1 FlowSeg Gas overview

FlowSeg Gas (hereafter FSG) is a flow controller instrument for gas or gases. The instrument by default includes two gas lines and two gas flow controllers inside a compact instrument case.

The instrument is controlled with computer software where user enters desired flow for each gas directly in immediate mode, or can set up segment programs for each gas line with unlimited step or ramps.

The software can calculate what mixture the resulting flows would form; all information for the whole mixture and each component gas: mass, volume in any desired unit, partial pressures, and parameters relating to evaporated fluids like relative humidity (RH) and absolute humidity (partial pressure of evaporated fluid) should the system be used with fluid pump.

Additionally the software can control any number of these instruments allowing for very elaborate setup with many flow controllers for gases and fluids. The software communicates with each device in parallel, avoiding the typical slowing down of multi-device networks (that operate in serial fashion).

2 Background

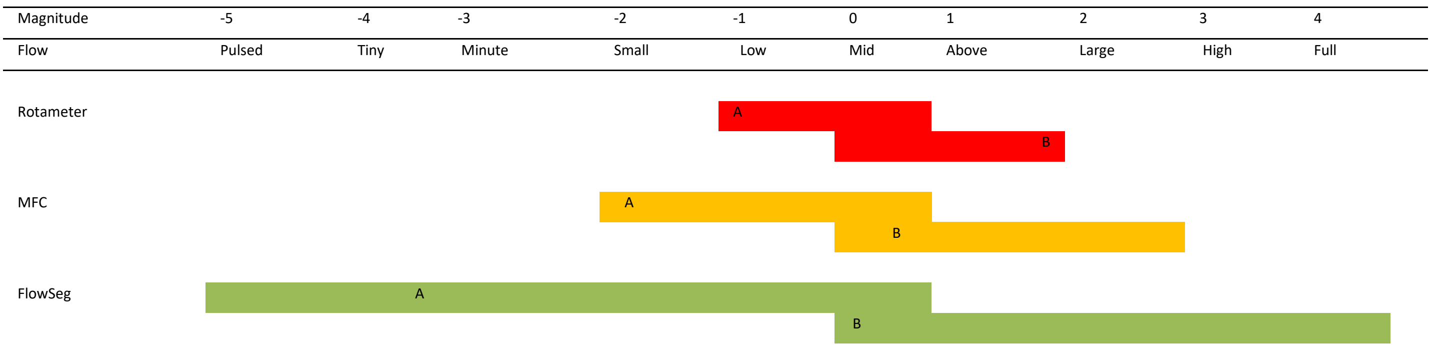
When mixing gases, the possible range of mixing, the total flow of the made mixture, and the overall pressure of the system are all points on interest. Flow control devices have usable range of flow they can accurately control and measure. This range is often defined as full range and turndown ratio, and means the maximum achievable flow and its ratio to the lowest possible flow. A device with full scale flow of 200 (the unit is here irrelevant) and a turndown ratio of 50, would have an effective control range of 4-200.

For a flow control device, the user can usually select the maximum flow range, whereas the turndown ratio is fixed and depends on the model, and ranges anything from 1:10 to 1:10 000.

Illustration covers three types of mixing devices. A pair of rotameters (red), pair of traditional mass flow controllers (yellow), and FlowSeg Gas (green).

Overall, rotameters have low accuracy and low turndown ratio, are operated manually with look-up table to convert the visual que to actual flow. Mass flow controllers operate automatically and have much improved accuracy, but do not match rotameters in simplicity and price. FlowSeg Gas uses state of the art flow control devices that are more accurate than conventional MFCs, and have two orders of magnitude higher turndown ratio.

To form a mixture, two of any said devices are used, we call them A and B. A control the flow of the gas to be diluted, and unit B controls the flow of the dilutant gas, and output from both is combined to form the mixture. The devices can have different flow ranges, lower flow for gas A, and higher flow for gas B, usually with some overlap in their ranges.



The overlap at mid flow is the region where the two flow control devices have same flow for both inputs and are able to produce mixtures close to 1:1 partial pressure ratio. For FlowSeg it is possible to increase the overlapping mid-range if and when necessary.

The further apart the minimum for A, and the maximum for B, the larger dilution ratios the mixer can achieve.

A mixture of A:B is marked on the chart. The dilution ratio is defined by the distance of A to B, and is same for each type of mixer, whereas the total necessary flow to form the said mixture is lower the further left (on the chart) the A-B combinations are. This means forming the same mixture can be achieved by using less gases overall, saving money.

FlowSeg is also able (when it suits the purpose) to pulse the flow A as function of time, to achieve additional order of magnitude of dilution. Flow B should not be pulsed as it forms the majority of the flow.

Overall, for mixers near 1:1 mixing it is good to increase the area of overlap, and for mixer aimed to produce large dynamic dilution ranges down to ppm levels, the overlap should be kept small. For ppb levels two units can be chained and product from one re-diluted with the next unit, the software supports input gases that are output gases from other FS units.

3 Physical

The FS Mix consists of an enclosure roughly 22 x 21 x 12 cm with two gas inputs and one gas output (1/8” or ¼”), data and power inlets and outlets.

For safety, the mixer has mains power switch with indication for power on/off. Turning the power off will cease any gas flow, which can only be resumed from the software.

4 Options

- The FS Mix is for all non-corrosive gases, or for a surcharge can be made for also the corrosive gases. See listed gases later in this document.
- The FS Wet option includes a humidifying stage, and a heated gas line to allow evaporating any amount of low viscosity fluids, typically pure H2O. This module can also be controlled from the same FlowSeg software.

5 FlowSeg Software

FS devices are controlled by software running on a Windows computer (computer not included). The software allows user to design and control flow patterns for single or multiple inputs as one output ‘mixture’, and will show the resulting flow in various units, partial pressures, RH%, etc. relevant information.

```
Name: Output from Virtual Mixer demo
Details: (Normalized mix) - PP:1 - MM:28,15344
  N2 - PP:0,965
  O2 - PP:0,035

            Molar mass        Mass     Partial
Components  g/mol         fraction    pressure
        N2  28.014 000  0.960 220   0.965 000
        O2  31.998 000  0.039 780   0.035 000

      Flow  Unit       Temperature    Pressure
      55.0  mln/min            0°C   1.013 bar
      60.0  ml/min            25°C   1.013 bar
      85.2  ml/min           150°C   1.013 bar
 0.069 045  g/min
 0.002 452  mol/min
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The software allows user to select the input gases or gas mixtures used in the mixer. The inputs can be elemental gases, default mixtures, user defined mixtures, or live mixtures; a dynamic mixture output from one FS mixer as input to another FS Mixer.

The user can design the the desired mixtures as constant flow or as a segment program with custom amount and length steps or ramps. One segment program can control multiple FS units, or each unit can have its own segment program or software instance running. When a segment program is finished it can stop the flow for one FS mixer, for all FS units, maintain last mixture and flow, or start over from beginning.

Segment programs can be saved and loaded for further use, and all performed flows are automatically saved to disk with dates and times for reference.

The software itself is free and included as part of either FS Mixer or Wet modules. The software has built-in virtual demo units to allow test use before having a physical FS units.

6 Specifications and order sheet

The default specifications can be altered to match user needs, please fill in the highlighted points on this document or otherwise convey the information.

Device nickname:

6.1 Pressure range

Maximum pressure:	11 bar a	bar a=atmospheric	bar g=reading on pressure gauge
Pressure option:	22 bar a	> 11 bar a pressure tradeoff is lower turndown ratio and reduced accuracy	
Minimum pressure:	0.7 bar a	(or absolute)	(above atmospheric)

The optimal situation is where the input pressure (gas supply) is roughly one bar more than the output pressure (experiment pressure). This one bar difference ensure there is enough force to reach the maximum specified gas flow when the valves are fully open, but not so much force that the PID controlled valve would have difficulties finetuning the orifice size for small flows and small flow changes.

	Default	User specified pressure
Input pressure:	2 bar a	
Output pressure:	1 bar a/near atmospheric	

6.2 Flow ranges and dilutions

A device for each input line has predetermined flow range in which the device is able to accurately control the flow. This range is indicated as the maximum flow, where the minimum possible flow is omitted but is a fraction of the maximum flow.

Flow range forth both input lines can be selected to best match the desired use case. This will affect the possible mixing ratio and total flow of the mixer. Any flow range is possible, from microliters to hundreds of liters. The defaults are for N2 and mixing situations where both gases have identical mass and viscosity. SCCM Standardized cubic centimeter per minute = milliliter per minute ml/m

	Defaults	User priority (if deviates)
Max flow input A	50 SCCM	
Max flow input B	500 SCCM	
Flow range for 1:1 mixing (4 magnitudes)	0.1 - 100 SCCM	
Max dilution (pulse A + max B)	1:1 000 000	

It is possible to increase or reduce the overlap, the mid-range, and accordingly (inversed) reduce or increase the maximum dilution range. In usually not necessary to aim for larger dilutions than 1:100 000, as source gases and leakages ensure ppm levels presence of undesired elements in the mixture in any case.

6.3 Humidification module

2Wet module: ☐

Intended fluids:

6.4 Suitable gases

All the listed gases and mixtures (listed on next page) are supported by default, other mixtures on request. Corrosive gases and refrigerants are possible but come with a surcharge.

Corrosive gases (surcharge): ☐

User desired mixtures:

6.5 Overall use purpose

Provide additional information on the intended use as possible, so we can best adjust the parameters.

All pure non-corrosive gases
Acetylene (C2H2), Air (clean, dry), Argon (Ar), Isobutane (i-C4H10), Normal Butane (n-C4H10), Carbon dioxide (CO2), Carbon monoxide (CO), Deuterium (D2), Ethane (C2H6), Ethylene (Ethene) (C2H4), Helium (He), Hydrogen (H2), Krypton (Kr), Methane (CH4), Neon (Ne), Nitrogen (N2), Nitrous Oxide (N2O), Oxygen (O2), Propane (C3H8), Sulfur Hexafluoride (SF6) 1, Xenon (Xe)

Bioreactor Gas Mixes
5% - 95% CH4/CO2 in 5% increments

Breathing Gases
Metabolic Exhalant, EAN-32, EAN-36, EAN-40, EA-40, EA-60, EA-80, Heliox-20, Heliox-21, Heliox-30, Heliox-40, Heliox-50, Heliox-60, Heliox-80, Heliox-99

Chromatography Gas Mixes
P-5, P-10

Fuel Gas Mixes
1% - 99% H2/Ar in 1% increments
1% - 99% H2/N2 in 1% increments
Coal Gas 50% H2, 35% CH4, 10% CO, 5% C2H4
Endothermic Gas 75% H2, 25% N2
HHO 66.67% H2, 33.33% O2
LPG HD-5 96.1% C3H8, 1.5% C2H6, 0.4% C3H6, 1.9% n-C4H10
LPG HD-10 85% C3H8, 10% C3H6, 5% n-C4H10

Laser Gas Mixes
4.5% CO2, 13.5% N2, 82% He
6.0% CO2, 14% N2, 80% He
7.0% CO2, 14% N2, 79% He
9.0% CO2, 15% N2, 76% He
9.4% CO2, 19.25% N2, 71.35% He
9.0% Ne, 91% He

Natural Gases
93.0% CH4, 3.0% C2H6, 1.0% C3H8, 2.0% N2, 1.0% CO2
95.0% CH4, 3.0% C2H6, 1.0% N2, 1.0% CO2
95.2% CH4, 2.5% C2H6, 0.2% C3H8, 0.1% C4H10, 1.3% N2, 0.7% CO2

Oxygen Concentrator Gas Mixes
89% O2, 7.0% N2, 4.0% Ar93% O2, 3.0% N2, 4.0% Ar95% O2, 1.0% N2, 4.0% Ar

Synthesis Gases
40% H2, 29% CO, 20% CO2, 11% CH4
64% H2, 28% CO, 1.0% CO2, 7.0 CH4
70% H2, 4.0% CO, 25% CO2, 1.0% CH4
83% H2, 14% CO, 3.0% CH4

Stack/Flue Gas Mixes
2.5% O2, 10.8% CO2, 85.7% N2, 1.0% Ar
2.9% O2, 14% CO2, 82.1% N2, 1.0% Ar
3.7% O2, 15% CO2, 80.3% N2, 1.0% Ar
7.0% O2, 12% CO2, 80% N2, 1.0% Ar
10% O2, 9.5% CO2, 79.5% N2, 1.0% Ar
13% O2, 7.0% CO2, 79% N2, 1.0% Ar

Welding Gases
C-2, C-8, C-10, C-15, C-20, C-25, C-50, C-75, He-25, He-50, He-75, He-90, A 1025, Stargon CS

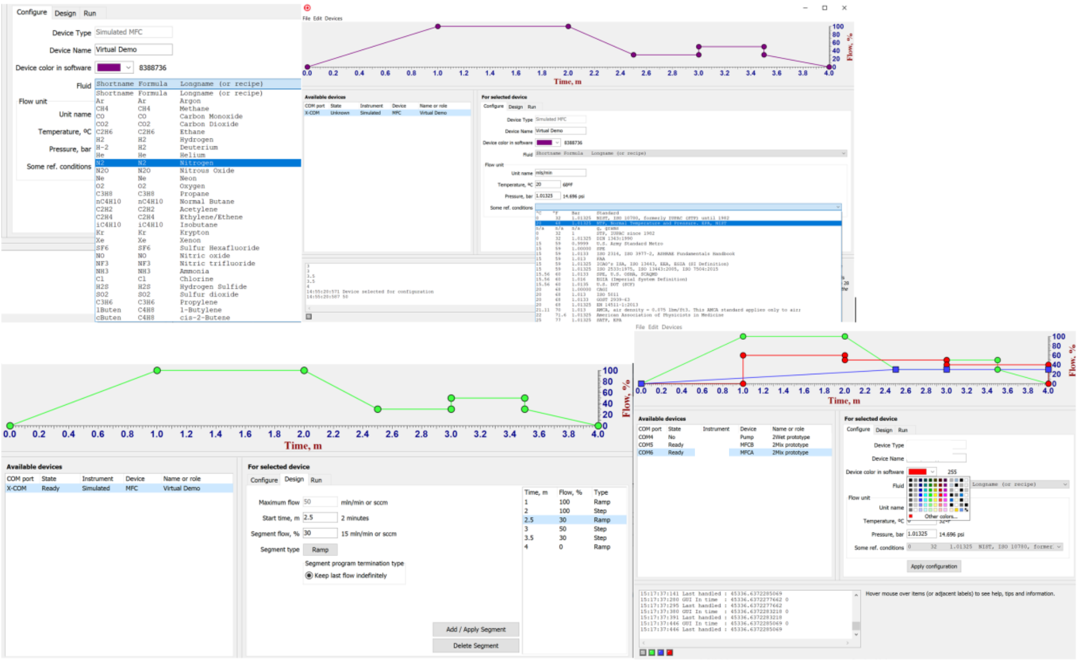
Pure Corrosive Gases (surcharge)
Ammonia (NH3)
Butylene (1-Buten)
Cis-Butene (c-Buten)
Isobutene (i-Buten)
Trans-Butene (t-Buten)
Carbonyl Sulfide (COS)
Chlorine (Cl2)
Dimethylether (DME)
Hydrogen Sulfide (H2S)
Nitrogen Trifluoride (NF3)
Nitric Oxide (NO)
Propylene (C3H6)
Silane (SiH4)
Sulfur Dioxide (SO2)

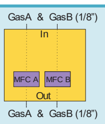
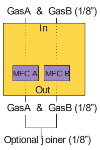
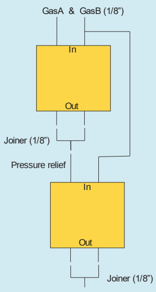
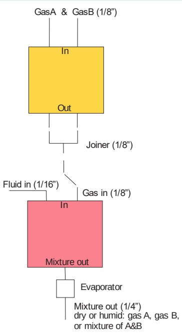
Refrigerants (surcharge)
R-11, R-14, R-22, R-23, R-32, R-115, R-116, R-124, R-125, R-134a, R-142b, R-143a, R-152a, R-318, R-404A, R-407C, R-410A, R-507A

7 Modular gas mixing and humidification system 2Mix

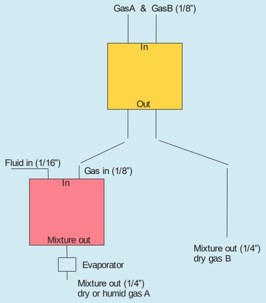
FS Gas	FS Fluid	FS software
Measure or Control flows of two gases separately, or mix them together Defaults: - Gas A: 0.005 – 50 mln/min - Gas B: 0.05 – 500 mln/min Flow range for both MFCs adjustable at time of order up to 20 ln/min. - Any non-corrosive gas or gas mixture - Max pressure 10 bar A - Size: 11 x 20 x 22 cm, 3kg Options (surcharge): - Corrosive gases - High flows, up to 5000 l/min - High pressure, 20 bar - Ultra high pressure, 250 bar - Custom builds with more MFCs	Add low viscosity fluid (like distilled H2O) to passing gas stream and evaporate the fluid. Added amount is adjustable and software will show RH% and partial pressure of fluid components. Defaults: - 0 to 100% absolute humidity - 0 to 100% relative humidity RH - Evaporator 150°C - Heating power 250W - 0 to 3g H_2O/min @ ATM - Size: 16 x 22 x 27 cm, 5kg - Evaporator 1.2 m, bend radius 30 cm - Max pressure: 5 Bar A Options (surcharge): - Heating power up to 5 kW - Higher fluid throughput - Custom static evaporator shapes - Larger syringe sizes up to 60 g H_2O / min - Higher temperature evaporator	Control any amount of FS devices from single MFC to dozens of MFCs, and fluid pumps. Defaults: - Manually specify device flow - Segment program with steps and ramps for any and all connected devices - Partial pressure calculations - Plot flows and mixtures on screen - Save flows and mixtures on file Options (surcharge): - High temperature equilibrium calculations - Dynamic input gas for 2Mix (allows mixture re-dilution by using 2x 2Mix in chain) - User defined custom input fluids - PLC integration (report flows via RS485/Modbus/ASCII, cut power relay)

At the simplest, the FS software is an easy way to control individual mass flow controller or many mass flow controllers with simple dial, and plot the flow, and record the flow as function of time to a file. The software allows user to view flows (per minute) in their preferred unit; % of full flow, grams, or standard volumetric units mln, mls, sccm, or custom volumetric units with user defined reference conditions (temperature and pressure). For the reference conditions the software uses °Celsius and Bar A, but accommodates also for users of °Fahrenheit and PSI.



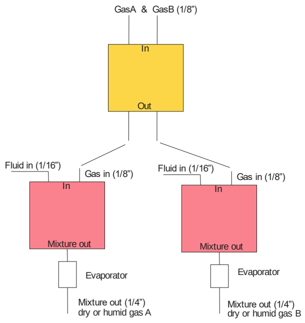
Name	Schematics	Use case	Notes
-Flow control **-Flow measurement** **-Fuel cell without humidification**		Control flow of each Gas A and Gas B individually. A & B can always be pure species or premade mixtures.	Constant flow, ramps, steps
A+B mixture		Create dynamic large range mixtures of Gas A and Gas B	Software reports partial pressures of all components at any given time
Re-dilution (A+B) + B		Take some of A+B mixture and re-dilute with large amounts of gas B for ppb levels of A in B	
Humidification pH2O of gas or gas mixture **Evaporate custom fluids in gas or gas mixture**		From bottle dry gas A, gas B, mixture of A+B to pure steam or any combination	

One sided humidification

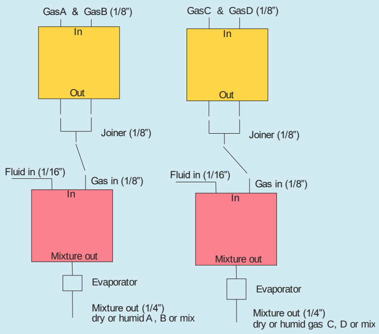


Gas A and Gas B can be premade mixtures from bottle or from another mixer.

Double sided humidification



Full control of two mixtures



8 Fluid pump throughput; syringe and heating power

Syringe size µL	Resolution nL	[1]Max dispense mL/min	[2]Max power needed W	[3]Max steam volume L/min
12.5[4]	0.5	0.31	16	0.6
25	1	0.63	31	1.2
50	2	1.25	63	2.4
100	4	2.50	125	4.8
125	5	3.13	156	6
250	10	6.25	313	12
500	21	12.50	625	24
1000	42	25.00	1.25 k	48
1250	52	31.25	1.56 k	60
2500	104	62.50	3.13 k	120
5000[5]	208	125.00	6.25 k	240
12500[6]	521	312.50	15.63 k	601

[1] It is advised not to run the syringe at these maximum speeds in order to optimize for syringe lifetime. It is better to select a larger syringe and run for example at 20% of maximum speed.

[2] Energy needed per second to heat, evaporate and again heat the max flow as H_2O, from 20°C to 150°C at 1.01325 bar pressure. Some additional power is required to heat the gas flow, and to maintain evaporator temperature against heat loss through insulation. Default heating power is ~250 W.

[3] Max fluid dispense as water vapour/steam at 150°C at 1.01325 bar pressure.

[4] Default syringe size is 12.5 µL unless otherwise specified on order. Smallest syringe has least uncertainty as accuracy is calculated from full dispense volume. For syringe and syringe pump lifetime select large syringe as it requires fewer repetitions to dispense same amount.

[5] Custom fluid tubing required.

[6] Custom fluid tubing required.