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Spirit IT
Innovative Technologies

Flow-X

Function Reference

Certified flow calculations
Flow and batch calculations
Worksheet functions

Product	**Flow-X** Function Reference
Reference number	01-0110-1
Revision	A.1
Date	June 2010
Authors	H.v.Dal

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Chapter 1 - Document Control

Revision Coding

Our documents are supplied with a revision code. This code has the following format: <major revision letter>.<minor revision number>. Initially, the document has revision code A.0. When in the next release of the document minor changes were implemented, the minor revision number increases. When major changes have been implemented, the major revision number increments.

Example document:

A.0	First revision
A.1	Second revision with minor changes implemented
A.2	Third revision, with other minor changes
B.0	Fourth revision, with (a) major change(s).

The revision coding will be modified for each new release of a document.

All software packages and software modules or components will be provided with a version number. This number consists of three parts: A release number, a major revision number and a minor revision number separated by decimal points. A release number identifies the generation number of the software, the major number refers to the main functionality of the program, seen from the user's point of view, while the minor revision number identify a new software version.

Example program:

1.01.001	Initial release
1.01.002	Minor change
1.02.001	Major change
2.01.001	Family change

Revision History

Revision A.0

Author : J.C.H.M. van Dal
Date : April 2009

Initial, release

Revision A.1

Author : J.C.H.M. van Dal
Date : June 2010

Added IUPAC Ethylene and IAWS-IF97 functions

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Chapter 2 - Introduction

This document describes the spreadsheet functions for the Flow-X series of flow computers. It also provides background information on related standards and calculation methods used in the industry for quality and quantity measurement of hydrocarbon and other type of fluids.
The document serves as a reference manual for application engineers who have in-depth knowledge of the configuration software used for programming the Flow-X products.

Flow-X Function Library

The Flow-X series of flow computer uses Microsoft Excel as its configuration environment. Each Flow-X application consists of a single Excel workbook that contains one or more worksheets.
Flow-X functions are configured as regular Excel functions. By using the output of one function as an input (argument) in another function a complete calculation scheme can be made. Functions can be defined on multiple sheets in order to organize the application.

API Petroleum Measurement Tables

History

The first version of the API Petroleum Measurement Tables was published in **1952**. In those days measurement readings were taken manually and the tables were used to convert the observed density or gravity at the observed temperature to the value at the reference temperature. So the table values were the actual standard.
The 1952 Tables consists of 58 tables containing all kind of correction and conversion factors used in the measurement of hydrocarbon liquids. Each table deals with a particular conversion of units, correction of density, or correction of volume. The 1952 tables that have to do with the conversion of density and volume are: 5, 6, 23, 24, 53 and 54.
Table 5, 6, 23 and 24 convert density or volume to or from to a reference temperature of 60°F, while tables 53 and 54 refer to 15°C.
In **1980** a complete new set of tables was published together with computer routines to allow electronic devices to automatically calculate the volume conversion factors and API gravity / (relative) density at the reference temperature. Back then most electronic devices were not capable of performing double-precision floating point calculations, so the standard prescribed all kind of rounding and truncating rules to make sure that the calculations would always provide the same result. For the 1980 version the calculation procedures are the standard rather than the table values.
In the 1980 version, which is also referred to as **API-2540,** the tables are divided into 3 product groups and a letter designation was used to distinguish between the sub-tables. "A" was used for crude oil, "B" for refined products and "C" for special applications. The 1980 tables, however, did not cover the LPGs and NGLs density ranges and the 1952 Tables were left valid for these products. Furthermore, the lubricating oil tables (designated as "D") were not complete at the time of the printing in 1980 and were released two years later. As opposed to the A, B and C tables no implementation procedures were defined for the D tables.
In 1988 the Institute of Petroleum released its Paper No. 3 with tables 59 and 60 that are based on a reference temperature of 20°C.
This resulted in the following Petroleum Measurement Tables dealing with the conversion of volume and density to and from a reference temperature.

Number	Title
5	API Gravity Reduction to 60°F
6	Reduction of Volume to 60°F Against API Gravity at 60°F
23	Reduction of Observed Specific Gravity to Specific Gravity 60/60°F
24	Reduction of Volume to 60o F Against Specific Gravity 60/60°F
53	Reduction of Observed Density to Density at 15°C
54	Reduction of Volume to 15°C Against Density at 15°C
59	Reduction of Observed Density to Density at 20°C
60	Reduction of Volume to 20°C Against Density at 20°C

In **2004** the API MPMS 11.1 1980 tables were superseded by a new set of tables primarily for the following reasons:

- API 11.1:2004 includes the correction for both temperature <u>and</u> pressure in one and the same algorithm
- Taken into account the progress in electronics (and for other reasons) the complex truncating and rounding rules were abandoned. Instead the calculation procedures use double-precision

floating point math. The input and output values are still rounded in order to obtain consistent results.

- The convergence methods for the correction of observed density to base density have been improved.
- On-line density measurement by densitometers became common practice, requiring the pressure and temperature correction to be incorporated in one ands the same procedure
- The tables are extended in both temperature and density to cover lower temperatures and higher densities.
- The previous standard used a significant digit format which resulted in 4 or 5 decimal places depending on whether the observed temperature was above or below the reference temperature. The new standard prescribes 5 decimal places if or both cases.
- The IP paper No. 3 tables were added to accommodate conversion to 20°C.

Tables for lubricating oils including the implementation procedures are now part of the standard.

Volume correction for pressure

The API MPMS 11.1:1980 Tables only cover the correction for temperature. The correction for pressure was published in API MPMS standards 11.2.1 and 11.2.2.
The correction for pressure is to the atmospheric pressure or, for products within the lower density range, to the equilibrium vapor pressure.
To calculate the equilibrium vapor pressure an Addendum was added to API MPMS 11.2.2. This addendum is also known as **GPA TP-15** (1988). In September 2007 the addendum was replaced by a new API standard 11.2.5 and at the same time GPA TP-15 (1988) was updated with a new 2007 revision.

NGL and LPG tables

For NGL and LPG products volume correction tables 24E and 23E (at 60 °F) were published in **GPA TP-25** (1988), so the letter 'E" was used to distinguish the tables from the related API MPMS A, B, C and D tables.
GPA TP-25 has been superseded by **GPA TP-27** / API MPMS 11.2.4 (2007), which includes tables 53E, 54E, 59E and 60E to convert to 15°C and 20°C as well. All text from TP-25 is included without technical change, so TP-25 is still viable for conversion to and from 60 °F.

Overview of hydrocarbon liquid conversion standards

- ASTM-IP Petroleum Measurement Tables, Historical Edition, 1952
- API MPMS Chapter 11.1 - 1980* (Temperature VCFs for Generalized Crude Oils, Refined Products, and Lubricating Oils): Historical; Published in 14 separate volumes

  Also known as

  - API Standard 2540 (API-2540)
  - ASTM D1250
  - IP 200

* In 1982 chapters XIII and XIV were published containing tables 5D, 6D, 53D and 54D for lubricating oils.

- API MPMS Chapter 11.1 - 2004 (Temperature & Pressure VCFs for Generalized Crude Oils, Refined Products and Lube Oils)
- API MPMS Chapter 11.2.1- 1984 (Compressibility Factors for Hydrocarbons: 0-90°API): Historical: now incorporated into Chapter 11.1-2004
- API MPMS Chapter 11.2.1M- 1984 (Compressibility Factors for Hydrocarbons: 638-1074 kg/m3): Historical: now incorporated into Chapter 11.1-2004
- API MPMS Chapter 11.2.2 - 1984 (Compressibility Factors for Hydrocarbons: 0.350-0.637 Relative Density and –50°F to 140°F)
- API MPMS Chapter 11.2.2M - 1986 (Compressibility Factors for Hydrocarbons: 350-637 kg/m3 Density (15°C) and –46°C to 60°C)
- API MPMS Chapter 11.2.2A - 1984 (Addendum to Correlation of Vapor Pressure Correction for NGL): Superseded by Chapter 11.2.5
- API Publication/GPA TP-25/ASTM Publication (Temperature Correction for the volume of Light Hydrocarbons – Tables 24E and 23E: Superseded by API MPMS Chapter 11.2.4

  GPA TP-25 was published in 1998 and replaced the 1952 tables 23, 24 for Light Hydrocarbon Liquids and GPA Technical Publication TP-16, which were previously used for volumetric measurement of LPG.

- API MPMS Chapter 11.2.4 - 2007 / GPA TP-27 / ASTM Publication (Temperature Correction for the Volume of NGL and LPG – Tables 23E, 24E, 53E, 54E, 59E, 60E): Supersedes GPA TP-25
- API MPMS Chapter 11.2.5 - 2007 / GPA TP-15 / ASTM Publication (A Simplified Vapor Pressure Correlation for Commercial NGLs): Supersedes Addendum to Chapter 11.2.2 (11.2.2A)
- IP No. 3 - 1988 (Energy Institute (formerly Institute of Petroleum), Petroleum Measurement Paper No 3 Computer Implementation Procedures for Correcting Densities and Volumes to 20 C. Superseded by IP No.3 - 1997
- IP No. 3 - 1997 (Energy Institute (formerly Institute of Petroleum), Petroleum Measurement Paper No 3 Computer Implementation Procedures for Correcting Densities and Volumes to 20 C. Supersedes IP No.3 - 1988
- ISO 91-1 - 1982 Petroleum measurement tables Part 1: Tables based on reference temperatures of 15 °C and 60 °F. Superseded by ISO 91-1 1992.
- ISO 91-1 - 1992 Petroleum measurement tables Part 1: Tables based on reference temperatures of 15 °C and 60 °F. Supersedes ISO 91-1 1982.
- ISO 91-2 - 1991 Petroleum measurement tables Part 2: Tables based on reference temperatures of 20 °C
- OIML R 63 - 1994 Petroleum measurement tables

Overview of the functions

The following table lists the volume conversion functions for hydrocarbon liquids as provided by the Flow-X series of flow computer.

Function	Temperature correction	Pressure correction	Input	Output
ASTM-IP Petroleum Measurement Tables 1952 - American Edition				
API_Table23 (1952)	Table 23 - Specific Gravity Reduction to 60 °F		SG (T)	SG (60°F)
API_Table24 (1952)	Table 24 - Volume Reduction to 60 °F		SG (60°F)	Ctl
Crude Oils, Refined Products and Lubricating Oils (API MPMS 11.1:1980 / API-2540)				
API_Table5 (1980)	API 11.1:1980 Tables 5A, 5B and 5D	API 11.2.1:1984	°API (T, P)	°API (60°F, Pe)
API_Table6 (1980)	API 11.1:1980 Tables 6A, 6B and 6D	API 11.2.1:1984	°API (60°F, Pe)	°API (T, P)
API_Table23 (1980)	API 11.1:1980 Tables 23A and 23B	API 11.2.1:1984	RD (T, P)	RD (60°F, Pe)
API_Table24 (1980)	API 11.1:1980 Tables 24A and 24B	API 11.2.1:1984	RD (60°F, Pe)	RD (T, P)
API_Table53 (1980)	API 11.1:1980 Tables 53A, 53B and 53D	API 11.2.1M:1984	Density (T, P)	Density (15°C, Pe)
API_Table54 (1980)	API 11.1:1980 Tables 54A, 54B and 54D	API 11.2.1M:1984	Density (15°C, Pe)	Density (T, P)
Crude Oils, Refined Products and Lubricating Oils (API MPMS 11.1:2004)				
API_Table5 (2004)	API 11.1:2004	API 11.1:2004	°API (T, P)	°API (60°F, 0 psig)
API_Table6 (2004)	API 11.1:2004	API 11.1:2004	°API (60°F, 0 psig)	°API (T, P)
API_Table23 (2004)	API 11.1:2004	API 11.1:2004	RD (T, P)	RD (60°F, 0 psig)
API_Table24 (2004)	API 11.1:2004	API 11.1:2004	RD (60°F, 0 psig)	RD (T, P)
API_Table53 (2004)	API 11.1:2004	API 11.1:2004	Density (T, P)	Density (15°C, 0 bar(g))
API_Table54 (2004)	API 11.1:2004	API 11.1:2004	Density (15°C, 0 bar(g))	Density (T, P)
API_Table59 (2004)	API 11.1:2004	API 11.1:2004	Density (T, P)	Density (20°C, 0 bar(g))
API_Table60 (2004)	API 11.1:2004	API 11.1:2004	Density (20°C, 0 bar(g))	Density (T, P)
API_Table6C (2004)	API 11.1:2004	*Not applicable*	Thermal expansion coefficient at 60°F	Ctl
NGL and LPG (API 11.2.4)				
API_Table23E	API 11.2.4: 2007 Table 23E	API 11.2.2:1986 GPA TP-15:1988 GPA TP-15:2007	RD (T, P)	RD (60°F, Pe)
API_Table24E	API 11.2.4: 2007 Table 24E	API 11.2.2:1986 GPA TP-15	RD (60°F, Pe)	RD (T, P)
API_Table53E	API 11.2.4: 2007 Table 53E	API 11.2.2:1986 GPA TP-15	Density (T, P)	Density (15°C, Pe)

Function	Temperature correction	Pressure correction	Input	Output
API_Table54E	API 11.2.4: 2007 Table 53E	API 11.2.2:1986 GPA TP-15	Density (15°C, Pe)	Density (T, P)
API_Table59E	API 11.2.4: 2007 Table 59E	API 11.2.2M:1986 GPA TP-15	Density (T, P)	Density (20°C, Pe)
API_Table60E	API 11.2.4: 2007 Table 60E	API 11.2.2M:1986 GPA TP-15	Density (20°C, Pe)	Density (T, P)

Hydrometer Correction

The API MPMS 11.1 1980 Standard (API-2540) assumes that the API gravity or relative density is observed with a glass hydrometer. Therefore a correction may be applied for the change of volume of the glass hydrometer with temperature.
The hydrometer correction applies for tables 5A, 5B, 23A, 23B, 53A and 53B.
The 2004 standard does not include a correction for a glass hydrometer.

API-2540 Input Data Limits

API MPMS 11.1:1980 (API 2540) is based on published data that lie within the so-called 'Data' range. The other table values were obtained from extrapolation and lie within the 'Extrapolated' range. It is recommended not to use API-2540 outside the 'Data' and 'Extrapolated' ranges.
For the lubricating oil tables no difference is made between data that is table values that are based on published data and table values that are determined by extrapolation.

Range	API Gravity [◦API]	Relative Density [-]	Density [kg/m³]	Temperature [◦F]	Temperature [◦C]
Data Range	0 .. 40 40 .. 50 50 .. 55	1.0760 .. 0.8250 0.8250 .. 0.7795 0.7795 .. 0.7585	1075.0 .. 824.0 824.0 .. 778.5 778.5 .. 758.0	0 .. 250 0 .. 200 0 .. 150	-18..120 -18..90 -18..60
Extrapolated Range	0 .. 40 40 .. 50 50 .. 55 55 .. 100	1.0760 .. 0.8250 0.8250 .. 0.7795 0.7795 .. 0.7585 0.7585 .. 0.6110	1075.0 .. 824.0 824.0 .. 778.5 778.5 .. 758.0 758.0 .. 610.5	250 .. 300 200 .. 250 150 .. 200 0 .. 200	120..150 90..125 60..95 -18..95
Applies for:	Table 5A Table 6A	Table 23A	Table 24A	Table 5A Table 6A Table 23A Table 24A	Table 5A Table 6A Table 23A Table 24A

Range	API Gravity [°API]	Relative Density [-]	Density [kg/m³]	Temperature [°F]	Temperature [°C]
Data Range	0 .. 40 40 .. 50 50 .. 85	1.0760 .. 0.8250 0.8250 .. 0.7795 0.7795 .. 0.6535	1075.0 .. 824.0 824.0 .. 778.5 778.5 .. 653.0	0 .. 250 0 .. 200 0 .. 150	-18..120 -18..90 -18..60
Extrapolated Range	0 .. 40 40 .. 50 50 .. 85	1.0760 .. 0.8250 0.8250 .. 0.7795 0.7795 .. 0.6535	1075.0 .. 824.0 824.0 .. 778.5 778.5 .. 653.0	250 .. 300 200 .. 250 150 .. 200	120..150 90..125 60..95
Applies for:	Table 5B Table 6B	Table 23B	Table 24B	Table 5B Table 6B Table 23B Table 24B	Table 53B Table 54B

Range	API Gravity [°API]	Relative Density [-]	Density [kg/m³]	Temperature [°F]	Temperature [°C]
Data Range	-10..45	0.8..1.165	800..1164	0 .. 300	-20..+150
Applies for:	Table 5D Table 6D	Table 23D* Table 24D*	Table 53D Table 54D	Table 5D Table 6D Table 23D* Table 24D*	Table 53D Table 54D

* Values derived from Table 5D/6D

API-2540 - Rounding and truncating rules

For each table API Standard 2540 specifies an explicit 'Calculation Procedure' that includes the rounding and truncating of all the input, intermediate and output values. The 'Calculation Procedure' is considered to be the standard rather than the table values or a set of equations.
The function provides the option to either apply the full API rounding and truncating requirements or to perform the calculation procedure without any rounding and truncating being applied.

For tables 6A, 6B, 24A, 24B and 54A and 54B the standard makes a distinction between computational and table values for the calculated VCF. The table values are always rounded to 4 decimal places, Whereas the computational values has 4 decimal places when the VFC >=1 and 5 decimal places when the VCF < 1.
When API rounding is enabled the convergence limit is set to the limit value as specified in the standard. When the API rounding is disabled the convergence limit is set to 0.00001 kg/m3 to obtain highest precision.

API-11.1:2004 Limits

Range	Density	Temperature	Pressure
Crude Oil	610.6..1163.5 kg/m3 @ 60°F 100..-10 API @ 60°F 0.61120..1.16464 RD @ 60°F 611.16..1163.79 kg/m3 @ 15°C 606.12..1161.15 kg/m3 @ 20°C	-58..302 °F -50..150 °C	0..1500 psig 0..103.4 bar(g)
Refined products	610.6..1163.5 kg/m3 @ 60°F 100..-10 API @ 60°F 0.61120..1.16464 RD @ 60°F 611.16..1163.86 kg/m3 @ 15°C 606.12..1160.62 kg/m3 @ 20°C	-58..302 °F -50..150 °C	0..1500 psig 0..103.4 bar(g)
Lubricating oils	800.9..1163.5 kg/m3 @ 60°F 45..-10 API @ 60°F 0.80168..1.1646 RD @ 60°F 801.25..1163.85 kg/m3 @ 15°C 798.11..1160.71 kg/m3 @ 20°C	-58..302 °F -50..150 °C	0..1500 psig 0..103.4 bar(g)

API constants in US customary units

For the tables in US customary units the following constants apply (both for the 1980 and the 2004 tables):

Product	API Table	K0	K1	K2
Crude oil	A	341.0957	0.0	0.0
Gasoline	B	192.4571	0.2438	0.0
Transition area	B	1489.0670	0.0	-0.00186840
Jet fuels	B	330.3010	0.0	0.0
Fuel oils	B	103.8720	0.2701	0.0
Lubricating oils	D	0.0	0.34878	0.0

API constants in metric units

For the tables in metric units the following constants apply (both for the 1980 and the 2004 tables):

Product	API Table	K0	K1	K2
Crude oil	A	613.9723	0.0	0.0
Gasoline	B	346.4228	0.4388	0.0
Transition area	B	2680.3206	0.0	-0.00336312
Jet fuels	B	594.5418	0.0	0.0
Fuel oils	B	186.9696	0.4862	0.0
Lubricating oils	D	0.0	0.6278	0.0

fx2CellSelection

Description

The function selects between 2 input cells (e.g. differential pressure cells) based on the actual measured value and the failure status of each cell.
The function can handle the following type of cell range configurations:

- Lo – Hi
- Hi – Hi

Where 'Lo' means low range, 'Mid' mid range and 'Hi' high range.

Function

Function inputs	Remark	EU	SW tag	Range	Default
Name					
Cell A value	Input value as percentage of span of cell A				
Cell A status	Input status of cell A 0: Normal <> 0 : Failure				
Cell B value	Input value as percentage of span of cell B				
Cell B status	Input status of cell B 0: Normal <> 0 : Failure				
Range type	For a description of the functionality refer to adjacent section 'Logic' 1: Lo Hi Cell A at low range Cell B at high range 2: Hi Hi Cell A and B at same range		RNGTYP		
Auto switchback	For a description of the functionality refer to adjacent section 'Logic' 0: Disabled 1: Enabled				
Switch-up percentage	Switch-up value expressed as percentage of span of the lower range	-	SWUPPERC	0..100	95
Switch-down percentage	Switch-down value expressed as percentage of span of the lower range	-	SWDNPERC	0..100	90

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range		STS	FIOOR	
Selected cell number	1: Cell 1 2: Cell 2		SELNR		1
Selected cell status	0: Normal 1: Failure		SELSTS		0

Logic

The function will switch from one cell to another at the following conditions:

Range type = 'Lo Hi'
When cell A is currently selected

- Select cell B when cell A value is above or equal to the switch-up percentage of its range and cell B is healthy.
- Select cell B when cell A fails while cell B is healthy

When cell B is currently selected

- Select cell A when cell A value is below or equal to the switch-down percentage of its range and cell A is healthy
- Select cell A when cell B fails and cell A is healthy

Range type = 'Hi Hi'
When cell A is currently selected

- Select cell B when cell A value fails and cell B is healthy

When cell B is currently selected

- Select cell A when cell A is healthy and 'Auto switchback' is enabled
- Select cell A when cell B fails and cell A is healthy.

fx3CellSelection

Description

The function selects between 3 input cells (typically differential pressure cells) based on the actual measured value and the failure status of each cell.
The function can handle the following type of cell range configurations:

- Lo – Mid – Hi
- Lo – Hi – Hi
- Hi – Hi – Hi

Where 'Lo' means low range, 'Mid' mid range and 'Hi' high range.

Function

Function inputs	Remark	EU	SW tag	Range	Default
Name					
Cell A value	Input value as percentage of span of cell A				
Cell A status	Input status of cell A 0: Normal <> 0 : Failure				
Cell B value	Input value as percentage of span of cell B				
Cell B status	Input status of cell B 0: Normal <> 0 : Failure				
Cell C value	Input value as percentage of span of cell C				
Cell C status	Input status of cell C 0: Normal <> 0 : Failure				
Range type	For a description of the functionality refer to adjacent section 'Logic' 1: Lo Mid Hi Cell A at low range Cell B at mid range Cell C at high range 2: Lo Hi Hi Cell A at low range Cell B and C at high range 3: Hi Hi Hi Cell A, B and C at same range		RNGTYP		
Auto switchback	For a description of the functionality refer to adjacent section 'Logic' 0: Disabled 1: Enabled				
Switch-up percentage	Switch-up value expressed as percentage of span of the lower range Does not apply for selection type 'Hi Hi	-	SWUPPERC	0..100	95

	Hi'				
Switch-down percentage	Switch-down value expressed as percentage of span of the lower range Does not apply for selection type 'Hi Hi Hi'	-	SWDNPERC	0..100	90

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range		STS	FIOOR	
Selected cell number	1: Cell 1 2: Cell 2 3: Cell 3		SELNR		1
Selected cell status	0: Normal 1: Failure		SELSTS		0

Logic

The function will switch from one cell to another at the following conditions:

Range type = 'Lo Mid Hi'
When cell A is currently selected

- Select cell B when cell A value is above or equal to the switch-up percentage of its range and cell B is healthy.
- Select cell B when cell A fails while cell B is healthy
- Select cell C when cell A and cell B fail and cell C is healthy

When cell B is currently selected

- Select cell C when cell B value is above or equal to the switch-up percentage of its range and cell C is healthy
- Select cell A when cell A value is below or equal to the switch-down percentage of its range and cell A is healthy
- Select cell A when cell B fails while cell A is healthy
- Select cell C when cell B and cell A fail and cell C is healthy

When cell C is currently selected

- Select cell B when cell B value is below or equal to the switch-down percentage of its range and cell B is healthy
- Select cell B when cell C fails while cell B is healthy
- Select cell A when cell C and cell B fail and cell A is healthy

Range type = 'Lo Hi Hi'
When cell A is currently selected

- Select cell B when cell A value is above or equal to the switch-up percentage of its range and cell B is healthy.

- Select cell C when cell A value is above or equal to the switch-up percentage of its range and cell B fails and cell C is healthy.
- Select cell B when cell A fails while cell B is healthy
- Select cell C when cell A and cell B fail and cell C is healthy

When cell B is currently selected

- Select cell A when cell A value is below or equal to the switch-down percentage of its range and cell A is healthy
- Select cell C when cell B fails while cell C is healthy
- Select cell A when cell B and cell C fail and cell A is healthy

When cell C is currently selected

- Select cell A when cell A value is below or equal to the switch-down percentage of its range and cell A is healthy
- Select cell B when cell B is healthy and ‘Auto switchback’ is enabled
- Select cell A when cell C and cell B fail and cell A is healthy

Range type = ‘Hi Hi Hi’
When cell A is currently selected

- Select cell B when cell A value fails and cell B is healthy
- Select cell C when cell A and cell B fail and cell C is healthy

When cell B is currently selected

- Select cell A when cell A is healthy and ‘Auto switchback’ is enabled
- Select cell A when cell B fails and cell A is healthy
- Select cell C when cell B and A fail and cell C is healthy

When cell C is currently selected

- Select cell A when cell A is healthy and ‘Auto switchback’ is enabled
- Select cell B when cell B is healthy and cell A fails and ‘Auto switchback’ is enabled
- Select cell A when cell C fails and cell A is healthy
- Select cell B when cell C and A fail and cell B is healthy

fxAGA10_M

The function calculates the speed of sound of a gas at the specified conditions of temperature and pressure using the formulae presented in the American Gas Association Report No 10.

Compliance

AGA Report No. 10 - Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases, January 2003

Input Data Limits

The AGA-10 calculation has defined uncertainty bounds for gas mixtures that lie within the 'Normal range'. Also an 'Expanded range' of gas mixtures is defined for which the AGA-10 calculation has a higher uncertainty. Using the AGA-10 calculation for gas mixtures that lie outside the 'Expanded range' is not recommended.
The AGA-10 standard specifies the same limits as the AGA-8 standard. Refer to the fxAGA8 function for details on the actual limit values used by this function to set output 'Range'.

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Pressure	Observed pressure	bar(a)		0..2000	
Temperature	Observed temperature	°C		- 200..+400	
Composition	Standard composition as defined in section 'Standard gas composition.	mol/mol	COMP	0..1	
neo-Pentane mode	Determines what to do when component neo-Pentane is larger than zero 1: Add to i-Pentane 2: Add to n-Pentane 3: Neglect	-	NEOC5_MODE		1

Function outputs	Remark	EU	SW tag	Alam	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence 4: Mole fractions do not add up to 1.0 +- 0.0001		STS	 FIOOR CALCERR NOCONV COMPOOR	
Speed of sound		m/s	SOS		0
Range	0: In Normal Range All inputs are within the 'Normal Range' 1: In Extended Range One or more inputs within the 'Extended Range, but none of the inputs outside the Extended rang (outputs values have higher uncertainty) 2: Out of Range		RANGE	OOR	0

	One or more inputs outside the 'Extended Range' (using the AGA10 calculation is not recommended in this case)				

Calculations

Calculations are as documented in the standard.

fxAGA10ex_M

The extended AGA 10 function provides an extensive set of gas properties at the specified conditions of temperature and pressure using the formulae presented in the American Gas Association Report No 10.

Compliance

AGA Report No. 10 - Speed of Sound in Natural Gas and Other Related Hydrocarbon Gases, January 2003

Input Data Limits

The AGA-10 calculation has defined uncertainty bounds for gas mixtures that lie within the 'Normal range'. Also an 'Expanded range' of gas mixtures is defined for which the AGA-10 calculation has a higher uncertainty. Using the AGA-10 calculation for gas mixtures that lie outside the 'Expanded range' is not recommended.
The AGA-10 standard specifies the same limits as the AGA-8 standard. Refer to the fxAGA8 function for details on the actual limit values used by this function to set output 'Range'.

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Pressure	Observed pressure	bar(a)		0..2000	
Temperature	Observed temperature	°C		-200..+400	
Composition	Standard composition as defined in section 'Standard gas composition.	mol/mol	COMP	0..1	
neo-Pentane mode	Determines what to do when component neo-Pentane is larger than zero 1: Add to i-Pentane 2: Add to n-Pentane 3: Neglect	-	NEOC5_MODE		1

Function outputs	Remark	EU	SW tag	Alam	Fall back
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence 4: Mole fractions do not add up to 1.0 +- 0.0001		STS	 FIOOR CALCERR NOCONV COMPOOR	
Molecular weight		kg/kmol	MOLMASS		
Molar density at base conditions		mol/m3	MOLDENSB		
Molar density at flowing conditions		mol/m3	MOLDENSF		
Mass density at base conditions		kg/m3	MASSDENSB		
Mass density at flowing conditions		kg/m3	MASSDENSF		
Ideal gas relative density		-	IRD		
Real gas relative density		-	RRD		
Velocity of sound		m/s	SOS		
Compressibility at base conditions		-	ZB		
Compressibility at flowing conditions		-	ZF		
Supercompressibility		-	FPV		
Ideal gas specific enthalpy		kJ/kg	MASSH0		
Real gas specific enthalpy		kJ/kg	MASSH		
Real gas specific entropy		kJ/kg/K	MASSS		
Ideal gas isobaric heat capacity		kJ/kg/K	MASSCP0		
Real gas isobaric heat capacity		kJ/kg/K	MASSCP		
Real gas isochoric heat capacity		kJ/kg/K	MASSCV		
Ideal gas isobaric heat capacity		kJ/kmol/K	MOLCP0		
Real gas isobaric heat capacity		kJ/kmol/K	MOLCP		
Real gas isochoric heat capacity		kJ/kmol/K	MOLCV		
Ratio of specific heats		-	CPCV		
Isentropic exponent		-	KAPPA		
Critical flow factor		-	CRITC		
Ideal gas specific enthalpy		kJ/kmol	MOLH0		
Real gas specific		kJ/kmol	MOLH		

enthalpy					
Isentropic perfect gas critical flow factor		-	CI		
Isentropic real gas critical flow factor		-	CRI		
Range	0: In Normal Range All inputs are within the 'Normal Range' 1: In Extended Range One or more inputs within the 'Extended Range, but none of the inputs outside the Extended rang (outputs values have higher uncertainty) 2: Out of Range One or more inputs outside the 'Extended Range' (using the AGA10 calculation is not recommended in this case)		RANGE	OOR	0

Calculations

Calculations are as documented in the standard.

fxAGA3_C

Description

The function calculates the mass flow rate for Orifice pressure differential flow devices according to the AGA-3 standard.
AGA-3 covers orifice meters with flange taps and pipe taps.

Compliance

- AGA Report No. 3 - Orifice Metering Measurement of fluid flow by means of pressure differential devices, 1991
- API Manual of Petroleum Measurement Standards, Chapter 14 Natural Gas Fluids Measurement, Section 3 - Concentric Square-edged Orifice Meters 1990.

Function

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Differential Pressure	Differential pressure over the primary flow device measured at the up- and downstream pressure tappings, which need to be in the positions as specified in the standard	inH2O @ 60°F		0..1000	0
Pressure	Down- or upstream pressure value of the fluid at metering conditions	psia		0..30000	0
Temperature	Down- or upstream temperature of the fluid at metering conditions	°F		-400..2000	0
Density	Down or upstream density of the fluid at metering conditions	lbm/ft3		0..200	0
Dynamic Viscosity	Dynamic viscosity of the fluid	lbm/ft.s	DYNVIS	0..1	6.9e-6
Isentropic Exponent	Also referred to as κ (kappa). For an ideal gas this coefficient is equal to the ratio of the specific heat capacity at constant pressure to the specific heat at constant volume. This ratio is commonly used when the real value is unknown.	-	KAPPA	0..10	1.3
Pipe Diameter	Internal diameter of the pipe at reference temperature	inches	PIPEDIAM	0..100	0
Pipe Expansion factor	The thermal expansion coefficient of the pipe material	1/°F	PIPEEXPF	0..1	6.2e-6
Pipe Reference temperature	The reference temperature that corresponds to the 'Pipe diameter' input value	°F	PIPEREFT	-400..2000	68
Orifice Diameter	Orifice diameter at reference	inches	ORIFDIAM	0..100	0

	temperature				
Orifice Expansion factor	The thermal expansion coefficient of the orifice material Typical values are:	1/°F	ORIFEXPF	0..1	9.25e-6
Orifice Reference Temperature	The reference temperature that corresponds to the 'Orifice diameter' input value	°F	ORIFREFT	-400..2000	68
Pressure Location	1: Upstream tapping Input 'Pressure' represents the pressure at the upstream pressure tapping (p_1). Since the absolute pressure is usually measured at the upstream tapping this is the most common setting. 2: Downstream tapping Input 'Pressure' represents the pressure at the downstream tapping (p_2).	-	PRESLOC		1
Temperature Location	1: Upstream tapping Input 'Temperature' represents the upstream temperature (t_1). 2: Downstream tapping Input 'Temperature represents the temperature at the downstream tapping (t_2). 3: Recovered pressure Input 'Temperature' represents the downstream temperature at a location Where the pressure has fully recovered (t_3). Since temperature measurement is usually downstream of the flow device this is the most common setting.	-	TEMPLOC		3
Temperature Correction	1: Use $(1-\kappa)/\kappa$ Isentropic expansion using $(1-\kappa)/\kappa$ as the temperature referral exponent	-	TEMPCOR		1

	2: Use temperature exponent Isentropic expansion using input 'Temperature Exponent' as the temperature referral exponent [-]				
Temperature Exponent	To correct the temperature from down- to upstream conditions (or vice versa) the formula (κ-1)/κ (isentropic expansion) will be used when the input value is set to 0, else the input value will be used. For more details refer to section 'Temperature correction'.		TEMPEXP		0
Density Location	This parameter specifies if and how the density should be corrected from downstream to upstream conditions. 1: Upstream tapping Input 'Density' represents the density at the upstream pressure tapping (ρ_1). 2: Downstream tapping Input 'Density' represents the density at the downstream tapping (ρ_2). 3: Recovered pressure Input 'Density' represents the density downstream at a location Where the pressure has fully recovered (ρ_3).	-	DENSLOC		0
Density Exponent.	This factor is used when density correction is enabled. The formula 1/κ will be used when the input value is set to 0, else the input value will be used. For more details refer to section function 'ISO5167- Orifice' 'Density correction'.	-	DENSEXP		0
Fluid	The type of fluid being measured 1: Gas 2: Liquid For liquid the expansion factor is set to 1, i.e. the fluid is considered to be incompressible.	-	FLUID		0
Drain hole	When input is > 0 then an additional correction on the orifice	in	DRAIN	0.. 100	0

	diameter will be applied to account for the drain hole, as explained further on.				
Fpwl	Local Gravitational Correction Factor for Deadweight Calibrators used to calibrate differential and static pressure Instruments. Directly applied on the calculated mass flow rate within each iteration.	-	FPWL	0.9..1.1	1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence		STS	 FIOOR CALCERR NOVONV	
Mass flow rate	The calculated mass flow rate	klbm/hr	MASSR		0
Beta ratio	Orifice to pipe diameter ratio at upstream temperature	-	BETA		0
Orifice diameter	At the upstream temperature	inches	ORIFUP		0
Pipe diameter	At the upstream temperature	inches	PIPEUP		0
Upstream pressure	Pressure at upstream tapping (p_1)	psia	PRESUP		0
Pressure at downstream tapping	Pressure at downstream tapping (p_2)	psia	PRESDN		0
Recovered downstream pressure	Fully recovered downstream pressure (p_3)	psia	PRESREC		0
Upstream temperature	Temperature at upstream tapping (t_1)	°F	TEMPUP		0
Temperature at downstream tapping	Temperature at downstream tapping (t_2)	°F	TEMPDN		0
Downstream Temperature	'Fully recovered' downstream temperature (t_3)	°F	TEMPREC		0
Upstream density	Density at upstream tapping (ρ_1)	lbm/ft3	DENSUP		0
Density at downstream tapping	Pressure at downstream tapping (ρ_2)	lbm/ft3	DENSDN		0
Downstream density	'Fully recovered' downstream density (ρ_3)	lbm/ft3	DENSREV		0
Reynolds number	The <u>pipe</u> Reynolds number, i.e. the Reynolds number upstream of the orifice and not the one	-	REYN		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
	within the device throat itself)				
Discharge coefficient		-	DISCF		0
Expansion Factor		-	EXPFAC		0
Velocity of Approach		-	VOA		0
Pressure out of range	0: Pressure is in valid range 1: Pressure is out of valid range	-	PRESOOR	PRESOOR	0
Reynolds out of range	0: Reynolds number is in valid range 1: Reynolds number is out of valid range	-	REYNOOR	REYNOOR	0
Diameter out of range	0: Device and pipe diameter and Beta ratio in valid range 1: Device diameter, pipe diameter and/or Beta ratio out of valid range	-	DIAMOOR	DIAMOOR	0

Calculations

The calculations are in accordance with the standard.

Pressure correction

- The relation between the pressure at the upstream tapping p_1 and the pressure at the downstream tapping (p_2) is as following:

$$p_2 = p_1 - \frac{\Delta p \cdot K_{units}}{1000}$$

- The relation between the pressure at the upstream tapping and the downstream tapping is as following:

$$p_3 = p_1 - p_{LOSS}$$

$$p_{LOSS} = \frac{\left(1 - \alpha \cdot \beta^2\right)}{\left(1 + \alpha \cdot \beta^2\right)} \cdot \Delta p \cdot K_{units}$$

$$\alpha = C \cdot E$$

$$E = \frac{1}{\sqrt{\left(1 - \beta^4\right)}}$$

Where:

p_1	Pressure at upstream tapping	psia
p_2	Pressure at downstream tapping	psia
p_3	Fully recovered downstream pressure	psia
Δp	Differential pressure	inH20 @ 60°F
p_{LOSS}	Pressure loss over the meter	psi
C	Discharge coefficient as calculated by the standard	-
α	Flow coefficient	-
β	Diameter ratio at the upstream pressure and temperature	-
E	Velocity of approach factor	-
K_{units}	Unit conversion factor to convert a value expressed in 'inH2O @60°F' to the corresponding expressed in 'psi' (conversion as specified in section 'Unit Types')	-

Temperature correction

- When input 'Temperature correction' is set to 1, then an isentropic expansion based on the isentropic coefficient is applied:

$$t_1 = (t_2 + 459.67) \cdot \left(\frac{p_2}{p_1} \right)^{\frac{1-\kappa}{\kappa}} - 459.67$$

$$t_1 = (t_3 + 459.67) \cdot \left(\frac{p_3}{p_1} \right)^{\frac{1-\kappa}{\kappa}} - 459.67$$

- When input 'Temperature correction' is set to 2, then an isentropic expansion based on input 'Temperature exponent' is applied:

$$t_1 = (t_2 + 459.67) \cdot \left(\frac{p_2}{p_1} \right)^{K_{TE}} - 459.67$$

$$t_1 = (t_3 + 459.67) \cdot \left(\frac{p_3}{p_1} \right)^{K_{TE}} - 459.67$$

Where:

t_1	Upstream temperature	°F
t_2	Temperature at the downstream tapping	°F
t_3	Temperature at the fully recovered downstream pressure	°F
p_1	Upstream pressure	psia
p_2	Pressure at the downstream tapping	psia
p_3	Fully recovered downstream pressure	psia
κ	Isentropic exponent	-
K_{TE}	Temperature exponent	-

Density correction

- When input 'Density exponent' = 0, then the following isentropic corrections are applied (depending on the type of Density Correction)

$$\rho_1 = \rho_2 \cdot \left(\frac{p_1}{p_2}\right)^{\frac{1}{\kappa}} \qquad \rho_1 = \rho_3 \cdot \left(\frac{p_1}{p_3}\right)^{\frac{1}{\kappa}}$$

- Else the value of input 'Density Exponent' is used

$$\rho_1 = \rho_2 \cdot \left(\frac{p_1}{p_2}\right)^{K_{DE}} \qquad \rho_1 = \rho_3 \cdot \left(\frac{p_1}{p_3}\right)^{K_{DE}}$$

Where:

ρ_1	Upstream density	lbm/ft3
ρ_2	Density at the downstream tapping	lbm/ft3
ρ_3	Density at the fully recovered downstream pressure	lbm/ft3
p_1	Upstream pressure	psia
p_2	Pressure at the downstream tapping	psia
p_3	Fully recovered downstream pressure	psia
κ	Isentropic exponent	-
K_{DE}	Density exponent	-

fxAGA5_C

The AGA 5 standard defines methods to calculate the mass and volume based calorific values at 60°F and 14.73 psia for a natural gas based on known molar fractions of the non-hydrocarbon gas components.

Compliance

- A.G.A. Transmission Measurement Committee Report No. 5 (Fuel gas Energy Metering) 1981
- A.G.A. Transmission Measurement Committee Report No. 5 (Fuel gas Energy Metering) 1996 (Reprinted 1999)

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Composition	Standard composition as defined in section 'Standard gas composition. Only the following components are considered by the calculation: N2 Nitrogen CO2 Carbon dioxide H2O Water H2S Hydrogen sulfide H2 Hydrogen CO Carbon monoxide O2 Oxygen He Helium Sum of these fractions may not exceed 1	molar fraction	COMP	0..1	0
Specific Gravity	Molar Mass Ratio, i.e. ratio of the molar mass of the gas and of the molar mass of air (specified in AGA-5 as 28.9644 kg/kmol (lbm/lbmol))	-	SG	0..1	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error		STS	 FIOOR CALCERR	
Calorific value mass	Mass based calorific value	Btu/lbm	CV_MASS		0
Calorific value volume	Volume calorific value at 60°F and 14.73 psia	Btu/scf	CV_VOL		0

Calculations

The Energy to Mass ratio is calculated according to Section III of the standard, which contains the calculation procedure for the gas mass to energy conversion. The equations based on the 'by volume' fractional values are used (and not the equations based on the 'by weight' values).

The Energy to Volume ratio is calculated according to Section II of the standard, which contains the calculation procedure for the gas volume to energy conversion.

fxAGA8_C

The compressibility and density of a gas are calculated from the composition, temperature and pressure in accordance with the ‘Detail Characterization’ method outlined in the AGA-8 standard, with the input and output values in **US Customary** units.

Compliance

- AGA Report No. 8, Second edition November 1992 - 2nd printing July 1994
- API MPMS 14.2, Second edition November 1992 - 2nd printing July 1994
- ISO 12213 Natural gas — Calculation of compression factor — Part 2: Calculation using molar-composition analysis, 1997

Input Data Limits

The AGA-8 calculation has defined uncertainty bounds for gas mixtures that lie within the 'Normal range'. Also an 'Expanded range' of gas mixtures is defined for which the AGA-8 calculation has a higher uncertainty. Using the AGA-8 calculation for gas mixtures that lie outside the 'Expanded range' is not recommended.

Input value	Normal Range	Expanded Range	EU
Pressure	0 .. 20000	0 .. 20000	psia
Temperature	-200 .. +400	-200 .. +400	°F
Mole fraction of Methane	0.45 .. 1.00	0.00 .. 1.00	-
Mole fraction of Ethane	0.00 .. 0.10	0.00 .. 1.00	-
Mole fraction of Propane	0.00 .. 0.04	0.00 .. 0.12	-
Mole fraction of Butanes	0.00 .. 0.01	0.00 .. 0.06	-
Mole fraction of Pentanes	0.00 .. 0.003	0.00 .. 0.04	-
Mole fraction of Hexanes Plus	0.00 .. 0.002	*	-
Mole fraction of Carbon monoxide	0.00 .. 0.03	0.00 .. 0.03	-
Mole fraction of Carbon dioxide	0.00 .. 0.30	0.00 .. 1.00	-
Mole fraction of Nitrogen	0.00 .. 0.50	0.00 .. 1.00	-
Mole fraction of Helium	0.00 .. 0.002	0.00 .. 0.03	-
Mole fraction of Argon	0.00 .. 0.00	0.00 .. 0.01	-
Mole fraction of Oxygen	0.00 .. 0.00	0.00 .. 0.21	-
Mole fraction of Hydrogen Sulphide	0.00 .. 0.0002	0.00 .. 1.00	-
Mole fraction of Hydrogen	0.00 .. 0.10	0.00 .. 1.00	-
Mole fraction of Water	0.00 .. 0.0005	*	-

* For these components the dew point temperature is the upper limit. Limit check is ignored for reason of simplicity.

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Pressure	Pressure value	psia		0..40000	1.01325
Temperature	Temperature value	°F		-250..+800	0
Composition	Standard composition as defined in section 'Standard gas composition.	mol/mol	COMP	0..1	0
neo-Pentane mode	Determines what to do when component neo-Pentane is larger than zero 1: Add to i-Pentane 2: Add to n-Pentane 3: Neglect	-	NEOC5_MODE		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence 4: Mole fractions do not add up to 1.0 +- 0.0001		STS	FIOOR CALCERR NOCONV COMPERR	
Compressibility factor		-	Z		1
Mass Density		lb/ft3	MASDENS		0
Mole Density		lbmol/ft3	MOLDENS		0
Molar Mass		lb/lbmol	MOLMASS		0
Range	0: In Normal Range All inputs are within the 'Normal Range' 1: In Extended Range One or more inputs within the 'Extended Range, but none of the inputs outside the Extended rang (outputs values have higher uncertainty) 2: Out of Range One or more inputs outside the 'Extended Range' (using the AGA8 calculation is not recommended in this case)		RANGE	OOR	0

Calculations

The calculations are as documented in the standard.

fxAGA8_M

The compressibility and density of a gas are calculated from its composition, temperature and pressure in accordance with the 'Detail Characterization' method outlined in the AGA8 standard, with the input and output values in **metric** units.

Compliance

- AGA Report No. 8, Second edition November 1992 - 2nd printing July 1994
- API MPMS 14.2, Second edition November 1992 - 2nd printing July 1994
- ISO 12213 Natural gas — Calculation of compression factor — Part 2: Calculation using molar-composition analysis, 1997

Input Data Limits

The AGA-8 calculation has defined uncertainty bounds for gas mixtures that lie within the 'Normal range'. Also an 'Expanded range' of gas mixtures is defined for which the AGA-8 calculation has a higher uncertainty. Using the AGA-8 calculation for gas mixtures that lie outside the 'Expanded range' is not recommended.

Input value	Normal Range	Expanded Range	EU
Pressure	0 .. 1379	0 .. 1379	bar(a)
Temperature	-129 .. +204	-129 .. +204	°C
Mole fraction of Methane	0.45 .. 1.00	0.00 .. 1.00	-
Mole fraction of Ethane	0.00 .. 0.10	0.00 .. 1.00	-
Mole fraction of Propane	0.00 .. 0.04	0.00 .. 0.12	-
Mole fraction of Butanes	0.00 .. 0.01	0.00 .. 0.06	-
Mole fraction of Pentanes	0.00 .. 0.003	0.00 .. 0.04	-
Mole fraction of Hexanes Plus	0.00 .. 0.002	*	-
Mole fraction of Carbon monoxide	0.00 .. 0.03	0.00 .. 0.03	-
Mole fraction of Carbon dioxide	0.00 .. 0.30	0.00 .. 1.00	-
Mole fraction of Nitrogen	0.00 .. 0.50	0.00 .. 1.00	-
Mole fraction of Helium	0.00 .. 0.002	0.00 .. 0.03	-
Mole fraction of Argon	0.00 .. 0.00	0.00 .. 0.01	-
Mole fraction of Oxygen	0.00 .. 0.00	0.00 .. 0.21	-
Mole fraction of Hydrogen Sulphide	0.00 .. 0.0002	0.00 .. 1.00	-
Mole fraction of Hydrogen	0.00 .. 0.10	0.00 .. 1.00	-
Mole fraction of Water	0.00 .. 0.0005	*	-

* For these components the dew point temperature is the upper limit. Limit check is ignored for reason of simplicity.

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Pressure	Pressure value	bar(a)		0..2800	1.01325
Temperature	Temperature value	°C		-150..+450	0
Composition	Standard composition as defined in section 'Standard gas composition.	mol/mol	COMP	0..1	0
neo-Pentane mode	Determines what to do when component neo-Pentane is larger than zero 1: Add to i-Pentane 2: Add to n-Pentane 3: Neglect	-	NEOC5_MODE		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence 4: Mole fractions do not add up to 1.0 +- 0.0001		STS	 FIOOR CALCERR NOCONV COMPERR	
Compressibility factor		-	Z		1
Mass Density		kg/m3	MASDENS		0
Mole Density		kmol/m3	MOLDENS		0
Molar Mass		kg/kmol	MOLMASS		0
Range	0: In Normal Range All inputs are within the 'Normal Range' 1: In Extended Range One or more inputs within the 'Extended Range, but none of the inputs outside the Extended rang (outputs values have higher uncertainty) 2: Out of Range One or more inputs outside the 'Extended Range' (using the AGA8 calculation is not recommended in this case)		RANGE	OOR	0

Calculations

The calculations are as documented in the standard.

fxAnalogInput

Each flow module supports a maximum of 6 analog input signals. The first 2 signals can be used as either a mA/VDC input or as a RTD input.
The Analog input function is used for mA and VDC inputs. For RTD inputs refer to function 'RTD Input'.
Analog signals are sampled at a rate of about 15 Hz. Every calculation cycle the samples are averaged and the average is scaled to a value in engineering units.
The output value can be equal to either the last sample or the average of the samples of the last calculation cycle. The average is either the arithmetic mean or the Root of the Mean of the Squares (RMS), Where the latter is meant for a differential pressure signal of a primary flow device (e.g. an orifice plate)

The input signal is considered to be faulty when the input circuitry has an open or a short circuit or when the measured value is outside a configurable range.

> Note: Function fxKeypadfallback provides the option to force the analog input value to a specific fallback value in case it should fail. It also provides the option to force the input value to a keypad value e.g. upon user request.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Channel number			CHAN	1..6	1
Input type	1: 4-20 mA 2: 0-20 mA 3: 1-5 VDC 4: 0-5 VDC		INPTYP		2
Averaging type	1: Arithmetic mean 2: Root Mean Square		AVGTYP		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Function Input argument out of range		STS	FIOOR	
Percentage value	Actual percentage of scale value	%	PERC		0

fxAnalogOutput

This function configures a single 4-20 mA output channel on the local Flow-X module. Use function 'SetAnalogOutput' to control the actual output signal.
The output current is either set directly or gradually changed to the required set point based on the specified filter method.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional Optional tag name, tag description and tag group				*<Empty>*
Channel number		1..4	CHAN		0
Filter setpoint	0 .. 15 0: No filtering 1: Fastest filter .. 15: Slowest filter		FILSP		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Function Input argument out of range		STS	FIOOR	
Percentage value	The actual (and filtered) output value expressed as a percentage	%	PERC		0

fxAPI_Dens15C_1952

Density (T, P) <--> Density (15°C, equilibrium pressure)

This function converts a density value at the observed temperature and pressure to the density at 15°C and the equilibrium pressure (typically 0 barg) or vice versa.
The temperature conversion is according to ASTM-IP Petroleum Measurements Tables 1952 (Also known as API-1952 tables) Table 54.

Note: this function is a combination of the API 1952 Tables and API 11.2.1M. For the calculation from observed to standard conditions an iterative calculation is required. The rounding and truncating of input and intermediate values is implemented such that the example calculations as specified in both standards are exactly reproduced.

Compliance

- ASTM-IP Petroleum Measurement Tables, Metric Edition, Metric Units of Measurement, 1952
- API MPMS 11.2.1M - Compressibility Factors for Hydrocarbons: 638 - 1074 Kilograms per Cubic Meter Range - First Edition, August 1984

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed Density	Depending on the conversion method this is the Density either at the observed temperature and observed pressure or at 15 °C and the equilibrium pressure	kg/m3		0..1300	0
Observed temperature		°C		-100..200	15
Observed pressure		bar(g)		-1..150	0
API 11.2.1 rounding	0: Disabled The calculation of the compressibility factor F is performed with full precision 1: Enabled API-MPMS 11.2.1 rounding and truncating rules are applied. The compressibility factor F is rounded to 3 decimal places as specified in the standard.	-	API1121RND		0

Function inputs	Remark	EU	SW tag	Range	Default
Equilibrium pressure	The equilibrium pressure is considered to be 0 bar(g) for liquids which have an equilibrium pressure less than atmospheric pressure (in compliance with API MPMS 12.2 par. 12.2.5.4).	bar(g)	EQUIPRES	0..150	0
Conversion method	1: From observed to standard conditions 2: From standard to observed conditions		CONVERSI ON		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	 1
Output Density	Depending on the conversion method this is the Density either at 15 °C and the equilibrium pressure or at the observed temperature and observed pressure	kg/m3	DENS		0
CTL	Volume correction factor for temperature.	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API 11.2.1 rounding'	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
F	Compressibility factor	-	F		0
CTL calc out of range	With respect to the standard used for the calculation of CTL the combination of input values is: 0: In Range 1: Out of Range			CTLOOR	0
CPL calc out of range	With respect to the standard used for the calculation of CPL the combination of input values is: 0: In Range 1: Out of Range			CPLOOR	0

Calculations

The calculations depend on the conversion method.

Conversion method 1: from observed to standard conditions.
The function performs the following iterative algorithm to calculate the Density at standard conditions:

1. At the start of the iteration the initial value for Density at [15 °C, equilibrium pressure] is set to the Observed Density. The initial CPL value is set to 1.

2. The CTL value is determined from the Density at [15 °C, equilibrium pressure] according to API 1952 Table 54.
3. The Density at [15 °C, equilibrium pressure] is calculated from the Observed Density, the new CTL value and the CPL value from the previous iteration.
4. The compressibility factor is calculated according to API MPMS 11.2.1M from the density at [15 °C, equilibrium pressure] and the 'Observed temperature'. If API 11.2.1M rounding is enabled then the density and temperature are rounded and the calculations are performed in accordance with the rounding and truncating rules of the standard.
5. The CPL value is calculated from the compressibility factor and the 'Observed pressure' and 'Equilibrium pressure' input values.
6. The Density at [15°C, equilibrium pressure] is calculated by dividing the Observed Density by the CTL and the new CPL value.
7. Steps 2 through 6 are repeated taking the Density value from step 7 as the start value for the next iteration until the absolute difference between two consecutive Density values is 0.0001.

Conversion method 2: from standard to observed conditions.
The function performs straightforward calculations to determine the Density at observed conditions:

1. The CTL value is calculated according to API 1952 Table 54
2. The compressibility factor is calculated according to API MPMS 11.2.1M from the input density and temperature'. If API 11.2.1M rounding is enabled then the input density and temperature are rounded and the calculations are performed in accordance with the rounding and truncating rules of the standard.
3. The CPL value is calculated from the compressibility factor and the 'Observed pressure' and 'Equilibrium pressure' input values.
4. The output Density (at observed temperature and pressure) is calculated from the input Density and the CTL and the CPL values.

fxAPI_Dens15C_1980

Description

Density (T, P) <--> Density (15°C, equilibrium pressure)

This function converts a density value at the observed temperature and pressure to the density value at 15°C and the equilibrium pressure (typically 0 bar(g)) or vice versa.
The temperature conversion is according to API-2540, Tables 53A/54A (Generalized Crude Oils) and 53B/54B (Refined Oil Products) and API MPMS 11.1 Chapter XIV Table 53D/54D: 1984 (Lubricating Oils), while the volume correction for pressure according to API MPMS 11.2.1M.
An iterative calculation needs to be applied to convert the observed density to the value at base conditions.

Note: this function is a combination of API2540 and API 11.2.1M. For the calculation from observed to standard conditions an iterative calculation is required. The rounding and truncating of input and intermediate values is implemented such that the example calculations as specified in both standards are exactly reproduced.

Compliance

- API MPMS 11.1 Volume X (API Standard 2540) - Table 53A - Generalized Crude Oils, Correction of Observed Density to Density at 15°C - First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 54A - Generalized Crude Oils, Correction of Volume to 15°C against Density at 15°C- First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 53B - Generalized Products, Correction of Observed Density to Density at 15°C - First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 54B - Generalized Products, Correction of Volume to 15°C against Density at 15°F - First Edition, August 1980
- API MPMS 11.1 Volume XIV - Table 53D - Generalized Lubricating Oils, Correction of Observed Density to Density at 15°C - January 1982
- API MPMS 11.1 Volume XIV - Table 54D - Generalized Lubricating Oils, Correction of Volume to 15°C against Density at 15°F - January 1982
- API MPMS 11.2.1M - Compressibility Factors for Hydrocarbons: 638 - 1074 Kilograms per Cubic Meter Range - First Edition, August 1984

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input density	Meaning depends on the input 'Conversion method'. 'Conversion method' = 1 Density at the observed temperature and pressure 'Conversion method' = 2 Density at 15 °C and the equilibrium pressure.	kg/m3		0..1300	0
Observed temperature		°C		-100..200	15
Observed pressure		bar(g)		-1..150	0
Product	1: A - Crude Oil 2: B - Auto select *Selection based on density at 15 °C* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP		1
API 2540 rounding	0: Disabled The calculations are performed with full precision and the final CTL value is rounded as specified by input 'CTL decimal places' 1: Enabled for computational value API-2540 rounding and truncating rules are applied and, in case of conversion method 2 (standard to observed), the **computational** value for CTL as specified in Table 54 is used, meaning that the CTL value has: 4 decimal places if CTL >=1 5 decimal places if CTL < 1. 2: Enabled for table value API-2540 rounding and truncating rules are applied and, in case of conversion method 2		API2540RND	-	0

Function inputs	Remark	EU	SW tag	Range	Default
	(standard to observed), the **table** value for CTL as specified in Table 54 meaning that the CTL value has 4 decimal places in all cases 3: Enabled with 5 decimal places API-2540 rounding and truncating rules are applied, and, in case of conversion method 2 (standard to observed), the CTL value has 5 decimal places in all cases. Note: although not strictly in accordance with the standard, this option is more commonly used than option 'Enabled for computational value' Note: for conversion type 1 'From observed to standard conditions' the CTL factor is rounded to 6 decimal places when input 'API 2540 rounding' > 0, as in accordance with table 53.				
Hydrometer correction	Only applies for conversion method '1: From observed to standard conditions' 0: Disabled 1: Enabled	-	HYDROCOR		0
API 11.2.1M rounding	0: Disabled The calculation of the compressibility factor F is performed with full precision. 1: Enabled API-MPMS 11.2.1M rounding and truncating rules are applied. The compressibility factor F is rounded to 3 decimal places as specified in the standard.	-	API1121RND		0

Function inputs	Remark	EU	SW tag	Range	Default
Equilibrium pressure	The equilibrium pressure is considered to be 0 bar(g) for liquids which have an equilibrium pressure less than atmospheric pressure (in compliance with API MPMS 12.2 par. 12.2.5.4)	bar(g)	EQUIPRES	0..150	0
Conversion method	1: From observed to standard conditions 2: From standard to observed conditions		CONVERSION		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	1
Output density	Meaning depends on the input 'Conversion method'. 'Conversion method' = 1 Density at 15 °C and the equilibrium pressure. 'Conversion method' = 2 Density at the observed temperature and pressure	kg/m3	DENS		0
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API2540 rounding''	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API 11.2.1M rounding''	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor	1/°C	ALPHA		0
F	Compressibility factor	-	F		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of tables 53B/54B	-	PRDCUR		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
	(enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.				
CTL calc out of range	With respect to the standard used for the calculation of CTL the combination of input values is: 0: In Range 1: Out of Range			CTLOOR	0
CPL calc out of range	With respect to the standard used for the calculation of CPL the combination of input values is: 0: In Range 1: Out of Range			CPLOOR	0

Calculations

The calculations depend on the conversion method.

Conversion method 1: from observed to standard conditions.
The function performs the following iterative algorithm to calculate the density at reference conditions:

1. First the inputs are rounded in accordance with the API2540 standard, provided that API2540 rounding is enabled.
2. The hydrometer correction on the input density is applied, provided that this correction is enabled
3. At the start of the iteration the density at [15 °C, equilibrium pressure] is set equal to the observed density and the initial CPL value is set to 1.
4. When the type of product is set to ‘B – Auto select’ (automatic selection of the refined product range) the K0, K1 and K2 factors are determined based on the density at [15 °C, equilibrium pressure]. The Transition area is only taken in consideration in the 2nd iteration loop, as specified in the standard.
5. The Alpha factor is calculated according from the density at [15 °C, equilibrium pressure] and the K0, K1 and K2 factor. If API2540 rounding is enabled, then the intermediate results are rounded or truncated as specified API-2540 Table 53.
6. The CTL value is calculated according to API-2540 Table 53 from the Alpha factor and the differential temperature (= observed temperature – 15°C). If API2540 rounding is enabled, then the intermediate results are rounded or truncated as specified API-2540 Table 53.
7. Depending on the type of API2540 rounding the calculated CTL value is rounded to 6 decimal places or not rounded at all.
8. The density at [15 °C, equilibrium pressure] is calculated by dividing the observed density by the new CTL value and the CPL value from the previous iteration.
9. The compressibility factor is calculated according to API MPMS 11.2.1M from the density at [15 °C, equilibrium pressure] and the 'Observed temperature'. If API 11.2.1M rounding is enabled then the density and temperature are rounded and the

calculations are performed in accordance with the rounding and truncating rules of the standard.

10. The CPL value is calculated from the compressibility factor and the 'Observed pressure' and 'Equilibrium pressure' input values.
11. The density at [15°C, equilibrium pressure] is calculated by dividing the observed density by CTL and the new CPL value.
12. If API2540 rounding is enabled then the density at [15°C, equilibrium pressure] value is rounded to 3 decimal places as specified in the standard.
13. Steps 4 through 12 are repeated taking the density value from step 12 as the starting value until the absolute difference between two consecutive density values is either 0.05 (or 0.07 for the transition area) or 0.000001, depending of API2540 rounding being enabled or not.
14. For refined products the entire iteration loop is repeated if the density at [15°C, equilibrium pressure] appears to be in a different product region than the observed input density. This is required because a different product region means different K0, K1 and K2 factors.
15. When API2540 rounding is enabled, the final density at [15°C, equilibrium pressure] is rounded to 1 decimal place.

Conversion method 2: from standard to observed conditions.
The function performs straightforward calculations to determine the density at observed conditions:

1. First the inputs are rounded in accordance with the API2540 standard, provided that API2540 rounding is enabled.
2. When the type of product is set to 'B – Auto select' (automatic selection of the refined product range) the K0, K1 and K2 factors are determined based on the input density
3. The Alpha factor is calculated according from the input density and the K0, K1 and K2 factor. If API2540 rounding is enabled, then the intermediate results are rounded or truncated as specified API-2540 Table 54.
4. The CTL value is calculated according to API-2540 Table 54 from the Alpha factor and the differential temperature (= observed temperature – 15°C If API2540 rounding is enabled, then the intermediate results are rounded or truncated as specified API-2540 Table 54.
5. Depending on the type of API2540 rounding the calculated CTL value is rounded to 4 or 5 decimal places or not rounded at all.
6. The compressibility factor is calculated according to API MPMS 11.2.1M from the input density and temperature'. If API 11.2.1M rounding is enabled then the input density and temperature are rounded and the calculations are performed in accordance with the rounding and truncating rules of the standard.
7. The CPL value is calculated from the compressibility factor and the 'Observed pressure' and 'Equilibrium pressure' input values.
8. The density at [15°C, equilibrium pressure] is calculated by multiplying the input density by the CTL and the CPL values.

fxAPI_Dens15C_NGL_LPG

Description

Density (T, P) <--> Density (15°C, Pe)

This function converts the density value at the observed temperature and pressure to the density value at 15°C and the equilibrium pressure or vice versa.
The temperature correction is according to API MPMS 11.2.4:2007 (GPA TP-27), while the pressure correction is according to API MPMS 11.2.2M:1984.
The calculation of the equilibrium pressure is according to GPA TP-15 (API MPMS 11.2.2 Addendum:1994).

Compliance

- API MPMS 11.2.4: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- GPA TP-27: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- API MPMS Chapter 11.2.2M - 1986 (Compressibility Factors for Hydrocarbons: 350-637 kg/m3 Density (15°C) and –46°C to 60°C)
- API MPMS 11.2.5: A Simplified Vapor Pressure Correlation for Commercial NGLs, September 2007
- GPA TP-15: A Simplified Vapor Pressure Correlation for Commercial NGLs, September 2007 (also covers GPA TP-15 1988)
- API MPMS 11.2.2 Addendum : Compressibility Factors for Hydrocarbons: Correlation of Vapor Pressure for Commercial Natural Gas Liquids (same as GPA TP-15:1988)

Function inputs

Name	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input density	Depending on the conversion method this represents the density either at the observed temperature and pressure or at 15 °C and the equilibrium pressure	-		0..750	0
Observed temperature	Temperature at which the density is observed	°C		-100..150	15
Observed pressure	Pressure at which the density is observed	bar(a)		-1..200	0

Name	Remark	EU	SW tag	Range	Default
API 11.2.4 rounding	0: Disabled The calculations are performed with full precision and the output values are not rounded 1: Enabled The related values are rounded as defined in the standard		API1124RND		0
API 11.2.2M rounding	0: Disabled The calculations are performed with full precision and the output values are not rounded 1: Enabled The related values are rounded as defined in the standard		API1122RND		0
Equilibrium pressure mode	1: Use Input The value of input 'Equilibrium pressure value' is used for the calculation of CPL 2: GPA TP-15 The equilibrium pressure is calculated in accordance with GPA TP-15		EQUIPMODE		2
Equilibrium pressure value	Only used when input 'Equilibrium pressure mode' is set to 'Use input'. The value will be used for the calculation of the CPL	bar(a)	EQUIPINP		0
GPA TP-15 rounding	Only used when 'Equilibrium pressure mode is set to 'GPA TP-15' 0: Disabled Full precision (no rounding and truncating applied) 1: Enabled Rounding as defined in ' GPA TP15:1988 / API MPMS 11.2.2 Addendum':1994	-	TP15RND		0
P100 Correlation	Only used when 'Equilibrium pressure mode is set to 'GPA TP-15' 0: Disabled The standard correlation is commonly used for pure products such as propane, butane and natural	-	P100CORR		0

Name	Remark	EU	SW tag	Range	Default
	gasoline. It only requires the relative density and the temperature to calculate the vapor pressure 1: Enabled The improved correlation requires the vapor pressure at 100°F (37.8 °C). This method is better suited for varied NGL mixes Where different product mixes could have the same specific gravity but different equilibrium pressures.				
Vapor pressure at 100°F	Only used when 'Equilibrium pressure mode is set to 'GPA TP-15' and the P100 correlation is enabled.	bar(a)	EQUIP100F	0..200	0
Conversion method	1: From observed to standard conditions 2: From standard to observed conditions		CONVMETH		1

Function outputs

Name	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	1
Output density	Depending on the conversion method this represents the density either at 15 °C and the equilibrium pressure or the observed temperature and pressure	kg/m3	DENS		0
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API 11.2.4 rounding'	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API 11.2.2M rounding'	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
F	Compressibility factor The output value will be either rounded or not depending input 'API	1/bar	F		0

Name	Remark	EU	SW tag	Alarm	Fallback
	rounding'				
Equilibrium pressure	The equilibrium pressure calculated by GPA TP-15 Will be set to 0 when equilibrium pressure is below atmospheric pressure	bar(a)	EQUIPCUR		0
CTL calc out of range	With respect to the API 11.2.4 standard the combination of input values is: 0: In Range 1: Out of Range The following range checks apply: *Conversion method 1: observed -> standard* • 0.21 <= RD <= 0.74 *with RD = Input density / 999.016/CPL* • -46 <= T <= 93 °C • Table 23E reference fluid ranges *Conversion method 1: standard -> observed* • 351.7 <= Input density <= 687.8 kg/m3 • -46 <= T <= 93 °C • Table 23E reference fluid ranges			CTLOOR	0
CPL calc out of range	With respect to API 11.2.2M the combination of input values is: 0: In Range 1: Out of Range The following range checks apply: • 350 <= Density 15 °C <= 637 kg/m3 • -46 °C <= T <= 60 °C			CPLOOR	0
GPA TP-15 out of range	Only set when the GPA TP-15 calculation is enabled With respect to the GPA TP-15 standard the combination of input	-			0

Name	Remark	EU	SW tag	Alarm	Fallback
	values is: 0: In Range 1: Out of Range The following range checks apply: For lower range: - 0.350 <= RD60 < 0.425 - -50 to (695.51*RD60 - 155.51) °F Higher range: - 0.425 <= RD60 <= 0.676 - -50 to 140 °F with RD60 being the relative density at 60°F			TP15OOR	

Calculations

The calculations depend on the conversion method.

Conversion method 1: from observed to standard conditions.
The function performs the following iterative algorithm to calculate the density at 15 °C and the equilibrium pressure.

1. When API 11.2.4 rounding is enabled, the input density and temperature values are rounded in accordance with the standard
2. At the start of the iteration the density at [15 °C, equilibrium pressure] is set equal to the observed density and the CPL value is set to 1.
3. First the density corrected for pressure is calculated by dividing the observed density by the CPL value.
4. The relative density corrected for pressure is calculated from the density corrected for pressure
5. The relative density at [60 °F, equilibrium pressure] is calculated from the relative density corrected for pressure and the observed temperature according to Table 23E
6. The relative density at [15 °C, equilibrium pressure] is calculated from the relative density at [60 °F, equilibrium pressure] converted to 15 °C according to Table 24E
7. The density at [15 °C, equilibrium pressure] is calculated from the relative density at [15 °C, equilibrium pressure]
8. The CTL value is calculated by dividing the density corrected for pressure by the density at [15 °C, equilibrium pressure]
9. Depending on the value of input 'Equilibrium pressure mode', either value of input 'Equilibrium pressure value' is used or the equilibrium pressure (vapor pressure) is calculated according to GPA TP-15. Whether the GPA TP-15 rounding and truncation rules are applied is dictated by input ‘GPA-TP15 rounding’

10. The compressibility factor F is calculated according to API MPMS 11.2.2M from the density at [15 °C, equilibrium pressure] and the 'Observed temperature', with, depending on input API 11.2.2M, rounding and truncation according to the standard.
11. The CPL value is calculated from the compressibility factor, the equilibrium pressure and the 'Observed pressure' input value.
12. The new value for density at [15°C, equilibrium pressure] is calculated by dividing the observed density by the CTL and CPL values.
13. Steps 3 though 12 are repeated taking the density value from step 12 as the staring value until the absolute difference between two consecutive density values is less than the convergence limit.

    To avoid convergence problems different convergence limits are applied, depending on the whether API 11.2.2M and/or GPA TP-15 rounding is applied:

    If API 11.2.2M rounding is enabled -> Limit = 0.05 kg/m3
    else if GPA TP-15 rounding is enabled -> Limit = 0.005 kg/m3
    else -> Limit = 0.00001 kg/m3

14. If API 11.2.4 rounding is enabled, then the density at [15°C, equilibrium pressure] is rounded to 0.1

Conversion method 2: from standard to observed conditions.
The function performs straightforward calculations to determine the density at observed conditions:

1. When API 11.2.4 rounding is enabled, the input density and temperature values are rounded in accordance with the standard
2. The CTL value and the relative density at [60 °F, equilibrium pressure] are calculated according to API MPMS 11.2.4 (GPA TP-27) Table 60E from the density at [15 °C, equilibrium pressure] and the 'Observed temperature'.
3. Depending on the value of input 'Equilibrium pressure mode', either value of input 'Equilibrium pressure value' is used or the equilibrium pressure (vapor pressure) is calculated according to GPA TP-15.
4. The compressibility factor is calculated according to API MPMS 11.2.2M from the density at [15 °C, equilibrium pressure] and the 'Observed temperature'.
5. The CPL value is calculated from the compressibility factor, the equilibrium pressure and the 'Observed pressure' input value.
6. If API 11.2.4 rounding is enabled, then the CTL value is rounded at [60°F, equilibrium pressure] is rounded to 0.00001
7. The density at the observed conditions is calculated by multiplying the density at [15 °C, equilibrium pressure] by the CTL value and the CPL value.

fxAPI_Dens20C_NGL_LPG

Description

Density (T, P) <--> Density (20°C, Pe)

This function converts the density value at the observed temperature and pressure to the density value at 20°C and the equilibrium pressure or vice versa.
The temperature correction is according to API MPMS 11.2.4:2007 (GPA TP-27), while the pressure correction is according to API MPMS 11.2.2M:1984.
The calculation of the equilibrium pressure is according to GPA TP-15 (API MPMS 11.2.2 Addendum:1994).

Compliance

- API MPMS 11.2.4: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- GPA TP-27: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- API MPMS Chapter 11.2.2M - 1986 (Compressibility Factors for Hydrocarbons: 350-637 kg/m3 Density (15°C) and –46°C to 60°C)
- API MPMS 11.2.5: A Simplified Vapor Pressure Correlation for Commercial NGLs, September 2007
- GPA TP-15: A Simplified Vapor Pressure Correlation for Commercial NGLs, September 2007 (also covers GPA TP-15 1988)
- API MPMS 11.2.2 Addendum : Compressibility Factors for Hydrocarbons: Correlation of Vapor Pressure for Commercial Natural Gas Liquids (same as GPA TP-15:1988)

Function inputs

Name	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input density	Depending on the conversion method this represents the density either at the observed temperature and pressure or at 20 °C and the equilibrium pressure	kg/m3		0..750	0
Observed temperature	Temperature at which the density is observed	°C		-100..150	20
Observed pressure	Pressure at which the density is observed	bar(a)		-1..200	0

Name	Remark	EU	SW tag	Range	Default
API 11.2.4 rounding	0: Disabled The calculations are performed with full precision and the output values are not rounded 1: Enabled The related values are rounded as defined in the standard		API1124RND		0
API 11.2.2M rounding	0: Disabled The calculations are performed with full precision and the output values are not rounded 1: Enabled The related values are rounded as defined in the standard		API1122RND		0
Equilibrium pressure mode	1: Use Input The value of input 'Equilibrium pressure value' is used for the calculation of CPL 2: GPA TP-15 The equilibrium pressure is calculated in accordance with GPA TP-15		EQUIPMODE		2
Equilibrium pressure value	Only used when input 'Equilibrium pressure mode' is set to 0. The value will be used for the calculation of the CPL	bar(a)	EQUIPINP		0
GPA TP-15 rounding	0: Disabled Full precision (no rounding and truncating applied) 1: Enabled Rounding as defined in ' GPA TP15:1988 / API MPMS 11.2.2 Addendum':1994	-	TP15RND		0
P100 Correlation	0: Disabled The standard correlation is commonly used for pure products such as propane, butane and natural gasoline. It only requires the relative	-	P100CORR		0

Name	Remark	EU	SW tag	Range	Default
	density and the temperature to calculate the vapor pressure 1: Enabled The improved correlation requires the vapor pressure at 100°F (37.8 °C). This method is better suited for varied NGL mixes Where different product mixes could have the same specific gravity but different equilibrium pressures.				
Vapor pressure at 100°F		bar(a)	EQUIP100F	0..200	0
Conversion method	1: From observed to standard conditions 2: From standard to observed conditions		CONVMETH		1

Function outputs

Name	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range *Outputs will be set to fallback values* 2: Calculation error *Outputs will be set to fallback values* 3: No convergence within 15 iterations *Outputs will be set to values of last iteration*	-	STS	 FIOOR CALC NOCONV	1
Output density	Depending on the conversion method this represents the density either at 20 °C and the equilibrium pressure or the observed temperature and pressure	kg/m3	DENS		0
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API 11.2.4 rounding'	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to	-	CPL		1

Name	Remark	EU	SW tag	Alarm	Fallback
	input 'API 11.2.2M rounding'				
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
F	Compressibility factor The output value will be either rounded or not depending input 'API rounding'	1/bar	F		0
Equilibrium pressure	The equilibrium pressure calculated by GPA TP-15 Will be set to 0 when equilibrium pressure is below atmospheric pressure	bar(a)	EQUIPCUR		0
CTL calc out of range	With respect to the API 11.2.4 standard the combination of input values is: 0: In Range 1: Out of Range The following range checks apply: *Conversion method 1: observed -> standard* - 0.21 <= RD <= 0.74 *with RD = Input density / 999.016/CPL* - -46 <= T <= 93 °C - Table 23E reference fluid ranges *Conversion method 1: standard -> observed* - 331.7 <= Input density <= 683.6 kg/m3 - -46 <= T <= 93 °C - Table 23E reference fluid ranges			CTLOOR	0
CPL calc out of range	With respect to API 11.2.2M the combination of input values is: 0: In Range 1: Out of Range The following range checks apply: - 350 <= Density 15 °C <= 637 kg/m3			CPLOOR	0

Name	Remark	EU	SW tag	Alarm	Fallback
	- -46 °C <= T <= 60 °C				
GPA TP-15 out of range	Only set when the GPA TP-15 calculation is enabled With respect to the GPA TP-15 standard the combination of input values is: 0: In Range 1: Out of Range The following range checks apply: For lower range: - 0.350 <= RD60 < 0.425 - -50 to (695.51*RD60 - 155.51) °F Higher range: - 0.425 <= RD60 <= 0.676 - -50 to 140 °F with RD60 being the relative density at 60°F	-		TP15OOR	0

Calculations

The calculations depend on the conversion method.

Conversion method 1: from observed to standard conditions.
The function performs the following iterative algorithm to calculate the density at 20 °C and the equilibrium pressure.

1. When API 11.2.4 rounding is enabled, the input density and temperature values are rounded in accordance with the standard
2. At the start of the iteration the density at [20 °C, equilibrium pressure] is set equal to the observed density and the CPL value is set to 1.
3. First the density corrected for pressure is calculated by dividing the observed density by the CPL value.
4. The relative density corrected for pressure is calculated from the density corrected for pressure
5. The relative density at [60 °F, equilibrium pressure] is calculated from the relative density corrected for pressure and the observed temperature according to Table 23E
6. The relative density at [20 °C, equilibrium pressure] is calculated from the relative density at [60 °F, equilibrium pressure] converted to 20 °C according to Table 24E
7. The density at [20 °C, equilibrium pressure] is calculated from the relative density at [20 °C, equilibrium pressure]
8. The CTL value is calculated by dividing the density corrected for pressure by the density at [20 °C, equilibrium pressure]

9. Depending on the value of input 'Equilibrium pressure mode', either value of input 'Equilibrium pressure value' is used or the equilibrium pressure (vapor pressure) is calculated according to GPA TP-15. Whether the GPA TP-15 rounding and truncation rules are applied is dictated by input ‘GPA-TP15 rounding’
10. API 11.2.2M requires the density at [15 °C, equilibrium pressure]. For this purpose the relative density at [15 °C, equilibrium pressure] is calculated according to Table 24E from the relative density at [60 °F, equilibrium pressure] and at 15 °C. This relative density value is then converted to the density at [15 °C, equilibrium pressure].
11. The compressibility factor F is calculated according to API MPMS 11.2.2M from the density at [15 °C, equilibrium pressure] and the 'Observed temperature', with, depending on input API 11.2.2M, rounding and truncation according to the standard.
12. The CPL value is calculated from the compressibility factor, the equilibrium pressure and the 'Observed pressure' input value.
13. The new value for density at [20°C, equilibrium pressure] is calculated by dividing the observed density by the CTL and CPL values.
14. Steps 2 though 6 are repeated taking the density value from step 6 as the staring value until the absolute difference between two consecutive density values is less than the convergence limit.

    To avoid convergence problems different convergence limits are applied, depending on the whether API 11.2.2M and/or GPA TP-15 rounding is applied:

    If API 11.2.2M rounding is enabled -> Limit = 0.05 kg/m3
    else if GPA TP-15 rounding is enabled -> Limit = 0.005 kg/m3
    else -> Limit = 0.00001 kg/m3

15. If API 11.2.4 rounding is enabled, then the density at [20°C, equilibrium pressure] is rounded to 0.1

Conversion method 2: from standard to observed conditions.
The function performs straightforward calculations to determine the density at observed conditions:

1. When API 11.2.4 rounding is enabled, the input density and temperature values are rounded in accordance with the standard
2. The CTL value and the relative density at [60 °F, equilibrium pressure] are calculated according to API MPMS 11.2.4 (GPA TP-27) Table 54 from the density at [20 °C, equilibrium pressure] and the 'Observed temperature'.
3. Depending on the value of input 'Equilibrium pressure mode', either value of input 'Equilibrium pressure value' is used or the equilibrium pressure (vapor pressure) is calculated according to GPA TP-15.
4. API 11.2.2M requires the density at [15 °C, equilibrium pressure]. For this purpose the relative density at [15 °C, equilibrium pressure] is calculated according to Table 24E from the relative density at [60 °F, equilibrium pressure] and at 15 °C. This relative density value is then converted to the density at [15 °C, equilibrium pressure].
5. The compressibility factor is calculated according to API MPMS 11.2.2M from the density at [15 °C, equilibrium pressure] and the 'Observed temperature'.

6. The CPL value is calculated from the compressibility factor, the equilibrium pressure and the 'Observed pressure' input value.
7. If API 11.2.4 rounding is enabled, then the CTL value is rounded at [60°F, equilibrium pressure] is rounded to 0.00001
8. The density at the observed conditions is calculated by multiplying the input density by the CTL value and the CPL value.

fxAPI_Gravity60F_1952

°API (T, P) <--> °API (60°F, equilibrium pressure)

This function calculates the API gravity value at the observed temperature and pressure to the API gravity value at 60°F and the equilibrium pressure (typically 0 psig) or vice versa.

The volume correction for temperature is according to 1952 API Table 5 and 6, while the volume correction for pressure is according to API MPMS 11.2.1.

Note: this function is a combination of the API 1952 Tables and API 11.2.1. For the calculation from observed to standard conditions an iterative calculation is required. The rounding and truncating of input and intermediate values is implemented such that the example calculations as specified in both standards are exactly reproduced.

Compliance

- ASTM-IP Petroleum Measurement Tables, American Edition, United States Units of Measurement, 1952
- API MPMS 11.2.1 - Compressibility Factors for Hydrocarbons: 0 - 90°API Gravity Range - First Edition, August 1984

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input API gravity	Depending of the conversion method this represents the API gravity at either the observed temperature and pressure or at 60 °F and the equilibrium pressure	°API		-20..120	0
Observed temperature	Temperature at which the API gravity is observed	°F		-100..400	60
Observed pressure	Pressure at which the API gravity is observed	psig		-10..2000	0

Function inputs	Remark	EU	SW tag	Range	Default
API 11.2.1 rounding	0: Disabled The calculation of the compressibility factor F is performed with full precision 1: Enabled API-MPMS 11.2.1 rounding and truncating rules are applied. The compressibility factor F is rounded to 3 decimal places as specified in the standard.	-	API1121RND		0
Equilibrium pressure	The equilibrium pressure is considered to be 0 psig for liquids which have an equilibrium pressure less than atmospheric pressure (in compliance with API MPMS 12.2 par. 12.2.5.4)	psig	EQUIPRES	0..2000	0
Conversion method	1: From observed to standard conditions 2: From standard to observed conditions		CONVERSION		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALC NOCONV	1
Output API gravity	Depending of the conversion method this represents the API gravity at either at 60 °F and the equilibrium pressure or the observed temperature and pressure	°API	API		0
CTL	Volume correction factor for temperature.	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API 11.2.1 rounding''	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
F CTL calc out of range	Compressibility factor With respect to the standard used for the calculation of CTL the combination of input values is: 0: In Range 1: Out of Range	-	F	CTLOOR	0 0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
CPL calc out of range	With respect to the standard used for the calculation of CPL the combination of input values is: 0: In Range 1: Out of Range			CPLOOR	0

Calculations

The calculations depend on the conversion method.

Conversion method 1: from observed to standard conditions.
The function performs the following iterative algorithm to calculate the API Gravity at standard conditions:

1. At the start of the iteration the initial value for API Gravity at [60 °F, equilibrium pressure] is set to the Observed API Gravity. The initial CPL value is set to 1.
2. The CTL value is determined from the API Gravity at [60 °F, equilibrium pressure] according to API 1952 Table 6.
3. The API Gravity at [60 °F, equilibrium pressure] is calculated from the Observed API gravity, the new CTL value and the CPL value from the previous iteration.
4. Because API 11.2.1 requires the API gravity value at 60 °F, the API gravity at [60 °F, equilibrium pressure] is calculated from the API gravity at [60 °F, equilibrium pressure].
5. The compressibility factor is calculated according to API MPMS 11.2.1 from the API gravity at [60 °F, equilibrium pressure] and the 'Observed temperature'. If API 11.2.1 rounding is enabled then the API gravity and temperature are rounded and the calculations are performed in accordance with the rounding and truncating rules of the standard.
6. The CPL value is calculated from the compressibility factor and the 'Observed pressure' and 'Equilibrium pressure' input values.
7. The API Gravity at [60°F, equilibrium pressure] is calculated by dividing the Observed API Gravity by the CTL and the new CPL value.
8. Steps 2 through 7 are repeated taking the API gravity value from step 7 as the start value for the next iteration until the absolute difference between two consecutive API gravity values is 0.01.

Conversion method 2: from standard to observed conditions.
The function performs straightforward calculations to determine the API Gravity at observed conditions:

2. The CTL value is calculated according to API 1952 Table 6
3. Because API 11.2.1 requires the API gravity value at 60 °F, the API gravity at 60 °F is calculated from the 'Input API Gravity'.
4. The compressibility factor is calculated according to API MPMS 11.2.1 from the API gravity and the 'Observed temperature'. If API 11.2.1 rounding is enabled then the input density and temperature are rounded and the calculations are performed in accordance with the rounding and truncating rules of the standard.

5. The CPL value is calculated from the compressibility factor and the 'Observed pressure' and 'Equilibrium pressure' input values.
6. The output API Gravity (at observed temperature and pressure) is calculated from the input API Gravity and the CTL and the CPL values.

fxAPI_Gravity60F_1980

°API (T, P) <--> °API (60°F, equilibrium pressure)

This function calculates the API gravity value at the observed temperature and pressure to the API gravity value at 60°F and the equilibrium pressure (typically 0 psig) or vice versa.
The volume correction for temperature is according to API-2540, Tables 5/6A (Generalized Crude Oils) and 5/6B (Refined Oil Products) and API MPMS 11.1 Chapter XIII Table 5D: 1984 (Lubricating Oils), while the volume correction for pressure according to API MPMS 11.2.1.

Note: this function is a combination of API2540 and API 11.2.1. For the calculation from observed to standard conditions an iterative calculation is required. The rounding and truncating of input and intermediate values is implemented such that the example calculations as specified in both standards are exactly reproduced.

Compliance

- API MPMS 11.1 Volume X (API Standard 2540) - Table 5A - Generalized Crude Oils, Correction of Observed API Gravity to API Gravity at 60°F - First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 5B - Generalized Products, Correction of Observed API Gravity to API Gravity at 60°F- First Edition, August 1980
- API MPMS 11.1 Volume XIII - Table 5D - Generalized Lubricating Oils, Correction of Observed API Gravity to API Gravity at 60°F - January 1982
- API MPMS 11.1 Volume X (API Standard 2540) - Table 6A - Generalized Crude Oils, Correction of Volume to 60°F against API Gravity at 60°F - First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 6B - Generalized Products, Correction of Volume to 60°F against API Gravity at 60°F - First Edition, August 1980
- API MPMS 11.1 Volume XIII - Table 6D - Generalized Lubricating Oils, Correction of Volume to 60°F against API Gravity at 60°F F - January 1982
- API MPMS 11.2.1 - Compressibility Factors for Hydrocarbons: 0 - 90°API Gravity Range - First Edition, August 1984

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input API gravity	Depending of the conversion method this represents the API gravity at either the observed temperature and pressure or at 60 °F and the equilibrium pressure	°API		-20..120	0
Observed temperature	Temperature at which the API gravity is observed	°F		-50..400	60
Observed pressure	Pressure at which the API gravity is	psig		-10..2000	0

Function inputs	Remark	EU	SW tag	Range	Default
	observed				
Product	1: A - Crude Oil 2: B - Auto select *Selection based on °API at 60 °F* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP	-	1
API-2540 rounding	0: Disabled The calculations are performed with full precision and the final CTL value is rounded as specified by input 'CTL decimal places' 1: Enabled for computational value API-2540 rounding and truncating rules are applied and, in case of conversion method 2 (standard to observed), the **computational** value for CTL as specified in Table 6 is used, meaning that the CTL value has: 4 decimal places if CTL >=1 5 decimal places if CTL < 1. 2: Enabled for table value API-2540 rounding and truncating rules are applied and, in case of conversion method 2 (standard to observed), the **table** value for CTL as specified in Table 6 meaning that the CTL value has 4 decimal places in all cases 3: Enabled with 5 decimal places API-2540 rounding and truncating rules are applied, and, in case of conversion method 2 (standard to observed), the CTL value has 5 decimal places in all cases.		API2540RND	-	0

Function inputs	Remark	EU	SW tag	Range	Default
	Note: although not strictly in accordance with the standard, this option is more commonly used than option 'Enabled for computational value' Note: for conversion type 1 ‘From observed to standard conditions’ the CTL factor is rounded to 6 decimal places when input ‘API 2540 rounding’ > 0, as in accordance with table 5.				
Hydrometer correction	Only applies for conversion method ‘1: From observed to standard conditions’ 0: Disabled 1: Enabled	-	HYDROCOR		0
API 11.2.1 rounding	0: Disabled The calculation of the compressibility factor F is performed with full precision 1: Enabled API-MPMS 11.2.1 rounding and truncating rules are applied. The compressibility factor F is rounded to 3 decimal places as specified in the standard.	-	API1121RND		0
Equilibrium pressure	The equilibrium pressure is considered to be 0 psig for liquids which have an equilibrium pressure less than atmospheric pressure (in compliance with API MPMS 12.2 par. 12.2.5.4)	psig	EQUIPRES	0..2000	0
Conversion method	1: From observed to standard conditions 2: From standard to observed conditions		CONVERSION		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	FIOOR CALC NOCONV	1
Output API gravity	Depending of the conversion method this represents the API gravity at either at 60 °F and the equilibrium pressure or the observed temperature and pressure	°API	API		0
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API2540 rounding'	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API 11.2.1 rounding'''	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor	1/°F	ALPHA		0
F	Compressibility factor	-	F		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table 5B / 6B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		0
CTL calc out of range	With respect to the standard used for the calculation of CTL the combination of input values is: 0: In Range 1: Out of Range			CTLOOR	0
CPL calc out of range	With respect to the standard used for the calculation of CPL the combination of input values is: 0: In Range 1: Out of Range			CPLOOR	0

Calculations

The calculations depend on the conversion method.

Conversion method 1: from observed to standard conditions.
The function performs the following iterative algorithm to calculate the API gravity at standard conditions:

1. First the inputs are rounded in accordance with the API2540 standard, provided that API2540 rounding is enabled.
2. The observed density [kg/m3] is calculated from the observed API gravity
3. The hydrometer correction on the observed density is applied, provided that this correction is enabled
4. At the start of the iteration the initial value for density and API gravity at [60 °F, equilibrium pressure] is set to respectively the observed density and the observed API gravity. The initial CPL value is set to 1.
5. When the type of product is set to 'B – Auto select' (automatic selection of the refined product range) the K0, K1 and K2 factors are determined based on the API gravity at [60 °F, equilibrium pressure]. The Transition area is only taken in consideration in the 2nd iteration loop, as specified in the standard.
6. The Alpha factor is calculated according from the density at [60 °C, equilibrium pressure] and the K0, K1 and K2 factor. If API2540 rounding is enabled, then the intermediate results are rounded or truncated as specified API-2540 Table 5.
7. The CTL value is calculated according to API-2540 Table 5 from the Alpha factor and the differential temperature (= observed temperature – 60°F). If API2540 rounding is enabled, then the intermediate results are rounded or truncated as specified API-2540 Table 5.
8. Depending on the type of API2540 rounding the calculated CTL value is rounded to 6 decimal places or not rounded at all.
9. The density at [60 °F, equilibrium pressure] is calculated by dividing the observed density by the new CTL value and the CPL value from the previous iteration.
10. The API gravity at [60 °F, equilibrium pressure] is calculated from the density at [60 °F, equilibrium pressure]
11. The compressibility factor is calculated according to API MPMS 11.2.1 from the API gravity at [60 °F, equilibrium pressure] and the 'Observed temperature'. If API 11.2.1 rounding is enabled then the API gravity and temperature are rounded and the calculations are performed in accordance with the rounding and truncating rules of the standard.
12. The CPL value is calculated from the compressibility factor and the 'Observed pressure' and 'Equilibrium pressure' input values.
13. The density at [60°F, equilibrium pressure] is calculated by dividing the observed density by CTL and the new CPL value.
14. If API2540 rounding is enabled then the density at [60°F, equilibrium pressure] value is rounded to 3 decimal places as specified in the standard.
15. The API gravity at [60 °F, equilibrium pressure] is calculated from the density at [60 °F, equilibrium pressure]
16. If API2540 rounding is enabled then the API gravity at [60°F, equilibrium pressure] value is rounded to 1 decimal place as specified in the standard.
17. Steps 5 through 16 are repeated taking the density value from step 14 as the start value for the next iteration until the absolute difference between two consecutive

density values is either 0.05 (or 0.07 for the transition area) or 0.000001, depending of API2540 rounding being enabled or not.

18. For refined products the entire iteration loop is repeated if the API gravity at [60°F, equilibrium pressure] appears to be in a different product region than the observed API gravity. This is required because a different product region means different K0, K1 and K2 factors.

Conversion method 2: from standard to observed conditions.
The function performs straightforward calculations to determine the API gravity at observed conditions:

1. First the inputs are rounded in accordance with the API2540 standard, provided that API2540 rounding is enabled.
2. The density at [60°F, equilibrium pressure] is calculated from the input API gravity
3. When the type of product is set to 'B – Auto select' (automatic selection of the refined product range) the K0, K1 and K2 factors are determined based on the input API gravity
4. The Alpha factor is calculated according from the density at [60°F, equilibrium pressure] and the K0, K1 and K2 factor. If API2540 rounding is enabled, then the intermediate results are rounded or truncated as specified API-2540 Table 6.
5. The CTL value is calculated according to API-2540 Table 6 from the Alpha factor and the differential temperature (= observed temperature – 60°F). If API2540 rounding is enabled, then the intermediate results are rounded or truncated as specified API-2540 Table 6.
6. Depending on the type of API2540 rounding the calculated CTL value is rounded to 4 or 5 decimal places or not rounded at all.
7. The compressibility factor is calculated according to API MPMS 11.2.1 from the input density and temperature'. If API 11.2.1 rounding is enabled then the input density and temperature are rounded and the calculations are performed in accordance with the rounding and truncating rules of the standard.
8. The CPL value is calculated from the compressibility factor and the 'Observed pressure' and 'Equilibrium pressure' input values.
9. The API gravity at observed temperature and pressure is calculated from the input API gravity and the CTL and the CPL values.

fxAPI_MPMS_11_2_1

The API MPMS 11.2.1 standard consists of a printed table that contains compressibility factors to correct hydrocarbon volumes under pressure to the corresponding volumes at the equilibrium pressure for the metered temperature.
The table contains compressibility factors related to meter temperature and API gravity at 60°F.
From the compressibility factor the volume correction for pressure is calculated according to API MPMS 12.2.

Compliance

- API MPMS 11.2.1 - Compressibility Factors for Hydrocarbons: 0 - 90°API Gravity Range - First Edition, August 1984
- API MPMS 12.2 - Calculation of Liquid Petroleum Quantities Measured by Turbine or Displacement Meters

Input Data Limits

API MPMS 11.2.1 defines the following limits on the input values:

- 0 to 90 °API
- -20 to +200 °F
- 0 to 1500 psig.

API Rounding

The actual standard is the printed table. It also includes the 'Calculation Procedure' to obtain the table values based on the rounding and truncating of all input, intermediate and output values.
The function provides the option to either output the table value (including the full API rounding and truncating requirements) or to perform the calculation procedure without any rounding and truncating being applied.

Name	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
API60	API gravity at 60°F	°API		0..120	0
Observed Temperature		°F		-50..400	60
Observed Pressure		psig		-10..2000	0
Equilibrium Pressure	The equilibrium pressure is considered to be 0 psig for liquids which have an equilibrium pressure less than atmospheric pressure (in compliance with API MPMS 12.2 par. 12.2.5.4)	psig	EQUIPRES	0..2000	0

Name	Remark	EU	SW tag	Range	Default
API 11.2.1 rounding	0: Disabled The calculation of the compressibility factor F is performed with full precision. 1: Enabled API-MPMS 11.2.1 rounding and truncating rules are applied. The compressibility factor F is rounded to 3 decimal places as specified in the standard.		APIROUND	-	0

Name	Remark	EU			Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error		STS	FIOOR CALERR	1
CPL	Volume correction factor for pressure Note: to achieve compliance with API MPMS 12.2 the CPL value needs to be rounded to 4 decimal places.	-	CPL		1
F	Compressibility factor The output value will rounded according to input 'API 11.2.1 rounding'	1/psi	F		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standards, depending on whether API rounding is enabled or not and on the actual number of decimal places for the CPL value (API MPMS 12.2 defines 4 decimal places for the CPL value). The CPL value is calculated as follows (in compliance with API MPMS 12.2):

If Pe > 0 then

$$CPL = \frac{1}{1 - F \cdot (Po - Pe)}$$

Else

$$CPL = \frac{1}{1 - F \cdot Po}$$

With:

CPL	Volume correction factor for pressure	-
F	Compressibility factor	1/psi
Po	Observed pressure	psig
Pe	Equilibrium pressure	psig

fxAPI_MPMS_11_2_1M

Description

The API MPMS 11.2.1M standard consists of a printed table that contains compressibility factors to correct hydrocarbon volumes under pressure to the corresponding volumes at the equilibrium pressure for the metered temperature.
The table contains compressibility factors related to meter temperature and density at 15°C.
This metric standard corresponds with API MPMS 11.2.1 (the customary version)

Compliance

- 11.2.1M - Compressibility Factors for Hydrocarbons: 638 - 1074 Kilograms per Cubic Meter Range - First Edition, August 1984
- API MPMS 12.2 - Calculation of Liquid Petroleum Quantities Measured by Turbine or Displacement Meters

Data Limits

API MPMS 11.2.1M defines the following limits on the input values:

- 638 to 1074 kg/m3
- -30 to 90 °C
- 0 to 103 bar(g).

It is advised not to use the standard outside these limits.

Function inputs

Name	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Density at 15°C		kg/m3		0..1300	0
Observed temperature		°C		-100..200	15
Observed pressure		bar(g)		-1..150	0
Equilibrium pressure	The equilibrium pressure is considered to be 0 bar(g) for liquids which have an equilibrium pressure less than atmospheric pressure (in compliance with API MPMS 12.2 par. 12.2.5.4)	bar(g)	EQUIPRES		0

Name	Remark	EU	SW tag	Range	Default
API 11.2.1M rounding	0: Disabled The calculation of the compressibility factor F is performed with full precision 1: Enabled API-MPMS 11.2.1M rounding and truncating rules are applied. The compressibility factor F is rounded in accordance with the standard.	-	APIROUND		0

Function outputs

Name	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error		STS	FIOOR CALC	1
CPL	Volume correction factor for pressure Note: to achieve compliance with API MPMS 12.2 the CPL value needs to be rounded to 4 decimal places.	-	CPL		1
F	Compressibility factor The output value will be either rounded or not depending input 'API 11.2.1M rounding '	1/bar	F		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standards, depending on whether API rounding is enabled or not and on the actual number of decimal places for the CPL value (API MPMS 12.2 defines 4 decimal places for the CPL value).
The CPL value is calculated as follows (in compliance with API MPMS 12.2):

If Pe > 0 then

$$CPL = \frac{1}{1 - F \cdot (Po - Pe)}$$

Else

$$CPL = \frac{1}{1 - F \cdot Po}$$

With:

CPL	Volume correction factor for pressure	-
F	Compressibility factor	1/bar
Po	Observed pressure	bar(g)
Pe	Equilibrium pressure	bar(g)

fxAPI_MPMS_11_2_2

The API MPMS 11.2.2 standard consists of a printed table that contains compressibility factors to correct hydrocarbon volumes under pressure to the corresponding volumes at the equilibrium pressure for the metered temperature.
The table contains compressibility factors related to meter temperature and the relative density at 60°F.

Compliance

- 11.2.2 - Compressibility Factors for Hydrocarbons: 0.350 - 0.637 Relative Density (60°F/60°F) and -50°F to 140°F Metering Temperature - Second Edition, October 1986

Input Data Limits

API MPMS 11.2.2 defines the following limits on the input values:

- 0.350 to 0.637 (relative density)
- -50 to 140 °F
- 0 to 2200 psig

API Rounding

The actual standard is the printed table. Also included is a 'Calculation Procedure' that illustrates how to obtain the table values including all required rounding and truncating of the input, intermediate and output values.
The function provides the option to either output the table value (including all the full API rounding and truncating requirements) or to perform the calculation procedure without any rounding and truncating being applied.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Relative density at 60°F	Relative density at 60°F	-		0..0.75	0
Observed Temperature		°F		-100..300	60
Observed Pressure		psig		-10..2500	0
Equilibrium Pressure	The equilibrium pressure is considered to be 0 psig for liquids which have an equilibrium pressure less than atmospheric pressure (in compliance with API MPMS 12.2 par. 12.2.5.4)	psig	EQUIPRES	0..2500	0

Function inputs	Remark	EU	SW tag	Range	Default
API 11.2.2 rounding	0: Disabled The calculation of the compressibility factor F and CPL is performed with full precision. 1: Enabled API-MPMS 11.2.2 rounding and truncating rules are applied. The compressibility factor F is rounded to 8 decimal places with a maximum of 4 significant digits as specified in the standard. The CPL value is rounded to 4 decimal places in compliance with the standard		APIROUND	-	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error		STS	 FIOOR CALCERR	1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API 11.2.2 rounding'	-	CPL		1
F	Compressibility factor The output value will be either rounded or not depending input 'API 11.2.2. rounding'	1/psi	F		0
Range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on the selected type of API rounding.

fxAPI_MPMS_11_2_2M

The API MPMS 11.2.2M standard consists of a printed table that contains compressibility factors to correct hydrocarbon volumes under pressure to the corresponding volumes at the equilibrium pressure for the metered temperature.
The table contains compressibility factors related to meter temperature and the density at 15°C.
This metric standard corresponds with API MPMS 11.2.2 (the U.S. customary version)

Compliance

- 11.2.2M - Compressibility Factors for Hydrocarbons: 350 - 637 Kilograms per Cubic Meter Density (15°C) and -46°C to 60 °C Metering Temperature - First Edition, October 1986

Input Data Limits

API MPMS 11.2.2M defines the following limits on the input values:

- 350 to 637 kg/m3
- -46 to 60 °C
- 0 to 152 bar(g)

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Density at 15°C		kg/m3		0..750	0
Observed Temperature		°C		-100..150	60
Observed Pressure		bar(g)		-1..200	0
Equilibrium Pressure	The equilibrium pressure is considered to be 0 psig for liquids which have an equilibrium pressure less than atmospheric pressure (in compliance with API MPMS 12.2 par. 12.2.5.4)	bar(g)	EQUIPRES	0..200	0
API 11.2.2M rounding	0: Disabled The calculation of the compressibility factor F and CPL is performed with full precision. 1: Enabled API-MPMS 11.2.2M rounding and truncating rules are applied. The compressibility factor F is rounded in accordance with the standard.		APIROUND	-	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error		STS	 FIOOR CALCERR	1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API 11.2.2M rounding'	-	CPL		1
F	Compressibility factor The output value will be either rounded or not depending input 'API 11.2.2M rounding'	1/bar	F		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on the selected type of API rounding.

fxAPI_MPMS_11_3_3_2

The API MPMS 11.3.3.2 standard consists of a table with the density values (lbm/ft3) of propylene liquid as a function of pressure and temperature. Also part of the standard is the Calculation Procedure to obtain the table values.

Compliance

- API MPMS 11.3.3.2 Propylene Compressibility Tables, 1974, Reaffirmed 1997.

Input Data Limits

The Calculation Procedure of API MPMS 11.3.3.2 defines the following limits on the input values:

- 30 to 165 °F
- 0 to 1600 psig

Function inputs and outputs

Function inputs	Remark	EU		Range	Default
Name	Optional tag name, tag description and tag group				
Observed temperature		°F		0..200	60
Observed pressure		psia		0..2000	0
API rounding	0: Disabled The calculations are performed with full precision. A convergence limit of 1e-10 lbm/ft3 will be applied for the iterative calculations. 1: Enabled The calculated density is rounded to 5 decimal places (same as table values). A convergence limit of 5e-6 lbm/ft3 will be applied as defined in the standard.	-			1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	1
Density	At the observed pressure and temperature	lbm/ft3	DENS		0
CTPL	Volume correction factor for temperature and pressure (also	-	CTPL		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
	referred to as the compressibility factor), equals the density at the observed conditions of pressure and temperature value divided by 32.6058 lbm/scf. The value of 32.6058 lbm/scf is specified in the Calculation Procedure of the standard as the propylene standard density at 60 °F and the corresponding vapor pressure.				
Equilibrium pressure	Equilibrium pressure at the observed temperature. Also referred to as vapor pressure or saturated pressure	psia	EQUIPRES		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in full or partial compliance with the standard depending on input ‘API rounding’.

fxAPI_RD60F_1980

Relative Density (T, P) <--> Relative Density (60°F, equilibrium pressure)

This function converts a relative density value at the observed temperature and pressure to the relative density at 60°F and the equilibrium pressure (typically 0 psig) or vice versa.
The temperature conversion is according to API-2540, Tables 23A/24A (Generalized Crude Oils) and 23B/24B (Refined Oil Products), while the volume correction for pressure according to API MPMS 11.2.1.
In 1982 API published tables 5D, 6D, 53D and 54D for lubricating oil products as part of API MPMS 11.1. Although tables 23D and 24D are not covered in an official API standard the Flow-X series of flow computer supports tables 23D and 24D as well by combining the calculation of tables 23A/B and 24A/B with the K0 and K1 constants published in the other tables for lubricating oils.

Note: this function is a combination of API2540 and API 11.2.1. For the calculation from observed to standard conditions an iterative calculation is required. The rounding and truncating of input and intermediate values is implemented such that the example calculations as specified in both standards are exactly reproduced.

Compliance

- API MPMS 11.1 Volume X (API Standard 2540) - Table 23A - Generalized Crude Oils, Correction of Observed Relative Density to Relative Density at 60/60°F - First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 23B - Generalized Products, Correction of Observed Relative Density to Relative Density at 60/60°F - First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 24A - Generalized Crude Oils, Correction of Volume to 60°F against Relative Density at 60/60°F - First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 24B - Generalized Products Correction of Volume to 60°F against Relative Density at 60/60°F - First Edition, August 1980
- API MPMS 11.2.1 - Compressibility Factors for Hydrocarbons: 0 - 90°API Gravity Range - First Edition, August 1984

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input relative density	Depending on the conversion method this is the relative density either at the observed temperature and observed pressure or at 60 °F and the equilibrium pressure	-		0..1.3	0
Observed temperature		°F		-100..400	60
Observed pressure		psig		-10..2000	0
Product	1: A - Crude Oil 2: B - Auto select *Selection based on relative density at 60 °F* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP	-	1
API-2540 rounding	0: Disabled The calculations are performed with full precision and the final CTL value is rounded as specified by input 'CTL decimal places' 1: Enabled for computational value API-2540 rounding and truncating rules are applied and, in case of conversion method 2 (standard to observed), the **computational** value for CTL as specified in Table 24 is used, meaning that the CTL value has: 4 decimal places if CTL >=1 5 decimal places if CTL < 1. 2: Enabled for table value API-2540 rounding and truncating rules are applied and, in case of		API2540RND	-	0

Function inputs	Remark	EU	SW tag	Range	Default
	conversion method 2 (standard to observed), the **table** value for CTL as specified in Table 24 meaning that the CTL value has 4 decimal places in all cases 3: Enabled with 5 decimal places API-2540 rounding and truncating rules are applied, and, in case of conversion method 2 (standard to observed), the CTL value has 5 decimal places in all cases. Note: although not strictly in accordance with the standard, this option is more commonly used than option 'Enabled for computational value' Note: for conversion type 1 ‘From observed to standard conditions’ the CTL factor is rounded to 6 decimal places when input ‘API 2540 rounding’ > 0, as in accordance with table 23.				
Hydrometer correction	Only applies for conversion method ‘1: From observed to standard conditions’ 0: Disabled 1: Enabled	-	HYDROCOR		0

Function inputs	Remark	EU	SW tag	Range	Default
API 11.2.1 rounding	0: Disabled The calculation of the compressibility factor F is performed with full precision 1: Enabled API-MPMS 11.2.1 rounding and truncating rules are applied. The compressibility factor F is rounded to 3 decimal places as specified in the standard.	-	API1121RND		0
Equilibrium pressure	The equilibrium pressure is considered to be 0 psig for liquids which have an equilibrium pressure less than atmospheric pressure (in compliance with API MPMS 12.2 par. 12.2.5.4)	psig	EQUIPRES	0..2000	0
Conversion method	1: From observed to standard conditions 2: From standard to observed conditions		CONVERSION		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	 1
Output relative density	Depending on the conversion method this is the relative density either at 60 °F and the equilibrium pressure or at the observed temperature and observed pressure	-	RD		0
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API2540 rounding'	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API 11.2.1 rounding'	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor	1/°F	ALPHA		0
F	Compressibility factor	-	F		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table 23B/24B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		0
CTL calc out of range	With respect to the standard used for the calculation of CTL the combination of input values is: 0: In Range 1: Out of Range			CTLOOR	0
CPL calc out of range	With respect to the standard used for the calculation of CPL the combination of input values is: 0: In Range 1: Out of Range			CPLOOR	0

Calculations

The calculations depend on the conversion method.

Conversion method 1: from observed to standard conditions.
The function performs the following iterative algorithm to calculate the relative density at standard conditions:

1. First the inputs are rounded in accordance with the API2540 standard, provided that API2540 rounding is enabled.
2. The observed density [kg/m3] is calculated from the observed relative density
3. The hydrometer correction on the observed density is applied, provided that this correction is enabled
4. At the start of the iteration the initial value for density and relative density at [60 °F, equilibrium pressure] is set to respectively the observed density and the observed relative density. The initial CPL value is set to 1.
5. When the type of product is set to 'B – Auto select' (automatic selection of the refined product range) the K0, K1 and K2 factors are determined based on the relative density at [60 °F, equilibrium pressure]. The Transition area is only taken in consideration in the 2^{nd} iteration loop, as specified in the standard.
6. The Alpha factor is calculated according from the density at [60 °C, equilibrium pressure] and the K0, K1 and K2 factor. If API2540 rounding is enabled, then the intermediate results are rounded or truncated as specified API-2540 Table 23.
7. The CTL value is calculated according to API-2540 Table 23 from the Alpha factor and the differential temperature (= observed temperature – 60°F). If API2540 rounding is enabled, then the intermediate results are rounded or truncated as specified API-2540 Table 23.

8. Depending on the type of API2540 rounding the calculated CTL value is rounded to 6 decimal places or not rounded at all.
9. The density at [60 °F, equilibrium pressure] is calculated by dividing the observed density by the new CTL value and the CPL value from the previous iteration.
10. The relative density at [60 °F, equilibrium pressure] is calculated from the density at [60 °F, equilibrium pressure]
11. Because API 11.2.1 requires the API gravity value at 60 °F, the API gravity at [60 °F, equilibrium pressure] is calculated from the density at [60 °F, equilibrium pressure].
12. The compressibility factor is calculated according to API MPMS 11.2.1 from the API gravity at [60 °F, equilibrium pressure] and the 'Observed temperature'. If API 11.2.1 rounding is enabled then the API gravity and temperature are rounded and the calculations are performed in accordance with the rounding and truncating rules of the standard.
13. The CPL value is calculated from the compressibility factor and the 'Observed pressure' and 'Equilibrium pressure' input values.
14. The density at [60°F, equilibrium pressure] is calculated by dividing the observed density by CTL and the new CPL value.
15. If API2540 rounding is enabled then the density at [60°F, equilibrium pressure] value is rounded to 3 decimal places as specified in the standard.
16. The relative density at [60 °F, equilibrium pressure] is calculated from the density at [60 °F, equilibrium pressure]
17. If API2540 rounding is enabled then the relative density at [60°F, equilibrium pressure] value is rounded to 4 decimal places as specified in the standard.
18. Steps 5 through 17 are repeated taking the density value from step 14 as the start value for the next iteration until the absolute difference between two consecutive density values is either 0.05 (or 0.07 for the transition area) or 0.000001, depending of API2540 rounding being enabled or not.
19. For refined products the entire iteration loop is repeated if the relative density at [60°F, equilibrium pressure] appears to be in a different product region than the observed relative density. This is required because a different product region means different K0, K1 and K2 factors.
20. If API 11.2.4 rounding is enabled, then the relative density value at [60°F, equilibrium pressure] is rounded to 0.0001

Conversion method 2: from standard to observed conditions.
The function performs straightforward calculations to determine the relative density at observed conditions:

1. First the inputs are rounded in accordance with the API2540 standard, provided that API2540 rounding is enabled.
2. The density at [60°F, equilibrium pressure] is calculated from the input relative density
3. When the type of product is set to ‘B – Auto select’ (automatic selection of the refined product range) the K0, K1 and K2 factors are determined based on the input relative density

4. The Alpha factor is calculated according from the density at [60°F, equilibrium pressure] and the K0, K1 and K2 factor. If API2540 rounding is enabled, then the intermediate results are rounded or truncated as specified API-2540 Table 24.
5. The CTL value is calculated according to API-2540 Table 24 from the Alpha factor and the differential temperature (= observed temperature – 60°F). If API2540 rounding is enabled, then the intermediate results are rounded or truncated as specified API-2540 Table 24.
6. Depending on the type of API2540 rounding the calculated CTL value is rounded to 4 or 5 decimal places or not rounded at all.
7. Because API 11.2.1 requires the API gravity value at 60 °F, the API gravity at [60 °F, equilibrium pressure] is calculated from the density at [60 °F, equilibrium pressure].
8. The compressibility factor is calculated according to API MPMS 11.2.1 from the input density and temperature'. If API 11.2.1 rounding is enabled then the input density and temperature are rounded and the calculations are performed in accordance with the rounding and truncating rules of the standard.
9. The CPL value is calculated from the compressibility factor and the 'Observed pressure' and 'Equilibrium pressure' input values.
10. The relative density at observed temperature and pressure is calculated from the input relative density and the CTL and the CPL values.

fxAPI_SG60F_1952

Specific Gravity (T, P) <--> Specific Gravity (60°F, equilibrium pressure)

This function converts a specific gravity value at the observed temperature and pressure to the specific gravity at 60°F and the equilibrium pressure (typically 0 psig) or vice versa.
The temperature conversion is according to ASTM-IP Petroleum Measurements Tables 1952 (Also known as API-1952 tables) Table 24.

Note: this function is a combination of the API 1952 Tables and API 11.2.1. For the calculation from observed to standard conditions an iterative calculation is required. The rounding and truncating of input and intermediate values is implemented such that the example calculations as specified in both standards are exactly reproduced.

Compliance

- ASTM-IP Petroleum Measurement Tables, American Edition, United States Units of Measurement, 1952
- API MPMS 11.2.1 - Compressibility Factors for Hydrocarbons: 0 - 90°API Gravity Range - First Edition, August 1984

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input Specific Gravity	Depending on the conversion method this is the Specific Gravity either at the observed temperature and observed pressure or at 60 °F and the equilibrium pressure	-		0..1.3	0
Observed temperature		°F		-100..400	60
Observed pressure		psig		-10..2000	0

Function inputs	Remark	EU	SW tag	Range	Default
API 11.2.1 rounding	0: Disabled The calculation of the compressibility factor F is performed with full precision 1: Enabled API-MPMS 11.2.1 rounding and truncating rules are applied. The compressibility factor F is rounded to 3 decimal places as specified in the standard.	-	API1121RND		0
Equilibrium pressure	The equilibrium pressure is considered to be 0 psig for liquids which have an equilibrium pressure less than atmospheric pressure (in compliance with API MPMS 12.2 par. 12.2.5.4).	psig	EQUIPRES	0..2000	0
Conversion method	1: From observed to standard conditions 2: From standard to observed conditions		CONVERSION		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	FIOOR CALCERR NOCONV	1
Output Specific Gravity	Depending on the conversion method this is the Specific Gravity either at 60 °F and the equilibrium pressure or at the observed temperature and observed pressure	-	RD		0
CTL	Volume correction factor for temperature.	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API 11.2.1 rounding'	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
F	Compressibility factor	-	F		0
CTL calc out of range	With respect to the standard used for the calculation of CTL the combination of input values is: 0: In Range 1: Out of Range			CTLOOR	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
CPL calc out of range	With respect to the standard used for the calculation of CPL the combination of input values is: 0: In Range 1: Out of Range			CPLOOR	0

Calculations

The calculations depend on the conversion method.

Conversion method 1: from observed to standard conditions.
The function performs the following iterative algorithm to calculate the Specific Gravity at standard conditions:

1. At the start of the iteration the initial value for Specific Gravity at [60 °F, equilibrium pressure] is set to the Observed Specific Gravity. The initial CPL value is set to 1.
2. The CTL value is determined from the Specific Gravity at [60 °F, equilibrium pressure] according to API 1952 Table 24.
3. The Specific Gravity at [60 °F, equilibrium pressure] is calculated from the Observed specific gravity, the new CTL value and the CPL value from the previous iteration.
4. Because API 11.2.1 requires the API gravity value at 60 °F, the API gravity at [60 °F, equilibrium pressure] is calculated from the Specific gravity at [60 °F, equilibrium pressure].
5. The compressibility factor is calculated according to API MPMS 11.2.1 from the API gravity at [60 °F, equilibrium pressure] and the 'Observed temperature'. If API 11.2.1 rounding is enabled then the API gravity and temperature are rounded and the calculations are performed in accordance with the rounding and truncating rules of the standard.
6. The CPL value is calculated from the compressibility factor and the 'Observed pressure' and 'Equilibrium pressure' input values.
7. The Specific Gravity at [60°F, equilibrium pressure] is calculated by dividing the Observed Specific Gravity by the CTL and the new CPL value.
8. Steps 2 through 7 are repeated taking the specific gravity value from step 7 as the start value for the next iteration until the absolute difference between two consecutive specific gravity values is 0.0001.

Conversion method 2: from standard to observed conditions.
The function performs straightforward calculations to determine the Specific Gravity at observed conditions:

1. The CTL value is calculated according to API 1952 Table 24
2. Because API 11.2.1 requires the API gravity value at 60 °F, the API gravity is calculated from the 'Input Specific Gravity'.
3. The compressibility factor is calculated according to API MPMS 11.2.1 from the API gravity and the 'Observed temperature'. If API 11.2.1 rounding is enabled then the input density and temperature are rounded and the calculations are performed in accordance with the rounding and truncating rules of the standard.

4. The CPL value is calculated from the compressibility factor and the 'Observed pressure' and 'Equilibrium pressure' input values.
5. The output Specific Gravity (at observed temperature and pressure) is calculated from the input Specific Gravity and the CTL and the CPL values.

fxAPI_RD60F_NGL_LPG

Description

Relative Density (T, P) <--> Relative Density (60°F, Pe)

This function converts the relative density value at the observed temperature and pressure to the relative density value at 60°F and the equilibrium pressure or vice versa.
The temperature correction is according to API MPMS 11.2.4:2007 (GPA TP-25 / GPA TP-27), while the pressure correction is according to API MPMS 11.2.2:1984.
The calculation of the equilibrium pressure is according to GPA TP-15 (API MPMS 11.2.2 Addendum:1994).

Compliance

- API MPMS 11.2.4: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- GPA TP-27: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- GPA TP-25: Temperature Correction for the volume of Light Hydrocarbons – Tables 24E and 23E, 1998
- API MPMS 11.2.2 - Compressibility Factors for Hydrocarbons: 0.350 - 0.637 Relative Density (60°F/60°F) and -50°F to 140°F Metering Temperature - Second Edition, October 1986
- API MPMS 11.2.5: A Simplified Vapor Pressure Correlation for Commercial NGLs, September 2007
- GPA TP-15: A Simplified Vapor Pressure Correlation for Commercial NGLs, September 2007 (also covers GPA TP-15 1988)
- API MPMS 11.2.2 Addendum : Compressibility Factors for Hydrocarbons: Correlation of Vapor Pressure for Commercial Natural Gas Liquids (same as GPA TP-15:1988)

Function inputs

Name	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input relative density	Depending on the conversion method this represents the relative density either at the observed temperature and pressure or at 60 °F and the equilibrium pressure	-		0..0.75	0
Observed temperature	Temperature at which the relative density is observed	°F		-100..300	60
Observed pressure	Pressure at which the relative density is observed	psia		-10..2500	0

Name	Remark	EU	SW tag	Range	Default
API 11.2.4 rounding	0: Disabled The calculations are performed with full precision and the output values are not rounded 1: Enabled The input and output values are rounded as defined in the standard		API1124RND		0
API 11.2.2 rounding	0: Disabled The calculations are performed with full precision and the output values are not rounded 1: Enabled The input and output values are rounded as defined in the standard		API1122RND		0
Equilibrium pressure mode	1: Use Input The value of input 'Equilibrium pressure value' is used for the calculation of CPL 2: GPA TP-15 The equilibrium pressure is calculated in accordance with GPA TP-15		EQUIPMODE		2
Equilibrium pressure value	Only used when input 'Equilibrium pressure mode' is set to 'Use input'. The value will be used for the calculation of the CPL	psia	EQUIPINP		0
GPA TP-15 rounding	0: Disabled Full precision (no rounding and truncating applied) 1: Enabled Rounding as defined in ' GPA TP15:1988 / API MPMS 11.2.2 Addendum':1994	-	TP15RND		0
P100 Correlation	0: Disabled The standard correlation is commonly used for pure products such as propane, butane and natural gasoline. It only requires the relative density and the temperature to calculate the vapor pressure 1: Enabled The improved correlation requires the vapor pressure at 100°F (37.8 °C). This method is better suited for varied NGL	-	P100CORR		0

Name	Remark	EU	SW tag	Range	Default
	mixes Where different product mixes could have the same specific gravity but different equilibrium pressures.				
Vapor pressure at 100°F		psia	EQUIP100F	0..2500	0
Conversion method	1: From observed to standard conditions 2: From standard to observed conditions		CONVMETH		1

Function outputs

Name	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	
Output relative density	Depending on the conversion method this represents the relative density either at 60 °F and the equilibrium pressure or at the observed temperature and pressure	-	DENS		Input *Input relative density*
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API 11.2.4 rounding'	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API 11.2.2. rounding'	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
F	Compressibility factor The output value will be either rounded or not depending input 'API rounding'	1/psi	F		0
Equilibrium pressure	The equilibrium pressure calculated by GPA TP-15 Will be set to 0 when equilibrium pressure is below atmospheric pressure	psia	EQUIPCUR		0
CTL calc out of range	With respect to the API 11.2.4 standard the combination of input values is: 0: In Range			CTLOOR	0

Name	Remark	EU	SW tag	Alarm	Fallback
	1: Out of Range The following range checks apply: • 0.21 <= RD <= 0.74 • -50.8 <= T <= 199.4 °F • Table 23E reference fluid ranges				
CPL calc out of range	With respect to API 11.2.2M the combination of input values is: 0: In Range 1: Out of Range The following range checks apply: • 350 <= Density 15 °C <= 637 kg/m3 • -46 °C <= T <= 60 °C			CPLOOR	0
GPA TP-15 out of range	Only set when the GPA TP-15 calculation is enabled With respect to the GPA TP-15 standard the combination of input values is: 0: In Range 1: Out of Range The following range checks apply: For lower range: • 0.350 <= RD60 < 0.425 • -50 to (695.51*RD60 - 155.51) °F Higher range: • 0.425 <= RD60 <= 0.676 • -50 to 140 °F with RD60 being the relative density at 60°F	-		TP15OOR	0

Calculations

The calculations depend on the conversion method.

Conversion method 1: from observed to standard conditions.
The function performs the following iterative algorithm to calculate the relative density at 60 °F and the equilibrium pressure.

1. When API 11.2.4 rounding is enabled, the input relative density and temperature values are rounded in accordance with the standard
2. At the start of the iteration the relative density at [60 °F, equilibrium pressure] is set equal to the observed relative density and the CPL value is set to 1.
3. First the relative density corrected for pressure is calculated by dividing the observed relative density by the CPL value.
4. The CTL value and the relative density at [60 °F, equilibrium pressure] is calculated from the relative density corrected for pressure and the observed temperature according to Table 23E
5. Depending on the value of input 'Equilibrium pressure mode', either value of input 'Equilibrium pressure value' is used or the equilibrium pressure (vapor pressure) is calculated according to GPA TP-15. Whether the GPA TP-15 rounding and truncation rules are applied is dictated by input 'GPA-TP15 rounding'
6. The compressibility factor F is calculated according to API MPMS 11.2.2 from the relative density at [60 °F, equilibrium pressure] and the 'Observed temperature', with, depending on input API 11.2.2, rounding and truncation according to the standard.
7. The CPL value is calculated from the compressibility factor, the equilibrium pressure and the 'Observed pressure' input value.
8. The new value for relative density at [60°F, equilibrium pressure] is calculated by dividing the observed density by the CTL and CPL values.
9. Steps 3 though 8 are repeated taking the density value from step 8 as the staring value until the absolute difference between two consecutive density values is less than the convergence limit.

   To avoid convergence problems different convergence limits are applied, depending on the whether API 11.2.2 and/or GPA TP-15 rounding is applied:

   If API 11.2.2M rounding is enabled -> Limit = 0.00005 kg/m3
   else if GPA TP-15 rounding is enabled -> Limit = 0.000005 kg/m3
   else -> Limit = 0.00000001 kg/m3
10. If API 11.2.4 rounding is enabled, then the relative density at [60°F, equilibrium pressure] is rounded to 0.0001

Conversion method 2: from standard to observed conditions.
The function performs straightforward calculations to determine the density at observed conditions:

1. When API 11.2.4 rounding is enabled, the input relative density and temperature values are rounded in accordance with the standard
2. The CTL value is calculated according to API MPMS 11.2.4 (GPA TP-27) Table 24E from the density at [15 °C, equilibrium pressure] and the 'Observed temperature'.
3. Depending on the value of input 'Equilibrium pressure mode', either value of input 'Equilibrium pressure value' is used or the equilibrium pressure (vapor pressure) is calculated according to GPA TP-15.
4. The compressibility factor is calculated according to API MPMS 11.2.2 from the input relative density and the 'Observed temperature'.

5. The CPL value is calculated from the compressibility factor, the equilibrium pressure and the 'Observed pressure' input value.
6. If API 11.2.4 rounding is enabled, then the CTL value is rounded at [60°F, equilibrium pressure] is rounded to 0.00001
7. The relative density at the observed conditions is calculated by multiplying the input relative density by the CTL value and the CPL value.

fxAPI_Table5_1952

°API (T) --> °API (60°F)

This function converts an API gravity value at the observed temperature to the API gravity value at 60°F in accordance with API 1952 Table 5.

Compliance

- ASTM-IP Petroleum Measurement Tables, American Edition, United States Units of Measurement, 1952

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed API	Observed API gravity	°API		-20..120	0
Observed temperature	Temperature at which the API gravity is observed	°F		-100..400	60

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	1
API at 60 °F	API gravity at 60°F	°API	API		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The table values are the standard, so no calculations are involved. The function performs an interpolation between the table values that correspond to the input values.

fxAPI_Table5_1980

°API (T) --> °API (60°F)

This function converts an API gravity value at the observed temperature to the API gravity value at 60°F. The temperature conversion is according to API MPMS 11.1:1980 (API-2540), Tables 5A (Generalized Crude Oils) and 5B (Refined Oil Products) and API MPMS 11.1 Chapter XIII Table 5D: 1984 (Lubricating Oils).

The function provides the option to correct for readings taken from a hydrometer as specified in the API-2540 standard.

Compliance

- API MPMS 11.1 Volume X (API Standard 2540) - Table 5A - Generalized Crude Oils, Correction of Observed API Gravity to API Gravity at 60°F - First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 5B - Generalized Products, Correction of Observed API Gravity to API Gravity at 60°F- First Edition, August 1980
- API MPMS 11.1 Volume XIII - Table 5D - Generalized Lubricating Oils, Correction of Observed API Gravity to API Gravity at 60°F - January 1982

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed API	Observed API gravity	°API		-20..120	0
Observed temperature	Temperature at which the API gravity is observed	°F		-100..400	60
Product	1: A - Crude Oil 2: B - Auto select *Selection based on °API at 60 °F* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP		1

Function inputs	Remark	EU	SW tag	Range	Default
API2540 rounding	0: Disabled The calculations are performed with full precision. A convergence limit of 0.000001 kg/m3 will be applied for the iterative calculations. 1: Enabled API-2540 rounding and truncating rules are applied. A convergence limit of 0.05 kg/m3 will be applied as defined in the standard.		APIROUND		0
Hydrometer correction	0: Disabled 1: Enabled		HYDROCOR		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	1
API at 60 °F	API gravity at 60°F	°API	API		0
CTL	Volume correction factor for temperature.	-	CTL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor	1/°F	ALPHA		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table 5B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in full or partial compliance with the standard depending on input 'API 2540 rounding'.

fxAPI_Table5_2004

Description

°API (T, P) --> °API (60°F, 0 psig)

This function converts an API gravity value at the observed temperature and pressure to the API gravity value at 60°F and 0 psig.
The temperature and pressure correction is according to API MPMS 11.1:2004.
An iterative calculation needs to be applied to convert the observed API gravity to the value at base conditions.
Note: As opposed to API-2540, the 2004 standard does not include a correction for readings taken from a hydrometer and assumes that the equilibrium pressure is below atmospheric pressure, so taking 0 psig as the base pressure.

Compliance

- API MPMS 11.1 Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products and Lubricating Oils, May 2004

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed API	Observed API gravity	°API		-20..120	0
Observed temperature	Temperature at which the API gravity is observed	°F		-100..400	60
Observed pressure	Pressure at which the API gravity is observed	psig		-10..2000	0
Product	1: A - Crude Oil 2: B - Auto select *Selection based on °API at 60 °F* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP		1

Function inputs	Remark	EU	SW tag	Range	Default
API rounding	0: Disabled The calculations are performed with full precision and the final CTL, CPL and CTPL values are rounded as specified by the inputs 'CTL / CPL/ CTPL decimal places' 1: Enabled The input and output values are rounded in compliance with the standard. The CTL, CPL and CTPL value are rounded to 5 decimal places.		APIROUND		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence within 15 iterations	-	STS	 FIOOR CALCERR NOCONV	
API at 60 °F	API gravity at 60°F and 0 psig	-	API		0
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API rounding'	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API rounding'	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor	1/°C	ALPHA		0
F	Compressibility factor	1/psi	F		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		0
Calculation out of range	With respect to the standard the input values are:	-		OOR	0

fxAPI_Table5_2004

Function outputs	Remark	EU	SW tag	Alarm	Fallback
	0: In Range 1: Out of Range				

Calculations

The calculations are in either full or partial compliance with the standard, depending on whether API rounding is enabled or not.

fxAPI_Table6_1952

°API (60°F, 0 psig) --> CTL

This function calculates the volume correction factor for temperature from the API gravity value at 60°F and the observed temperature according to API 1952 Table 6.

Compliance

- ASTM-IP Petroleum Measurement Tables, American Edition, United States Units of Measurement, 1952

Input Data Limits

Table 6 contains values for the following range:

Input value	Normal Range	EU
API Gravity at 60 °F	0 .. 100	°API
Observed temperature	0 .. 300	°F

Note that the table does not cover the full range, e.g. for an API gravity of 70 the table only specifies values between 0 .. 150 °F

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
API at 60 °F	API gravity at 60°F and the equilibrium pressure	°API		-20..120	0
Observed temperature		°F		-100..400	60

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error	-	STS	FIOOR CALC	1
CTL	Volume correction factor for temperature.	-	CTL		1
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The table values are the standard, so no calculations are involved. The function performs an interpolation between the table values that correspond to the input values.

fxAPI_Table6_1980

°API (60°F, 0 psig) --> CTL

This function calculates the volume correction factor for temperature from the API gravity value at 60°F and the observed temperature.
The temperature conversion is according to API-2540, Tables 6A (Generalized Crude Oils) and 6B (Refined Oil Products) and API MPMS 11.1 Chapter XIII Table 6D: 1984 (Lubricating Oils).

Compliance

- API MPMS 11.1 Volume X (API Standard 2540) - Table 6A - Generalized Crude Oils, Correction of Volume to 60°F against API Gravity at 60°F - First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 6B - Generalized Products, Correction of Volume to 60°F against API Gravity at 60°F - First Edition, August 1980
- API MPMS 11.1 Volume XIII - Table 6D - Generalized Lubricating Oils, Correction of Volume to 60°F Against API Gravity at 60°F - January 1982

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
API at 60 °F	API gravity at 60°F and the equilibrium pressure	°API		-20..120	0
Observed temperature		°F		-100..400	60
Product	1: A - Crude Oil 2: B - Auto select *Selection based on °API at 60 °F* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP	-	1

Function inputs	Remark	EU	SW tag	Range	Default
API2540 rounding	0: Disabled The calculations are performed with full precision and the final CTL value is rounded as specified by input 'CTL decimal places' 1: Enabled for computational value API-2540 rounding and truncating rules are applied and the **computational** value for CTL as specified in the standard is used, meaning that the CTL value has: 4 decimal places if CTL >=1 5 decimal places if CTL < 1. 2: Enabled for table value API-2540 rounding and truncating rules are applied and the **table** value for CTL as specified in the standard meaning that the CTL value has 4 decimal places in all cases 3: Enabled with 5 decimal places API-2540 rounding and truncating rules are applied, while the CTL value has 5 decimal places in all cases. Note: although not strictly in accordance with the standard, this option is more commonly used than option 'Enabled for computational value'		APIROUND	-	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error	-	STS	 FIOOR CALC	1
CTL	Volume correction factor for temperature.	-	CTL		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
	Value will be rounded according to input 'API2540 rounding'				
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor	1/°F	ALPHA		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table 6B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in full or partial compliance with the standard depending on input ‘API 2540 rounding’.

fxAPI_Table6_2004

Description

°API (60°F, 0 psig) --> °API (T, P)

This function converts an API gravity value at 60°F and 0 psig to the API gravity value at the observed temperature and pressure.
The temperature and pressure correction is according to API MPMS 11.1:2004.
Note: As opposed to API-2540 that the equilibrium pressure is below atmospheric pressure, so taking 0 psig as the base pressure.

Compliance

- API MPMS 11.1 Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products and Lubricating Oils, May 2004

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
API at 60 °F	API gravity at 60°F and 0 psig	°API		-20..120	0
Observed temperature	Temperature at which the API gravity is observed	°F		-100..400	60
Observed pressure	Pressure at which the API gravity is observed	psig		-10..2000	0
Product	1: A - Crude Oil 2: B - Auto select *Selection based on °API at 60 °F* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP		1
API rounding	0: Disabled The calculations are performed with full precision 1: Enabled The input and output values are rounded in compliance with the standard. The CTL, CPL and CTPL value are rounded to 5 decimal places.		APIROUND		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error	-	STS	 FIOOR CALC	
Observed API	API gravity at the observed temperature and pressure	-	API		0
CTL	Volume correction factor for temperature.	-	CTL		1
CPL	Volume correction factor for pressure	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor	1/°F	ALPHA		0
F	Compressibility factor	1/psi	F		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on whether API rounding is enabled or not.

fxAPI_Table23_1952

Specific Gravity (T) --> Specific Gravity (60°F)

This function converts a specific gravity value at the observed temperature to the specific gravity at 60° according to the API 1952 Table 23.

Compliance

- ASTM-IP Petroleum Measurement Tables, American Edition, United States Units of Measurement, 1952

Input Data Limits

Table 23 contains values for the following range:

Input value	Normal Range	EU
Observed specific gravity	0.420 .. 1.099	
Observed temperature	0 .. 150	°F

Note that the table does not cover the full range, e.g. for an Observed specific gravity of 0.420 the table only specifies values between 120 .. 140 °F

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed specific gravity	Specific gravity at the observed temperature.	-		0..1.3	0
Observed temperature		°F		-100..400	60

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range	-	STS	FIOOR	
Specific gravity 60 °F	Specific gravity at 60°F	-	RD		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The table values are the standard, so no calculations are involved. The function performs an interpolation between the table values that correspond to the input specific gravity and input temperature.

In case the combination of input values ('Observed specific gravity' and Observed temperature') is not covered by the table, the output 'Specific gravity at 60 °F' is set to 0 and output 'Calculation out of range' is set to 1.

fxAPI_Table23_1980

Relative Density (T) --> Relative Density (60°F)

This function converts a relative density value at the observed temperature to the relative density at 60°. The temperature conversion is according to API-2540, Tables 23A (Generalized Crude Oils) and 23B (Refined Oil Products.

In 1982 API published tables 5D, 6D, 53D and 54D for lubricating oil products as part of API MPMS 11.1. Although tables 23d and 24d are not covered in an official API standard the Flow-X series of flow computer supports tables 23D and 24D as well by combining the calculation of tables 23A/B and 24A/B with the K0 and K1 constants published in the other tables for lubricating oils.

An iterative calculation needs to be applied to convert the observed relative density to the value at base conditions.

The function provides the option to correct for readings taken from a hydrometer as specified in the API-2540 standard.

Compliance

- API MPMS 11.1 Volume X (API Standard 2540) - Table 23A - Generalized Crude Oils, Correction of Observed Relative Density to Relative Density at 60/60°F - First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 23B - Generalized Products, Correction of Observed Relative Density to Relative Density at 60/60°F - First Edition, August 1980

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed relative density	Relative density at observed temperature and pressure	-		0..1.3	0
Observed temperature		°F		-100..400	60
Product	1: A - Crude Oil 2: B - Auto select *Selection based on relative density at 60 °F* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP		1

fxAPI_Table23_1980

Function inputs	Remark	EU	SW tag	Range	Default
API2540 rounding	0: Disabled The calculations are performed with full precision. A convergence limit of 0.000001 kg/m3 will be applied for the iterative calculations. 1: Enabled API-2540 rounding and truncating rules are applied. A convergence limit of 0.05 kg/m3 will be applied as defined in the standard.		APIROUND		0
Hydrometer correction	0: Disabled 1: Enabled		HYDROCOR		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALC NOCONV	
Relative density 60 °F	Relative density at 60°F and the equilibrium pressure	-	RD		0
CTL	Volume correction factor for temperature.	-	CTL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor	1/°F	ALPHA		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table 23B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in full or partial compliance with the standard depending on input ‘API 2540 rounding’.

fxAPI_Table23_2004

Description

Relative Density (T, P) --> Relative Density (60°F, 0 psig)

This function converts a relative density value at the observed temperature and pressure to the relative density value at 60°F and 0 psig.
The temperature and pressure correction is according to API MPMS 11.1:2004.
An iterative calculation needs to be applied to convert the observed relative density to the value at base conditions.
Note: As opposed to API-2540, the 2004 standard does not include a correction for readings taken from a hydrometer and assumes that the equilibrium pressure is below atmospheric pressure, so taking 0 psig as the base pressure.

Compliance

- API MPMS 11.1 Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products and Lubricating Oils, May 2004

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed Relative density	Relative density at the observed temperature and pressure	-		0 ..1.3	0
Observed temperature	Temperature at which the relative density is observed	°F		-100..400	60
Observed pressure	Pressure at which the relative density is observed	psig		-10..2000	0
Product	1: A - Crude Oil 2: B - Auto select *Selection based on relative density at 60 °F* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP		1

Function inputs	Remark	EU	SW tag	Range	Default
API rounding	0: Disabled The calculations are performed with full precision and the final CTL, CPL and CTPL values are rounded as specified by the inputs 'CTL / CPL/ CTPL decimal places' 1: Enabled The input and output values are rounded in compliance with the standard. The CTL, CPL and CTPL value are rounded to 5 decimal places.		APIROUND		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range *Outputs will be set to fallback values* 2: Calculation error *Outputs will be set to fallback values* 3: No convergence within 15 iterations *Outputs will be set to values of last iteration*	-			1
Relative density at 60 °F	Relative density at 60°F and 0 psig	-	RD		0
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API rounding'	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API rounding'	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor	1/°F	ALPHA		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
F	Compressibility factor	1/psi	F		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on whether API rounding is enabled or not.

fxAPI_Table23E

Description

Relative Density (T) --> Relative Density (60°F)

This function converts the relative density value at the observed temperature to the corresponding relative density at 60°F.
The temperature correction is according to API MPMS 11.2.4:2007 (GPA TP-25 / GPA TP-27).

Compliance

- API MPMS 11.2.4: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- GPA TP-27: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- GPA TP-25: Temperature Correction for the volume of Light Hydrocarbons – Tables 24E and 23E, 1998

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed relative density	Relative density at the observed temperature	-		0..0.75	0
Observed temperature	Temperature at which the relative density is observed	°F		-100..300	60
API rounding	0: Disabled The calculations are performed with full precision and the output values are not rounded 1: Enabled The input and output values are rounded as defined in the standard		APIROUND		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	1
Relative density at 60 °F	Relative density at 60°F		RD		0
CTL	Volume correction factor for temperature.	-	CTL		1
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on the selected type of API rounding.

fxAPI_Table24_1952

Specific Gravity (60°F) --> CTL

This function returns the volume correction factor for temperature Ctl from the observed temperature and the specific gravity at 60° according to the API 1952 Table 24.

Compliance

- ASTM-IP Petroleum Measurement Tables, American Edition, United States Units of Measurement, 1952

Input Data Limits

Table 23 contains values for the following range:

Input value	Normal Range	EU
Observed specific gravity	0.500 .. 1.100	
Observed temperature	-50 .. +300	°F

Note that the table does not cover the full range, e.g. for an Specific gravity at 60 °F of 0.500 the table only specifies values between -50 .. 95 °F

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Specific gravity 60 °F	Specific gravity at 60°F	-		0..1.3	0
Observed temperature		°F		-100..400	60

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range	-	STS	FIOOR	
CTL	Volume correction factor for temperature.	-	CTL		1
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The table values are the standard, so no calculations are involved. The function performs an interpolation between the table values that correspond to the input specific gravity and input temperature.

In case the combination of input values ('Specific gravity 60 °F' and Observed temperature') is not covered by the table, the output 'CTL' is set to 1 and output 'Calculation out of range' is set to 1.

fxAPI_Table24_1980

Relative Density (60°F) --> CTL

This function calculates the volume correction factor for temperature CTL from the relative density value at 60°F and the observed temperature.
The temperature conversion is according to API-2540, Tables 24A (Generalized Crude Oils) and 24B (Refined Oil Products.
In 1982 API published tables 5D, 6D, 53D and 54D for lubricating oil products as part of API MPMS 11.1. Although tables 23d and 24d are not covered in an official API standard the Flow-X series of flow computer supports tables 23D and 24D as well by combining the calculation of tables 23A/B and 24A/B with the K0 and K1 constants published in the other tables for lubricating oils.

Compliance

- API MPMS 11.1 Volume X (API Standard 2540) - Table 24A - Generalized Crude Oils, Correction of Volume to 60°F against Relative Density at 60/60°F - First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 24B - Generalized Products, Correction of Volume to 60°F against Relative Density at 60/60°F - First Edition, August 1980

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Relative Density at 60 °F	Relative density at 60°F and the equilibrium pressure	-		0..1.3	0
Observed temperature		°F		-100..400	60
Product	1: A - Crude Oil 2: B - Auto select *Selection based on relative density at 60 °F* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP	-	1

Function inputs	Remark	EU	SW tag	Range	Default
API2540 rounding	0: Disabled The calculations are performed with full precision and the final CTL value is rounded as specified by input 'CTL decimal places' 1: Enabled for computational value API-2540 rounding and truncating rules are applied and the **computational** value for CTL as specified in the standard is used, meaning that the CTL value has: 4 decimal places if CTL >=1 5 decimal places if CTL < 1. 2: Enabled for table value API-2540 rounding and truncating rules are applied and the **table** value for CTL as specified in the standard meaning that the CTL value has 4 decimal places in all cases 3: Enabled with 5 decimal places API-2540 rounding and truncating rules are applied, while the CTL value has 5 decimal places in all cases. Note: although not strictly in accordance with the standard, this option is more commonly used than option 'Enabled for computational value'		APIROUND	-	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error	-	STS	FIOOR CALCERR	
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API2540 rounding'	-	CTL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor	1/°F	ALPHA		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table 24B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		Input *Product*
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in full or partial compliance with the standard depending on input ‘API 2540 rounding’.

fxAPI_Table24_2004

Description

Relative Density (60°F, 0 psig) --> Relative Density (T, P)

This function converts a relative density value at 60°F and 0 psig to the relative density value at the observed temperature and pressure.
The temperature and pressure correction is according to API MPMS 11.1:2004.
Note: The 2004 standard assumes that the equilibrium pressure is below atmospheric pressure, so taking 0 psig as the base pressure.

Compliance

- API MPMS 11.1 Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products and Lubricating Oils, May 2004

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Relative density at 60 °F	Relative density at 60°F and 0 psig	-		0 ..1.3	0
Observed temperature	Temperature at which the API gravity is observed	°F		-100..400	60
Observed pressure	Pressure at which the API gravity is observed	psig		-10..2000	0
Product	1: A - Crude Oil 2: B - Auto select *Selection based on relative density at 60 °F* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP		1

Function inputs	Remark	EU	SW tag	Range	Default
API rounding	0: Disabled The calculations are performed with full precision and the final CTL, CPL and CTPL values are rounded as specified by the inputs 'CTL / CPL/ CTPL decimal places' 1: Enabled The input and output values are rounded in compliance with the standard. The CTL, CPL and CTPL value are rounded to 5 decimal places.		APIROUND		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error	-	STS	 FIOOR CALCERR	
Observed relative density	Relative density at the observed temperature and pressure	-	RD		0
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API rounding'	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API rounding'	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor	1/°F	ALPHA		0
F	Compressibility factor	1/psi	F		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on whether API rounding is enabled or not.

fxAPI_Table24E

Description

Relative Density (60°F) --> CTL

This function calculates the volume correction factor for temperature from the relative density value at 60°F and the observed temperature.
The temperature correction is according to API MPMS 11.2.4:2007 (GPA TP-25 / GPA TP-27).

Compliance

- API MPMS 11.2.4: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- GPA TP-27: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- GPA TP-25: Temperature Correction for the volume of Light Hydrocarbons – Tables 24E and 23E, 1998

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Relative density at 60 °F	Relative density at 60°F	-		0..0.75	0
Observed temperature	Temperature at which the relative density is observed	°F		-100..300	60
API rounding	0: Disabled The calculations are performed with full precision and the output values are not rounded 1: Enabled The input and output values are rounded as defined in the standard		APIROUND		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALC	
CTL	Volume correction factor for temperature Value will be rounded according to inputs 'API rounding'	-	CTL		1
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on the selected type of API rounding.

fxAPI_Table53_1952

Density (T) --> Density (15°C)

This function converts a density value at the observed temperature to the density at 15°C according to the API 1952 Table 53.

Compliance

- ASTM-IP Petroleum Measurement Tables, Metric Edition, Metric Units of Measurement, 1952

Input Data Limits

Table 53 contains values for the following range:

Input value	Normal Range	EU
Observed density	420 .. 1099	kg/m3
Observed temperature	-25 .. 125	°C

Note that the table does not cover the full range, e.g. for an Observed specific gravity of 0.420 the table only specifies values between 45 .. 60 °C

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed density	Density at the observed temperature.	kg/m3		0..1300	0
Observed temperature		°C		-100..200	15

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range	-	STS	FIOOR	
Density at 15 °C	Density at 15 °C	kg/m3	DENS15		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The table values are the standard, so no calculations are involved. The function performs an interpolation between the table values that correspond to the input specific gravity and input temperature.

In case the combination of input values ('Observed density' and Observed temperature') is not covered by the table, the output 'Density at 15 °C' is set to 0 and output 'Calculation out of range' is set to 1.

fxAPI_Table53_1980

Density (T) --> Density (15°C)

This function converts a density value at the observed temperature to the density value at 15°C.
The temperature conversion is according to API-2540, Tables 53A (Generalized Crude Oils) and 53B (Refined Oil Products) and API MPMS 11.1 Chapter XIV Table 53D: 1984 (Lubricating Oils).
The function provides the option to correct for readings taken from a hydrometer as specified in the API-2540 standard.

Compliance

- API MPMS 11.1 Volume X (API Standard 2540) - Table 53A - Generalized Crude Oils, Correction of Observed Density to Density at 15°C - First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 53B - Generalized Products, Correction of Observed Density to Density at 15°C - First Edition, August 1980
- API MPMS 11.1 Volume XIV - Table 53D - Generalized Lubricating Oils, Correction of Observed Density to Density at 15°C - January 1982

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed density	Density at observed temperature	kg/m3		0..1300	0
Observed temperature		°C		-100..200	15
Product	1: A - Crude Oil 2: B - Auto select *Selection based on density at 15 °C* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP		1

fxAPI_Table53_1980

Function inputs	Remark	EU	SW tag	Range	Default
API2540 rounding	0: Disabled The calculations are performed with full precision. A convergence limit of 0.000001 kg/m3 will be applied for the iterative calculations. 1: Enabled API-2540 rounding and truncating rules are applied. A convergence limit of 0.05 kg/m3 will be applied as defined in the standard.		APIROUND		0
Hydrometer correction	0: Disabled 1: Enabled		HYDROCOR		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	
Density at 15 °C	Density at 15°C	kg/m3 (s)	DENS15		0
CTL	Volume correction factor for temperature.	-	CTL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor	1/°C	ALPHA		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table 53B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in full or partial compliance with the standard depending on input ‘API 2540 rounding’.

fxAPI_Table53_2004

Description

Density (T, P) --> Density (15°C, 0 bar(g))

This function converts a density value at the observed temperature and pressure to the density value at 15°C and 0 bar(g).
The temperature and pressure correction is according to API MPMS 11.1:2004.
An iterative calculation needs to be applied to convert the observed density to the value at base conditions.
Note: As opposed to API-2540, the 2004 standard does not include a correction for readings taken from a hydrometer and assumes that the equilibrium pressure is below atmospheric pressure, so taking 0 psig as the base pressure.

Compliance

- API MPMS 11.1 Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products and Lubricating Oils, May 2004

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed density	Density at the observed temperature and pressure	kg/m3		0..1300	0
Observed temperature	Temperature at which the density is observed	°C		-100..200	15
Observed pressure	Pressure at which the density is observed	bar(g)		-1..150	0
Product	1: A - Crude Oil 2: B - Auto select *Selection based on density at 15 °C* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP		1

API rounding	0: Disabled The calculations are performed with full precision and the final CTL, CPL and CTPL values are rounded as specified by the inputs 'CTL / CPL/ CTPL decimal places' 1: Enabled The input and output values are rounded in compliance with the standard. The CTL, CPL and CTPL value are rounded to 5 decimal places.		APIROUND		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	
Density at 15 °C	Density at 15°C and 0 bar(g)	-	DENS15		0
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API rounding'	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API rounding'	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor at 60 °F !	1/°F	ALPHA		0
F	Compressibility factor	1/bar	F		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		0
Calculation out of range	With respect to the standard the input values are:	-		OOR	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
	0: In Range 1: Out of Range				

Calculations

The calculations are in either full or partial compliance with the standard, depending on whether API rounding is enabled or not.

fxAPI_Table53E

Description

Density (T) --> Density (15°C)

This function converts the density value at the observed temperature to the corresponding density at 15°C.
The temperature correction is according to API MPMS 11.2.4:2007 (GPA TP-27).

Compliance

- API MPMS 11.2.4: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- GPA TP-27: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed density	Density at the observed temperature	kg/m3		0..750	0
Observed temperature	Temperature at which the relative density is observed	°C		-100..150	15
API rounding	0: Disabled The calculations are performed with full precision and the output values are not rounded 1: Enabled The input and output values are rounded as defined in the standard				0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	
Density at 15°C			DENS15		
CTL	Volume correction factor for temperature.	-	CTL		1
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on the selected type of API rounding.

fxAPI_Table54_1952

Density (15°C) --> CTL

This function determines the volume correction factor for temperature CTL from the relative density value at 15°C and the observed temperature according to the API 1952 Table 54.

Compliance

- ASTM-IP Petroleum Measurement Tables, Metric Edition, Metric Units of Measurement, 1952

Input Data Limits

Table 54 contains values for the following range:

Input value	Normal Range	EU
Density at 15 °C	500 .. 1100	kg/m3
Observed temperature	-50 .. +150	°C

Note that the table does not cover the full range, e.g. for a Density at 15 °C of 500 kg/m3the table only specifies values between -50 .. 55 °C

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Density 15 °C	Specific gravity at 60°F	Kg/m3		0..1300	0
Observed temperature		°C		-100..200	15

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range	-	STS	FIOOR	
CTL	Volume correction factor for temperature.	-	CTL		1
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The table values are the standard, so no calculations are involved. The function performs an interpolation between the table values that correspond to the input specific gravity and input temperature.

In case the combination of input values ('Specific gravity 60 °F' and Observed temperature') is not covered by the table, the output 'CTL' is set to 1 and output 'Calculation out of range' is set to 1.

fxAPI_Table54_1980

Density (15°C) --> CTL

This function calculates the volume correction factor for temperature CTL from the relative density value at 15°C and the observed temperature.
The temperature conversion is according to API-2540, Tables 54A (Generalized Crude Oils) and 54B (Refined Oil Products) and API MPMS 11.1 Chapter XIV Table 54D: 1984 (Lubricating Oils).

Compliance

- API MPMS 11.1 Volume X (API Standard 2540) - Table 54A - Generalized Crude Oils, Correction of Volume to 15°C against Density at 15°F - First Edition, August 1980
- API MPMS 11.1 Volume X (API Standard 2540) - Table 54B - Generalized Products, Correction of Volume to 15°C against Density at 15°C - First Edition, August 1980
- API MPMS 11.1 Volume XIV - Table 54D - Generalized Lubricating Oils, Correction of Volume to 15°C Against Density at 15°C - January 1982

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Density at 15 °C	Density at 15°C and the equilibrium pressure	kg/m3		0..1300	0
Observed temperature		°C		-100..200	15
Product	1: A - Crude Oil 2: B - Auto select 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP	-	1

Function inputs	Remark	EU	SW tag	Range	Default
API2540 rounding	0: Disabled The calculations are performed with full precision and the final CTL value is rounded as specified by input 'CTL decimal places' 1: Enabled for computational value API-2540 rounding and truncating rules are applied and the **computational** value for CTL as specified in the standard is used, meaning that the CTL value has: 4 decimal places if CTL >=1 5 decimal places if CTL < 1. 2: Enabled for table value API-2540 rounding and truncating rules are applied and the **table** value for CTL as specified in the standard meaning that the CTL value has 4 decimal places in all cases 3: Enabled with 5 decimal places API-2540 rounding and truncating rules are applied, while the CTL value has 5 decimal places in all cases. Note: although not strictly in accordance with the standard, this option is more commonly used than option 'Enabled for computational value'		APIROUND	-	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error		STS	 FIOOR CALCERR	
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API2540 rounding'	-	CTL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor	1/°C	ALPHA		
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table 54B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	

Calculations

The calculations are in full or partial compliance with the standard depending on input 'API 2540 rounding'.

fxAPI_Table54_2004

Description

Density (15°C, 0 bar(g)) --> Density (T, P)

This function converts a density value at 15°C and 0 bar(g) to the density value at the observed temperature and pressure.
The temperature and pressure correction is according to API MPMS 11.1:2004.
Note: The 2004 standard assumes that the equilibrium pressure is below atmospheric pressure, so taking 0 psig as the base pressure.

Compliance

- API MPMS 11.1 Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products and Lubricating Oils, May 2004

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Density at 15 °C	Density at 15°C and 0 bar(g)	kg/m3		0..1300	0
Observed temperature	Temperature at which the density is observed	°C		-100..200	15
Observed pressure	Pressure at which the density is observed	bar(g)		-1..150	0
Product	1: A - Crude Oil 2: B - Auto select *Selection based on density at 15 °C* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP		1
API rounding	0: Disabled The calculations are performed with full precision and the final CTL, CPL and CTPL values are rounded as specified by the inputs 'CTL / CPL/ CTPL decimal places' 1: Enabled The input and output values are rounded in compliance with the standard. The CTL, CPL and CTPL value are rounded to 5 decimal		APIROUND		0

Function inputs	Remark	EU	SW tag	Range	Default
	places.				

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence		STS	FIOOR CALCERR	
Observed density	Density at the observed temperature and pressure	-	DENS		0
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API rounding'	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API rounding'	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor at 60 °F !	1/°F	ALPHA		0
F	Compressibility factor	1/bar	F		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		0
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on whether API rounding is enabled or not.

fxAPI_Table54E

Description

Density (15°C) --> CTL

This function calculates the volume correction factor for temperature from the relative density value at 15°C and the observed temperature.
The temperature correction is according to API MPMS 11.2.4:2007 (GPA TP-27).

Compliance

- API MPMS 11.2.4: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- GPA TP-27: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Density at 15°C		-		0..750	0
Observed temperature	Temperature at which the relative density is observed	°C		-100..150	15
API rounding	0: Disabled The calculations are performed with full precision and the output values are not rounded 1: Enabled The input and output values are rounded as defined in the standard				0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR	1
CTL	Volume correction factor for temperature Value will be rounded according to input 'API rounding'	-	CTL		1
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on the selected type of API rounding.

fxAPI_Table59_2004

Description

Density (T, P) --> Density (20°C, 0 bar(g))

This function converts a density value at the observed temperature and pressure to the density value at 20°C and 0 bar(g).
The temperature and pressure correction is according to API MPMS 11.1:2004.
An iterative calculation needs to be applied to convert the observed density to the value at base conditions.
Note: As opposed to API-2540, the 2004 standard does not include a correction for readings taken from a hydrometer and assumes that the equilibrium pressure is below atmospheric pressure, so taking 0 psig as the base pressure.

Compliance

- API MPMS 11.1 Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products and Lubricating Oils, May 2004

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed density	Density at the observed temperature and pressure	kg/m3		0..1300	0
Observed temperature	Temperature at which the density is observed	°C		-10..200	20
Observed pressure	Pressure at which the density is observed	bar(g)		-1..150	0
Product	1: A - Crude Oil 2: B - Auto select *Selection based on density at 20 °C* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP		1

Function inputs	Remark	EU	SW tag	Range	Default
API rounding	0: Disabled The calculations are performed with full precision and the final CTL, CPL and CTPL values are rounded as specified by the inputs 'CTL / CPL/ CTPL decimal places' 1: Enabled The input and output values are rounded in compliance with the standard. The CTL, CPL and CTPL value are rounded to 5 decimal places.		APIROUND		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	
Density at 20 °C	Density at 20°C and 0 bar(g)	-	DENS20		0
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API rounding'	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API rounding'	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor at 60 °F !	1/°F	ALPHA		0
F	Compressibility factor	1/bar	F		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table B (enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.	-	PRDCUR		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on whether API rounding is enabled or not.

fxAPI_Table59E

Description

Density (T) --> Density (20°C)

This function converts the density value at the observed temperature to the corresponding density at 20°C.
The temperature correction is according to API MPMS 11.2.4:2007 (GPA TP-27).

Compliance

- API MPMS 11.2.4: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- GPA TP-27: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Observed density	Density at the observed temperature	kg/m3		0..750	0
Observed temperature	Temperature at which the relative density is observed	°C		-100..200	20
API rounding	0: Disabled The calculations are performed with full precision and the output values are not rounded 1: Enabled The input and output values are rounded as defined in the standard		APIROUND		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR NOCONV	
Density at 20°C			DENS20		0
CTL	Volume correction factor for temperature.	-	CTL		1
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on the selected type of API rounding.

fxAPI_Table60_2004

Description

Density (20°C, 0 bar(g)) --> Density (T, P)

This function converts a density value at 20°C and 0 bar(g) to the density value at the observed temperature and pressure.
The temperature and pressure correction is according to API MPMS 11.1:2004.
Note: The 2004 standard assumes that the equilibrium pressure is below atmospheric pressure, so taking 0 psig as the base pressure.

Compliance

- API MPMS 11.1 Temperature and Pressure Volume Correction Factors for Generalized Crude Oils, Refined Products and Lubricating Oils, May 2004

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Density at 20 °C	Density at 20°C and 0 bar(g)	kg/m3		0..1300	0
Observed temperature	Temperature at which the density is observed	°C		-100..200	60
Observed pressure	Pressure at which the density is observed	bar(g)		-1..150	0
Product	1: A - Crude Oil 2: B - Auto select *Selection based on density at 20 °C* 3: B - Gasoline 4: B - Transition Area 5: B - Jet Fuels 6: B - Fuel Oil 7: D - Lubricating Oil		PRDTYP		1

Function inputs	Remark	EU	SW tag	Range	Default
API rounding	0: Disabled The calculations are performed with full precision and the final CTL, CPL and CTPL values are rounded as specified by the inputs 'CTL / CPL/ CTPL decimal places' 1: Enabled The input and output values are rounded in compliance with the standard. The CTL, CPL and CTPL value are rounded to 5 decimal places.		APIROUND		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	 FIOOR CALCERR	
Observed density	Density at the observed temperature and pressure	-	DENS		0
CTL	Volume correction factor for temperature. Value will be rounded according to input 'API rounding'	-	CTL		1
CPL	Volume correction factor for pressure Value will be rounded according to input 'API rounding'	-	CPL		1
CTPL	Combined volume correction factor CTPL = CTL * CPL	-	CTPL		1
K0	Actual value of constant K0 used for CTL calculation	-	K0		0
K1	Actual value of constant K1 used for CTL calculation	-	K1		0
K2	Actual value of constant K2 used for CTL calculation	-	K2		0
Alpha	Thermal expansion factor at 60 °F !	1/°F	ALPHA		0
F	Compressibility factor	1/bar	F		0
Product	When input 'Product' is 'B - Auto select', then the output is set to the actual selected product of table B	-	PRDCUR		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
	(enumerative value as defined for input 'Product'), else the output is set equal to input 'Product'.				
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on whether API rounding is enabled or not.

fxAPI_Table60E

Description

Density (20°C) --> CTL

This function calculates the volume correction factor for temperature from the relative density value at 20°C and the observed temperature.
The temperature correction is according to API MPMS 11.2.4:2007 (GPA TP-27).

Compliance

- API MPMS 11.2.4: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007
- GPA TP-27: Temperature Correction for the Volume of NGL and LPG Tables 23E, 24E, 53E, 54E, 59E & 60E, September 2007

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Density at 20°C		-		0..750	0
Observed temperature	Temperature at which the relative density is observed	°C		-100..150	20
API rounding	0: Disabled The calculations are performed with full precision and the output values are not rounded 1: Enabled The input and output values are rounded as defined in the standard		APIROUND		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence	-	STS	FIOOR CALCERR	
CTL	Volume correction factor for temperature Value will be rounded according to input 'API rounding'	-	CTL		1
Calculation out of range	With respect to the standard the input values are: 0: In Range 1: Out of Range	-		OOR	0

Calculations

The calculations are in either full or partial compliance with the standard, depending on the selected type of API rounding.

fxBatchFWA

Description

The function calculates a **f**low-**w**eighted **a**verage (FWA) for a batch.
A batch can be any batch type of process, such as product loading, meter proving or transmitter validation.
The function weights the input value with a flow increment and updates the average accordingly. The flow increment is provided by either a 'fxTotalizerDelta' or a 'xTotalizerRate' function.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag-prefix and retentive storage.				
Input value	Value to be averaged	*Same as linked cell*		-1e11..1e11	
Enabled	0: Disabled 1: Enabled		EN		
Increment	Flow increment with which the input value is weighed. Must refer to the corresponding output from a 'TotalizerRate' or 'TotalizerDelta' function Negative values will be ignored.	*Same as linked cell*		0..1e11	
Reset command	Trigger to reset the batch. At a batch reset the current average is stored in the previous value and the current value is reset to 0				
Identification	Batch identification. Can be any string of maximum 255 characters long. If multiple identifications need to be stored for future referral, e.g. the batch number, the ship name and the nomination number, then the individual strings should be concatenated with an "." character in-between.		ID		

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current average	Average calculated over the current batch.	*Same as input 'Input value'*	CB		0
Previous average	Average of the previous batch.	*Same as input 'Input value'*	PB		0

fxBatchHistData

Description

The function retrieves historical 'batch' data from the flow computer persistent memory.
A 'batch' can be any batch type of process, such as product loading, meter proving or transmitter validation.
The function retrieves one or more historical values for the specified function instance. The function instance must be one of the following function types:

- fxBatchFWA
- fxBatchLatch
- fxBatchStore
- fxBatchTotal
- fxBatchTWA
- fxBatchWatch

The function instance is referred to by its name (i.e. the 1st argument of the referred function).

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag-prefix and retentive storage.				
First ID	Optional. Batch identification of the first historical batch for which the value has to be retrieved.		FIRSTID		
Last ID	Optional. Batch identification of the last historical batch for which the value has to be retrieved.		LASTID		
Sequence	Sequence in which the retrieved values must be copied to the function outputs. 1: Ascending order (Value 1 contains oldest value) 2: Descending order (Value 1 contains newest value)				1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Number of values	Number of historical values that was retrieved from the flow computer memory according to the input criteria		ACTSIZE		
Value 1	The 1st retrieved historical data value		1		
Value 2	The 2nd retrieved historical data value		2		
etc.					

fxBatchLatch

Description

The function latches a value at every batch reset.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag-prefix and retentive storage.				
Input value	Value to be latched	*Same as linked cell*			
Latch command *	Trigger to latch the value				
Reset command *	Trigger to reset the batch. At every batch reset the last latched value is stored in the previous latch output value and the current latch output value is reset to 0				
Identification	Batch identification. Can be any string of maximum 255 characters long.		ID		

Note: When the latch and reset commands are given at the same time, then the current value becomes the 'Previous latch' output value and the current latch is reset to 0.

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current latch	Value that is latched since the last batch reset. Is reset to 0 at every batch reset.	*Same as input 'Input value'*	CB		0
Previous latch	Value that was latched during the previous batch. If no value was latched during the previous batch, then the value is set to 0.	*Same as input 'Input value'*	PB		0

fxBatchMax

Description

The function determines the maximum for a particular input value over a batch.
A batch can be any batch type of process, such as product loading, meter proving or transmitter validation.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag-prefix and retentive storage.				
Input value	Value for which the maximum has to be determined	*Same as linked cell*		-1e11..1e11	
Enabled	0: Disabled 1: Enabled		EN		
Reset command	Trigger to reset the batch. At a batch reset the current average is stored in the previous value and the current value is reset to 0				
Identification	Batch identification. Can be any string of maximum 255 characters long. If multiple identifications need to be stored for future referral, e.g. the batch number, the ship name and the nomination number, then the individual strings should be concatenated with an "." character in-between.		ID		

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current minimum	Minimum over the current batch.	*Same as input 'Input value'*	CB		0
Previous minimum	Minimum over the previous batch.	*Same as input 'Input value'*	PB		0

fxBatchMin

Description

The function determines the minimum for a particular input value over a batch.
A batch can be any batch type of process, such as product loading, meter proving or transmitter validation.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag-prefix and retentive storage.				
Input value	Value for which the minimum has to be determined	*Same as linked cell*		-1e11..1e11	
Enabled	0: Disabled 1: Enabled		EN		
Reset command	Trigger to reset the batch. At a batch reset the current average is stored in the previous value and the current value is reset to 0				
Identification	Batch identification. Can be any string of maximum 255 characters long. If multiple identifications need to be stored for future referral, e.g. the batch number, the ship name and the nomination number, then the individual strings should be concatenated with an "." character in-between.		ID		

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current minimum	Minimum over the current batch.	*Same as input 'Input value'*	CB		0
Previous minimum	Minimum over the previous batch.	*Same as input 'Input value'*	PB		0

fxBatchTotal

Description

The function accumulates a flow increment into a batch total. At every batch reset the current batch total is stored into the previous value and the current value is reset to 0.
The flow increment originates from a 'TotalizerRate' or 'TotalizerDelta' function.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag-prefix and retentive storage.				
Increment	Increment value to be added to the batch total. Negative values will be ignored, so the batch total will not decrease.	*Same as linked cell*		0..1e11	
Enabled	0: Disabled 1: Enabled		EN		
Reset command	Trigger to reset the batch. At a batch reset the current total is stored in the previous value and the current total is reset to 0				
Identification	Batch identification. Can be any string of maximum 255 characters long. If multiple identifications need to be stored for future referral, e.g. the batch number, the ship name and the nomination number, then the individual strings should be concatenated with an "." character in-between.		ID		
Rollover value	The batch total will be reset to 0 when it reaches the rollover value	*Same as input Increment*	ROVAL	0..1e15	1e12
Decimal places	Defines the number of decimal places for the current and previous total output values. -1 means full precision (no rounding applied)		DECPLS	-1..10	-1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current total	Accumulated total for the current batch, so since the last batch reset.	*Same as input 'Increment'*	CB		0
Previous total	Accumulated total for the previous batch	*Same as input 'Increment'*	PB		0
Rollover flag	Flag indicating a rollover to 0.	0		ROALM	

Function outputs	Remark	EU	SW tag	Alarm	Fallback
	0: Off 1: On Note: stays 'On' for one calculation cycle only)				

fxBatchTWA

Description

The function calculates a **t**ime-**w**eighted **a**verage (TWA) for a batch. At a batch reset the current average is stored in the previous value and the current value is reset to 0.
The function weights the input value with the time (in fact the actual calculation cycle time) and updates the average accordingly.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag-prefix and retentive storage.				
Input value	Value to be averaged	*Same as linked cell*		-1e11..1e11	
Enabled	0: Disabled 1: Enabled		EN		
Reset command	Trigger to reset the batch. At a batch reset the current latch is stored in the previous value and the current latch is reset to 0				
Identification	Batch identification. Can be any string of maximum 255 characters long. If multiple identifications need to be stored for future referral, e.g. the batch number, the ship name and the nomination number, then the individual strings should be concatenated with an "." character in-between.		ID		

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current average	Average calculated over the current batch.	*Same as input 'Input value'*	CB		0
Previous average	Average of the previous batch.	*Same as input 'Input value'*	PB		0

fxBatchWatch

Description

The function 'remembers' that a condition has been valid during a batch.
A typical example is a transmitter that was overridden with a keypad value.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag-prefix and retentive storage.				
Condition	0: Condition is not valid <>0: Condition is valid				
Enabled	0: Disabled 1: Enabled	EN			
Reset command	Trigger to reset the batch. At a batch reset the current watched value is stored in the previous value and the current watched value is reset to 0				
Identification	Batch identification. Can be any string of maximum 255 characters long. If multiple identifications need to be stored for future referral, e.g. the batch number, the ship name and the nomination number, then the individual strings should be concatenated with an "." character in-between.		ID		

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current watch	Indicates whether or not the condition has been valid during the current batch: 0: Not valid 1: Valid		CB		0
Previous watch	Indicates whether or not the condition has been valid during the previous batch: 0: Not valid 1: Valid		PB		0

fxConvertUnit

Description

This function converts a value expressed in a particular unit into the corresponding value expressed in another unit.

The input and output unit must belong category, otherwise the conversion fails.

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name					
Input value	The value to be converted				
Input unit	Unit of the value to be converted Use one of the "xu_..." unit constants.				
Output unit	Unit of the output value Use one of the "xu_..." unit constants.				

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Output value		<Output unit>	VAL		0
Conversion failure	The conversion fails when the input unit and output unit do not belong to the same unit category (or also when the input unit and / or output unit are not a valid unit). 0: Normal 1: Failure		CONVFAIL		

fxDeviationAlarm

Description

The function watches the deviation, or the difference or discrepancy, between two values and generates an alarm when the deviation exceeds the specified limit.

> Note: Alarm delays and dead bands can be defined outside this function through the alarm dialog.

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input value 1	Must be linked to another cell	*Same as linked cell*		-1e11..1e11	0
Input value 2	Must be linked to another cell	*Must be same as for input value 1*		-1e11..1e11	0
Deviation type	Determines whether the absolute or the relative difference needs to be checked. The unit of the deviation limit will be in accordance. 1: Absolute 2: Relative		DEVTYP		1
Deviation limit	The unit depends on the 'Deviation type'	*Absolute: Same as input value 1* *Relative : %*	DEVLIM	0..1e11	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Deviation alarm	0: Normal 1: Alarm	-	DEVALM	DEVALM	

Logic

Deviation type = 1 (Absolute)

- A deviation alarm is raised when the absolute difference between the two values is greater than the 'Discrepancy limit'.

Deviation type = 2 (Relative)

- A deviation alarm is raised when the absolute difference between the two values divided by the minimum of the two values times 100 % is greater than the 'Discrepancy limit'.

fxDigitalInput

The Digital Input function processes a single digital input and outputs either the actual input signal or the latched input signal.

Function inputs	Remark	EU	SW tag	Default
Name	Optional tag name, tag description and tag group			
Channel number	1..16		CHAN	1
Logic	1: Positive 2: Negative		LOGIC	1
Mode	1: Actual 2: Latched		MODE	1
Threshold	Each digital input has 2 threshold levels that determine whether the signal is considered to be either high (above the threshold) or low (below the threshold). The threshold levels are as follows (all relative to signal ground): Channels 1 through 8: 1: + 1.25 Volts 2: + 12 Volts Channels 9 through 16: 1: + 3.75 Volts 2: + 12 Volts		THRESHOLD	1

Function outputs	Remark	SW tag	Alarm	EU
Status	0: Normal 1: Input argument out of range	STS	FIOOR	-
Signal State	0: Off 1: On Meaning depends on the input Logic and Mode, refer to the table below.	SIGSTATE		-

Calculations

The following table summarizes the relationship between the input signal and the output 'State', depending on the inputs 'Logic and 'Mode'.

Logic	**Mode**	**Signal state = Off**	**Signal State = On**
Positive	Actual	Actual signal is low	Actual signal is high
Positive	Latched	Signal has not been high during last calculation cycle	Signal has been high during last calculation cycle
Negative	Actual	Actual signal is high	Actual signal is low
Negative	Latched	Signal has not been low during last calculation cycle	Signal has been low during last calculation cycle

fxDigitalOutput

The Digital Output function configures a single digital output on the local module. Use function 'fxSetDigitalOutput' to control the actual output signal.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name for output 'Signal State'				
Channel number	One of the 16 digital I/O channels.		CHAN	1..16	1
Logic	1: Positive 2: Negative		LOGIC		1
Delay	Period of time that the control signal must be high (> 0) without interruption before the output will be activated. The value 0 disables the delay function If the control signal becomes 0 before the time has elapsed, then the output signal will not be activated.	ms	DELAY	>= 0	0
Minimum activation time	Minimum period of time that the signal will remain activated. After the minimum activation time has elapsed the output signal will remain activated until the control value becomes 0.	ms	MINACTITM	>= 0	0

Function outputs	Remark	SW tag	Alarm	EU	Fallback
Status	0: Normal 1: Input argument out of range or conflict	STS	FIOOR	-	0
Signal State	0: Not activated 1: Activated	SIGSTATE		-	0

Calculations
The following table summarizes the relationship between the output signal, the input 'Logic and the control value as set by function 'fxSetDigitalOutput'.

Control Value	Logic	Signal state
0	Positive	Output signal is not activated
<> 0	Positive	Output signal is activated
0	Negative	Output signal is activated
<> 0	Negative	Output signal is not activated

fxDoubleChronometry

The function provides double chronometry measurement for meter proving and calibration purposes with a resolution of 100 nanoseconds.
The function monitors a (dual) pulse input signal provided by the meter under test and by one or more digital signals that represent the start and stop of the measurement.
The digital inputs used for start and stop of the measurement are typically connected to the sphere detector switches of a pipe prover or the piston detectors of a compact prover.
The start / stop signal may also be any other type of signal, e.g. a digital output from another flow computer. This allows for flexible master meter configurations in which a single prove measurement is performed by two separate flow computers, one that monitors the meter under test and one that monitors the reference or master meter.

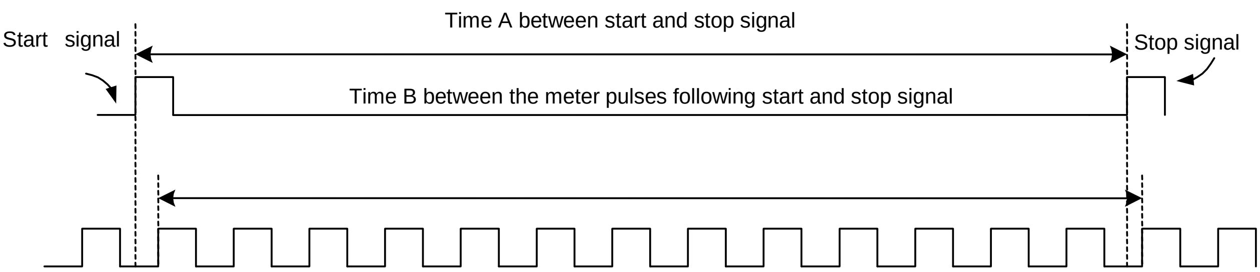
By using multiple Double Chronometry functions multiple prove measurements can be performed at the same time by one and the same flow module.
Some examples of simultaneous prove measurements are:

- For a prover with 2 begin and 2 end detector switches the flow meter can be proved against all 4 the calibrated prover volumes at the same time.

  With 2 detectors at one end of the prover (A and B) and 2 at the other end (C and D) there are 4 possible detector combinations A-C, A-D, B-C and B-D, resulting in four available prover volumes. By defining 4 Prove measurement functions all 4 prove volumes can be used to prove the meter by a single prove sequence. The operator selects the primary detector combination that will be used for calculating the new K factor or meter factor. The result of the 4 detector combinations are compared to each other and an alarm is raised in case of discrepancy.
- Meters that operate in series can all be proved at the same time.
- For meters that provide more than flow signal all signals can be proved at the same time
- For provers with a range of calibrated prover volumes to accommodate proving of meters of different capacities, multiple prover volumes can be processed at the same time.

Combinations of these scenarios are possible as well.

The double chronometry method comprises the measurement of the time between the start and stop signals and the time between the two meter pulses that immediately follow the start and stop signals. The flow module then determines the interpolated number of meter pulses that correspond to the measurement start and stop signals as follows:



$$\text{Interpolated pulse count} = \text{whole pulses} \cdot \frac{\text{time A}}{\text{time B}}$$

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Index	Index number		INDEX	1..4	1
Flow input channel number	Number of the digital input channel		FLOWCHAN		
Start DI channel number	Channel number of the digital input that is to be used as the Start signal		STRTCHAN		0
Start DI logic	1: Positive 2: Negative		STRTLOGIC		
Stop DI channel number	Channel number of the digital input that is to be used as the Stop signal. Note: the same digital input may be used for both Start and Stop of measurement		STOPCHAN		0
Stop DI logic	1: Positive 2: Negative		STOPLOGIC		
Start minimum delay time *	After the Reset command has been given the function will wait for at least this delay time before considering the activation of the Start digital input	sec	STRTMINDLY	0..1e9	0
Start maximum delay time *	After the Reset command has been given the function will wait for no longer than this delay time before the Start digital input must have been activated 0 disables this delay check	sec	STRTMAXDLY	0..1e9	0
Stop minimum delay time *	After the Reset command has been given the function will wait for at least this delay time before considering the activation of the Stop digital input. 0 disables this delay check Note: The stop minimum delay time must be defined when a common digital input is used as both the Start and Stop signals	sec	STOPMINDLY	0..1e9	0
Stop maximum delay time *	After the Reset command has been given the function will wait for no longer than this delay time before the Stop digital input must have been activated.	sec	STOPMAXDLY	0..1e9	0

Function inputs	Remark	EU	SW tag	Range	Default
	0 disables this delay check				
Number of pulses per revolution	Applies for flow meter that provide a direct pulse signal (typically turbine and Positive Displacement (PD) meters) To exclude the influence of geometrical imperfections of the primary metering device the function may be forced to accumulate a number of pulses that corresponds to a whole number of flow meter revolutions. E.g. suppose that at the stop signal 6754 pulses have been accumulated and that corresponding turbine meter provides 20 pulses for each turbine revolution, the function will accumulate another 6 pulses before the measurement is stopped.		PLSPERREV	1..1e9	1
Start	0 No action <> 0 Starts the double chronometry If the double chronometry function is already running, then it will be restarted.		START		0
Reset	0 No action <> 0 Resets all outputs to 0 or, where applicable, FALSE.		RST		

Function outputs	Remark	SW tag	Alarm	EU
Status	0: Normal 1: Input argument out of range or conflict	STS	FIOOR	-
Interpolated pulse count	Equals : Whole pulse count * Time A / Time B According to API requirements the interpolated pulse count should be used when less than 10000 pulses are acquired	INPOLCNT		
Whole pulse count	The number of meter pulses that were acquired within the measurement period (time B). Could be used instead of interpolated pulses when more than 10000 pulses are acquired Note: Whole pulse count = the decimal part of Interpolated pulse count	WHOLECNT		
Time between start and stop	Time period between start and stop signal	INPOLTIM		sec
Time between pulses	Time between the meter pulses	WHOLETIM		sec

Function outputs	Remark	SW tag	Alarm	EU
	immediately following the start and stop signals			
In Progress	Status bit that indicates that the measurement is in progress	INPRG		
Completed	Prove measurement has been completed	COMPL		
Start time-out	Prove measurement has been aborted - Start signal time-out	STRTTO		
Stop time-out	Aborted - Stop signal time-out	STOPTO		

fxEnableProverOutput

This function enables or disables the prover output function for the specified pulse input.
The prover output function is provided to allow for systems with separate stream and prover flow computers. The prover output signal of all the stream flow computers is connected to a common prover bus. The prover bus is also connected as a pulse input signal to the prover flow computer.
By enabling the prover output of the stream flow computer of the meter on prove the corrected pulse signal of the related flow meter is outputted on the prover bus. The prover flow computer uses the prover bus signal as its flow meter pulse input signal during the prove measurement.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				*<Empty>*
Module	Flow-X module index number		MOD	>= 0	0
Index	0: Disables the function 1: Index 1 (only 1 prover output per module)		INDEX	0..1	
Enable	0: No action <> 0 Incoming meter pulses are 'copied' to the output		EN		

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range or in conflict	-	STS	FIOOR	
Out of range	The combination of temperature and pressure is out of the valid range of the standard.		OOR	OOR	

fxEthylene_IUPAC_C

Description

The function calculates the compressibility factor and the density of Ethylene (C2H4, also called Ethene) based on the Equation Of State published by IUPAC and in **US customary units**.

References

- Ethylene (Ethene), International Thermodynamic Tables of the Fluid State Vol. 10 (1988), IUPAC, ISBN 0-63201-7090.

Input Data Limits

The limits of the tables are 104 K to 320 K (-272 .. +116 °F) for pressures up to 270 MPa (39160 psi) and 104K to 450K (-272 .. +350 °F) for pressures up to 40 MPa (5800 psi).

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Temperature		°F	-300..400	0
Pressure		psia	0..50000	0

Function outputs	Remark	EU	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence		
Density		lbm/ft3	0
Compressibility		-	0
Equilibrium pressure	Equilibrium pressure at the observed temperature. Also referred to as vapor pressure or saturated pressure	psia	0
Range	With respect to the combination of temperature and pressure is: 0: In Range 1: Out of Range	-	0

Calculations

The calculations are in compliance with the standard.

Because the IUPAC Equation Of State specifies the calculation of the pressure from a known temperature and density iteration is required to determine the density from the input pressure. A convergence limit of 0.0005 kg/m3 (+- 0.00003 lbm/ft3) is applied. A maximum of 20 iterations is applied.

fxEthylene_IUPAC_M

Description

The function calculates the compressibility factor and the density of Ethylene (C2H4, also called Ethene) based on the Equation Of State published by IUPAC and in **metric units**.

References

- Ethylene (Ethene), International Thermodynamic Tables of the Fluid State Vol. 10 (1988), IUPAC, ISBN 0-63201-7090.

Input Data Limits

The limits of the tables are 104 K to 320 K (-170 .. +47 °C) for pressures up to 270 MPa (2700 bar) and 104K to 450K (-170 .. +177 °C) for pressures up to 40 MPa (400 bar).

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Temperature		°C	-200..200	0
Pressure		bar(a)	3000	0

Function outputs	Remark	EU	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence		
Density		kg/m3	0
Compressibility		-	0
Equilibrium pressure	Equilibrium pressure at the observed temperature. Also referred to as vapor pressure or saturated pressure	bar(a)	0
Range	With respect to the combination of temperature and pressure is: 0: In Range 1: Out of Range	-	0

Calculations

The calculations are in compliance with the standard.

Because the IUPAC Equation Of State specifies the calculation of the pressure from a known temperature and density iteration is required to determine the density from the input pressure. A convergence limit of 0.0005 kg/m3 is applied. A maximum of 20 iterations is applied.

fxGenerateReport

This function generates prints and stores a report.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Report definition Must be the name of the report definition (**Flow-Xpress**, section *Reports*).				
Event	Event to generate the report. Event occurs when value changes from zero to non-zero (or from FALSE to TRUE).				
Identifier	Optional report file name, defined as a string When defined the *Identifier* is used as the report file name . When left empty, the *UniqueMethod* setting as defined for the report definition is used for the report file name (**Flow-Xpress**, section *Reports*).				
Printer	Optional printer. Must be the name of one of the printers that are defined in **Flow-Xpress**. When defined this printer is used instead of the printer that is assigned to the report template (**Flow-Xpress**, section *Reports*). When left empty the printer that is assigned to the report template is used.				
Number of copies	Number of copies to print. This setting is ignored when no printer is defined.				1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range or in conflict 2: Latest report could not be generated	-	STS	 FIOOR RPTERR	

fxGPA_TP15

Description

The GPA-TP15 standard defines a generalized correlation method to determine the vapor pressure (i.e. the equilibrium pressure) for natural gas liquids (NGL).
The vapor pressure is required by the API 11.2.2 and API 11.1:2004 calculations of the CPL value for light hydrocarbon liquids that have a vapor pressure above atmospheric pressure.

References

- API MPMS 11.2.2 Addendum - Compressibility Factors for Hydrocarbons: Correlation Factors of Vapor Pressure for Commercial Natural Gas Liquids - First Edition, December 1994
- GPA Technical Publication TP-15 A Simplified Vapor Pressure Correlation for Commercial NGLs - 1988
- API MPMS 11.2.5 - A Simplified Vapor Pressure Correlation for Commercial NGLs - September 2007
- GPA Technical Publication TP-15 A Simplified Vapor Pressure Correlation for Commercial NGLs - September 2007
- ASTM Technical Publication [Stock No. PETROLTBL-TP15] - September, 2007

Note: the first two and the last three refer to one and the same standard. The current standard GPA-TP15 (2007) / API MPMS 11.2.5 extends the applicable range of the previous standard GPA TP-15 (1988) / API MPMS 11.2.2 Addendum 1994 while preserving the calculations and constants of the previous standard.

Input Data Limits

The GPA TP-15:1988 / API MPMS 11.2.2 Addendum:1994 correlation method is valid for the following range.

- 0.490 to 0.676 (RD60)
- -50 to 140 °F

The GPA TP-15:2007 / API MPMS 11.2.5:2007 correlation method has been extended for lower density and is valid for the following ranges.

Lower range:

- 0.350 to 0.425 (RD60)
- -50 to (695.51*RD60 - 155.51) °F

  with RD60 being the relative density at 60°F

Higher range:

- 0.425 to 0.676 (relative density)
- -50 to 140 °F

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Relative density at 60°F		-	0.3 .. 0.75	0
Observed Temperature		°F	-100..200	60
API rounding	0: Disabled Full precision (no rounding applied) 1: Enabled Rounding as defined in ' GPA TP15:1988 / API MPMS 11.2.2 Addendum':1994	-		0
P100 Correlation	0: Disabled The standard correlation is commonly used for pure products such as propane, butane and natural gasoline. It only requires the relative density and the temperature to calculate the vapor pressure 1: Enabled The improved correlation requires the vapor pressure at 100°F (37.8 °C). This method is better suited for varied NGL mixes Where different product mixes could have the same specific gravity but different equilibrium pressures.	-		0
Vapor pressure at 100°F		psia	0..500	0

Function outputs	Remark	EU	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error		
Vapor pressure	Vapor pressure at 60°F	psia	0
Range	With respect to the 2007 standard the combination of relative density and temperature is: 0: In Range 1: Out of Range	-	0

Calculations

The calculations are in either full or partial compliance with the standards, depending on the selected type of API rounding.

fxGPA2172_96_C

This uses the procedure for calculating heating value, specific gravity and compressibility factor at **customary** (imperial) conditions from the compositional analysis of a natural gas mixture.
GPA2172 describes the calculation methods to determine the compositional properties based on the individual component values and it refers to the GPA Standard 2145 (GPA2145) standard for these individual component values.
The effect of water on the calculations is rather complicated and is accounted for with a simplified equation that is considered to be adequate for custody transfer applications.
Therefore compositional properties are calculated for the following gas compositions:

- Wet gas composition
  the water fraction of input "Composition' is taken as the actual water fraction.
- Dry gas composition
  the water fraction is set to 0 and the composition is normalized to unity.
- Saturated gas composition
  the water fraction is set to the value when the gas is saturated with water and the composition is normalized to unity

GPA-2172 prescribes that the most recent edition of GPA2145 used for the individual component values. The function provides the option to use the values from editions 2000 and 2003. In order to verify the function based on the examples of GPA2172 the function provides the option to GPA2145-89 (edition 1989) as well.

Compliance

- GPA Standard 2172-96, Calculation of Gross Heating Value, Relative Density and Compressibility Factor for Natural Gas Mixtures from Compositional Analysis - 1996
- API MPMS 14.5
- ASTM D3588-98 (Reapproved 2003)
- GPA Standard 2145-89, Table of Physical Constants
- GPA Standard 2145-00, Table of Physical Constants
- GPA Standard 2145-03, Table of Physical Constants

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Composition	Standard composition as defined section 'Standard Gas Composition'	mol/mol	COMP	0..1	0
Edition	Refers to the base conditions and the editions of the GPA2145 values. Note that these base conditions are used for both the density and the heating value. 1: 60°F, 14.696 psia, GPA2145-89 (1989) 2: 60°F, 14.696 psia, GPA2145-00 (2000)	-	EDITION		2

Function inputs	Remark	EU	SW tag	Range	Default
	3: 60°F, 14.696 psia, GPA2145-03 (2003)				
neo-Pentane mode	Determines what to do when component neo-Pentane is larger than zero 1: Add to i-Pentane 2: Add to n-Pentane 3: Neglect	-	NEOC5_MODE		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: Composition error - Composition does not add up to 100% +- 0.01% In case of an error the output values will be set to the fallback values	-	STS	FIOOR CALCERR COMPERR	
Gross Heating Value (Wet)		Btu/ft3	VOLGHV_WET		0
Molar Mass (Wet)		lbm/lbmol	ISG_WET		0
Molar Mass Ratio (Wet)			RRD_WET		0
Relative Density (Wet)	Based on the compressibility of wet air	-	Z_WET		0
Gross Heating Value (Wet)		Btu/lbm	MASGHV_WET		0
Net Heating Value (Wet)		Btu/ft3	VOLNHV_WET		0
Gross Heating Value (Dry)		Btu/ft3	VOLGHV_DRY		0
Molar Mass (Dry)		-	MOLMASS_DRY		0
Molar Mass		lbm/lbmol	ISG_DRY		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Ratio (Dry)					
Relative Density (Dry)			RRD_DRY		0
Compressibility (Dry)		-	Z_DRY		0
Gross Heating Value (Dry)		Btu/lbm	MASGHV_DRY		0
Net Heating Value (Dry)		Btu/ft3	VOLNHV_DRY		0
Gross Heating Value (Saturated)	The saturated Gross Heating Value is commonly used for custody transfer energy calculations	Btu/ft3	VOLGHV_SAT		0
Molar Mass (Saturated)		lbm/lbmol	MOLMASS_SAT		0
Molar Mass Ratio (Saturated)	Ideal specific gravity	-	ISG_SAT		0
Relative Density (Saturated)	Based on the compressibility of saturated air	-	RRD_SAT		0
Compressibility (Saturated)		-	Z_SAT		0
Gross Heating Value (Saturated)		Btu/lbm	MASGHV_SAT		0
Net Heating Value (Saturated)		Btu/ft3	VOLNHV_SAT		0

Calculations

The calculations are as documented in the GPA-2172 standard using the GPA2145 table values. However the calculations are performed at full precision, so not with intermediate rounding as shown in the examples of the standard.

Please note that the function uses the input composition ‘as is’:

- When the water fraction input value is above the water fraction of the saturated gas then the function continues its calculations without any correction.
- GPA-2145 standard editions 2000 and 2003 do not specify properties for hydrogen, argon and carbon monoxide. The function processes these components like the other components but with all property values set to 0.

fxGPA2172_96_M

This function uses the procedure for calculating heating value, specific gravity and compressibility factor at **metric** conditions from the compositional analysis of a natural gas mixture.
GPA2172 describes the calculation methods to determine the compositional properties based on the individual component values and it refers to the GPA Standard 2145 (GPA2145) standard for these individual component values.
The effect of water on the calculations is rather complicated and is accounted for with a simplified equation that is considered to be adequate for custody transfer applications.
Therefore compositional properties are calculated for the following gas compositions:

- Wet gas composition
  the water fraction of input "Composition' is taken as the actual water fraction.
- Dry gas composition
  the water mole fraction of input ''Composition' is set to 0 and the composition is normalized to unity.
- Saturated gas composition
  the water fraction value of input ''Composition' is set to the water saturated mole fraction and the composition is normalized to unity

GPA-2172 prescribes that the most recent edition of GPA2145 used for the individual component values. The function provides the option to use the values from GPA2145 edition 2000 or 2003.

Compliance

- GPA Standard 2172-96, Calculation of Gross Heating Value, Relative Density and Compressibility Factor for Natural Gas Mixtures from Compositional Analysis - 1996
- API MPMS 14.5 (same as GPA2172-96)
- GPA Standard 2145-00, Table of Physical Constants
- GPA Standard 2145-03, Table of Physical Constants

fxGPA2172_96_M

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Composition	Standard composition as defined section 'Standard Gas Composition'.	mol/mol	COMP	0..1	0
Edition	Refers to the base conditions and the editions of the GPA2145 values. Note that the same temperature value is used for the density and heating value. 1: 15°C, 1.01325 bar(a), GPA2145-00 2: 15°C, 1.01325 bar(a), GPA2145-03	-	EDITION		2 -
neo-Pentane mode	Determines what to do when component neo-Pentane is larger than zero 1: Add to i-Pentane 2: Add to n-Pentane 3: Neglect	-	NEOC5_MODE		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: Composition error • Composition does not add up to 100% +- 0.01% In case of an error the output values will be set to the fallback values	-	STS	FIOOR CALCERR COMPERR	
Gross Heating Value (Wet)		MJ/m3	VOLGHV_WET		0
Relative Density (Wet)		kg/kmol	ISG_WET		0
Molar Mass (Wet)		-	RRD_WET		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Molar Mass Ratio (Wet)		-	Z_WET		0
Relative Density (Wet)		-	MASGHV_WET		0
Gross Heating Value (Wet)		MJ/kg	VOLNHV_WET		0
Net Heating Value (Wet)		MJ/m3	VOLGHV_DRY		0
Gross Heating Value (Dry)		MJ/m3	MOLMASS_DRY		0
Molar Mass (Dry)		kg/kmol	ISG_DRY		0
Molar Mass Ratio (Dry)		-	RRD_DRY		0
Relative Density (Dry)		-	Z_DRY		0
Compressibility (Dry)		-	MASGHV_DRY		0
Gross Heating Value (Dry)		MJ/kg	VOLNHV_DRY		0
Net Heating Value (Dry)		MJ/m3	VOLGHV_SAT		0
Gross Heating Value (Saturated)	The saturated Gross Heating Value is commonly used for custody transfer energy calculations	MJ/m3	MOLMASS_SAT		0
Molar Mass (Saturated)		kg/kmol	ISG_SAT		0
Molar Mass Ratio (Saturated)		-	RRD_SAT		0
Relative Density (Saturated)	Real value, so at the base conditions of pressure and temperature	-	Z_SAT		0
Compressibility (Saturated)		-	MASGHV_SAT		0
Gross Heating Value (Saturated)		MJ/kg	VOLNHV_SAT		0
Net Heating Value (Saturated)		MJ/m3			0

Calculations

The calculations are as documented in the GPA-2172 standard using the GPA2145 table values. However the calculations are performed at full precision, so not with intermediate rounding as shown in the examples of the standard.

Please note that the function uses the input composition 'as is':

- When the water fraction input value is above the water fraction of the saturated gas then the function continues its calculations without any correction.

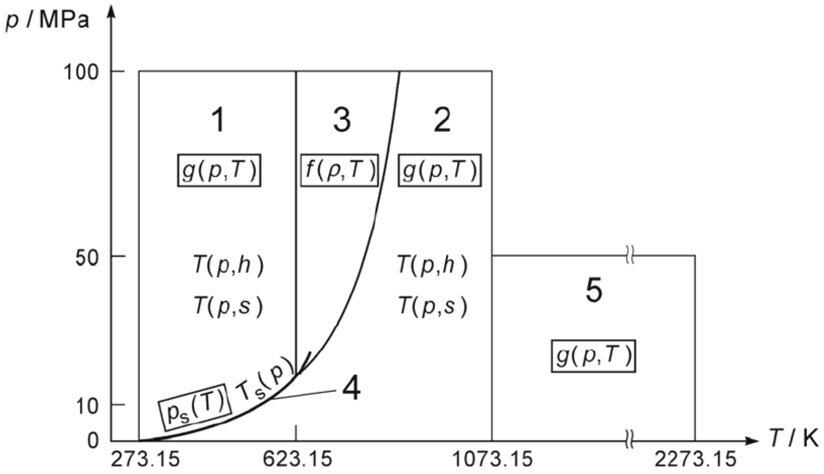
- GPA-2145 standard editions 2000 and 2003 do not specify properties for hydrogen, argon and carbon monoxide. The function processes these components like the other components but with all property values set to 0.

fxIAPWS_IF97_C

Description

The function calculates the density and enthalpy of steam and water according to AIPWS-IF97 in **US Customary units**.

IAPWS-IF97 defines calculations for 5 regions as shown in the picture below.



Region 1: Water
Region 2: Superheated steam
Region 3: Water
Region 4: Saturation line (saturated steam / water)
Region 5: Superheated steam

References

- Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam, August 2007.

Input Data Limits

The IAPWS Industrial Formulation 1997 consists of a set of equations for different regions which cover the following range of validity:

- 32 ≤ T ≤ 1472 °F   p ≤ 14500 psia
- 1472 ≤ T ≤ 3632 °F   p ≤ 7250 psia

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Temperature		°F	0 .. 4000	0

Pressure		psia	0..15000	0
Phase	The phase (water or steam) can be calculated automatically or be set to either steam or water. 1: Auto-select (calculate from t and p inputs) 2: Steam 3: Water If 'Steam' or 'Water' is selected, while the combination of temperature and pressure indicates the opposite phase, then the function uses either the saturation pressure (region 4) or the boundary pressure (intersection regions 2 and 3) instead of the input pressure for its calculations.			1

Function outputs	Remark	EU	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence		
Density		lbm/ft3	0
Enthalpy	Energy flow = Mass flow * Enthalpy	btu/lbm	0
Region	Actual IAPWS-IF97 region 0: Combination of t and p is outside the valid range 1: Water 2: Steam 3: Pressurized water 4: At the saturation line 5: High temperature steam (1472 ≤ T ≤ 3632 °F)	-	0
Saturation pressure	Saturation pressure at the input temperature. Note: only calculated up to the critical temperature of 647.096 K (+- 705 °F), set to 0 for higher temperatures	psia	0
Dynamic viscosity	The dynamic viscosity is required for flow rate calculations based on a differential pressure measurement (e.g. orifice)	lbm/ft.s	0
Ratio of specific heats	Equals the ratio of the specific heats cp / cv cp : specific heat at constant pressure cv : specific heat at constant volume	-	0

Function outputs	Remark	EU	Fallback
	This ratio can be used as the isentropic exponent value (also called 'kappa') when the real value is unknown. The isentropic exponent is required for flow rate calculations based on a differential pressure measurement (e.g. orifice)		

Calculations

The calculations are in compliance with the standard.

For regions 1, 2 and 5 the density can be calculated directly from the temperature in pressure. For region 3 an iterative calculation is required because the Equation Of State for this region calculates the pressure from a known temperature and density iteration. A convergence limit of 0.00001 kg/m3 (+- 0.000006 lbm/ft3) is applied. A maximum of 20 iterations is applied.

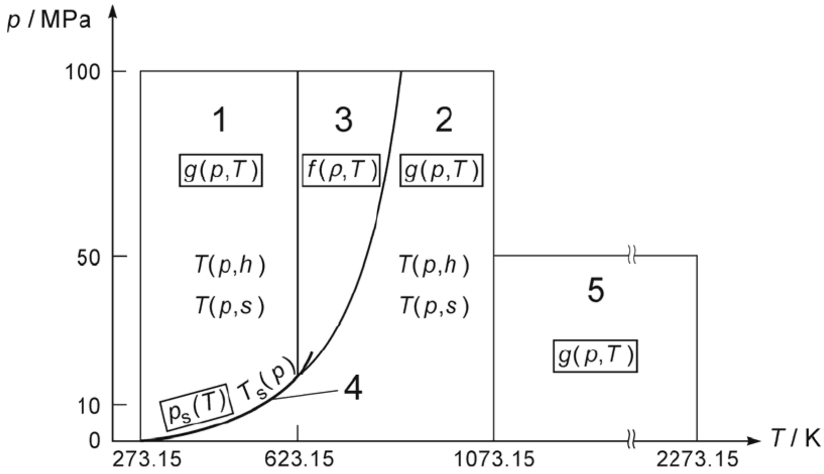
The other properties can be calculated directly from the temperature and pressure for all regions.

fxIAPWS_IF97_M

Description

The function calculates the density and enthalpy of steam and water according to AIPWS-IF97 in **Metric units**.

IAPWS-IF97 defines calculations for 5 regions as shown in the picture below.



Region 1: Water
Region 2: Superheated steam
Region 3: Water
Region 4: Saturation line (saturated steam / water)
Region 5: Superheated steam

References

- Revised Release on the IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam, August 2007.

Input Data Limits

The IAPWS Industrial Formulation 1997 consists of a set of equations for different regions which cover the following range of validity:

- 0 ≤ T ≤ 800 °C   p ≤ 1000 bar(a)
- 800 ≤ T ≤ 2000 °C   p ≤ 500 bar(a)

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			

Function inputs	Remark	EU	Range	Default
Temperature		°C	-50 .. 2200	0
Pressure		bar(a)	0..1100	0
Phase	The phase (water or steam) can be calculated automatically or be set to either steam or water. 1: Auto-select (calculate from t and p inputs) 2: Steam 3: Water If 'Steam' or 'Water' is selected, while the combination of temperature and pressure indicates the opposite phase, then the function uses either the saturation pressure (region 4) or the boundary pressure (intersection regions 2 and 3) instead of the input pressure for its calculations.			1

Function outputs	Remark	EU	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence		
Density		kg/m3	0
Enthalpy	Energy flow = Mass flow * Enthalpy	MJ/kg	0
Region	Actual IAPWS-IF97 region 0: Combination of t and p is outside the valid range 1: Water 2: Steam 3: Pressurized water 4: At the saturation line 5: High temperature steam (800 ≤ T ≤ 2000 °C)	-	0
Saturation pressure	Saturation pressure at the input temperature Note: only calculated up to the critical temperature of 647.096 K (+- 374 °C), set to 0 for higher temperatures	bar(a)	0
Dynamic viscosity	The dynamic viscosity is required for flow rate calculations based on a differential pressure measurement (e.g. orifice)	lbm/ft.s	0
Ratio of specific heats	Equals the ratio of the specific heats cp / cv cp : specific heat at constant pressure cv : specific heat at constant volume	-	0

Function outputs	Remark	EU	Fallback
	This ratio can be used as the isentropic exponent value (also called 'kappa') when the real value is unknown. The isentropic exponent is required for flow rate calculations based on a differential pressure measurement (e.g. orifice)		

Calculations

The calculations are in compliance with the standard.

For regions 1, 2 and 5 the density can be calculated directly from the temperature in pressure. For region 3 an iterative calculation is required because the Equation Of State for this region calculates the pressure from a known temperature and density iteration. A convergence limit of 0.00001 kg/m3 is applied. A maximum of 20 iterations is applied.

The enthalpy can be calculated directly from the temperature and pressure for all regions.

fxIndex

The 'fxIndex' provides the same functionality as the Excel Index function with the addition of the creation of tag names.
A spreadsheet cell that contains a 'fxIndex' function obtains the tag name as defined by its 'Name' input with the tag inheriting all properties including the value and units from the referred tag.
When the referred cell contains a writable tag (i.e. a value and no function) than the cell with the 'fxIndex' function also represents a writable tag with the same properties.
When the referred cell contains a tag that represents one or more alarms, then the same alarms are created for the cell with the 'fxIndex' function.
The 'fxIndex' is especially useful for setting up generic (template) applications as illustrated by the following examples:

- For each of the 6 analog inputs the application contains one 'Analog input' function that generates tag names with prefix, "AIN1_", "AIN2_ etc. Also more meaningful tag names such as "..PT" (pressure transmitter), ".._TT" are used in the application. When changing the high alarm limit for the pressure transmitter (e.g. through an OPC interface) it makes more sense to address the tag as "..PT_HISCALE" instead of "..AIN3_HISCALE" (assuming AIN 3 being used for the pressure transmitter). This can be achieved by using the 'fxIndex' function for the cell that represents the '..PT_HISCALE' tag.
- In some cases one and the same input signal is used for multiple process variables that are defined in the generic application. E.g. when the generic application assumes a prover inlet temperature input signal as well as a prover outlet temperature signal (and has corresponding tag names), while there is only a temperature transmitter in the prover loop, then the input tags of both signals can refer to the same "AIN" signal by using the 'fxIndex' function.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Tag name for the cell that contains the function				
Reference	Reference to one or more cell ranges				1
Row number	Optional Number of the row in reference from which to return a reference				1
Column number	Optional. Number of the column in reference from which to return a reference				1
Area number	Optional Selects a range in reference from which to return the intersection of 'Row number' and 'Column number'. The first area selected or entered is numbered 1, the second is 2, and so on.				1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Value	The cell obtains a tag name that consist of the prefix as defined by input 'Name' with the addition of the suffix as was generated for the tag that is being referred to. The same applies for an alarm if one has been defined for the referred tag.	*Same as referred cell*	See *Remark*		

fxInterpolationCurve

This function calculates the output value from a set of reference points and the actual input value. The function can take an arbitrary number of reference points.
The function is typically used for applying a calibration curve to a K factor or a meter factor (liquid) or a meter error curve (gas).
Besides of the 1st calibration point (which is always used) the function will only use the calibration points (starting from the 2nd point) for which the x value is greater than the previous x value. All further points will be ignored.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input value	Reference to the cell containing the actual input value (e.g. flow rate or pulse frequency)				
Reference values	Array of reference values, assuming the following sequence: *Point 1 - Input value* *Point 1 - Output value* *Point 2 - Input value* *Point 2 - Output value* *etc....* The array must contain an even number of values with the input values in ascending order. So it is required that *Input 1* < *Input 2* < *Input 3* etc. However, when an input value equals 0, then the function will not use this point and all subsequent points of the array.		REFVAL		
Extrapolation mode	Determines whether or not extrapolation must be applied when the input value is outside the linearization curve. When disabled either the first or last output value will be used. 0: Disabled 1: Enabled		EXPMODE		

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Output value	Interpolated value	*Same as input 'Output reference 1'*	VAL		0
Date/time	Latest modification date and time		DTTM		

Function outputs	Remark	EU	SW tag	Alarm	Fallback
	of the any of the reference point values				
Out of range	Input value is outside the range that is covered by the reference values			OOR	

Calculations

$$y = (x - In_L) \cdot \frac{Out_H - Out_L}{In_H - In_L} + Out_L$$

Where:

x	Input value
y	Interpolated value
In_L	Closest input reference value that is smaller than the input value
In_H	Closest input reference value that is larger than the input value
Out_L	Output reference value that corresponds with In_L
Out_H	Output reference value that corresponds with In_H

fxISO5167_ISA1932Nozzle

The function calculates the mass flow rate for **ISA1932 Nozzle** pressure differential flow devices according to the ISO-5167 standard.

Compliance

ISO-5167 - 1991 Measurement of fluid flow by means of pressure differential devices, 1st edition, 1991
ISO-5167 Amd.1 : 1998(E)
ISO-5167 - 2003 Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full, 2nd edition, 2003

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Differential Pressure	Differential pressure over the primary flow device measured at the up- and downstream pressure tappings, which need to be in the positions as specified in the standard	mbar		0
Pressure	Upstream pressure value of the fluid at metering conditions	bar(a)		0
Temperature	Down- or upstream temperature of the fluid at metering conditions	°C		0
Density	Down or upstream density of the fluid at metering conditions	kg/m3		0

Function inputs	Remark	EU	Range	Default
Dynamic Viscosity	Dynamic viscosity of the fluid	Pa.s		0
Isentropic Exponent	Also referred to as κ (kappa). For an ideal gas this coefficient is equal to the ratio of the specific heat capacity at constant pressure to the specific heat at constant volume. According to the ISO standard this ratio may be used, when the real value is unknown.			0
Pipe Diameter	Internal diameter of the pipe at reference temperature	mm		0
Pipe Expansion factor	The thermal expansion coefficient of the pipe material	1/°C		0.0000108
Pipe Reference temperature	The reference temperature that corresponds to the 'Pipe diameter' input value	°C		20
ISA1932 Nozzle Diameter	ISA1932 Nozzle diameter at reference temperature	mm		0
ISA1932 Nozzle Expansion factor	The thermal expansion coefficient of the ISA1932 Nozzle material	1/°C		0.0000163
ISA1932 Nozzle Reference Temperature	The reference temperature that corresponds to the 'ISA1932 Nozzle diameter' input value	°C		20
Pressure Location	1: Upstream Input 'Pressure' represents the pressure at the upstream pressure tapping (p_1). Since the absolute pressure is usually measured at the upstream tapping this is the most common setting. 2: Downstream Input 'Pressure' represents the pressure at the downstream tapping (p_2).	-		1
Temperature Location	1: Upstream Input 'Temperature' represents the upstream temperature (t_1). 2: Downstream Input 'Temperature represents the temperature at the downstream tapping (t_2). 3: Recovered Input 'Temperature' represents the downstream temperature at a location Where the pressure has fully recovered (t_3). Since temperature measurement is usually downstream of the flow device this is the most common setting.	-		2

Function inputs	Remark	EU	Range	Default
Temperature Correction	This parameter specifies how the temperature should be corrected from downstream to upstream conditions (or vice versa) 1: (1-κ)/κ Isentropic expansion using (1-κ)/κ as the temperature referral exponent 2: Constant Isentropic expansion using input 'Temperature Exponent' as the temperature referral exponent [-]. Please note that this value must be < 0 3: Joule Thomson Isenthalpic expansion using input 'Temperature Exponent' as the Joule Thomson coefficient [°C/bar]. This method is prescribed by ISO5167-1:2003.			3
Temperature Exponent	Refer to input Temperature Correction Unit depends on input Temperature Correction value	- - °C/bar		0
Density Location	This parameter specifies if and how the density should be corrected from downstream to upstream conditions (or vice versa). 1: Upstream Input 'Density' represents the density at the upstream pressure tapping (ρ_1). 2: Downstream Input 'Density' represents the density at the downstream tapping (ρ_2). 3: Recovered Input 'Density' represents the density downstream at a location Where the pressure has fully recovered (ρ_3).	-		1
Density Exponent.	This factor is used when density correction is enabled. The formula 1/κ will be used when the input value is set to 0, else the input value will be used. For more details refer to section 'Density correction'.	-		0
Fluid	The type of fluid being measured 1: Gas	-		1

Function inputs	Remark	EU	Range	Default
	2: Liquid			
Year Of Edition	1: Edition 1991 2: Edition 1998 3: Edition 2003 Only used for calculation of pressure loss, with options 1 and 2 giving the same result	-		3

Function outputs	Remark	EU
Status	0: Normal (No error condition) 1: Input argument out of range 2: No convergence	-
Mass flow rate	The calculated mass flow rate	tonne/h
Beta ratio	Nozzle to pipe ratio at upstream temperature	-
Nozzle diameter	At the upstream temperature	mm
Pipe diameter	At the upstream temperature	mm
Upstream pressure	Pressure at upstream tapping (p_1)	bar(a)
Pressure at downstream tapping	Pressure at downstream tapping (p_2)	bar(a)
Recovered downstream pressure	Fully recovered downstream pressure (p_3)	bar(a)
Upstream temperature	Temperature at upstream tapping (t_1)	°C
Temperature at downstream tapping	Temperature at downstream tapping (t_2)	°C
Downstream Temperature	'Fully recovered' downstream temperature (t_3)	°C
Upstream density	Density at upstream tapping (ρ_1)	kg/m3
Density at downstream tapping	Pressure at downstream tapping (ρ_2)	kg/m3
Downstream density	'Fully recovered' downstream density (ρ_3)	kg/m3
Reynolds number	The pipe Reynolds number (this is the Reynolds number upstream of the ISA1932 Nozzle and not the one within the device throat itself	-
Discharge coefficient		-
Expansion Factor		-
Velocity of Approach		
Pressure Range	0: Pressure is in valid range 1: Pressure is out of valid range	-
Reynolds Range	0: Reynolds number is in valid range 1: Reynolds number is out of valid range	-
Diameter Range	0: Device and pipe diameter and Beta ratio in valid range 1: Device diameter, pipe diameter and/or Beta ratio out of valid range	-

fxISO5167_LongRadiusNozzle

The function calculates the mass flow rate for **Long Radius Nozzle** pressure differential flow devices according to the ISO-5167 standard.

Compliance

ISO-5167 - 1991 Measurement of fluid flow by means of pressure differential devices, 1st edition, 1991
ISO-5167 Amd.1 : 1998(E)
ISO-5167 - 2003 Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full, 2nd edition, 2003

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Differential Pressure	Differential pressure over the primary flow device measured at the up- and downstream pressure tappings, which need to be in the positions as specified in the standard	mbar		0
Pressure	Upstream pressure value of the fluid at metering conditions	bar(a)		0
Temperature	Down- or upstream temperature of the fluid at metering conditions	°C		0
Density	Down or upstream density of the fluid at metering conditions	kg/m3		0
Dynamic Viscosity	Dynamic viscosity of the fluid	Pa.s		0
Isentropic Exponent	Also referred to as κ (kappa). For an ideal gas this coefficient is equal to the ratio of the specific heat capacity at constant pressure to the specific heat at constant volume. According to the ISO standard this ratio may be used, when the real value is unknown.	-		0
Pipe Diameter	Internal diameter of the pipe at reference temperature	mm		0
Pipe Expansion factor	The thermal expansion coefficient of the pipe material	1/°C		0.0000108
Pipe Reference temperature	The reference temperature that corresponds to the 'Pipe diameter' input value	°C		20
Long Radius Nozzle Diameter	Long Radius Nozzle diameter at reference temperature	mm		0
Long Radius Nozzle Expansion factor	The thermal expansion coefficient of the Long Radius Nozzle material	1/°C		0.0000163
Long Radius Nozzle Reference Temperature	The reference temperature that corresponds to the 'Long Radius Nozzle diameter' input value	°C		20
Pressure Location	1: Upstream	-		1

	Input 'Pressure' represents the pressure at the upstream pressure tapping (p_1). Since the absolute pressure is usually measured at the upstream tapping this is the most common setting. 2: Downstream Input 'Pressure' represents the pressure at the downstream tapping (p_2).			
Temperature Location	1: Upstream Input 'Temperature' represents the upstream temperature (t_1). 2: Downstream Input 'Temperature represents the temperature at the downstream tapping (t_2). 3: Recovered Input 'Temperature' represents the downstream temperature at a location Where the pressure has fully recovered (t_3). Since temperature measurement is usually downstream of the flow device this is the most common setting.	-		2
Temperature Correction	This parameter specifies how the temperature should be corrected from downstream to upstream conditions (or vice versa) 1: (1-κ)/κ Isentropic expansion using (1-κ)/κ as the temperature referral exponent 2: Constant Isentropic expansion using input 'Temperature Exponent' as the temperature referral exponent [-]. Please note that this value must be < 0 3: Joule Thomson Isenthalpic expansion using input 'Temperature Exponent' as the Joule Thomson coefficient [°C/bar].			3

	This method is prescribed by ISO5167-1:2003.			
Temperature Exponent	Refer to input Temperature Correction Unit depends on input Temperature Correction value	- - °C/bar		0
Density Location	This parameter specifies if and how the density should be corrected from downstream to upstream conditions (or vice versa). 1: Upstream Input 'Density' represents the density at the upstream pressure tapping (ρ_1). 2: Downstream Input 'Density' represents the density at the downstream tapping (ρ_2). 3: Recovered Input 'Density' represents the density downstream at a location Where the pressure has fully recovered (ρ_3).	-		1
Density Exponent.	This factor is used when density correction is enabled. The formula $1/\kappa$ will be used when the input value is set to 0, else the input value will be used. For more details refer to section 'Density correction'.	-		0
Fluid	The type of fluid being measured 1: Gas 2: Liquid	-		1
Year Of Edition	1: Edition 1991 2: Edition 1998 3: Edition 2003 Only used for calculation of pressure loss, with options 1 and 2 giving the same result	-		3

Function outputs	Remark	EU
Status	0: Normal (No error condition) 1: Input argument out of range 2: No convergence	-
Mass flow rate	The calculated mass flow rate	tonne/h
Beta ratio	Nozzle to pipe ratio at upstream temperature	
Nozzle diameter	At the upstream temperature	
Pipe diameter	At the upstream temperature	
Upstream pressure	Pressure at upstream tapping (p_1)	bar(a)

Pressure at downstream tapping	Pressure at downstream tapping (p_2)	bar(a)
Recovered downstream pressure	Fully recovered downstream pressure (p_3)	bar(a)
Upstream temperature	Temperature at upstream tapping (t_1)	°C
Temperature at downstream tapping	Temperature at downstream tapping (t_2)	°C
Downstream Temperature	'Fully recovered' downstream temperature (t_3)	°C
Upstream density	Density at upstream tapping (ρ_1)	kg/m3
Density at downstream tapping	Pressure at downstream tapping (ρ_2)	kg/m3
Downstream density	'Fully recovered' downstream density (ρ_3)	kg/m3
Reynolds number	The pipe Reynolds number (this is the Reynolds number upstream of the Long Radius Nozzle and not the one within the device throat itself	-
Discharge coefficient		-
Expansion Factor		-
Velocity of Approach		
Pressure Range	0: Pressure is in valid range 1: Pressure is out of valid range	-
Reynolds Range	0: Reynolds number is in valid range 1: Reynolds number is out of valid range	-
Diameter Range	0: Device and pipe diameter and Beta ratio in valid range 1: Device diameter, pipe diameter and/or Beta ratio out of valid range	-

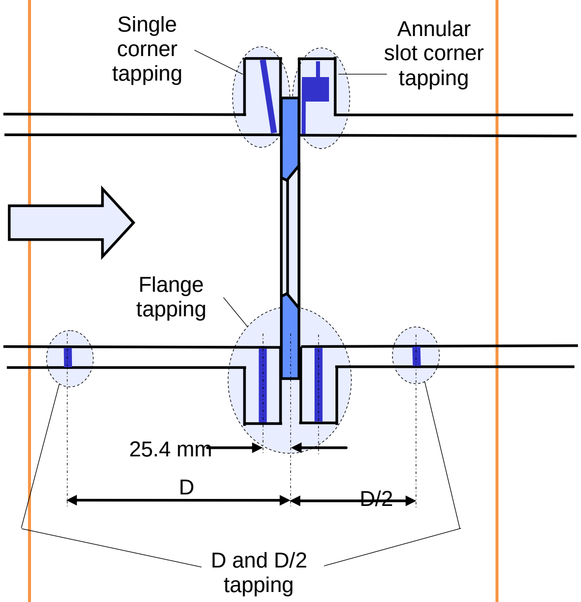
fxISO5167_Orifice

The function calculates the mass flow rate for **Orifice** pressure differential flow devices according to the ISO-5167 standard.
Optionally an additional correction for the drain hole is applied.

Reference

ISO5167 - 1991	*ISO 5167 - Measurement of fluid flow by means of pressure differential devices, 1991*
ISO5167 - 1998	*ISO 5167 - Measurement of fluid flow by means of pressure differential devices, 1991 - Amendment 1 1998*
ISO5167 - 2003	*ISO 5167 - Measurement of fluid flow by means of pressure differential devices, 2003*
	British standard 1042: Part 1: 1964

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Differential Pressure	Differential pressure over the primary flow device measured at the up- and downstream pressure tappings, which need to be in the positions as specified in the standard	mbar	0..2000	0
Pressure	Down- or upstream pressure value (p_1) of the fluid at metering conditions	bar (a)	0..2000	0
Temperature	Down- or upstream temperature of the fluid at metering conditions	°C	-300..1000	0
Density	Down or upstream density of the fluid at metering conditions	kg/m3	0..2000	0
Dynamic Viscosity	Dynamic viscosity of the fluid	Pa.s	0..1	0
Isentropic Exponent	Also referred to as κ (kappa). For an ideal gas this coefficient is equal to the ratio of the specific heat capacity at constant pressure to the specific heat at constant volume. According to the ISO standard this ratio may be used, when the real value is unknown.	-	0..10	0
Pipe Diameter	Internal diameter of the pipe at reference temperature	mm	0..2000	0
Pipe Expansion factor	The thermal expansion coefficient of the pipe material	1/°C	0..1	0.0000108
Pipe Reference temperature	The reference temperature that corresponds to the 'Pipe diameter' input value	°C	-300..1000	20
Orifice Diameter	Orifice diameter at reference temperature	mm	0..2000	0
Orifice Expansion factor	The thermal expansion coefficient of the orifice material	1/°C	0..1	0.0000163

Function inputs	Remark	EU	Range	Default
Orifice Reference Temperature	The reference temperature that corresponds to the 'Orifice diameter' input value	°C	-300..1000	20
Configuration	The location of the pressure tappings. Several configurations are permitted by the ISO5167 standard. Each configuration has a different calculation of the discharge coefficient and of the expansion factor 1: Corner tappings (single and annular slot) 2: D and D/2 tappings 3: Flange tappings  	-		2
Pressure Location	1: Upstream Input 'Pressure' represents the pressure at the upstream pressure tapping (p_1). Since the absolute pressure is usually measured at the upstream tapping this is the most common setting. 2: Downstream Input 'Pressure' represents the pressure at the downstream tapping (p_2).	-		1

Function inputs	Remark	EU	Range	Default
Temperature Location	1: Upstream Input 'Temperature' represents the upstream temperature (t_1). 2: Downstream Input 'Temperature represents the temperature at the downstream tapping (t_2). 3: Recovered Input 'Temperature' represents the downstream temperature at a location Where the pressure has fully recovered (t_3). Since temperature measurement is usually downstream of the flow device this is the most common setting.	-		2
Temperature Correction	This parameter specifies how the temperature should be corrected from downstream to upstream conditions (or vice versa) 1: (1-κ)/κ Isentropic expansion using (1-κ)/κ as the temperature referral exponent 2: Constant Isentropic expansion using input 'Temperature Exponent' as the temperature referral exponent [-]. Please note that this value must be < 0 3: Joule Thomson Isenthalpic expansion using input 'Temperature Exponent' as the Joule Thomson coefficient [°C/bar]. This method is prescribed by ISO5167-1:2003.			3
Temperature Exponent	Refer to input Temperature Correction Unit depends on input Temperature Correction value	- - °C/bar		0

Function inputs	Remark	EU	Range	Default
Density Location	This parameter specifies if and how the density should be corrected from downstream to upstream conditions (or vice versa). 1: Upstream Input 'Density' represents the density at the upstream pressure tapping (ρ_1). 2: Downstream Input 'Density' represents the density at the downstream tapping (ρ_2). 3: Recovered Input 'Density' represents the density downstream at a location Where the pressure has fully recovered (ρ_3).	-		1
Density Exponent.	This factor is used when density correction is enabled. The formula $1/\kappa$ will be used when the input value is set to 0, else the input value will be used. For more details refer to section 'Density correction'.	-		0
Fluid	The type of fluid being measured 1: Gas 2: Liquid	-		1
Year Of Edition	1: Edition 1991 2: Edition 1998 3: Edition 2003	-		3
Drain hole	When input is > 0 then an additional correction on the orifice diameter will be applied to account for the drain hole, as explained further on.	mm		0

Function outputs	Remark	EU	Fallback
Status	0: Normal (No error condition) 1: Input argument out of range 2: No convergence		
Mass flow rate	The calculated mass flow rate	kg/s	0
Beta ratio	Orifice to pipe diameter ratio at upstream temperature	-	0
Orifice diameter	At the upstream temperature and optionally with a correction for the drain hole	mm	0
Pipe diameter	At the upstream temperature	mm	0
Upstream pressure	Pressure at upstream tapping (p_1)	bar(a)	0
Pressure at downstream tapping	Pressure at downstream tapping (p_2)	bar(a)	0

Function outputs	Remark	EU	Fallback
Recovered downstream pressure	Fully recovered downstream pressure (p_3)	bar(a)	0
Upstream temperature	Temperature at upstream tapping (t_1)	°C	0
Temperature at downstream tapping	Temperature at downstream tapping (t_2)	°C	0
Downstream Temperature	'Fully recovered' downstream temperature (t_3)	°C	0
Upstream density	Density at upstream tapping (ρ_1)	kg/m3	0
Density at downstream tapping	Pressure at downstream tapping (ρ_2)	kg/m3	0
Downstream density	'Fully recovered' downstream density (ρ_3)	kg/m3	0
Reynolds number	The pipe Reynolds number (this is the Reynolds number upstream of the orifice and not the one within the device throat itself	-	0
Discharge coefficient		-	0
Expansion Factor		-	0
Velocity of Approach		-	0
Pressure Range	0: Pressure is in valid range 1: Pressure is out of valid range	-	0
Reynolds Range	0: Reynolds number is in valid range 1: Reynolds number is out of valid range	-	0
Diameter Range	0: Device and pipe diameter and Beta ratio in valid range 1: Device diameter, pipe diameter and/or Beta ratio out of valid range	-	0

Pressure correction

- The relation between the pressure at the upstream tapping p_1 and the pressure at the downstream tapping (p_2) is as following:

$$p_2 = p_1 - \Delta p / 1000$$

- The relation between the pressure at the upstream tapping and the fully recovered pressure (p3) is as following:

$$p_3 = p_1 - p_{LOSS}$$

The calculation of P_{LOSS} is as defined in the standard.

Where:

p_1	Pressure at upstream tapping	[bar(a)]
p_2	Pressure at downstream tapping	[bar(a)]
p_3	Fully recovered downstream pressure	[bar(a)]
Δp	Differential pressure	[mbar]
p_{LOSS}	Pressure loss over the meter	[bar]

Temperature correction

- When input 'Temperature correction' is set to 1, then an isentropic expansion based on the isentropic coefficient is applied:

$$t_2 = (t_3 + 273.15) \cdot \left(\frac{p_3}{p_2} \right)^{\frac{1-\kappa}{\kappa}} - 273.15$$

$$t_1 = (t_3 + 273.15) \cdot \left(\frac{p_3}{p_1} \right)^{\frac{1-\kappa}{\kappa}} - 273.15$$

- When input 'Temperature correction' is set to 2, then an isentropic expansion based on input 'Temperature exponent' is applied:

$$t_2 = (t_3 + 273.15) \cdot \left(\frac{p_3}{p_2} \right)^{K_{TE}} - 273.15$$

$$t_1 = (t_3 + 273.15) \cdot \left(\frac{p_3}{p_1}\right)^{K_{TE}} - 273.15$$

- When input 'Temperature correction' is set to 3, then an isenthalpic expansion based on the linear Joule Thomson correction as defined in ISO5167-1:2003, taking input 'Temperature exponent' as the Joule Thomson coefficient:

$$t_1 = t_2 + (p_1 - p_2) \cdot \mu_{JT} \qquad t_1 = t_3 + (p_1 - p_3) \cdot \mu_{JT}$$

Where:

t_1	Upstream temperature	°C
t_3	Downstream temperature	°C
p_1	Upstream pressure	bar(a)
p_3	Fully recovered downstream pressure	bar(a)
κ	Isentropic exponent	-
K_{TE}	Temperature exponent	-
μ_{JT}	Joule Thomson coefficient	°C/bar

ISO-5167 edition 2003 prescribes an isenthalpic expansion instead of an isentropic expansion. This can be achieved by assigning a fixed Joule Thomson coefficient to input 'Temperature Exponent'.
Note: ISO is working a method to calculate the Joule Thomson rather than using a fixed value.

Density correction

- When input 'Density exponent' = 0, then the following isentropic corrections are applied (depending on the type of Density Correction)

$$\rho_1 = \rho_2 \cdot \left(\frac{p_1}{p_2}\right)^{\frac{1}{\kappa}} \qquad \rho_1 = \rho_3 \cdot \left(\frac{p_1}{p_3}\right)^{\frac{1}{\kappa}}$$

- Else the value of input 'Density Exponent' is used

$$\rho_1 = \rho_2 \cdot \left(\frac{p_1}{p_2}\right)^{K_{DE}} \qquad \rho_1 = \rho_3 \cdot \left(\frac{p_1}{p_3}\right)^{K_{DE}}$$

Where:

ρ_1	Upstream density	[kg/m3]
ρ_2	Density at the downstream tapping	[kg/m3]
ρ_3	Density at the fully recovered downstream pressure	[kg/m3]
p_1	Upstream pressure	[bar(a)]
p_2	Pressure at the downstream tapping	[bar(a)]
p_3	Fully recovered downstream pressure	[bar(a)]

κ	Isentropic exponent	[-]
K_{DE}	Density exponent	[-]

Note: In March 2007 the British DTI (Department of Trade and Industry) has recommended that the density correction method should not be based on isentropic expansion but on isenthalpic expansion instead.

The correction assumes that the density is measured at p_2 (downstream pressure tapping pressure) and t_3 (downstream recovered temperature). For this situation the following density correction is defined:

$$\rho_1 = \rho_M \cdot \frac{p_1 \cdot t_3 \cdot Z(p_2, t_3)}{p_2 \cdot t_1 \cdot Z(p_1, t_1)}$$

Where:

ρ_1	Upstream density	[kg/m3]
ρ_M	Measured density from the densitometer at p_2 and t_3	[kg/m3]
p_1	Upstream pressure	[bar(a)]
p_2	Pressure at the downstream tapping	[bar(a)]
t_1	Upstream temperature	°C
t_3	Temperature at downstream side Where pressure has fully recovered	°C
$Z(p_1,t_1)$	AGA 8 compressibility at p_1 and t_1	[-]
$Z(p_2,t_3)$	AGA 8 compressibility at p_2 and t_3	[-]

When required, this correction should be applied outside the ISO5167 function by defining an additional compressibility calculation (e.g. AGA8) at p_2 and t_3 in the application and calculating the upstream density, Where the value of p_2 is provided as an output by the ISO5167 function. Subsequently the upstream density is calculated and fed into the ISO5167 function (input 'Density') with input 'Density Correction' set to 'Upstream density'.

Correction for drain hole

When input 'Drain hole' is > 0 then the following correction factor is applied on the orifice diameter according to the British standard 1042: Part 1: 1964.

$$C_{DH} = 1 + 0.55 * \left(\frac{d_{DH}}{d_0} \right)^2$$

Where:

C_{DH}	Darin hole correction factor on orifice diameter	[-]
d_{DH}	Darin hole diameter	[mm]
d_0	Orifice diameter at reference temperature (i.e. input 'Orifice diameter')	[mm]

fxISO5167_Venturi

The function calculates the mass flow rate for **classical Venturi** tube pressure differential flow devices according to the ISO-5167 standard.

Compliance

ISO-5167 - 1991 Measurement of fluid flow by means of pressure differential devices, 1st edition, 1991
ISO-5167 Amd.1 : 1998(E)
ISO-5167 - 2003 Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full, 2nd edition, 2003

Function inputs and outputs

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Differential Pressure	Differential pressure over the primary flow device measured at the up- and downstream pressure tappings, which need to be in the positions as specified in the standard	mbar		0
Pressure	Upstream pressure value of the fluid at metering conditions	bar(a)		0
Temperature	Down- or upstream temperature of the fluid at metering conditions	°C		0
Density	Down or upstream density of the fluid at metering conditions	kg/m3		0
Dynamic Viscosity	Dynamic viscosity of the fluid	Pa.s		0
Isentropic Exponent	Also referred to as κ (kappa). For an ideal gas this coefficient is equal to the ratio of the specific heat capacity at constant pressure to the specific heat at constant volume. According to the ISO standard this ratio may be used, when the real value is unknown.	-		0
Pipe Diameter	Internal diameter of the pipe at reference temperature	mm		0
Pipe Expansion factor	The thermal expansion coefficient of the pipe material	1/°C		0.0000108
Pipe Reference temperature	The reference temperature that corresponds to the 'Pipe diameter' input value	°C		20
Venturi Diameter	Venturi diameter at reference temperature	mm		0
Venturi Expansion factor	The thermal expansion coefficient of the Venturi material	1/°C		0.0000163
Venturi Reference Temperature	The reference temperature that corresponds to the 'Venturi diameter' input value	°C		20
Configuration	The type of classical venturi tube. Three configurations are permitted by the ISO5167 standard. Each configuration has a different calculation of the discharge	-		2

Function inputs	Remark	EU	Range	Default
	coefficient and of the expansion factor 1: As cast convergent section 2: Rough welded 3: Machined 4: User-defined (not according to the standard!) When 'User-defined' is selected then the input 'Discharge coefficient' will be used in the calculations instead.			
Pressure Location	1: Upstream Input 'Pressure' represents the pressure at the upstream pressure tapping (p_1). Since the absolute pressure is usually measured at the upstream tapping this is the most common setting. 2: Downstream Input 'Pressure' represents the pressure at the downstream tapping (p_2).	-		1
Temperature Location	1: Upstream Input 'Temperature' represents the upstream temperature (t_1). 2: Downstream Input 'Temperature represents the temperature at the downstream tapping (t_2). 3: Recovered Input 'Temperature' represents the downstream temperature at a location Where the pressure has fully recovered (t_3). Since temperature measurement is usually downstream of the flow device this is the most common setting.	-		2
Temperature Correction	This parameter specifies how the temperature should be corrected from downstream to upstream conditions (or vice versa) 1: $(1-\kappa)/\kappa$ Isentropic expansion using $(1-\kappa)/\kappa$ as the temperature referral exponent 2: Constant Isentropic expansion using input 'Temperature Exponent' as the			3

Function inputs	Remark	EU	Range	Default
	temperature referral exponent [-]. Please note that this value must be < 0 3: Joule Thomson Isenthalpic expansion using input 'Temperature Exponent' as the Joule Thomson coefficient [°C/bar]. This method is prescribed by ISO5167-1:2003.			
Temperature Exponent	Refer to input Temperature Correction Unit depends on input Temperature Correction value	- - °C/bar		0
Density Location	This parameter specifies if and how the density should be corrected from downstream to upstream conditions (or vice versa). 1: Upstream Input 'Density' represents the density at the upstream pressure tapping (ρ_1). 2: Downstream Input 'Density' represents the density at the downstream tapping (ρ_2). 3: Recovered Input 'Density' represents the density downstream at a location Where the pressure has fully recovered (ρ_3).	-		1
Density Exponent.	This factor is used when density correction is enabled. The formula $1/\kappa$ will be used when the input value is set to 0, else the input value will be used. For more details refer to section 'Density correction'.	-		0
Fluid	The type of fluid being measured 1: Gas 2: Liquid	-		1
Pressure Loss Mode	The method for determining the pressure loss 1: Absolute value in mbar The value of input 'Pressure Loss Value' is taken as a value in mbar 2: Percentage of differential pressure The value of input 'Pressure Loss Value' is taken as a percentage from input 'Differential Pressure'	-		1
Pressure Loss Value	Value in mbar or %, depending on the	mbar		0

Function inputs	Remark	EU	Range	Default
	'Pressure Loss Mode'. The pressure loss over the Venturi is used to calculate the downstream fully recovered pressure. The pressure loss equals the difference between the upstream pressure (p_1) and the fully recovered downstream pressure (p_3) The standard prescribes that only the pressure loss that is caused by the venturi tube should be included (so it should not include the pressure loss that occurred between the two pressure tappings before the venturi tube was installed).	%		
Discharge coefficient	This value will used instead of the discharge coefficient as specified in the standard. Only used when input 'Configuration' is set to 'User-defined'.	-		0

Function outputs	Remark	EU	Fallback
Status	0: Normal (No error condition) 1: Input argument out of range 2: No convergence		
Mass flow rate	The calculated mass flow rate	tonne/h	0
Beta ratio	Venturi to pipe diameter ratio at upstream temperature	-	0
Venturi diameter	At the upstream temperature	mm	0
Pipe diameter	At the upstream temperature	mm	0
Upstream pressure	Pressure at upstream tapping (p_1)	bar(a)	0
Pressure at downstream tapping	Pressure at downstream tapping (p_2)	bar(a)	0
Recovered downstream pressure	Fully recovered downstream pressure (p_3)	bar(a)	0
Upstream temperature	Temperature at upstream tapping (t_1)	°C	0
Temperature at downstream tapping	Temperature at downstream tapping (t_2)	°C	0
Downstream Temperature	'Fully recovered' downstream temperature (t_3)	°C	0
Upstream density	Density at upstream tapping (ρ_1)	kg/m3	0
Density at downstream tapping	Pressure at downstream tapping (ρ_2)	kg/m3	0
Downstream density	'Fully recovered' downstream density (ρ_3)	kg/m3	0
Reynolds number	The pipe Reynolds number (this is the Reynolds number upstream of the Venturi and not the one within the device throat itself	-	0
Discharge coefficient		-	0
Expansion Factor		-	0

Function outputs	Remark	EU	Fallback
Velocity of Approach			0
Pressure Range	0: Pressure is in valid range 1: Pressure is out of valid range	-	0
Reynolds Range	0: Reynolds number is in valid range 1: Reynolds number is out of valid range	-	0
Diameter Range	0: Device and pipe diameter and Beta ratio in valid range 1: Device diameter, pipe diameter and/or Beta ratio out of valid range	-	0

fxISO5167_VenturiNozzle

The function calculates the mass flow rate for **Venturi Nozzle** pressure differential flow devices according to the ISO-5167 standard.

Compliance

ISO-5167 - 1991 Measurement of fluid flow by means of pressure differential devices, 1st edition, 1991
ISO-5167 Amd.1 : 1998(E)
ISO-5167 - 2003 Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full, 2nd edition, 2003

Function inputs	Remark		EU	Default
Name	Optional tag name, tag description and tag group			
Differential Pressure	Differential pressure over the primary flow device measured at the up- and downstream pressure tappings, which need to be in the positions as specified in the standard		mbar	0
Pressure	Upstream pressure value of the fluid at metering conditions		bar(a)	0
Temperature	Down- or upstream temperature of the fluid at metering conditions		°C	0
Density	Down or upstream density of the fluid at metering conditions		kg/m3	0
Dynamic Viscosity	Dynamic viscosity of the fluid		Pa.s	0
Isentropic Exponent	Also referred to as κ (kappa). For an ideal gas this coefficient is equal to the ratio of the specific heat capacity at constant pressure to the specific heat at constant volume. According to the ISO standard this ratio may be used, when the real value is unknown.			0
Pipe Diameter	Internal diameter of the pipe at reference temperature		mm	0
Pipe Expansion factor	The thermal expansion coefficient of the pipe material		1/°C	0.0000108
Pipe Reference temperature	The reference temperature that corresponds to the 'Pipe diameter' input value		°C	20
Venturi Nozzle Diameter	Venturi Nozzle diameter at reference temperature		mm	0
Venturi Nozzle Expansion factor	The thermal expansion coefficient of the Venturi Nozzle material		1/°C	0.0000163
Venturi Nozzle Reference Temperature	The reference temperature that corresponds to the 'Venturi Nozzle diameter' input value		°C	20
Pressure Location	1	Input 'Pressure' represents the pressure at the upstream pressure tapping (p_1). Since the absolute pressure is usually measured at the upstream tapping this is the most common setting.	-	1
	2	Input 'Pressure' represents the pressure at the downstream tapping (p_2).		
Temperature Location	1	Input 'Temperature' represents the upstream temperature (t_1).	-	2

Function inputs	Remark		EU	Default
	2	Input 'Temperature represents the temperature at the downstream tapping (t_2).		
	3	Input 'Temperature' represents the downstream temperature at a location Where the pressure has fully recovered (t_3). Since temperature measurement is usually downstream of the flow device this is the most common setting.		
Temperature Correction	1	Isentropic expansion using (1-κ)/κ as the temperature referral exponent		3
	2	Isentropic expansion using input 'Temperature Exponent' as the temperature referral exponent [-]		
	3	Isenthalpic expansion using input 'Temperature Exponent' as the Joule Thomson coefficient [°C/bar]. This method is prescribed by ISO5167-1:2003.		
Temperature Exponent	Refer to input Temperature Correction		- °C/bar	0
Density Location	This parameter specifies if and how the density should be corrected from downstream to upstream conditions.		-	1
	1	Input 'Density' represents the density at the upstream pressure tapping (ρ_1).		
	2	Input 'Density' represents the density at the downstream tapping (ρ_2).		
	3	Input 'Density' represents the density downstream at a location Where the pressure has fully recovered (ρ_3).		
Density Exponent.	This factor is used when density correction is enabled. The formula 1/κ will be used when the input value is set to 0, else the input value will be used. For more details refer to function 'ISO5167 - Orifice' section 'Density correction'		-	0
Fluid	The type of fluid being measured 1: Gas 2: Liquid		-	1
Pressure Loss Mode	The method for determining the pressure loss		-	1
	1	Absolute value in mbar The value of input 'Pressure Loss Value' is taken as a value in mbar		
	2	Percentage of differential pressure The value of input 'Pressure Loss Value' is taken as a percentage from input 'Differential Pressure'		
Pressure Loss Value	Value in mbar or %, depending on the 'Pressure Loss Mode'. The pressure loss over the Venturi nozzle is used to calculate the downstream fully recovered pressure. The pressure loss equals the difference between the upstream pressure (p_1) and the fully recovered downstream pressure (p_3) The standard prescribes that only the pressure loss that is caused by the venturi nozzle should be included (so it should not include		mbar %	0

Function inputs	Remark	EU	Default
	the pressure loss that occurred between the two pressure tappings before the venturi nozzle was installed).		

Function outputs	Remark	EU	Fallback
Status	0: Normal (No error condition) 1: Input argument out of range 2: No convergence		
Mass flow rate	The calculated mass flow rate	tonne/h	0
Beta ratio	Venturi nozzle to pipe diameter ratio at upstream temperature		0
Venturi Nozzle diameter	At the upstream temperature		0
Pipe diameter	At the upstream temperature		0
Upstream pressure	Pressure at upstream tapping (p_1)	bar(a)	0
Pressure at downstream tapping	Pressure at downstream tapping (p_2)	bar(a)	0
Recovered downstream pressure	Fully recovered downstream pressure (p_3)	bar(a)	0
Upstream temperature	Temperature at upstream tapping (t_1)	°C	0
Temperature at downstream tapping	Temperature at downstream tapping (t_2)	°C	0
Downstream Temperature	'Fully recovered' downstream temperature (t_3)	°C	0
Upstream density	Density at upstream tapping (ρ_1)	kg/m3	0
Density at downstream tapping	Pressure at downstream tapping (ρ_2)	kg/m3	0
Downstream density	'Fully recovered' downstream density (ρ_3)	kg/m3	0
Reynolds number	The pipe Reynolds number (this is the Reynolds number upstream of the Venturi nozzle and not the one within the device throat itself	-	0
Discharge coefficient		-	0
Expansion Factor		-	0
Velocity of Approach			0
Pressure Range	0: Pressure is in valid range 1: Pressure is out of valid range	-	0
Reynolds Range	0: Reynolds number is in valid range 1: Reynolds number is out of valid range	-	0
Diameter Range	0: Device and pipe diameter and Beta ratio in valid range 1: Device diameter, pipe diameter and/or Beta ratio out of valid range	-	0

Temperature correction

- When input ''Temperature exponent' = 0, then an isentropic expansion is applied:

$$t_1 = (t_3 + 273.15) \cdot \left(\frac{p_3}{p_1} \right)^{\frac{1-\kappa}{\kappa}} - 273.15$$

- Else the value of input 'Temperature exponent' is used:

$$t_1 = (t_3 + 273.15) \cdot \left(\frac{p_3}{p_1} \right)^{K_{TE}} - 273.15$$

Where:

t_1	Upstream temperature	[°C]
t_3	Downstream temperature	[°C]
p_1	Upstream pressure	[bar(a)]
p_3	Fully recovered downstream pressure	[bar(a)]
κ	Isentropic exponent	[-]
K_{TE}	Temperature exponent	[-]

fxISO6976_1983_M

ISO standard 6976 defines component properties and calculations to determine the calorific value, density and relative density for a gas composition at the specified metering and combustion reference temperatures and 1.01325 bar(a).

Compliance

- International standard, Natural Gas - Calculation of calorific values, density, relative density and Wobbe index (ISO 6976:1983)

Input Data Limits

ISO6976:1983 does not define limits for its input data.

Function inputs and outputs

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Composition	Standard composition as defined in section 'Standard gas composition.	mol/mol	0..1	0
Metering reference temperature	Temperature used for calculating the compressibility, the density and the real relative density values 1: 0 °C 2: 15 °C	-		1
Calorific value reference temperature	Temperatures used for calculating the calorific values. 1st value represents the combustion reference temperature and the 2nd value the Gas volume reference temperature 1: 25 °C / 0 °C 2: 0 °C / 0 °C 3: 15 °C / 0 °C 4: 15 °C / 15 °C 5: 60 °F / 60 °F	-		1

Function outputs	Remark	EU	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: Mole fractions do not add up to 1.0 +- 0.0001		
Superior calorific value	Real value at the reference conditions of temperature and pressure	MJ/m3	0
Density	At the reference conditions of temperature and pressure	kg/m3	0
Compressibility		-	1
Relative density		-	0
Molar mass		kg/kmol	0

Calculations

Calculations are performed in accordance with the standard, using the values as listed in the tables of the standard.

fxISO6976_1995_M

ISO standard 6976 edition 1995 defines component properties and calculations to determine the calorific value, density, relative density and Wobbe index for a gas composition at the specified metering and combustion reference temperatures and 1.01325 bar(a).
Both the definitive and alternative methods of calculating the calorific value on a mass and volumetric basis are included.

Input data limits

The valid ranges for molar fractions are as follows:

- Methane 0.5 <= .. <= 1.0
- Nitrogen 0.0 <= .. <= 0.3
- Ethane 0.0 <= .. <= 0.15
- Carbon dioxide 0.0 <= .. <= 0.15
- All others 0.0 <= .. <= 0.05

Compliance

- International standard, Natural Gas - Calculation of calorific values, density, relative density and Wobbe index (ISO 6976:1995/BS7589)

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Composition	Standard composition as defined in section 'Standard gas composition.	mol/mol	0..1	0
Reference conditions	The reference temperature for combustion / metering: 1: 15°C / 15°C 2: 0°C / 0°C 3: 15°C / 0°C 4: 25°C / 0°C 5: 20°C / 20°C 6: 25°C / 20°C			1
Molar mass table method	1: Calculate Calculates the molar mass from the atomic masses as defined in the note of Table 1 of the standard 2: Table Uses the values from Table 1 of the standard	-		1
Calorific value calculation method	Refer to paragraph 6.1 and 7.1 of the standard 1: Definitive method Calculates the mass based calorific value from the molar based calorific values from table 3 and	-		1

Function inputs	Remark	EU	Range	Default
	from the calculated molar mass values. Calculates the volume based calorific value by multiplying the molar based calorific values from table 3 by p2/R.T2 2: Alternative method Uses the values from tables 3, 4 and 5 as listed in the standard.			

Function outputs	Remark	EU	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: Mole fractions do not add up to 1.0 +- 0.0001		
Superior calorific value	Real superior calorific value on volume basis at the reference conditions of temperature and pressure	MJ/m3	0
Density	At the reference conditions of temperature and pressure	kg/m3	0
Compressibility		-	1
Relative density		-	0
Molar mass		kg/kmol	0
Superior calorific value	Real superior calorific value on mass basis at the reference conditions of temperature and pressure	MJ/kg	0
Superior calorific value	Real superior calorific value on mole basis at the reference conditions of temperature and pressure	MJ/kmol	0
Inferior calorific value	Real inferior calorific value on volume basis at the reference conditions of temperature and pressure	MJ/m3	0
Inferior calorific value	Real inferior calorific value on mass basis at the reference conditions of temperature and pressure	MJ/kg	0
Inferior calorific value	Real superior calorific value on mole basis at the reference conditions of temperature and pressure	MJ/kmol	0
Wobbe index		MJ/m3	0
Data range	With respect to the ISO6976-1995 standard the combination of input values is: 0: In Range 1: Out of Range		-

Calculations

Calculations are performed in accordance with the standard.

fxKeypadFallback

This function provides a generic interface to any input signal, such as a pressure, temperature, density or flow input. It provides the option to override the 'live' value with a keypad value and to fallback to a specific value when the input value is faulty.
When the input signal fails, the in-use value may fall back to the last good value, the keypad value or additionally a separate fallback value. The fallback value allows the user to define a fixed value (e.g. 0) that is independent from the current keypad value.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input status	Status of he input signal 0: Normal <> 0: Failure Must be linked to the Status output of the related input function		INPSTS		
Input value	Value of the input signal Must be linked to the (scaled) value output of the related input function.		INPVAL		
Fallback type	Determines what to do when input fails 1: Use last good value 2: Use fallback value 3: Use keypad value 4: Use measured		FBTYP		
Fallback value	Used when output 'Input status' becomes 'Faulty' and 'Fallback type' is set to 'Use fallback value'	*Same as input*	FBVAL		
Keypad mode	Forces the usage of the keypad value 0: Disabled 1: Enabled		KPMOD	-	0
Keypad value	Used when output 'Input status' becomes 'Faulty' and 'Fallback type' is set to 'Use fallback value'	*Same as input*	KPVAL		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Argument out of range 2: Keypad 3: Fail Last Good 4: Fail Keypad 5: Fail Fallback 6: Fail Measured *Only for status 'Function Input argument out of range' the output vales will revert to the corresponding fallback value.*		STS	 FIOOR FAILLG FAILKP FAILFB KEYPAD FAILMS	
In-use value		*Same as*	CUR		0

		input			

fxKeypadFallbackArray

This function provides a generic interface to an array of input values, typically a gas composition. It provides the option to override the 'live' values with keypad values and to fallback to specific values when the set of input values is faulty.
When the input signals fail, the in-use values may fall back to the last good values, the keypad values or additionally separate fallback values. The fallback values allow the user to define a fixed values (e.g. 0) that is independent from the current keypad values.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input status	Status of the input signals 0: Normal <> 0: Failure		INPSTS		
Input values	**Array** if input values		INPVAL		
Fallback type	Determines what to do when input fails 1: Use last good value 2: Use fallback value 3: Use keypad value 4: Use measured		FBTYP		
Fallback value	**Array** of fallback values. Used when output 'Input status' becomes 'Faulty' and 'Fallback type' is set to 'Use fallback value'	*Same as input*	FBVAL		
Keypad mode	Forces the usage of the keypad value 0: Disabled 1: Enabled		KPMOD	-	0
Keypad value	**Array** of keypad values. Used when output 'Input status' becomes 'Faulty' and 'Fallback type' is set to 'Use fallback value'	*Same as input*	KPVAL		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Argument out of range 2: Keypad 3: Fail Last Good 4: Fail Keypad 5: Fail Fallback 6: Fail Measured *Only for status 'Function Input argument out of range' the output vales will revert to the corresponding fallback value.*		STS	 FIOOR FAILLG FAILKP FAILFB KEYPAD FAILMS	
In-use value	**Array** of in-use values	*Same*	CUR		0

		as input			

fxLatch

The 'fxLatch' function provides generic latching functionality.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Tag name for the cell that contains the 'fxLatchValue' function.				
Latch trigger	Trigger to latch the input value				
Input value	Value to be latched. May be a constant a formula or a reference to another cell or tag.				
Reset trigger	Optional Trigger to resets the latched value to the reset value				
Reset value	Optional Reset value (default 0). May be a constant or a formula.				

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Latched value	The most recent latched value Note: this value is persistent and will be reloaded upon startup	Same as of input *Input Value*	Input *Name*		

fxLimitAlarm

Description

The function applies alarm limits on any value. A rate of change alarm can be applied as well.

> Note: Alarm delays and dead bands can be defined outside this function through the alarm dialog.

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input value	Must be linked to another cell	*Same as linked cell*	INPVAL	-1e11..1e11	0
Low limit value		*Same as Input value*	LLIM	-1e11..1e11	-1e11
High limit value		*Same as Input value*	HLIM	*Low limit value ..* 1e11	-1e11
Low low limit value		*Same as Input value*	LLLIM	-1e11.. *Low limit value*	1e11
High high limit value		*Same as Input value*	HHLIM	*High limit value ..* 1e11	1e11
Deadband	TO BE DEFINED				

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Alarm status	0: Normal 1: Low alarm 2: High alarm 3: Low low alarm 4: High high alarm	-	ALMSTS	 LALM HALM LLALM HHALM	

Logic

The order of priority in setting the alarm status output is as follows:

1. *If process value is below the 'Low low limit value' then the status becomes '3: Low low alarm'.*
2. *Else if process value is above the 'High high limit value' then the status becomes '4: High high alarm'.*
3. *Else if process value is below the 'Low limit value' then the status becomes '1: Low alarm'.*
4. *Else if process value is above the 'High limit value' then the status becomes '2: High alarm' and the 'High high alarm' is raised*
5. *Else the status becomes '0: Normal'.*

fxName

The 'fxName' function creates a string that defines the prefix, description and group for any function that generates tags, except for function fxTag.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name for the tag				
Description	Optional description for the tag				*<Empty>*
Group	Optional Group for the tag, including optional parent groups. The parent group must proceed the child group and be separated by the '\' character. E.g. "Meter setup\Meter data" defines that the tag belongs to group 'Meter data' which is a subgroup of group "Meter setup".				*<Empty>*

Function outputs	Remark	EU	SW tag	Alarm	Fallback
	String containing the name, description and group for the tag(s) to be created.				

fxNX19_M

Description

The AGA NX-19 standard describes a method to calculate the (super-) compressibility for natural gases and was developed in 1962.
The 1962 standard describes a standard method for calculating the super-compressibility factor that is based on the actual pressure and temperature, the specific gravity and the mole fractions of the carbon dioxide and nitrogen.
The 1962 standard also specifies 3 alternate methods, which are based on a full compositional analysis (1st alternate method), the relationship between methane and specific gravity (2nd alternate method) and the relationship between the heating value and the specific gravity
The function only performs the standard method as specified by the standard and none of the alternate methods.
The function provides the option to perform the PTB G9 correction instead of the 1962 standard method. This consists of the modified NX-19 method (NX-19-mod) per Herning & Wolowsky and the additional 'BR.KORR.3H' correction for high-caloric gases (gross heating value >= 39.8 MJ/m3).

> Note: the definition of the specific gravity as used in the standard is that of the ratio of the density of the gas to that of air at base conditions, so the real specific gravity or real relative density.

Compliance

- AGA Par Research Project NX-19 - Manual for the Determination. of the Supercompressibility Factors for Natural Gas, 1962
- Berechnung von Realgasfaktoren und Kompressibilitätszahlen für Erdgas, Technische Richtlinie G9 der Physikalisch - Technische Bundesanstalt für meßgeräte für Gas (PTB), TRG 9 8/82

Input data limits

The following bounds apply for the input values. Using the standard for conditions that lie outside this range will yield to a higher uncertainty and is not recommended.

Input value	AGA-NX-19 (1962)	AGA-NX-19-mod	AGA-NX-19-mod.BR. KORR.3H	EU
Name	Optional tag name, tag description and tag group			
Pressure	0 .. 350	0 .. 137.9	0..80	bar(a)
Temperature	-40..115.6	-40..115.6	0..30	°C
Relative density	0.554 .. 01.000	0.554..0.75	0.554..0.691	-
Gross heating value	*Not used*	31.8..39.8	39.8..46.2	MJ/m3
Nitrogen	0.00 .. 0.15	0.00 .. 0.15	0.00..0.025	mol/mol
Carbon dioxide	0.00 .. 0.15	0.00 .. 0.15	0.00..0.07	mol/mol

Function inputs and outputs

Function inputs	Remark	EU	Range	Default
Pressure	Observed pressure	bar(a)	0..200	1.01325
Temperature	Observed temperature	°C	-100..300	0
Specific gravity	Ratio of density of gas and density of air at the applicable reference conditions of pressure and temperature, i.e. the real specific gravity (real relative density). If setting 'PTB G9 correction' is disabled the reference conditions are 60°F and 14.73 psia. Else the specific gravity value shall be at the applicable reference conditions of pressure and temperature.	-	0..2	0
Gross heating value	At the applicable reference conditions of pressure and temperature Only required when the 'PTB G9 correction' is enabled.	MJ/m3	0..100	0
Nitrogen		mol/mol	0..1	0
Carbon dioxide		mol/mol	0..1	0
PTB G9 correction	Determines if the AGA-NX-19-mod / AGA-NX-19-mod.BR.KORR.3H is used instead of the AGA-NX-19-1962 standard calculation. 0: Disabled 1: Enabled	-		1

Function outputs	Remark	EU	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence		
Compressibility factor		-	1
Range	0: All input values are within the 'Normal Range' 1: One or more input values are outside the 'Normal Range	-	0

Calculations

The calculations are as specified in the standards.

fxPeriodFWA

Description

The function calculates a **f**low-**w**eighted **a**verage (FWA) for a particular period.
The function weights the input value with a flow increment and updates the average accordingly. The flow increment is provided by a 'TotalizerDelta' or 'TotalizerRate' function.
At the end of the period the current average is stored in the previous value and the current value is reset to 0.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag prefix and retentive storage.				
Input value	Value to be averaged	*Same as linked cell*			
Enabled	0: Disabled <> 0: Enabled		EN		
Increment	Flow increment with which the input value is weighed. Must refer to the corresponding output from a 'TotalizerRate' or 'TotalizerDelta' function Negative values will be ignored.	*Same as linked cell*			
Period type	Type of period: 1: Second 2: Minute 3: Hour 4: Day 5: Week 6: Month 7: Quarter 8: Year		TYP		
Period count	Number of periods (e.g. 5 minutes, 8 hours)		CNT	1..1e11	
Period start	Absolute start date and time of the period. This will be used as the reference point to calculate the next period rollover from. The value may be defined in the past or the future. The next rollover period will be calculated accordingly (so forwards or backwards in time).		START	<DATETIME>	

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current average	Average calculated over the current period.	*Same as input 'Input value'*	CUR		0
Previous average	Average of the previous period.	*Same as input 'Input value'*	PRV		0
Pre-previous average	Average of the pre-previous period (i.e. the period before the previous period).	*Same as input 'Input value'*	PPRV		0

fxPeriodLatch

Description

The function latches a value at the end of a repeating period of time.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag prefix and retentive storage.				
Input value	Value to be latched	*Same as linked cell*		*Not applied*	
Period type	Type of period: 1: Second 2: Minute 3: Hour 4: Day 5: Week 6: Month 7: Quarter 8: Year		TYP		
Period count	Number of periods (e.g. 5 minutes, 8 hours)		CNT	1..1e11	
Period start	Absolute start date and time of the period. This will be used as the reference point to calculate the next period rollover from. The value may be defined in the past or the future. The next rollover period will be calculated accordingly (so forwards or backwards in time).		START	<DATETIME>	

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current latch	Value that is latched at start of the current period (end of previous period)	*Same as input 'Input value'*	CUR		0
Previous latch	Value that is latched at the start of the previous period	*Same as input 'Input value'*	PRV		0
Pre-previous latch	Value that is latched at the start of the pre-previous period (i.e. the period before the previous period).	*Same as input 'Input value'*	PPRV		0

fxPeriodMax

Description

The function determines a maximum value over a particular period.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag prefix and retentive storage.				
Input value	Value for which the maximum has to be determined	*Same as linked cell*			
Enabled	0: Disabled <> 0: Enabled		EN		
Period type	Type of period: 1: Second 2: Minute 3: Hour 4: Day 5: Week 6: Month 7: Quarter 8: Year		TYP		
Period count	Number of periods (e.g. 5 minutes, 8 hours)		CNT	1..1e11	
Period start	Absolute start date and time of the period. This will be used as the reference point to calculate the next period rollover from. The value may be defined in the past or the future. The next rollover period will be calculated accordingly (so forwards or backwards in time).		START	<DATETIME>	

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current maximum	Maximum over the current period.	*Same as input 'Input value'*	CUR		0
Previous maximum	Maximum over the previous period.	*Same as input 'Input value'*	PRV		0
Pre-previous maximum	Maximum over the pre-previous period (period before the previous period).	*Same as input 'Input value'*	PPRV		0

fxPeriodMin

Description

The function determines a minimum value over a particular period.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag prefix and retentive storage.				
Input value	Value for which the minimum has to be determined	*Same as linked cell*			
Enabled	0: Disabled <> 0: Enabled		EN		
Period type	Type of period: 1: Second 2: Minute 3: Hour 4: Day 5: Week 6: Month 7: Quarter 8: Year		TYP		
Period count	Number of periods (e.g. 5 minutes, 8 hours)		CNT	1..1e11	
Period start	Absolute start date and time of the period. This will be used as the reference point to calculate the next period rollover from. The value may be defined in the past or the future. The next rollover period will be calculated accordingly (so forwards or backwards in time).		START	<DATETIME>	

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current minimum	Minimum over the current period.	*Same as input 'Input value'*	CUR		0
Previous minimum	Minimum over the previous period.	*Same as input 'Input value'*	PRV		0
Previous maximum	Minimum over the pre-previous period (i.e. period before the previous period).	*Same as input 'Input value'*	PPRV		0

fxPeriodTotal

Description

The function accumulates a flow increment into a period total. At the end of the period the current total is stored into the previous value and the current value is reset to 0.
The flow increment originates from a 'TotalizerRate' or 'TotalizerDelta' function.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag prefix and retentive storage.				
Increment	Increment value to be added to the period total. Negative values will be ignored, so the period total will not decrease.	*Same as linked cell*		0..1e11	
Enabled	0: Disabled 1: Enabled		EN		
Period type	Type of period: 1: Second 2: Minute 3: Hour 4: Day 5: Week 6: Month 7: Quarter 8: Year		TYP		
Period count	Number of periods (e.g. 5 minutes, 8 hours)		CNT	1..1e11	
Period start	Absolute start date and time of the period. This will be used as the reference point to calculate the next period rollover from. The value may be defined in the past or the future. The next rollover period will be calculated accordingly (so forwards or backwards in time).		START	<DATETIME>	
Rollover value	The period total will be reset to 0 when it reaches the rollover value	*Same as input Increment*	ROVAL	0..1e15	1e12
Decimal places	Defines the number of decimal places for the current and previous total output values. -1 means full precision (no rounding applied)		DECPLS	-1..10	-1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current total	Accumulated total for the current period	*Same as input 'Increment'*	CUR		0
Previous total	Accumulated total for the previous period	*Same as input 'Increment'*	PRV		0
Rollover flag	Flag indicating a rollover to 0. 0: Off 1: On Note: stays 'On' for one calculation cycle only).			ROALM	
Pre-previous total	Accumulated total for the pre-previous period (i.e. the period before the previous period	Same as input 'Increment'	PPRV		0

fxPeriodTWA

Description

The function calculates a **t**ime-**w**eighted **a**verage (TWA) for a particular period. At the end of a period the current average is stored in the previous value and the current value is reset to 0.
The function weights the input value with the time (in fact the actual calculation cycle time) and updates the average accordingly.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag prefix and retentive storage.				
Input value	Value to be averaged	*Same as linked cell*		-1e11..1e11	
Enabled	0: Disabled 1: Enabled		EN		
Period type	Type of period: 1: Second 2: Minute 3: Hour 4: Day 5: Week 6: Month 7: Quarter 8: Year		TYP		
Period count	Number of periods (e.g. 5 minutes, 8 hours)		CNT	1..1e11	
Period start	Absolute start date and time of the period. This will be used as the reference point to calculate the next		START	<DATETIME>	

	period rollover from. The value may be defined in the past or the future. The next rollover period will be calculated accordingly (so forwards or backwards in time).				

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current average	Average calculated over the current period	*Same as input 'Input value'*	CUR		0
Previous average	Average of the previous period	*Same as input 'Input value'*	PRV		0
Pre-previous average	Average of the pre-previous period (i.e. the period before the previous period)	*Same as input 'Input value'*	PPRV		0

fxPeriodWatch

Description

The function 'remembers' that a condition has been valid during a period of time.
A typical example is a transmitter that was overridden with a keypad value.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name used for tag-prefix and retentive storage.				
Condition	The condition to be watched 0: Condition is not valid <>0: Condition is valid				
Enabled	0: Disabled 1: Enabled		EN		
Period type	Type of period: 1: Second 2: Minute 3: Hour 4: Day 5: Week 6: Month 7: Quarter 8: Year		TYP		
Period count	Number of periods (e.g. 5 minutes, 8 hours)		CNT	1..1e11	
Period start	Absolute start date and time of the period. This will be used as the reference point to calculate the next period rollover from. The value may be defined in the past or the future. The next rollover period will be calculated accordingly (so forwards or backwards in time).		START	<DATETIME>	

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Current watch	Indicates whether or not the condition has been valid during the current period: 0: Not valid 1: Valid		CUR		0
Previous watch	Indicates whether or not the condition has been valid during the previous period: 0: Not valid 1: Valid		PRV		0
Pre-previous watch	Indicates whether or not the condition has been valid during the pre-previous period (period before		PPRV		0

	the previous period): 0: Not valid 1: Valid				

fxPID

PID control is a generic method to control a process variable by means of a feedback control loop and is widely used in the industry.
A PID controller adjusts its control output by applying a Proportional, Integral and Derivative algorithm based on the error between the measured process variable and the desired setpoint.
The Proportional part of the algorithm determines the reaction to the current error. The Integral part reacts to the recent errors accumulated over a sliding time window, while the Derivative part reacts to the change rate of the error. The 3 actions are added up by applying individual weigh factors and the sum is used to adjust a control device, e.g. the position of a control valve.

> Note: In flow measurement systems typically only PI control is applied, so the derivative action is disabled.

The Flow-X PID function provides several features for enhanced PID control such as:

- In cascade control there are two PID control loops arranged with one loop controlling the set point of the other loop. Within the outer loop the primary physical parameter is controlled, such as fluid level or velocity. The inner loop reads the output of the outer loop as its set point and usually controls a more rapid changing parameter such as flow rate or acceleration.
- For systems with a slow responsiveness to disturbances or setpoint changes feed forward control may be beneficial. Besides of the closed PID loop an open feed-forward loop is added that reacts immediately to a change in process or setpoint value.
- The function provides the option for bumpless transfers between auto and manual mode and vice versa. The actual process value is copied into the required setpoint value while manual mode is enabled (PV tracking). When reverting to auto mode the process will stay on the current process value. For the same reason the actual output % is copied to the manual output % while Auto mode is enabled.
- When the control output reaches its limit (e.g. control valve is fully opened) there is the risk for wind-up of the integral part, because the error will continue to be integrated. This results in the integral part to become very large, so the error must have the opposite value for a long time before the control loop returns to normal. In order to avoid this windup (i.e. achieve anti-windup) the function compensates the integral part when the control output has reached its limit.
- To avoid that a change in setpoint value will result in an impulse in the control signal the function provides the feature to define a maximum for the setpoint clamp rate and the control output slew rate. The setpoint clamp rate causes the setpoint to change gradually until it has caught up with the required value. The slew rate directly limits the rate of change of the control output.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Process value	This represents the actual process value that is being controlled	EU			

Function inputs	Remark	EU	SW tag	Range	Default
Setpoint value	The control loop will try to achieve this input value provided that both the 'Manual mode' and 'Cascade mode' are disabled.	EU			
Proportional gain	Proportional gain factor	-			
Integral gain	Integral gain factor The value 0 disables the integral part of the PID algorithm	s			
Derivative gain	Derivative gain factor The value 0 disables the derivative part of the PID algorithm	s			
Low scale value	Process / setpoint value that corresponds to 0% of the control output	EU			
High scale value	Process / setpoint value that corresponds to 100% of the control output	EU			
Reverse	Selects the direct or reverse action of control 0: Forward -> Error = (PV - SP) 1: Reverse -> Error = (SP - PV)				0
Manual mode	0: Disabled <> 0: Enabled When this input is enabled the 'Control output %' is set to input 'Manual output %'. When this input is disabled the PID algorithm is applied and either the 'Setpoint value' or Cascade value' is used depending on the 'Cascade mode'.				0
Manual output %	The control output % will be set this value when 'Manual mode' is enabled	%			0
Upwards SP clamp rate	The setpoint will not be allowed to increase faster than this limit Enter 0 disable this feature	EU/s			0
Downwards SP clamp rate	The setpoint will not be allowed to decrease faster than this limit	EU/s			0
Upwards OP slew rate	The control output % will not be allowed to increase faster than this limit	%/s			0
Downwards OP slew rate	The control output % will not be allowed to decrease faster than this limit	%/s			0
Low limit value	The control output % will not be allowed to go below this limit	%			0
High limit value	The control output % will not be allowed to go above this limit	%			100
Manual at startup	Forces manual mode at restart of flow computer 0: Disabled				0

Function inputs	Remark	EU	SW tag	Range	Default
	1: Enabled				
Bumpless transfer	When this input is enabled bump-less transfers between auto and manual mode and vice versa will be performed. When enabled and when the mode changes from manual to auto, input 'Setpoint value' will be set to the scaled value that corresponds with the current control output %. When the mode changes from auto to manual, then input 'Manual output %' will be set to the current output %. 0: Disabled <> 0: Enabled				1
Permissive flag	When the Permissive flag is not set the output is forced to the 'Idle output %' This input can be used for user-defined logic 0: Disabled <> 0 : Enabled				1
Idle output %	Value used for control output when the PID permissive flag is not set				0
Cascade mode	0: Disabled <>0 : Enabled When this input is enabled while Manual mode is disabled, the PID algorithm is applied using the 'Cascade input %' (after scaling) as the set point value.				0
Cascade input %	The control loop will try to achieve this input value (after scaling) provided that 'Manual mode' is disabled and 'Cascade mode' is enabled Must be linked to the output 'Control output" of the primary PID controller.	%			0
Tracking mode	0: Disabled <> 0: Enabled This output is meant for cascade control. If this function acts as the primary (Master) PID controller in a cascade configuration, this input needs to be connected to output 'Tracking mode' of the secondary (Slave) PID function. This input tells this function that the secondary (Slave) PID function is not using its Cascade input, but its Manual output % or Setpoint value instead. This allows the primary PID function to track				0

Function inputs	Remark	EU	SW tag	Range	Default
	the secondary process or setpoint value enabling a **bumpless** transfer between modes. 0: Disabled <> 0 : Enabled				
Tracking value	This output is meant for cascade control. If this function acts as the primary (Master) PID controller in a cascade configuration, this input needs to be connected to output 'Tracking value' of the secondary (Slave) PID function. The value represents the process or setpoint value of the secondary (Slave) PID function as percentage of scale.	%			0
Feed forward	Value is directly added to the control output The advantage of feed forward control is that corrective action is taken for a change in a disturbance input before it affects the controlled parameter.	%			0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Control output	The actual output value as percentage of scale that shall be used for actual control. Equals the required control output including the slew rate and min/max limitations.	%			
Setpoint value	The actual setpoint in-use (may differ from the required setpoint because of the SP clamp rate)	EU			
Tracking mode	0: Disabled <> 0: Enabled This output is meant for cascade control. If this function acts as the secondary (Slave) PID controller in a cascade configuration, this input needs to be connected to output 'Tracking mode' of the primary (Master) PID function This output tells the primary (Master) PID function that the Slave PID function is not using the Cascade input, but the Manual				

	output % or Setpoint value instead. This allows the primary PID function to track the secondary process or setpoint value enabling a **bumpless** transfer between modes.				
Tracking value	This output is meant for cascade control. If this function acts as the secondary (Slave) PID controller in a cascade configuration, this input needs to be connected to output 'Tracking value' of the primary (Master) PID function The value depends on the Manual and Cascade mode: If Manual mode is enabled, this output equals the percentage of scale of input 'Process value', else this output equals the percentage of scale of input 'Setpoint value'.	%			
Error	Current error				
P	Current proportional part				
I	Current integral part				
D	Current derivative part				
v	Required control output as percentage of scale (refer to section calculations). This output is for information only and shall not be used for actual control	%			

Logic

Symbols

PV_{CUR} *process value in current cycle [EU]*
PV_{PREV} *process value in previous cycle [EU]*
SP_{REQ} *required setpoint value [EU]*
SP_{CUR} *in-use setpoint value in current cycle [EU]*
SP_{PRV} *in-use setpoint value in previous cycle [EU]*
e_{CUR} *error in current cycle [EU]*
e_{PRV} *error in previous cycle [EU]*
Δu *control output deviation value [%]*
v_{CUR} *required control output value in current cycle [%]*
v_{PRV} *required control output value in previous cycle [%]*
u_{CUR} *actual control output value in current cycle [%]*
u_{PRV} *actual control output value in previous cycle [%]*
u_{MIN} *low limit for control output [%]*
u_{MAX} *high limit for control output [%]*
Δt *calculation cycle time [s]*
K_P *Proportional gain factor*

K_I *Integral gain factor*
K_D *Derivation gain factor*
P *Proportional part of current cycle*
I_{CUR} *Integral part of current cycle*
I_{PRV} *Integral part of previous cycle*
D *Derivative part of current cycle*

Control output logic

The logic for the control output depends on the current manual and tracking modes.

Manual mode = Enabled

- Set current output equal to manual input value

  v_{CUR} = 'Manual output %'

Manual mode = Disabled AND Tracking mode = Enabled

- Set current output equal to tracking input value

  v_{CUR} = 'Tracking value' (input)

Manual mode = Disabled AND Tracking mode = Disabled

- Determine the current setpoint

  If cascade mode enabled **then**

  SP_{CUR} = Cascade input value * (High scale value - Low scale value) + Low scale value

  Else

  $SP_{CUR} = SP_{REQ}$

- Check if the current setpoint needs to be gradually ramped up or down to the required setpoint:

  If ($SP_{CUR} - SP_{PRV}$) > (Upwards SP clamp rate * Δt) **then**

  $SP_{CUR} = SP_{PRV}$ + (Upwards SP clamp rate * Δt)

  Else if ($SP_{PRV} - SP_{CUR}$) > (Downwards SP clamp rate * Δt) **then**

  $SP_{CUR} = SP_{PRV}$ - (Downwards SP clamp rate * Δt)

- Calculate the current error:

  If Control direction = Forward **then**

  $e_{CUR} = SP_{CUR} – PV_{CUR}$

  Else

  $e_{CUR} = PV_{CUR} – SP_{CUR}$

- Calculate the Proportional part:

  $P = K_P * e_{CUR}$

- Calculate the Integral part:

  $I_{CUR} = I_{PRV} + Ki * \Delta t * (e_{CUR} + (u_{PRV} - v_{PRV})$*(High scale value - Low scale value)/100)

  Note: the latter part is required to avoid anti-windup.

- Calculate the Derivative part:

  $D = Kd / \Delta t * (e_{CUR} - e_{PRV})$

- Calculate the required control output:

  v_{CUR} = [P + I_{CUR} + D - Low scale value] / [High scale vale – Low scale value]

- Check if change in control output is within the slew rate

  If $v_{CUR} - u_{PRV}$ > Upwards slew rate * Δt then

  $u_{CUR} = u_{PRV}$ + (Upwards slew rate * Δt)

  Else if Δu < - (Downwards slew rate * Δt) then

  $u_{CUR} = u_{PRV}$ - (Downwards slew rate * Δt)

  Else

  $u_{CUR} = v_{CUR}$

- Check if new control output is outside its limits

  If $u_{CUR} > u_{MAX}$ then

  $u_{CUR} = u_{MAX}$

  Else If $u_{CUR} < u_{MIN}$ then

$u_{CUR} = u_{MIN}$

Bumpless transfer logic

If bumpless transfer is enabled, then the following logic is applied.

Setpoint tracking

IF Manual mode = Enabled OR Tracking mode = Enabled

$SP_{REQ} = PV_{CUR}$

ELSE IF Cascade mode = Enabled

$SP_{REQ} = SP_{CUR}$

Manual output tracking

IF Manual mode = Disabled

'Manual output %' = u_{CUR}

Tracking mode and value

Outputs 'Tracking mode' and 'Tracking value' are set as follows:

Tracking mode

'Tracking mode' = ('Manual mode' = Enabled) OR ('Cascade mode' = Disabled)

Tracking value

IF 'Manual mode' = Enabled

'Tracking value' = (PV_{CUR} * - Low scale value) / (High scale value - Low scale value) * 100

IF 'Manual mode' = Disabled

'Tracking value' = (SP_{CUR} * - Low scale value) / (High scale value - Low scale value) * 100

fxPt100Input

Each flow module provides 2 inputs for **Pt-100** sensors.
A Pt-100 sensor is a Platinum Resistance Thermometer (**PRT**) element with a resistance of 100 Ω at 0°C. 'Pt' is the symbol for platinum.
Resistance thermometers as such are also referred to as Resistance Temperature Detectors (**RTD**).
The resistance changes linearly with temperature. For Pt-100 elements the linearity coefficient is 0.385 Ohm/°C for European elements and 0.392 Ohm/°C for American elements
For each sample the temperature value is obtained from the measured Ohms by means of the standard RTD quadratic equation.
The input signal is considered to be faulty when the input circuitry has an open or a short circuit or when the measured value is outside its range (as defined in table below).

Function inputs	Remark	EU	Default
Name	Optional tag name, tag description and tag group		
Channel number		1..2	1
Input Type	1: European, 0.00385 Ω/ Ω /°C As per DIN 43760, BS1905,IEC751 Range - 200..+850 °C 2: American, 0.00392 Ω/ Ω /°C Range - 100..+457 °C		1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	Status output 0: Normal 1: Input argument out of range 2: Under range failure 3: Over range failure 4: Open circuit 5: Short circuit		STS	 FIOOR (*) (*) (*) (*)	
Value	Temperature in degrees Celsius	°C			0
Resistance	Resistance	Ohm			0

(*) Note that no alarm is generated for this status output value. This is to avoid an unnecessary alarm in case the input is not used

fxPt100Table

This function converts a resistance value (Ohm) into a temperature value (°C) according to the Pt-100 conversion tables. A Pt-100 sensor is a Platinum Resistance Thermometer (**PRT**) element with a resistance of 100 Ω at 0°C. 'Pt' is the symbol for platinum.
Resistance thermometers as such are also referred to as Resistance Temperature Detectors (**RTD**).
The resistance changes linearly with temperature. For Pt-100 elements the linearity coefficient is 0.385 Ohm/°C for European elements and 0.392 Ohm/°C for American elements
For each sample the temperature value is obtained from the measured Ohms by means of the standard RTD quadratic equation.

The input signal is considered to be faulty when the input circuitry has an open or a short circuit or when the measured value is outside its range (as defined in table below).

Function inputs	Remark	EU	Default
Name	Optional tag name, tag description and tag group		
Ohm Input Type	Measured temperature in Ohms 1: European, 0.00385 Ω/ Ω /°C As per DIN 43760, BS1905,IEC751 Range - 200..+850 °C 2: American, 0.00392 Ω/ Ω /°C Range - 100..+457 °C	Ohm	 1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Value		°C			0

fxRTDInput

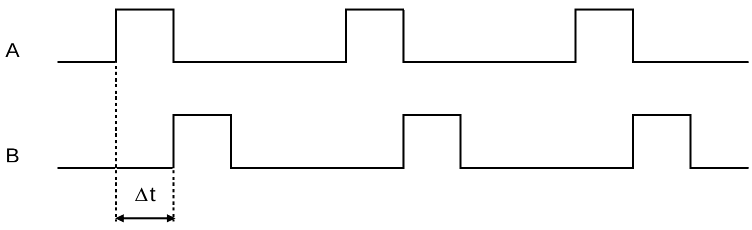
Function inputs	Remark	EU	Default
Name	Optional tag name, tag description and tag group		
Channel number		1..2	1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	Status output 0: Normal 1: Input argument out of range 2: Under range failure 3: Over range failure 4: Open circuit 5: Short circuit		STS	 FIOOR (*) (*) (*) (*)	
Value		Ohm			0

fxPulseInput

The 'fxPulseInput' function is meant for a flow meter that provides a single or a dual pulse output signal. Each flow module supports either 1 single or 1 dual pulse input.
A dual pulse signal is a set of two pulse signals ('pulse trains') A and B that originate from the same flow meter. The two pulse trains are similar but shifted in phase (typically 90°).
The primary purpose of the dual signal is to allow for **pulse integrity checking**. Added or missing pulses on either pulse train are detected and corrected for and simultaneous noise pulses are rejected.
The function provides detailed information on the raw, corrected and bad pulses for both channels and for both the forward and reverse flow direction.

The phase shifted pulse train signal also allows for automatic detection of flow direction. Each A pulse is followed by a B pulse within a time period (Δt) in case the flow runs in the forward direction. In case the flow runs in the reverse direction, the opposite is the case, i.e. each B pulse is followed by an A pulse within the same time period Δt.



Channel B lags channel A

The function also provides the option to output the raw pulse signals, which is useful in case a separate flow computer is used for proving purposes. The proving flow computer takes the pulse output from the flow computer that processes the meter on prove to perform prove measurements including double chronometry if required. The prover output signal is generated at 20 MHz, the same frequency at which the raw pulse input signals are sampled.

Compliance

ISO 6551:1982, Petroleum liquids and gases -- Fidelity and security of dynamic measurement -- Cabled transmission of electric and/or electronic pulsed data
Note: The Flow/X series of flow computers provides **Level A** pulse_security as defined in ISO 6551, which means that bad pulses are not only detected (level B) but also corrected for.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Index	Index number. Always 1.		INDEX	1..1	1
Channel A	Input channel number for pulse A 0 disables the entire function		CHANA	0..16	0
Channel B	Input channel number for pulse B Enter 0 in a case of single pulse input		CHANB	0..16	*Input Channel A + 1*
Pulse fidelity threshold	All pulse fidelity checking will be disabled when the corrected pulse frequency is below the 'Pulse fidelity threshold' Enter a 0 to disable this functionality (the default value)	Hz	FRQTHD	0..1e5	0
Error pulses limit	When the total number of missing pulses, added and simultaneous pulses for either channel becomes larger than this value, the status becomes 'Error Pulses' The value 0 disables the error pulses limit check.		ERRLIM	0..1e99	0

Function inputs	Remark	EU	SW tag	Range	Default
Missing pulses limit	When the total number of missing pulses on channel A or B becomes larger than this value, the status becomes 'Missing Pulses Channel x' (with x either A or B) The value 0 disables the missing pulses limit check.	-	MISLIM	0..1e99	0
Added pulses limit	When the total number of added pulses on channel A or B becomes larger than this value, the status becomes 'Added Pulses Channel x' (with x either A or B) The value 0 disables the added pulses limit check.	-	ADDLIM	0..1e99	0
Simultaneous pulses limit	When the total number of simultaneous pulses on both channels becomes larger than this value, the status becomes Simultaneous Pulses ' The value 0 disables the simultaneous pulses limit check.	-	SIMLIM	0..1e99	0
Good pulse reset limit	When the number of good pulses since the last 'bad' pulse has reached this value, all the bad pulse count and alarms will be reset automatically. The value 0 disables the automatic reset function.	-	RSTLIM	0..1e99	0
Bad pulse reset command	When the value changes the bad pulse count and alarms are reset. Can be used reset the bad pulses manually or automatically e.g. at a every new batch.	-	RSTCMD	Any value	0
Error rate limit	When the difference in frequency between the two raw pulse trains is larger than this limit within the last calculation cycle, the status becomes 'Pulse Rate Error' The value 0 disables the error rate limit check	%	ERRLIM	0..100	0
Pulse A output channel	Number of digital I/O channel that is used to output the raw A pulses. 0: Not used 1: Digital I/O channel 1 .. 16: Digital I/O channel 16	-	POCHANA		0
Pulse B output channel	Number of digital I/O channel that is used to output the raw B pulses.	-	POCHANA		0

Function inputs	Remark	EU	SW tag	Range	Default
	0: Not used 1: Digital I/O channel 1 .. 16: Digital I/O channel 16				
Pulse A output mode	Used to switch the pulse A output on and off. 0 : Pulse output A is disabled <> 0 : Pulse output A is enabled		POMODA		0
Pulse B output mode	Used to switch the pulse B output on and off. 0 : Pulse output B is disabled <> 0 : Pulse output B is enabled		POMODA		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: No A pulses (while B pulses) 3: No B pulses (while A pulses) 4: Missing pulses channel A 5: Missing pulses channel B 6: Added pulses channel A 7: Added pulses channel B 8: Simultaneous pulses 9: Pulse rate error 10: Low frequency (above 0 and below cut-off) 11: Error pulses Note: during normal operation status 'Low frequency' occurs for a relative short time whenever the flow starts or stops. In order to avoid unnecessary alarms the corresponding alarm delay time shall be defined accordingly (default 5 sec).	-	STS	 FIOOR NOPLSA NOPLSB MISPLSA MISPLSB ADDPLSA ADDPLSB SIMPLS ERRRATE LOFRQ ERRPLS	
Corrected pulse increment	Number of good pulses within the last calculation cycle	-		CORINC	
Corrected frequency	Frequency that corresponds to the last corrected pulse increment the last calculation cycle	Hz		CORFRQ	
Error pulse increment	Number of bad pulses within the last calculation cycle			ERRINC	
Error pulse rate	Number of bad pulses within the last calculation cycle divided by the last calculation cycle time in seconds	Hz		ERRFRQ	

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Flow direction	0: Forward 1: Reverse	-		FLOWDIR	
Raw pulse increment channel A	Number of raw pulses of channel A within the last calculation cycle			RAWINCA	
Raw pulse increment channel B	Number of raw pulses of channel B within the last calculation cycle			RAWINCB	
Missing pulse count channel A	Total missing pulse count channel A since the last reset	-		MISCNTA	
Added pulse count channel A	Total added pulse count channel A since the last reset	-		ADDCNTA	
Missing pulse count channel B	Total missing pulse count channel B since the last reset	-		MISCNTB	
Added pulse count channel B	Total added pulse count channel B since the last reset	-		ADDCNTB	
Simultaneous pulses	Total simultaneous pulse count since the last reset			SIMPLSF	
Phase difference	Last measured phase difference between A and B pulse expressed as the ratio of the time delay between the last A and B and the time between two A pulses. A typical phase difference is 90° corresponding to a value of 0.25.	-		PHASEDIF	

fxPulseOutput

This function is used to feed pulses to an electro-mechanical (E/M) counter.
The function uses a reservoir to accumulate the pulses. On one hand the number of pulses that need to be added to the reservoir is calculated from inputs 'Increment' and 'Significance factor'. On the other hand pulses are taken from the reservoir and fed to the E/M counter at a rate that will not exceed the specified output rate.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Index	Index number 1..4.		INDEX	1..4	1
Channel	Digital I/O channel number 0 disables the function		CHAN	0..16	0
Significance factor	Factor that specifies the relation between the Increment value and the number of output pulses. E.g. a value of 100 means that 1 pulse is generated whenever 100 increment units have been accumulated.	-	SIGFCT	0..1e99	1
Pulse width	Time that each output pulse remains active (high) in millisecond *Restriction (pulse duty cycle is 50%):* *Pulse width <= 1000 / (2* max. output rate)*	ms	PLSWID	0..1e6	20
Max. output rate	Maximum pulse output rate. When output pulses are generated at a frequency higher than the maximum output rate, the superfluous pulses will be accumulated in the pulse reservoir. *Restriction when pulse duty cycle should not exceed 50%:* *Max. output rate <= 1000 / (2* Pulse width)*	Hz	MAXFREQ	0..1e6	40
Reservoir alarm limit	Alarm limit for the number of pulses in the reservoir buffer	-	RSVLIM	0..1e99	1e9

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range or in conflict	-	STS	FIOOR	
Pulse reservoir	Number of pulses that are accumulated in the reservoir.	-	RSVPLS		0
Reservoir alarm status	With respect to the 'Reservoir alarm limit' the number of pulses in the reservoir is: 0: Within limit 1: Out of limit	-	RSVSTS	RSVALM	0

Calculations

Every calculation cycle a number of pulses is added to the reservoir that is equal to input value 'Increment' divided by input value Significance factor.

fxResetErrorCount

This function resets the error pulse counters (error, added, missing and simultaneous pulses) of the pulse input of one of the modules part of the same configuration.
It is required that the pulse input of the specified module is configured by function 'fxPulseInput'.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				*<Empty>*
Module	Flow-X module index number 0: Local module 1: Module 1 etc.		MOD	>= 0	0
Index	Index number as defined in the corresponding fxPulseInput function 0 disables the function		INDEX	0..4	
Reset	0: No action <> 0 All error counters are reset to 0		RESET		

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range or in conflict	-	STS	FIOOR	

fxROCAlarm

Description

The function checks if a value does not change its value at a rate that is higher than a specific limit ('rate of change').

Function inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Input value	Must be linked to another cell	*Same as linked cell*		-1e11..1e11	0
Rate of change limit	The unit depends on the 'Deviation type'	*Absolute: Same as input value 1 / s* *Relative : % /s*	ROCLIM	0..1e11	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Rate of change alarm	0: Normal 1: Alarm	-	ROCALM	ROCALM	

Logic

A 'Rate of change alarm' is raised when the absolute difference between two consecutive values divided by the calculation cycle time in seconds is more than the limit.

fxSarasota_C

The function calculates the density from a frequency input signal provided by a Sarasota densitometer and corrects it for temperature and pressure effects in **US customary** units.
Note: The calibration constants also need to be in US customary units (°F, psi and lbm/ft3).

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Periodic time	In microseconds Equals 1000 divided by the frequency in [Hz]	µs		0..1e6	0
Line temperature	Used when temperature correction is enabled	°F		-273.15..+500	20
Line pressure	Used when pressure correction is enabled	psig		0..200	0
Temperature correction	0: Disabled 1: Enabled	-	TEMPCOR		1
Pressure correction	0: Disabled 1: Enabled	-	PRESCOR		1
Reference temperature	Used when temperature correction is enabled	°F	REFTEMP	0..100	20
Reference pressure	Used when pressure correction is enabled	psig	REFPRES	0..100	0
d_0	Constant from calibration certificate Note: value required in lbm/ft3	lbm/ft3	D0	0..2000	0
τ_0	Constant from calibration certificate	µs	T0	0..1e6	0
K	Spool calibration constant from calibration certificate	-	K	0..3e3	0
Temperature coefficient	Constant from calibration certificate	µs/°F	TEMPCOEF	-1e6..1e6	0
Pressure coefficient	Constant from calibration certificate	µs/psi	PRESCOEF	-1e6..1e6	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error		STS	FIOOR CALC	
Corrected density	Density corrected for temperature and pressure	lbm/ft3	CORDENS		0

Calculations

The corrected density ρ_C is calculated by

$$\rho_C = d_0 \cdot \frac{\tau - \tau_C}{\tau_C} \cdot \left(2 + K \cdot \frac{\tau - \tau_C}{\tau_C} \right)$$

$$\tau_C = \tau_0 + t_{COEF} \cdot (t - t_{CAL}) + p_{COEF} \cdot (p - p_{CAL})$$

Where:

ρ_C	The corrected density	lbm/ft^3
d_0	Obtained from the calibration certificate	lbm/ft^3
τ_0	Obtained from the calibration certificate	µs
K	Obtained from the calibration certificate	-
p_{COEF}	Obtained from the calibration certificate	µs/psi
t_{COEF}	Obtained from the calibration certificate	µs/°F
t	Line temperature	°F
t_{CAL}	Reference temperature	°F
p	Line temperature	psig
p_{CAL}	Reference pressure	psig
τ_C	Time periodic input corrected for temperature and pressure	µs
τ	Measured time period	µs

fxSarasota_M

The function calculates the density from a frequency input signal provided by a Sarasota densitometer and corrects it for temperature and pressure effects in **metric** units.
Note: Calibration constants also need to be in metric units (°C, bar and kg/m3).

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Periodic time	In microseconds.Equals 1000 divided by the frequency in [Hz]	μs	0..1e6	**0**
Line temperature	Used when temperature correction is enabled	°C	-273.15..+500	**20**
Line pressure	Used when pressure correction is enabled	bar(g)	0..200	**0**
Temperature correction	0: Disabled 1: Enabled	-		**1**
Pressure correction	0: Disabled 1: Enabled	-		**1**
Reference temperature	Used when temperature correction is enabled	°C	0..100	**20**
Reference pressure	Used when pressure correction is enabled	bar(g)	0..100	**0**
d_0	Constant from calibration certificate	kg/m3	0..3000	**0**
τ_0	Constant from calibration certificate	μs	0..1e6	**0**
K	Spool calibration constant from calibration certificate	-	0..3e3	**0**
Temperature coefficient	Constant from calibration certificate	μs/°C	-1e6..1e6	**0**
Pressure coefficient	**Constant from calibration certificate.** **Note: value required in μs/bar**	**μs/bar**	**-1e6..1e6**	**0**

Function outputs	Remark	EU			Fallback
Status	0: Normal 1: Input argument out of range *Outputs will be set to fallback values* 2: Calculation error *Outputs will be set to fallback values*	STS	FIOOR CALC		
Corrected density	Density corrected for temperature and pressure	kg/m3	CORDENS		0

Calculations

The corrected density ρ_C is calculated by

$$\rho_C = d_0 \cdot \frac{\tau - \tau_C}{\tau_C} \cdot \left(2 + K \cdot \frac{\tau - \tau_C}{\tau_C} \right)$$

$$\tau_C = \tau_0 + t_{COEF} \cdot (t - t_{CAL}) + p_{COEF} \cdot (p - p_{CAL})$$

Where:

ρ_C	The corrected density	kg/m3
d_0	Obtained from the calibration certificate	kg/m3
τ_0	Obtained from the calibration certificate	µs
K	Obtained from the calibration certificate	-
d_0	Obtained from the calibration certificate	-
p_{COEF}	Obtained from the calibration certificate	µs/bar
t_{COEF}	Obtained from the calibration certificate	µs/°C
t	Line temperature	°C
t_{CAL}	Reference temperature	°C
p	Line temperature	bar(g)
p_{CAL}	Reference pressure	bar(g)
τ_C	Time periodic input corrected for temperature and pressure	µs
τ	The time period in µS	µs

fxSetOnChange

The 'fxSetOnChange function sets a tag or cell to a specific value whenever another value changes

Function inputs	Remark	EU	SW tag	Range	Default
Module	Number of the Flow-X/M module. -1 : local module 1..8 : module 1 through 8			-1 .. 8	
Target	The cell or tag that has to be set. This must be a direct reference to a cell.				
Value	Value to be assigned. May be a constant a formula or a reference to another cell or tag.				
Change	A change if this value will set the Target to the Value. This must be a direct reference to a cell.				

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Date and time	Date and time that the most recent change has occurred				

fxSetOnCondition

The 'fxSetOnCondition' function sets a tag or cell to a specific value whenever a condition is true.
It is a generic function that is especially useful for implementing logic for controlling output signals (e.g. valve commands) and state machines (e.g. prove sequences).

Function inputs	Remark	EU	SW tag	Range	Default
Module	Number of the Flow-X/M module. -1 : local module 1..8 : module 1 through 8			-1 .. 8	
Target	The cell or tag that has to be set. This must be a direct reference to a cell.				
Value	Value to be assigned. May be a constant a formula or a reference to another cell or tag.				
Condition	Boolean expression. When the expression outcome is TRUE (<> 0), then the target is set to the value.				

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Date and time	Date and time that the most recent event has occurred				

fxSetOnEvent

The 'fxSetOnEvent' function sets a tag to a specific value whenever an event occurs.

It is a generic function that is especially useful for implementing logic for controlling output signals (e.g. valve commands) and state machines (e.g. prove sequences).

Function inputs	Remark	EU	SW tag	Range	Default
Module	Number of the Flow-X/M module. -1 : local module 1..8 : module 1 through 8			-1 .. 8	-1
Target	The cell or tag that has to be set. This must be a direct reference to a cell.				
Value	Value to be assigned. May be a constant a formula or a reference to another cell or tag.				
Event	Boolean expression. When the expression outcome changes from FALSE to TRUE (or from 0 to <> 0), then the target is set to the value.				
Condition	Optional condition that needs to be valid while the event occurs. If the condition is not valid, then teh target will not be set to the value.				TRUE

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Date and time	Date and time that the most recent event has occurred				

fxSetIndexOnChange

The 'fxSetIndexOnChange function sets one tag from an array of tags to a specific value whenever another value changes.

Function inputs	Remark	EU	SW tag	Range	Default
Module	Number of the Flow-X/M module. -1 : local module 1..8 : module 1 through 8			-1 .. 8	-1
Index	The index number of the target tag to be set				
Value	Value to be assigned. May be a constant a formula or a reference to another cell or tag.				
Change	A change if this value will set the Target to the Value. This must be a direct reference to a cell.				
Target 1	The tag that has to be set when the				

	index number is 1. This must be a direct reference to a cell.				
Target 2	The tag that has to be set when the index number is 2. This must be a direct reference to a cell.				
etc.					

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Date and time	Date and time that the most recent change has occurred				

fxSetIndexOnCondition

The 'fxSetIndexOnCondition' function sets one tag from an array of tags to a specific value whenever a condition is true.
It is a generic function that is especially useful for implementing logic for controlling output signals (e.g. valve commands) and state machines (e.g. prove sequences).

Function inputs	Remark	EU	SW tag	Range	Default
Module	Number of the Flow-X/M module. -1 : local module 1..8 : module 1 through 8			-1 .. 8	-1
Index	The index number of the target tag to be set				
Value	Value to be assigned. May be a constant a formula or a reference to another cell or tag.				
Condition	Boolean expression. When the expression outcome is TRUE (<> 0), then the target is set to the value.				
Target 1	The tag that has to be set when the index number is 1. This must be a direct reference to a cell.				
Target 2	The tag that has to be set when the index number is 2. This must be a direct reference to a cell.				
etc.					

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Date and time	Date and time that the most recent event has occurred				

fxSetIndexOnEvent

The 'fxSetIndexOnEvent' function sets one tag from an array of tags to a specific value whenever an event occurs.
It is a generic function that is especially useful for implementing logic for controlling output signals (e.g. valve commands) and state machines (e.g. prove sequences).

Function inputs	Remark	EU	SW tag	Range	Default
Module	Number of the Flow-X/M module. -1 : local module 1..8 : module 1 through 8			-1 .. 8	-1
Index	The index number of the target tag to be set				
Value	Value to be assigned. May be a constant a formula or a reference to another cell or tag.				
Event	Boolean expression. When the expression outcome <u>changes</u> from FALSE to TRUE (or from 0 to <> 0), then the target is set to the value.				
Condition	Condition that needs to be valid while the event occurs. If the condition is not valid, then the target will not be set to the value.				
Target 1	The tag that has to be set when the index number is 1. This must be a direct reference to a cell.				
Target 2	The tag that has to be set when the index number is 2. This must be a direct reference to a cell.				
etc.					

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Date and time	Date and time that the most recent event has occurred				

fxSGERG_C

Description

This function performs the SGERG calculation in **US Customary** units.
The Standard (or Simplified) GERG TM5 1991 Virial Equation (SGERG or SGERG-88) has defines a method to calculate the Compressibility Factor (Z) for Natural Gases. The SGERG calculation is equivalent to the AGA8 Gross Characterisation Method.
Instead of the full compositional analysis (as used by the AGA 8 Detailed Characterization method), the Gross Characterisation Method (SGERG) uses a restricted set of input variables for its equation, comprising Relative Density, Superior Calorific Value, Carbon Dioxide and Nitrogen together with pressure and temperature.

Compliance

AGA 8, Second edition November 1992 - 2nd printing July 1994

- AGA Report No. 8, Second edition November 1992 - 2nd printing July 1994
- API MPMS 14.2, Second edition November 1992 - 2nd printing July 1994
- ISO 12213 Natural gas — Calculation of compression factor — Part 3: Calculation using physical properties, 1997
- GERG Technical Monograph 5, Standard GERG Virial Equation, 1991

Input data limits

The AGA8 standard has defined uncertainty bounds for gas mixtures that lie within the 'Normal range'. Also an 'Expanded range' of gas mixtures is defined for which the AGA-8 Gross Characterization Method calculation has a higher uncertainty. Using the calculation for gas mixtures that lie outside the 'Expanded range' is not recommended.

Input value	Normal Range	Expanded Range	EU
Pressure	0 .. 1740	0 .. 20000	psia
Temperature	-17.6 .. +144	-200 .. +399	°F
Gross heating value	475 .. 1210	0..1771	Btu/ft3
Relative density	0.554 .. 0.87	0.07 .. 1.52	-
Carbon dioxide	0.00 .. 0.30	0.00 .. 1.00	mol/mol
Nitrogen	0.00 .. 0.50	0.00 .. 1.00	mol/mol
Hydrogen	0.00 .. 0.10	0.00 .. 1.00	mol/mol

Function inputs and outputs

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Pressure	Observed pressure	psia	0..30000	
Temperature	Observed temperature	°F	-250 ..500	0
Relative density	At the reference conditions according to input 'Reference conditions'	-	0..2	0

Gross heating value	At the combustion and reference conditions according to input 'Reference conditions'	Btu/ft3	0..2500	0
Nitrogen		mol/mol	0..1	0
Carbon dioxide		mol/mol	0..1	0
Hydrogen		mol/mol	0..1	0
Method	Calculation method: 1: All inputs are known 2: Unknown Nitrogen mole fraction 3: Unknown Carbon Dioxide mole fraction 4: Unknown Gross Heating Value 5: Unknown Relative Density	-		0
Reference conditions	Reference conditions that correspond with the values of inputs 'Relative density' and 'Gross heating value'. Combustion temp. / metering temp. / pressure 1: 60°F / 60 °F / 14.73 psia 2: 60 °F / 60 °F / 1.01592 bar Note: the calculations are based on 25°C / 0°C / 1.01325 bar(a). For the other conditions conversion factors are applied as specified in *GERG Technical Monograph 5, Standard GERG Virial Equation, 1991.* Refer to section 'Calculations' for more details			1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence		STS	 FIOOR CALCERR NOCONV	
Compressibility factor		-			1
Molar mass		lb/lbmol			0
Range	0: In Normal Range All components are within the 'Normal Range' 1: In Extended Range One or more components within the 'Extended Range, but none of the components outside the		RANGE	OOR	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
	Extended rang (outputs values have higher uncertainty) 2: Out of Range One or more components outside the 'Extended Range' (using the AGA8 calculation is not recommended in this case)				

Calculations

The calculations are in accordance with the standard.
As specified in the standard and depending on the selected reference conditions (input 'Reference conditions') one of the following set of conversions is carried out to obtain the input values of the relative density (RD) at 0°C and 1.01325 bar(a) and the gross heating value (GHV) at 25°C and 1.01325 bar(a) combustion and 0°C and 1.01325 bar(a) metering conditions.

Input 'Reference Conditions'	*Multiply input GHV with*	*Multiply input RD with*
60 °F, 60 °F @ 14.73 psia	*1.0543/26.85*	*1.0002*
60 °F, 60 °F @ 1.01592 bar(a)	*1.0543/26.86*	*1.0002*

fxSGERG_M

Description

This function performs the SGERG calculation in **metric** units.
The Standard (or Simplified) GERG TM5 1991 Virial Equation (SGERG or SGERG-88) has defines a method to calculate the Compressibility Factor (Z) for Natural Gases. The SGERG calculation is equivalent to the AGA8 Gross Characterisation Method.
Instead of the full compositional analysis (as used by the AGA 8 Detailed Characterization method), the Gross Characterisation Method (SGERG) uses a restricted set of input variables for its equation, comprising Relative Density, Superior Calorific Value, Carbon Dioxide and Nitrogen together with pressure and temperature.

Compliance

AGA 8, Second edition November 1992 - 2nd printing July 1994

- AGA Report No. 8, Second edition November 1992 - 2nd printing July 1994
- API MPMS 14.2, Second edition November 1992 - 2nd printing July 1994
- ISO 12213 Natural gas — Calculation of compression factor — Part 3: Calculation using physical properties, 1997
- GERG Technical Monograph 5, Standard GERG Virial Equation, 1991

Input data limits

The AGA8 standard has defined uncertainty bounds for gas mixtures that lie within the 'Normal range'. Also an 'Expanded range' of gas mixtures is defined for which the AGA-8 Gross Characterisation Method calculation has a higher uncertainty. Using the calculation for gas mixtures that lie outside the 'Expanded range' is not recommended.

Input value	Normal Range	Expanded Range	EU
Pressure	0 .. 120	0 .. 1379	bar(a)
Temperature	-8 .. +62	-129 .. +204	°C
Gross heating value	18.7 .. 45.1	0..66	MJ/m3
Relative density	0.554 .. 0.87	0.07 .. 1.52	-
Carbon dioxide	0.00 .. 0.30	0.00 .. 1.00	mol/mol
Nitrogen	0.00 .. 0.50	0.00 .. 1.00	mol/mol
Hydrogen	0.00 .. 0.10	0.00 .. 1.00	mol/mol

Function inputs and outputs

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Pressure	Observed pressure	bar(a)	0..2000	1.01325
Temperature	Observed temperature	°C	-200..300	0
Relative density	At the reference conditions according to input 'Reference conditions'	-	0..2	0
Gross heating value	At the combustion and reference	MJ/m3	0..100	0

Function inputs	Remark	EU	Range	Default
	conditions according to input 'Reference conditions'			
Nitrogen		mol/mol	0..1	0
Carbon dioxide		mol/mol	0..1	0
Hydrogen		mol/mol	0..1	0
Method	Calculation method: 1: All inputs are known 2: Unknown Nitrogen mole fraction 3: Unknown Carbon Dioxide mole fraction 4: Unknown Gross Heating Value 5: Unknown Relative Density	-		0
Reference conditions	Reference conditions that correspond with the values of inputs 'Relative density' and 'Gross heating value'. Combustion temp. / metering temp. / pressure 1: 25°C / 0°C / 1.01325 bar(a) 2: 0°C / 0 °C / 1.01325 bar(a) 3: 15°C / 15°C / 1.01325 bar(a) Note: the calculations are based on 25°C / 0°C / 1.01325 bar(a). For the other conditions conversion factors are applied as specified in *GERG Technical Monograph 5, Standard GERG Virial Equation, 1991.* Refer to section 'Calculations' for more details			1

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error 3: No convergence		STS	 FIOOR CALCERR NOCONV	
Compressibility factor		-			1
Molar mass		kg/kmol			0
Range	0: In Normal Range All components are within the 'Normal Range' 1: In Extended Range One or more components within the 'Extended Range, but none of the components outside the Extended rang (outputs values have higher uncertainty) 2: Out of Range One or more components outside the 'Extended Range' (using the AGA8 calculation is not recommended in this case)		RANGE	OOR	0

Calculations

The calculations are in accordance with the standard.
As specified in the standard and depending on the selected reference conditions (input 'Reference conditions') one of the following set of conversions is carried out to obtain the input values of the relative density (RD) at 0°C and 1.01325 bar(a) and the gross heating value (GHV) at 25°C and 1.01325 bar(a) combustion and 0°C and 1.01325 bar(a) metering conditions.

Input 'Reference Conditions'	Multiply input GHV with	Multiply input RD with
25°C / 0 °C / 1.01325 bar(a)	*Not applicable*	*Not applicable*
0 °C, 0 °C @ 1.01325 bar(a)	*0.9974*	*Not applicable*
15 °C, 15°C @ 1.01325 bar(a)	*1.0543*	*1.0002*

fxSolartron_Gas_C

Description

The function calculates the density from a frequency input signal provided by a Solartron 7810, 7811 or 7812 gas densitometer and corrects it for temperature and velocity of sound effects in **US customary** units.
The function requires that the calibration constants are based on the following units:

- Temperature °F
- Pressure psi
- Density g/cc

Compliance

The calculations are in accordance with documents:

- 78125010 'Solartron 7812 Gas Density Transducer Manual', 2001.
- 78125040 Rev. C, 'Micro Motion 7812 Gas Density Meter', October 2007.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Periodic time	In microseconds Equals 1000 divided by the frequency in [Hz]	µs		0..1e6	0
Line temperature	Used when temperature correction is enabled	°F		-459.67..+1000	20
Temperature correction	0: Disabled 1: Enabled	-	TEMPCOR		1
VOS correction	0: Disabled 1: Enabled	-	VOSCOR		1
Reference temperature	Used when temperature correction is enabled	°F	REFTEMP	0..200	60
K0	Constant K0 from calibration certificate	-	K0	-1e9..1e9	
K1	Constant K1 from calibration certificate	-	K1	-1e9..1e9	
K2	Constant K2 from calibration certificate	-	K2	-1e9..1e9	
K18	Constant K18 from calibration certificate	-	K18	-1e9..1e9	
K19	Constant K19 from calibration certificate	-	K19	-1e9..1e9	
K3	Constant K3 from calibration certificate	-	K3	-1e9..1e9	
K4	Constant K4 from calibration certificate	-	K4	-1e9..1e9	
Calibration gas	Constant Kc from calibration	-	KC	-1e9..1e9	

Function inputs	Remark	EU	SW tag	Range	Default
constant	certificate				
G value method	Method of determining value G, which is the ratio of Gas Specific Gravity and the Ratio of Specific Heats 1: Use input 'G value' 2: Uses ratio of inputs Uses the ratio of inputs 'Specific Gravity' and 'Ratio of Specific Heats'	-	GMETHOD		1
G value	Value will be used when VOS correction is enabled and the G value method is 'Use input G value'	-	GVAL		
Specific gravity	Value will be used when VOS correction is enabled and the G value method is 'Use ratio of inputs'	-	SG	0..2	0
Ratio of specific heats	Value will be used when VOS correction is enabled and the G value method is 'Use ratio of inputs'	-	CP_CV	0.01..10	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error		STS	FIOOR CALCERR	
Corrected density	Density corrected for temperature and VOS	lbm/ft3	CORDENS		0
Density corrected for temperature	Density corrected for temperature	lbm/ft3	TCORDENS		0
Uncorrected density	Uncorrected (indicated density	lbm/ft3	UNCDENS		0

Calculations

Density calculations are performed in g/cc, while the function outputs are in lbm/ft3

The uncorrected density ρ_i is calculated by

$$\rho_i = K0 + K1 \cdot \tau + K2 \cdot \tau^2$$

Where:

ρ_i The uncorrected density g/cc

K0	Obtained from the calibration certificate	-
K1	Obtained from the calibration certificate	-
K2	Obtained from the calibration certificate	-
τ	The time period in µS	µs

The temperature corrected density ρt is calculated by

$$\rho_t = \rho_i \cdot [1 + K18 \cdot (t - t_R)] + K19 \cdot (t - t_R)$$

Where:

ρ_t	The density corrected for temperature	g/cc
K18	Obtained from the calibration certificate	-
K19	Obtained from the calibration certificate	-
t	The line temperature	°F
t_R	The reference temperature	°F

The density value corrected for Velocity of Sound is calculated as follows:

$$\rho_{VOS} = \rho_t \left[1 + \frac{K_3}{(\rho_t + K_4)} \cdot \left(Kc - \frac{G}{t + 273} \right) \right]$$

$$Kc = \frac{Cc}{t_C + 273}$$

Where:

ρ_{VOS}	The density corrected for temperature and VOS	g/cc
K3	Obtained from the calibration certificate	-
K4	Obtained from the calibration certificate	-
Kc	Calibration gas constant from the calibration certificate	-
G	G value. Equals either input 'G value' or the ratio of inputs 'Specific gravity' and 'Ratio of specific heats', depending on input 'G value method'	-
t	The line temperature	°F
Cc	Specific Gravity/Ratio of specific heats of calibration gas	-
tc	Calibration temperature	°F

fxSolartron_Gas_M

Description

The function calculates the density from a frequency input signal provided by a Solartron 7810, 7811 or 7812 gas densitometer and corrects it for temperature and velocity of sound effects in **metric** units.
The function requires that the calibration constants are based on the following units:

- Temperature °C
- Pressure bar
- Density kg/m3

Compliance

The calculations are in accordance with documents:

- 78125010 'Solartron 7812 Gas Density Transducer Manual', 2001.
- 78125040 Rev. C, 'Micro Motion 7812 Gas Density Meter', October 2007.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Periodic time	In microseconds Equals 1000 divided by the frequency in [Hz]	μs		0..1e6	0
Line temperature	Used when temperature correction is enabled	°C		-273..+500	20
Temperature correction	0: Disabled 1: Enabled	-	TEMPCOR		1
VOS correction	0: Disabled 1: Enabled	-	VOSCOR		1
Reference temperature	Used when temperature correction is enabled	°C	REFTEMP	0..100	20
K0	Constant K0 from calibration certificate	-	K0	-1e9..1e9	-1.104252E+2
K1	Constant K1 from calibration certificate	-	K1	-1e9..1e9	-1.882012E-2
K2	Constant K2 from calibration certificate	-	K2	-1e9..1e9	4.749797E-4
K18	Constant K18 from calibration certificate	-	K18	-1e9..1e9	-1.360E-5
K19	Constant K19 from calibration certificate	-	K19	-1e9..1e9	8.440E-4
K3	Constant K3 from calibration certificate	-	K3	-1e9..1e9	354
K4	Constant K4 from calibration certificate	-	K4	-1e9..1e9	57.4
Calibration gas	Constant Kc from calibration	-	KC	-1e9..1e9	0.00236

Function inputs	Remark	EU	SW tag	Range	Default
constant	certificate				
G value method	Method of determining value G, which is the ratio of Gas Specific Gravity and the Ratio of Specific Heats 1: Use input 'G value' 2: Uses ratio of inputs Uses the ratio of inputs 'Specific Gravity' and 'Ratio of Specific Heats'	-	GMETHOD		1
G value	Value will be used when VOS correction is enabled and the G value method is 'Use input G value'	-	GVAL	0..100	0
Specific gravity	Value will be used when VOS correction is enabled and the G value method is 'Use ratio of inputs'	-	SG	0..2	0
Ratio of specific heats	Value will be used when VOS correction is enabled and the G value method is 'Use ratio of inputs'	-	CP_CV	0..10	0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error		STS	FIOOR CALCERR	
Corrected density	Density corrected for temperature and VOS	kg/m3	CORDENS		0
Density corrected for temperature	Density corrected for temperature	kg/m3	TCORDENS		0
Uncorrected density	Uncorrected (indicated density	kg/m3	UNCDENS		0

Calculations

The uncorrected density ρ_i is calculated by

$$\rho_i = K0 + K1 \cdot \tau + K2 \cdot \tau^2$$

Where:

ρ_i	The uncorrected density	kg/m3
K0	Obtained from the calibration certificate	-
K1	Obtained from the calibration certificate	-

K2	Obtained from the calibration certificate	-
τ	The time period in µs	µs

The temperature corrected density ρt is calculated by

$$\rho_t = \rho_i \cdot [1 + K18 \cdot (t - t_R)] + K19 \cdot (t - t_R)$$

Where:

ρ_t	The density corrected for temperature	kg/m3
K18	Obtained from the calibration certificate	-
K19	Obtained from the calibration certificate	-
t	The line temperature	°C
t_R	The reference temperature	°C

The density value corrected for Velocity of Sound is calculated as follows:

$$\rho_{VOS} = \rho_t \left[1 + \frac{K_3}{(\rho_t + K_4)} \cdot \left(Kc - \frac{G}{t + 273} \right) \right]$$

$$Kc = \frac{Cc}{t_C + 273}$$

Where:

ρ_{VOS}	The density corrected for temperature and VOS	kg/m3
K3	Obtained from the calibration certificate	-
K4	Obtained from the calibration certificate	-
Kc	Calibration gas constant from the calibration certificate	-
G	G value. Equals either input 'G value' or the ratio of inputs 'Specific gravity' and 'Ratio of specific heats', depending on input 'G value method'	-
t	The line temperature	°C
Cc	Specific Gravity/Ratio of specific heats of calibration gas	-
tc	Calibration temperature	°C

fxSolartron_Liquid _C

Description

The function calculates the density from a frequency input signal provided by a Solartron 7835, 7845, 7846 or 7847 liquid densitometer and corrects it for temperature, pressure and velocity of sound effects using **US Customary** units.
The function requires that the calibration constants are based on the following units:

- Temperature °F
- Pressure psi
- Density g/cc

Compliance

The calculations are in accordance with documents:

- 78355010 'Solartron 7835, 7845, 7846 & 7847 Advanced Liquid Density Transducer Manual', 2001
- 78355080, Rev. C, 'Micro Motion 7835, 7845, 7846 & 7847 Liquid Density Transducer', October 2007

Function inputs and outputs

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Periodic time	In microseconds Equals 1000 divided by the frequency in [Hz]	μs	0..1e6	0
Line temperature	Used when temperature correction is enabled	°F	-459.67..+100	0
Line pressure	Used when pressure correction is enabled	psig	0..3000	0
Temperature correction	0: Disabled 1: Enabled	-		1
Pressure correction	0: Disabled 1: Enabled	-		1
VOS correction	0: Disabled 1: Based on Kr / Kj Constants Solartron manual edition 1985 2: Based on VOS value Solartron manual edition 1996 and later	-		2
Reference temperature	Used when temperature correction is enabled	°F	0..200	60
Reference pressure	Used when pressure correction is enabled	psig	0..1500	0
K0	Constant from calibration certificate	-	-1e9..1e9	

Function inputs	Remark	EU	Range	Default
K1	Constant from calibration certificate	-	-1e9..1e9	
K2	Constant from calibration certificate	-	-1e9..1e9	
K18	Constant from calibration certificate	-	-1e9..1e9	
K19	Constant from calibration certificate	-	-1e9..1e9	
K20A	Constant from calibration certificate	-	-1e9..1e9	
K20B	Constant from calibration certificate	-	-1e9..1e9	
K21A	Constant from calibration certificate	-	-1e9..1e9	
K21B	Constant from calibration certificate	-	-1e9..1e9	
Kr	Used when VOS method is set to 'Based on Kr / Kj Constants'. Constant needs to be obtained from Solartron	-		
Kj	Used when VOS method is set to 'Based on Kr / Kj Constants'. Constant needs to be obtained from Solartron	lbm/ft3		
Liquid VOS	Velocity of sound of liquid Used when VOS method is set to ' Based on VOS value'	ft/s		

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error		STS	FIOOR CALCERR	
Corrected density	Density corrected for temperature, pressure and VOS	lbm/ft3	CORDENS		0
Density corrected for temperature		lbm/ft3	TCORDENS		0
Density corrected for temperature and pressure		lbm/ft3	PTCORDENS		0
Uncorrected density		lbm/ft3	UNCDENS		0

Calculations

Density calculations are performed in g/cc and m/s, while the function inputs and outputs are in lbm/ft3 and ft/s

The indicated density ρ_i is calculated by

$$\rho_i = K0 + K1 \cdot \tau + K2 \cdot \tau^2$$

Where:

ρ_i	The indicated density	g/cc
K0	Obtained from the calibration certificate	-

K1	Obtained from the calibration certificate	-
K2	Obtained from the calibration certificate	-
τ	The time period in µS	µs

The temperature corrected density ρt is calculated by

$$\rho_t = [\rho_i \cdot [1 + K18 \cdot (t - t_R)] + K19 \cdot (t - t_R)]$$

Where:

ρ_t	The density corrected for temperature	g/cc
K18	Obtained from the calibration certificate	-
K19	Obtained from the calibration certificate	-
t	The line temperature	°F
t_R	The reference temperature	°F

The pressure and temperature corrected density ρ_{PT} is calculated by

$$\rho_{pt} = [\rho_t \cdot [1 + K20 \cdot (p - p_{REF})] + K21 \cdot (p - p_{REF})]$$

$$K20 = K20A + K20B \cdot (p - p_{REF})$$

$$K21 = K21A + K21B \cdot (p - p_{REF})$$

Where:

ρ_{pt}	The density corrected for pressure and temperature	g/cc
K20A	Obtained from the calibration certificate	-
K20B	Obtained from the calibration certificate	-
K21A	Obtained from the calibration certificate	-
K21B	Obtained from the calibration certificate	-
p	The line pressure	psig
p_R	The reference pressure	psig

When 'VOS Correction' is set to 'Based on Kr and Kj Constants' the following correction for velocity of sound is applied:

$$\rho_{VOS} = \rho_{pt} + K_{r.} \cdot (\rho_{pt} - K_j)^3$$

When 'VOS Correction' is set to 'Based on VOS value', the following correction for velocity of sound is applied:

$$\rho_{VOS} = \rho_{pt} \cdot \left[1 + \frac{1.4e^6}{1000 \cdot \rho_{pt} + 1.4} \cdot \left(\frac{1}{V_C^2} + \frac{1}{V_A^2}\right)\right]$$

When 0.3 <= ρ_{pt} <= 1.1:

$$V_C = (100 + 1455 \cdot \rho_{pt})$$

When 1.1 < ρ_{pt} <= 1.6:

$$V_C = 2690 - 900 \cdot \rho_{pt}$$

Else (ρ_{pt} < 0.3 or ρ_{pt} > 1.4) the VOS of sound correction is not performed.

Where:

ρ_{VOS}	The density corrected for temperature	g/cc
K_r	Constant obtained from Solartron	-
K_j	Constant obtained from Solartron	g/cc
V_C	Calibration VOS	m/s
V_A	Liquid VOS	m/s

fxSolartron_Liquid_M

The function calculates the density from a frequency input signal provided by a Solartron 7835, 7845, 7846 or 7847 liquid densitometer and corrects it for temperature, pressure and velocity of sound effects using **metric** units.

The function requires that the calibration constants are based on the following units:

- Temperature °C
- Pressure bar
- Density kg/m3

Compliance

The calculations are in accordance with documents:

- 78355010 'Solartron 7835, 7845, 7846 & 7847 Advanced Liquid Density Transducer Manual', 2001
- 78355080, Rev. C, 'Micro Motion 7835, 7845, 7846 & 7847 Liquid Density Transducer', October 2007

Function inputs and outputs

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Periodic time	In microseconds Equals 1000 divided by the frequency in [Hz]	µs	0..1e6	0
Line temperature	Used when temperature correction is enabled	°C	-273.15..+500	0
Line pressure	Used when pressure correction is enabled	bar(g)	0..200	0
Temperature correction	0: Disabled 1: Enabled	-		1
Pressure correction	0: Disabled 1: Enabled	-		1
VOS correction	0: Disabled 1: Based on Kr / Kj Constants Solartron manual edition 1985 2: Based on VOS value Solartron manual edition 1996 and later	-		2
Reference temperature	Used when temperature correction is enabled	°C	0..100	20
Reference pressure	Used when pressure correction is enabled	bar(g)	0..100	0
K0	Constant from calibration certificate	-	-1e9..1e9	1.7418E2
K1	Constant from calibration	-	-1e9..1e9	-1.10493e0

Function inputs	Remark	EU	Range	Default
	certificate			
K2	Constant from calibration certificate	-	-1e9..1e9	3.703268e-4
K18	Constant from calibration certificate	-	-1e9..1e9	-6.415e-4
K19	Constant from calibration certificate	-	-1e9..1e9	-5.674e-1
K20A	Constant from calibration certificate	-	-1e9..1e9	2.888e-4
K20B	Constant from calibration certificate	-	-1e9..1e9	-5.581e-6
K21A	Constant from calibration certificate	-	-1e9..1e9	-4.467e-1
K21B	Constant from calibration certificate	-	-1e9..1e9	-8.633e-3
Kr	Used when VOS method is set to 'Based on Kr / Kj Constants'. Constant needs to be obtained from Solartron	-	-1..+1	0.0
Kj	Used when VOS method is set to 'Based on Kr / Kj Constants'. Constant needs to be obtained from Solartron	kg/m3	0..2000	0.0
Liquid VOS	Velocity of sound of liquid Used when VOS method is set to ' Based on VOS value'	m/s	0..2000	0.0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error		STS	 FIOOR CALCERR	
Corrected density	Density corrected for temperature, pressure and VOS (provided that particular correction is enabled)	kg/m3	CORDENS		0
Density corrected for temperature		kg/m3	TCORDENS		0
Density corrected for temperature and pressure		kg/m3	PTCORDENS		0
Uncorrected density		kg/m3	UNCDENS		0

Calculations

The indicated density ρ_i is calculated by

$$\rho_i = K0 + K1 \cdot \tau + K2 \cdot \tau^2$$

Where:

ρ_i	The indicated density	kg/m3
K0	Obtained from the calibration certificate	-
K1	Obtained from the calibration certificate	-
K2	Obtained from the calibration certificate	-
τ	The time period in µS	µs

The temperature corrected density ρt is calculated by

$$\rho_t = [\rho_i \cdot [1 + K18 \cdot (t - t_R)] + K19 \cdot (t - t_R)]$$

Where:

ρ_t	The density corrected for temperature	kg/m3
K18	Obtained from the calibration certificate	-
K19	Obtained from the calibration certificate	-
t	The line temperature	°C
t_R	The reference temperature	°C

The pressure and temperature corrected density ρ_{PT} is calculated by

$$\rho_{pt} = [\rho_t \cdot [1 + K20 \cdot (p - p_{REF})] + K21 \cdot (p - p_{REF})]$$

$$K20 = K20A + K20B \cdot (p - p_{REF})$$

$$K21 = K21A + K21B \cdot (p - p_{REF})$$

Where:

ρ_{pt}	The density corrected for pressure and temperature	kg/m3
K20A	Obtained from the calibration certificate	-
K20B	Obtained from the calibration certificate	-
K21A	Obtained from the calibration certificate	-
K21B	Obtained from the calibration certificate	-
p	The line pressure	bar(g)
p_R	The reference pressure	bar(g)

When 'VOS Correction' is set to 'Based on Kr and Kj Constants' the following correction for velocity of sound is applied:

$$\rho_{VOS} = \rho_{pt} + K_{r.} \cdot \left(\rho_{pt} - K_j\right)^3$$

When 'VOS Correction' is set to 'Based on VOS value', the following correction for velocity of sound is applied:

$$\rho_{VOS} = \rho_{pt} \cdot \left[1 + \frac{1.4e^6}{\rho_{pt} + 1400} \cdot \left(\frac{1}{V_C^2} + \frac{1}{V_A^2}\right)\right]$$

When 300 <= ρ_{pt} <= 1100:

$$V_C = 100 + 1.455 \cdot \rho_{pt}$$

When 1100 < ρ_{pt} <= 1600:

$$V_C = 2690 - 0.9 \cdot \rho_{pt}$$

Else (ρ_{pt} < 300 or ρ_{pt} > 1600) the VOS of sound correction is not performed.

Where:

ρ_{VOS}	The density corrected for temperature	kg/m3
K_r	Constant obtained from Solartron	-
K_j	Constant obtained from Solartron	kg/m3
V_C	Calibration VOS	m/s
V_A	Liquid VOS	m/s

fxSolartron_SG

The function calculates the specific gravity from a frequency input signal provided by a Solartron 3096 or 3098 Specific Gravity transducer.

Compliance

The calculations are in accordance with documents:

- 30985020 'Solartron 3098 Gas Specific Gravity Transducer Manual', 2001
- 30985020, Rev. B, 'Micro Motion 3098 Gas Specific Gravity Meter', October 2007

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Periodic time	In microseconds Equals 1000 divided by the frequency in [Hz]	μs		0..1e6	0
K0	Constant from calibration certificate	-	K0	-10000..0	-11.952
K2	Constant from calibration certificate	-	K2	0..1	4.719593e-5

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range 2: Calculation error		STS	 FIOOR CALCERR	
Specific Gravity	Ratio of the molecular weight of the gas (mixture) to that of the molecular weight of dry air (i.e. the ideal Specific Gravity).	-	SG		0

Calculations

The specific gravity is calculated by

$$SG = K0 + K2 \cdot \tau^2$$

Where:

SG	Specific gravity	-
τ	Periodic time	μs
K0	Obtained from the calibration certificate	-
K2	Obtained from the calibration certificate	-

If the calibration certificate contains factors Gx, Gy, tx and ty then K2 must be calculated as follows:

$$K2 = \frac{Gx - Gy}{t_X^2 - t_Y^2}$$

Gx	Specific gravity of calibration gas x	-
Gy	Specific gravity of calibration gas y	-
τx	Periodic time of calibration gas x	μs
τy	Periodic time of calibration gas y	μs

fxStartDoubleChronometry

This function starts a new double chronometry measurement on one of the Flow-X modules part of the same configuration.
It is required that the specified double chronometry channel is configured through function 'fxDoubleChronometry'.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional prefix for tag name				
Module	Flow-X module index number for the digital output 0: Local module 1: Module 1 etc.		MODNR	>= 0	
Index	Index number of the double chronometry measurement on the specified module		INDEX	0..4	
Start command	Resets the previous measurement results and starts a new measurement		RESET		

Function outputs	Remark	SW tag	Alarm	EU	Fallback
Status	0: Normal 1: Input argument out of range or conflict	STS	FIOOR	-	

fxTag

The 'fxTag' function creates a tag for the cell that contains the 'fxTag' function.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Name for the tag				
Description	Description for the tag				
Value	May contain a value or a formula. In case of a formula or a reference to a cell or another tag, the tag becomes read-only. On the other hand when it is a value the tag is writable and the specified value is considered at the initial value.				
Unit	Defines an engineering unit, enumeration date/time, or a special data type, e.g. 'xt_bool', 'xu_kg_s' or 'xe_period').				
Write level	Applies for writeable tags only. Security access level that is required to write a new value to the tag. Only applies when input 'Value' contains a value and not a formula. When not defined (i.e. function argument is left empty) the tag is only internally writable by a spreadsheet function but not externally writable through the display or communications				
Retentive	Applies for writable tags only Defines whether or not the value needs to be 'remembered' (retentive). When not defined (i.e. function argument is left empty) the tag is retentive provided that the tag is writable and AutoReset is not enabled				
AutoReset	Applies for writeable tags only. Automatically resets the tag to its initial value after it has been written to.				
Minimum	Minimum value that is accepted when the tag is externally writable. May be left empty, in which case no minimum check is applied				
Maximum	Maximum value that is accepted when the tag is externally writable May be left empty, in which case no maximum check is applied				

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Value	Depends on setting 'Mode' - *Mode = 'This Cell'* Cell shows the value or the result of the formula that is defined for input 'Value' - *Mode = 'Referred Cell'* Cell returns TRUE when the 'fxTag' function evaluates successfully or FALSE otherwise	Input *Unit*	Input *Name*		

fxTimePeriodInput

This function measures the time period between two pulses with a high resolution (100 nanoseconds) and is typically used for densitometer inputs. The measurement is performed continuously in the background and the function returns the average value since the previous calculation cycle.
The measured time period value can be linked to a subsequent densitometer-specific (Solartron, Sarasota, UGC) function that calculates the density at the densitometer conditions.
Abnormal measurements are filtered out and alarmed for.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Channel	Channel number for the signal	-	CHAN	1..16	0
Time period differential limit	Maximum allowable difference in microseconds. When the time period between two consecutive pulses differs more than this limit from the previous time period, the reading is considered to be abnormal. Following an abnormal reading there must be 3 consecutive readings within the limit before the time period value is considered normal again. When no 3 consecutive readings within the limit are available in the last 5 readings then the input signal is considered to be invalid. Resolution of the limit value is 100 nanoseconds.	μs			

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal 1: Input argument out of range *Outputs will be set to fallback values* 2: No valid measurement *Outputs will be set to fallback values*		INPSTS	INPERR (*)	
Time period	Average (arithmetic mean) in microseconds of the last calculation cycle	μs	TIME		0
Frequency	Average (arithmetic mean) of the last calculation cycle	Hz	FREQ		0
MinPeriodAlm				MINPALM	
MaxPeriodAlm				MAXPALM	

(*) Note that no alarm is generated for this status output value. This is to avoid an unnecessary alarm in case the input is not used

fxTimer

The 'fxTimer' function provides generic timer functionality.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Start	Trigger to start the timer. Sets output Running to 1 and starts accumulation of the actual waited time, provided that the Enable condition is true (<> 0) If the timer is already running, then it will be restarted, i.e. the Wait Time will be set to 0 and Elapsed status will be reset to False (in case it was True)		START		
Reset	Trigger to resets the timer. Sets outputs Elapsed, Running and Wait time to 0		RST		
Limit	Time-out period for the timer. When the actual wait time is larger than the limit output Elapsed is set to 1. The limit value is expressed in seconds and may contain a fractional part The actual wait time however will be a multifold of the flow computer cycle time. When the limit value does not match an exact number of cycles, then the actual limit value will be rounded upwards to match the 'next' number of cycles. E.g. when the flow computer cycle time is 250 ms and the Limit is set to 3.15 sec, the actual limit value being used will be 3.25 sec.	sec	LIM		
Enable	Condition that controls the accumulation of actual waited time. 0: Disabled 1: Enabled When disabled the actual wait time will be frozen until the timer is enabled again.		EN		

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Elapsed	Flag that indicates that timer has timed out, i.e. the actual wait time is larger than the limit		ELAP		
Running	Flag that indicates that the timer is running, i.e. has been started and not been reset yet, irrespective of the Enable condition		RUN		
Wait time	Time accumulated since the latest start and while being enabled. When this time reached the limit, the Elapsed output is set to 1. Time	sec	TIM		

	will remain accumulated even when the timer has elapsed.				

fxTotalizerDelta

Description

The function accumulates a **flow increment** into a cumulative (eternal) total.
Besides of the cumulative total the function also outputs the flow increment that represents the increase in flow quantity in the last calculation cycle. This increment value serves as an input for related batch and period flow-weighted averaging and totalization functions.

> Note: As opposed to the flow increment input value, the flow increment output value is set to 0 when the totalization is disabled and has the proper units and is therefore better suited as input for other functions.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group and retentive storage.				
Flow increment	Actual flow increment to be accumulated. Negative values will be ignored, so the cumulative total will not decrease.	*Defined by 'Input unit'*		0..1e11	
Enabled	Dictates whether the flow accumulation is enabled or not. When disabled the cumulative total will not be updated and the increment will be set to 0. 0: Disabled 1: Enabled		EN		
Input unit	Unit of input 'Flow increment'.				
Output unit	Unit to be used for total and increment. Refer to the next section 'Unit conversion' for more information. Changing the unit will only be possible when the cumulative total value equals 0.				
Rollover value	The cumulative total will be reset to 0 when it reaches the rollover value	*Defined by 'Output unit'*	ROVAL	0..1e15	1e12
Decimal places	Defines the number of decimal places for the total and increment output values. -1 means full precision (no rounding applied)		DECPLS	-1..10	-1
Reset	***This should be used with great care*!** Command to reset the cumulative total to 0 0: No reset 1: Reset				0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Cumulative total	Total quantity accumulated so far since the last rollover or reset	*Defined by 'Input unit'*	CUM		
Increment	Increment in last calculation cycle	*Defined by 'Input unit'*	INCR		
Rollover flag	Flag indicating a rollover to 0. 0: Off 1: On Note: stays 'On' for one cycle only.			ROALM	
Reset flag	Flag indicating a reset to 0. 0: Off 1: On Note: stays 'On' for one cycle only			RESET	
Recoverable reload error	Flag that indicates that at startup only 2 of the 3 copies were equal and that that value is used as the initial total. 0: Off 1: On Note: stays 'On' for one cycle only			RTOTERR	
Fatal reload error	Flag that indicates that at startup all 3 copies were different and the total was reset to 0 0: Off 1: On Note: stays 'On' for one cycle only			FTOTERR	

Unit conversion

The function will automatically apply the required conversion based on the unit of the flow increment input value (Input unit) and the selected 'Output unit' for the flow quantity.
E.g. when flow rate input is in 'scf' the output unit is 'MMscf' then the following conversions are applied:

1. The flow increment input value is converted to the corresponding base unit, which is 'sm3' for a 'Volume' unit
2. The flow increment is converted from 'sm3' to 'MMscf' before the cumulative total and increment output values are updated.

Similar conversions are applied for flow increments that are expressed in mass, volume, normal volume and energy units.

fxTotalizerRate

Description

The function accumulates a **flow rate** into a cumulative (eternal) total.
Besides of the cumulative total the function also outputs the flow increment that represents the increase in flow quantity in the last calculation cycle. This increment value serves as an input for related batch and period flow-weighted averaging and totalization functions.

Inputs and outputs

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group and retentive storage.				
Flow rate	Actual flow rate to be accumulated. Negative values will be ignored, so the cumulative total will not decrease.	*Defined by 'Input unit'*		0..1e11	
Enabled	Dictates whether the flow accumulation is enabled or not. When disabled the cumulative total will not be updated and the increment will be set to 0. 0: Disabled 1: Enabled		EN		
Input unit	Unit of input 'Flow rate.				
Output unit	Unit to be used for total and increment. Refer to the next section 'Unit conversion' for more information. Changing the unit will only be possible when the cumulative total value equals 0.				
Rollover value	The cumulative total will be reset to 0 when it reaches the rollover value	*Defined by 'Output unit'*	ROVAL	0..1e15	1e12
Decimal places	Defines the number of decimal places for the total and increment output values. -1 means full precision (no rounding applied)		DECPLS	-1..10	-1
Reset	***This should be used with great care*!** Command to reset the cumulative total to 0 0: No reset 1: Reset				0

Function outputs	Remark	EU	SW tag	Alarm	Default
Cumulative total	Total quantity accumulated so far since the last rollover or reset	*Defined by Input unit'*	CUM		
Increment	Increment in last calculation cycle	*Defined by 'Input unit'*	INCR		
Rollover flag	Flag indicating a rollover to 0. 0: Off 1: On Note: stays 'On' for one cycle only.			ROALM	
Reset flag	Flag indicating a reset to 0. 0: Off 1: On Note: stays 'On' for one cycle only			RESET	
Reload warning	Flag that indicates that at startup only 2 of the 3 copies were equal and that that value is used as the initial total. 0: Off 1: On Note: stays 'On' for one cycle only			RLWARN	
Reload error	Flag that indicates that at startup all 3 copies were different and the total was reset to 0 0: Off 1: On Note: stays 'On' for one cycle only			RLERR	

Unit conversion

The function will automatically apply the required conversion based on the unit of the flow rate input value (Input unit) and the selected 'Output unit' for the flow quantity.
E.g. when flow rate input is in 'kg/hr' the selected unit is 'tonne' then the following conversions are applied:

3. The flow rate value is converted to the corresponding base unit, which is 'kg/s' for a 'Mass per Time' unit
4. The flow increment over the last calculation cycle is calculated from the 'kg/s' value and the actual calculation cycle time, resulting in a value expressed in 'kg' (i.e. the base unit for 'Mass').
5. The flow increment is converted from 'kg' to 'tonne' before the cumulative total and increment output values are updated.

Similar conversions are applied for flow rates that are expressed in volume, standard volume, normal volume and energy units.

fxUGC_C

The function calculates the density from a frequency input signal provided by a UGC densitometer and corrects it for temperature and pressure effects in **US customary** units.

Note: Calibration constants also need to be in US customary units.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Periodic time	In microseconds Equals 1000 divided by the frequency in [Hz]	µs		0..1e6	
Line temperature	Used when temperature correction is enabled	°F		-459.67..+1000	
Line pressure	Used when pressure correction is enabled	psig		0..3000	
Temperature correction	0: Disabled 1: Enabled	-	TEMPCOR		1
Pressure correction	0: Disabled 1: Enabled	-	PRESCOR		1
Reference temperature	Used when temperature correction is enabled	°F	REFTEMP	0..200	60
Reference pressure	Used when pressure correction is enabled	psig	REFPRES	0..1500	0
K0	Constant K0 from calibration certificate	-	K0	-1e9..1e9	
K1	Constant K1 from calibration certificate	-	K1	-1e9..1e9	
K2	Constant K2 from calibration certificate	-	K2	-1e9..1e9	
KT1	Constant KT1 from calibration certificate		KT1	-1e9..1e9	
KT2	Constant KT2 from calibration certificate		KT2	-1e9..1e9	
KT3	Constant KT3 from calibration certificate		KT3	-1e9..1e9	
KP1	Constant KP1 from calibration certificate		KP1	-1e9..1e9	
KP2	Constant KP2 from calibration certificate		KP2	-1e9..1e9	
KP3	Constant KP3 from calibration certificate		KP3	-1e9..1e9	

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal (No error condition) 1: Input argument out of range 2: Calculation error		STS	FIOOR CALC	
Corrected density	Density corrected for temperature and pressure	lbm/ft3	CORDENS		0
Uncorrected density	Uncorrected (indicated) density	lbm/ft3	UNCDENS		0

Calculations

The uncorrected density ρ_i is calculated by

$$\rho_i = K0 + K1 \cdot \tau + K2 \cdot \tau^2$$

Where:

ρ_i	The uncorrected density	lbm/ft3
K0	Obtained from the calibration certificate	-
K1	Obtained from the calibration certificate	-
K2	Obtained from the calibration certificate	-
τ	The time period in µS	µs

The temperature and pressure corrected density ρt is calculated by

$$\rho_t = \rho_i + \left[K_{P1} + K_{P2} \cdot \rho_i + K_{P3} \cdot \rho_i^{\ 2}\right] \cdot (p - p_R) + \left[K_{T1} + K_{T2} \cdot \rho_i + K_{T3} \cdot \rho_i^{\ 2}\right] \cdot (t - t_R)$$

Where:

ρ_t	The density corrected for temperature and pressure	lbm/ft3
K_{P1}	Obtained from the calibration certificate	-
K_{P2}	Obtained from the calibration certificate	-
K_{P3}	Obtained from the calibration certificate	-
K_{T1}	Obtained from the calibration certificate	-
K_{T2}	Obtained from the calibration certificate	-
K_{T3}	Obtained from the calibration certificate	-
t	The line temperature	°F
t_R	The reference temperature	°F
p	The line pressure	psig
p_R	The reference pressure	psig

fxUGC_M

The function calculates the density from a frequency input signal provided by a UGC densitometer and corrects it for temperature and pressure effects in **metric** units. Calibration constants also need to be in metric units.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				
Periodic time	In microseconds Equals 1000 divided by the frequency in [Hz]	µs		0..1e6	
Line temperature	Used when temperature correction is enabled	°C		-273.15..+500	
Line pressure	Used when pressure correction is enabled	bar(g)		0..200	
Temperature correction	0: Disabled 1: Enabled	-	TEMPCOR		1
Pressure correction	0: Disabled 1: Enabled	-	PRESCOR		1
Reference temperature	Used when temperature correction is enabled	°C	REFTEMP	0..100	20
Reference pressure	Used when pressure correction is enabled	bar(g)	REFPRES	0..100	0
K0	Constant K0 from calibration certificate	-	K0	-1e9..1e9	
K1	Constant K1 from calibration certificate	-	K1	-1e9..1e9	
K2	Constant K2 from calibration certificate	-	K2	-1e9..1e9	
KT1	Constant KT1 from calibration certificate		KT1	-1e9..1e9	
KT2	Constant KT2 from calibration certificate		KT2	-1e9..1e9	
KT3	Constant KT3 from calibration certificate		KT3	-1e9..1e9	
KP1	Constant KP1 from calibration certificate		KP1	-1e9..1e9	
KP2	Constant KP2 from calibration certificate		KP2	-1e9..1e9	
KP3	Constant KP3 from calibration certificate		KP3	-1e9..1e9	

Function outputs	Remark	EU	SW tag	Alarm	Fallback
Status	0: Normal (No error condition) 1: Input argument out of range 2: Calculation error		STS	 FIOOR CALC	
Corrected density	Density corrected for temperature and pressure	kg/m3	CORDENS		0
Uncorrected density	Uncorrected (indicated) density	kg/m3	UNCDENS		0

Calculations

The uncorrected density ρ_i is calculated by

$$\rho_i = K0 + K1 \cdot \tau + K2 \cdot \tau^2$$

Where:

ρ_i	The uncorrected density	kg/m3
K0	Obtained from the calibration certificate	-
K1	Obtained from the calibration certificate	-
K2	Obtained from the calibration certificate	-
τ	The time period in µS	µs

The temperature and pressure corrected density ρt is calculated by

$$\rho_t = \rho_i + \left[K_{P1} + K_{P2} \cdot \rho_i + K_{P3} \cdot \rho_i^2\right] \cdot (p - p_R) + \left[K_{T1} + K_{T2} \cdot \rho_i + K_{T3} \cdot \rho_i^2\right] \cdot (t - t_R)$$

Where:

ρ_t	The density corrected for temperature and pressure	kg/m3
K_{P1}	Obtained from the calibration certificate	-
K_{P2}	Obtained from the calibration certificate	-
K_{P3}	Obtained from the calibration certificate	-
K_{T1}	Obtained from the calibration certificate	-
K_{T2}	Obtained from the calibration certificate	-
K_{T3}	Obtained from the calibration certificate	-
t	The line temperature	°C
t_R	The reference temperature	°C
p	The line pressure	bar(g)
p_R	The reference pressure	bar(g)

fxWatchUpdate

This function raises a flag whenever a value has been updated in the latest calculation cycle.

It is a generic function that can be used for any purpose, e.g. to report the number of times that a gas chromatograph has sent updates of the gas composition.

Use function fxTotalizerDelta to accumulate the number of times the flag has been raised.

Function inputs	Remark	EU	SW tag	Range	Default
Name	Optional tag name, tag description and tag group				*<Empty>*
Value	The value that needs to be checked for updates		VAL		0
Neglect zeros	Controls if the value 0 has to be considered as an update or not. 0: Disabled The value 0 is also an update 1: Enabled The value 0 is not considered as an update		NGLZERO		0

Function outputs	Remark	EU	SW tag	Alarm	Fallback
UpdateFlag	Update flag 0: Value has not changed 1: Value has not changed Flag is automatically cleared (set to 0) at next cycle		UPDATEFLAG		0

fxVCone_C

Description

This function calculates the mass flow rate for a measured differential pressure over a McCrometer V-Cone meter in U.S. customary units.
The calculation, as specified by the meter supplier, is essentially a modified ISO 5167 flow rate calculation. As opposed to ISO-5167 the discharge coefficient is a function input. Because the discharge coefficient is a function of Reynolds number an optional calibration correction needs to be applied outside this function.

Compliance

McCrometer: Flow Calculations for the V-Cone Flow meter Literature part #24509-54 Rev 3.1/02-05 2005

Function inputs and outputs

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Differential Pressure	Differential pressure over the V-Cone device measured at the up- and downstream pressure taps	inH2O @ 60°F	0..100	0

Function inputs	Remark	EU	Range	Default
Pressure	Upstream pressure value of the fluid at metering conditions	psia	0..30000	0
Temperature	Down- or upstream temperature of the fluid at metering conditions	°F	-400 ..2000	0
Density	Down or upstream density of the fluid at metering conditions	lbm/ft3	0..200	0
Dynamic Viscosity	Dynamic viscosity of the fluid	cP	0..1e-4	6.9e-6
Isentropic Exponent	Also referred to as κ (kappa). For an ideal gas this coefficient is equal to the ratio of the specific heat capacity at constant pressure to the specific heat at constant volume. According to the ISO standard this ratio may be used, when the real value is unknown.	-	0..10	1.3
Pipe Diameter	Internal diameter of the pipe at reference temperature	inches	0..100	0
Pipe Expansion factor	The thermal expansion coefficient of the pipe material	1/°F	0..1e-4	6.2e-6
Pipe Reference temperature	The reference temperature that corresponds to the 'Pipe diameter' input value	°F	-400..2000	68
Cone Diameter	Cone diameter at reference temperature	inches	0.. *'Pipe Diameter'*	0
Cone Expansion factor	The thermal expansion coefficient of the Cone material	1/°F	0..1e-4	9.25e-6
Cone Reference Temperature	The reference temperature that corresponds to the 'Cone diameter' input value	°F	-400 ..2000	68
Configuration	The type of McCrometer V-Cone meter. This setting is used to select the appropriate equation for determination of the gas expansion factor as specified by McCrometer 1: Standard V-Cone 2: Wafer-Cone Note of input 'Fluid' is set to 'Liquid', then this input is not used (because the expansion factor is set to 1)	-		1
Pressure Location	1: Upstream Input 'Pressure' represents the pressure at the upstream pressure tapping (p_1). Since the absolute pressure is usually measured at the upstream tapping this is the most common setting. 2: Downstream Input 'Pressure' represents the pressure at the downstream tapping (p_2).	-		1
Temperature Location	1: Upstream Input 'Temperature' represents the	-		2

Function inputs	Remark	EU	Range	Default
	upstream temperature (t_1). 2: Downstream Input 'Temperature represents the temperature at the downstream tapping (t_2). 3: Recovered Input 'Temperature' represents the downstream temperature at a location Where the pressure has fully recovered (t_3). Since temperature measurement is usually downstream of the flow device this is the most common setting.			
Temperature Correction	This parameter specifies if and how the temperature should be corrected from downstream to upstream conditions (or vice versa) 1: (1-κ)/κ Isentropic expansion using (1-κ)/κ as the temperature referral exponent 2: Constant Isentropic expansion using input 'Temperature Exponent' as the temperature referral exponent [-] 3: Joule Thomson Isenthalpic expansion using input 'Temperature Exponent' as the Joule Thomson coefficient [°F/psi]. This method is prescribed by ISO5167-1:2003.			1
Temperature Exponent	Refer to input Temperature Correction Unit depends on input Temperature Correction value	- - °F/psi		0
Density Location	This parameter specifies if and how the density should be corrected from downstream to upstream conditions (or vice versa). 1: Upstream Input 'Density' represents the density at the upstream pressure tapping (ρ_1). 2: Downstream Input 'Density' represents the density at the downstream tapping (ρ_2). 3: Recovered Input 'Density' represents the density downstream at a location Where the pressure has fully recovered (ρ_3).	-		1
Density Exponent.	This factor is used when density correction is enabled. The formula 1/κ will be used when the input value is set to 0, else the input value will be	-		0

Function inputs	Remark	EU	Range	Default
	used. For more details refer to section 'Density correction'.			
Fluid	The type of fluid being measured 1: Gas 2: Liquid	-		1
Discharge coefficient	The McCrometer reference document states that the discharge coefficient is a function of Reynolds number. A calibration correction needs to be implemented through an additional function and input 'Discharge coefficient' needs to be linked to the corresponding output of this additional function.	-	0..2	0.85

Function outputs	Remark	EU	Fallback
Status	0: Normal (No error condition) 1: Input argument out of range 2: No convergence		
Mass flow rate	The calculated mass flow rate	klbm/hr	0
Beta ratio	Cone to pipe diameter ratio at upstream temperature	-	Input *Cone diameter* / Input *Pipe diameter*
Cone diameter	At the upstream temperature	inches	Input *Cone diameter*
Pipe diameter	At the upstream temperature	inches	Input *Pipe diameter*
Upstream pressure	Pressure at upstream tapping (p_1)	psia	Input *Pressure*
Pressure at downstream tapping	Pressure at downstream tapping (p_2)	psia	Input *Pressure*
Recovered downstream pressure	Fully recovered downstream pressure (p_3)	psia	Input *Pressure*
Upstream temperature	Temperature at upstream tapping (t_1)	°F	Input *Temperature*
Temperature at downstream tapping	Temperature at downstream tapping (t_2)	°F	Input *Temperature*
Downstream Temperature	'Fully recovered' downstream temperature (t_3)	°F	Input *Temperature*
Upstream density	Density at upstream tapping (ρ_1)	lbm/ft3	Input *Density*
Density at downstream tapping	Pressure at downstream tapping (ρ_2)	lbm/ft3	Input *Density*
Downstream density	'Fully recovered' downstream density (ρ_3)	lbm/ft3	Input *Density*
Reynolds number		-	0
Discharge coefficient	Same as input value	-	
Expansion Factor		-	0

Function outputs	Remark	EU	Fallback
Velocity	Pipeline velocity	Ft/s	0
Expansion Factor Range	The McCrometer reference document states that for gas applications the expansion factor should not get below 0.84 0: Expansion factor is in valid range 1: Expansion factor is out of valid range	-	0

Calculations

The flow calculation is as specified in the McCrometer reference document.
The downstream to upstream correction (and vice versa) for pressure, temperature and density are as specified for function 'ASME MFC-3M Orifice'.

fxVCone_M

Description

This function calculates the mass flow rate for a measured differential pressure over a McCrometer V-Cone meter in metric units.
The calculation, as specified by the meter supplier, is essentially a modified ISO 5167 flow rate calculation. As opposed to ISO-5167 the discharge coefficient is a function input. Because the discharge coefficient is a function of Reynolds number an optional calibration correction needs to be applied outside this function.

Compliance

McCrometer: Flow Calculations for the V-Cone Flow meter Literature part #24509-54 Rev 3.1/02-05 2005

Function inputs and outputs

Function inputs	Remark	EU	Range	Default
Name	Optional tag name, tag description and tag group			
Differential Pressure	Differential pressure over the V-Cone device measured at the up- and downstream pressure taps	mbar	0..2000	0
Pressure	Upstream pressure value of the fluid at metering conditions	bar(a)	0..2000	0
Temperature	Down- or upstream temperature of the fluid at metering conditions	°C	-300..1000	0
Density	Down or upstream density of the fluid at metering conditions	kg/m3	0..2000	0
Dynamic Viscosity	Dynamic viscosity of the fluid	Pa.s	0..1	0
Isentropic Exponent	Also referred to as κ (kappa). For an ideal gas this coefficient is equal to the ratio of the specific heat capacity at constant pressure to the specific heat at constant volume. According to the ISO standard this ratio may be used, when the real value is unknown.	-	0..2	0
Pipe Diameter	Internal diameter of the pipe at reference temperature	mm	0..2000	0
Pipe Expansion factor	The thermal expansion coefficient of the pipe material	1/°C	0..1	0.0000108
Pipe Reference temperature	The reference temperature that corresponds to the 'Pipe diameter' input value	°C	-300..1000	20
Cone Diameter	Cone diameter at reference temperature	mm	0	0
Cone Expansion factor	The thermal expansion coefficient of the Cone material	1/°C		0.0000163
Cone Reference Temperature	The reference temperature that corresponds to the 'Cone diameter' input value	°C	-300 .. 1000	20
Configuration	The type of McCrometer V-Cone meter. This setting is used to select the appropriate equation for determination of the gas	-		1

Function inputs	Remark	EU	Range	Default
	expansion factor as specified by McCrometer 1: Standard V-Cone 2: Wafer-Cone Note of input 'Fluid' is set to 'Liquid', then this input is not used (because the expansion factor is set to 1)			
Pressure Location	1: Upstream Input 'Pressure' represents the pressure at the upstream pressure tapping (p_1). Since the absolute pressure is usually measured at the upstream tapping this is the most common setting. 2: Downstream Input 'Pressure' represents the pressure at the downstream tapping (p_2).	-		1
Temperature Location	1: Upstream Input 'Temperature' represents the upstream temperature (t_1). 2: Downstream Input 'Temperature represents the temperature at the downstream tapping (t_2). 3: Recovered Input 'Temperature' represents the downstream temperature at a location Where the pressure has fully recovered (t_3). Since temperature measurement is usually downstream of the flow device this is the most common setting.	-		2
Temperature Correction	This parameter specifies if and how the temperature should be corrected from downstream to upstream conditions (or vice versa) 1: (1-κ)/κ Isentropic expansion using (1-κ)/κ as the temperature referral exponent 2: Constant Isentropic expansion using input 'Temperature Exponent' as the temperature referral exponent [-] 3: Joule Thomson Isenthalpic expansion using input			1

Function inputs	Remark	EU	Range	Default
	'Temperature Exponent' as the Joule Thomson coefficient [°C/bar]. This method is prescribed by ISO5167-1:2003.			
Temperature Exponent	Refer to input Temperature Correction Unit depends on input Temperature Correction value	- - °C/bar		0
Density Location	This parameter specifies if and how the density should be corrected from downstream to upstream conditions (or vice versa). 1: Upstream Input 'Density' represents the density at the upstream pressure tapping (ρ_1). 2: Downstream Input 'Density' represents the density at the downstream tapping (ρ_2). 3: Recovered Input 'Density' represents the density downstream at a location Where the pressure has fully recovered (ρ_3).	-		1
Density Exponent.	This factor is used when density correction is enabled. The formula $1/\kappa$ will be used when the input value is set to 0, else the input value will be used. For more details refer to section 'Density correction'.	-		0
Fluid	The type of fluid being measured 1: Gas 2: Liquid	-		1
Discharge coefficient	The discharge coefficient of the meter as specified by the manufacturer. The McCrometer reference document states that the discharge coefficient is a function of Reynolds number. It is advised that the meter is calibrated across the range of Reynold numbers for which the meter is used. The resulting correction curve can be implemented through function fxInterolationCurve. Input 'Discharge coefficient' needs to be linked to the corresponding output of this additional function.	-	0..2	0.85

Function outputs	Remark	EU	Fallback
Status	0: Normal (No error condition) 1: Input argument out of range 2: No convergence		
Mass flow rate	The calculated mass flow rate	tonne/h	0
Beta ratio	Cone to pipe diameter ratio at upstream temperature	-	Input *Cone diameter* / Input *Pipe diameter*
Cone diameter	At the upstream temperature	mm	Input *Cone diameter*
Pipe diameter	At the upstream temperature	mm	Input *Pipe diameter*
Upstream pressure	Pressure at upstream tapping (p_1)	bar(a)	Input *Pressure*
Pressure at downstream tapping	Pressure at downstream tapping (p_2)	bar(a)	Input *Pressure*
Recovered downstream pressure	Fully recovered downstream pressure (p_3)	bar(a)	Input *Pressure*
Upstream temperature	Temperature at upstream tapping (t_1)	°C	Input *Temperature*
Temperature at downstream tapping	Temperature at downstream tapping (t_2)	°C	Input *Temperature*
Downstream Temperature	'Fully recovered' downstream temperature (t_3)	°C	Input *Temperature*
Upstream density	Density at upstream tapping (ρ_1)	kg/m3	Input *Density*
Density at downstream tapping	Pressure at downstream tapping (ρ_2)	kg/m3	Input *Density*
Downstream density	'Fully recovered' downstream density (ρ_3)	kg/m3	Input *Density*
Reynolds number		-	0
Discharge coefficient	Same as input value	-	
Expansion Factor		-	0
Velocity	Pipeline velocity	m/s	0
Expansion Factor Range	The McCrometer reference document states that for gas applications the expansion factor should not get below 0.84 0: Expansion factor is in valid range 1: Expansion factor is out of valid range	-	0

Calculations

The flow calculation is as specified in the McCrometer reference document.
The downstream to upstream correction (and vice versa) for pressure, temperature and density are as specified for function 'ISO 5167 Orifice'.

Unit Types

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
Acceleration	meters per second squared	m/s2		xu_m_s2		
	kilometers per second squared	km/s2	m/s2	xu_km_s2	1.0 E+03	**Exact**
	inch per second squared	in/s2	m/s2	xu_in_s2	2.54 E-02	**Exact**
	foot per second squared	ft/s2	m/s2	xu_ft_s2	3.048 E-01	**Exact**
Area	square meter	m2		xu_m2		
	square millimeter	mm2	m2	xu_mm2	1.0 E-06	**Exact**
	square centimeter	cm2	m2	xu_cm2	1.0 E-04	**Exact**
	square kilometer	km2	m2	xu_km2	1.0 E+06	**Exact**
	square inch	in2	m2	xu_in2	6.4516 E-04	**Exact**
	square foot	ft2	m2	xu_ft2	9.290304 E-02	**Exact**
Dynamic Viscosity	pascal second	Pa.s		xu_Pa.s		
	poise	poise	Pa.s	xu_poise	1.0 E-01	**Exact**
	centipoise	cP	Pa.s	xu_cP	1.0 E-03	**Exact**
	kilogram force second per square meter	kgf.s/m2	Pa.s	xu_kgf.s_m2	9.80665	**Exact**
	pound-mass per foot second	lbm/ft.s	Pa.s	xu_lbm_ft.s	0.45359237 / 0.3048	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
Energy	joules	J		xu_J		
	kilojoules	kJ	J	xu_kJ	1.0 E+03	**Exact**
	megajoules	MJ	J	xu_MJ	1.0 E+06	**Exact**
	gigajoules	GJ	J	xu_GJ	1.0 E+09	**Exact**
	terajoules	TJ	J	xu_TJ	1.0 E+12	**Exact**
	watt hour	W.h	J		3.6 E+03	**Exact**
	kilowatt hour	kW.h	J		3.6 E+06	**Exact**
	watt second	W.s	J		1	**Exact**
	British thermal unit	Btu	J		1.05505585262 E+03	**Exact**
	kilo British thermal unit	kBtu	J		1.05505585262 E+06	**Exact**
	million British thermal unit	MMBtu	J		1.05505585262 E+09	**Exact**
	calorie	cal	J		4.1868	**Exact**
	kilocalorie	kcal	J		4.1868 E+03	**Exact**
	megacalorie	Mcal	J		4.1868 E+09	**Exact**
	decatherm	dT	J		1.05505585262 E+09	**Exact**
Energy per Mass	joule per kilogram	J/kg				
	kilojoule per kilogram	kJ/kg	J/kg		1.0 E+03	**Exact**
	megajoule per kilogram	MJ/kg	J/kg		1.0 E+06	**Exact**
	British thermal unit per pound (avoirdupois)	Btu/lbm	J/kg		2.32601 E+03	**Exact**
	kilo British thermal unit per pound (avoirdupois)	kBtu/lbm	J/kg		2.32601 E+06	**Exact**
	calorie per kilogram	cal/kg	J/kg		4.1868	**Exact**
	kilocalorie per kilogram	kcal/kg	J/kg		4.1868 E+03	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	million calorie per kilogram	MMcal/kg	J/kg		4.1868 E+06	**Exact**
Energy per Mole	joules per mole	J/mol				
	kilojoules per mole	kJ/mol	J/mol		1.0 E+03	**Exact**
	megajoules per mole	MJ/mol	J/mol		1.0 E+06	**Exact**
	kilojoules per kilomole	kJ/kmol	J/mol		1	**Exact**
	megajoules per kilomole	MJ/kmol	J/mol		1.0 E+03	**Exact**
	British thermal unit per pound mole	Btu/lbmol	J/mol		2.326 E+03	**Exact**
	kilo British thermal unit per pound mole	kBtu/lbmol	J/mol		2.326 E+06	**Exact**
	calorie per mole	cal/mol	J/mol		4.1868	**Exact**
	kilocalorie per mole	kcal/mol	J/mol		4.1868 E+03	**Exact**
	megacalorie per mole	Mcal/mol	J/mol		4.1868 E+06	**Exact**
Energy per Time	joules per second	J/s				
	megajoules per hour	MJ/hr	J/s		(1.0/3600) E+06	**Exact**
	gigajoules per hour	GJ/hr	J/s		(1.0/3600) E+09	**Exact**
	megajoules per day	MJ/day	J/s		(1.0/86400) E+06	**Exact**
	gigajoules per day	GJ/day	J/s		(1.0/86400) E+09	**Exact**
	kilo British thermal unit per hour	kBtu/hr	J/s		(1.05505585262 / 3600) E+06	**Exact**
	million British thermal unit per hour	MMBtu/hr	J/s		(1.05505585262 / 3600) E+09	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	kilo British thermal unit per day	kBtu/d	J/s		(1.05505585262 / 86400) E+06	**Exact**
	million British thermal unit per day	MMBtu/d	J/s		(1.05505585262 / 86400) E+09	**Exact**
	mega calorie per hour	Mcal/hr	J/mol		(4.1868/3600) E+06	**Exact**
	giga calorie per hour	Gcal/hr	J/mol		(4.1868/3600) E+09	**Exact**
	million calorie per day	Mcal/d	J/mol		(4.1868/86400) E+06	**Exact**
	giga calorie per day	Gcal/d	J/mol		(4.1868/86400) E+09	**Exact**
Energy per Volume	joules per cubic meter	J/m3				
	kilojoules per cubic meter	kJ/m3	J/m3		1.0 E+03	**Exact**
	megajoules per cubic meter	MJ/m3	J/m3		1.0 E+06	**Exact**
	British thermal unit per cubic foot	Btu/ft3	J/m3		(1.05505585262 / 0.02831685) E+03	**Exact**
	kilo British thermal unit per cubic foot	kBtu/ft3	J/m3		(1.05505585262 / 0.02831685) E+06	**Exact**
	calorie per cubic meter	cal/m3	J/mol		4.1868	**Exact**
	kilocalorie per cubic meter	kcal/m3	J/mol		4.1868 E+03	**Exact**
Energy per Standard Volume	joules per standard cubic meter	J/sm3				
	kilojoules per standard cubic meter	kJ/sm3	J/sm3		1.0 E+03	**Exact**
	megajoules per standard cubic meter	MJ/sm3	J/sm3		1.0 E+06	**Exact**
	British thermal unit	Btu/scf	J/sm3		(1.05505585262 / 0.02831685)	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	per standard cubic foot				E+03	
	kilo British thermal unit per standard cubic foot	kBtu/scf	J/sm3		(1.05505585262 / 0.02831685) E+06	**Exact**
	calorie per standard cubic meter	cal/sm3	J/sm3		4.1868	**Exact**
	kilocalorie per standard cubic meter	kcal/sm 3	J/sm3		4.1868 E+03	**Exact**
Energy per Normal Volume	joules per standard cubic meter	J/m3(n)				
	kilojoules per standard cubic meter	kJ/m3(n)	J/m3(n)	xu_J/m3n	1.0 E+03	**Exact**
	megajoules per standard cubic meter	MJ/m3(n)	J/m3(n)		1.0 E+06	**Exact**
	calorie per standard cubic meter	cal/m3(n)	J/m3(n)		4.1868	**Exact**
	kilocalorie per standard cubic meter	kcal/m3 (n)	J/m3(n)		4.1868 E+03	**Exact**
Factor	scaling value	Decimal				
	percent	%	Decimal		1.0 E-02	**Exact**
	parts per million	ppm	Decimal		1.0 E-06	**Exact**
Force	Newton	N				
	kilogram-force	kgf	N		9.80665	**Exact**
	pound-force	lbf	N		4.44822161526 05	**Exact**
Frequency	Hertz	Hz				

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
Heat Capacity per Mass	Joule per kilogram per degree Celsius	J/kg.°C		xu_J_kg.degC		
	Joule per kilogram per degree Celsius	kJ/kg.°C	J/kg.°C		1.0 E+03	**Exact**
	British thermal unit per pound (avoirdupois) per degree Fahrenheit	Btu/lbm .°F	J/kg. °C		4186.8	**Exact**
Heat Capacity per Mole	Joule per mole per degree Celsius	J/mol.°C				
	kilo Joule per kilo mole per degree Celsius	kJ/kmol. °C	J/mol.°C		1	**Exact**
	British thermal unit per mole per degree Fahrenheit	Btu/lbm ol.°F	J/mol.°C		2.326E+03 / 1.8	**Exact**
Kinematic Viscosity	square meter per second	m2/s				
	square millimeter per second	mm2/s	m2/s		1.0 E-06	**Exact**
	centistokes	cSt	m2/s		1.0 E-06	**Exact**
	stokes	St	m2/s		1.0 E-04	**Exact**
Length	meter	m				
	centimeter	cm	m		1.0 E-02	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	millimeter	mm	m		1.0 E-03	**Exact**
	kilometer	km	m		1.0 E+03	**Exact**
	micron	µ	m		1.0 E-06	**Exact**
	foot	ft	m		3.048 E-01	**Exact**
	inch	in	m		2.54 E-02	**Exact**
Length per Temperature	meter per degree Celsius	m/°C				
	meter per degree Fahrenheit	m/°F	m/°C		1.8	**Exact**
	centimeter per degree Celsius	cm/°C	m/°C		1.0 E-02	**Exact**
	centimeter per degree Fahrenheit	cm/°F	m/°C		1.8 E-02	**Exact**
	millimeter per degree Celsius	mm/°C	m/°C		1.0 E-03	**Exact**
	millimeter per degree Fahrenheit	mm/°F	m/°C		1.8 E-03	**Exact**
	feet per degree Celsius	ft/°C	m/°C		3.048 E-01	**Exact**
	feet per degree Fahrenheit	ft/°F	m/°C		5.4864 E-01	**Exact**
	inches per degree Celsius	in/°C	m/°C		2.54 E-02	**Exact**
	inches per degree Fahrenheit	in/°F	m/°C		4.572 E-02	**Exact**
Mass	kilogram	kg				
	gram	g	kg		1.0 E-03	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	milligram	mg	kg		1.0 E-06	**Exact**
	pound mass (avoirdupois)	lbm	kg		4.5359237 E-01	**Exact**
	kilopound mass (avoirdupois)	klbm	kg		4.5359237 E+02	**Exact**
	Million pound mass (avoirdupois)	Mlbm	kg		4.5359237 E+05	**Exact**
	metric ton	tonne	kg		1.0 E+03	**Exact**
	short ton (equals 2000 lb, also called tonUS)	short ton	kg		9.0718474 E+02	**Exact**
	long ton (equals 2240 lb, also called tonUK)	long ton	kg		1.016046909 E+03	**Exact**
Mass per Mass	mass fraction	mass/mass				
	mass percentage	%mass	mass/mass		1.0 E-02	**Exact**
Mass per Mole	kilograms per mole	kg/mol				
	kilograms per kilomole	kg/kmol	kg/mol		1.0 E-03	**Exact**
	grams per mole	g/mol	kg/mol		1.0 E-03	**Exact**
	pound per pound mole	lbm/lbmol	kg/mol		1.0 E-03	**Exact**
	kilopound per kilopound mole	klbm/klbmol	kg/mol		1.0 E-03	**Exact**
Mass per Pulse	kilograms per pulse	kg/pulse				
	grams per pulse	g/pulse	kg/pulse		1.0 E-03	**Exact**
	pounds mass per pulse	lbm/pulse	kg/pulse		4.535924 E-01	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
Mass per Time	kilogram per second	kg/s				
	kilogram per hour	kg/hr	kg/s		(1.0/3600)	**Exact**
	ton (metric) per hour	tonne/hr	kg/s		(1.0/3600) E+03	**Exact**
	ton (short) per hour	short ton/hr	kg/s		(9.071847/3600) E+02	**Exact**
	ton (long) per hour	long ton/hr	kg/s		(1.016046909/3600) E+03	**Exact**
	pound mass (avoirdupois) per second	lbm/s	kg/s		4.535924 E-01	**Exact**
	pound mass (avoirdupois) per hour	lbm/hr	kg/s		(4.535924/3600) E-01	**Exact**
	kilopound mass (avoirdupois) per hour	klbm/hr	kg/s		(4.535924/3600) E+02	**Exact**
	kilogram per day	kg/d	kg/s		(1.0/86400)	**Exact**
	ton (metric) per day	tonne/d	kg/s		(1.0/86400) E+03	**Exact**
	ton (short) per day	short ton/d	kg/s		(9.071847/86400) E+02	**Exact**
	ton (long) per day	long ton/d	kg/s		(1.016046909/86400) E+03	**Exact**
	pound mass (avoirdupois) per day	lbm/d	kg/s		(4.535924/86400) E-01	**Exact**
	kilopound mass (avoirdupois) per day	klbm/d	kg/s		(4.535924/86400) E+02	**Exact**
Mass per Volume	kilogram per cubic meter	kg/m3				
	gram per cubic centimeter	g/cm3	kg/m3		1.0 E03	**Exact**
	pound per cubic foot	lbm/ft3	kg/m3		1.601846337 E+01	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	API gravity [1]	°API	kg/m3		$\rho_{H2O,60°F}$ * 141.5 / (°API+131.5) [2]	**Exact** [3]
	Specific Gravity at 60 degrees Fahrenheit [1]	SG @ 60°F	kg/m3		$\rho_{H2O,60°F}$ [2]	**Exact** [3]
	Relative Density at 60 degrees Fahrenheit [1]	RD @ 60°F	kg/m3		$\rho_{H2O,60°F}$ [2]	**Exact** [3]
	[1] This conversion only applies when conversion is to /from the 'Mass per Volume' value at 60 °F [2] $\rho_{H2O,60°F}$ the density of water at 60 °F is a global setting with a default value of 999.012 kg/m3 [2] The conversion is exact, however the resulting value is an approximation because of $\rho_{H2O,60°F}$					
Mass per Standard Volume	kilogram per standard cubic meter	kg/sm3				
	gram per standard cubic centimeter	g/scm3	kg/sm3		1.0 E03	**Exact**
	pound per standard cubic foot	lbm/scf	kg/sm3		1.601846337 E+01	**Exact**
Mass per Normal	kilogram per normal cubic	kg/m3(n)				

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
Volume	meter					
	gram per normal cubic centimeter	g/cm3(n)	kg/m3(n)		1.0 E-03	**Exact**
Mole	mole A mole resembles 6.0251 x 10^23 molecules of a substance, a standard number of molecules known as Avogadro's number.	mol				
	kilomole	kmol	mol		1.0 E+03	**Exact**
	pound mole In English units, the pound-mass (lbm) is the standard unit of mass. In order to use the same molecular weights as those listed on the periodic chart, the pound-mol, (lbmol, sometimes lb-mol, lbm-mol, or lbm-mole) is defined	lbmol	mol		4.5359237 E-01	**Exact**
	kilopound mole	klbmol	mol		4.5359237 E+02	**Exact**
Mole per	mole fraction	mole/m				

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
Mole		ole				
	mole percentage	%mole	mole/mole		1.0 E-02	**Exact**
Mole per Volume	mole per cubic meter	mol/m³				
	mole per cubic centimeter	mol/cm³	mol/m³		1.0 E+6	**Exact**
	mole per litre	mol/l	mol/m³		1.0 E+3	**Exact**
	kilomole per cubic meter	kmol/m³	mol/m³		1.0 E+3	**Exact**
	kilomole per cubic centimeter	kmol/cm³	mol/m³		1.0 E+9	**Exact**
	kilomole per litre	kmol/l	mol/m³		1.0 E+6	**Exact**
	kilomole per cubic feet	kmol/ft³	mol/m³		1 / 28.31685 E -03	**Exact**
Power	watt	W				
	kilowatt	kW	W		1.0 E+03	**Exact**
	megawatt	MW	W		1.0 E+06	**Exact**
	gigawatt	GW	W		1.0 E+09	**Exact**
Pressure (differential)	pascal	Pa				
	kilo pascal	kPa	Pa		1.0 E+03	**Exact**
	kilogram-force per square meter	kgf/m2	Pa		9.80665	**Exact**
	kilogram-force per square centimeter	kgf/cm2	Pa		9.80665 E+04	**Exact**
	pound-force per square foot	lbf/ft2	Pa		47.8803	**Exact**
	pound-force	lbf/in2	Pa		6894.76	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	per square inch (psi)					
	pound-force per square inch (psi)	psi	Pa		6894.76	**Exact**
	bar	bar	Pa		1.0 E+05	**Exact**
	millibar	mbar	Pa		1.0 E+02	**Exact**
	millimeter of mercury, convential	mmHg	Pa		133.322387415	**Exact**
	millimeter of water, convential	mmH2O	Pa		9.80665	**Exact**
	millimeter of water @ 60°F	mmH2O @ 60°F	Pa		248.84/25.4	**Approximate**
	inch of mercury, convential	inHg con	Pa		3386.38864	**Exact**
	inch of mercury @ 32°F (0°C)	inHg @ 32°F	Pa		3386.38	**Approximate**
	inch of mercury @ 60°F	inHg @ 60°F	Pa		3376.85	**Approximate**
	inch of water, convential	inH2O con	Pa		249.08891	**Exact**
	inch of water @ 39.2°F (4°C)	inH2O @ 39.2°F	Pa		249.082	**Approximate**
	inch of water @ 60°F	inH2O @ 60°F	Pa		248.84	**Approximate**
	inch of water @ 68°F	inH2O @ 68°F	Pa		248.64108	**Approximate**
Pressure (absolute)	pascal absolute	Pa(a)				
	kilo pascal absolute	kPa(a)	Pa(a)		1.0 E+03	**Exact**
	pound-force per square inch (psi) absolute	psia	Pa(a)		6894.76	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	bar absolute	bar(a)	Pa(a)		1.0 E+05	**Exact**
	millibar absolute	mbar(a)	Pa(a)		1.0 E+02	**Exact**
	millimeter of mercury, convential absolute	mmHga	Pa(a)		133.322387415	**Exact**
	millimeter of water, convential absolute	mmH2O a	Pa(a)		9.80665	**Exact**
	millimeter of water @ 60°F absolute	mmH2O a @ 60°F	Pa(a)		248.84/25.4	**Approximat e**
	inch of mercury, convential absolute	inHga con	Pa(a)		3386.38864	**Exact**
	inch of mercury @ 32°F (0°C) absolute	inHga @ 32°F	Pa(a)		3386.38	**Approximat e**
	inch of mercury @ 60°F absolute	inHga @ 60°F	Pa(a)		3376.85	**Approximat e**
	inch of water, convential absolute	inH2Oa con	Pa(a)		249.08891	**Exact**
	inch of water @ 39.2°F (4°C) absolute	inH2Oa @ 39.2°F	Pa(a)		249.082	**Approximat e**
	inch of water @ 60°F absolute	inH2Oa @ 60°F	Pa(a)		248.84	**Approximat e**
	inch of water @ 68°F absolute	inH2Oa @ 68°F	Pa(a)		248.64107	**Approximat e**
Pressure (gauge)	pascal gauge	Pa(g)				
	kilo pascal gauge	kPa(g)	Pa(g)		1.0 E+03	**Exact**
	pound-force per square inch (psi)	psig	Pa(g)		6894.76	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	gauge					
	bar gauge	bar(g)	Pa(g)		1.0 E+05	**Exact**
	millibar gauge	mbar(g)	Pa(g)		1.0 E+02	**Exact**
	millimeter of mercury, convential gauge	mmHgg	Pa(g)		133.322387415	**Exact**
	millimeter of water, convential gauge	mmH2O g	Pa(g)		9.80665	**Exact**
	millimeter of water @ 60°F gauge	mmH2O g @ 60°F	Pa(g)		248.84/25.4	**Approximate**
	inch of mercury, convential gauge	inHgg con	Pa(g)		3386.38864	**Exact**
	inch of mercury @ 32°F (0°C) gauge	inHgg @ 32°F	Pa(g)		3386.38	**Approximate**
	inch of mercury @ 60°F gauge	inHgg @ 60°F	Pa(g)		3376.85	**Approximate**
	inch of water, convential gauge	inH2Og con	Pa(g)		249.08891	**Exact**
	inch of water @ 39.2°F (4°C) gauge	inH2Og @ 39.2°F	Pa(g)		249.082	**Approximate**
	inch of water @ 60°F gauge	inH2Og @ 60°F	Pa(g)		248.84	**Approximate**
Pressure inverse	per pascal	1/Pa				
	per kilo pascal	1/kPa	1/Pa		1.0 E-03	**Exact**
	per Mega pascal	1/MPa	1/Pa		1.0 E-06	
	per pound-force per square inch (psi)	1/psi	1/Pa		1/6894.76	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	per bar	1/bar	1/Pa		1.0 E-05	**Exact**
Pressure per Mass	pascals per kilogram	Pa/kg				
	kilopascals per kilogram	kPa/kg	Pa/kg		1.0 E+03	**Exact**
	megapascals per kilogram	MPa/kg	Pa/kg		1.0 E+06	**Exact**
	pounds mass (avoirdupois) per square inch per kilogram	psi/kg	Pa/kg		6894.76	**Exact**
	bar per per kilogram	bar/kg	Pa/kg		1.0 E+05	**Exact**
Pulses per Mass	pulses per kilogram	pulses/kg				
	pulses per gram	pulses/g	pulses/kg		1.0 E+03	**Exact**
	pulses per pound mass (avoirdupois)	pulses/lbm	pulses/kg		1/0.4535924	**Exact**
Pulses per Volume	pulses per cubic meter	pulses/m3				
	pulses per cubic centimeter	pulses/cm3	pulses/m3		1.0 E-06	**Exact**
	pulses per litre	pulses/lb	pulses/m3		1.0 E-03	**Exact**
	pulses per cubic inch	pulses/in	pulses/m3		1/0.0000163871	**Exact**
	pulses per cubic feet	pulses/ft3	pulses/m3		1/0.0283168	**Exact**
Temperature	Kelvin	K				
	degree Celsius	°C	K		T[K] = t[°C] + 273.15	**Exact**
	degree Fahrenheit	°F	K		T[K] = (t[°F] + 459.67)/1.8	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	Rankine	R	K		T[K] = T[R]/1.8	**Exact**
Temperature inverse	per Kelvin	1/K				
	per degree Celsius	1/°C	1/K		1.0	**Exact**
	per degree Fahrenheit	1/°F	1/K		1.8	**Exact**
	per Rankine	1/R	1/K		1.8	**Exact**
Temperature per Pressure	degree Celsius per bar (Joule-Thomson coefficient)	°C/bar				
		°F/psi	°C/bar		1.8/6894.76	**Exact**
Time	second	s				
	milli second	ms	s		1.0 E-03	**Exact**
	micro second	µs	s		1.0 E-06	**Exact**
	nano second	ns	s		1.0 E-09	**Exact**
	minute	min	s		6.0 E+01	**Exact**
	hour	H	s		3.6 E+03	**Exact**
	day	D	s		8.64 E+04	**Exact**
Velocity	meters per second	m/s				
	kilometers per second	km/s	m/s		1.0 E+03	**Exact**
	kilometers per hour	km/hr	m/s		(1/3600) E+03	**Exact**
	foot per second	ft/s	m/s		3.048 E-01	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
Volume	cubic meter	m3				
	cubic centimeter	cm3	m3		1.0 E-06	**Exact**
	kilo cubic meter	km3	m3		1.0 E+03	**Exact**
	mega cubic meter	Mm3	m3		1.0 E+06	**Exact**
	liter	L	m3		1.0 E-03	**Exact**
	cubic inch	in3	m3		16.38706 E+06	**Exact**
	cubic foot	ft3	m3		28.31685 E -03	**Exact**
	kilo cubic foot	kft3	m3		28.31685	**Exact**
	million cubic foot	MMft3	m3		28.31685 E +03	**Exact**
	barrel (42 US liquid gallons exactly)	bbl	m3		0.158987295	**Exact**
	US liquid gallon (231 cubic inches exactly)	US.gal	m3		3.785411784 E-03	**Exact**
	Imperial (U.K.) gallon	UK.gal	m3		4.54609 E-03	**Exact**
Standard Volume	standard cubic meter	sm3				
	kilo standard cubic meter	ksm3	sm3		1.0 E+03	**Exact**
	mega standard cubic meter	Msm3	sm3		1.0 E+06	**Exact**
	standard cubic foot	scf	sm3		28.31685 E -03	**Exact**
	kilo standard cubic foot	kscf	sm3		28.31685	**Exact**
	million standard cubic foot	MMscf	sm3		28.31685 E +03	**Exact**
	barrel (standard)	bbl (s)	sm3		0.158987295	**Exact**
Normal	normal cubic	m3(n)				

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
Volume	meter					
	kilo normal cubic meter	km3(n)	m3(n)		1.0 E+03	**Exact**
	mega normal cubic meter	Mm3(n)	m3(n)		1.0 E+06	**Exact**
Volume per Volume	volume fraction	vol/vol				
	volume percentage	%vol	vol/vol		1.0 E-02	**Exact**
Volume per Pulse	cubic meters per pulse	m3/puls e				
	cubic centimeters per pulse	cm3/pul se	m3/pulse		1.0 E-06	**Exact**
	litres per pulse	l/pulse	m3/pulse		1.0 E-03	**Exact**
	cubic inches per pulse	in3/puls e	m3/pulse		1.63871E-05	**Exact**
	cubic feet per pulse	ft3/puls e	m3/pulse		0.0283168	**Exact**
Volume per Time	cubic meter per second	m3/s				
	cubic meter per hour	m3/hr	m3/s		1/3600	**Exact**
	cubic meter per day	m3/d	m3/s		1/86400	**Exact**
	kilo cubic meter per second	km3/s	m3/s		1.0 E+03	**Exact**
	kilo cubic meter per hour	km3/hr	m3/s		(1/3600) E+03	**Exact**
	kilo cubic meter per day	km3/d	m3/s		(1/86400) E+03	**Exact**
	mega cubic meter per hour	Mm3/hr	m3/s		(1/3600) E+06	**Exact**
	mega cubic meter per	Mm3/d	m3/s		(1/86400) E+06	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	day					
	cubic feet per hour	ft3/hr	m3/s		0.02831685/3600	**Exact**
	cubic feet per day	ft3/d	m3/s		0.02831685/86400	**Exact**
	kilo cubic feet per hour	kft3/hr	m3/s		28.31685/3600	**Exact**
	kilo cubic feet per day	kft3/d	m3/s		28.31685/86400	**Exact**
	million cubic feet per hour	Mft3/hr	m3/s		28316.85/3600	**Exact**
	million cubic feet per day	Mft3/d	m3/s		28316.85/86400	**Exact**
	barrels per hour	bbl/hr	m3/s		0.158987295/3600	**Exact**
	barrels per day	bbl/d	m3/s		0.158987295/86400	**Exact**
Standard Volume per Time	standard cubic meter per second	sm3/s				
	standard cubic meter per hour	sm3/hr	sm3/s		1/3600	**Exact**
	standard cubic meter per day	sm3/d	sm3/s		1/86400	**Exact**
	kilo standard cubic meter per second	ksm3/s	sm3/s		1.0 E+03	**Exact**
	kilo standard cubic meter per hour	ksm3/hr	sm3/s		(1/3600) E+03	**Exact**
	kilo standard cubic meter per day	ksm3/d	sm3/s		(1/86400) E+03	**Exact**
	mega standard cubic meter per hour	Msm3/hr	sm3/s		(1/3600) E+06	**Exact**
	mega standard cubic meter per day	Msm3/d	sm3/s		(1/86400) E+06	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	standard cubic feet per hour	scf/hr	sm3/s		0.02831685/3600	**Exact**
	standard cubic feet per day	scf/d	sm3/s		0.02831685/86400	**Exact**
	kilo standard cubic feet per hour	kscf/hr	sm3/s		28.31685/3600	**Exact**
	kilo standard cubic feet per day	kscf/d	sm3/s		28.31685/86400	**Exact**
	million standard cubic feet per hour	MMscf/hr	sm3/s		28316.85/3600	**Exact**
	million standard cubic feet per day	MMscf/d	sm3/s		28316.85/86400	**Exact**
	barrels per hour (standard)	bbl/hr	sm3/s		0.158987295/3600	**Exact**
	barrels per day (standard)	bbl/d	sm3/s		0.158987295/86400	**Exact**
Normal Volume per Time	normal cubic meter per second	m3(n)/s				
	normal cubic meter per hour	m3(n)/hr	m3(n)/s		1/3600	**Exact**
	normal cubic meter per day	m3(n)/d	m3(n)/s		1/86400	**Exact**
	kilo normal cubic meter per second	km3(n)/s	m3(n)/s		1.0 E+03	**Exact**
	kilo normal cubic meter per hour	km3(n)/hr	m3(n)/s		(1/3600) E+03	**Exact**
	kilo normal cubic meter per day	km3(n)/d	m3(n)/s		(1/86400) E+03	**Exact**

Type of unit	Description	Unit	Convert to	Excel constant	Multiply by	Conversion
	mega normal cubic meter per hour	Mm3(n) /hr	m3(n)/s		(1/3600) E+06	**Exact**
	mega normal cubic meter per day	Mm3(n) /d	m3(n)/s		(1/86400) E+06	**Exact**

Terminology

Term	Description	Same as
Heating Value	Usually the same as Gross Heating Value	
Calorific Value	Usually the same as Superior Calorific Value	
Superior Calorific Value	Heating value when assuming that water formed at the combustion stays in the gaseous state. From ISO6976.	Gross Heating Value
Inferior Calorific Value	Heating value when assuming that water formed at the combustion has totally condensed to the liquid state. From ISO6976.	Net Heating Value
Gross Heating Value	Heating value when assuming that water formed at the combustion stays in the gaseous state Term used in GPA2172.	Superior Calorific Value
Net Heating Value	Heating value when assuming that water formed at the combustion has totally condensed to the liquid state. Term used in GPA2172.	Inferior Calorific Value
Molar Mass Ratio	Ratio of molar mass of gas and molar mass of air at the base conditions	Specific Gravity Ideal Specific Gravity Ideal Relative Density
Relative Density	Ratio of real mass density of gas and real mass density of air at the base conditions	Real Relative Density Real Specific Gravity
Specific Gravity	Ratio of real mass density of gas and real density of air at the base conditions	Molar Mass Ratio Ideal Specific Gravity Ideal Relative Density

Standard composition

The Standard Composition is a standard array of mole fractional values that is used by all functions that require a (partial) compositional analysis.
The following table defines the sequence of the components and also defines which function uses which component.

Component	Used in AGA8 / AGA10	Used in ISO6976	Used in GPA2172	Used in AGA5
Methane	√	√	√	
Nitrogen	√	√	√	√
Carbon Dioxide	√	√	√	√
Ethane	√	√	√	
Propane	√	√	√	
Water	√	√	2)	√
Hydrogen Sulphide	√	√	√	√
Hydrogen	√	√		√
Carbon Monoxide	√	√		√
Oxygen	√	√	√	√
i-Butane	√	√	√	
n-Butane	√	√	√	
i-Pentane	√	√	√	
n-Pentane	√	√	√	
n-Hexane	√	√	√	
n-Heptane	√	√	√	
n-Octane	√	√	√	
n-Nonane	√	√	√	
n-Decane	√	√	√	
Helium	√	√	√	√
Argon	√	√		
Neo-Pentane	(1)	√	(1)	

1) Depending on function input 'Neo-Pentane mode' the value is added to i-Pentane or n-Pentane or it is neglected.
2) GPA2172 uses the specified water fraction for wet gas calculation only.

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