TELEDYNE HASTINGS INSTRUMENTS

INSTRUCTION MANUAL

HFM-I-401 AND HFM-I-405 INDUSTRIAL FLOW METERS

ISO 9001:2000
KEMA CERTIFICATE
Accredited by ANSI-RAB NAP
Accredited by the Dutch Council for Accreditation (RvA)

TELEDYNE INSTRUMENTS
Hastings Instruments
A Teledyne Technologies Company

Manual Print History

The print history shown below lists the printing dates of all revisions and addenda created for this manual. The revision level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new revision is created, all addenda associated with the previous revision of the manual are incorporated into the new revision of the manual. Each new revision includes a revised copy of this print history page.

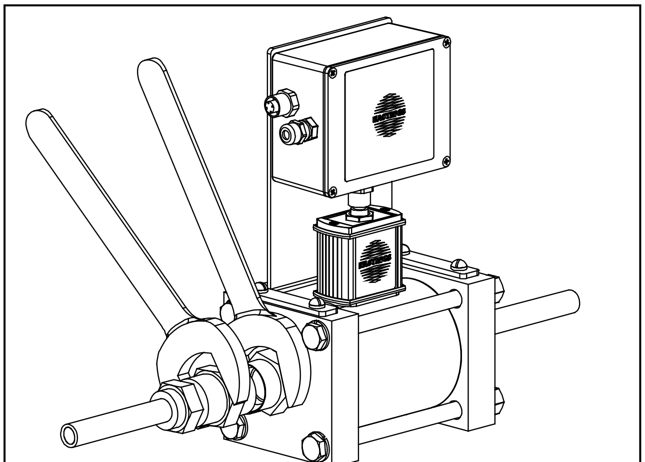
Revision A (Document Number 171-042008) ....March 1999

Visit www.teledyne-hi.com for WEEE disposal guidance.

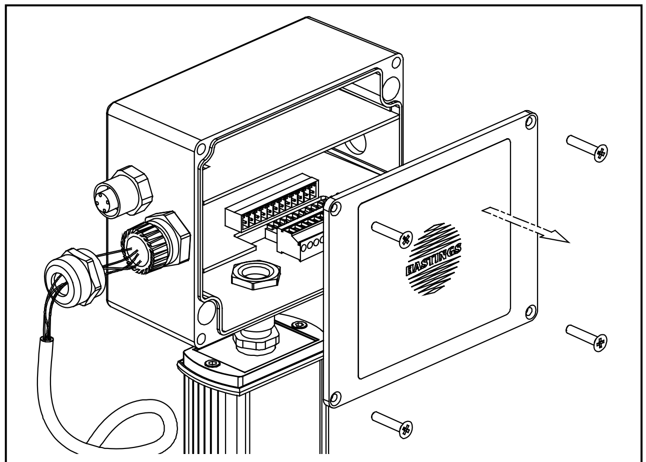
Description of Symbols and Messages used in this manual

WARNING	This indicates a potential personnel hazard. It calls attention to a procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in injury to personnel.
CAUTION	This indicates a potential equipment hazard. It calls attention to an operating procedure, practice, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of all or part of the product.
NOTE	This indicates important information. It calls attention to a procedure, practice, condition or the like, which is worthy of special mention.

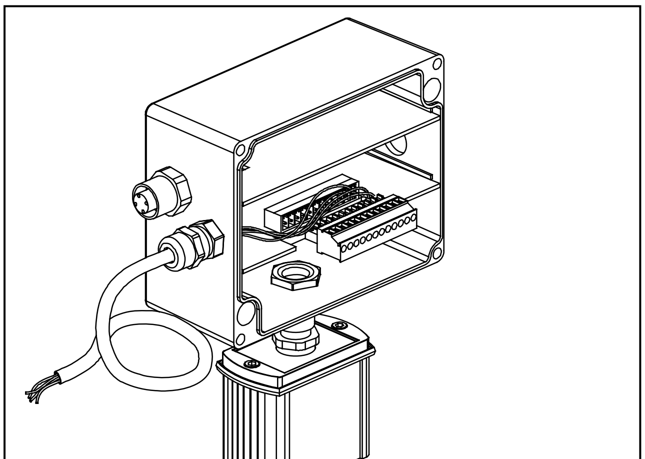
Quick Start Instructions



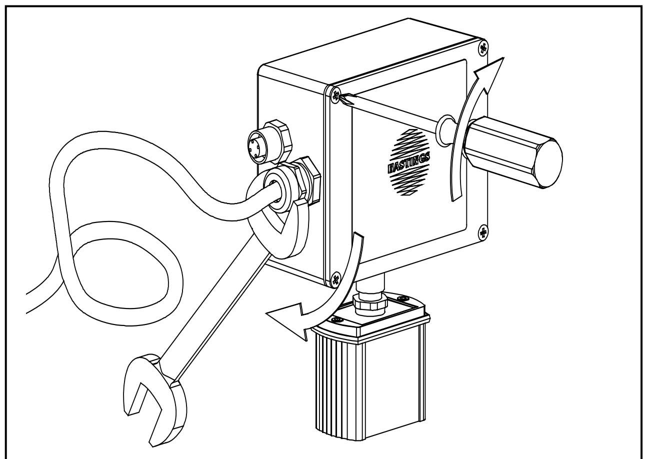
Connect dry, clean gas and ensure connections are leak free.



Connect Cable for power and analog signal output.

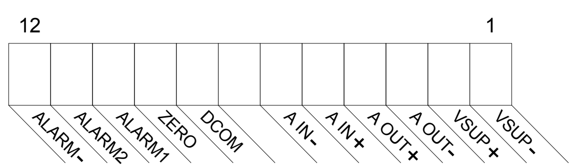


Check that electrical connections are correct.
(See diagrams below)

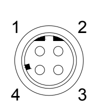


Replace front cover and cable feed-through ensuring gasket is seated and fasteners are secure.

Terminal Strip



Digital Connector



PINS	RS232	RS485	ETHERNET
SHIELD	GROUND	GROUND	GROUND
1	TRANSMIT	TX+ (A)	TD+
2	RECEIVE	RX+ (A)	RD+
3	UNUSED	TX- (B)	TD-
4	UNUSED	RX- (B)	RD-

For detailed set up instructions, see Section 2-Installation

CAUTION	This instrument is available with multiple pin-outs. Ensure electrical connections are correct.

CAUTION	The 400-I series flow meters are designed for IEC Installation/Over voltage Category II – single phase receptacle connected loads.

NOTE	The Hastings 400 Series flow meters are designed for INDOOR and OUTDOOR operation.

CAUTION	In order to maintain the integrity of the Electrostatic Discharge immunity both parts of the remote mounted version of the HFM-I-400 instrument must be screwed to a well grounded structure.

CAUTION	In order to maintain the environmental integrity of the enclosure the power/signal cable jacket must have a diameter of .157 - .315” (4 – 11 mm). The nut on the cable gland must be tightened down sufficiently to secure the cable. This cable must be rated for at least 85°C.

Table of Contents

General Information

1. General Information

1.1. Overview

1.1.1. 400 Series Family

The Hastings 400 Series is a family of flow instruments which is specifically designed to meet the needs of the industrial gas flow market. The “I” family in the 400 Series features an IP-65 enclosure which allows the use of the instrument in a wide variety of environments. The 400 I products consist of four configurations: a flow meter, HFM-I-401, which has a nominal nitrogen full scale between 10 SLM and 300 SLM and a corresponding flow controller, the HFC-I-403; a larger flow meter, HFM-I-405, which ranges from 100 SLM to 2500 SLM, and a corresponding flow controller, the HFC-I-407. These instruments are configured in a convenient in-line flow-through design with standard fittings. Each instrument in the series can be driven by either a +24 VDC power supply or a bipolar ±15 volt supply. The electrical connection can be made via either a terminal strip located inside the enclosure or optionally through an IP-65 compatible electrical connector. Also, these instruments include both analog and digital communications capabilities.

1.1.2. 400 Series Meters

The Hastings HFM-I-401 and HFM-I-405 thermal mass flow meters are designed to provide very accurate measurements over a wide range of flow rates and environmental conditions. The design is such that no damage will occur from moderate overpressure or overflows and no maintenance is required under normal operating conditions when using clean gases.

1.1.3. Measurement Approach

The instrument is based on mass flow sensing. This is accomplished by combining a high-speed thermal transfer sensor with a parallel laminar flow shunt (see Figure 1-1). The flow through the meter is split between the sensor and shunt in a constant ratio set by the full scale range. The thermal sensor consists of a stainless steel tube with a heater at its center and two thermocouples symmetrically located upstream and downstream of the heater. The ends of the sensor tube pass through an aluminum block and into the stainless steel sensor base. With no flow in the tube the thermocouples report the same elevated temperature; however a forward flow cools the upstream thermocouple relative to the downstream. This temperature difference generates a voltage signal in the sensor which is digitized and transferred to the main processor in the electronics enclosure. The processor uses this real-time information and the sensor/shunt characteristics stored in non-volatile memory to calculate and report the flow.

To ensure an inherently linear response to flow, both the thermal sensor and the shunt have been engineered to overcome problems common to other flow meter designs. For example, nonlinearities and performance variations often arise in typical flow meters due to pressure-related effects at the entrance and exit areas of the laminar flow shunt. Hastings has designed the 400 Series meters such that the flow-critical splitting occurs at locations safely downstream from the entrance effects and well upstream from the exit effects. This vastly improves the stability of the flow ratio between the sensor and shunt. The result of this design feature is a better measurement when the specific gravity of the flowing medium varies, for instance due to changes in pressure or gas type. Also, a common problem in typical flow meters is a slow response to flow changes. To improve response time, some flow meter designs introduce impurities such as silica gel. Alternatively, Hastings has designed the 400 Series sensor with reduced thermal mass to improve the response time without exposing additional materials to the gas stream.

1.1.4. Additional Functions

These instruments contain a number of functions in addition to reporting flow which include:

- Settable alarms and warnings with semiconductor switch outputs
- A digitally reported status of alarms and warnings such as overflow/underflow
- A flow totalizer to track the amount of gas added to a system
- A digitizing channel for an auxiliary analog signal
- An internal curve fitting routine for "fine tuning" the base calibration
- An alternate calibration set of 8 different ranges/gases

1.2. Specifications

WARNING	Do not operate this instrument in excess of the specifications listed below. Failure to heed this warning can result in serious personal injury and/or damage to the equipment.

Performance	*HFM-I-401*	*HFM-I-405*
Full Scale Flow Ranges (in N_2)	0-10 slm up to 0-350 slm	0-100 slm up to 0-2500 slm
Accuracy[1]	**Standard:** ± 1% full scale Optional: ± (0.5% reading + 0.2%FS)	**Standard:** ± 1% full scale Optional: ± (0.5% reading + 0.2%FS)
Repeatability	± 0.1% of F.S.	± 0.1% of F.S.
Operating Temperature	-20 to 70°C	-20 to 70°C
Warm up time	30 min for optimum accuracy 2 min for ± 2% of full scale	30 min for optimum accuracy 2 min for ± 2% of full scale
Settling Time/Reponse Time	< 2.5 seconds (to within ± 2% of full scale)	< 2.5 seconds (to within ± 2% of full scale)
Temperature Coefficient of Zero	< ±0.05% of Full Scale /°C	< ±0.05% of Full Scale /°C
Temperature Coefficient of Span	< ±0.16% of reading/°C	< ±0.16% of reading/°C
Operating Pressure - Maximium	**Standard:** 500 psig Optional: 1500 psig	**Standard:** 500 psig Optional: 1000 psig
Pressure Coefficient of Span	< 0.01%of reading /psi (N_2, 0-1000 psig)	< 0.01%of reading /psi (N_2, 0-1000 psig)
Pressure Drop(N_2@14.7 psia)	< 1.1 psi at full scale flow	< 5.1 psi at full scale flow
Attitude Sensitivity of Zero	< 2% of F.S.	< 2% of F.S.
Electrical		
Power Requirements	18-38 VDC, 3.5 watts(Ethernet) 2.5 watts(RS232/485)	18-38 VDC, 3.5 watts(Ethernet) 2.5 watts(RS232/485)
Analog Output	**Standard:** 4 – 20 mA Optional: 0-10 VDC, 0-20 mA, 0-5 VDC, 1-5 VDC	**Standard:** 4 – 20 mA Optional: 0-10 VDC, 0-20 mA, 0-5 VDC, 1-5 VDC
Digital Output	**Standard:** RS 232 Optional: RS 485 Optional: Ethernet	**Standard:** RS 232 Optional: RS 485 Optional: Ethernet
Analog Connector	**Std:** Terminal Block – PG 9 Cable Gland Optional: 12 pin Circular Connector	**Std:** Terminal Block – PG 9 Cable Gland Optional: 12 pin Circular Connector

Digital Connector	4 pin, D-coded M12	4 pin, D-coded M12
Mechanical		
Fittings	**Standard:** 1/2" Swagelok Optional: ½" VCO®, ½" VCR®, ¾" Swagelok, 10mm Swagelok, 3/8" male NPT, ½" male NPT 12mm Swagelok, ¾"-16 SAE/MS straight thread	**Standard:** 1" Swagelok Optional: 1" VCO®,1" VCR®, ¾" Swagelok, , 1" male NPT, ¾" male NPT, 1 5/16"-12 straight thread
Leak Integrity	< $1x10^{-8}$ sccs He	< $1x10^{-8}$ sccs He
Wetted Materials	316L SS, Nickel 200, 302 SS, Viton®	316L SS, Nickel 200, 302 SS, Viton®
Weight (approx.)	12 lb (5.5 kg)	18 lb (8 kg)

Viton® is a trademark of DuPont Dow Elastomers, LLC.
Swagelok®, VCO®and VCR® are trademarks of the Swagelok Company.

Installation

2. Installation

CAUTION	Many of the functions described in this section require removing the enclosure front plate. Care must be taken when reinstalling this plate to ensure that the sealing gasket is properly positioned and the fasteners are secure to maintain an IP65 compliant seal.

2.1. Receiving Inspection

Your instrument has been manufactured, calibrated, and carefully packed so it is ready for operation. However, please inspect all items for any obvious signs of damage due to shipment. Immediately advise Teledyne Hastings and the carrier if any damage is suspected.

Use the packing slip as a check list to ensure all parts are present (e.g. flow meter, power supply, cables etc.) and that the options are correctly configured (output, range, gas, connector).

If a return is necessary, obtain an RMA (Return Material Authorization) number from Teledyne Hastings' Customer Service Department at 1-800-950-2468 or hastings_instruments@teledyne.com.

2.2. Environmental and Gas Requirements

Use the following guidelines prior to installing the flow meter:

- Ensure that the temperature of all components and gas supply are between -20° and 70° C
- Ensure that the gas line is free of debris and contamination
- Ensure that the gas is dry and filtered (water and debris may clog the meter and/or affect its performance)
- If corrosive gases are used, purge ambient (moist) air from the gas lines

2.3. Mechanical Connections

The meter can be mounted in any orientation unless using dense gases or pressures higher than 250 psig in which case a "flow horizontal" orientation is required. The meter's measured flow direction is indicated by the arrow on the electronics enclosure.

A straight run of tubing upstream or downstream is *not* necessary for proper operation of the meter. The flow meter incorporates elements that pre-condition the flow profile before the measurement region. So for example, an elbow may be installed upstream from the flow meter entrance port without affecting the flow performance.

Compression fittings should be connected and secured according to recommended procedures for that fitting. Two wrenches should be used when tightening fittings (as shown in the Quick Start Guide on page iii) to avoid subjecting the flow meter body to undue torque and related stress.

The fittings are not intended to support the weight of the meter. For mechanical structural support, four mounting holes (#1/4-20 thread, 3/8" depth) are located in the bottom of the meter. The position of these holes is documented on the outline drawing in Appendix 3 (Section 6.3).

Leak-check all fittings according to an established procedure appropriate for the facility.

2.4. Mounting the Electronics Remotely

CAUTION	In order to maintain the integrity of the Electrostatic Discharge immunity both parts of the remote mounted version of the HFM-I-400 instrument must be screwed to a well grounded structure. The ferrite that is shipped with the instrument must be installed on the cable next to the electronics enclosure.

The electronics enclosure can be separated and relocated up to 30 feet away from the flow meter base. This requires a cable which is supplied with the instrument if ordered as a cable mounted unit. Alternatively, a 2, 5, or 10 meter cable can be purchased separately. See section 4.2 for ordering information and part numbers.

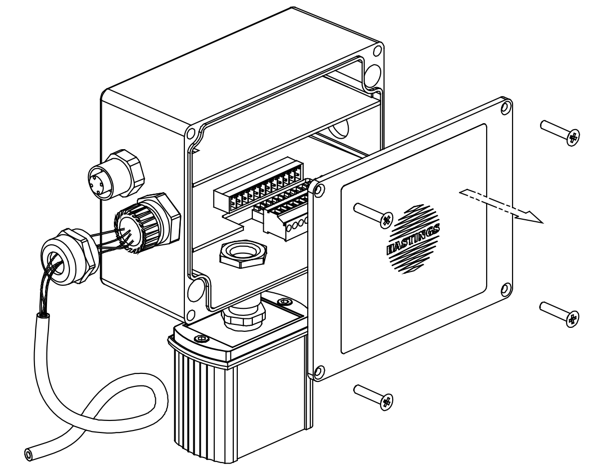


Figure 2-1 Accessing the terminal strip

When remote mounting the electronics enclosure, the support bracket can remain attached to either the flow meter base or the electronics. To separate the electronics enclosure from the support bracket, remove the two screws located on the back of the support bracket. To separate the flow meter base from the support bracket, remove the four screws that mount the bracket to the top of the flow meter base. Unscrew the electrical connector between electronics enclosure and the flow meter base. Remove the electronics enclosure from the flow meter base. Connect the female end of the remote electronics cable to the flow meter base and the male end to the electronics enclosure. The electronics enclosure can be mounted remotely by using the two threaded holes in the enclosure. The size and spacing of these two holes are specified on the outline drawing in Appendix 3 (Section 6.3). These holes may be used by inserting fasteners from behind through a new mounting bracket or they may be accessed from the front side by temporarily removing the enclosure panel. This enables mounting the enclosure to a wall or other solid structure. Alternatively, if the instrument was originally configured as a bracket mounted unit the bracket may be directly mounted to a support structure. The bracket mounting holes locations are the same as those for the flow meter base mounting. (See the outline drawing in Appendix 3, Section 6.3.)

Terminal Strip Pin-out **(Pins numbered right to left as viewed from the front)**	
1	- Power Supply
2	+ Power Supply
3	- Flow Output
4	+ Flow Output
5	+ Auxiliary Input
6	- Auxiliary Input
7	No Connection
8	Digital Common
9	Remote Zero
10	Alarm 1
11	Alarm 2
12	Alarm Common

Figure 2-2 Electrical connections for analog inputs/outputs and power

2.5. Electrical Connection

There are two electrical connectors on the Hastings 400-I Series flow meters—an analog terminal strip (located within the electronics enclosure) and a digital connector. The analog connector provides for the power supply to the meter along with analog signals and functions. As such, its use is required for operation. The digital connector is used for communications in either of RS232, RS485, or Ethernet mode depending on the instrument's configuration. The digital connector does not have to be used if the meter is operated as an analog-only instrument.

CAUTION	In order to maintain the environmental integrity of the enclosure the power/signal cable jacket must have a diameter of .157 - .315" (4 – 11 mm). The nut on the cable gland must be tightened down sufficiently to secure the cable. This cable must be rated for at least 85°C.

2.5.1. Power Supply

Ensure that the power source meets the requirements detailed in the specifications section. Hastings offers several power supply and readout products that meet these standards and are CE marked. If multiple flow meters or other devices are sharing the same power supply, it must have sufficient capability to provide the combined maximum current.

Power is delivered to the instrument through pins 1 and 2 of the analog terminal strip located within the electronics enclosure (see Figure 2-1). As shown in the pin-out diagram Figure 2-2, the positive polarity of the power supply is connected to pin 2 and the negative is connected to pin 1. (For a unipolar power supply, pin 1 is power common and pin 2 is +24V. For a bipolar ±15V power supply, pin 1 is -15V and pin 2 is + 15V.) To allow for inadvertent reversal of the power polarity, an internal diode bridge will ensure that the proper polarity is applied to the internal circuitry. A green LED located next to the terminal strip will illuminate when the meter is properly powered. The power supply inputs are galvanically isolated from all other analog and digital circuitry.

2.5.2. Analog Output

The indicated flow output signal is found on pins 3 and 4 of the terminal strip as shown in Figure 2-2. The negative output pin 3 is galvanically isolated from chasis ground and from the power supply input common. The 400 Series meters can be configured to provide one of many available current and voltage outputs; the standard 4 -20 mA or the optional 0 -20 mA, 0-5 Vdc, 1-5 Vdc, or 0-10 Vdc.

NOTE	When the meter is configured with milliamp output it cannot generate a signal that is below the zero current value; therefore the 0-20 mA unit is limited in its ability to indicate a negative flow with the analog signal.

2.5.2.1. Current Loop Output

The standard instrument output is a 4 - 20 mA signal proportional to the measured flow (i.e. 4 mA = zero flow and 20 mA = 100% FS). An optional current output of 0 – 20 mA (where 0 mA = zero flow and 20 mA = 100% FS) may be selected at the time of ordering.

If either current loop output has been selected, the flow meter acts as a passive transmitter. It neither sources nor sinks the current signal. The polarity of the loop must be such that pin 4 is at a higher potential than pin 3 on the flow meter terminal strip. Loop power must be supplied with a potential in the range of 5-28 Vdc from a source external to the flow meter. The loop supply can be the same supply as that for the instrument power or it can be an isolated loop supply.

Figure 2-3 shows a typical setup using the same supply. This method requires a jumper from pin 2 to pin 4 on the terminal strip while connecting pin 3 to a wire that carries this signal to the indicator (for example, a process ammeter, data acquisition system, or PLC board). To complete the current loop, another wire carries the return signal from the flow indicator back to the negative end of the input supply.(Alternatively, the loop current can be measured on the "high potential side" by connecting the indicator between the pins 2 and 4 while connecting pin 3 to pin 1.)

Figure 2-4 shows an arrangement using a separate loop supply which is isolated from the instrument power supply.

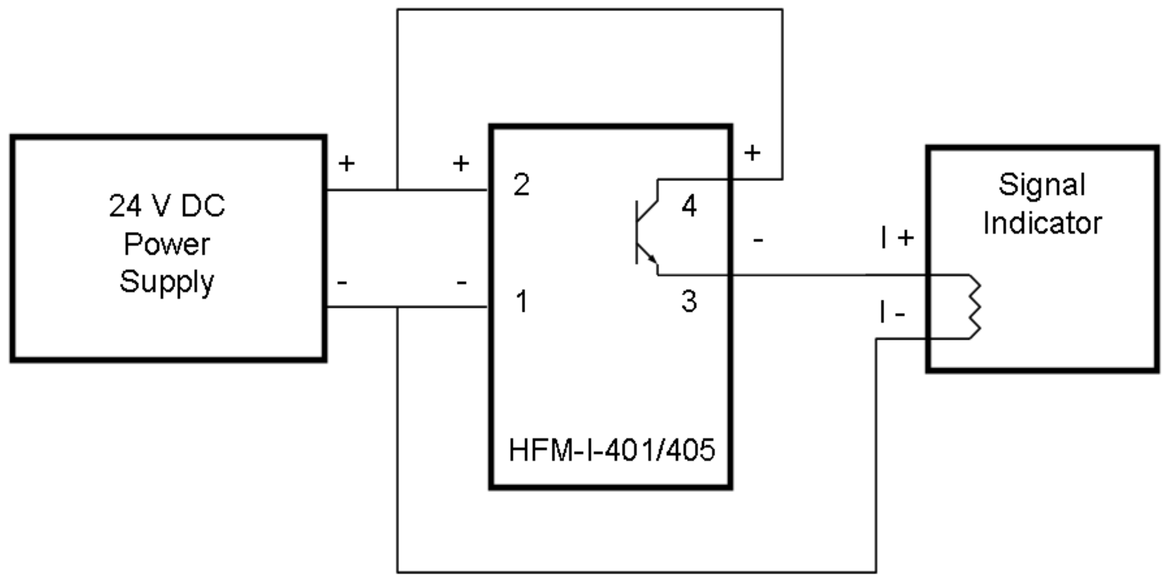


Figure 2-3 Wiring diagram showing the current loop supply powered by the instrument supply

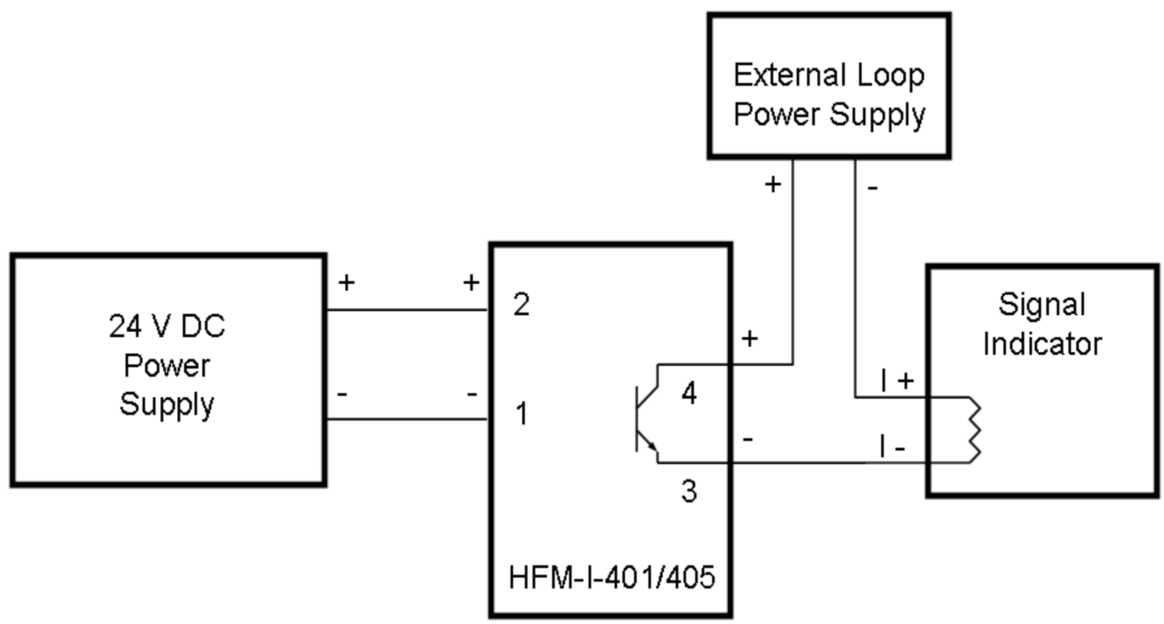


Figure 2-4 Wiring diagram showing the current loop powered by an external supply

2.5.2.2. Voltage output

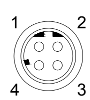
If the flow meter is configured for a voltage output, the signal will be available as a positive potential on pin 4 relative to pin 3 of the terminal strip. Since these pins are galvanically isolated, the signal cannot be read by an indicator between pin 4 and pin 1 of the terminal strip. Pin 3 must be used as the return to properly read the output on pin 4. If an output that is referenced to power supply common is desired then pins 3 and 1 must be connected. It is recommended that these signals be transmitted through shielded cable, especially for installations where long cable runs are required or if the cable is located near equipment that emits RF energy or uses large currents.

Note: When the meter is configured with a voltage output it cannot generate a signal that is more than a few mV below the zero volt value; therefore the 0-5 volt and 0-10 volt units are limited in their ability to indicate a negative flow with the analog signal.

2.6. Digital Connection

The digital signals are available on a sealed female D-coded M12 connector that is designed for use on industrial Ethernet connections. There are many options for connecting to the M12. Hastings offers an 8 foot cable (stock# CB-RS232-M12) with a compatible male M12 connector to a 9-pin D connector suitable for connecting the 400 I series instrument directly to the RS232 port on a PC. A cable to convert USB to RS232 9-pin is available from Hastings (stock# CB-USB-RS232). Also, a 5 meter M12 male–male cable suitable for digital communications can be purchased from Hastings (stock# CB-ETHERNET-M12). Other length cables are available from Lumberg (#0985 342 100/5 M) or Phoenix. Converters from the M12 connector to a standard modular Ethernet connector are available from Hastings or from Lumberg (#0981 ENC 100). A compatible M12 connector suitable for field wiring can be acquired from Harting (21 03 281 1405) or Mouser (617-21-03-281-1405).

The pin-out for the digital connector is shown in Figure 2-5.



PINS	RS232	RS485	ETHERNET
SHIELD	GROUND	GROUND	GROUND
1	TRANSMIT	TX+ (A)	TD+
2	RECEIVE	RX+ (A)	RD+
3	UNUSED	TX- (B)	TD-
4	UNUSED	RX- (B)	RD-

Figure 2-5 Digital connector pin-out

2.7. Digital Configuration

A Hastings 400-I Series flow meter is available with one of three digital communications interfaces, RS232, RS485, or Ethernet. Unless specified differently at the time of ordering, the flow meter is configured for RS232 operation. For each interface, there are changes that can be made to the configuration, either via software or hardware settings. A brief overview of these is included here. For more detailed information, consult the Hastings 400 Series Software Manual.

Jumper	Enabled	Disabled
1	RS485	RS232
2	Half Duplex	Full Duplex
3	TX Terminated	Unterminated
4	RX Terminated	Unterminated
5	9600 Baud	Software Selected
6	Addr = 99	Software Selected

Figure 2-6 Functions for digital jumper field

2.7.1. RS-232

The default configuration for the RS-232 interface is 19200 baud, 8 data bits, no–parity, one stop bit. The baud rate is software selectable and can be overridden by a hardware setting. Hardware settings for RS-232 and RS-485 are enacted on 12 pin jumper field located on the left end of the top circuit board in the electronics enclosure. Only the state of jumpers 1, 2, and 5 affect the RS-232 operation. These jumpers are installed vertically over two pins when enabled and are numbered from left to right. Jumper 1 must be disabled for RS-232; jumper 2 is used to select half or full duplex; and jumper 5 is enabled when a hardware override of the baud rate (forcing it to 9600) is desired. These functions are summarized in Figure 2-6.

2.7.2. RS-485

If RS485 is specified on the order, the flow meter is set to the default values: address 61, unterminated Tx and Rx lines. While the default address is 61, all instruments will respond to an address of FF. Hardware settings for RS-232 and RS-485 are enacted on 12 pin jumper field located on the left end of the top circuit board in the electronics enclosure. Only the state of jumpers 1, 3, 4, and 6 affect the RS-485 operation (see Figure 2-6). These jumpers are installed vertically over two pins when enabled and are numbered from left to right. Jumper 1 must be enabled for RS-485. Enabling jumpers 3 and 4 effect a 120 ohm resistance across the transmit and receive signal pairs respectively. These should only be enabled in the last instrument on a long buss. Enabling jumper 6 forces the address to 99; this is sometimes used when initiating communications.

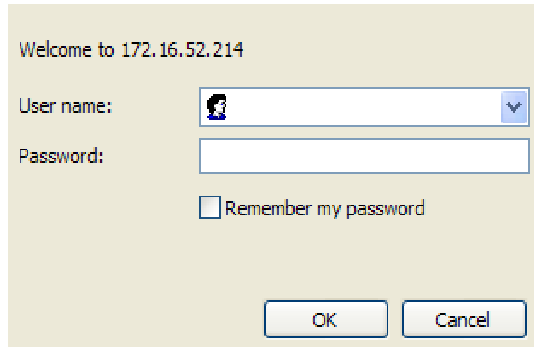


Figure 2-7 Web browser screen

2.7.3. Ethernet

If Ethernet is specified on the order, the flow meter has IP address 172.16.52.250 and communication port number 10001. There are no hardware settings required or available to modify the configuration. This IP address can be changed using a web browser to access the configuration of the instrument by typing the IP address into the URL section of the browser. Press OK to ignore the username/password screen as shown in Figure 2-7. Select the new IP address under the network section of the web page configuration utility. If this address cannot be reached, the instrument can be reconfigured by downloading and installing the Lantronix Device Installer routine from: http://www.lantronix.com/device-networking/utilities-tools/device-installer.html.

A standard web browser cannot be used to send and receive messages (such as flow readings) from the main processor of the flow meter. An Ethernet capable software program is required to communicate with the meter's processor. Suitable examples of such programs are "Hyperterminal" (typically installed as standard on PCs and shown in Figure 2-8) or custom Ethernet capable software such as LabView®. For more information see the Software Manual.

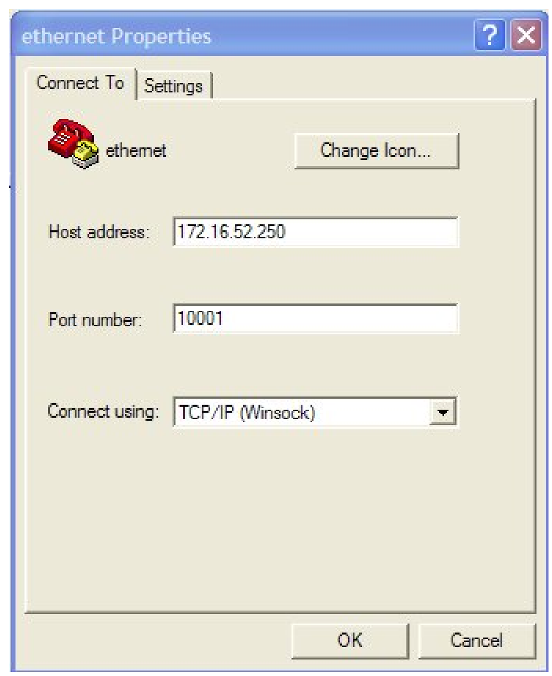


Figure 2-8 Example Hyperterminal window

2.8. Alarm Output Connection

The Hastings 400 Series flow meters include two software settable hardware alarms. Each is an open-collector transistor functioning as a semiconductor switch designed to conduct DC current when activated. (See Figure 2-9.) These sink sufficient current to illuminate an external LED or to activate a remote relay and can tolerate up to 70Vdc across the transistor. The alarm lines and the alarm common are galvanically isolated from all other circuit components. The connections for Alarm 1, Alarm 2 and Alarm Common are available as pins 10, 11, and 12 respectively on the analog terminal strip (see Quick Start Guide on page iii).

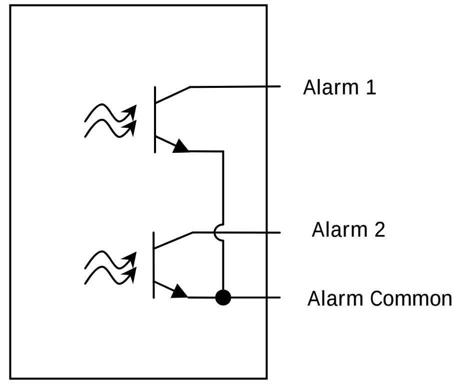


Figure 2-9 Alarm circuit diagram

Since the alarms act as switches they do not produce a voltage or current signal. However, they can be used to generate a voltage signal on an Alarm Out line. This is done by connecting a suitable pull-up resistor between an external voltage supply and the desired alarm line while connecting Alarm Common to the common of the power supply. When activated, the alarm line voltage will be pulled toward the alarm common line generating a sudden drop in the signal line voltage.

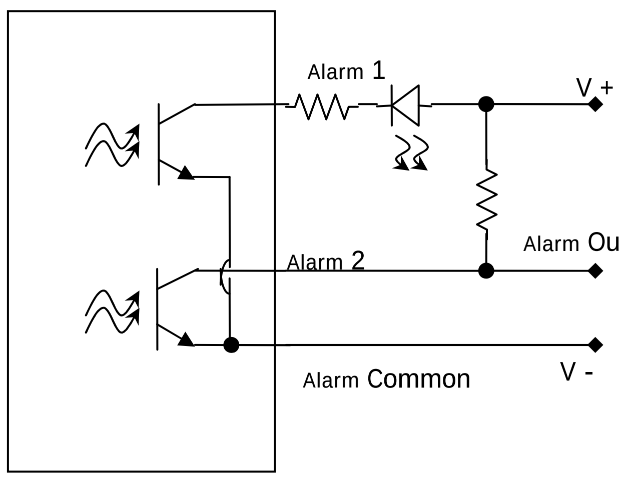


Figure 2-10 Alarm circuit diagram for LED operation

To use the alarm to illuminate an LED connect the positive terminal of the LED to a suitable power supply and connect the other end to a current limiting resistor. This resistor should be sized such that the current is less than 20 mA when the entire supply voltage is applied. Connect the other end of the resistor to Alarm 1 or Alarm 2. Connect Alarm Common to the circuit common of the power supply. When activated, the alarm line is pulled toward the alarm common generating sufficient current through the LED to cause it to illuminate.

Figure 2-10 shows an example of the LED circuit arrangement applied to Alarm 1 while Alarm 2 is configured with a suitable pull-up resistor to provide a voltage output on an Alarm Out line.

Since the Alarm Common is a shared contact, if both alarms are being used independently they must each be wired such that the current passes through the external signaling device before reaching the alarm line.

The alarm settings and activation status are available via software commands and queries. The software interprets an activated Alarm 1 as an “Alarm” condition, while an activated Alarm2 is interpreted as a “Warning” condition. The software manual includes the detailed descriptions for configuring and interpreting the activation of these alarms.

2.9. Auxiliary Input Connection

The Hastings 400 Series flow meters provide an auxiliary analog input function. The flow meter can read the analog value present between pins 5 and 6 on the terminal strip (as shown in Figure 2-2) and make its value available via the digital interface. The accepted electrical input signal is the same as that configured for the analog output signal (4 – 20 mA, 0 -20 mA, 0-5 Vdc, 1-5 Vdc, or 0-10 Vdc). Unlike the analog output signal, which is isolated and capable operating at common mode offsets of over 1000V, the analog input signal cannot be galvanically isolated from ground potential.

2.10. Rotary Gas Selector

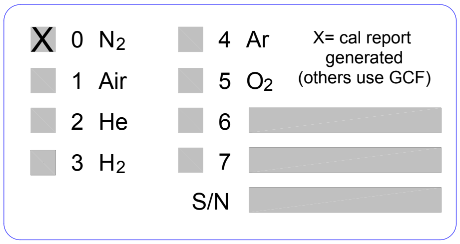
The Hastings 400 Series flow meters can have up to eight different calibrations stored internally. These are referred to as gas records. These records are used to select different gases, but they can also be useful in other ways; for instance reporting the flow in an alternate range, flow unit or reference temperature. The records are referred to by their number label from #0 – #7.

The first six records will, by default, be setup for most common six gases as shown in Figure 2-11. If a gas other than one of these six is specified on the customer order it will be placed in record #6. If a second different gas is selected, it will be placed in record #7. If multiple different gases or ranges are specified they will replace some of the standard six gases.

Record#	Gas
0	Nitrogen
1	Air
2	Helium
3	Hydrogen
4	Argon
5	Oxygen
6	Custom
7	Custom

Figure 2-11 Gas record table

The purchased calibration certificate is provided for the gas (or gases) specified by the customer when ordering. This gas will be indicated with an "X" on the Gas Label (diagram below) that is located on the top of the 400 Series Mass flow meter's electronics enclosure. The remaining gas records will have a different full scale value and an unverified calibration. The full scale range can be calculated by using the Gas conversion factor or GCF. A comprehensive list is found in Appendix 2 in this manual.



Record#	Gas	Full S Rang
0	Nitrogen	100 slm
1	Air	100.15 slm
2	Helium	140 slm
3	Hydrogen	100.38 slm
4	Argon	140.37 slm
5	Oxygen	97.95 slm
6	Custom	Not included i specified
7	Custom	Not included i specified

Example 1

To convert the calibration of a full scale range of 100 slm of Nitrogen to the other full scale ranges:

$$FS_2 = FS_1 \frac{GCF_2}{GCF_1}$$

1. Calculate full scale value of Helium

Calibrated gas = Nitrogen (GCF_1 = 1.000)

Full scale range (FS_1) = 100 slm

Secondary gas (FS_2) = Helium (GCF_2 = 1.40)

1.40/1 = 1.40, 1.40 x 100 = 140 slm of Helium

2. Calculate full scale value of Hydrogen

Calibrated gas = Nitrogen (GCF_1 = 1.000)

Full scale range (FS_1) = 100 slm

Secondary gas (FS_2) = Hydrogen (GCF_2 = 1.0038)

1.0038/1 = 1.0038, 1.0038 x 100 = 100.38 slm of Hydrogen

Example 2- Changing the active gas record

Selecting the active gas record is accomplished in one of two ways:

1. Hardware setting
2. Software setting

Hardware:

The hardware setting is selected by accessing a rotary encoder on the upper PC board in the electronics enclosure. When set to a number position from 0 to 7 it activates the corresponding gas record. If a number greater than 7 is selected, then gas record control is passed to software.

Software:

See Section 3.7 Multi-Gas Calibrations and the software manual for more information about the software control capabilities.

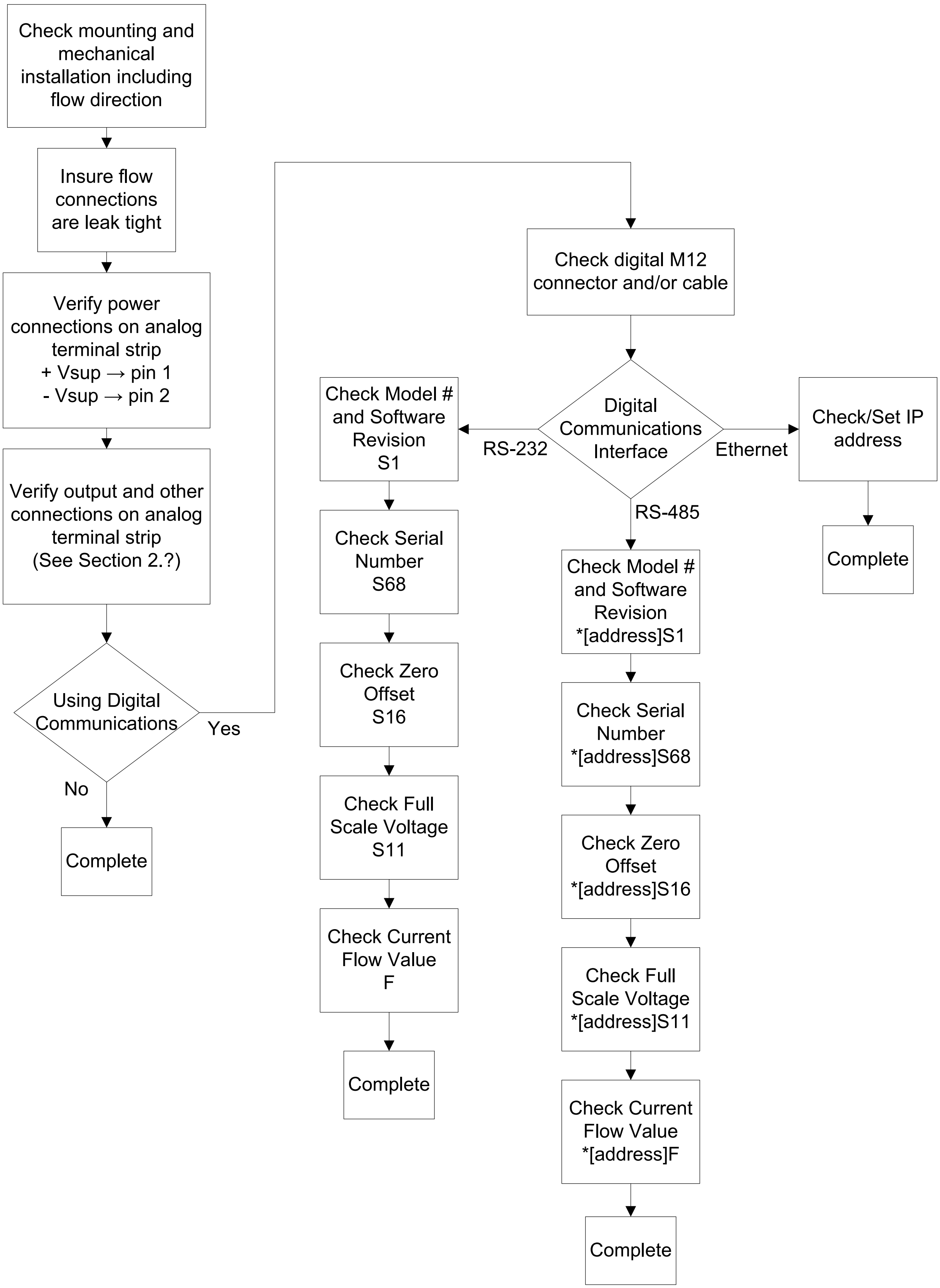
The software setting will override the hardware settings. If gas records are changed through the software setting and the rotary encoder is not changed, the software setting will be active. However, when the meter is powered down and subsequently powered up, the active setting will be based on the rotary encoder setting.

2.11. Electrical Remote Zero Connection

The Hastings 400 Series allows the flow meter zeroing operation to be activated remotely using pins 8 and 9 of the analog terminal strip. (See Drawing in Quick Start Guide.) If these pins are connected together, the meter initiates an internal routine that measures the current reading, stores it in nonvolatile memory as a zero offset, and removes this value from all subsequent readings. When the pin 9 is electrically isolated the flow meter operates normally. The typical implementation of this type of remote zeroing operation involves connecting a remote switch or relay to pins 8 and 9 of the terminal strip. (For more about the zeroing operation, see Section 3.4)

2.12. Check Installation Prior to Operation

Before applying gas to the meter it is advisable to ensure that the mechanical and electrical connections and digital communications (if applicable) are established and operating properly. This can be done by following the guideline procedure below:


Check mounting and mechanical installation including flow direction
Insure flow connections are leak tight
Verify power connections on analog terminal strip
+ Vsup → pin 1
- Vsup → pin 2
Verify output and other connections on analog terminal strip
(See Section 2.?)
Using Digital Communications
Yes
No
Complete
Check digital M12 connector and/or cable
Digital Communications Interface
RS-232
Ethernet
RS-485
Check Model # and Software Revision
S1
Check Serial Number
S68
Check Zero Offset
S16
Check Full Scale Voltage
S11
Check Current Flow Value
F
Complete
Check Model # and Software Revision
*[address]S1
Check Serial Number
*[address]S68
Check Zero Offset
*[address]S16
Check Full Scale Voltage
*[address]S11
Check Current Flow Value
*[address]F
Complete
Check/Set IP address
Complete

3. Operation

The Hastings 400 Series flow meters are designed for operation with clean dry gas and in specified environmental conditions (See Section 1.2). The properly installed meter measures and reports the mass flow as an analog signal and, depending on the configuration and set up, as a digital response. Other features can assist in the measurement operation and provide additional functions. The following sections serves as a guide for correctly interpreting the analog and digital flow output, optimizing the performance, and using the additional features of the instrument.

3.1. Environmental and Gas Conditions

For proper operation, the ambient and gas temperatures must be such that the flow meter remains between -10 and 70°C. Optimal performance is achieved when the environment and gas temperatures are equilibrated and stable. The 400 I series is intended for use with clean, non-condensing gases only. Particles, contamination, condensate, or any other liquids which enter the flow meter body may obstruct critical flow paths in the sensor or shunt, thus causing erroneous readings.

3.2. Interpreting the Analog Output

The analog output signal is proportional to mass flow rate. Each instrument is configured to provide one of the available forms of analog output as described in Section 2.2. The signal read by an indicator (for example, a process ammeter, data acquisition system, or PLC board) can be mapped to the measured flow rate by applying the proper conversion equation selected from the table below.

Table 3-1 The Signal → Flow mapping equations

Analog Output Configuration	Mapping Equation
4 -20 mA	Flow = FS flow * (I_{out} – 4)/ 16
0 -20 mA	Flow = FS flow * I_{out} / 20
0 – 5 Vdc	Flow = FS flow * V_{out} / 5
0 – 10 Vdc	Flow = FS flow * V_{out} / 10
1 – 5 Vdc	Flow = FS flow * (V_{out} -1)/ 4

Alternatively an analog display meter can indicate the flow rate directly in the desired flow units by setting the offset and scaling factors properly.

The flow meter is typically able to measure and report flow which slightly exceeds the full scale value. Reverse or “negative” flows are indicated (to values up to 25% of full scale) by meters with 4-20 mA or 1-5 volt output. However, meters with 0-5 Volt, 0-10 volt or 0-20 mA output are limited in their ability to indicate a negative flow with the analog signal since negative currents or voltages cannot be generated by the meter’s circuitry.

3.3. Digital Communications

Many of the Hastings 400 Series flow meter’s operating parameters such as the flow measurement, alarm settings, status, or gas type can be read or changed by digital communications. The digital communications commands and protocols for each particular interface (RS-232, RS-485, and Ethernet) are treated in detail in the Software Manual. However, the function and interpretation of flow output and auxiliary input are also briefly presented here.

3.3.1. Digitally Reported Flow Output

The flow rate can be read digitally by sending an ascii "F" command (preceded by the address for RS-485). The instrument will respond with an ascii representation of the numerical value of the flow rate in the units of flow specified on the nameplate label.

Example: A meter with RS-232 communications, calibrated for 500 slm FS N_2
Computer transmits: {F}
HFM flow meter replies: {137.5}
This is interpreted as 137.5 slm of nitrogen equivalent flow.

In most situations, the flow meter can measure beyond its range (i.e. a flow that exceeds the full scale or a reverse flow) and report the value via the digital output. While the meter can perform beyond its stated range, the accuracy of these values has not been verified during the calibration process. Flows that exceed 160% of the nominal shunt range (S46 response) should not be relied upon. See the software manual for further information.

3.3.2. Digitally Reported Analog Input

The flow meter can read the analog value present on pins 5 & 6 of the terminal strip (See Section 2.9). This function is typically used to read the analog output from a nearby sensor such as a pressure sensor or vacuum gauge. This value is spanned for the same range as the analog output signal; it reads volts for flow meter configured for 0-5, 0-10 or 1-5 volt output and milliamps for a flow meter configured for 0-20 or 4-20 milliamp output. The value is accessed via the "S26" software query as shown below.

Example: A meter calibrated for 0-5 volt output and RS-232 communications.
Computer transmits: {S26}
HFM flow meter replies: {2.532}
This is interpreted as 2.532 volts.

3.4. Zeroing the Instrument

A proper zeroing of the flow meter is recommended after initial installation and warm-up. It is also advisable to check the zero flow indication periodically during operation. Any uncertainty at zero flow is an offset value which affects all subsequent flow readings. The frequency of these routine checks depends on factors such as: the environmental conditions, the desired level of accuracy, and the desire to measure low flow rates (relative to the meter full scale). To achieve the most precise flow readings, the zeroing procedure is done while the meter is at the expected operating conditions including temperature, line pressure, and gas type. This is especially true for cases where the flow meter is operating at high pressure or with very dense gas.

3.4.1. Preparing for a Zero Check

Before checking or adjusting the meter's zero, the following three requirements must be satisfied:

Warm-up – The instrument must be powered and in the operating environment for at least 30 minutes. Even though the meter will operate within a few minutes after power is applied, the entire warm-up period is needed to establish a suitable zero reading.

No Flow – There must be an independent method to ensure that all flow through the instrument has completely ceased before checking or adjusting the zero. Typically this is achieved by closing valve downstream from the flow meter and waiting a sufficient time for any transient flow to decay. This is especially critical for low flow units that have long piping lengths before or after the flow meter. In such situations, it can require a significant settling time for the flow cease and enable a precise zero.

Stability – The flow meter must stabilize for at least 3 minutes at zero flow, especially following a high flow or overflow condition. This will allow all parts of the sensor to come to thermal equilibrium resulting in the best possible zero value.

3.4.2. Adjusting Zero

The pre-conditions required for a zero check must also be followed when making a zero adjustment. The zero adjustment is a digitally controlled “reset” type operation. When commanded, the meter initiates an internal routine that performs the following sequence: measure the current flow reading, store it in nonvolatile memory as a zero offset, and remove this value from all subsequent readings.

NOTE	If the instrument is inadvertently or improperly zeroed, for example while flow is passing through the instrument, the flow reading is subtracted from all future flow readings. This will produce large flow indication errors.

This offset value can be accessed via the “S40” software query. The reported value is relative to an internal, un-spanned sensor voltage. As an interpretation guideline, an offset that exceeds 0.15 volts typically indicates that a faulty zero value is present.

There are three different methods to activate the zero reset function--manually, digitally, and electrically.

Manually – With the electronics enclosure cover plate removed, a pushbutton switch on the upper board is pressed.

CAUTION	Accessing the manual zero pushbutton requires removing the enclosure front plate. Care must be taken when reinstalling this plate to ensure that the sealing gasket is properly positioned and the fasteners are secure to maintain an IP65 compliant seal.

Digitally – A “ZRO” (“*[address]ZRO” for RS485) command is received properly by the flow meter’s main processor.

Electrically – An external contact closure generates continuity between pins 8 and 9 of the terminal strip.

3.5. High Pressure Operation

When operating at high pressure, the meter’s performance can be affected in two distinct and separate ways—a zero shift and a span (calibration) shift.

3.5.1. Zero Shift

The zero offset can occur as the result of natural convection flow through the sensor tube if the instrument is not mounted in a level orientation with flow horizontal. This natural convection effect causes a zero shift proportional to the system pressure. The overall effect is more pronounced for gases with higher density. Normally the shift is within the allowable zero offset range and can be removed by activating the zero reset at the operating pressure.

3.5.2. Span Shift

The gas properties which form the basis for the flow measurement, such as viscosity and specific heat, exhibit a slight dependence on the gas pressure. Fortunately, this pressure dependence is predictable and can be corrected for in cases where it has an impact on accuracy (typically only significant for pressures in excess of 100 psig). The graph shown in Figure 3-1 shows the expected span shift as a function of pressure for nitrogen. This behavior is similar for most diatomic gases (O_2, H_2, etc), whereas this effect is insignificant for the monatomic gases (He, Ar, etc). This span shift must be considered and accounted for as appropriate for accurate flow measurements at high pressure conditions.

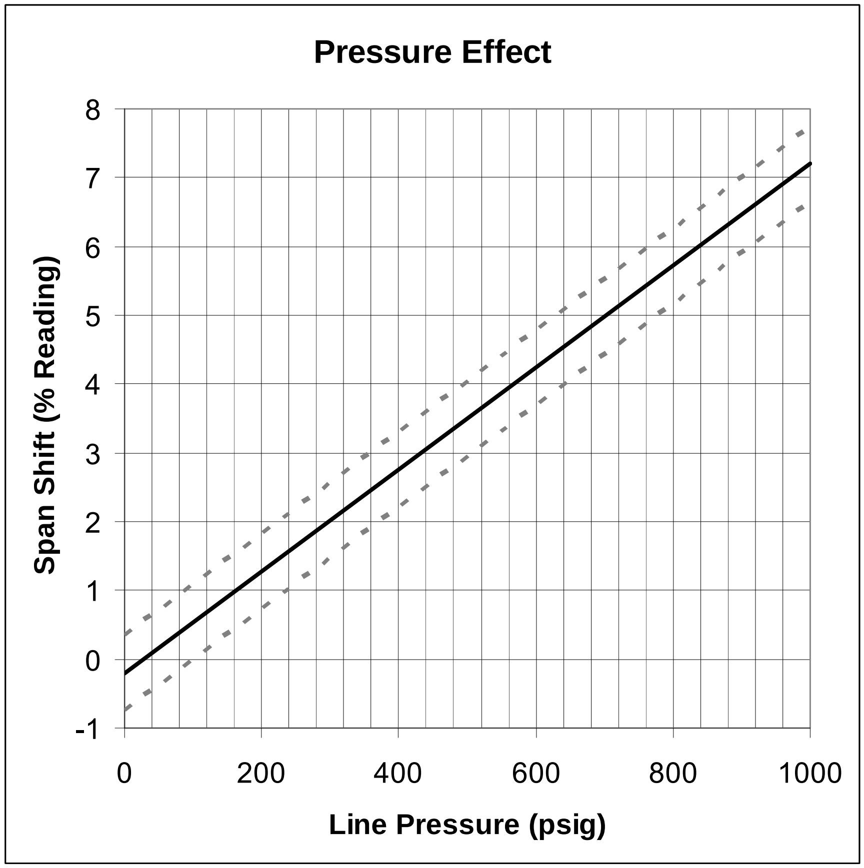


Figure 3-1 The pressure effect on flow calibration (for nitrogen)

3.6. Warnings/Alarms

There are two alarm contacts on the terminal strip connector within the electronics enclosure (See Section 2.8). These function as isolated semiconductor switches sharing a single, isolated common line. In its normal state each switch is "open"; when an alarm is activated the switch is "closed".

The meter's processor can be configured via the digital interface to establish the internal condition for activating each alarm. There are many choices for internal alarms and warnings including overflow, underflow, or various instrument error conditions. Each alarm can also be given a selectable "wait time"—a period for which it must remain in the alarm condition before the physical alarm is activated. See the Software Manual for detailed alarm setting and configuration information.

3.7. Multi-gas Calibrations

The Hastings 400 Series flow meters can have up to eight different calibrations stored internally. These are referred to as gas records. These records are typically used to represent different gases, but they can also be useful in other ways; for instance reporting the flow in an alternate range, flow unit or reference temperature. The records are referred to by their number label from #0 – #7. The first six records are, by default, setup for the same range in the most common six gases as shown in Figure 2-11. If a gas other than one of these six is specified on the customer order it will be placed in record #6. If a second different gas is selected, it will be placed in record #7. If multiple different gases or ranges are specified they will replace some of the standard six gases. Only the gas(es) specified on the order will be verified. The other records will use nominal gas factors to approximate the gas sensitivity until an actual calibration is performed to correct for individual instrument variations. Selecting the active gas record can be done in one of two ways—a hardware setting or a software setting. The hardware setting is done by accessing a rotary encoder on the upper PC board in the electronics enclosure. When set to a number position from 0 to 7 it activates the corresponding gas record. When set to a number greater than 7, the gas record control is passed to software. If the software setting mode is enabled, then the "S6" digital command can be used to set the active gas record as shown in the example below.

Example: To first determine and then change the active gas record using RS-232,

Computer transmits: {S6}

HFM flow meter replies: {0}

This indicates that gas record #0 is currently active.

Computer transmits: {S6=4}

This changes the active gas record to #4.

See the Software Manual for further information including how to setup a new gas record and how to reconfigure an existing gas record.

CAUTION	Accessing the rotary encoder requires removing the enclosure front plate. Care must be taken when reinstalling this plate to ensure that the sealing gasket is properly positioned and the fasteners are secure to maintain an IP65 compliant seal.

NOTE	The software command to change the active gas record will not be executed unless the rotary encoder is set to a number greater than 7. However, the software query will return the current active gas record number even when it has been set by the hardware.

3.8. Flow Totalization

The Hastings 400 Series flow meters are capable of providing a value for the "total amount of gas" that has passed through the flow meter since the last time the totalization function was reset. This value can be used to determine for example, the amount of gas used to fill a chamber or drawn from a supply vessel. To initialize the totalization function, reset the totalized flow value to zero using the S36 digital command as shown in the example below. All subsequent flow readings are added over time and stored as the totalized flow value. The totalized flow value can be read by querying the flow meter digitally as in the example below. The totalized flow is reported in the flow units chosen for the active gas without the time unit. For example, if the flow units are standard liters per minute, the totalized flow is reported in standard liters; if flow units are standard cubic feet per hour, the totalized flow is reported in standard cubic feet.

Example: For a 100 slm FS flow meter, to first reset/start the flow totalization function and then later read the value using RS-232,

Computer transmits: {S36=0}

This resets the totalized value to zero and starts the totalization function. At some point later in time:

Computer transmits: {S36}

HFM flow meter replies: {45.7}

This is interpreted as a total gas amount of 45.7 standard liters has passed through the meter since the flow totalizer was started.

3.9. Additional Digital Capabilities

The Hastings 400 series flow meters have a wide selection of other functions, operating parameters, and values that can be reported and configured via digital communications such as the calibration date, the instrument temperature, the number of hours that gas has been flowing, etc. See the Software Manual for detailed information on these additional digital features.

Parts and Accessories

4. Parts & accessories

These are parts and accessories that are available by separate order from Teledyne Hastings Instruments.

4.1. Power Pod - Power & Display units

THPS-100 Singel Channel Power Supply

The Teledyne Hastings Instruments microprocessor based Power^{Pod}-100 Thermal Mass Flow Power Supply is a self-contained power supply and display for gas thermal mass flow meters, pressure transducers or any device with a voltage output. The unit features an automatically generated set point (0-5V or 0-10V), making it ideal for use with thermal mass flow controllers and pressure controllers. Features include 4.5display, ±15 volt, 250mA transducer supply and an integrated +/- 15vdc @ 250ma power supply is available providing a well regulated, short circuit and thermal overload protected output, and CE compliance.
See the Teledyne Hastings Instruments Product Bulletin for the complete specification on this product.

THPS-400 Four Channel Power Supply

The Teledyne Hastings Instruments Digital 4-Channel Power^{Pod} is featured in a half-rack profile for simple drop-in replacement of the existing Model 200 and 400 units, or be used as a bench top unit.
The Power^{Pod}-400 is equipped with a four line by twenty-character, vacuum fluorescent display (VFD). The display emulates a liquid crystal display in its command structure but the VFD gives the unit a greater viewing angle than available with most conventional LED or LCD displays.
The Power^{Pod} incorporates many features including an integrated totalizer with a count-up or count-down option; user selected filtering of readings; serial or Ethernet communications.
The unit also offers a simultaneous display of all four channels or selective blanking of unused channels, ratio control with analog outputs for stacking multiple power supplies, and easy to follow menu driven calibration and setup.
The digital design of the Power^{Pod} allows the user to set both the minimum and maximum display values corresponding to specific voltage or current inputs. One advantage of this approach is that it negates the need to access hard to reach transducers to re-zero them. Should the analog signal from the transducer change due to a zero shift, the digital counts seen by the Power^{Pod} can be changed to display zero either manually from the front panel or via serial communication with the unit.

4.2. Fittings

Fittings	Hastings#
HFM-I-401	
1/2" Swagelok Fittings	**41-03-086**
1/2" VCO Fittings	**41-03-119**
1/2" VCR Fittings	**41-03-090**
3/4" Swagelok Fitting	**41-03-152**
10 mm Swagelok	**41-03-153**
3/8" Male NPT	**41-03-154**
1/2" Male NPT	**41-03-155**
12 mm Swagelok	**41-03-160**
3/4-16 SAE/MS Straight Female (no fitting)	**N/A**
HFM-I-405	
1" Swagelok fitting	**41-03-142**
3/4" Swagelok	**41-03-149**
1" VCO Fitting	**41-03-147**
1" VCR fitting	**41-03-148**
1" Male NPT	**41-03-150**
3/4" Male NPT	**41-03-151**
1 5/16-12 Female SAE/MS straight thread (no fitting)	**N/A**

4.3. Cables

Description	Hastings Stock#
Remote Electronics Cables	
2 meter cable remote mounting cable	CB-8P-M12-2MRA
5 meter remote mounting cable	CB-8P-M12-5MRA
10 meter remote mounting cable	CB-8P-M12-10MRA
401 Local Bracket - mount direct to sensor	14-03-002
405 Local Bracket - mount direct to sensor	14-03-001
Digital Communications	
9 pin RS232 to 400 series M12 connector	CB-RS232-M12
Digital M12 connector to M12 connector	CB-ETHERNET-M12
USB to 9 pin RS232 connector	CB-USB-RS232
RJ45 Ethernet to M12 Ethernet connector	CB-RJ45-M12
Analog I/O	
8 foot D connector to 8 bare leads	CB-D15-Lead-8
25 foot D connector to 8 bare leads	CB-D15-Lead-25
100 foot D connector to 8 bare leads	CB-D15-Lead-100

5. Warranty

5.1. Warranty Repair Policy

Hastings Instruments warrants this product for a period of one year from the date of shipment to be free from defects in material and workmanship. This warranty does not apply to defects or failures resulting from unauthorized modification, misuse or mishandling of the product. This warranty does not apply to batteries or other expendable parts, nor to damage caused by leaking batteries or any similar occurrence. This warranty does not apply to any instrument which has had a tamper seal removed or broken.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty as to fitness for a particular use. Hastings Instruments shall not be liable for any indirect or consequential damages.

Hastings Instruments, will, at its option, repair, replace or refund the selling price of the product if

Hastings Instruments determines, in good faith, that it is defective in materials or workmanship during the warranty period. Defective instruments should be returned to Hastings Instruments, **shipment prepaid,** together with a written statement of the problem and a Return Material Authorization (RMA) number.

Please consult the factory for your RMA number before returning any product for repair. Collect freight will not be accepted.

5.2. Non-Warranty Repair Policy

Any product returned for a non-warranty repair must be accompanied by a purchase order, RMA form and a written description of the problem with the instrument. If the repair cost is higher, you will be contacted for authorization before we proceed with any repairs. If you then choose not to have the product repaired, a minimum will be charged to cover the processing and inspection. Please consult the factory for your RMA number before returning any product repair.

TELEDYNE HASTINGS INSTRUMENTS
804 NEWCOMBE AVENUE
HAMPTON, VIRGINIA 23669 U.S.A.
ATTENTION: REPAIR DEPARTMENT

TELEPHONE	(757) 723-6531
	1-800-950-2468
FAX	(757) 723-3925
E MAIL	hastings_instruments@teledyne.com
INTERNET ADDRESS	http://www.hastings-inst.com

Repair Forms may be obtained from the "Information Request" section of the Hastings Instruments web site.

6. Appendices

6.1. Appendix 1- Volumetric versus Mass Flow

Mass flow measures just what it says, the mass or weight of the gas flowing through the instrument. Mass flow (or weight per unit time) units are given in pounds per hour (lb/hour), kilograms per sec (kg/sec) etc. When your specifications state units of flow to be in mass units, there is no reason to reference a temperature or pressure. Mass does not change based on temperature or pressure.

However, if you need to see your results of gas flow in volumetric units, like liters per minute, cubic feet per hour, etc. you must consider the fact that volume DOES change with temperature and pressure.

A mass flow meter measures MASS (grams) and then converts mass to volume. To do this the density (grams/liter) of the gas must be known and this value changes with temperature and pressure.

When you heat a gas, the molecules have more energy and they move around faster, so when they bounce off each other, they become more spread out, therefore the volume is different for the same number of molecules.

Think about this:

The density of Air at 0° C is 1.29 g/liter

The density of Air at 25C is 1.19 g/liter

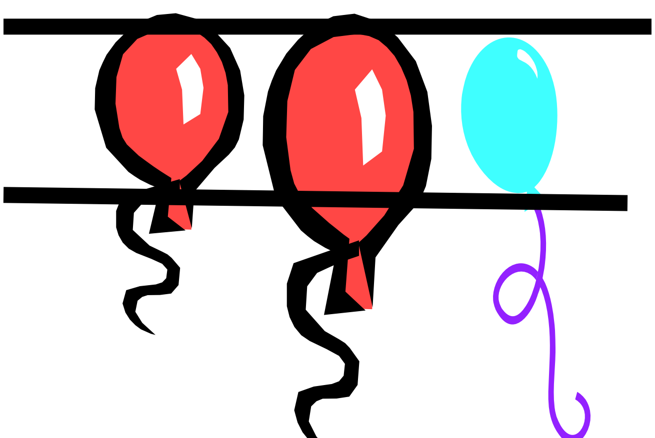
The difference is 0.1 g/liter. If you are measuring flows of 100 liters per minute, and you don't use the correct density factor then you will have an error of 10 g/minute!

Volume also changes with pressure. Think about a helium balloon with a volume of 1 liter. If you could scuba dive with this balloon and the pressure on it increases. What do you think happens to the weight of the helium? It stays the same. What would happen to the volume (1 liter)? It would shrink.

Why is the word standard included with the volume terms liters and cubic feet in mass flow applications?

A mass flow meter measures mass …and we know we can convert to volume.

To use density we must pick one (or **standard)** temperature and pressure to use in our calculation. When this calculation is done,



1 Liter	1.08 Liter	1 Liter
0° C	25 C	25° C
0..179 grams/1 liter	0.179 g/1.08 liters	0.164 grams

Using the example to the left, we can see a standard liter can be defined differently. The first balloon contains 0.179 grams of Helium at 0 ° C and 760 Torr (density of 0.179 grams/liter). Heat up that balloon to room temperature and the volume increases, but the mass has not changed – but the volume is not 1 liter anymore, it is 1.08 liters.

So to define a standard liter of Helium at 25 C, we must extract only one liter from the second balloon and that liter weighs only 0.175 grams.

If a mass flow meter is set up for STP at 0 C and 760 Torr, when it measures 0.179 grams of He, it will give you results of 1 SLM.
If a second meter is set up for STP at 25 C and 760 Torr, when it measures 0.164 grams, it will give results of 1 SLM.

the units are called **standard** liters per minute (SLM) or **standard** cubic feet per minute (SCFM), etc because it is referenced to a standard temperature and pressure when the volume is calculated.

6.2. Appendix 2 - Gas Conversion Factors

The gas correction factors (GCF's) presented in this manual were obtained by one of four methods. The following table summarizes the different methods for determining GCF's and will help identify for which gases the highest degree of accuracy may be achieved when applying a correction factor.

1. Empirically determined
2. Calculated from virial coefficients of other investigator's empirical data
3. From NIST tables
4. Calculated from specific heat data at 0° C at 1 atmosphere

The most accurate method is by direct measurement. Gases that are easily handled with safety such as inert gases, gases common in the atmosphere or gases that are otherwise innocuous can be run through a standard flow meter and the GCF determined empirically.

Many gases that have been investigated sufficiently by other researchers, can have their molar specific heat (C' p) calculated. The gas correction factor is then calculated using the following ratio:

GCF = C 'apN2

C'apGasX

GCF's calculated in this manner have been found to agree with the empirically determined GCF's within a few tenths of a percent.

The National Institute of Standards[LH1] and Technology (NIST) maintains tables of thermodynamic properties of certain fluids. Using these tables, one may look up the necessary thermophysical property and calculate the GCF with the same degree of accuracy as going directly to the referenced investigator.

Lastly, for rare, expensive gases or gases requiring special handling due to safety concerns, one may look up specific heat properties in a variety of texts on the subject. Usually, data found in this manner applies only in the ideal gas case. This method yields GCF's for ideal gases but as the complexity of the gas increases, its behavior departs from that of an ideal gas. Hence the inaccuracy of the GCF increases.

Hastings Instruments will continue to search for better estimations of the GCF's of the difficult gases and will regularly update the list. Most Hastings flow meters and controllers are calibrated using nitrogen. The correction factors published by Hastings are meant to be applied to these instruments. To apply the GCF's, simply multiply the gas flow reading times the GCF for the process gas in use.

Example:

Calculate the actual flow of argon passing through a nitrogen-calibrated meter that reads 20 sccm, multiply the reading times the GCF for argon.

20.000 x 1.3978 = 27.956

Conversely, to determine what reading to set a nitrogen-calibrated meter in order to get a desired flow rate of a process gas other than nitrogen, you divide the desired rate by the GCF.

For example, to get a desired flow of 20 sccm of argon flowing through the meter, divide 20 sccm by 1.3978

20.000 / 1.3978 = 14.308

That is, you ` (adjust the gas flow) to read 14.308 sccm.

Some meters, specifically the high flow meters, are calibrated in air. The flow readings must then be corrected twice. Convert once from air to nitrogen, then from nitrogen to the gas that will be measured with the meter. In this case, multiply the reading times the ratio of the process gas' GCF to the GCF of the calibration gas.

Example:

A meter calibrated in air is being used to flow propane. The reading from the meter is multiplied by the GCF for propane and then divided by the GCF of air.

20 x (0.3499/1.0015) = 6.9875

To calculate a target setting (20 sccm) to achieve a desired flow rate of propane using a meter calibrated to air, invert the ratio above and multiply.

20 x (1.0015/0.3499) = 57.2449

Gas Conversion Table for Nitrogen

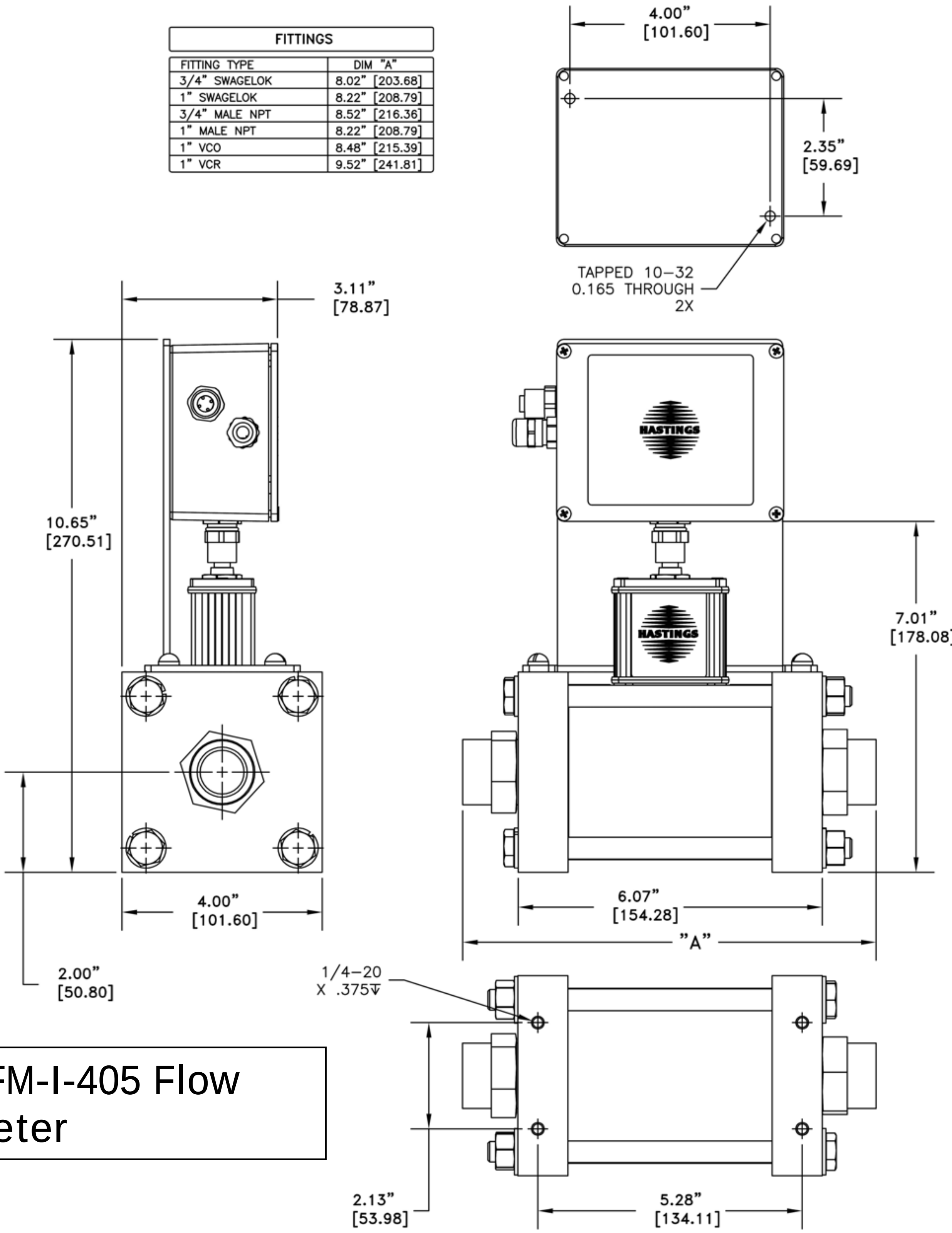
Rec #	Gas	Symbol	GCF	Derived	Density (g/L) 25° C / 1 atm	Z
1	Acetic Acid	$C_2H_4F_2$	0.4155	4	2.700	2.0301
2	Acetic Acid, Anhydride	$C_4H_6O_3$	0.2580	4	4.173	2.3384
3	Acetone	C_3H_6O	0.3556	4	2.374	1.7504
4	Acetonitryl	C_2H_3N	0.5178	4	1.678	1.4462
5	Acetylene	C_2H_2	0.6255	4	1.064	0.9792
6	Air	Air	1.0015	1	1.185	1.0930
7	Allene	C_3H_4	0.4514	4	1.638	1.3876
8	Ammonia	NH_3	0.7807	2	0.696	0.6409
9	Argon	Ar	1.4047	1	1.633	2.1243
10	Arsine	AsH_3	0.7592	5	3.186	4.0839
11	Benzene	C_6H_6	0.3057	4	3.193	2.0636
12	Boron Trichloride	BCl_3	0.4421	4	4.789	3.6531
13	Boron Triflouride	BF_3	0.5431	4	2.772	2.4109
14	Bromine	Br_2	0.8007	4	6.532	1.0000
15	Bromochlorodifluoromethane	$CBrClF_2$	0.3684	4	6.759	4.2789
16	Bromodifluoromethane	$CHBrF_2$	0.4644	4	5.351	4.3990
17	Bromotrifluormethane	$CBrF_3$	0.3943	4	6.087	4.1546
18	Butane	C_4H_{10}	0.2622	2	2.376	1.6896
19	Butanol	$C_4H_{10}O$	0.2406	4	3.030	1.9233
20	Butene	C_4H_8	0.3056	4	2.293	1.6700
21	Carbon Dioxide	CO_2	0.7526	1	1.799	1.7511
22	Carbon Disulfide	CS_2	0.6160	4	3.112	3.0744
23	Carbon Monoxide	CO	1.0012	4	1.145	1.0433
24	Carbon Tetrachloride	CCl_4	0.3333	4	6.287	3.6196
25	Carbonyl Sulfide	COS	0.6680	4	2.456	2.4230
26	Chlorine	Cl_2	0.8451	4	2.898	3.9995
27	Chlorine Trifluoride	ClF_3	0.4496	5	3.779	2.8970
28	Chlorobenzene	C_6H_5Cl	0.2614	4	4.601	2.4954
29	Chlorodifluoroethane	$C_2H_3ClF_2$	0.3216	4	4.108	2.5119

30	Chloroform	$CHCl_3$	0.4192	4	4.879	3.5284
31	Chloropentafluoroethane	C_2ClF_5	0.2437	4	6.314	2.9778
32	Chloropropane	C_3H_7Cl	0.3080	4	3.210	2.0756
33	Cisbutene	C_4H_8	0.3004	4	2.293	1.6672
34	Cyanogen	C_2N_2	0.4924	4	2.127	1.7626
35	Cyanogen Chloride	ClCN	0.6486	5	2.513	2.4405
36	Cyclobutane	C_4H_8	0.3562	4	2.293	1.7091
37	Cyclopropane	C_3H_6	0.4562	4	1.720	1.4440
38	Deuterium	$H^2{}_2$	1.0003	4	0.165	0.3102
39	Diborane	B_2H_6	0.5063	5	1.131	1.0486
40	Dibromodifluoromethane	CBr2F2	0.3590	4	8.576	5.2998
41	Dichlorofluoromethane	$CHCl_2F$	0.4481	4	4.207	3.2249
42	Dichloromethane	CH_2Cl_2	0.5322	4	3.472	3.0592
43	Dichloropropane	$C_3H_6Cl_2$	0.2698	4	4.618	2.5291
44	Dichlorosilane	H_2SiCl_2	0.4716	5	4.129	3.3176
45	Diethyl Amine	$C_4H_{11}N$	0.2256	4	2.989	1.9080
46	Diethyl Ether	$C_4H_{10}O$	0.2235	4	3.030	1.9215
47	Diethyl Sulfide	$C_4H_{10}S$	0.2255	4	3.686	2.1300
48	Difluoroethylene	$C_2H_2F_2$	0.4492	4	2.617	2.0457
49	Dimethylamine	C_2H_7N	0.3705	4	1.843	1.4793
50	Dimethyl Ether	C_2H_6O	0.4088	4	1.883	1.5211
51	Dimethyl Sulfide	C_2H_6S	0.3623	4	2.540	1.8455
52	Divinyl	C_4H_6	0.3248	4	2.211	1.6433
53	Ethane	C_2H_6	0.4998	2	1.229	1.1175
54	Ethane, 1-chloro-1,1,2,2-tetrafluoro-	C_2HClF_4	0.2684	4	5.578	2.8629
55	Ethane, 1-chloro-1,2,2,2-tetrafluoro-	C_2HClF_4	0.2719	4	5.578	2.8806
56	Ethanol	C_2H_6O	0.4046	4	1.883	1.5187
57	Ethylacetylene	C_4H_6	0.3256	4	2.211	1.6438
58	Ethyl Amine	C_2H_7N	0.3694	4	1.843	1.4789
59	Ethylbenzene	C_8H_{10}	0.2001	4	4.339	2.3099
60	Ethyl Bromide	C_2H_5Br	0.4124	4	4.454	3.1724
61	Ethyl Chloride	C_2H_5Cl	0.4212	4	2.637	2.0018
62	Ethyl Fluoride	C_2H_5F	0.4430	4	1.964	1.5967
63	Ethylene	C_2H_4	0.6062	1	1.147	1.0475
64	Ethylene Dibromide	$C_2H_4Br_2$	0.3173	4	7.679	4.1196
65	Ethylene Dichloride	$C_2H_4Cl_2$	0.3475	4	4.045	2.5846
66	Ethylene Oxide	C_2H_4O	0.5308	4	1.801	1.5495
67	Ethyleneimine	C_2H_4N	0.4790	4	1.719	1.4552
68	Ethylidene Dichloride	$C_2H_4Cl_2$	0.3506	4	4.045	2.5976
69	Ethyl Mercaptan	C_2H_6S	0.3654	4	2.540	1.8499
70	Fluorine	F_2	0.9115	4	1.553	1.5574
71	Formaldehyde	CH_2O	0.7912	4	1.227	1.1232
72	Freon 11	CCl_3F	0.3535	4	5.615	3.4473
73	Freon 12	CCl_2F_2	0.3712	4	4.942	3.2026
74	Freon 13	$CClF_3$	0.3792	4	4.270	2.8572
75	Freon 14	CF_4	0.4422	4	3.597	2.7242
76	Freon 22	$CHClF_2$	0.4857	4	3.534	2.8794
77	Freon 23	CHF_3	0.5282	4	2.862	2.4487
78	Freon 114	$C_2Cl_2F_4$	0.2327	4	6.986	3.1174
79	Furan	C_4H_4O	0.3889	4	2.783	2.0253
80	Helium	He	1.4005	1	0.164	0.2304
81	Heptafluoropropane	C_3HF_7	0.1987	4	6.950	2.9681
82	Hexamethyldisilazane	$C_6H_{19}NSi_2$	0.1224	4	6.597	3.2710
83	Hexamethyldisiloxane	$C_6H_{18}OSi_2$	0.1224	4	6.637	3.2794
84	Hexane	C_6H_{14}	0.1828	4	3.522	2.1062
85	Hexafluorobenzene	C_6F_6	0.1733	4	7.605	3.0771
86	Hexene	C_6H_{12}	0.1918	4	3.440	2.0677
87	Hydrazine	N_2H_4	0.5506	4	1.310	1.1757
88	Hydrogen	H_2	1.0038	1	0.082	0.3895

89	Hydrogen Bromide	HBr	1.0028	4	3.307	7.6975
90	Hydrogen Chloride	HCl	1.0034	4	1.490	1.5183
91	Hydrogen Cyanide	CHN	0.7772	4	1.105	1.0003
92	Hydrogen Fluoride	HF	1.0039	4	0.818	0.6845
93	Hydrogen Iodide	HI	0.9996	4	5.228	1.0000
94	Hydrogen Selenide	H_2Se	0.8412	5	3.309	5.1920
95	Hydrogen Sulfide	H_2S	0.8420	4	1.393	1.3174
96	Isobutane	C_4H_{10}	0.2725	2	2.376	1.6912
97	Isobutanol	$C_4H_{10}O$	0.2391	4	3.030	1.9228
98	Isobutene	C_4H_8	0.2984	4	2.293	1.6663
99	Isopentane	C_5H_{12}	0.2175	4	2.949	1.8975
100	Isopropyl Alcohol	C_3H_8O	0.2931	4	2.456	1.7335
101	Isoxazole	C_3H_3NO	0.4333	4	2.823	2.1501
102	Ketene	C_2H_2O	0.5732	4	1.718	1.5127
103	Krypton	Kr	1.4042	4	3.425	1.0000
104	Methane	CH_4	0.7787	1	0.656	0.6105
105	Methanol	CH_4O	0.6167	4	1.310	1.1818
106	Methyl Acetate	$C_3H_6O_2$	0.3083	4	3.028	1.9967
107	Methyl Acetylene	C_3H_4	0.4430	4	1.638	1.3847
108	Methylamine	CH_5N	0.5360	4	1.269	1.1449
109	Methyl Bromide	CH_3Br	0.6358	4	3.881	4.3841
110	Methyl Chloride	CH_3Cl	0.6639	4	2.064	1.9480
111	Methylcyclohexane	C_7H_{14}	0.1853	4	4.013	2.2334
112	Methyl Ethyl Amine	C_3H_9N	0.2692	4	2.416	1.7065
113	Methyl Ethyl Ether	C_3H_8O	0.2844	4	2.456	1.7285
114	Methyl Ethyl Sulfide	C_3H_8S	0.2743	4	3.113	1.9816
115	Methyl Fluoride	CH_3F	0.7247	4	1.391	1.2790
116	Methyl Formate	$C_2H_4O_2$	0.3975	4	2.455	1.8491
117	Methyl Iodide	CH_3I	0.6514	4	5.802	10.2105
118	Methyl Mercaptan	CH_4S	0.5409	4	1.966	1.6930
119	Methylpentene	C_6H_{12}	0.2037	4	3.440	2.0555
120	Methyl Vinyl Ether	C_3H_6O	0.3435	4	2.374	1.7377
121	Neon	Ne	1.4043	4	0.825	0.6173
122	Nitric Oxide	NO	0.9795	4	1.226	1.1430
123	Nitrogen	N_2	1.0000	1	1.145	1.0434
124	Nitrogen Dioxide	NO_2	0.7604	4	1.880	1.8624
125	Nitrogen Tetroxide	N_2O_4	0.3395	4	3.761	2.4128
126	Nitrogen Trifluoride	NF_3	0.5406	5	2.902	2.5277
127	Nitromethane	CH_3NO_2	0.4653	4	2.495	1.9912
128	Nitrosyl Chloride	$NOCl$	0.6357	4	2.676	2.6013
129	Nitrous Oxide	N_2O	0.7121	1	1.799	1.7098
130	n-Pentane	C_5H_{12}	0.2121	4	2.949	1.9008
131	Octane	C_8H_{18}	0.1386	4	4.669	2.6119
132	Oxygen	O_2	0.9779	1	1.308	1.2483
133	Oxygen Difluoride	F_2O	0.6454	4	2.207	2.0766
134	Ozone	O_3	0.7022	4	1.962	1.8868
135	Pentaborane	B_5H_9	0.1499	5	2.580	1.9855
136	Pentane	C_5H_{12}	0.2175	4	2.949	1.8975
137	Perchloryl Fluoride	$ClFO_3$	0.4155	4	4.188	3.0075
138	Perfluorocyclobutane	C_4F_8	0.1711	4	8.176	3.1946
139	Perfluoroethane	C_2F_6	0.2530	4	5.641	2.8112
140	Perfluoropropane	C_3F_8	0.1818	4	7.685	3.0998
141	Phenol	C_6H_6O	0.2489	4	3.847	2.2089
142	Phosgene	$COCl_2$	0.4812	4	4.043	3.3063
143	Phosphine	PH_3	0.7859	5	1.390	1.2956
144	Phosphorus Trifluoride	PF_3	0.4973	5	3.596	2.9936
145	Propane	C_3H_8	0.3499	1	1.802	1.4516
146	Propyl Alcohol	C_3H_8O	0.3061	4	2.456	1.7427
147	Propyl Amine	C_3H_9N	0.2860	4	2.416	1.7126
148	Propylene	C_3H_6	0.4048	2	1.720	1.4223
149	Pyradine	C_5H_5N	0.3222	4	3.233	2.1151
150	R32	CH_2F_2	0.6197	2	2.126	1.9458

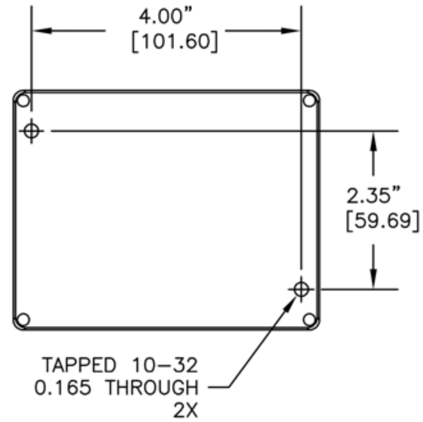
151	R123	$C_2HCl_2F_3$	0.2583	2	6.251	3.0368
152	R123A	$C_2HCl_2F_3$	0.2699	4	6.251	3.1065
153	R125	C_2HF_5	0.2826	2	4.906	2.6844
154	R134	$C_2H_2F_4$	0.2996	4	4.170	2.4595
155	R134A	$C_2H_2F_4$	0.3110	2	4.170	2.5001
156	R143	$C_2H_3F_3$	0.3451	4	3.435	2.2693
157	R143A	$C_2H_3F_3$	0.3394	4	3.435	2.2533
158	R152A	$C_2H_4F_2$	0.3877	4	2.700	1.9753
159	R218	C_3F_8	0.1818	4	7.685	3.0998
160	R1416	$C_2H_3Cl_2F$	0.3047	4	4.780	2.7342
161	Radon	Rn	1.4043	4	9.074	1.0000
162	Sec-butanol	$C_4H_{10}O$	0.2327	4	3.030	1.9213
163	Silane	SiH_4	0.6809	5	1.313	1.1934
164	Silicone Tetrafluoride	SiF_4	0.3896	5	4.254	2.9041
165	Sulfur Dioxide	SO_2	0.6878	4	2.619	2.7013
166	Sulfur Hexafluoride	SF_6	0.2701	1	5.970	3.0092
167	Sulfur Tetrafluoride	SF_4	0.3752	4	4.417	2.9215
168	Sulfur Trifluoride	SF_3	0.4368	4	3.640	2.7312
169	Sulfur Trioxide	SO_3	0.5397	4	3.273	2.8922
170	Tetrachloroethylene	C_2Cl_4	0.2926	4	6.778	3.4711
171	Tetrafluoroethylene	C_2F_4	0.3395	4	4.088	2.5732
172	Tetrahydrofuran	C_4H_8O	0.3271	4	2.947	1.9924
173	Tert-butanol	$C_4H_{10}O$	0.2298	4	3.030	1.9210
174	Thiophene	C_4H_4S	0.3538	4	2.783	1.9586
175	Toluene	C_7H_8	0.2448	4	3.766	2.1756
176	Transbutene	C_4H_8	0.2053	4	2.293	1.6978
177	Trichloroethane	$C_2H_3Cl_3$	0.3133	4	5.453	3.0712
178	Trichloroethylene	C_2HCl_4	0.3423	4	6.820	3.9903
179	Trichlorotrifluoroethane	$C_2Cl_3F_3$	0.2253	4	7.659	3.2607
180	Triethylamine	$C_6H_{15}N$	0.1619	4	4.136	2.3280
181	Trimethyl Amine	C_3H_9N	0.2822	4	2.416	1.7109
182	Tungsten Hexafluoride	WF_6	0.2453	5	12.174	4.7379
183	Uranium Hexafluoride	UF_6	0.1859	4	14.389	4.4681
184	Vinyl Bromide	C_2H_3Br	0.4768	4	4.372	3.5770
185	Vinyl Chloride	C_2H_3Cl	0.4956	4	2.555	2.0988
186	Vinyl Flouride	C_2H_3F	0.5716	5	1.882	1.6528
187	Water Vapor	H_2O	0.7992	5	0.742	0.6715
188	Xenon	Xe	1.4042	4	5.366	1.0000
189	Xylene, m-	C_8H_{10}	0.2036	4	4.339	2.3103
190	Xylene, o-	C_8H_{10}	0.1953	4	4.339	2.3108
191	Xylene, p-	C_8H_{10}	0.2028	4	4.339	2.3102

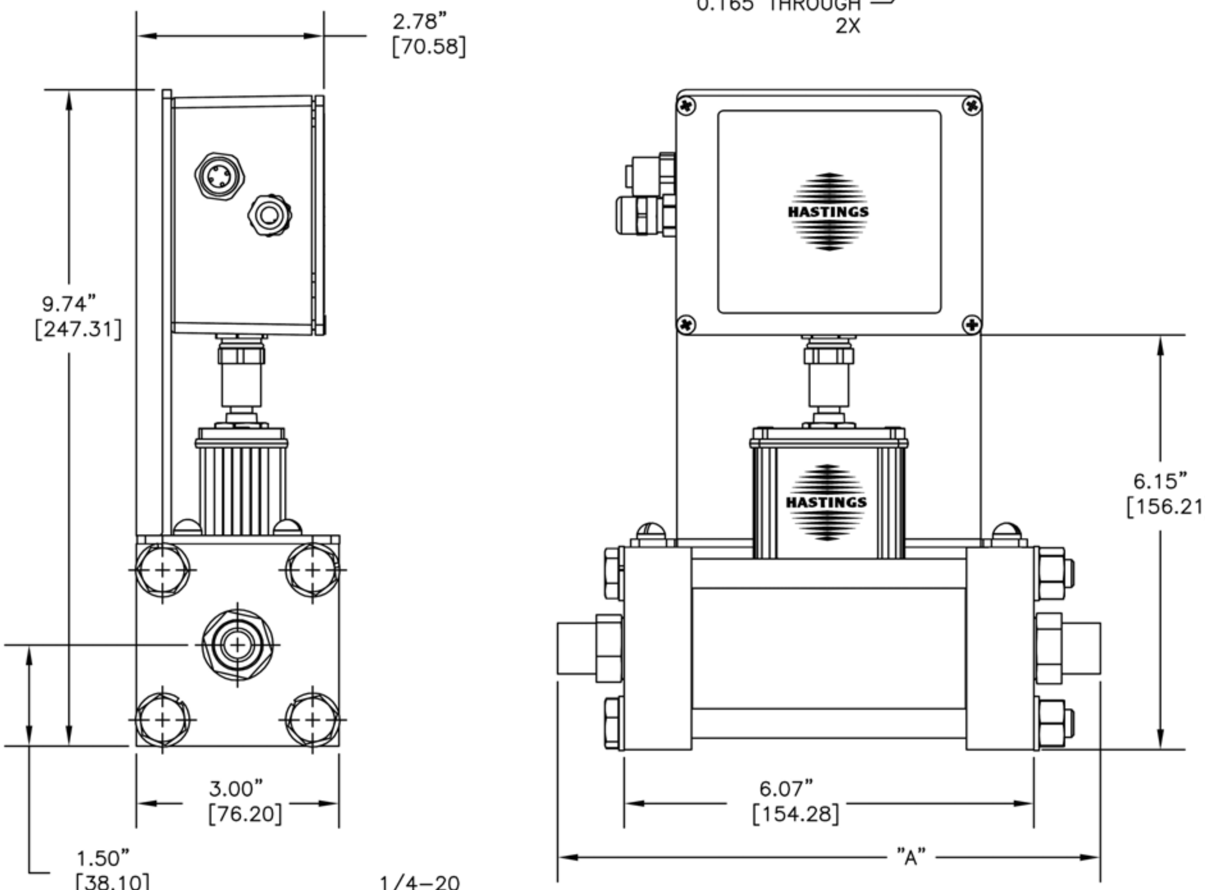
FITTINGS	
FITTING TYPE	DIM "A"
3/4" SWAGELOK	8.02" [203.68]
1" SWAGELOK	8.22" [208.79]
3/4" MALE NPT	8.52" [216.36]
1" MALE NPT	8.22" [208.79]
1" VCO	8.48" [215.39]
1" VCR	9.52" [241.81]

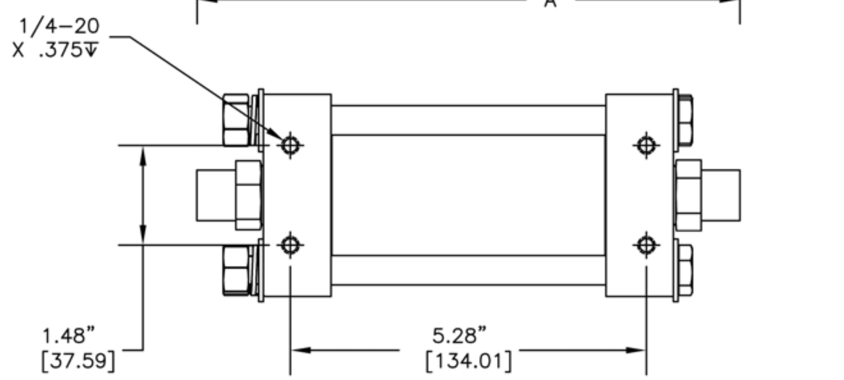


HFM-I-405 Flow meter

FITTINGS	
FITTING TYPE	DIM "A"
10mm SWAG. 3/4"-16	7.72" [196.09]
12mm SWAG. 3/4"-16	7.72" [196.09]
1/2" SWAG. 3/4"-16	7.69" [195.28]
3/4" SWAG. 3/4'-16	8.01" [203.58]
1/2" VCO 3/4"-16	8.14" [206.76]
3/8" NPT 3/4"-16	8.25" [209.55]
1/2" NPT 1/2"-16	8.25" [209.55]
1/2" VCR	8.56" [217.50]







HFM-I-401
Flow Meter