Haslevollen 3E
NO-0579 Oslo
Norway

HumiStat v2 Manual

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Contents

1 Introduction to HumiStat

HumiStat is a gas mixer. It forms one mixture from two input gases A and B, and from one input fluid C, with combinations such as A, AB, AC, B, BC, C, ABC, in dynamic ratios.

This made mixture is heated with the (included) heated gas delivery line and the fluid component is injected at this stage, evaporating the fluid. The standard heated gas line has temperature of 150ºC.

The mixer is controlled with a software on a computer with Windows operating system through a USB port, and controlled with dedicated software. The software and the USB cable are included in the system, while the computer is not.

The devices to regulate gas flow, called mass flow controllers, are calibrated with real gas. This gives the benefit of the mixer being very accurate, but this also means that the intended gases to be used, must be specified at the time of the order. This also adds to the delivery time. Each mass flow controller A and B can both hold up to 10 gas calibrations. These can be pure gases or premixed gases. Four gas calibrations are included in the standard price and there is a surcharge for more than four gas calibrations.

1.1 Operating principle in brief

Pressurized gas lines are connected at inputs A and B. The mixer controls the flow of each gas from the input line before the mixer, to lower pressure after the mixer by using magnetic valves and very quick redback loops. These valves vary the size of a small opening. When the opening is closed, no gas flows, when the opening is small, just a little bit of gas flows through, and when the opening is fully open, larger amounts of gas flow through. All this is automated, very quick and accurate per desired user parameters.

The input C is for fluid, which is pulled in, and added to the made mixture by the use of a syringe pump and automatic three-way valve. The fluid is pushed into the heated gas line and evaporated.

1.2 Flow matrix

When deciding which gas calibrations to include, it can be useful to ask for a preliminary flow matrix such as this example:

```
Mass flow controller (MFC) calibration breakdown
Minimum flow is usually 1/100th of maximum flow
=============================================
               min flow    max flow     notes
MFC A          mln/min     mln/min
  Air             0.50       50.00
  CH4             0.50       50.00

MFC B          mln/min     mln/min
  He              1.50      150.00
  N2              0.50       50.00

Listing of possible mixtures with largest possible dilutions
All listed mixtures with 0 to 100% absolute H2O or other evaporated fluid
===========================================================
  Air in He    1/216375       log(pAir)=-5.3
    => O2      1/940761       log(pO2)= -6.0
  He in Air    1/5            log(pHe)=-0.7
  Air in N2    1/10300        log(pAir)=-4.0
    => O2      1/44782        log(pO2)= -4.7
  N2 in Air    1/97           log(pN2)=-2.0
  CH4 in He    1/120300       log(pCH4)=-5.1
  He in CH4    1/8            log(pHe)=-0.9
  CH4 in N2    1/5727         log(pCH4)=-3.8
  N2 in CH4    1/175          log(pN2)=-2.2
```

2 Unpacking

The 'Unpacking' section in the manual is printed as separate sheet and included with the shipment.

2.1 The three components

HumiStat consists of the physical humidifier, the heated gas supply line and the software. The mixer, it's power supply, USB cable and the heated gas line are included in the shipment. The software download link is mentioned later in this manual.

2.2 HumiStat gas mixer

The humidifier is a compact desktop box of roughly 20 x 20 x 30 cm.

On the front panel are inputs for gases A and B, and input for liquid C, a PID controller to control the heated gas line, and the valve & syringe of the fluid pump.

All HumiStat components operate at 24 VDC, and the mixer comes with mains power supply.

2.2.1 Input gas(es)

Usually, the gas on line A is the one to be diluted the most, and gas line B is typically the dilutant, and the flow range for both gases is typically 0.5 - 50 mln/min (or 1 to 100), but any other range can be selected at the time of order.

2.2.2 Input fluid

Most low viscosity fluids and fluid mixtures are possible. The used liquid must be free of anything that will clog the gas line where the liquid vaporizes. For example, water must be demineralized, deionized or distilled. The tubing in contact with the fluid is brass, copper, stainless steel and PTFE. Other materials are possible on request. External fluid container is not included, only 30 cm piece of 1/16" PTFE line is provided.

2.2.3 PID controller

The controller allows setting and maintaining temperature of the heated gas line. The controller uses PID algorithm, on a thermocouple feedback from the heated gas line to regulate the power to the heated gas line. The selected temperature should be high enough to ensure the added fluid is vaporized, for example >100°C for H_2O.

The power of the heated gas line is roughly 200 watts. With the good insulation of the heated gas line, is enough to produce small amounts of pure steam. High power HumiStat systems for high steam and/or high pressure output are available on request.

2.3 Heated gas line

The heated gas line of 1.22 m length is somewhat flexible. The sharpest bending radius 25 cm, e.g. curve diameter 50 cm, any sharper turns will damage both the corrugated gas line. The heated gas line has stainless steel, 1/4 inch Swagelok tube fitting connects at each end to connect the mixer to the process or sample holder such as ProboStat (adapter for ProboStat included).

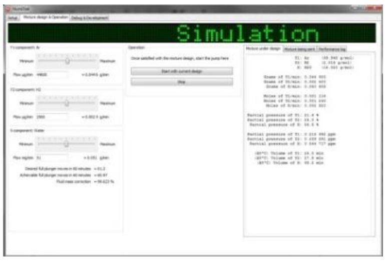
The heated gas line is equipped with plugs to connect to the humidifier for power and thermocouple feedback. The surface temperature is near ambient slightly warm to touch (it is still advised not to touch the gas line when it is in operation), and the maximum inside temperature is typically limited to 150°C. Higher temperatures are possible on request.

2.4 Power supply

CE marked power supply is included in the system. It supplies 24 volts DC and is capable of 10 A current, enough to power the instrument and heat up the heated gas line. The 6 pin connector is a snap-on model, connects to the back side of. The cable included has Hybrid CEE 7/7 plug. If unsuitable, the user can replace the cable with one that fit better to the local sockets. The Adapter itself is suitable for 110-230 VAC and both 50 and 60 Hz. The socket for the main power cable is type IEC320-C14. A cable fitting the C14 socket with CEE 7/7 type plug (European) will be included. Countries with alternative types of mains sockets must use an adapter (not included) or acquire a suitable cable.

For higher power system the power supply and other power related components are different, typically DIN rail mountable high power AC/DC transformer, such as 40 A 24 VDC

2.5 Software



The HumiStat software connects to the humidifier from a Windows PC with a USB cable. The software allows user to select gases from the available pool, and allows the user to design mixtures with specific partial pressures of the three components. The instructions can be a multi-segment automatic mixing program where each step has custom content and duration. Gradients are not supported but should there be interest, let us know. The software is downloaded from:

http://www.norecs.com/index.php?page=Software -> HumiStat -> Latest Version

2.5.1 Setup tab

The setup tab is used to verify the connection between the software and the HumiStat, and to select the gases used.

2.5.2 Pump & fluid details

The Pump & fluid details tab allows defining the volume of the syringe used, the properties of the fluid used and user specified conditions to calculate volumetric parameters for the made gas mixture.

The software automatically creates a file with .ini ending, and keeps all settings stored in that file and these are automatically loaded on startup.

2.5.3 Mixture design and operation

This tab is for designing mixtures and segment programs as well as executing them, in short, operating the mixer.

2.5.4 Debug & Development

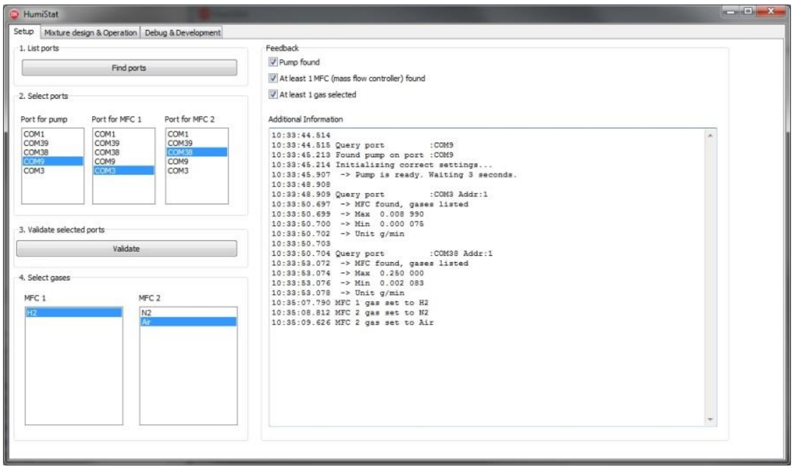
This tab allows demonstrating the software even when no mixer is connected to the computer, by defining virtual gases to be used for calculations. Additionally, this tab allows sending direct commands to the fluid pump while the HumiStat is not in use.

When adding, changing or priming the syringe or the valve, the user will need to use this tab to control the syringe position or pump the fluid.

3 Setup

3.1 Software

Connect the HumiStat USB cable to the computer, and the 24 VDC adapter to the HumiStat and to the mains power, and execute the HumiStat software. The software is just a single .exe file requiring no installation. The .exe file can be downloaded from http://www.norecs.com/index.php?page=Software -> Humistat -> Latest version



The software will write files and folders directly under its own location, so the windows user account must have file writing permissions to the location in question. In other words; do not place the .exe file under 'program files' or 'system' folders as Windows operating system limits the file writing access in these folders.

The setup tab allows the user to connect the HumiStat to a new computer in an easy way and to verify the connections in case USB cables have been changed since last use.

The mixer uses "USB to virtual COM port" type approach. The correct drivers for the MFC ports are identified automatically by Windows in most cases but may require user to install drivers in case where Windows itself cannot find or install them automatically.

In such case, the drivers can be found from

- http://www.ftdichip.com/Drivers/VCP.htm

The correct drivers are called VCP (do **not** use the D2XX type drivers).

The areas of this tab are numbered and correspond to the order things should be done. First click should be 'Find ports'. This will list all existing serial ports, real or virtual, in the three list boxes. The software should show three or more separate COM ports on the list boxes. Inside the HumiStat the USB cable is split, and the mass flow controllers and the pump are all connected to USB and thus show up as virtual COM ports.

The devices used do not support automatic detection, so the user must select a port for each device and then click 'Validate selected ports'. Which device is behind which port (without said automatic detection) is a guessing game. Fortunately the possible combinations are relatively low.

This checking process lasts about 10 seconds during which the software will check if the instruments can be found on the assigned ports. The process will give feedback if the selected ports were wrong, or if the instruments were found and initialized. Until both types (pump and MFC(s)) are found, the user cannot proceed further. Once correct ports are found, the software saves the selections on a file so it will not be necessary to repeat this process.

The software can also be operated in 'simulation' mode. The simulation mode allows user to feel and try around the software, but will not do anything real or physical.

Once all instruments are found and confirmed by the two checkboxes, it is time to select the gas(es) to be used. The mass flow controllers (MFCs) may be calibrated for more than one type of gas. Even in the case the MFC only includes one gas, the gas(es) must be selected before the mixer is ready for real use. The gases selected must correspond to the gases physically connected to the mixer; otherwise the calculation about the mixture will not be accurate.

3.2 External fluid container

The external fluid container is not included, but a short PTFE fluid input line (1/16") is included. This line is to be connected to the C_{in} and the other end of the line submerged in the fluid to be used. The line should be submerged in the fluid container in a reliable way so that it is not possible accidentally to remove the line.

Depending on the container design, the fluid may or may not be in contact with ambient air, which will dissolve into the fluid, and corresponding amount of dissolved gases will end up into the made mixture. Oxygen has solubility of 0.009 g O_2/ liter of H_2O at 25°C and 1013 mbar. The fluid designer of the software allows for taking this into account.

If any dissolved gas is undesired, a fluid container with heater, and/or protective gas must be considered.

3.3 Syringe

12.5 µL Syringe is included in the delivery, but it is not installed on the mixer in order to protect the sensitive syringe from damage and particles. The syringe is installed to the front side of the mixer when the syringe lever is at the bottom position. The position can be controlled from the Debug tab.

3.4 Priming the syringe

When first installing the syringe, or after some use (due to gas solubility changes due to temperature gradients) gas may form bubbles in the syringe.

A good way to remove gas bubbles from the syringe is to first prime the system with fluid, then remove the syringe and submerge it in a fluid. Under the fluid remove the plunger from the tube until all bubbles are removed, and then installing the syringe back to the pump.

For long term tests using lot of fluid, in case the fluid is stored in closed vessel, a solution to compensate for the reducing volume/pressure must be considered, such as using IV bags with purified water.

Use the Debug & Development tab and the “Extend plunger all the way down” button to have suitable access to mount or dismount the syringe.

3.5 Priming the mixer

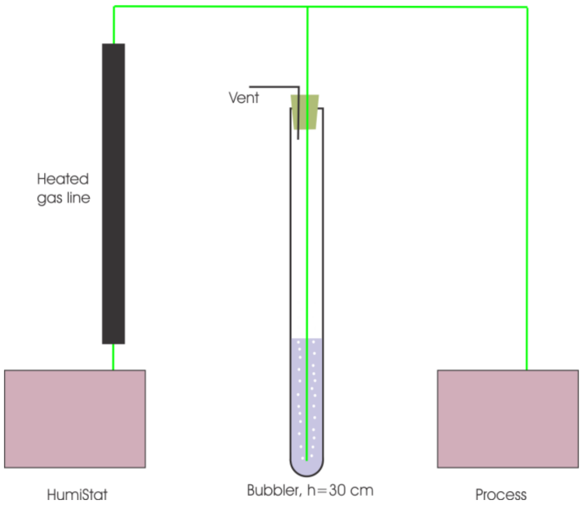
Ensure the heated gas line still disconnected (alternatively remove it) and that the syringe is in place and primed. Open the software and proceed through the setup as instructed elsewhere. From the Debug & Development-tab click the Pump fluid only button and wait. The pump will go through multiple input/output cycles. Wait until the mixer falls silent. Repeat, until the fluid stops coming out (during fluid change) or until the fluid is visible at the output. It may take multiple cycles of "click and wait" until the volume is mostly clear of fluid. It may require several rounds of priming the syringe and the whole fluid system to get rid of all gas trapped in the system. Any bubbles in the syringe will affect the accuracy and continuity of the mixture.

All this needs to be done also when changing from one type of fluid to another.

3.6 Bending the fluid line

It is advised to slightly bend the fluid supply line, so that it rests against the inside of the heated gas line wall. This ensures good heat transfer from the gas line wall to the fluid delivery line and to the fluid itself. If the fluid delivery line is ‘hanging’ in the middle, surface tension, gravity and flow rate may form oscillating droplet-system. Dispensing the fluid directly on the surface of the heated gas line ensures smoother operation.

3.7 Pressure relief



The amount of gas mixture coming out of HumiStat may vary between different steps.

Some instruments that can be used with HumiStat (such as thermogravimeters) have their own mass flow controllers limiting the amount of ingoing gas.

If the out-flow of gas from HumiStat is limited, the operation of the mixer is compromised, and the mixture will not be what was designed.

A pressure relief valve between the two instruments will alleviate this problem.

In the case where the process pressure is atmospheric, a simple relief valve system could be just a glass tube with some low-vapor pressure fluid such as mineral oil. Increasing the bubbler height and/or the fluid density allows for higher pressure and driving force. NORECS sells such simple pressure reliefs with inert, high density (1.86 g/cm^3) mineral oil.

For example, a 30 cm column with fluid of 1.86 density gives 0.3m * 9.81 m/s^2 * 1860kg/m^3 = pressure in pascals = 0.055 bar over atmospheric pressure.

This 0.055 bar overpressure is enough driving force to push the made mixture through most typical instruments, and can be increased by increasing the length of the column.

In case explosive gases are used, such bubbler must be made of non-shattering material (and not from glass), or placed inside safety confinement. The bubbler vent must be connected to appropriate ventilation system that corresponds to the types of used gases.

The pressure relief bubbler described here is not suitable to be used with high steam content; such use requires another type of pressure relief design, outside the scope of this manual.

Always program HumiStat to make somewhat more mixture than the instrument behind is using, this is easily verifiable by the column bubbling the excess mixture away.

3.8 Condensation

When the mixer is used with C-component, the heated gas line is always necessary and must be set notably above the boiling point of the used fluid to ensure that all the added fluid remains in gaseous form.

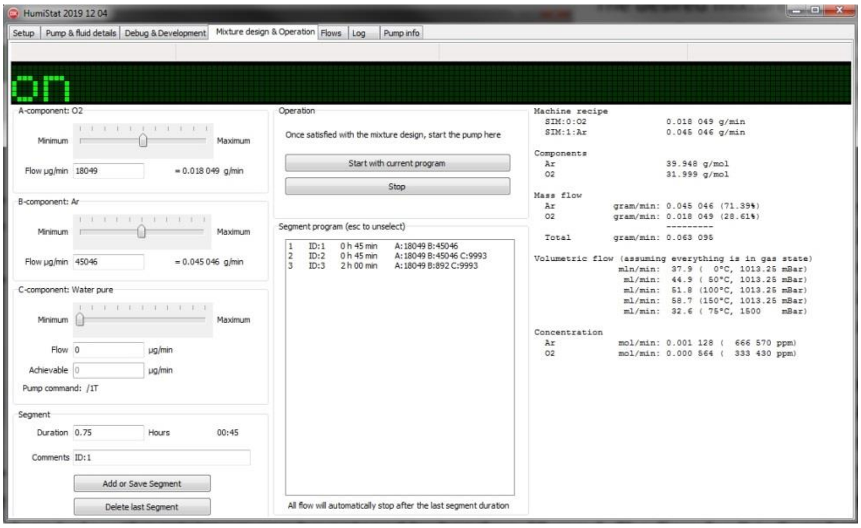
Connections from the heated gas line to process, instruments, etc. will also have to remain above the boiling point or condensation will happen. Insulation and heating must be solved by the end user. Sign for condensation in the line is irregular for pulsed flow.

The “Pump and fluid details” tab has “Artificial upper limit for fluid component in the mixture” field with unit ppm. Using a value in this field will prevent the user accidentally designing mixtures with higher C-content than allowed here.

If the process or instrument is sensitive to condensation, in addition to the artificial ppm limit the user should consider “cold trap” before the process or instrument.

4 Software features

4.1 Mixture calculations



The desired mixture is designed and executed on this view. It is possible to change the amount of any of the three components within the range specific for the instruments, as defined during order.

Values for gases A and B, and fluid C can be changed using the sliders or by typing into the corresponding text field. Unit of these contributions are given as µg/min. The 0 value is used to specify that none of the component in question should be added to the mixture. The A component can be freely selected to any value between 0 and the maximum flow of the mass flow controller A. With slider the value is between minimum and maximum of the mass flow controller, but values below the minimum can be entered by hand. For component A, the possible flow is [0-max]. The flow for B is 0, or between the minimum and maximum flow for the mass flow controller B, the possible flow is [0, min-max]. The flow for component C has some restrictions due instrument resolution and closest possible flow to the desired flow is shown in the 'Achievable' field.

The pump requires time for periodically retracting the syringe, and additionally the pump only understands pumping speeds given in full integer frequencies. As result the exact amount of fluid pumped is not same as the desired amount, but slightly off. The correction is applied automatically and the value in the field 'Achievable' is used in the calculations.

On the right side of the tab various details about the mixture can be seen. Once the mixture is as desired, the user needs to decide for how long this mixture is made. Enter duration in hours to the Segment field, and click "Add or Save Segment". A segment with another composition can be now designed and added to the segment program. Once all desired segments are added to the program, the whole program can be initiated by clicking "Start with current program".

Before user have started the segment program it is possible to view and edit segments by clicking them. This recalls the slider positions, number field values and and the info about the mixture on the right.

On the 'Mixture under design' the components A, B and C and their molar masses, and how many grams of each is being added to the mixture per minute are shown. Total amount of moles is calculated from this information. Partial pressure of each component is calculated and displayed. Partial pressure, partial volume and mole fraction are identical physical quantities, and are the most precise way to define a gas mixture.

For reference and convenience, the total volume of the mixture per minute is also displayed (for several conditions). The first unit is mln/min, aka 'Normalized' volume, meaning in this case, that if the mixture was at 0°C, and in case the fluid was a gas at that temperature, and in case the pressure was 1013.25 mbar, the mixture would occupy the given volume. Note that this is only one of the two dozen 'standard' volumetric definitions in world, and in this context means: 0°C at 1013.25 mbar pressure, designated here as 'normalized'; mln aka millilitres normalized.

The mixture volume per minute is also displayed for 50°C, 100°C and 150°C and the aforementioned pressure. For our friends in Mexico City or other elevated places with ambient pressures such as 750 mbar, or for users with pressurized processes, a 'custom conditions flow' is also displayed. User can define both the custom temperature and the custom pressure in the in the pump & fluids tab, and the software will display the actual volume of mixture per minute in those conditions.

```
Machine recipe
  SIM:0:02                  0.018 049 g/min
  SIM:1:Ar                  0.045 046 g/min
  SIM:2:Water pure          0.000 995 g/min

Components
  Ar                        39.948 g/mol
  02                        31.999 g/mol
  Water pure                18.015 g/mol

Mass flow
  Ar              gram/min: 0.045 046 (70.29%)
  02              gram/min: 0.018 049 (28.16%)
  H20             gram/min: 0.000 995 (1.55%)
                            ---------
  Total           gram/min: 0.064 090

Volumetric flow (assuming everything is in gas state)
                 mln/min:  39.2 (  0°C, 1013.25 mBar)
                  ml/min:  46.3 ( 50°C, 1013.25 mBar)
                  ml/min:  53.5 (100°C, 1013.25 mBar)
                  ml/min:  60.7 (150°C, 1013.25 mBar)
                  ml/min:  43.5 ( 30°C, 1013    mBar)

Concentration
  Ar             mol/min: 0.001 128 (  645 499 ppm)
  02             mol/min: 0.000 564 (  322 889 ppm)
  H20            mol/min: 0.000 055 (   31 612 ppm)

             *******************************************
             *   for 30°C, 1013 mbar
             *      ppm @ 100% RH ->    41 925 ppm
             *        Current ppm ->    31 612 ppm
             *                 RH ->        75 %
```

4.1.1 Relative humidity

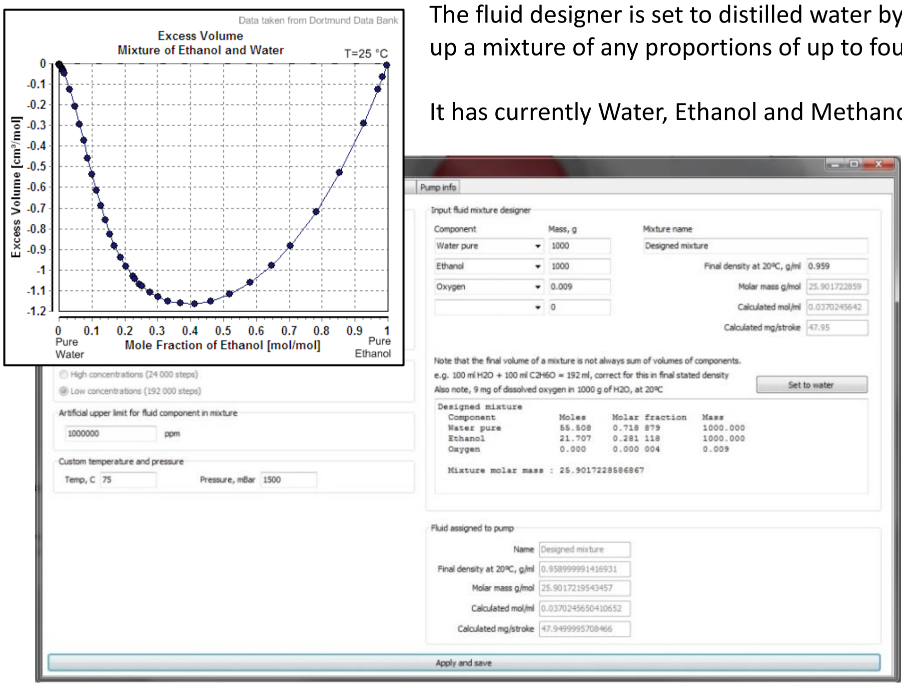
If the made mixture contains H_2O, then the mixture details-area also shows relative humidity (%RH) for the custom conditions (temperature and pressure) defined in the 'Pump and fluid details' tab.

4.1.2 Saved program

Any time when the 'Start with current program' button is pressed, the software automatically saves the segment program, and the fluid design into a text file in \userdata folder. This file is meant to be a reference for the user of what the mixer has been doing each time it is used.

This file cannot be opened back to the mixer, instead the design must be created by hand each time to ensure safety of the operation. Many users use explosive or toxic gases, so this convenience is disabled by design.

4.2 Fluid designer



The fluid designer is set to distilled water by default, but allows user to make up a mixture of any proportions of up to four components.

It has currently Water, Ethanol and Methanol as fluids, and any new fluid can be easily added to the software on user request.

The mixture can also include dissolved gases such as the 9 mg of Oxygen per liter of fluid present in room temperature water.

Everything is calculated automatically, except the final mixture density, which the user must provide. As you may know, the total volume of mixed polar fluids (such as water) is not the sum of the volumes of the reagents, while the mass is. The density of the mixture is important in knowing how much fluid by mass the syringe (volumetric device after all) adds to the made gas mixture. For the density, one would weigh the components, and measure the volume after mixing to verify the volume deviation.

4.3 Pump log tab

The syringe periodically will refill, this takes roughly 1.6 seconds, and will affect the mixture stability. On the mentioned tab some calculation info is shown, and the value for 'Syringe refill interference cycle' will give the frequency of the syringe refill event in minutes.

In HumiStat v2 this information is obsolete and not to be considered.

4.4 Fluid content

The ppm fluid content can be limited on the settings tab, to avoid accidentally introducing more fluid than the process can handle.

5 Operation

5.1 Modes

The mixer can be in few distinct modes as follows: Simulation, Stopped, and Running. In simulation the software can be tested even without the physical instrument. When instrument is present and validated the mixer can be either stopped or running. Stopped does nothing, and when running, the mixer performs the assigned segment program and then goes to stopped mode after the program is finished.

5.2 Segment program

Each designed mixture can be added to segment program with notes and duration. Segments can be edited and deleted. Once the full segment program is ready, clicking the 'Start with current program' will start performing it from the first segment. The mixer will form a mixture as designed and keep producing this until the duration of that segment is reached. If another segment exists afterwards it is performed, otherwise the mixer is stopped. Editing segments that are already performing will not have effect on the made mixture anymore.

5.3 Stop

Clicking the stop button will stop performing the segment program. In case of communication failure, software error or emergency, all flow will stop when power to the mixer is turned off.

5.4 Accuracy, stability and settling times

5.5 Accuracy

The HumiStat uses high accuracy fluid pump and real gas calibrated mass flow controllers for precision control of inputs. The MFC is self-regulating with PID algorithm and the pumps speed is calculated and kept constant. There is no feedback loop; knowing accurately what is added to the mixture is more accurate than measuring the output and having feedback loop. Measuring the output can be done by the end user to validate the made mixture, but as the mixer can have various gases, gas ranges, fluids, and mixture temperatures, it is not possible to have all possible combinations covered by a sensor.

5.6 Stability

Every now and then the syringe needs to retract to pull more fluid in, this step takes ~1.6 seconds. This pulsing of input may affect the stability of the mixture on some settings, but by the time the mixture reaches the process or the sample in the ProboStat, the local variations caused by the pulsing have largely evened out as result of gas diffusion in the volume leading to the process. The tube itself is corrugated shape, with lot of small nooks and coves to disturb and buffer the flow of the mixture, and the process or sample holder volume, and high temperature, will further dilute and stabilize any possible variations.

5.7 Settling times

While added gas supply line length and volume help improving the stability of the mixture, the same also increase the time required for the mixture to settle into a new setpoint.

Good practice is to use the mixer with long initial flush step at the beginning, and start with the most diluted and dry segments first and advance towards richer mixtures. If it is necessary to go down on A- or fluid concentration, add a dilution segment into the program between the real steps. Few minutes of high flow of gas B already brings down the concentrations significantly in the % range. For ppm range the flush must be longer and/or larger flow.

If an instant transition from one mixture to another is paramount, this can be achieved by using two HumiStat mixers both producing different mixtures, and a with a crossover valve selecting which mixture is led to the process.

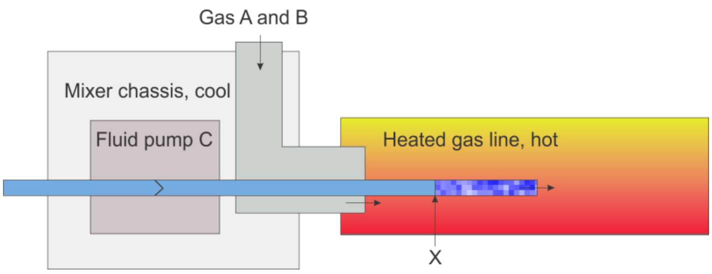
When a mixture is designed and applied, the produced mixture at the output of the heated gas line will not instantly be what is specified. The liquid pumping speed and the gas line heating must first reach equilibrium, before that the humidity may be less or more than expected. This delay and fluctuation will be visible from other process parameters and will settle in some minutes, depending on a number of other things. One can speed this transition by adding a transition-step into the program, with high flows and same or exaggerated properties of the target mixture, for example to go to 1% RH first send 5 minutes of completely dry gas.

5.8 Low fluid concentrations

Always measure from dry gases towards wet gases, with a long flush with dry gas before actual measurement.

When dry gases are necessary and there is no plan to use the fluid component C, consider 'priming' the 'fluid system' with gas instead of a fluid.

5.8.1 Background information about the fluid evaporation



The fluid (component C) is injected to the heated gas through 1/16 inch stainless steel tube. This tiny tube enters the heated gas line tube and the two tubes overlap in the hot zone. When adding large amounts of fluid, the fluid flows into the heated gas line and evaporates there.

For low amounts of added fluid; it will take a while to reach equilibrium. While the speed of injection of fluid is regulated and known, the evaporation of the already present fluid in the fluid delivery line may back up in the tube (marked with point X) and cause higher than desired C-content of the made mixture. The inner volume of the fluid delivery line is small, but not insignificant. Dry gases, their flow rate, and heat contribute to the point-X moving left while the pumped additional fluid contributes to point-X moving right. Mixture will not be accurate until equilibrium between these forces is reached. Again, good policy is to move towards elevated C-contents in the segment program to avoid this issue, with one exception, explained below.

For completely dry gas mixture the evaporation point-X will keep traveling back left until it reaches the mechanical valve at the fluid pump. In the early phases of this all-dry step there may be humidity in the mixture. Additionally, if the next step is one with low fluid content, it will take time for the fluid delivery tube to fill in. The lower the desired humidity level is, the longer it will take for the volume of the fluid delivery tube to fill in. Also the longer the previous dry step was, will also move the point-X further and make the filling take longer.

5.9 Normal humidity

No special arrangements required.

5.10 High fluid concentrations

In general steam can be wet or dry steam, wet meaning mist (floating droplets). The mixture is wet steam at first, as the injected fluid boils on the wall of the gas line. These tiny droplets are carried away in the flow. The less fluid is added to the mixture the quicker the small droplets evaporate completely and form dry steam.

If the made mixture is led to a ProboStat sample holder or in other high temperature process where the temperature is significantly higher, all droplets evaporate by the time the mixture reaches the process.

Cold areas on the gas system before the process will cause condensation, and may end up causing the flow of gas mixture to be erratic (mixture bubbling through the condensed liquid). In such cases add insulation and/or external heating to parts of the system where condensation is suspected or observed.

5.11 Junction insulation

The junction between the heated gas line and the Process device or ProboStat is a potential weak point in the system. By default there is no heating, and no insulation cover in the area. Stainless steel itself does not conduct heat very well, and the amount of energy carried by the steam is not enough to heat this exposed area. Therefore, it is necessary to insulate this area well after attaching the heated gas line to ProboStat. In case junctions require better insulation use additional insulation such as glass fibre, or contact NORECS for insulation pads and/or loose glass fibre. If the connection is unmade and made repeatedly it is advisable to acquire more consumables for this insulation. Pieces of rock wool and thick aluminium foil make for easy and cheap although not so good-looking insulation. Gloves and mask are advisable when handling any insulation fibres, as the fibres irritate skin and are harmful if inhaled.

It may even be necessary to add external heating to this point in case condensation here is observed. This strongly depends of the purpose of the application and surroundings, so HumiStat tries not to solve this but leaves the issue up to the end user.

5.12 Flushing the mixer

In some cases, the gas A can alternatively be calibrated for both the fuel and the oxidant, such as H_2 and O_2. With such mixer the used gas should not be switched directly from one to the other, but instead inert intermediate gas should be used in between to flush the mixer, as follows:

1. Connect inert gas such as N_2 to the gas inlets A and B.
2. Start the mixer software, and select gases for A and B from what is available, even if the list does not match the connected gases.
3. When asked to confirm the gas A and B, click OK.
4. Design a mixture using maximum amount of gas A and gas B, and run the mixture for a few minutes. The gas lines are now filled with N_2 and whatever was in the mixer earlier is now sufficiently diluted.
5. Turn off the mixture, the software, and start over, this time with the intended gases and correct gas lines connected.

5.13 Heated gas line temperature

The PID controller (Wachendorf) mounted on the front panel, maintains a set temperature (setpoint) in the heated gas line. The user may select suitable setpoint using the buttons on the controller arrow up increases the setpoint, arrow down decreases it. The unit of the setpoint is °C.

6 Advanced features in the .ini file

On the first run, or anytime when the software cannot find .ini file in the same folder where it is running, the software will create a .ini file with default settings. It is a text file that can be opened with notepad or similar text editor but this is discouraged approach.

[Syringe]
Steps=24000
MaxSpeed=1000
Volume MicroLiter=12.5
[Logging]
Type[Off|File|Live]=Off
[Graph]
Points=1000
Average sample size=358
[MFCA]
DynamicRangeCull=20
[MFCB]
DynamicRangeCull=10
[Custom flow conditions]
TemperatureC=75
PressuremBar=1500
[Fluid]
Mixture name=Water pure
Mixture custom density=0.997735023498535
Mixture molar mass=18.0152797698975
Max PPM=1000000
Mix1ID=gH2O
Mix1Mass=1000
Mix2ID=
Mix2Mass=0
Mix3ID=
Mix3Mass=0
Mix4ID=
Mix4Mass=0

6.1 Logging

The software can create a log of events and save it as a file to HumiStat home folder. This feature requires CSDispatcher.exe to be located in the same folder as HumiStat. The aforementioned can be downloaded in from the Tools folder from http://www.norecs.com/work/_files/__PUBLIC_FILES__/software/HumiStat/

The feature is enabled by changing the ini file [Logging] section Type[Off|File|Live] value to File

6.2 Moving average of flow of gas A

Moving average describes well the buffers of gas line volume and process volume. The size of this moving average can be defined as samples. The default value is 358 samples, and one sample with HumiStat on average computer takes less than a second. To help the user, the software displays the resulting moving average value and the duration (once all the 358 samples have been taken).

6.3 Flow graph

Flow of gas A and B as well as the moving average is displayed on a graph on a separate tab. The amount of visible points is kept to a default of 700, changeable in the ini file, in order to keep the software running fast.

6.4 Minimum flow range limit

The DynamicRangeCull settings narrow down the available flow range area each MFC has, from the lower side. Increasing those values in the .ini file may help establishing smoother flow for the gases, when other means such as lower gas line pressure does not help. The values should not be changed without consulting NORECS. In any values outside 0 to 50 will cause errors or unwanted mixer behaviour.

7 Use tips

7.1 Fuel cells

Using two separate HumiStat units allows full control of atmosphere on both sides of the cell.

7.2 Chemical gradient - crossover valve

When using separate atmospheres on each side of a sample, a good way to validate results (such as voltage over sample) is to use a crossover valve. Crossover valve allows user to quickly invert the used gases during measurement reversing the measured value. This 'Reverse and average' can also be used to identify offsets (such as thermovoltage on the measurement wires) that would otherwise possibly go unnoticed.

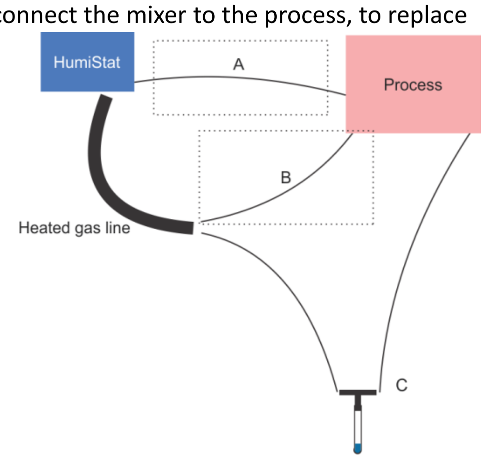
7.3 Custom gas supply line

In some cases the heated gas delivery line is too bulky, and the bend-radius is not small enough. For such cases the user may replace the heated gas line, provided the original functionality of the heated gas line in understood.

First of all, the heated gas line has significant volume, and specific uneven internal shape, and these features ensure that the input gases mix well before they come out from the gas line. This is more important if the user has a process that has a small internal volume, quick reactions, or the mixture has extreme dilution ratios, such as 50 ppm of O_2 in N_2. On the other hand, if the process has a large volume, if the mix of gases is in the % range, or if the process reacts slowly, then the volume and delay of the heated gas supply line is not important.

The second purpose of the heated gas line, and the heat it has, is to evaporate the input liquid. Small amounts of fluid will evaporate into the dry gas without additional heat, so mixtures with low humidity it is possible to use the mixer without the heated gas line.

Copper tube of 1/4 inch diameter can be made into a specific shape to connect the mixer to the process, to replace the heated gas line (A) or to act as an adapter (B and C). For option (A), to check if the intended mixture will work fine without the heated gas line, leave the new line unconnected from the process, run the mixture for few hours, and then check for liquid in the gas line. If no fluid is found, the setup works, at least in atmospheric pressure.



Better way is to use the heated gas line anyway, and then add suitable adapter gas line to connect the end of the heated gas supply line to the process (B). If the humidity is too high, the user may experience condensation in the gas line (B), and not be aware of it. Therefore it is recommend to add a low point to this gas line, with a small T-join, and add a closed off transparent vial at the bottom (C). This way any possible condensation will be visible and the user will know to add more insulation or heating to the adapter gas line arrangement, or lower the fluid component in the mixture, or control some other factor having an impact.

8 Specification

The exact specifications depend on the end user requirements, and are given in more detail in the HumiStat specification brochure, what follows is generic.

8.1 Mass flow controllers

In general the mass flow controllers used (Vögtlin) are real gas calibrated and considered the most accurate in the market with absolute accuracy better than 0.3% FS and 0.5% reading.

8.2 Fluid pump

24000 steps to control 12.5 µL syringe

8.3 HumiStat definition

- Dynamic range gas mixer with humidity control: ratios from ppm to 100%
- Two gas inputs (A and B), one fluid input (C)
- Fluid refill during continuous operation
- Mixture calculated from input amounts
- High performance input gas controllers, accuracy 0.3% full scale & 0.5% Measured value, real gas calibrated
- Control through customer PC, software & USB cable included
- PID regulated gas line heating for 1.2 m gas line, user temperature setpoint, RT to 150°C
- Including power supply
- Any variations on request (surcharge)
- Available gases: Air, Ar, C_2H_2, C_2H_4, C_2H_6, C_3H_8, C_4H_6, C_4H_{10}, $CHClF_2$, CF_4, CH_4, CO, CO_2, D_2, H_2, He, Kr, N_2, N_2O, Ne, O_2, SF_6, Xe, i-C_4H_{10}, CCl_2F_2, R-134a, NH_3, pre-mixed gases such as 5%H_2 in Ar. Some gases such as mixtures will have price surcharge and lower accuracy.

8.4 Inputs

Gas line A and gas line B inputs are 1/8" (inch) Swagelok brass bulkheads, part number B-200-61. These connect to a copper or PTFE gas line of size 1/8". Gas line is not included.

Fluid line C input is a Swagelok brass bulkheads, part number B-100-61. These connect to a PTFE gas fluid line of size 1/16". A short piece of PTFE line is included.

8.5 Output

The gas mixture output is a 1/4" stainless steel tube with Swagelok nut pre-installed. Some systems have adapter to 1/8" tube included.

8.6 Imperial sizes

The inch based sizes are selected due to wide use of imperial gas line equipment in many laboratories, and to ensure compatibility with ProboStat sample holder.

We are happy to include suitable adapters to any metric gas lines. Specify the sizes you are using during your enquiry, and we can add the suitable adapters to our quote.

8.7 Pressure

The mixer can operate up to 6 bars pressure

Haslevollen 3E
NO-0579 Oslo
Norway

9 Unpacking

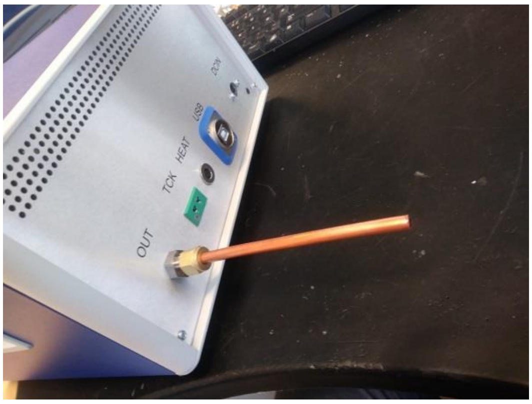
The mixer comes in a box of 60 x 60 x 60 cm and weight 10 kg.

Inside is packed:

- This page
- HumiStat mixer in a transparent bag (15 x 23 x 28 cm and 4 kg)
- Heated gas line
- Power supply
- Input cable for power supply (optional, depending on destination country)
- Piece of 1/16" PTFE line for fluid input C in a transparent bag
- Copper piece protecting the fluid output on the mixer
- 1/4" to 1/8" Swagelok tube adapter (with orders including ProboStat sample holder only)
- USB cable
- PID controller manual
- CE declaration of conformity for the mixer
- CE declaration for power supply

Before disposing of the packaging, make sure you have all the mentioned items.

The software and the manual can be downloaded from http://www.norecs.com/index.php?page=Software -> HumiStat -> Folder with the serial number of HumiStat in question. Or better yet to ensure you get the latest version ask for it at post@norecs.com



On the back side of the mixer a piece of copper tube is placed over the fluid outlet tube. The purpose of this piece is just to protect the fluid line from bending while in transit. The copper piece can be discarded.

You are now ready to proceed to the setup-chapter.

EC Declaration of Conformity

Thursday, 16 August 2018

Manufacturer: NORECS AS

Address: Haslevollen 3E, NO-0579 Oslo, Norway

We declare under our sole responsibility that the products:

Model:	HumiStat
Description:	Low pressure, mass flow controller -based gas mixing system for scientific measurements.

Are in conformity as follows:

- Compliance with this directive is under Sound Engineering Practice (SEP).
- The equipment includes external mains adapter supplying the 24 VDC required by the equipment. This adapter falls under both the EMC (2014/30/EU) and LVD (2014/35/EU) directives. The power supply is CE marked on its surface, and a separate declaration of conformity for the adapter is available on request, and also included in this documentation (CE Power supply GST220A24-R7B.pdf)
- The product operates at near atmospheric pressure. The total volume of the part of the mixer that may be at elevated pressures is significantly lower than 1000 cm^3 and therefore falls outside category I of the pressure equipment directive (PED 2014/68/EU), and thus does not require CE marking related to PED.
- The product operates with 24 V DC, lower than the 50 V defined in (LVD 2014/35/EU), and therefore does not require CE marking related to LVD.
- Complies with 2011/65/EU (RoHS directive)

Robert Jalarvo
NORECS AS

220W AC-DC Single Output Desktop GS220 series

■ Features :

- Universal AC input / Full range
- 3 pole AC inlet IEC320-C14
- Built-in active PFC function, PF>0.91
- Protections: Short circuit / Overload / Over voltage / Over temperature
- Fully enclosed plastic case
- Approvals: UL / CUL / PSE / TUV / BSMI / CCC / CB / FCC / CE
- Class Ⅰ power (with earth pin)
- LED indicator for power on
- No load power consumption<0.5W
- ErP step2 compliant (level Ⅴ)
- NRCan compliant
- MEPS compliant
- Meet EISA 2007 (Energy Independence and Security Act)
- 2 years warranty

(except for 48V)

SPECIFICATION

ORDER NO.		GS220A12-R7B	GS220A15-R7B	GS220A20-R7B	GS220A24-R7B	GS220A48-R7B
OUTPUT	SAFETY MODEL NO.	GS220A12	GS220A15	GS220A20	GS220A24	GS220A48
	DC VOLTAGE Note.2	12V	15V	20V	24V	48V
	RATED CURRENT	15A	13.4A	11A	9.2A	4.6A
	CURRENT RANGE	0 ~ 15A	0 ~ 13.4A	0 ~ 11A	0 ~ 9.2A	0 ~ 4.6A
	RATED POWER (max.)	180W	201W	220W	221W	221W
	RIPPLE & NOISE (max.) Note.3	80mVp-p	100mVp-p	150mVp-p	180mVp-p	240mVp-p
	VOLTAGE TOLERANCE Note.4	±5.0%	±5.0%	±4.0%	±3.0%	±2.0%
	LINE REGULATION Note.5	±1.0%	±1.0%	±1.0%	±1.0%	±1.0%
	LOAD REGULATION	±5.0%	±5.0%	±4.0%	±3.0%	±2.0%
	SETUP, RISE TIME Note.7	2000ms, 20ms / 230VAC 2000ms, 20ms / 115VAC at full load				
	HOLD UP TIME (Typ.)	20ms / 230VAC 20ms / 115VAC at full load				
INPUT	VOLTAGE RANGE Note.8	90 ~ 264VAC 127 ~ 370VDC				
	FREQUENCY RANGE	47 ~ 63Hz				
	POWER FACTOR (Typ.)	PF>0.91 / 230VAC PF>0.98 / 115VAC at full load				
	EFFICIENCY (Typ.)	90%	90%	92%	93.5%	94.5%
	AC CURRENT (Typ.)	4A / 115VAC 2A / 230VAC				
	INRUSH CURRENT (max.)	120A / 230VAC				
	LEAKAGE CURRENT(max.)	1.5mA / 240VAC				
PROTECTION	OVERLOAD	105 ~ 135% rated output power Protection type : Hiccup mode, recovers automatically after fault condition is removed				
	OVER VOLTAGE	105 ~ 135% rated output voltage Protection type : Shut down o/p voltage, re-power on to recover				
	OVER TEMPERATURE	95℃ ±5℃ (TSW1) detect on heatsink of power transistor Protection type : Shut down o/p voltage, recovers automatically after temperature goes down				
ENVIRONMENT	WORKING TEMP.	-30 ~ +60℃ (Refer to "Derating Curve")				
	WORKING HUMIDITY	20% ~ 90% RH non-condensing				
	STORAGE TEMP., HUMIDITY	-40 ~ +85℃, 10 ~ 95% RH				
	TEMP. COEFFICIENT	±0.03% / ℃ (0~50℃)				
	VIBRATION	10 ~ 500Hz, 2G 10min./1cycle, period for 60min. each along X, Y, Z axes				
SAFETY & EMC (Note. 6)	SAFETY STANDARDS	UL60950-1, TUV EN60950-1, BSMI CNS14336, CCC GB4943, J60950-1(except for 48V) approved				
	WITHSTAND VOLTAGE	I/P-O/P: 3KVAC				
	ISOLATION RESISTANCE	I/P-O/P:100M Ohms / 500VDC / 25℃ / 70% RH				
	EMC EMISSION	Compliance to EN55022 class B, EN61000-3-2,3, FCC PART 15 / CISPR22 class B, CNS13438 class B, GB9254, GB17625.1				
	EMC IMMUNITY	Compliance to EN61000-4-2,3,4,5,6,8,11, light industry level, criteria A				
OTHERS	MTBF	191.3K hrs min. MIL-HDBK-217F(25℃)				
	DIMENSION	210*85*46mm (L*W*H)				
	PACKING	1.1Kg; 12pcs/14.2Kg/0.73CUFT				
CONNECTOR	PLUG	See page 2 ; Other type available by customer requested				
	CABLE	See page 2 ; Other type available by customer requested				
NOTE		1. All parameters are specified at 230VAC input, rated load, 25℃ 70% RH ambient. 2. DC voltage: The output voltage set at point measure by plug terminal & 50% load. 3. Ripple & noise are measured at 20MHz by using a 12" twisted pair terminated with a 0.1uf & 47uf capacitor. 4. Tolerance: includes set up tolerance, line regulation, load regulation. 5. Line regulation is measured from low line to high line at rated load. 6. The power supply is considered as an independent unit, but the final equipment still need to re-confirm that the whole system complies with the EMC directives. 7. Length of set up time is measured at first cold start. Turning ON/OFF the power supply may lead to increase of the set up time. 8. Derating may be needed under low input voltage. Please check the derating curve for more details.				

File Name:GS220-SPEC 2013-05-06

10 Order details form

	Example	Customer specifications
HumiStat dilutes gas from mass flow controller A with gas from mass flow controller B, and adds evaporated fluid to made mixture; allowing a matrix of mixtures A x B x Fluid with dynamic ratios between these components.		
Desired gas(es) for mass flow controller A Surcharge for more than 4 gases in total (A+B)	CH4, H2	
Desired gas(es) for mass flow controller B	N2	
One of the features of HumiStat is that gas A is diluted with gas B. If very low gas A concentration important?	Yes / No or I need ppm levels of CH4 in N2	
Desired total flow of mixture mln/min	100 mln/min	
Pressure in the gas delivery lines in bar(a). bar(a) = atmospheric/ambient/absolute	2 bar(a)	
Pressure after the mixer, pressure in the process or the experiment, bar(a)	My bio-reactor is at ambient pressure	
Adapters The mixer has Swagelok 1/8" gas inputs, 1/16" fluid input, and 1/4" mixture output.	Please include suitable adapters. Our lab has 6 mm PTFE gas delivery lines. My application has 8 mm input line.	
Please explain the intended purpose for the mixer. Please identify which features; what area of the mixing range etc. is the most important feature.	Vary CH4 and H2O in N2 around 1:10 region, low flows <50 mln/min, for fuel cell testing. OR Very low amounts of H2 in Ar, and it needs to be as accurate as possible, I do not care about what the total flow is. OR Full range of steam	
Other remarks		