Special Documentation
Proline Prowirl 200

Air + Industrial Gases application package

Endress+Hauser
People for Process Automation

Table of contents

1 Document information

1.1 Document function

This document is part of the Operating Instructions and serves as a reference for application-specific parameters and notes.

It provides detailed information on:
- Every individual parameter in the operating menu
- Advanced technical specifications
- General principles and application tips

1.2 Using this document

1.2.1 Information on the document structure

For information on the arrangement of the parameters in accordance with the menu structure **Operation** menu, **Setup** menu, **Diagnostics** menu along with a short description, see the Operating Instructions for the device.

For information about the operating philosophy, see the "Operating philosophy" chapter in the device's Operating Instructions

1.3 Symbols used

1.3.1 Symbols for certain types of information

Symbol	Meaning
	Tip Indicates additional information.
	Reference to documentation Refers to the corresponding device documentation.
	Reference to page Refers to the corresponding page number.
	Reference to graphic Refers to the corresponding graphic number and page number.
	Operation via local display Indicates navigation to the parameter via the local display.
	Operation via operating tool Indicates navigation to the parameter via the operating tool.
	Write-protected parameter Indicates a parameter that can be locked against changes by entering a user-specific code.

1.3.2 Symbols in graphics

Symbol	Meaning
1, 2, 3 ...	Item numbers
A, B, C, ...	Views
A-A, B-B, C-C, ...	Sections

1.4 Documentation

This manual is Special Documentation and is not a substitute for the Operating Instructions supplied with the device. Refer to the Operating Instructions and other documentation for detailed information.

The Special Documentation is an integral part of the following Operating Instructions:

1.4.1 Device documentation

All devices are supplied with Brief Operating Instructions. These Brief Operating Instructions are not a substitute for the Operating Instructions pertaining to the device!

Detailed information about the device can be found in the Operating Instructions and the other documentation:
- On the CD-ROM supplied (is not included in the delivery for all device versions).
- Available for all device versions via:
  - Internet: www.endress.com/deviceviewer
  - Smart phone/tablet: *Endress+Hauser Operations App*

The information required to retrieve the documentation can be found on the nameplate of the device .

Technical documentation can also be downloaded from the Download Area of the Endress+Hauser web site: www.endress.com→ Download. However this technical documentation applies to a particular instrument family and is not assigned to a specific device.

W@M Device Viewer

1. Launch the W@M Device Viewer: www.endress.com/deviceviewer
2. Enter the serial number (Ser. no.) of the device: see nameplate .
   ↳ All the associated documentation is displayed.

Endress+Hauser Operations App

The *Endress+Hauser Operations App* is available for Android (Google play) and iOS (App Store).

Via the serial number:

1. Launch the *Endress+Hauser Operations App*.
2. Enter the serial number (Ser. no.) of the device: see nameplate .
   ↳ All the associated documentation is displayed.

Via the 2-D matrix code (QR code):

1. Launch the *Endress+Hauser Operations App*.
2. Scan the 2-D matrix code (QR code) on the nameplate .
   ↳ All the associated documentation is displayed.

1.4.2 Standard documentation

Measuring device	Documentation code		
	HART	FOUNDATION Fieldbus	PROFIBUS PA
Prowirl C 200	BA01152D	BA01215D	BA01220D
Prowirl D 200	BA01153D	BA01216D	BA01221D
Prowirl F 200	BA01154D	BA01217D	BA01222D

Measuring device	Documentation code		
	HART	FOUNDATION Fieldbus	PROFIBUS PA
Prowirl O 200	BA01155D	BA01218D	BA01223D
Prowirl R 200	BA01156D	BA01219D	BA01224D

1.4.3 Content and scope

This Special Documentation contains a description of the additional parameters and technical data that are provided with the **Air + Industrial Gases (Single Gas + Mixtures)** application package. All the parameters that are not relevant for air and industrial gases are described in the Operating Instructions.

General information about air and industrial gases can be found in the "General principles" section (→ 25).

2 Product features and availability

2.1 Product features

2.1.1 Air + Industrial Gases (Single Gas + Gas Mixtures) application package

The **Air + Industrial Gases (Single Gas + Gas Mixtures)** application package enables users to calculate the density and energy of air and industrial gases (single gases and gas mixtures). The calculations are based on time-tested standard calculation methods.

The influence of pressure and temperature can be compensated for automatically:
- Via an external value (via current input/HART/PROFIBUS PA)
- Via a fixed value
  (Navigation: **Setup** menu → **Advanced setup** submenu → **External compensation** submenu → **Fixed process pressure** parameter/**Fixed temperature** parameter)

With this application package it is possible to output the energy flow, normal volume flow and mass flow measured variables of the following media:
- Single gas
- Gas mixture
- Air
- User-specific gas

The calculations are based on the following standards:
- Enthalpy calculation:
  ISO 6976 (contains GPA 2172)
- Density calculation:
  NEL 40

2.2 Availability

The **Air + Industrial Gases (Single Gas + Gas Mixtures)** application package is only available for:
- For Prowirl D, F, R:
  Order code for *"Sensor version"*, option 3 *"Mass flow (integrated temperature measurement)"*
- For Prowirl C, O:
  Order code for *"Sensor version"*, option 6 *"Mass flow, Alloy 718"*

If the **Air + Industrial Gases (Single Gas + Gas Mixtures)** application package was ordered for the flowmeter ex works, this package is available when the measuring device is delivered to the customer. The function is accessed via the operating interfaces of the measuring device or via Endress+Hauser's FieldCare asset management software. No particular measures are required to put the application package into operation.

Ways to check function availability in the measuring device:
Using the serial number:
W@M Device viewer [1] → *Order code for "Application package", option ET "Air + Industrial Gases (Single Gas+Gas Mixtures)"*

If the application package is not available in the measuring device it can be activated during the life cycle of the device. On most flowmeters it is possible to activate the package without having to upgrade the firmware.

1) www.endress.com/deviceviewer

Activation without firmware upgrade is possible with the following firmware versions or higher:
- HART: 01.02.zz
- PROFIBUS DP: 01.01.zz
- FOUNDATION Fieldbus: 01.00.zz

For all earlier firmware versions, the firmware must be upgraded in order to enable the package.

2.2.1 Enabling without performing a firmware upgrade

You require a conversion kit from Endress+Hauser to enable the application package without upgrading the firmware. This kit contains a release code which must be entered via the operating menu in order to activate the application package.

Once activated the application package is permanently available in the measuring device.

2.2.2 Enabling by performing a firmware upgrade

If you have a measuring device that requires a firmware upgrade before the function can be activated, please contact your Endress+Hauser service organization.

This function requires service-level access to the device.

Please contact your Endress+Hauser service or sales organization for further information regarding availability and firmware upgrades for existing measuring devices.

3 Commissioning

3.1 Configuring the measuring device

Using the **Medium selection** wizard it is possible to set all the parameters that are needed to configure the measuring device for the application with air and industrial gases.

Perform the following to configure the measuring device:

1. Select the medium and gas type (→ 🖹 9).
2. Specify the medium properties and gas composition (→ 🖹 12).

3.2 Selecting the medium and gas type

Single gas

Perform the following to configure the **Single gas** gas type:

1. Call up the **Medium selection** wizard .
2. In the **Select medium** parameter (→ 🖹 11), select the **Gas** option.
3. In the **Select gas type** parameter (→ 🖹 11), select the **Single gas** option.
   ↳ The density is determined according to NEL 40.

   The enthalpy (energy) is determined according to ISO 6976.
4. In the **Fixed process pressure** parameter (→ 🖹 11), enter the value of the process pressure present.
   ↳ **NOTE!**

   A value > 0 must be entered.

Gas mixture

Perform the following to configure the **Gas mixture** gas type:

1. Call up the **Medium selection** wizard .
2. In the **Select medium** parameter (→ 🖹 11), select the **Gas** option.
3. In the **Select gas type** parameter (→ 🖹 11), select the **Gas mixture** option.
   ↳ The density is determined according to NEL 40.

   The enthalpy (energy) is determined according to ISO 6976.
4. In the **Fixed process pressure** parameter (→ 🖹 11), enter the value of the process pressure present.
   ↳ **NOTE!**

   A value > 0 must be entered.

Air

Perform the following to configure the **Air** gas type:

1. Call up the **Medium selection** wizard .
2. In the **Select medium** parameter (→ 🖹 11), select the **Gas** option.
3. In the **Select gas type** parameter (→ 🖹 11), select the **Air** option.
   ↳ The density is determined according to NEL 40.
4. In the **Fixed process pressure** parameter (→ 🖹 11), enter the value of the process pressure present.
   ↳ **NOTE!**

   A value > 0 must be entered.

User-specific gas

Perform the following to configure the **User-specific gas** gas type:

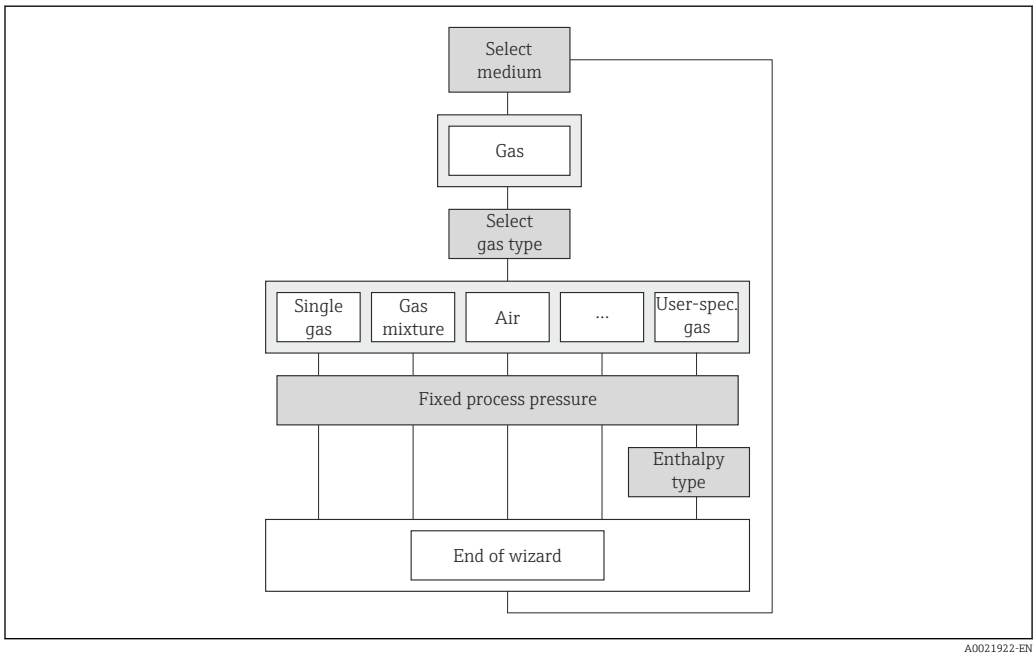
1. Call up the **Medium selection** wizard .
2. In the **Select medium** parameter (→ 11), select the **Gas** option.
3. In the **Select gas type** parameter (→ 11), select the **User-specific gas** option.
4. In the **Enthalpy type** parameter (→ 11), select one of the following options:
   - **Heat** option (for calculating the thermal heat flow)
   - **Calorific value** option (for calculating the energy flow of the potential combustion energy)
5. In the **Fixed process pressure** parameter (→ 11), enter the value of the process pressure present.
   - **NOTE!**

     A value > 0 must be entered.

Endress+Hauser recommends the use of active pressure compensation. This fully rules out the risk of measured errors due to pressure variations and incorrect entries (→ 12).

Navigation

"Setup" menu → Medium selection → Select gas type



Parameter overview with brief description

Parameter	Prerequsite	Description	Selection / User entry	Factory setting
Select medium	–	Select medium type.	Gas	Steam
Select gas type	For the following order codes: ▪ *"Sensor version", option "Mass flow"* ▪ *"Application package ", option "Air + Industrial gases" or option "Natural gas"* In the **Select medium** parameter the **Gas** option must be selected.	Select measured gas type.	▪ Single gas ▪ Gas mixture ▪ Air ▪ User-specific gas	User-specific gas
Fixed process pressure	–	Enter fixed value for process pressure. *Dependency* The unit is taken from the **Pressure unit** parameter	0 to 250 bar abs.	0 bar abs.
Enthalpy type	If the **User-specific gas** option is selected in the **Select gas type** parameter.	Define which kind of enthalpy is used.	▪ Heat ▪ Calorific value	Heat

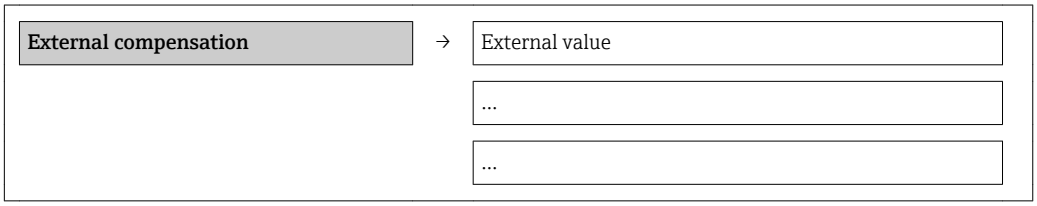
3.2.1 Activating pressure compensation

Users can choose to also perform active pressure compensation in order to minimize the effect of pressure variations. The pressure can be read in via the current input or fieldbuses.

For detailed information on reading in the pressure, see the Operating Instructions for the device (→ 5)

1. Call up the **External compensation** submenu.
2. In the **External value** parameter (→ 12), select the **Pressure** option.

Navigation
"Setup" menu → Advanced setup → External compensation



Parameter overview with brief description

Parameter	Description	Selection	Factory setting
External value	Assign variable from external device to process variable.	Pressure	Off

3.3 Specifying the medium properties and gas composition

Specify the medium properties for a single gas

1. In the **Calorific value type** parameter (→ 18) select the basis for the type of calorific value.
   ↳ The net calorific value describes the maximum useful quantity of heat when the selected gas is combusted without condensation of the water vapor contained in the waste-gas. The net calorific value is therefore lower than the gross calorific value.

   One of the following options is selected:

   - **Gross calorific value volume** option (Gross calorific value of the fluid in relation to normal volume)
   - **Net calorific value volume** option (Net calorific value of the fluid in relation to normal volume)
   - **Gross calorific value mass** option (Gross calorific value of the fluid in relation to mass)
   - **Net calorific value mass** option (Net calorific value of the fluid in relation to mass)
2. In the **Reference combustion temperature** parameter (→ 18) enter the value for calculating the natural gas energy value.
   ↳ Temperature that is used as a static reference for combustion. This makes it possible to compare combustion processes at different temperatures.
3. In the **Reference pressure** parameter (→ 18) enter the reference pressure for calculating the reference density.

↳ Pressure that is used as a static reference for combustion. This makes it possible to compare combustion processes at different pressures.

4. In the **Reference temperature** parameter (→ 🖹 18) enter the temperate for calculating the reference density.
5. In the **Gas composition** submenu select the **Gas type** parameter (→ 🖹 19).
6. In the **Gas type** parameter (→ 🖹 19) select the gas type for the measuring application.
   ↳ Choice of 21 gases:
   - **Hydrogen H2** option [2)]
   - **Helium He** option [3)]
   - **Neon Ne** option [3)]
   - **Argon Ar** option [3)]
   - **Krypton Kr** option [2)]
   - **Xenon Xe** option [2)]
   - **Nitrogen N2** option [3)]
   - **Oxygen O2** option [3)]
   - **Chlorine Cl2** option [3)]
   - **Ammonia NH3** option [3)]
   - **Carbon monoxide CO** option [2)]
   - **Carbon dioxide CO2** option [3)]
   - **Sulfur dioxide SO2** option [3)]
   - **Hydrogen sulfide H2S** option [2)]
   - **Hydrogen chloride HCl** option [3)]
   - **Methane CH4** option [2)]
   - **Ethane C2H6** option [2)]
   - **Propane C3H8** option [2)]
   - **Butane C4H10** option [2)]
   - **Ethylene C2H4** option [3)]
   - **Vinyl Chloride C2H3Cl** option [3)]

The gas type for the measuring application has been selected.

Specify the medium properties for a gas mixture

A gas mixture can be defined from a maximum of eight gases.

1. In the **Calorific value type** parameter (→ 🖹 18) select the basis for the type of calorific value.
   ↳ The net calorific value describes the maximum useful quantity of heat when the selected gas is combusted without condensation of the water vapor contained in the waste-gas. The net calorific value is therefore lower than the gross calorific value (condensation energy is factored into the calculation).

   One of the following options is selected:

   - **Gross calorific value volume** option (Gross calorific value of the fluid in relation to normal volume)

2) It is possible to calculate the potential combustion energy and specify the energy flow.
3) It is not possible to calculate the potential combustion energy and specify the energy flow.

- **Net calorific value volume** option (Net calorific value of the fluid in relation to normal volume)
- **Gross calorific value mass** option (Gross calorific value of the fluid in relation to mass)
- **Net calorific value mass** option (Net calorific value of the fluid in relation to mass)

2. In the **Reference combustion temperature** parameter (→ 18) enter the value for calculating the natural gas energy value.
   ↳ Temperature that is used as a static reference for combustion. This makes it possible to compare combustion processes at different temperatures.
3. In the **Reference pressure** parameter (→ 18) enter the reference pressure for calculating the reference density.
   ↳ Pressure that is used as a static reference for combustion. This makes it possible to compare combustion processes at different pressures.
4. In the **Reference temperature** parameter (→ 18) enter the temperate for calculating the reference density.
5. In the **Gas composition** submenu select the **Gas mixture** parameter (→ 20).
6. In the **Gas mixture** parameter (→ 20) select the gas mixture for the measuring application.
   ↳ From the gases listed select the constituents of the gas mixture by ticking the box E:
   - ❑ **Hydrogen H2** option [4)]
   - ❑ **Helium He** option [5)]
   - ❑ **Neon Ne** option [3)]
   - ❑ **Argon Ar** option [3)]
   - ❑ **Krypton Kr** option [2)]
   - ❑ **Xenon Xe** option [2)]
   - ❑ **Nitrogen N2** option [3)]
   - ❑ **Oxygen O2** option [3)]
   - ❑ **Chlorine Cl2** option [3)]
   - ❑ **Ammonia NH3** option [3)]
   - ❑ **Carbon monoxide CO** option [2)]
   - ❑ **Carbon dioxide CO2** option [3)]
   - ❑ **Sulfur dioxide SO2** option [3)]
   - ❑ **Hydrogen sulfide H2S** option [2)]
   - ❑ **Hydrogen chloride HCl** option [3)]
   - ❑ **Methane CH4** option [2)]
   - ❑ **Ethane C2H6** option [2)]
   - ❑ **Propane C3H8** option [2)]
   - ❑ **Butane C4H10** option [2)]
   - ❑ **Ethylene C2H4** option [3)]
   - ❑ **Vinyl Chloride C2H3Cl** option [3)]
   - ❑ **Others** option [6)]

4) It is possible to calculate the potential combustion energy and specify the energy flow.
5) It is not possible to calculate the potential combustion energy and specify the energy flow.

At the end of the list select ❑ **Accept** to confirm the options selected

Once you have selected the gas constituents enter the percentage share of the selected gases in Mol% (e.g. in the **Mol% Ar** parameter).

N.B.: The sum of the gas constituents may not exceed or fall below 100 %!

You have defined the gas mixture.

Specify the medium properties for air

1. In the **Reference pressure** parameter (→ 🖹 18) enter the reference pressure for calculating the reference density.
   ↳ Pressure that is used as a static reference for combustion. This makes it possible to compare combustion processes at different pressures.
2. In the **Reference temperature** parameter (→ 🖹 18) enter the temperate for calculating the reference density.
3. In the **Gas composition** submenu select the **Relative humidity** parameter (→ 🖹 24).
   ↳ The relative humidity can be entered in %. The relative humidity is converted internally to absolute humidity and is then factored into the density calculation according to NEL 40.

The medium properties for air are specified.

Specify the medium properties for user-specific gas

1. In the **Enthalpy type** parameter (→ 🖹 11) define which type of enthalpy is used.
   ↳ One of the following options is selected:
   - **Heat** option: For calculating the thermal heat flow.
   - **Calorific value** option: For calculating the energy flow of the potential combustion energy.
2. If the **Calorific value** option has been selected in the **Enthalpy type** parameter (→ 🖹 11), then select the basis for the type of calorific value in the **Calorific value type** parameter.
   ↳ The net calorific value describes the maximum useful quantity of heat when the selected gas is combusted without condensation of the water vapor contained in the waste-gas. The net calorific value is therefore lower than the gross calorific value (condensation energy is factored into the calculation).

   One of the following options is selected:
   - **Gross calorific value volume** option (Gross calorific value of the fluid in relation to normal volume)
   - **Net calorific value volume** option (Net calorific value of the fluid in relation to normal volume)
   - **Gross calorific value mass** option (Gross calorific value of the fluid in relation to mass)
   - **Net calorific value mass** option (Net calorific value of the fluid in relation to mass)
3. In the **Reference density** parameter (→ 🖹 18) enter a fixed value for the reference density.
4. In the **Reference pressure** parameter (→ 🖹 18) enter the reference pressure for calculating the reference density.

6) As soon as the **Others** option is selected for a component of the gas mixture, the measured values for viscosity, sound velocity and the Z-factor can no longer be calculated. The **Calorific value type** parameter, **Reference combustion temperature** parameter, **Reference density** parameter, **Reference pressure** parameter, **Reference temperature** parameter, **Reference Z-factor** parameter, **Calorific value** parameter, **Z-factor** parameter and **Dynamic viscosity** parameter appear on the display.

↳ Pressure that is used as a static reference for combustion. This makes it possible to compare combustion processes at different pressures.

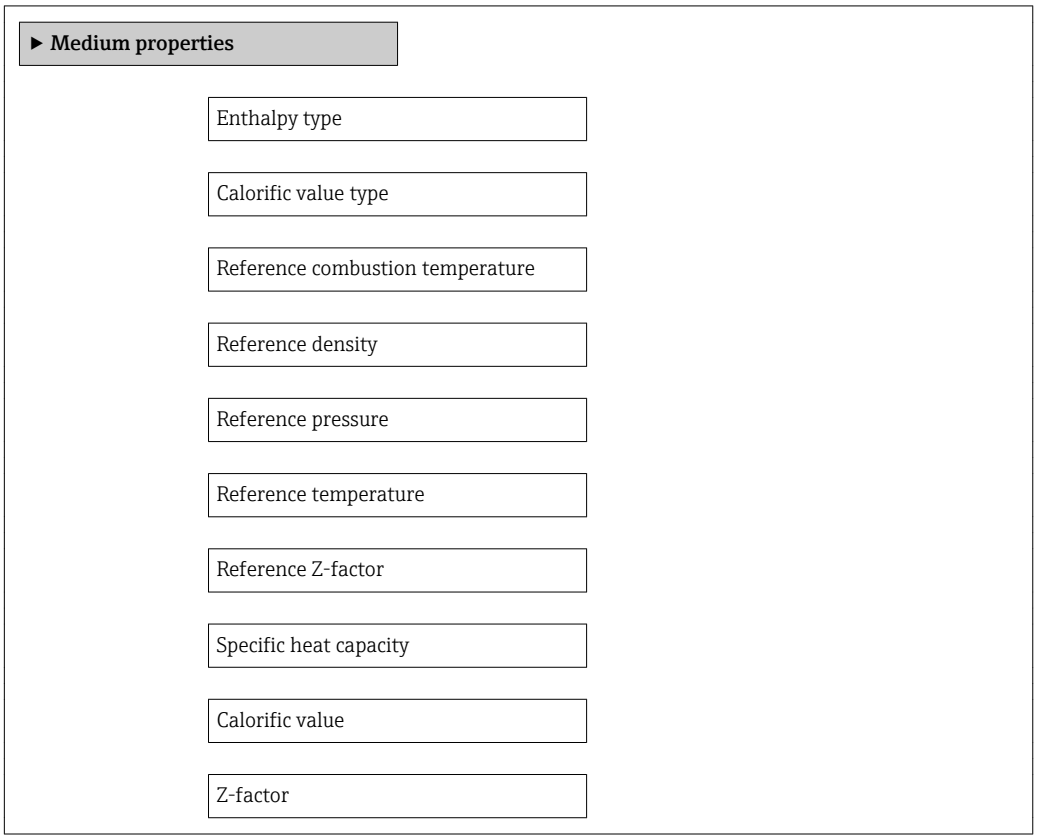
5. In the **Reference temperature** parameter (→ 🖹 18) enter the temperate for calculating the reference density.
6. In the **Reference Z-factor** parameter (→ 🖹 18) enter the Z-factor for the gas under normal conditions.
7. If the **Heat** option is selected in the **Enthalpy type** parameter (→ 🖹 11), then continue with **a**. If the **Calorific value** option is selected in the **Enthalpy type** parameter, then continue with **b**.
   ↳ **a**: In the **Specific heat capacity** parameter (→ 🖹 18) define the specific heat capacity of the medium.

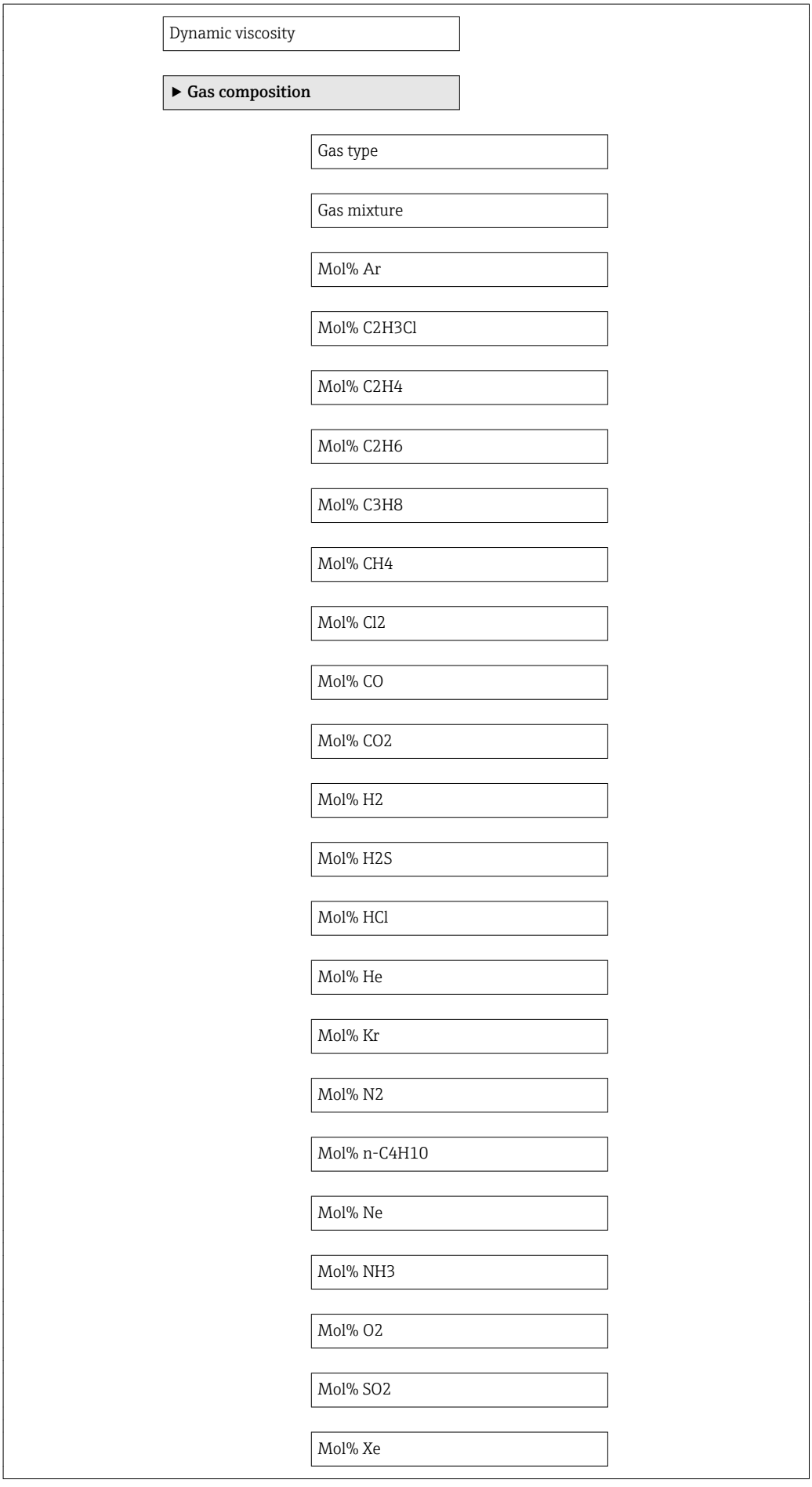
   b: In the **Calorific value** parameter (→ 🖹 19) enter the gross calorific value to calculate the energy flow.
8. In the **Z-factor** parameter (→ 🖹 19) enter the Z-factor for gas under operating conditions.
9. In the **Dynamic viscosity** parameter (→ 🖹 19) enter the value for dynamic viscosity.

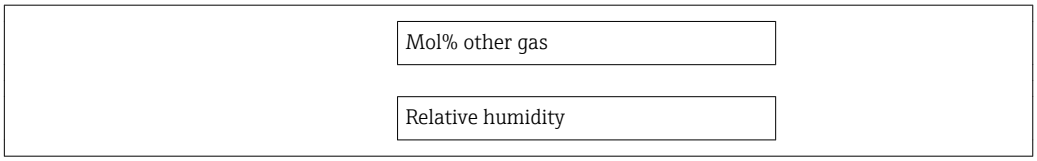
The medium properties for user-specific gas are specified.

Navigation
"Setup" menu → Advanced setup → Medium properties

Depending on the selected gas type (→ 🖹 9), not all parameters are available. Information on this can be found in the parameter description under **"Prerequisite"**.




Dynamic viscosity
▶ Gas composition
Gas type
Gas mixture
Mol% Ar
Mol% C2H3Cl
Mol% C2H4
Mol% C2H6
Mol% C3H8
Mol% CH4
Mol% Cl2
Mol% CO
Mol% CO2
Mol% H2
Mol% H2S
Mol% HCl
Mol% He
Mol% Kr
Mol% N2
Mol% n-C4H10
Mol% Ne
Mol% NH3
Mol% O2
Mol% SO2
Mol% Xe



Parameter overview with brief description

Parameter	Prerequsite	Description	Selection / User entry	Factory setting
Enthalpy type	If the **User-specific gas** option is selected in the **Select gas type** parameter.	Define which kind of enthalpy is used.	▪ Heat ▪ Calorific value	Heat
Calorific value type	If the **Calorific value type** parameter is visible.	Select calculation based on gross calorific value or net calorific value.	▪ Gross calorific value volume ▪ Net calorific value volume ▪ Gross calorific value mass ▪ Net calorific value mass	Gross calorific value mass
Reference combustion temperature	If the **Reference combustion temperature** parameter is visible.	Enter reference combustion temperature to calculate the natural gas energy value.	−200 to 450 °C	20 °C
Reference density	If the **User-specific gas** option is selected in the **Select gas type** parameter.	Enter fixed value for reference density.	0.01 to 15 000 kg/m³	1 000 kg/m³
Reference pressure	If all of the following conditions are met: ▪ Order code for *"Sensor version"*, option *"Mass flow (integrated temperature measurement)"* ▪ If the **Gas** option is selected in the **Select medium** parameter.	Enter reference pressure for the calulation of the reference density. *Dependency* The unit is taken from the **Pressure unit** parameter	0 to 250 bar	1.01325 bar
Reference temperature	If the **Gas** option is selected in the **Select medium** parameter.	Enter reference temperature for calculating the reference density.	−200 to 450 °C	20 °C
Reference Z-factor	If the **User-specific gas** option is selected in the **Select gas type** parameter.	Enter real gas constant Z for gas under reference conditions.	0.1 to 2	1
Specific heat capacity	If the following conditions are met: ▪ Selected medium: In the **Select gas type** parameter, the **User-specific gas** option is selected. ▪ In the **Enthalpy type** parameter, the **Heat** option is selected.	Enter the specific heat capacity of the medium.	0 to 50 kJ/(kgK)	4.187 kJ/(kgK)

Parameter	Prerequsite	Description	Selection / User entry	Factory setting
Calorific value	If the following conditions are met: ▪ Selected medium: In the **Select gas type** parameter, the **User-specific gas** option is selected. ▪ In the **Enthalpy type** parameter, the **Calorific value** option is selected. ▪ In the **Calorific value type** parameter, the **Gross calorific value volume** option or the **Gross calorific value mass** option is selected.	Enter gross calorific value to calculate the energy flow.	Positive floating-point number	50 000 kJ/kg
Z-factor	If the **User-specific gas** option is selected in the **Select gas type** parameter.	Enter real gas constant Z for gas under operation conditions.	0.1 to 2.0	1
Dynamic viscosity	If the following conditions are met: ▪ Order code for *"Sensor version"*, option *"Volume flow"* ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ Or in the **Select gas type** parameter, the **User-specific gas** option is selected.	Enter the value of dynamic viscosity for a user-specific gas.	Positive floating-point number	0.015 cP
Gas type	If all of the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Single gas** option is selected.	Select measured gas type.	▪ Hydrogen H2 ▪ Helium He ▪ Neon Ne ▪ Argon Ar ▪ Krypton Kr ▪ Xenon Xe ▪ Nitrogen N2 ▪ Oxygen O2 ▪ Chlorine Cl2 ▪ Ammonia NH3 ▪ Carbon monoxide CO ▪ Carbon dioxide CO2 ▪ Sulfur dioxide SO2 ▪ Hydrogen sulfide H2S ▪ Hydrogen chloride HCl ▪ Methane CH4 ▪ Ethane C2H6 ▪ Propane C3H8 ▪ Butane C4H10 ▪ Ethylene C2H4 ▪ Vinyl Chloride C2H3Cl	Methane CH4

Parameter	Prerequsite	Description	Selection / User entry	Factory setting
Gas mixture	If all of the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected.	Select measured gas mixture.	▪ Hydrogen H2 ▪ Helium He ▪ Neon Ne ▪ Argon Ar ▪ Krypton Kr ▪ Xenon Xe ▪ Nitrogen N2 ▪ Oxygen O2 ▪ Chlorine Cl2 ▪ Ammonia NH3 ▪ Carbon monoxide CO ▪ Carbon dioxide CO2 ▪ Sulfur dioxide SO2 ▪ Hydrogen sulfide H2S ▪ Hydrogen chloride HCl ▪ Methane CH4 ▪ Ethane C2H6 ▪ Propane C3H8 ▪ Butane C4H10 ▪ Ethylene C2H4 ▪ Vinyl Chloride C2H3Cl ▪ Others	Methane CH4
Mol% Ar	If the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Argon Ar** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% C2H3Cl	If all of the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Vinyl Chloride C2H3Cl** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% C2H4	If all of the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Ethylene C2H4** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %

Parameter	Prerequsite	Description	Selection / User entry	Factory setting
Mol% C2H6	If the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Ethane C2H6** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% C3H8	If the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Propane C3H8** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% CH4	If the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Methane CH4** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	100 %
Mol% Cl2	If all of the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Chlorine Cl2** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% CO	If the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Carbon monoxide CO** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %

Parameter	Prerequsite	Description	Selection / User entry	Factory setting
Mol% CO2	If the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Carbon dioxide CO2** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% H2	If the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter the **Hydrogen H2** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% H2S	If the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Hydrogen sulfide H2S** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% HCl	If all of the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Hydrogen chloride HCl** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% He	If the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Helium He** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %

Parameter	Prerequsite	Description	Selection / User entry	Factory setting
Mol% Kr	If all of the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Krypton Kr** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% N2	If the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter the **Nitrogen N2** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% n-C4H10	If the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Butane C4H10** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% Ne	If all of the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Neon Ne** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% NH3	If all of the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Ammonia NH3** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %

Parameter	Prerequsite	Description	Selection / User entry	Factory setting
Mol% O2	If the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Oxygen O2** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% SO2	If all of the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Sulfur dioxide SO2** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% Xe	If all of the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Xenon Xe** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Mol% other gas	If all of the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Gas mixture** option is selected. ▪ In the **Gas mixture** parameter, the **Others** option is selected.	Enter amount of substance for the gas mixture.	0 to 100 %	0 %
Relative humidity	If all of the following conditions are met: ▪ In the **Select medium** parameter, the **Gas** option is selected. ▪ In the **Select gas type** parameter, the **Air** option is selected.	Enter humidity content of air in %.	0 to 100 %	0 %

4 General principles

4.1 Air and industrial gases

4.1.1 Definition

Industrial gases are pure gases and defined mixtures that are used as starting materials, in process optimization or as end products and as fuels. The principle gases are air, oxygen, nitrogen, argon, hydrogen, carbon dioxide and hydrocarbons as well as other gases and mixtures.

4.1.2 Uses

Oxygen is used in steel production and in coal liquefaction. Nitrogen is used to protect products from oxidation and to keep containers inert.

The main applications are in the following industries:
- Chemical industry
- Environment
- Foods
- Primaries
- Metals
- Plastics
- Semiconductors
- Water/wastewater

4.1.3 Distribution

Industrial gases are transported in pipelines and containers for road, rail and sea transportation.

Gases can be handled and transported in all states of aggregation (gaseous, liquid, or solid in the case of dry ice). Industrial gas manufacturers also produce the required gases at the end customer's site. These facilities are sometimes also operated by these manufacturers however.

4.2 Gas types

4.2.1 Single gases

Production process

Air is cooled until it liquefies. The individual gas components are then separated by fractional distillation. This is a very energy-intensive process. In the Joule Thomson refrigeration cycle, expansion turbines are used to produce the low temperatures in the air separation unit. For improved efficiency these turbines also drive the air compressor at the inlet.

The following are the main steps in the cryogenic process:
- Dust filtration
- Compression to typically 6 to 11 bar abs. (87.02 to 159.54 psi abs.) [7], water is condensed out
- Filtration with molecular sieves to remove water vapor, carbon dioxide and hydrocarbon
- Cooling, liquefaction, distillation and gas enrichment
- Heating or cooling and distribution

Air separation plants produce nitrogen, oxygen and argon - frequently as cryogenic liquids - using the Joule-Thomson effect. In this way other gases can be produced, such as neon (lighting, lasers, plasma screens), krypton (lighting), xenon (lighting, laser, computer tomography, anesthesia), and helium (superconductors, welding, balloons, aviation).

Non-cryogenic air separation involves the following main processes. Separation of oxygen and nitrogen from the air at ambient conditions (and vacuum) using pressure swing adsorption (PSA). Under high pressure gases tend to be attracted to the surface of solids, or "adsorbed". When the pressure is reduced, the gas is released. Different gases are attracted to different surfaces. Some of the gas stays adsorbed on the surface and the remaining gas is enriched. When the adsorbent surface reaches the end of its capacity to adsorb the desired gas, the pressure is reduced. This releases the desired gas and a new cycle begins. Two vessels are used alternately and feed one another to enable the continuous production of the desired gas.

Membrane technologies provide alternative low-energy approaches to air separation in order to produce oxygen for example. Polymeric membranes are used at ambient temperature to produce oxygen-enriched air (25 to 50 % oxygen). At higher temperatures it is possible to use ceramic membranes (ion transport membranes) and oxygen transport membranes to produce high-purity oxygen (90 %).

Other processes for the production of gases comprise steam reforming, electrolysis (e.g. hydrogen), compression (e.g. air) and cracking.

Argon and nitrogen

Argon is a completely inert gas and is therefore the best gas for the production of steel and for welding applications that require high quality. In steel production, oxygen is blown through the molten pig iron to lower the carbon content. In the process, inert gases (argon or nitrogen) are blown in to mix the molten metal and eliminate impurities. A large amount of stainless steels and alloys are "refined" with argon and oxygen. Argon (or nitrogen) is mixed with oxygen and injected into the furnace. In ladle furnaces alloy materials are added and argon or nitrogen are injected to lend the steel other properties. Argon is used to rinse molds in the casting process and to prevent re-oxidation. Given the fact that it is relatively expensive, argon is often replaced by nitrogen and carbon dioxide.

4.2.2 Gas mixtures

Many other gases are used in industrial processes, e.g. compressed air, natural gas or biogas. All the examples mentioned change their density, volume and other properties (e.g. compressibility) depending on the pressure and temperature. This presents a particular challenge for flow measurement.

7) abs. = absolute

4.2.3 Inert gases

Carbon dioxide CO_2

Properties - gas
- Colorless and odorless
- Asphyxiant gas, toxic in high concentrations
- Heavier than air
- Water-soluble, corrosive
- Reacts at high temperatures

Properties - liquid
Boiling point: 78.5 °C (173.3 °F)

Advantages
- Well suited as a gas blanket
- Is therefore used in chemical processes
- Cryogenic storage
- Liquid superconductor

Applications
- Foodstuffs, drinks and tobacco: refrigerant, carbonation, dispensing equipment, packaging, purging, gas blanket
- Chemical industry: substitute for CFCs
- Electronic cleaning
- Agriculture: production, pest control
- Environment, water and wastewater: treatment, pH control
- Metals: MIG welding, welding of carbon steel and stainless steel, shielding gas for plasma cutting, inert environments

Nitrogen N_2

Properties - gas
- Colorless and odorless
- Asphyxiant gas
- Heavier than air
- Inert
- Sparingly soluble in water
- Reacts at very high temperatures

Properties - liquid
Boiling point: −196 °C (−320.8 °F)

Advantages
- Well suited as a gas blanket
- Forms nitride at very high temperatures
- Reduces oxidation

Applications
- Shielding gas for metalworking
- Purging or inerting of reactors or storage vessels to prevent combustion and product degradation
- Protective atmosphere for beverages, packaging and quick refrigeration or drying of perishable goods
- Inert atmosphere for PCBs and float glass technology
- Metals: mixing, purging, degassing, desulfurization and heat treatment of metals
- Transfer of liquids
- Shrink fitting

Argon Ar

Properties - gas
- Colorless and odorless
- Asphyxiant gas
- Heavier than air
- Inert
- Low thermal conductivity

Properties - liquid
Boiling point: −186 °C (−302.8 °F)

Advantages
- Low ionization potential (arc furnace)
- Inert and does not react with liquid metals

Applications
- High-density shielding gas for MIG or WIG welding and lasers, plasma welding, cutting
- Window insulation
- Electronics: growing semiconductor crystals
- Metals: decarbonization, degasification, desulfurization

4.2.4 Oxidizing gases

Compressed air

On average 10 to 15 % of the electricity consumed by an industrial operation is used for the generation of compressed air. Compressed air is a very expensive power source: it can be more than 20 times more expensive than electricity.

Properties
- Colorless and odorless
- Non-toxic
- Supports combustion

Applications
- Soldering and brazing
- Plasma cutting
- Metallurgical processes such as die-casting and blast furnaces
- Pneumatic systems
- Carbon coating, e.g. aluminum extrusion and glass manufacture

Oxygen O_2

Properties - gas
- Colorless and odorless
- Supports combustion
- Non-toxic at atmospheric pressure

Properties - liquid
- Boiling point: −183 °C (−297.4 °F)
- Highly reactive

Advantages
- High flame temperature
- Arc stabilization and reduction of surface tension
- Higher plasma cutting speed

Applications
- High-temperature cutting, welding and soldering
- Metals: efficient, high-speed metal machining
- Semiconductor production
- Chemical industry: increase reaction speed and yield

- Food: aeration and aerobic fermentation
- Steel: higher temperature, production and efficiency
- Water treatment: oxygen injection

4.2.5 Reactive gas or fuel gas

Hydrogen H_2

Properties - gas
- Compressed gas
- Colorless and odorless
- Highly flammable
- Highly reactive

Properties - liquid
Boiling point: −253 °C (−423.4 °F)

Applications
- Foodstuffs: hydrogenation of vegetable oils
- Chemical industry: hydrogenation of non-edible vegetable oils
- Pharmaceutics: vitamin production
- Electronics: semiconductor production
- Energy: turbine cooling and fuel cells
- Aerospace: fuel
- Iron and steel: heat treatment, plasma welding and cutting
- Oil and gas: desulfurization
- Glass: protective atmosphere

4.3 Engineering units

The Prowirl 200 primarily measures the operating volume flow regardless of whether the medium used is a liquid, gas or steam. Neither the pressure nor the temperature of the medium is factored into the measured operating volume. However, if the medium used is a gas - and more particularly a natural gas - the user is interested in measuring the normal volume or the mass. The measured value should be output in mass units, normal volume units or energy units.

A list of international normal and standard conditions is provided in the table below:

Conditions	Pressure	Temperature
Normal	1.01325 bar (14.696 psi)	0 °C (+32 °F)
Standard	1.01325 bar (14.696 psi)	+15 °C (+59 °F)
Standard	1.01325 bar (14.696 psi)	+15.6 °C (+60 °F)
Standard	1.01008 bar (14.65 psi)	+20 °C (+68 °F)

A normal cubic meter of a gas is the volume corrected to normal or standard conditions as indicated above. The normal volume is therefore the mass of the gas divided by its reference density under the conditions above. Therefore the normal volume is a unit of mass. Here the temperature has the greatest influence when determining the normal volume.

Example

In the United States the standard temperature is typically defined as 60 °F or 70 °F, but not always. If the wrong reference temperature is used, this results in a significant change in the volume at the same mass.

For example a mass flow of 1000 kg/h of air at 1.01325 bar (14.696 psi) and 0 °C (+32 °F) results in a normal volume flow of 773.4 Nm^3/h (455 SCFM) [8].

However if the reference temperature under the same conditions is set at +60 °F (+15.6 °C) - the temperature commonly used in the US - the result is a normal volume flow of 836.8 Nm^3/h (481 SCFM), i.e. a deviation of more than 8 %.

In European countries (e.g. Germany, France and Great Britain) Nm^3 at 0 °C (+32 °F) is typically used, whereas other countries, such as the US, refer to Nm^3 at +15 °C (+59 °F) and Sm^3 at +15 °C (+59 °F).

NOTICE

There is no internationally accepted standard for reference conditions.
Therefore Prowirl 200 offers a wide range of options to cover the majority of the different versions used worldwide.

- ▶ Always check the standard conditions that apply in your country. For pressure, a reference value for absolute pressure of 1.01325 bar abs. (14.696 psi abs.) or 1.0 bar abs. (14.504 psi abs.) applies worldwide.

abs. = absolute

4.4 Flow computer

Vortex meters measure the operating volume. Therefore, when measuring gases, compensation calculations are needed to convert the operational state to normal or standard conditions (e.g. 0 °C (+32 °F) and 1.01325 bar abs. (14.969 psi abs.). Prowirl 200 combines an integrated flow computer with an integrated temperature sensor. The Prowirl 200 can read in an external pressure value via the optional current input/HART/PROFIBUS PA. This ensures the best results under varying process conditions.

The flow computer corrects the gas properties in accordance with the pressure and temperature for single gases and gas mixtures. Endress+Hauser's flow computer provides users with a software-based database of typical industrial gases and their associated properties. It calculates the properties of gas mixtures based on the percentage composition of the gas. This makes it possible to accurately calculate the normal volume, mass and energy of single gases and gas mixtures (the flow computer is based on the database of the UK National Engineering Laboratory (NEL); Endress+Hauser is a license holder of this database).

Standard gases are:
- Hydrogen H2
- Helium He
- Neon Ne
- Argon Ar
- Krypton Kr
- Xenon Xe
- Nitrogen N2
- Oxygen O2
- Chlorine Cl2
- Ammonia NH3
- Carbon monoxide CO
- Carbon dioxide CO2
- Sulfur dioxide SO2
- Hydrogen sulfide H2S
- Hydrogen chloride HCl
- Methane CH4
- Ethane C2H6
- Propane C3H8
- Butane C4H10
- Ethylene C2H4
- Vinyl Chloride C2H3Cl

8) $Nm^3 = m^3$ under normal conditions (SCFM = standard cubic feet per minute)

Users can quickly and easily enter all possible mixtures of the gases listed above by specifying the percentage mixture.

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