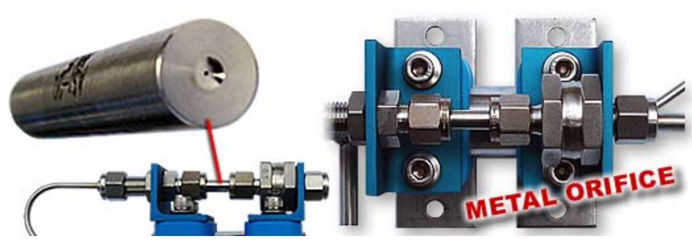
ASI MODEL DM-100 SERIES DILUTING MODULES

The ASI Model DM-100 Series Diluting Modules have been developed to meet the requirements of some of our more specialized applications, where our standard in-situ dilution probe or a rather complex and expensive ex-situ (extractive) dilution system is simply not practical. Whether your primary diluting device is to be used as a stand-alone unit for laboratory applications, or integrated within an OEM's heated filter system design for CEM Systems (thereby producing a basic ex-situ diluting sampler), or even integrated into your ambient level gas analyzer for process monitoring, the DM-100 is a great solution. Originally designed as a second stage diluting unit, downstream of an in-situ or ex-situ dilution probe, the DM-100 can also produce extremely high dilution ratios should your application call for it.

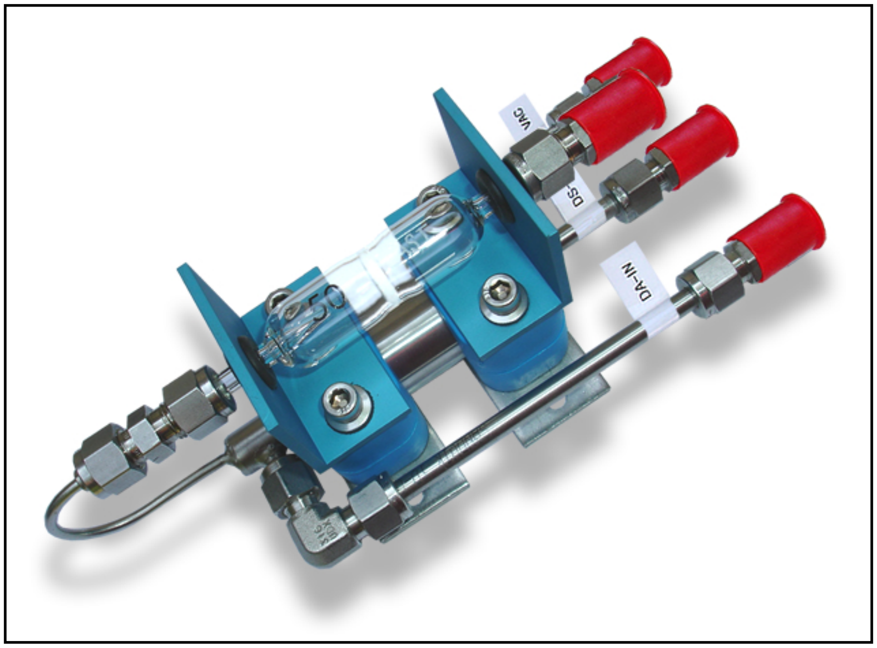
Key Features:

- Extremely low sample flow rates
- Compact and lightweight design
- Reduces the moisture content in the sample stream
- Reduces the maintenance and prolongs analyzer life when dealing with harsh samples
- Permits use of ambient level (low range) analyzers to measure highly concentrated streams
- Normal dilution ratios from 12:1 up to 350:1. Ratios to 122,500:1 can be achieved when modules are in series (or module used as secondary diluter to an in-situ or ex-situ dilution probe)
- Can be used in hazardous areas; no steam or electrical service required (non-heated version)
- Installation flexibility; mounting brackets supplied as standard to allow for installation of the diluter within your pneumatic controller enclosure or analyzer

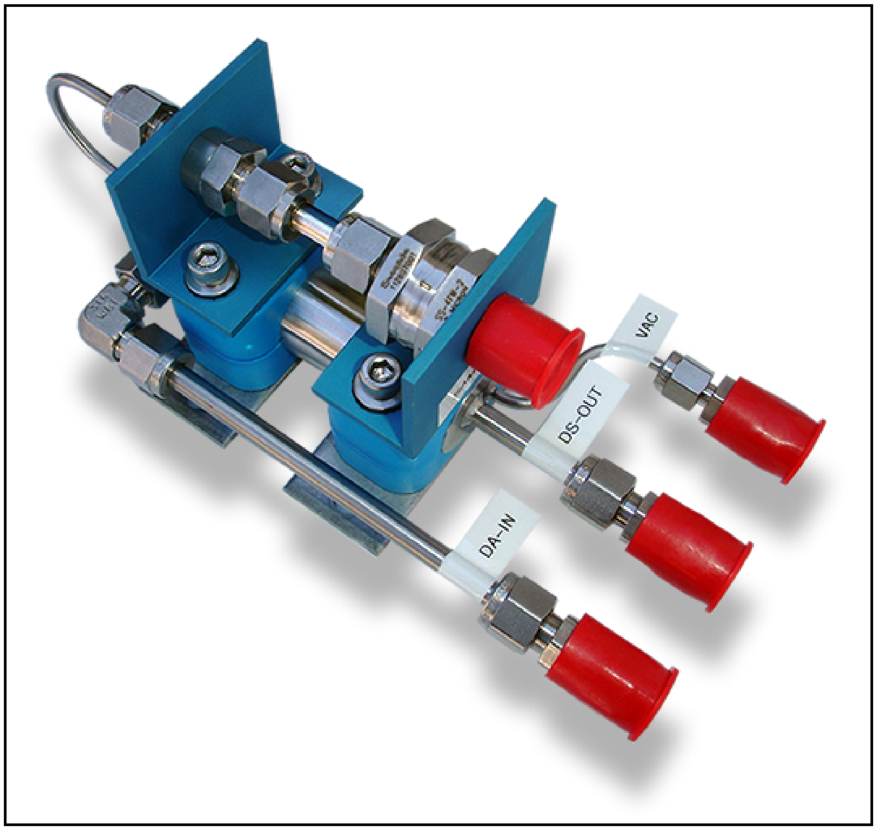


- Special mounting provisions will allow for installation in your heated enclosure to ensure temperature stability as needed and can be heated to well over 350°F (177°C)
- Wetted parts from stainless 316/316L. Complete with all fittings, mounting brackets and one critical orifice (available in Glass, Monel-400, or Stainless-316)
- Special coatings by SilcoTek® (such as SilcoNert®, Dursan®, and Silcolly®) are also available

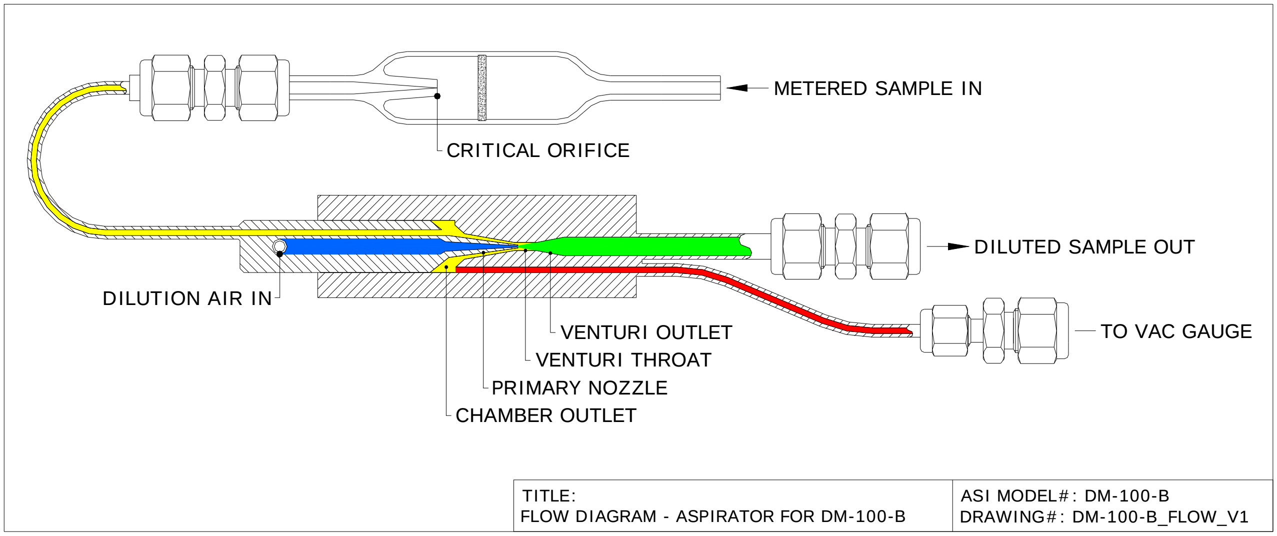
DM-100-B (WITH STANDARD *GLASS* CRITICAL ORIFICE)



DM-100-B2 (WITH SPECIAL *METAL* CRITICAL ORIFICE)



Principal of Operation:



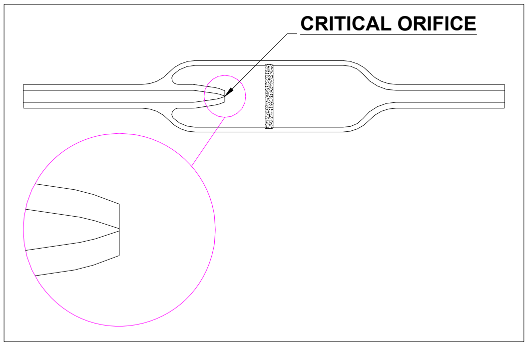
Three to ten l/min (liters per minute) of clean, pressurized dilution air is transported to the diluting module via a tube in the umbilical cord (one of four tubes in the bundle). The dilution air is directed into the *dilution air line*. Dilution air is then blown through the sharp *primary nozzle* of the ejector pump (air driven aspirator) into the *venturi throat*. The flow of pressurized air through the nozzle creates a partial vacuum within the *chamber outlet*, which is also connected to the low pressure end of the *critical orifice*. This vacuum, in turn, extracts a constant flow of sample from the *stack or process*, through the *critical orifice bore*, and to the *venturi outlet* where it is diluted and mixed with the clean, pressurized air. The *diluted sample* is then transported at positive pressure to the analyzer(s) via the unheated sample outlet line in the umbilical cord.

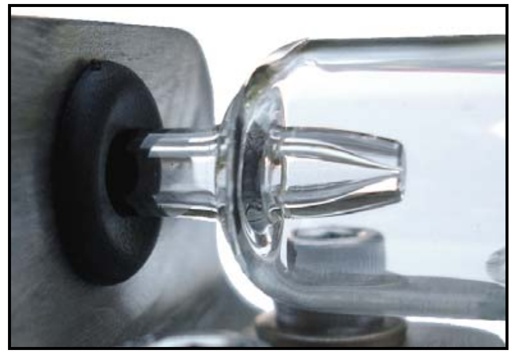
Note: Special considerations must be taken when the source gas is at a significant distance from the diluting module, as sample delay times may pose a challenge. A secondary high flow eductor (bypass pump) may need to be integrated into your sampling system design.

Theoretically, critical flow for air occurs when the ratio of the absolute pressure at the chamber outlet to the absolute pressure at the inlet (smoke stack, duct or process) is less than or equal to 0.53. In order to maintain a constant flow rate through the critical orifice (and keep the orifice functioning within its critical range), the partial vacuum applied to the outlet of the orifice is kept at a gauge pressure below 0.47bar (13.87inHg). This vacuum is measured via a gauge located on the system's control panel, the connection to the probe at the *vacuum line* which uses one of the four lines the umbilical cord.

Calibration gas can be supplied to the diluter via a separate line in the umbilical. This line can be connected (typically via a Swagelok® "T" fitting) at the inlet to the critical orifice. The volume of Calibration gas is typically set to a minimum flow rate of 4x the critical orifice nominal flow rate, to ensure that the critical orifice has a sufficient inlet gas supply while providing an excess which is normally vented back into the process or common exhaust gas manifold. The excess calibration gas that is vented past the critical orifice as bypass flow will serve as a barrier to the process sample gas and prevent cross contamination during calibration. A separate connection, independent of the calibration line, can be made to allow for monitoring of the sampling pressures during both normal sampling and during calibration if the need arises.

Critical Orifice (Sonic Orifice)





The critical orifice determines the flow rate at which sample is extracted from the source, as well as the ratio of dilution air volume to sample gas volume. It may be made from either standard glass (borosilicate) or special application metal (Monel® or Stainless-316) material, depending on various application parameters.

The glass orifice is connected to the pump section of the diluting module via stainless steel Swagelok® fittings and graphite ferrules (metal ferrules are not used). The metal orifice uses standard Swagelok® fittings with stainless steel ferrules. The front section (inlet end) of the orifice contains a fine/depth filter, consisting of ultra-pure quartz wool, as well as a fixed fritted disc. This filtering collects particulate and is exceptionally well-suited for trapping the gummy solids of moist gas streams and dry solids. Extreme care is taken during the packing of the filter to avoid channeling of the material.

Special attention has been paid to the geometry of the bore in the orifice. In this bore, the speed of the gas reaches the speed of sound (this type of critical orifice is also known as a sonic orifice). The factors influencing the flow through the orifice are expressed in the following equation:

$$G = \frac{C \cdot O \cdot P}{\sqrt{T}}$$

where, G = Air flow through the bore in grams per second

C = Constant
O = Surface area of bore
T = Temperature in degrees K
P = Absolute pressure at bore inlet

Theoretically, when the pressure at the bore outlet becomes less than 53% of the inlet pressure, further lowering the pressure at the outlet has no influence on the value of G. However, this theoretically defined constant of 0.53 is only valid for the use of a bore with infinite short length.

The actual constant depends on both the geometry of the bore and the nature of the gas, with values ranging between 0.2 and 0.8. Typically, glass capillaries have constants from 0.4 to 0.7 while hypodermic needles, in contrast, have much greater values (and therefore are not suitable for this type of application). Standard Dilution Ratios are noted in Table 2 (below):

TABLE 2	
Average Dilution Range	Critical Orifice Nominal Flow Rate
215:1 to 350:1	20 ml/minute
95:1 to 150:1	50 ml/minute
44:1 to 75:1	100 ml/minute
32:1 to 50:1	150 ml/minute
27:1 to 37:1	200 ml/minute
20:1 to 30:1	250 ml/minute
12:1 to 16:1	500 ml/minute

Dilution Air into Diluting Aspirator: Q_1 *ml/min*
Source Gas into Critical Orifice: Q_2 *ml/min*
Diluted Sample to Analyzer: $Q_1 + Q_2$ *ml*/min

Dilution Ratio is $\frac{Q_1 + Q_2}{Q_2}$

Selecting the Appropriate Critical Orifice Flow:

The dilution ratio required by a CEM system is dependent on two factors:

1) The measurement range of the analyzer
2) The lowest ambient temperature possible

The dilution ratio required under the first of these factors is determined by simply dividing the maximum expected gas concentration (in the stack) by the maximum concentration the analyzer can measure. For example, if the maximum gas concentration in the stack is 560 ppm of SO2 and it will be measured by an analyzer with a measurement range of 0 to 10 ppm, a dilution ratio of 56:1 (560/10) is required.

The second factor, the lowest ambient temperature possible, must be considered to ensure that no condensation will occur within the line carrying the diluted sample to the analyzer. The dilution ratio must be such that the moisture content of the diluted sample is reduced to a level below the dew point at the lowest expected ambient temperature. The required dilution ratio is calculated by dividing the water vapor concentration in the stack by the percent water vapor at the lowest expected temperature as shown in the Dew Point Table.

TABLE 1

Over Ice					Over Water				
Temperature		H_2O = Saturation Vapor Pressure @ 101325 Pa		% H_2O by Volume	Temperature		H_2O = Saturation Vapor Pressure @ 101325 Pa		% H_2O by Volume
°C	°F	Pa	mm Hg		°C	°F	Pa	mm Hg	
-90	-130	0.01	0.00007	>0.001	-15	5	191	1.44	0.189
-80	-112	0.05	0.0004	>0.001	-10	14	287	2.15	0.284
-70	-94	0.26	0.002	>0.001	-5	23	422	3.16	0.418
-60	-76	1	0.008	0.001	0	32	610	4.58	0.607
-50	-58	4	0.03	0.004	5	41	872	6.54	0.869
-40	-40	13	0.10	0.013	10	50	1228	9.21	1.227
-35	-31	23	0.17	0.022	15	59	1705	12.79	1.771
-30	-22	38	0.29	0.038	20	68	2338	17.54	2.363
-25	-13	63	0.48	0.062	25	77	3167	23.76	3.229
-20	-4	103	0.78	0.102	30	86	4243	31.82	4.375
-15	5	165	1.24	0.163	35	95	5623	42.18	5.882
-10	14	260	1.95	0.257	40	104	7376	55.32	7.862
-5	23	402	3.01	0.398	45	113	9583	71.88	10.461
-0	32	610	4.58	0.607	50	122	12333	92.51	13.884

760 mm Hg = 29.921 in Hg   1 mm Hg = 133.32 Pa = 1.3332 mbar   100 Pa = 1 mbar
Source: CRC Handbook of Chemistry and Physics, 69th Edition. A Guide to the Measurement of Humidity, The Institute of Measurement and Control / National Physical Laboratory UK

For example, if the minimum ambient temperature is -10°C (14°F) and the sample in the stack has a water vapor concentration of 20%, the dilution ratio required to prevent sample line condensation is 70:1 (20/0.284).

However, since both calculated dilution ratios must be satisfied (56:1 and 70:1), a critical orifice with the proper dilution range must be selected. As indicated in Table 2, which references performance data on the different critical orifices available from, this dilution range may be achieved by using a critical orifice with a nominal flow rate of 100 ml/min.

Determining the exact dilution ratio of the critical orifice under specific stack conditions is performed via dynamic calibration. The calibration gas is transported through the umbilical cord to the tip of the dilution probe, diluted using the same ratio as the sample from the stack, and then measured by the analyzer. Dividing the measured concentration by the actual concentration of the calibration gas (before dilution) yields an accurate value for the dilution ratio. For example, if the calibration gas has a concentration value of 560 ppm and the measured value at the analyzer is 9.5 ppm, then the dilution value is 0.016942 (560/9.5) or about a 59:1 dilution ratio. The actual dilution value is used by the data acquisition system to automatically convert analyzer readings to stack concentration values.

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TEST & PERFORMANCE CERTIFICATE [EXAMPLE]

Date: 06/25/04 Customer: ______ Cust. PO#: ______

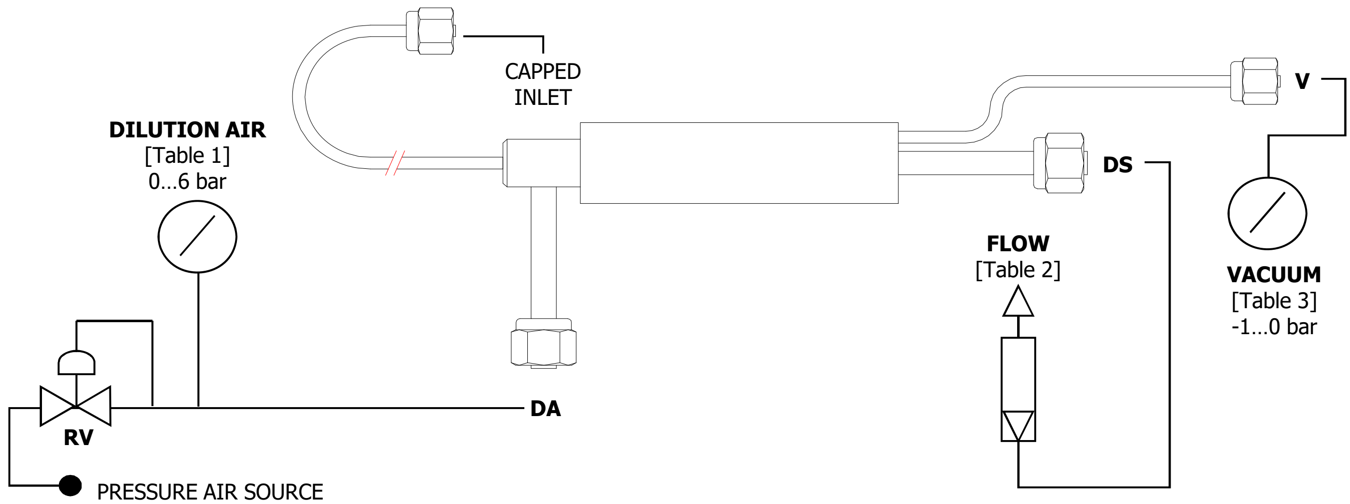
Dilution Probe Model: ASI DM-100-B Serial Number: 12345

Table 1	Table 2	Table 3	
DA	Flow	Vacuum	
bar (psi)	liters/min	-bar	inHg
2 (29)	4.0	- 0.50	14.77
3 (43+)	5.4	- 0.66	19.49
4 (58)	6.9	- 0.70	20.67
5 (72+)	8.4	- 0.66	19.49
6 (87)	9.8	- 0.58	17.13

Remarks:
INSTALL CRITICAL ORIFICE BEFORE ATTEMPTING TO USE DILUTER. IF GLASS TYPE CRITICAL ORIFICE IS TO BE USED, BE SURE TO INSTALL 1/4" ID GRAPHITE FERRULES ON EACH END OF THE CRITICAL ORIFICE. STAINLESS STEEL FERRULES ARE NOT TO BE USED!!

GLASS ORIFICE NOTE: TIGHTEN NUT CONTAINING GRAPHITE FERULE ONTO ORIFICE STEM, **BY HAND**, UNTIL FERRULE SNUG ONTO ORIFICE. BACK OUT THE ORIFICE BY ABOUT **1mm** FROM UNION, THEN TIGHTEN NUT **1/2 TURN** WITH WRENCH. IF FERRULE IS "RE-USED" (COMPRESSED) USE **1/4 TURN** FROM FINGER TIGHT.

Test Procedure for Dilution Probe Aspirator:
Pressurized air is supplied to the DA inlet of diluter (DA = Dilution Air). Pressure is set with RV to the values listed in Table 1. The air flow through the pump is measured with a mass flow meter, calibrated in liters/min. The measured flow is listed in Table 2. The partial vacuum generated by the aspirator is listed in Table 3. The connector for the critical orifice is capped off during this test which is performed at room temperature. Sample suction of the pump is zero during this test because of the stop plug. Note: Configuration of lines may differ than that of the illustration blow.



"S" = SERVICE LINE (CALIBRATION LINE)
"V" = VACUUM LINE
"DS" = DILUTED SAMPLE LINE
"DA" = DILUTION AIR LINE
"RV" = REDUCING VALVE (REGULATOR)

Pressure Conversions

bar x 29.53 = inHg (inch of mercury (32° F))
bar x 401.463 = inH_20 (inch of water (39.2° F))
bar x 14.5038 = lbf/in^2 (pound force per square inch)

IMPORTANT !!

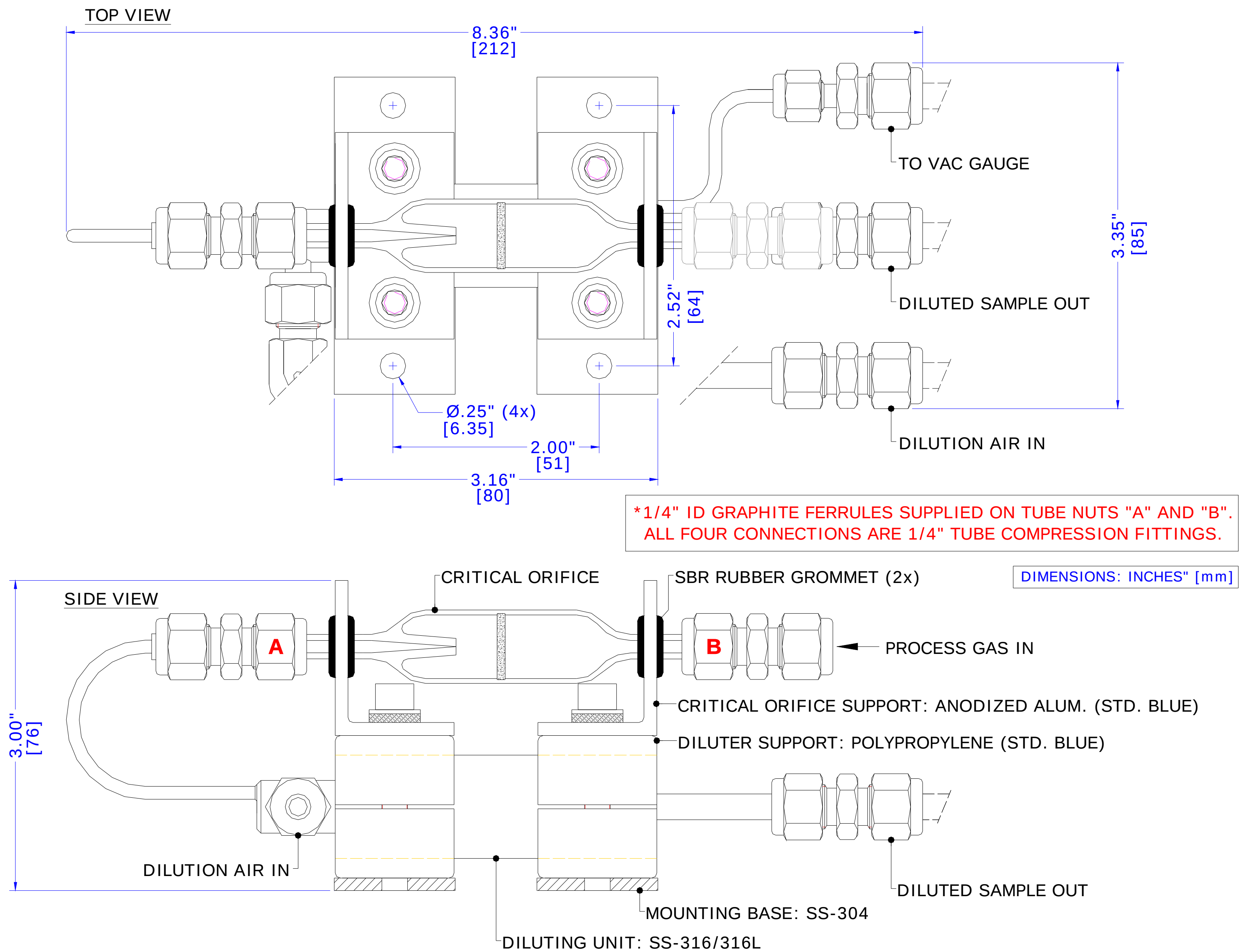
Maximum Operating Temperatures:

Please note that the standard polypropylene saddles are rated to 194°F (90°C), the neoprene backed washers are rated to 250°F (121°C), and the SBR grommets (as used with the glass orifice version diluting module) are rated to 200°F (93°C). For higher application temperatures (e.g., the diluting module will be used in your heated box or enclosure), please ask for the **"High Temperature" conversion kit!!** This conversion kit shall replace the poly saddles with aluminum, the neoprene backed washers with silicone backed washers, and the SBR grommets (where applicable) with silicone grommets. This will effectively allow the unit to be heated to **well over 350°F (177°C)**.

Installation & Applications Notes for the DM-100 Diluting Modules:

If the diluting module that ASI produces is to be used in "other than laboratory" applications, or integrated into a CEM analyzer shelter, there are a few points to always consider before making the decision to integrate the ASI diluting module. The diluting unit will, in some instances, may need to be built into some type of compact insulated enclosure. And to ensure temperature stability some applications may benefit by heating the unit by some means. Further, if the diluting phase of the sample system is located some significant distance from the source gas (sample gas extraction point) you may need to have an extra pump (electric pump, or the more desirable air driven eductor) to draw sample at a continuously higher volume out to the dilution component to keep delay times within application minimums if need be. ASI does design and manufacture these small eductor pumps, please contact us for more information. There are other considerations as well, such as an inlet tube/pipe (heated or unheated). This would be used for the source gas sample transport path, from the source to dilution component (diluting module). Possible coarse pre-filters at the sample extraction point, or at the tip of the extraction probe/tube/pipe, should also be implemented. ASI does not have such a complete turn-key system, as we normally utilize the standard "in-situ dilution probe" in most of our CEMS installations or RATA setups. However, it should be a relatively straight forward approach to integrate the diluting module into such a system as noted above. Keep in mind that many of the components required to make it an "ex-situ" (extractive dilution) sampling system, or a portable dilution instrument, need to be designed and/or supplied by the customer or the integrator. In either case, be it our in-situ dilution probe, or utilizing our compact diluting module, it is up to the customer to provide the proper pneumatic controls and function gauges for the instrument (usually built into the instrument rack, 19" panel at the analyzer location or shelter for example). Please note that ASI is happy to help with this by supplying information and suggestions on what minimum panel controls and gauges should be used as standard, considerations for generating zero air (dilution air). We can also can offer some basic design guidance if the ASI diluting module becomes the desirable approach and you wish to develop it into a custom ex-situ or portable sample conditioner. Please let us know, and we can discuss your application requirements further.

When we work with process monitoring using the dilution method (regardless if it is the in-situ dilution or ex-situ dilution) we want to make sure that you will have source sample gas at ambient levels for the diluting unit (specifically the critical orifice) to sample from. A partial negative pressure is usually acceptable, however, the critical orifice should not be subjected to high positive pressure sampling into orifice inlet. You would risk errors with gas density and higher than expected flow rate through the critical orifice. If you anticipate positive pressure from the source, you would need to vent the stream and extract sample from the bypass stream to ensure no excessive overpressure. Please be sure that you setup the sample stream properly to ensure a functional gas sampling and diluting system.



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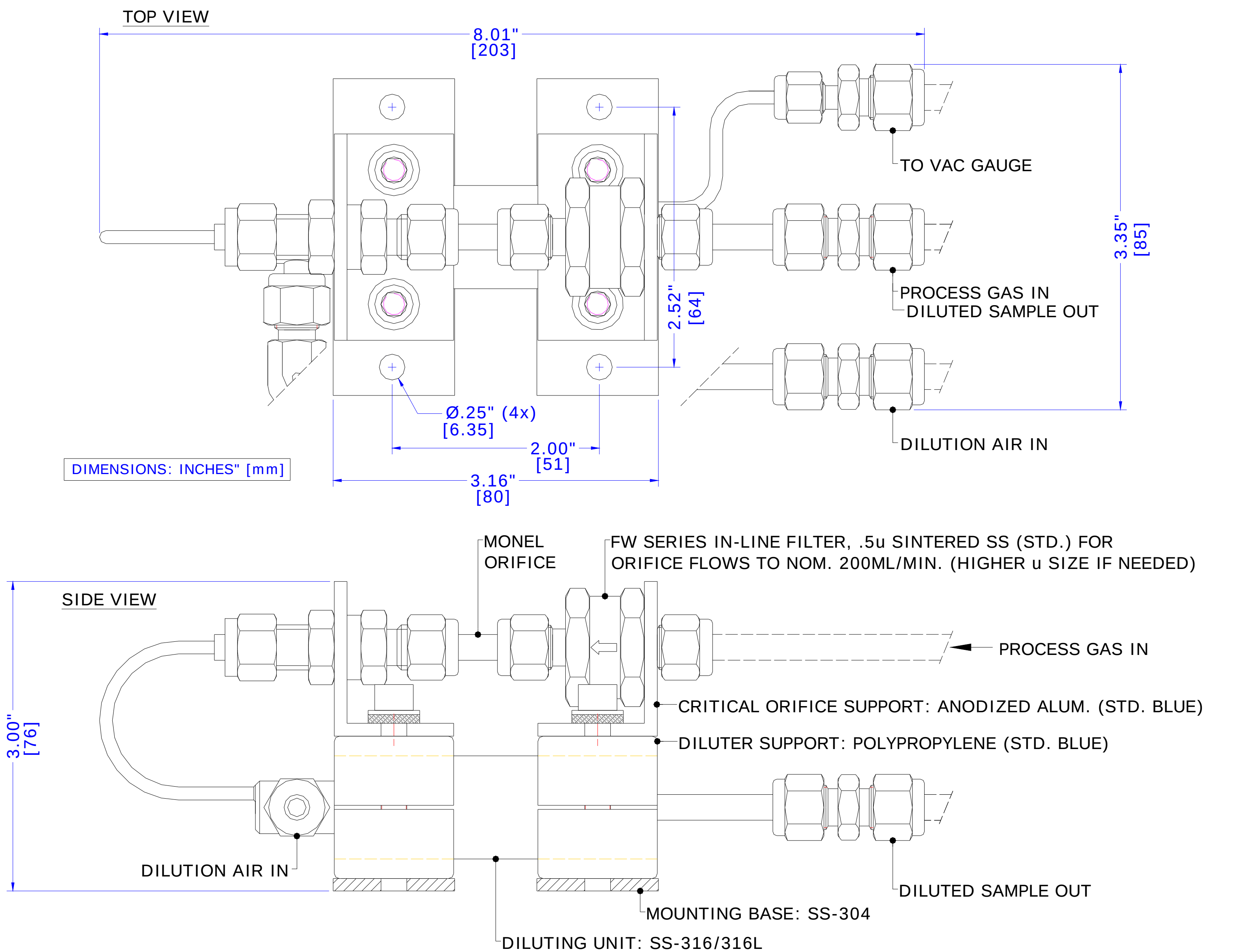

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TITLE: BASIC OVERALL DIMENSIONS FOR DM-100-B2	ASI MODEL#: DM-100-B2 DRAWING#: DM-100-B2_DIMS_V1b