1 2Mix overview

2Mix is a gas mixer for mixing two input gases (A and B) into a mixture. The mixer is controlled with computer software where user enters desired mixing profile of freely selectable dilutions, flows, ramps, steps, and delays. The software can control multiple 2Mix units, and/or optional 2Wet units that allows adding (and evaporating) fluids.

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 2Mix (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. 2Mix 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.

Magnitude	-5	-4	-3	-2	-1	0	1	2	3	4
Flow	Pulsed	Tiny	Minute	Small	Low	Mid	Above	Large	High	Full
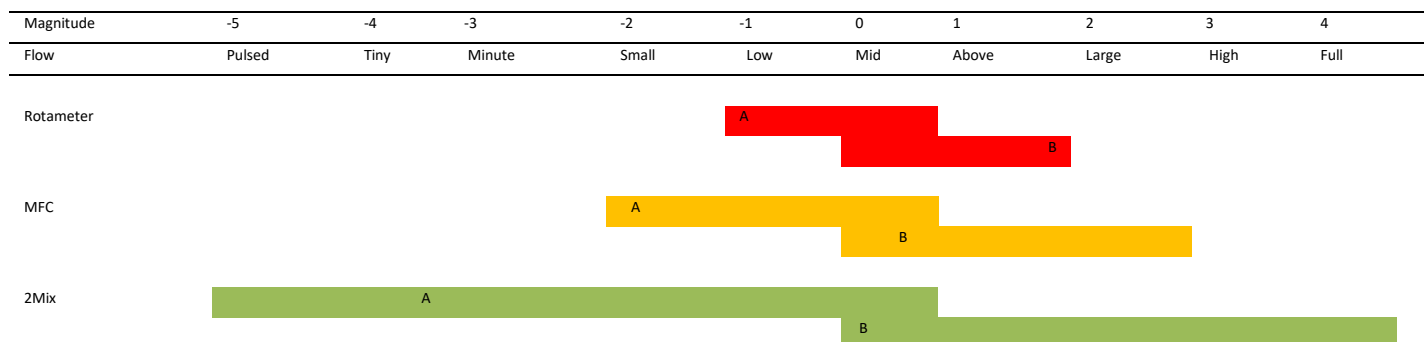
The overlap at mid flow is the region where the two flow control devices have same flow for both inputs and are able to produce mixtures close to 1:1 partial pressure ratio. For 2Mix it is possible to increase the overlapping mid-range if and when necessary.

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.

2Mix 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 2Mix units.

3 Physical

The 2Mix consists of an enclosure roughly 15 x 15 x 15 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 2Mix 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 2Wet 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 2Mix software.

5 2Mix Software

2Mix is 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.

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 2Mix as input to another 2Mix.

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 2Mix 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 2Mix, for all 2Mix units, maintain last mixture and flow, or start over from beginning.

```
Name: Output from Virtual 2Mix 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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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 2Mix or 2Wet modules. The software has built-in virtual demo units to allow test use before having a physical 2Mix of 2Wet unit.

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.

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.

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
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.

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

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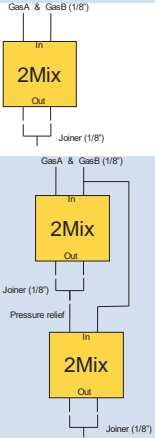
R-11, R-14, R-22, R-23, R-32, R-115, R-116, R-124, R-125, R-134a, R-142b, R-143a, R-152a, R-318, R-404A, R-407C, R-410A, R-507A

7 Modular gas mixing and humidification system 2Mix

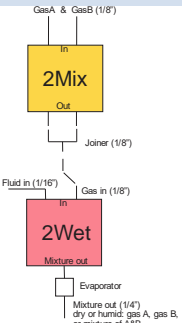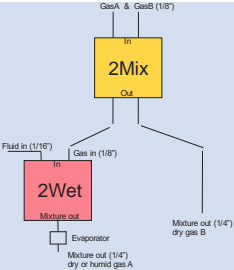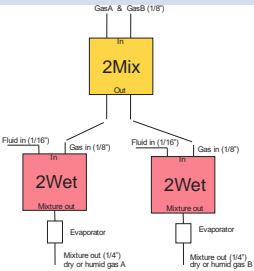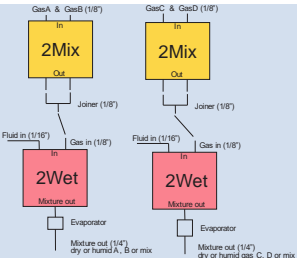| 2Mix	2Wet	2Mix software
Measure or Control flows of two gases separately, or mix them together Defaults: - Gas A: 0.005 – 50 mln/min - Gas B: 0.05 – 500 mln/min Flow range for both MFCs adjustable at time of order up to 20 ln/min - Any non-corrosive gas or gas mixture - Max pressure 10 bar A - Size: 11 x 20 x 22 cm, 3kg Options (surcharge): - Corrosive gases - High flows, 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 2Mix and 2Wet devices from single MFC to dozens of MFCs, 2Mix and 2Wet devices. 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 2Mix 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.
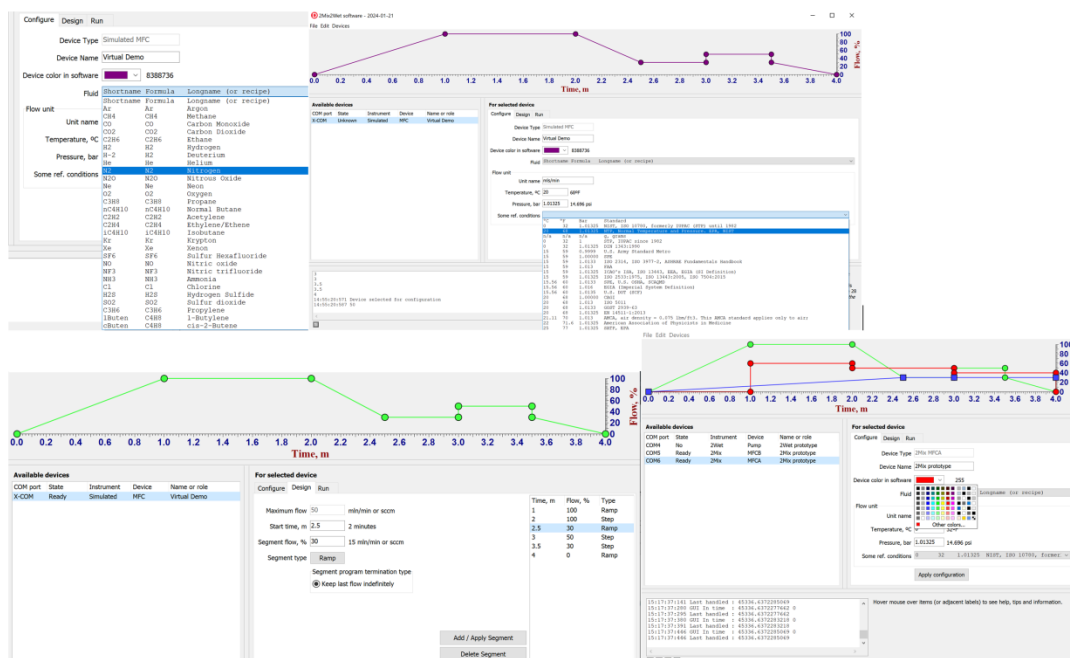
Name	Schematics	Use case	Notes
-Flow control -Flow measurement -Fuel cell without humidification	GasA & GasB (1/8") In **2Mix** Out	Control flow of each Gas A and Gas B individually. A & B can always be pure species or premade mixtures.	Constant flow, ramps, steps
A+B mixture	GasA & GasB (1/8") In **2Mix** Out Joiner (1/8")	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	GasA & GasB (1/8") In **2Mix** Out Joiner (1/8") Pressure relief In **2Mix** Out Joiner (1/8")	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	GasA & GasB (1/8") In **2Mix** Out Joiner (1/8") Fluid in (1/16") Gas in (1/8") In **2Wet** Mixture out Evaporator Mixture out (1/4") dry or humid: gas A, gas B, or mixture of A&B	From bottle dry gas A, gas B, mixture of A+B to pure steam or any combination	
One sided humidification	GasA & GasB (1/8") In **2Mix** Out Fluid in (1/16") Gas in (1/8") In **2Wet** Mixture out Evaporator Mixture out (1/4") dry or humid gas A Mixture out (1/4") dry gas B	Gas A and Gas B can be premade mixtures from bottle or from another mixer.	
Double sided humidification	GasA & GasB (1/8") In **2Mix** Out Fluid in (1/16") Gas in (1/8") Fluid in (1/16") Gas in (1/8") In In **2Wet** **2Wet** Mixture out Mixture out Evaporator Evaporator Mixture out (1/4") Mixture out (1/4") dry or humid gas A dry or humid gas B		
Full control of two mixtures	GasA & GasB (1/8") GasC & GasD (1/8") In In **2Mix** **2Mix** Out Out Joiner (1/8") Joiner (1/8") Fluid in (1/16") Gas in (1/8") Fluid in (1/16") Gas in (1/8") In In **2Wet** **2Wet** Mixture out Mixture out Evaporator Evaporator Mixture out (1/4") Mixture out (1/4") dry or humid A, B or mix dry or humid gas C, D or mix		

8 2Wet 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.