal	0.138	1	0.497	0.031	$3.11x10^{-5}$	0.014
ozf	0.278	2.012	1	0.0625	$6.25x10^{-5}$	0.028
lbf	4.448	32.258	16	1	0.001	0.454
kip	4545.45	32154.3	16000	1000	1	453.594
kgf	9.806	71.428	35.714	2.2	0.002	1

DENSITY CONVERSION TABLE			
from \ to	**kg/m^3**	**$slugs/ft^3$**	**lb/ft^3**
kg/m^3	1	0.00194	0.0624
$slugs/ft^3$	515.3788	1	32.17096
lb/ft^3	16.02	0.03108	1

MASS CONVERSION TABLE				
from \ to	**kg**	**g**	**slug**	**lb**
kg	1	1000	0.0685	2.205
g	0.001	1	$6.85x10^{-5}$	0.0022
slug	14.594	14593.9	1	32.174
lb	0.454	453.59	0.031	1

TEMPERATURE CONVERSION TABLE		
CONVERT FROM	**CONVERT TO**	**FORMULA**
Fahrenheit	**Celsius**	(F - 32) / 1.8
Fahrenheit	**Kelvin**	(F + 459.67) / 1.8
Fahrenheit	**Rankine**	F + 459.67
Rankine	**Kelvin**	R / 1.8
Rankine	**Celsius**	(R - 491.67) / 1.8
Rankine	**Fahrenheit**	R - 459.67
Celsius	**Fahrenheit**	(1.8 ×C) + 32
Celsius	**Rankine**	(1.8 × C) + 491.67
Celsius	**Kelvin**	C + 273.15
Kelvin	**Rankine**	1.8 x K
Kelvin	**Fahrenheit**	(1.8 × K) - 459.67
Kelvin	**Celsius**	K - 273.15

LENGTH CONVERSION TABLE						
from \ to	**m**	**mm**	**mile**	**yard**	**ft**	**in**
m	1	1000	0.0006	1.0934	3.281	39.37
mm	0.001	1	6.21×10^{-7}	0.0011	0.0033	0.039
mile	1609.3	1.61×10^{6}	1	1760	5280	63360
yard	0.9146	914.4	0.0006	1	3	36
ft	0.3048	304.8	0.0002	0.333	1	12
in	0.0254	25.4	1.58×10^{-5}	0.0278	0.0833	1

SI PREFIXES	
Prefix	**multiplying factor**
tera (T)	1 000 000 000 000
giga (G)	1 000 000 000
mega (M)	1 000 000
kilo (k)	1 000
milli (m)	0.001
micro (μ)	0.000 001
nano (n)	0.000 000 001
pico (p)	0.000 000 000 001