

## 1. Product sizing for gas mixtures

When product sizing for gas mixtures, you need to enter the density and the viscosity for the gas mixture in the sizing tool.

SITRANS FC Sizing Program - Siemens A/S, Flow Instruments

### Selecting the right flowmeter for the job

Please enter the relevant data in the fields below and press "Next" when done.  
The data will be used to determine the best SITRANS FC mass flowmeter size for your application.

Gas: Other gas

Gas Name: mix of oxygen, argon and helium

Minimum flow rate: 1 kg/h

Maximum flow rate: 10 kg/h

Operating pressure: 10 bar

Temperature: 25 °C

Density at operating pressure: kg/m<sup>3</sup>

Viscosity: cP (mPa\*s)

No. of atoms in gas molecule: >2 atoms

Max allowable pressure drop: 1 bar

Preferred meter size: (This field can be left blank)

Next > Reset

Please note: The pressure must be entered as absolute pressure. Example: BarA = BarG + 1

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Maybe your customer does not know the values. Then you need to calculate them. The following pages describe how to do this.

## 2. Average density calculation for gas mixture

The first step is to calculate the average density of the gas mixture. Use the following formula:

$$\rho_m = \frac{(\rho_1 v_1 + \rho_2 v_2 + \dots + \rho_n v_n)}{(v_1 + v_2 + \dots + v_n)}$$

$\rho_m$  : density of gas mixture at operating conditions

$\rho_1 \dots \rho_n$  : densities of the individual gas components at operating conditions

$v_1 \dots v_n$  : volume share of each gas component (m<sup>3</sup>, ft<sup>3</sup> etc.)

## Example:

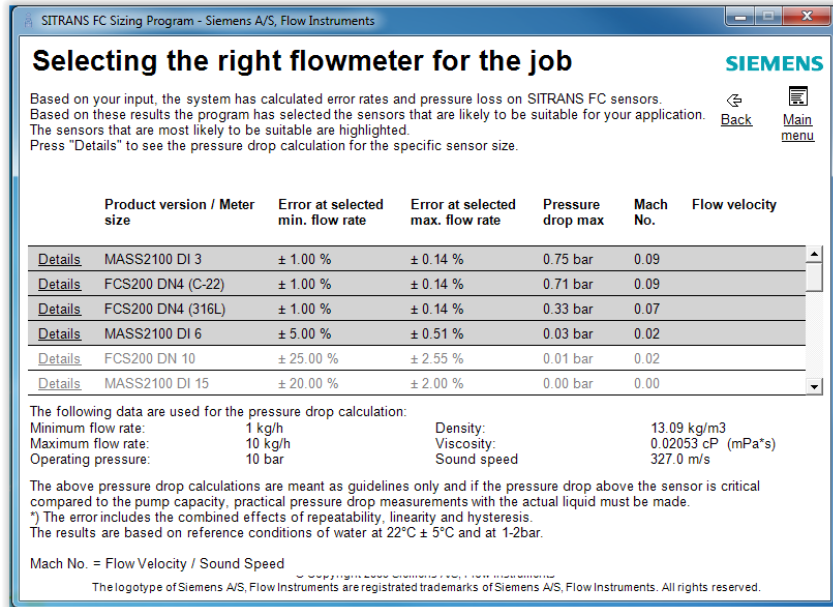
A gas mixture consists of oxygen, argon and helium. They have an equal volume share of 33.3 %. The process pressure is 10 bara and the temperature is 25 °C. With this knowledge you can use the flow sizing tool to calculate the individual gas densities and viscosities at the operating conditions.

The screenshot shows the 'SITRANS FC Sizing Program - Siemens A/S, Flow Instruments' window. The title bar includes standard window controls. The main content area is titled 'Selecting the right flowmeter for the job' and features the Siemens logo in the top right corner. Below the title, there are instructions: 'Please enter the relevant data in the fields below and press "Next" when done. The data will be used to determine the best SITRANS FC mass flowmeter size for your application.' To the right of these instructions are 'Back' and 'Main menu' buttons. The input fields are as follows: 'Gas:' is a dropdown menu set to 'Oxygen (O2)'; 'Minimum flow rate:' is a text box with '1' and a unit dropdown set to 'kg/h'; 'Maximum flow rate:' is a text box with '10' and a unit dropdown set to 'kg/h'; 'Operating pressure:' is a text box with '10' and a unit dropdown set to 'bar'; 'Temperature:' is a text box with '25' and a unit dropdown set to '°C'; 'Max allowable pressure drop:' is a text box with '1' and a unit dropdown set to 'bar'; 'Preferred meter size:' is an empty dropdown menu with the note '(This field can be left blank)'. At the bottom of the form are 'Next >' and 'Reset' buttons. A note at the bottom states: 'Please note: The pressure must be entered as absolute pressure. Example: BarA = BarG + 1'. The footer contains copyright information: '© Copyright 2009 Siemens A/S, Flow Instruments. The logotype of Siemens A/S, Flow Instruments are registered trademarks of Siemens A/S, Flow Instruments. All rights reserved.'

The values you enter for min. and max. flow are not important since you are not going to size the flowmeter yet.

Note: The process pressure must be in bara.

Press NEXT to calculate the values for density and viscosity.



Repeat this for helium and argon to end up with the following:

Gas	Density [kg/m <sup>3</sup> ]	Viscosity [cP]
Oxygen	13.09	0.02053
Helium	1.634	0.01897
Argon	16.33	0.02237

For now you are going to use the densities only. The viscosities must be kept for the viscosity calculation (see 3.).

If you want to end up with the final density unit in kg/m<sup>3</sup>, you can in this example assume that each gas has a volume share of 0.333 m<sup>3</sup>. The total volume will then be 1 m<sup>3</sup>. If you want to have the density in a different unit, e.g. lb/ft<sup>3</sup>, you must make a unit conversion.

The average gas density is calculated as follows:

$$\rho_m = \frac{(13.09 \cdot 0.333 + 16.33 \cdot 0.333 + 1.634 \cdot 0.333)}{(0.333 + 0.333 + 0.333)} = 10.35 \text{ kg/m}^3$$

### 3. Average viscosity calculation for gas mixture

The next step is to calculate the average viscosity of the gas mixture. Use the following formula:

$$\mu = \frac{\sum_{i=1}^n r_i \mu_i \sqrt{M_i T_{ci}}}{\sum_{i=1}^n r_i \sqrt{M_i T_{ci}}}$$

$\mu$ : Dynamic or absolute viscosity of gas mixture

$r_i$ : Volume share of component  $i$  (in %)

$\mu_i$ : Dynamic or absolute viscosity of component  $i$  <sup>1)</sup>

$M_i$ : Molar mass of component  $i$  <sup>2)</sup>

$T_{ci}$ : Critical temperature of component  $i$  <sup>3)</sup>

<sup>1)</sup>: The value must be calculated at the given process conditions. Use the values you found in the previous step.

<sup>2)</sup>: The molar mass of the specific gas can be found in the table on next page or on the WEB

<sup>3)</sup>: The critical temperature of the specific gas can be found in the table on next page or on the WEB

#### Example:

To calculate the average viscosity of the previously mentioned gas mixture consisting of 33.3% oxygen, 33.3% helium and 33.3 % argon use the following values. The process pressure is 10 bara and the temperature is 25 °C:

Gas	$r_i$ [%]	$\mu_i$ [cP]	$M_i$ [g/mole]	$T_{ci}$ [°K]
Oxygen	33.3	0.02053	32	154.6
Helium	33.3	0.01897	4.003	5.19
Argon	33.3	0.02237	39.94	150.8

The given equation has a numerator and a denominator. Calculate the numerator and the denominator values for each of the gases and then the sum of them. The actual gas viscosity is then finally calculated as the sum of numerators divided by the sum of denominators.

You can use Excel for calculation of the actual gas mixture viscosity.

Process conditions : P = 10 bar abs, t = 25 °C					numerator	denominator
gas	ri [%]	μi [cP]	Mi [g/mole]	Tci [°K]	ri * ui * sqrt(Mi * Tci)	ri * sqrt(Mi * Tci)
oxygen	33,33	0,02053	32	154,6	48,129	2344,310
helium	33,33	0,01897	4,003	5,19	2,882	151,919
argon	33,33	0,02237	39,94	150,8	57,864	2586,664
sum of numerators					108,874	
sum of denominators						5082,893
actual gas viscosity		0,0214	(sum of numerators divided by sum of denominators)			

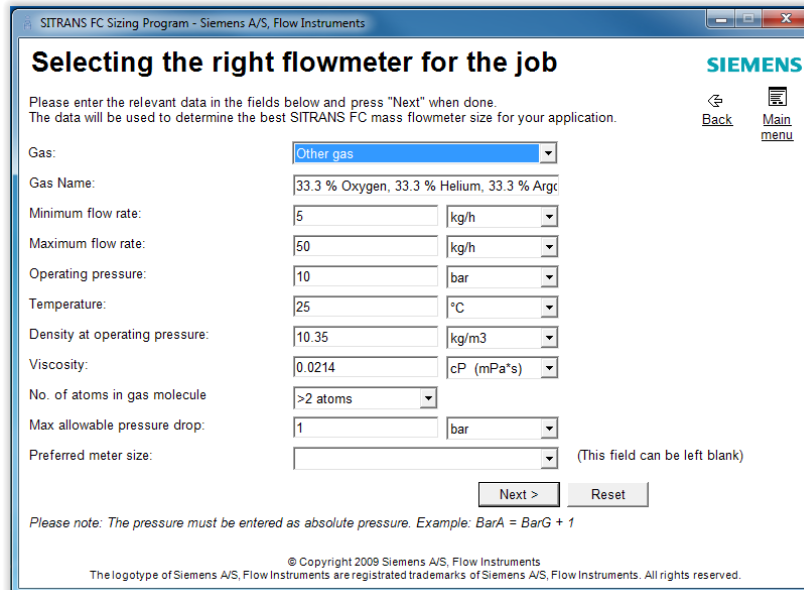
The resulting viscosity for the gas mixture in this example is **0.0214 cP**

### Constants for some common gases:

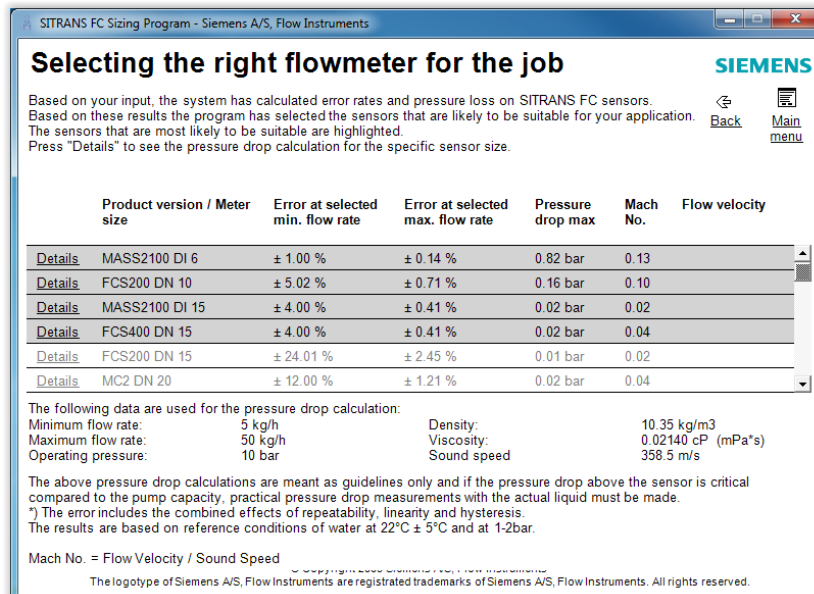
Gas	Molecular weight [g/mole]	Critical temperature [°K]
Argon, Ar	39.94	150.8
Acetylene	26.04	308.36
Ammonia, NH4	17	150.1
Carbon Dioxide, CO2	44.01	304.19
Carbon Monoxide, CO	28.01	132.96
Helium, He	4.003	5.19
Hydrogen, H2	2.016	33.2
Methane, CH4	16.04	190.8
Nitrogen, N2	28.02	126.2
Oxygen, O2	32	154.6
Propane, C3H8	44.09	369.86
Air	28.97	132.45

## 4. Product sizing

Enter the calculated density and viscosity of the gas mixture in the flow sizing tool to find a flow sensor suitable for the application. Enter the application data including the correct values for minimum and maximum flow.



For gas mixtures the field “No. of atoms in gas molecule” must be “>2 atoms”. Click NEXT to see a number of applicable sensors. The flow sensors listed on grey background fit the application best.



	Product version / Meter size	Error at selected min. flow rate	Error at selected max. flow rate	Pressure drop max	Mach No.	Flow velocity
<a href="#">Details</a>	MASS2100 DI 6	± 1.00 %	± 0.14 %	0.82 bar	0.13	
<a href="#">Details</a>	FCS200 DN 10	± 5.02 %	± 0.71 %	0.16 bar	0.10	
<a href="#">Details</a>	MASS2100 DI 15	± 4.00 %	± 0.41 %	0.02 bar	0.02	
<a href="#">Details</a>	FCS400 DN 15	± 4.00 %	± 0.41 %	0.02 bar	0.04	
<a href="#">Details</a>	FCS200 DN 15	± 24.01 %	± 2.45 %	0.01 bar	0.02	
<a href="#">Details</a>	MC2 DN 20	± 12.00 %	± 1.21 %	0.02 bar	0.04	

The following data are used for the pressure drop calculation:

Minimum flow rate:	5 kg/h	Density:	10.35 kg/m3
Maximum flow rate:	50 kg/h	Viscosity:	0.02140 cP (mPa*s)
Operating pressure:	10 bar	Sound speed	358.5 m/s

The above pressure drop calculations are meant as guidelines only and if the pressure drop above the sensor is critical compared to the pump capacity, practical pressure drop measurements with the actual liquid must be made.  
 \*) The error includes the combined effects of repeatability, linearity and hysteresis.  
 The results are based on reference conditions of water at 22°C ± 5°C and at 1-2bar.

Mach No. = Flow Velocity / Sound Speed

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The final selection depends on customer requirements such as accuracy, pressure drop, sensor type, sensor cost etc.

The Mach number is an important parameter when measuring gases. The Mach number is the ratio flow speed / gas sound speed, and it must never exceed 0.2 for a given sensor.

Note: The sizing tool does not incorporate the increased sensor non-linearity present when measuring gases. Thus,  $\pm 0.5\%$  must be added to the listed errors.