Agilent Precision Gas Flow Meter

Reference Manual

Agilent Technologies

Notices

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Safety Notices

CAUTION

A **CAUTION** notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a **CAUTION** notice until the indicated conditions are fully understood and met.

WARNING

A WARNING notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

Thank you for purchasing an Agilent Precision gas flow meter

Please take the time to read the information contained in this manual. This will help to ensure that you get the best possible service from your instrument.

Refer to the Agilent Precision Gas Flow Meter Operating Manual that accompanied your meter for information on installation, operation, troubleshooting, maintenance and recalibration, and the power supply.

Protect your warranty and extend the life of your product

CAUTION

Failure to follow general safety and operating procedures as presented in this manual violates the safety standards and intended use of this meter and may impair the functionality of the meter. The manufacturer assumes no liability for the user's failure to comply with these requirements.

IMPORTANT: This manual contains information critical to the proper operation and maintenance of your meter. The information contained in this manual should be read and understood by those responsible for the operation and maintenance of this meter. Save this manual for future reference.

Cautions for meter applications

CAUTION

Do not attempt to disassemble, substitute parts, or perform unauthorized modifications to this meter. Doing so will void the warranty. This meter contains no user serviceable components and should be serviced by authorized personnel only.

Do not use this meter in explosive, wet, or corrosive environments.

Do not flow any corrosive gases such as ammonia, propylene, HCl, SO_2, H_2S, NO_2, NO, silane, chlorine, etc.

Do not flow gas in conditions that can cause condensing water vapor to be trapped inside the meter as the pressure sensors can be destroyed.

Do not use this flow meter outside a range of 640 ml/min.

Cautions for meter installations

CAUTION

Do not use snap shutting/opening valves where the meter can be exposed to high pressure transients – this is especially important for low-flow range.

Do not expose the meter's outer surface to any liquids, the meter does not have a watertight electronics package.

Do power your meter with the correct polarity, voltage, and amperage.

Do carefully check your wiring hookups before power up when using a DC-61 or other blunt cut cable.

Advice for meter operation

NOTE

Do take note of what gas calibration setting is selected.

Do consider that changing or mixing gases can reduce accuracy and give unexpected results. Refer to "Gas Viscosity" on page 13 for instructions on correcting to alternate gas viscosities.

Do tare the meter often, while making sure there is absolutely no flow during the tare.

Do keep meter running for best performance.

1
Operating Principles

The Agilent Precision gas flow meter is based on the accurate measurement of volumetric flow. The volumetric flow rate is determined by creating a pressure drop across a unique internal restriction, known as a laminar flow element (LFE), and measuring differential pressure across it. The restriction is designed so that the gas molecules are forced to move in parallel paths along the entire length of the passage; hence, laminar (streamline) flow is established for the entire range of operation of the meter. Unlike other flow measuring meters, in laminar flow meters the relationship between pressure drop and flow is linear. The underlying principle of operation of the Agilent Precision gas flow meter is known as the Poiseuille Equation:

$Q = (P_1 - P_2)\ \pi r^4/8\eta L$ (Equation 1)

Where:	Q	=	Volumetric flow rate
	P_1	=	Static pressure at the inlet
	P_2	=	Static pressure at the outlet
	r	=	Radius of the restriction

η	=	(eta) absolute viscosity of the fluid
L	=	Length of the restriction

Since π, r, and L are constant, Equation 1 can be rewritten as:

$Q = K (\Delta P/\eta)$ (Equation 2)

Where K is a constant factor determined by the geometry of the restriction. Equation 2 shows the linear relationship between volumetric flow rate (Q), differential pressure (ΔP), and absolute viscosity (η) in a simpler form.

Gas viscosity

In order to get an accurate volumetric flow rate, the gas being measured must be selected (see the Gas Select Mode section in the Operating Manual for more information). This is important because the meter calculates the flow rate based on the viscosity of the gas at the measured temperature. If the gas being measured is not what is selected, an incorrect value for the viscosity of the gas will be used in the calculation of flow, and the resulting output will be inaccurate in direct proportion to the ratio between the two gases' viscosities.

Gas viscosity, and thus gas composition, can be very important to the meter's accuracy. Anything that has an effect on the gas viscosity (for example, water vapor, odorant additives, etc.) will have a direct proportional effect on the meter's accuracy. Selecting methane and measuring natural gas, for instance, will result in a fairly decent reading, but it is not highly accurate (errors are typically < .6%) because natural gas contains small and varying amounts of other gases, such as butane and propane, that result in a viscosity that is somewhat different than that of pure methane.

Absolute viscosity changes very little with pressure (within the operating range of this meter); therefore, a true volumetric reading does not require a correction for pressure. Changes in gas temperature do affect viscosity. For this reason, the AgilentPrecision gas flow meter internally compensates for this change.

Other gases

The gas flow meter can easily be used to measure the flow rate of gases other than those listed as long as **noncorrosive** gas compatibility is observed. For example, a flow meter that has been set for air can be used to measure the flow of argon.

The conversion factor needed for measuring the flow of different gases is linear and is simply determined by the ratio of the absolute viscosity of the gases. This factor can be calculated as follows:

$Q_{og} = Q_1 [\eta_1 / \eta_{og}]$

Where:	Q_1	=	Flow rate indicated by the flow meter
	η_1	=	Viscosity of the calibrated gas at the measured temperature
	Q_{og}	=	Flow rate of the alternate gas
	η_{og}	=	Viscosity of the alternate gas at the measured temperature

Say we have a meter set for air and we want to flow argon through it. With argon flowing through the meter, the display reads 110 standard Liters/minute (slpm). For ease of calculation, let us say the gas temperature is 25 °C. What is the actual flow of argon?

Q_{og}	=	Actual argon flow rate
Q_1	=	Flow rate indicated by meter (110 slpm)
η_1	=	Viscosity of gas selected or calibrated for by the meter at the measured temperature
η_{og}	=	Viscosity of gas flowing through the meter at the measured temperature

At 25 °C, the absolute viscosity of air (η_1) and argon (η_{og}) is 184.918 and 225.593 micropoise, respectively.

$$Q_{og} = Q1 (\eta 1 / \eta_{og})$$

$$Q_{og} = 110 \text{ slpm } (184.918 / 225.593)$$

$$Q_{og} = 90.17 \text{ slpm}$$

So, the actual flow of argon through the meter is 90.17 slpm. As you can see, because the argon gas is more viscous than the air the meter is set for, the meter indicates a higher flow than the actual flow.

A good rule of thumb is: “At a given flow rate, the higher the viscosity, the higher the indicated flow.”

Volume flow vs. mass flow

At room temperature and low pressures the volumetric and mass flow rate will be nearly identical; however, these rates can vary drastically with changes in temperature and/or pressure because the temperature and pressure of the gas directly affects the volume. For example, assume a volumetric flow reading was used to fill balloons with 250 mL of helium, but the incoming line ran near a furnace that cycled on and off, intermittently heating the incoming helium. Because the volumetric meter simply measures the volume of gas flow, all of the balloons would initially be the same size. However, if all the balloons are placed in a room and allowed to come to an equilibrium temperature, they would generally all come out to be different sizes. If, on the other hand, a mass flow reading were used to fill the balloons with 250 **standard** mL of helium, the resulting balloons would initially be different sizes, but when allowed to come to an equilibrium temperature, they would all turn out to be the same size.

This parameter is called corrected mass flow because the resulting reading has been compensated for temperature and pressure and can therefore be tied to the mass of the gas. Without knowing the temperature and pressure of the gas and thus the density, the mass of the gas cannot be determined.

Once the corrected mass flow rate at standard conditions has been determined and the density at standard conditions is known (see “Gas Viscosity, Density, and Compressibility” on page 41), a true mass flow can be calculated as detailed in the following example:

Mass flow meter reading = 250 sccm (standard cubic centimeters/minute)
Gas: Helium
Gas density at 25 °C and 14.696 psia = 0.16353 grams/Liter
True mass flow = (Mass flow meter reading) × (Gas density)
True mass flow = (250 CC/min) × (1 Liter/1,000 CC) × (0.16353 grams/Liter)
True mass flow = 0.0409 grams/min of helium

Volumetric and mass flow conversion

In order to convert volume to mass, the density of the gas must be known. The relationship between volume and mass is as follows:

Mass = Volume × Density

The density of the gas changes with temperature and pressure and therefore the conversion of volumetric flow rate to mass flow rate requires knowledge of density change. Using ideal gas laws, the effect of temperature on density is:

$\rho_a / \rho_s = T_s / T_a$

Where:	ρ_a	=	Density @ flow condition
	T_a	=	Absolute temp @ flow condition in °Kelvin
	ρ_s	=	Density @ standard (reference) condition
	T_s	=	Absolute temperature @ standard (reference) condition in °Kelvin
	°K	=	°C + 273.15 Note: °K = °Kelvin

The change in density with pressure can also be described as:

$\rho_a / \rho_s = P_a / P_s$

Where:	ρ_a	=	Density @ flow condition
	P_a	=	Flow absolute pressure
	ρ_s	=	Density @ standard (reference) condition
	P_s	=	Absolute pressure @ standard (reference) condition

Therefore, in order to determine mass flow rate, two correction factors must be applied to volumetric rate: temperature effect on density and pressure effect on density.

Compressibility

Heretofore, we have discussed the gases as if they were **ideal** in their characteristics. The ideal gas law is formulated as:

$PV = nRT$

Where:	P	=	Absolute pressure
	V	=	Volume (or volumetric flow rate)
	n	=	Number moles (or molar flow rate)
	R	=	Gas constant (related to molecular weight)
	T	=	Absolute temperature

Most gases behave in a nearly ideal manner when measured within the temperature and pressure limitations of Agilent products. However, some gases (such as propane and butane) can behave in a less than ideal manner within these constraints. The nonideal gas law is formulated as:

$PV = ZnRT$

Where: *Z* is the compressibility factor. This can be seen in an increasingly blatant manner as gases approach conditions where they condense to liquid. As the compressibility factor goes down ($Z = 1$ is the ideal gas condition), the gas takes up less volume than what one would expect from the ideal gas calculation.

This reduces to: $P_a V_a / Z_a T_a = P_s V_s / Z_s T_s$, eliminating R and n.

The Agilent Precision gas flow meter models gas flows based upon the nonideal gas characteristics of the calibrated gas. The flow corrections are normally made to 25 °C, 14.696 psia, and the compressibility factor of the gas under those conditions. This allows the user to multiply the mass flow rate by the density of the real gas at those standard conditions to get the mass flow rate in grams per minute.

Because we incorporate the compressibility factor into our full gas model, attempts to manually compute mass flows from only the P, V, and T values shown on the display will sometimes result in modest errors.

NOTE

Although the correct units for mass are expressed in grams, kilograms, etc., it has become standard that mass flow rate is specified in slpm (standard Liters/minute), sccm (standard cubic centimeters/minute), or SmL/M (standard milliliters/minute).

This means that mass flow rate is calculated by normalizing the volumetric flow rate to some standard temperature and pressure (STP). By knowing the density at that STP, one can determine the mass flow rate in grams per minute, kilograms per hour, etc.

STP is usually specified as the sea level condition; however, no single standard exists for this convention. Examples of common reference conditions include:

0 °C	and	14.696 psia
25 °C	and	14.696 psia
0 °C	and	760 torr (mmHG)
70 °C	and	14.696 psia
68 °C	and	29.92 inHG
20 °C	and	760 torr (mmHG)

The flow meter references 25 °C and 14.696 psia (101.32 kPa), unless ordered otherwise. Refer to the calibration sheet to confirm the reference point.

2
RS-232 Output and Input

Configuring HyperTerminal

1 Open your HyperTerminal RS-232 terminal program (installed under the **Accessories** menu on all Microsoft Windows® operating systems).
2 Select **Properties** from the file menu.
3 Click on the **Configure** button under the **Connect To** tab. Be sure the program is set for 19,200 baud (or matches the baud rate selected in the RS-232 communications menu on the meter) and an 8-N-1-None (8 Data Bits, No Parity, 1 Stop Bit, and no Flow Control) protocol.
4 Under the **Settings** tab, make sure the Terminal Emulation is set to ANSI or Auto Detect.
5 Click the **ASCII Setup** button and be sure that the **Send Line Ends with Line Feeds** box **is not** checked and the **Echo Typed Characters Locally** box and the **Append Line Feeds to Incoming Lines** boxes **are** checked. Those settings not mentioned here are normally okay in the default position.
6 Save the settings, close HyperTerminal, and reopen it.

In Polling mode, the screen should be blank except the blinking cursor. In order to get the data streaming to the screen, hit the **Enter** key several times to clear any extraneous information. Type ***@=@** followed by **Enter** (or, using the RS-232 communication select menu, select **@** as identifier and exit the screen). If data still does not appear, check all the connections and com port assignments.

Changing from Streaming to Polling mode

When the meter is in the Streaming mode, the screen is updated approximately 10 to 60 times per second (depending on the amount of data on each line) so that the user sees the data essentially in real time. It is sometimes desirable, and necessary when using more than one meter on a single RS-232 line, to be able to poll the meter.

In Polling mode the meter measures the flow normally, but only sends a line of data when it is “polled.” Each meter can be given its own unique identifier or address. Unless otherwise specified each meter is shipped with a default address of capital A. Other valid addresses are B through Z.

Once you have established communication with the meter and have a stream of information filling your screen:

1 Type *@=A followed by **Enter** (or using the RS-232 communication select menu, select **A** as identifier and exit the screen) to stop the Streaming mode of information. Note that the flow of information will not stop while you are typing and you will not be able to read what you have typed. Also, the meter does not accept a backspace or delete in the line so it must be typed correctly. If you are in doubt, simply hit **Enter** and start again. If the meter does not get exactly what it is expecting, it will ignore it. If the line has been typed correctly, the data will stop.

2 You may now poll the meter by typing **A** followed by **Enter**. This does an instantaneous poll of meter A and returns the values once. You may type **A Enter** as many times as you like. Alternately you could resume Streaming mode by typing ***@=@** followed by **Enter**. Repeat step 1 to remove the meter from the Streaming mode.

3 To assign the meter a new address, type ***@=New Address** (for example, ***@=B**). Care should be taken not to assign an address to a meter if more than one meter is on the RS-232 line as all of the addresses will be reassigned. Instead, each should be individually attached to the RS-232 line, given an address, and taken off. After each meter has been given a

unique address, they can all be put back on the same line and polled individually.

Tare

Tareing (or zeroing) the flow meter provides it with a reference point for zero flow. This is a simple but important step in obtaining accurate measurements. It is good practice to zero the flow meter each time it is powered up. A meter may be tared by following the instructions in the “Main Mode” section of Chapter 2 in the Operating Manual or it may be tared via RS-232 input.

To send a tare command via RS-232, enter the following strings:

In Streaming mode: **$$V<Enter>**

In Polling mode: **Address$$V<Enter>** (for example, **B$$V<Enter>**)

Gas select

The selected gas can be changed via RS-232 input. To change the selected gas, enter the following commands:

In Streaming mode: **$$#<Enter>**

In Polling mode: **Address$$#<Enter>** (for example, **B$$#<Enter>**)

Where **#** is the number of the gas selected from the table below. Note that this also corresponds to the gas select menu on the flow meter screen.

Fo example, to select Propane, enter: **$$12<Enter>**.

Table 1 Gas number for RS-232 input

#	Gas	Abbreviation
0	Air	Air
1	Argon	Ar
2	Methane	CH_4
3	Carbon Monoxide	CO
4	Carbon Dioxide	CO_2
5	Ethane	C_2H_6
6	Hydrogen	H_2
7	Helium	He
8	Nitrogen	N_2
9	Nitrous Oxide	N_2O
10	Neon	Ne
11	Oxygen	O_2
12	Propane	C_3H_8
13	normal-Butane	n-C_4H_{10}
14	Acetylene	C_2H_2

Table 1 Gas number for RS-232 input (continued)

#	Gas	Abbreviation
15	Ethylene	C_2H_4
16	iso-Butane	i-C_4H_{10}
17	Krypton	Kr
18	Xenon	Xe
19	Sulfur Hexafluoride	SF_6
20	75% Argon / 25% CO_2	C-25
21	90% Argon / 10% CO_2	C-10
22	92% Argon / 8% CO_2	C-8
23	98% Argon / 2% CO_2	C-2
24	75% CO_2 / 25% Argon	C-75
25	75% Argon / 25% Helium	A-75
26	75% Helium / 25% Argon	A-25
27	90% Helium / 7.5% Argon / 2.5% CO_2 (Praxair - Helistar A1025)	A1025
28	90% Argon / 8% CO_2 / 2% Oxygen (Praxair - Stargon CS)	Star29
29	95% Argon / 5% Methane	P-5

Collecting data

The RS-232 output updates to the screen many times per second. Very short-term events can be captured simply by disconnecting (there are two telephone symbol icons at the top of the HyperTerminal screen for disconnecting and connecting) immediately after the event in question. The scroll bar can be driven up to the event and all of the data associated with the event can be selected, copied, and pasted into Microsoft® Excel® or other spreadsheet program as described below.

For longer term data, it is useful to capture the data in a text file. With the desired data streaming to the screen, select **Capture Text** from the **Transfer** Menu. Type in the path and file name you wish to use. Push the **start** button. When the data collection period is complete, simply select **Capture Text** from the **Transfer** Menu and select **Stop** from the sub-menu that appears.

Data that is selected and copied, either directly from HyperTerminal or from a text file, can be pasted directly into Excel®. When the data is pasted it will all be in the selected column. Select **Text to Columns...** under the **Data** menu in Excel® and a **Text to Columns Wizard** (dialog box) will appear. Make sure that **Fixed Width** is selected under **Original Data Type** in the first dialog box and click **Next**. In the second dialog box, set the column widths as desired, but the default is usually acceptable. Click **Next** again. In the third dialog box, make sure the column data format is set to **General**, and click **Finish**. This separates the data into columns for manipulation and removes symbols such as the plus signs from the numbers. Once the data is in this format, it can be graphed or manipulated as desired. For extended term data capture, see "Sending a simple script file to HyperTerminal" on page 30.

Data format

The data stream on the screen represents the flow parameters of the Main mode in the units shown on the display.

For mass flow meters, there are 5 columns of data representing pressure, temperature, volumetric flow, mass flow and the selected gas. The first column is absolute pressure (normally in psia), the second column is temperature (normally in °C), the third column is volumetric flow rate (in the units specified at time of order and shown on the display), and the fourth column is mass flow (also in the units specified at time of order and shown on the display). For instance, if the meter was ordered in units of scfm, the display on the meter would read 2.004 scfm and the last two columns of the output below would represent volumetric flow and mass flow in cubic feet/minute and standard cubic feet/minute, respectively. The fifth column shows the totalized mass flow in units specified for the flow.

Table 2 Example M Series mass flow meter data format

+014.70	+025.00	+02.004	+02.004	00201.7	Air
+014.70	+025.00	+02.004	+02.004	00201.7	Air
+014.70	+025.00	+02.004	+02.004	00201.7	Air
+014.70	+025.00	+02.004	+02.004	00201.7	Air
+014.70	+025.00	+02.004	+02.004	00201.7	Air
+014.70	+025.00	+02.004	+02.004	00201.7	Air

Sending a simple script file to HyperTerminal

It is sometimes desirable to capture data for an extended period of time. Standard Streaming mode information is useful for short term events; however, when capturing data for an extended period of time, the amount of data and thus the file size can become too large very quickly. Without any special programming skills, the user can use HyperTerminal and a text editing program such as Microsoft Word® to capture text at user-defined intervals.

1 Open your text editing program, MS Word for example.

2 Set the cap lock on so that you are typing in capital letters.

3 Beginning at the top of the page, type **A<Enter>** repeatedly. If you're using Microsoft Word®, you can tell how many lines you have by the line count at the bottom of the screen. The number of lines will correspond to the total number of times the flow meter will be polled, and thus the total number of lines of data it will produce.

   For example: A

   A

   A

   A

   A

   A

   will get a total of six lines of data from the flow meter, but you can enter as many as you like.

   The time between each line will be set in HyperTerminal.

4 When you have as many lines as you wish, go to the **File** menu and select **Save**. In the **Save** dialog box, enter a path and file name as desired. In the **Save as Type** box, select the plain text (.txt) option. It is important that it be saved as a generic text file for HyperTerminal to work with it.

5 Click **Save**.

6 A file conversion box will appear. In the **End Lines With** drop-down box, select **CR Only**. Everything else can be left as default.

7 Click **OK**.

8 You have now created a **script** file to send to HyperTerminal. Close the file and exit the text editing program.

9 Open HyperTerminal and establish communication with your flow meter as outlined in the manual.

10 Set the flow meter to Polling mode as described in the manual. Each time you type **A<Enter>**, the meter should return one line of data to the screen.

11 Go to the **File** menu in HyperTerminal and select **Properties**.

12 Select the **Settings** tab.

13 Click on the **ASCII Setup** button.

14 The **Line Delay** box is defaulted to 0 milliseconds. This is where you will tell the program how often to read a line from the script file you've created. Since 1,000 milliseconds is one second, if you want a line of data every 30 seconds, for example, you would enter 30000 into the box. If you want a line every 5 minutes, you would enter 300000 into the box.

15 When you have entered the value you want, click **OK** and **OK** in the **Properties** dialog box.

16 Go the **Transfer** menu and select **Send Text File...** (**not Send File...**).

17 Browse and select the text **script** file you created.

18 Click **Open**.

19 The program will begin executing your script file, reading one line at a time with the line delay you specified and the flow meter will respond by sending one line of data for each poll it receives, when it receives it.

You can also capture the data to another file as described in "Collecting data" on page 28. You will be simultaneously sending it a script file and capturing the output to a separate file for analysis.

RS-232 digital output signal

If you will be using the RS-232 output signal, it is necessary to connect the RS-232 output signal (pin 5), the RS-232 input signal (pin 3), and ground (pin 8) to your computer serial port as shown in the Operating Manual. Adapter cables are available from the manufacturer or they can be constructed in the field with parts from an electronics supply house. In Figure 2 in the Operating Manual, the diagrams represent the “port” side of the connections (that is, the connector on top of the meter and the physical DB-9 serial port on the back of the computer). The cable ends will be mirror images of the diagram shown in Figure 2 in the Operating Manual. (See the “Volt Battery Pack” chapter.)

3
Standard Gas Data Tables

If you have older (manufactured before October 2005) Agilent products, you may notice small discrepancies between the gas property tables of your old and new meters. Agilent has recently incorporated the latest data sets from NIST (including its REFPROP 7 data) in our products' built-in gas property models.

Be aware that calibrators that you may be spot-checking against may be using older data sets, such as the widely distributed Air Liquide data. This may generate apparent calibration discrepancies of up to 0.6% of reading on well-behaved gases and as much as 3% of reading on some gases, such as propane and butane, unless the standard was directly calibrated on the gas in question. As the older standards are phased out of the industry, this difference in readings will cease to be a problem.

If you see a difference between the Agilent meter and your in-house standard, in addition to calling Agilent, call the manufacturer of your standard for clarification as to which data set it used in its calibration. This comparison will in all likelihood resolve the problem.

Table 3 Gas viscosities, densities, and compressibilities at 25 °C

Gas Number	Short Form	Long Form	Viscosity* 25 °C 14.696 psia	Density† 25 °C 14.696 psia	Compressibility 25 °C 14.696 psia
0	Air	Air	184.918	1.1840	0.9997
1	Ar	Argon	225.593	1.6339	0.9994
2	CH_4	Methane	111.852	0.6569	0.9982
3	CO	Carbon Monoxide	176.473	1.1453	0.9997
4	CO_2	Carbon Dioxide	149.332	1.8080	0.9949
5	C_2H_6	Ethane	93.540	1.2385	0.9924
6	H_2	Hydrogen	89.153	0.08235	1.0006
7	He	Helium	198.457	0.16353	1.0005
8	N_2	Nitrogen	178.120	1.1453	0.9998
9	N_2O	Nitrous Oxide	148.456	1.8088	0.9946
10	Ne	Neon	311.149	0.8246	1.0005
11	O_2	Oxygen	204.591	1.3088	0.9994
12	C_3H_8	Propane	81.458	1.8316	0.9841
13	n-C_4H_{10}	normal-Butane	74.052	2.4494	0.9699
14	C_2H_2	Acetylene	104.448	1.0720	0.9928
15	C_2H_4	Ethylene	103.177	1.1533	0.9943
16	i-C_4H_{10}	iso-Butane	74.988	2.4403	0.9728
17	Kr	Krypton	251.342	3.4274	0.9994
18	Xe	Xenon	229.785	5.3954	0.9947
19	SF_6	Sulfur Hexafluoride	153.532	6.0380	0.9887
20	C-25	75% Argon / 25% CO_2	205.615	1.6766	0.9987
21	C-10	90% Argon / 10% CO_2	217.529	1.6509	0.9991
22	C-8	92% Argon / 8% CO_2	219.134	1.6475	0.9992
23	C-2	98% Argon / 2% CO_2	223.973	1.6373	0.9993

Table 3 Gas viscosities, densities, and compressibilities at 25 °C (continued)

Gas Number	Short Form	Long Form	Viscosity* 25 °C 14.696 psia	Density† 25 °C 14.696 psia	Compressibility 25 °C 14.696 psia
24	C-75	75% CO_2 / 25% Argon	167.451	1.7634	0.9966
25	A-75	75% Argon / 25% Helium	230.998	1.2660	0.9997
26	A-25	75% Helium / 25% Argon	234.306	0.5306	1.0002
27	A1025	90% Helium / 7.5% Argon / 2.5% CO_2 (Praxair - Helistar A1025)	214.840	0.3146	1.0003
28	Star29	90% Argon / 8% CO_2 / 2% Oxygen (Praxair - Stargon CS)	218.817	1.6410	0.9992
29	P-5	95% Argon / 5% Methane	223.483	1.5850	0.9993

* in micropoise (1 Poise = gram / [cm] [sec]) (NIST REFPROP 7 database)

† Grams/Liter

Table 4 Gas viscosities, densities, and compressibilities at 0 °C

Gas Number	Short Form	Long Form	Viscosity* 0 °C 14.696 psia	Density† 0 °C 14.696 psia	Compressibility 0 °C 14.696 psia
0	Air	Air	172.588	1.2927	0.9994
1	Ar	Argon	209.566	1.7840	0.9991
2	CH_4	Methane	103.657	0.7175	0.9976
3	CO	Carbon Monoxide	165.130	1.2505	0.9994
4	CO_2	Carbon Dioxide	137.129	1.9768	0.9933
5	C_2H_6	Ethane	86.127	1.3551	0.9900
6	H_2	Hydrogen	83.970	0.08988	1.0007
7	He	Helium	186.945	0.17849	1.0005
8	N_2	Nitrogen	166.371	1.2504	0.9995
9	N_2O	Nitrous Oxide	136.350	1.9778	0.9928

Table 4 Gas viscosities, densities, and compressibilities at 0 °C (continued)

Gas Number	Short Form	Long Form	Viscosity* 0 °C 14.696 psia	Density† 0 °C 14.696 psia	Compressibility 0 °C 14.696 psia
10	Ne	Neon	293.825	0.8999	1.0005
11	O_2	Oxygen	190.555	1.4290	0.9990
12	C_3H_8	Propane	74.687	2.0101	0.9787
13	n-C_4H_{10}	normal-Butane	67.691	2.7048	0.9587
14	C_2H_2	Acetylene	97.374	1.1728	0.9905
15	C_2H_4	Ethylene	94.690	1.2611	0.9925
16	i-C_4H_{10}	iso-Butane	68.759	2.6893	0.9627
17	Kr	Krypton	232.175	3.7422	0.9991
18	Xe	Xenon	212.085	5.8988	0.9931
19	SF_6	Sulfur Hexafluoride	140.890	6.6154	0.9850
20	C-25	75% Argon / 25% CO_2	190.579	1.8309	0.9982
21	C-10	90% Argon / 10% CO_2	201.897	1.8027	0.9987
22	C-8	92% Argon / 8% CO_2	203.423	1.7989	0.9988
23	C-2	98% Argon / 2% CO_2	208.022	1.7877	0.9990
24	C-75	75% CO_2 / 25% Argon	154.328	1.9270	0.9954
25	A-75	75% Argon / 25% Helium	214.808	1.3821	0.9995
26	A-25	75% Helium / 25% Argon	218.962	0.5794	1.0002
27	A1025	90% Helium / 7.5% Argon/ 2.5% CO_2 (Praxair - Helistar A1025)	201.284	0.3434	1.0002
28	Star29	90% Argon / 8% CO_2 / 2% Oxygen (Praxair - Stargon CS)	203.139	1.7918	0.9988
29	P-5	95% Argon / 5% Methane	207.633	1.7307	0.9990

* in micropoise (1 Poise = gram / [cm] [sec]) (NIST REFPROP 7 database)

† Grams/Liter

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Technical Specifications

The following specifications are for the standard configuration of the Agilent product as shipped from the factory.

Table 5 Technical data for 500 cc flow meter

Specification	Mass meter	Description
Accuracy	± (0.8% of reading + 0.2% of full scale)	At calibration conditions after tare
High accuracy option	± (0.4% of reading + 0.2% of full scale)	At calibration conditions after tare
Repeatability	± 0.2%	Full scale
Operating range	1 to 100% full scale	Measure
Typical response time	10	Milliseconds (adjustable)
Standard conditions (STP)	25 °C and 14.696 psia	Mass reference conditions
Operating temperature	–10 to +50	°Celsius
Zero shift	0.02%	Full scale / °Celsius / Atm
Span shift	0.02%	Full scale / °Celsius / Atm
Humidity range	0 to 100%	Noncondensing
Measurable flow rate	128%	Full scale
Maximum pressure	1000_(145)	kPa_(psig)
Output signal digital	Mass, volume, pressure, and temperature, totalized flow	RS-232 Serial
Output signal analog	Mass flow	0 to 5 Vdc
Electrical connections	8-pin	Mini-DIN
Supply voltage	7 to 30 Vdc	
Supply current	0.035 amp	
Mounting attitude sensitivity	0%	Tare after installation
Warm-up time	< 1	Second
Wetted materials	303 and 302 stainless steel, Viton, silicone RTV (rubber), glass-reinforced nylon, aluminum	

Table 6 Technical data for 500 cc flow meter - Mechanical specifications

Full scale flow mass meter	Mechanical dimensions	Process connections*	Pressure drop†
500 sccm	10.4x6.1x2.8cm 4.1_H×2.4_W×1.1_D-(inch)	1/8-inch NPT female	6.9kPa 1.0 psid

* Compatible with Beswick, Swagelok tube, Parker, face seal, push connect, and compression adapter fittings.

† Venting to atmosphere.

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Gas Properties and Coversion Factors

Table 7 Gas viscosity, density, and compressibilty

#	Gas	Abbr.	Absolute viscosity* 25 °C	Density† 25 °C 14.696 psia	Compressibility 25 °C 14.696 psia
0	Air	Air	184.918	1.1840	0.9997
1	Argon	Ar	225.593	1.6339	0.9994
2	Methane	CH_4	111.852	0.6569	0.9982
3	Carbon Monoxide	CO	176.473	1.1453	0.9997
4	Carbon Dioxide	CO_2	149.332	1.8080	0.9949
5	Ethane	C_2H_6	93.540	1.2385	0.9924
6	Hydrogen	H_2	89.153	0.08235	1.0006
7	Helium	He	198.457	0.16353	1.0005
8	Nitrogen	N_2	178.120	1.1453	0.9998
9	Nitrous Oxide	N_2O	148.456	1.8088	0.9946
10	Neon	Ne	311.149	0.8246	1.0005
11	Oxygen	O_2	204.591	1.3088	0.9994
12	Propane	C_3H_8	81.458	1.8316	0.9841
13	normal-Butane	n-C_4H_{10}	74.052	2.4494	0.9699
14	Acetylene	C_2H2_2	104.448	1.0720	0.9928
15	Ethylene	C_2H_4	103.177	1.1533	0.9943
16	iso-Butane	i-C_4H_{10}	74.988	2.4403	0.9728

Table 7 Gas viscosity, density, and compressibilty (continued)

#	Gas	Abbr.	Absolute viscosity* 25 °C	Density† 25 °C 14.696 psia	Compressibility 25 °C 14.696 psia
17	Krypton	Kr	251.342	3.4274	0.9994
18	Xenon	Xe	229.785	5.3954	0.9947
19	Sulfur Hexafluoride	SF_6	153.532	6.0380	0.9887
20	75% Argon / 25% CO_2	C-25	205.615	1.6766	0.9987
21	90% Argon / 10% CO_2	C-10	217.529	1.6509	0.9991
22	92% Argon / 8% CO_2	C-8	219.134	1.6475	0.9992
23	98% Argon / 2% CO_2	C-2	223.973	1.6373	0.9993
24	75% CO_2 / 25% Argon	C-75	167.451	1.7634	0.9966
25	75% Argon / 25% Helium	A-75	230.998	1.2660	0.9997
26	75% Helium / 25% Argon	A-25	234.306	0.5306	1.0002
27	90% Helium / 7.5% Argon / 2.5% CO_2 (Praxair - Helistar A1025)	A1025	214.840	0.3146	1.0003
28	90% Argon / 8% CO_2 / 2% Oxygen (Praxair - Stargon CS)	Star29	218.817	1.6410	0.9992
29	95% Argon / 5% Methane	P-5	223.483	1.5850	0.9993

* in micropoise (1 Poise = gram / [cm] [sec]) (NIST REFPROP 7 database)

† Grams/Liter

Flow conversions

SCFM	1.00	=	28.3160	slpm	slpm	100.00	=	3.5316	SCFM
SCFH	1.00	=	0.4719	slpm	slpm	100.00	=	211.9093	SCFH
SCIM	100.00	=	1.6390	slpm	slpm	1.00	=	61.0128	SCIM
SCIH	1000.00	=	0.2732	slpm	slpm	1.00	=	3660.7688	SCIH