

General Purpose Thermal Mass Flowmeter

Model 4040/4043/4045

Operation and Service Manual

1980339, Revision F
January 2009



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| | |
|---|---|
|  | WARNING |
| | These flowmeters employ a heated platinum sensor. They should not be used with flammable or explosive gases or mixtures. |

| | |
|---|--|
|  | Caution |
| | TSI flowmeters are not medical devices under FDA 510k and in no situation should they be utilized for human respiration measurements. |

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Seller warrants the goods sold hereunder, under normal use and service as described in the operator's manual, shall be free from defects in workmanship and material for twelve (12) months, or the length of time specified in the operator's manual, from the date of shipment to the customer. This warranty period is inclusive of any statutory warranty. This limited warranty is subject to the following exclusions:

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- b. Parts repaired or replaced as a result of repair services are warranted to be free from defects in workmanship and material, under normal use, for 90 days from the date of shipment.
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Service Policy

Knowing that inoperative or defective instruments are as detrimental to TSI as they are to our customers, our service policy is designed to give prompt attention to any problems. If any malfunction is discovered, please call TSI's Customer Service department at +1 651 490-2811.

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Chapter 1

Unpacking and Parts Identification

Carefully unpack the instrument and accessories from the shipping container. Check the individual parts against the list of components in Table 1. If any parts are missing or damaged, notify TSI immediately.

Table 1. List of Components

| Qty | Item Description | Part/Model |
|------------|--|--|
| 1 | Mass Flowmeter, 22 mm ISO tapered inlet/outlet Mass Flowmeter, 0.50 inch inlet/outlet Mass Flowmeter, 0.75 inch inlet/outlet | 4040 4043 4045 |
| 1 | Computer Cable | 1303583 |
| 1 | Analog Cable | 1303584 |
| 1 | Filter 22 mm ISO-taper (for Model 4040) 3/8" Female NPT (for Model 4043/45) | 1602292 1602300 |
| 1 | AC Adapter 120 V, North America, ungrounded 100-240 V, NEMA 5-15 plug, grounded 100-240 V, Europlug, CEE 7/16, grounded 100-240 V, Great Britain, grounded, fused 100-240 V, Australia/NZ | 2613033FLO 8918-NA 8918-EC 8918-GB 8918-AT |
| 1 | Operation and Service Manual | 1980339 |
| 1 | RS232 Serial Command Set manual | 1980340 |
| 1 | Carrying Case (optional accessory) | 1319176 |

Parts Identification

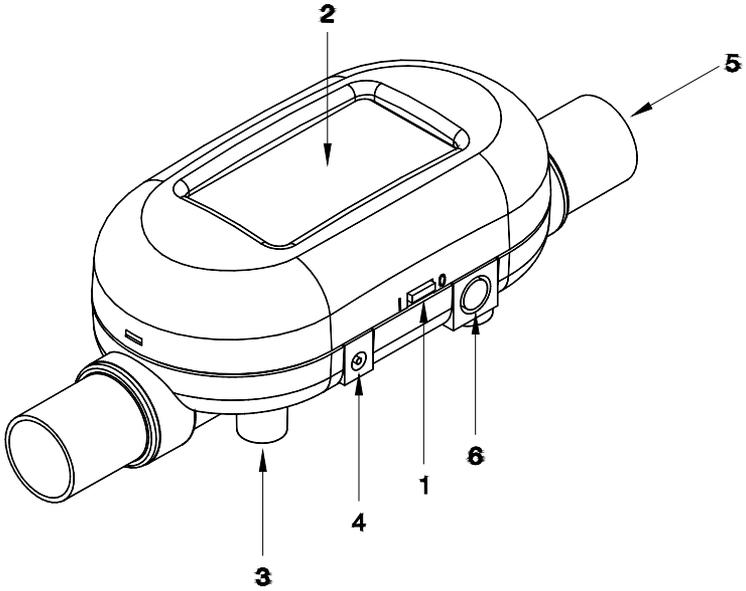


Figure 1-1 Model 4040/4043/4045 Mass Flowmeter

- | | |
|-------------------------|---|
| 1. On/Off Switch | 4. DC Power Input |
| 2. Display | 5. Flow Inlet |
| 3. Mounting Inserts (2) | 6. Computer Serial Interface and Analog Output and Optional Power Input Connector |

Chapter 2

Setting-Up

Supplying Power

The flowmeter can be powered in one of two ways: through the power jack using the supplied AC adapter or through the mini-DIN connector. The DC power input connector is shown below along with the power requirements.

Power Supply: 7.5 VDC \pm 1.5 V, 300 mA maximum



When supplying power through the TSI-supplied interface cable, line up the arrow on the connector with the bottom side of the flowmeter. Flowmeter connector pin-out designations are shown below.

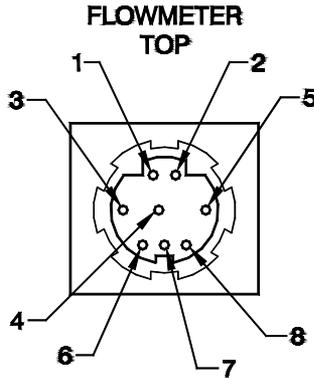


Table 2. List of Connector Pin-outs and Cable Color Code Designations

| Pin | Function | Cable Color Code |
|-----|----------------------|------------------|
| 1 | Power Input (+) | Black |
| 2 | Power Ground (-) | Green |
| 3 | Analog Output (+) | Red |
| 4 | Analog Ground (-) | Brown |
| 5 | (no connection) | Blue |
| 6 | RS232 Receive (in) | White |
| 7 | RS232 Transmit (out) | Yellow |
| 8 | Logic Ground | Gray |

Connecting Filter and Flow Tubes

The Models 4040/4043/4045 have an exposed thermal flow sensor, which must be protected from foreign matter and particles in the gas flow. TSI has supplied a filter, which should be connected to the inlet of the flowmeter, however, any filter will work as long as it has a minimum efficiency of 99.9%.

| | |
|---|--|
|  | Caution |
| | Always use a filter on inlet of flowmeter. Failure to filter the gas flow may change the calibration and/or permanently damage the sensor. |

Note: Flow direction is identified by the large arrow printed on the bottom side of the flowmeter.

After attaching the filter, connect the flow tube, to the inlet, of the filter. Connecting a tube to the outlet of the flowmeter will create back pressure. See Appendix A for flowmeter accuracy specifications when operating at various pressures. In general, minimize back pressure on the flowmeter to maintain higher accuracy.

RS232 Configuration and Operation

Many flowmeter operating parameters can be easily configured through the RS232 serial port. Likewise, the flow rate, temperature, pressure, and volume can be read through the serial port. Refer to the *Series 4000/4100 RS232 Serial Command Set* manual for a detailed description of the commands and command syntax.

RS232 Settings: Baud Rate..... 38.4 k
 Data Bits 8
 Parity..... None
 Stop Bits 1
 Flow Control..... None

Table 3. Changeable Operating Parameters

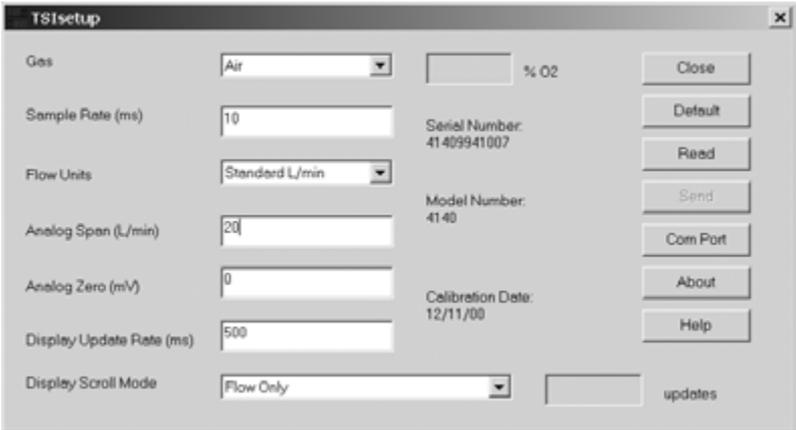
| Function | Command |
|---|---------|
| Select Gas Calibration (air, oxygen, mixture) | SG |
| Select Oxygen Concentration in Air (21% to 99%) | SGM |
| Select Standard or Volumetric Flow Measurement | SU |
| LCD Display Update Rate (controls averaging) | SUR |
| Select Data Update Rate for Analog Output | SSR |
| Set Analog Output Full-Scale Flow Rate Value | SAS |
| Set Analog Output Zero Value | SAZ |

Configuration Software

TSI has several software utilities to help you communicate with your flowmeter to change parameters and to obtain flow data. You can download the latest versions of these at no charge from our web site:

<http://flowmeters.tsi.com>

1. If you only want to change one or more of the operating parameters shown in Table 3 (above), the easiest way is to use the software utility called “*TSI setup.*” This uses convenient drop-down menus to help change these parameters. After you have made your changes, be sure to click on “Send” to store the changes in the flowmeter’s memory.



2. If you want to communicate directly with the flowmeter using the basic RS232 commands shown in the *Serial Command Set Manual*, you can use a terminal program. HyperTerminal is a common terminal program that is included with most versions of the Microsoft operating system. You can download a document from our web site that helps you configure HyperTerminal. Download the document called “**Using HyperTerminal to communicate with TSI Flowmeters.**”

3. If you plan to develop a more sophisticated program for data collection and control using LabVIEW, you can download a demonstration program called “*Real-time Demo Program*” and the source code “*Source Code for Real-time Demo Program.*” This program is intended to be a basic demonstration program and not a practical laboratory tool. It does, however, have a convenient implementation of the VOLUME measurement function that can be useful for basic tests.

Chapter 3

Operation

| | |
|---|---|
|  | Caution |
| | TSI flowmeters are not medical devices under FDA 510k and in no situation should they be utilized for human respiration measurements. |

Overview

The Models 4040/4043/4045 Flowmeters measure mass flow rate, temperature and absolute pressure of the gas inside the flow tube. All measurements made by the Model 4040/4043/4045 are traceable to NIST.

ON/OFF Switch

Slide the switch to the ON position. The power switch is marked in the international symbols 'I' for *on* and 'O' for *off*. The flowmeter will begin to simultaneously display flow rate, temperature and pressure.

Flow Rate Measurement

Flow rate data can be obtained from the Models 4040/4043/4045 through the LCD display, RS232 serial port or the linearized analog output. The analog output is a 0 to 10 volt DC linear signal representing 0 to 300 Std L/min (Model 4043: 200 Std. L/min) (analog output scaling is user selectable). Refer to the RS232 Serial Command Set manual for instructions on how to obtain flow data through the serial port.

Gas calibrations (air, 100% nitrogen, 100% oxygen, or air/oxygen mixtures) can be selected through the RS232 serial port. Refer to the RS232 Serial Command Set manual for instructions on how to select gas calibrations. The LCD display will indicate the calibration being utilized, air or O₂. When air/oxygen mixtures are being measured, the LCD display will illuminate both the air and oxygen symbols. When nitrogen is selected no gas type is displayed on the LCD.

Flow can be displayed in units of standard liters per minute (Std L/min*) or in volumetric units of liters per minute (L/min). Refer to Appendix B for a description between the two measurements. Selecting between the two measurements is accomplished through the serial port. Refer to the RS232 Serial Command Set manual for instructions on how to select between flow units.

*TSI instruments defines standard conditions as 21.1°C (70° F) and 101.3 kPa (14.7 psia, 1 bar).

Temperature Measurement

The Models 4040/4043/4045 have an independent temperature transducer in the flow tube to measure the gas temperature. The temperature sensor is used for temperature compensation of flow rate and for converting flow from standard to volumetric units. Temperature is displayed on the LCD and is available through the RS232 serial port in the units of degrees Celsius (°C).

Note: At low flow rates, the temperature inside of the flow tube will increase because of the heat generated by the thermal flow sensor. This effect is normal and the temperature of the incoming gas will be measured once flow resumes.

Pressure Measurement

The Models 4040/4043/4045 measure absolute pressure near the outlet of the flowmeter in the SI units of kilo-Pascals (kPa). Pressure measurements are required when converting from standard to volumetric flow. Absolute pressure measurements are displayed on the LCD display and are available through the RS232 serial port.

Volume Measurement

The Models 4040/4043/4045 measure total volume by integrating flow over time. This is a calculated measurement performed by the flowmeter and is only available using the RS232 serial port. Volume is not displayed on the LCD display. Refer to the Models 4040/4043/4045 RS232 Serial Command Set manual for instructions on using the volume function.

Chapter 4

Maintenance

Flow Sensor

Periodically inspect the flow sensor by looking into the outlet of the flowmeter. Remove dust, particles and fibers from the sensor, with clean, dry compressed air. The flow sensor will break if touched. Never run liquids through the flowmeter and never touch the sensor with a brush. Dust or other deposits on the flow sensor will degrade the 4040/4043/4045's flow accuracy.

| | |
|---|---|
|  | Caution |
| | The flowmeter must be switched off for cleaning. Only use clean, dry, compressed air when attempting to remove contamination from the sensor. |

Re-certification

To maintain a high degree of confidence in the measurements made by the Models 4040/4043/4045, TSI recommends that you return the instrument to TSI every 12 months for re-certification. For a nominal fee, we will recalibrate the unit and return it to you with a certificate of calibration and US National Institute of Standards Technology (NIST) traceability. This “annual checkup” assures you of consistently accurate readings; it is especially important in applications where strict calibration records must be maintained.

Cases

If the instrument case or storage case needs cleaning, wipe it off with a soft cloth dipped in isopropyl alcohol or mild detergent. **Never** submerge the flowmeter.

Storage

When storing the flowmeter, always cover the ends of flow tubes with the provided caps to prevent dust or other foreign matter from entering the tube.

Chapter 5

Troubleshooting

Table 4 lists the symptoms, possible causes, and recommended solutions for common problems encountered with the flowmeter. If your symptom is not listed, or if none of the solutions solves your problem, please contact TSI.

Table 4. Troubleshooting

| Symptom | Possible Causes | Corrective Action |
|--|--|--|
| No display. | Unit not switched on. | Switch on the unit. |
| | No power to instrument. | Plug in AC adapter or check power source on mini-DIN connector. |
| Temperature reads high at low or zero flows. | Temperature sensor is being heated from the flow sensor. | This is normal. Once flow exceeds 1 Std L/min, the temperature will track the flowing gas temperature. |
| Flow readings fluctuate badly. | The flow is fluctuating. | Improve inlet conditions or increase display averaging time. |
| Display shows flows over-range with no flow passing through flow tube. | The sensor may be damaged or broken. | Return flowmeter to TSI for service. |

Appendix A

Specifications

| | Specifications |
|--|---|
| Flow Measurement Measurement Range Accuracy Resolution (Display) Response | Models 4040/4045: 0 to 300 Std L/min. Model 4043 only: 0 to 200 Std L/min. Air, O ₂ : 2% of reading or 0.05 Std L/min, whichever is greater N ₂ , Air/O ₂ mixtures: 3% of reading or 0.1 Std L/min, whichever is greater Accuracy stated at standard conditions: 21.1°C and 101.3 kPa) See notes 1 through 6 below. 0.01 Std L/min between 0 and 90 Std L/min 0.1 Std L/min between 90 and 300 Std L/min Less than 4 msec, 63% of final value at full scale flow |
| Temperature Measurement Measurement Range Accuracy Resolution (Display) Response | 0 to 50°C ±1°C, at flows greater than 1 L/min. See note 2 below. 0.1°C Less than 75 msec, 63% of final value for 20°C step change in temperature at full scale flow |
| Static Pressure Measurement Measurement Range Accuracy Resolution (Display) Response Over Pressure | Measured inside flow tube near the exit 50 to 199 kPa Absolute ±1 kPa, See note 7 below 0.1 kPa Less than 4 msec. 63% of final value for 30 kPa step change 620 kPa |
| Burst Pressure | Tested to 690 kPa without rupture. Do not exceed 690 kPa. |
| Pressure Drop | See Chart. |
| Volume Measurement Range Accuracy | 0.001 to 999.999 Liters 2% of Reading at flows greater than 2.5 Std L/min See notes 1 through 6 below. |
| Instrument Temp. Range Operation, Ambient Storage, Ambient | 0 to 50°C -20 to 60°C |

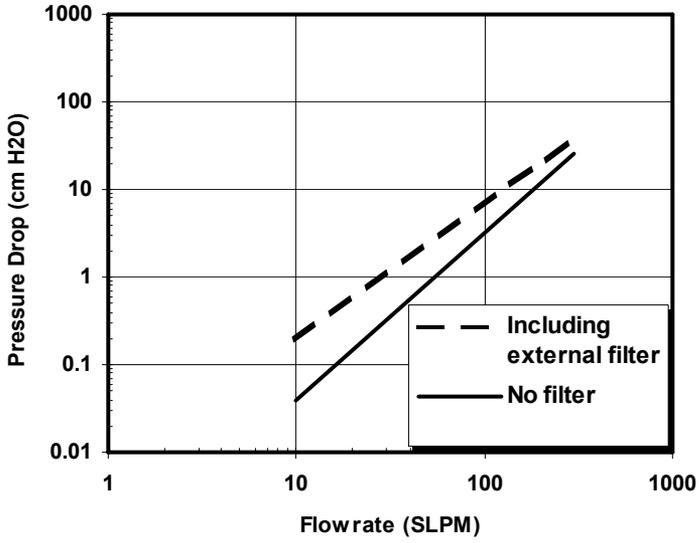
| Specifications | |
|--|--|
| Physical Dimensions External Dimensions Tube Adapters (Inlet & Outlet) Weight Flow Body Material | See Diagram Model 4040: 22 mm male ISO Taper Model 4043: ½ inch straight Model 4045: ¾ inch straight 180 grams PolyCarbonate |
| Computer Interface | Connector 8 pin mini-DIN Type RS232 Serial Baud Rate 38.4 k Data Bits 8 Parity None Stop Bits 1 Flow Control None |
| Analog Output (Flow Only) Range Resolution Maximum Current Flow Accuracy | 0 to 10 V 13 bit 10 mA See note 6 below. |
| Power | AC adapter or power supplied through mini-DIN 7.5 VDC ± 1.5 V, 300 mA maximum |

Notes:

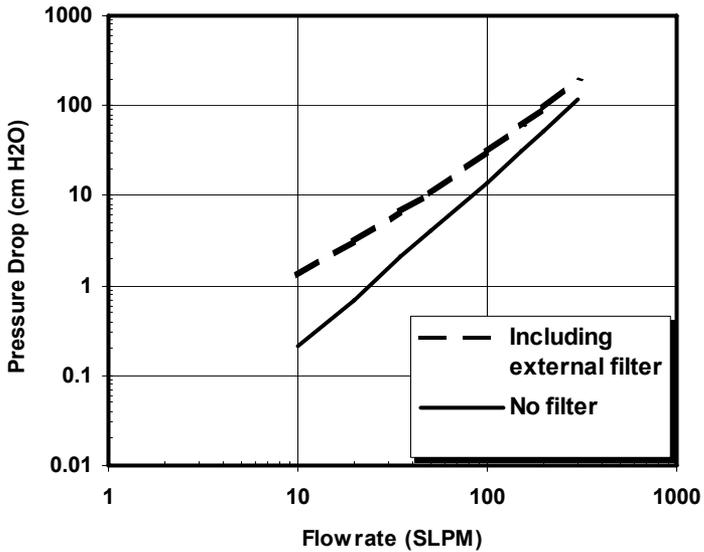
- 1 Accuracy stated at standard conditions of 21.1°C and 101.3 kPa.
 - Add an additional 0.075% of reading per 1°C away from standard conditions when operating within the range of 0°C to 50°C.
 - Add an additional 0.015% of reading per 1 kPa above 101.3 kPa or
 - Add an additional 0.022% of reading per 1 kPa below 101.3 kPa when operating within the pressure range of 70 kPa to 170 kPa.
- 2 Accuracy stated with gas temperature and flow body temperature within ±10°C of one another.
- 3 Accuracy stated measuring dry gas (less than 10% R.H.).
- 4 Includes ±0.5% of reading repeatability.
- 5 Volumetric flow rate is calculated from the mass flow measurement. Add an additional 0.25% of reading to the flow accuracy to account for the uncertainty in measuring gas temperature and pressure.
- 6 For analog output, accuracy offset increases from 0.05 to 0.1 Std L/min.
- 7 Add uncertainty of 0.2 kPa for every 10°C away from 21.1°C.

Specifications subject to change without notice.

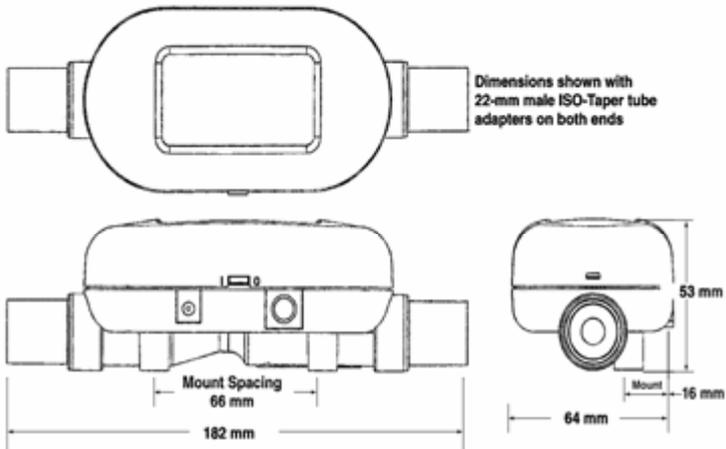
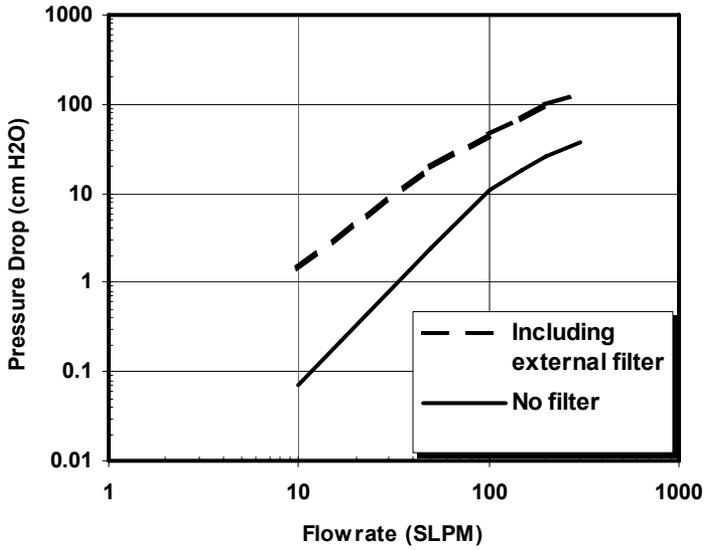
Pressure Drop - Model 4040



Pressure Drop - Model 4043



Pressure Drop - Model 4045



Appendix B

Standard Flow Rate vs. Volumetric Flow Rate

Since thermal flow sensors are sensitive to changes in air density and air velocity, all thermal flowmeters indicate flow rates with reference to a set of standard conditions. For TSI instruments, standard conditions are defined as 21.1° C (70° F) and 101.3 kPa (14.7 psia). Other manufacturers may use different values.

Standard flow rate is the flow rate the air would be moving if the temperature and pressure were at standard conditions. It is usually the most useful measure of airflow because it defines the heat-carrying capacity of the air.

Volumetric flow rate is the true volume flow of the gas exiting the flowmeter.

In some instances, volumetric flow rate rather than standard flow rate may be of interest. To display volumetric flow rate, the Models 4040/4043/4045 will multiply the standard flow measurement by the following density correction factor:

$$VolumetricFlow = (StandardFlow) \left[\frac{273.15 + T_m}{273.15 + 21.11} \right] \frac{101.3}{P_m}$$

Where

T_m = Gas temperature measured in flow tube in units of degrees Celsius

P_m = Absolute pressure measured in flow tube in units of kPa

To demonstrate the difference in output, consider the following.

Measured flow displays 100 Std L/min at 15C and 117kPa. The volumetric flow as calculated by the Models 4040/4043/4045 would be as follows.

$$VolumetricFlow = (100) \left[\frac{273.15 + 15}{273.15 + 21.11} \right] \frac{101.3}{117} = 84.78L / \text{min}$$

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