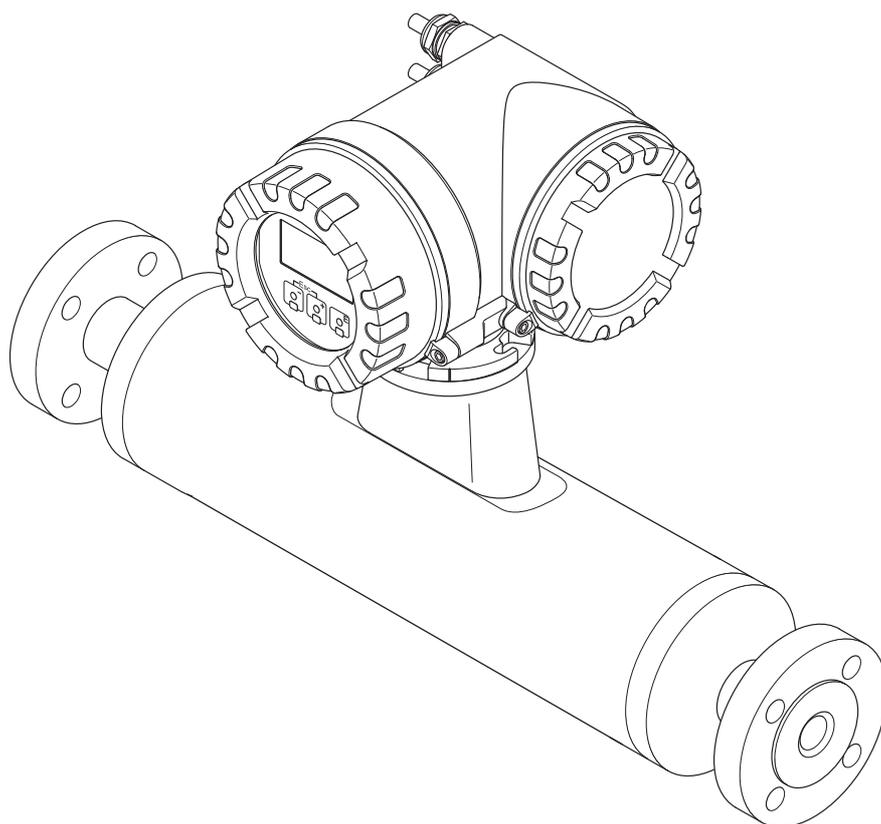


Special documentation for viscosity measurement

Proline Promass 83I

Coriolis Mass Flow Measuring System



SD102D/06/en/07.08
71079004

Valid as of version:
V 2.00.XX (Device software)

Endress+Hauser 

People for Process Automation

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1 Parameters for viscosity measurement

1.1 General

1.1.1 The optional “viscosity” software package

With the optional “viscosity” software package, you can perform various viscosity measurements for liquids. This Special Documentation describes the additional functions that are available with the “viscosity” software package.

The Special Documentation is an integral part of the Operating Instructions “Proline Promass 83” (BA059D/06/en) and the “Proline Promass 83, Description of Device Functions” manual (BA060D/06/en) and may only be used in conjunction with these documents.

1.2 Functions for viscosity measurement

With the optional “viscosity” software package, you can perform the following viscosity measurements for liquids.

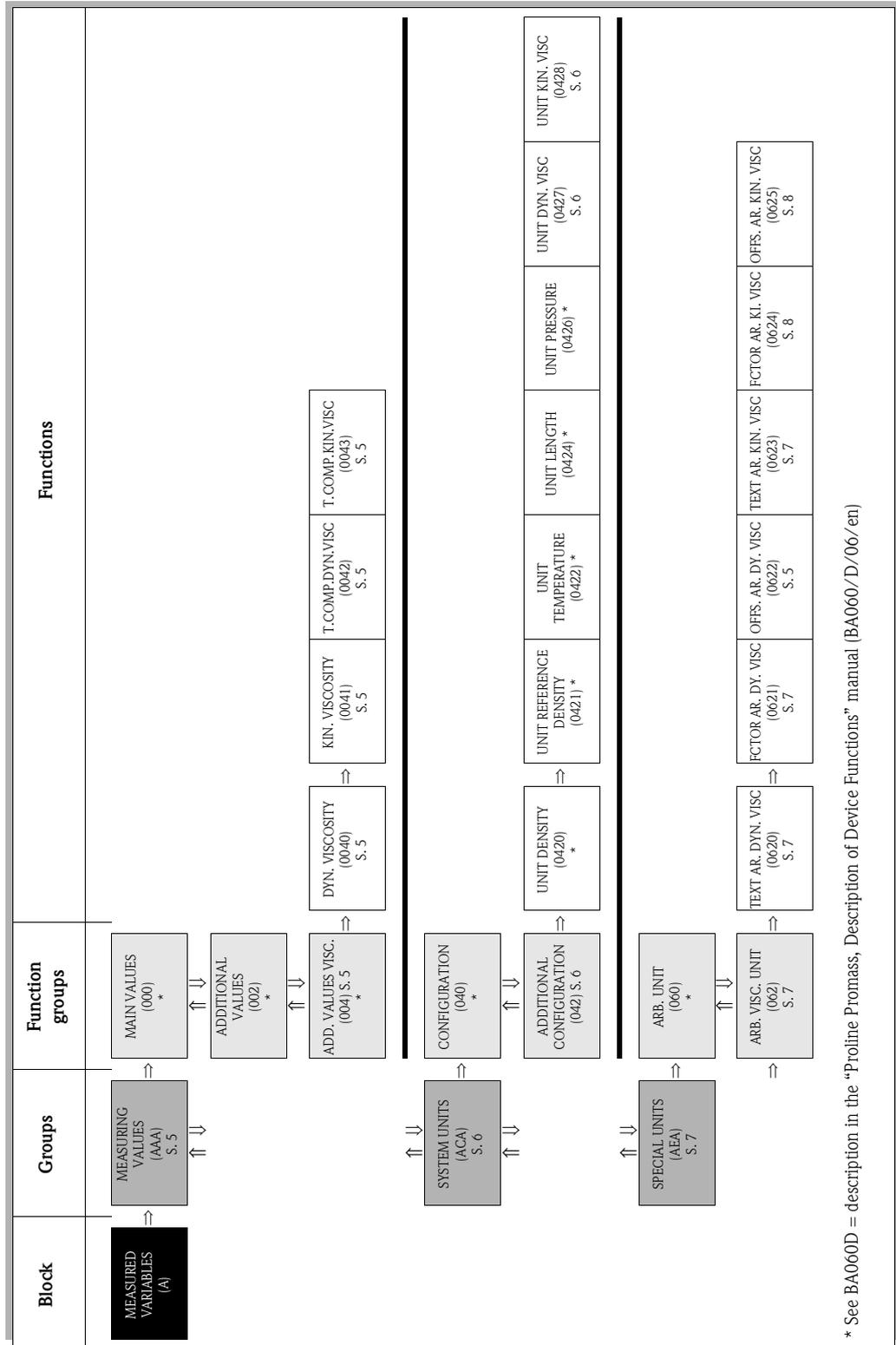
- Dynamic viscosity
- Kinematic viscosity
- Temperature-compensated viscosity (related to reference temperature)

In addition, the “viscosity” software package also enables commissioning of all functions relevant for viscosity measurement by means of a “Quick Setup”, assign user-defined units and to output the measured variable directly via an output or as a limit value.

A description of all the additional functions available is provided on the following pages. The structure of this document follows that of the “Proline Promass 83, Description of Device Functions” manual (BA060D/06/en) and is split into Blocks → Groups → Function Groups → Functions

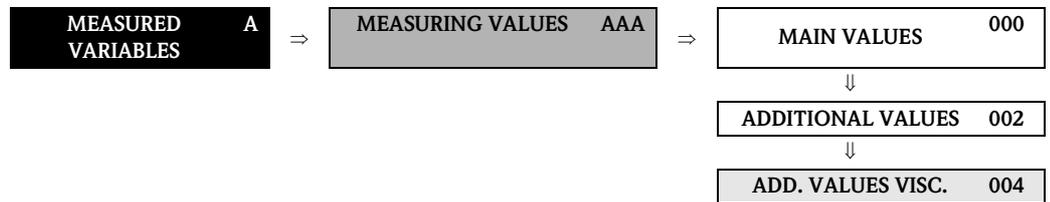
Please note that all the functions not relevant to viscosity are described in the “Proline Promass 83, Description of Device Functions” manual (BA060D/06/en).

2 Block MEASURED VARIABLES



2.1 Group MEASURING VALUES

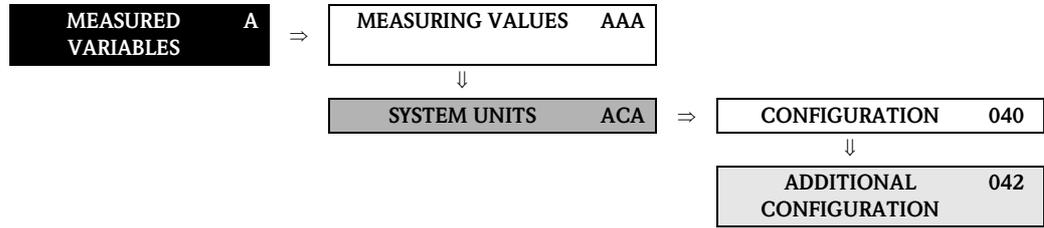
2.1.1 Function group ADD. VALUES VISC.



Functional description MEASURED VARIABLES → MEASURING VALUES → ADD. VALUES VISC.	
DYNAMIC VISCOSITY (0040)	<p>Use this function to display the dynamic viscosity.</p> <p>Display: 5-digit floating-point number, incl. unit. (e.g. 462.87 cP; 731.63 mPa·s etc.)</p>
KINEMATIC VISCOSITY (0041)	<p>Use this function to display the calculated kinematic viscosity.</p> <p>Display: 5-digit floating-point number, incl. unit. (e.g. 5.5445 mm²/s; 1.4359 cSt)</p>
TEMPERATURE COMPENSATED DYNAMIC VISCOSITY (0042)	<p>Use this function to display the temperature-compensated dynamic viscosity.</p> <p>Display: 5-digit floating-point number, incl. unit. (e.g. 462.87 cP; 731.63 mPa·s etc.)</p>
TEMPERATURE COMPENSATED KINEMATIC VISCOSITY (0043)	<p>Use this function to display the temperature-compensated kinematic viscosity.</p> <p>Display: 5-digit floating-point number, incl. unit. (e.g. 5.5445 mm²/s; 1.4359 cSt)</p>

2.2 Group SYSTEM UNITS

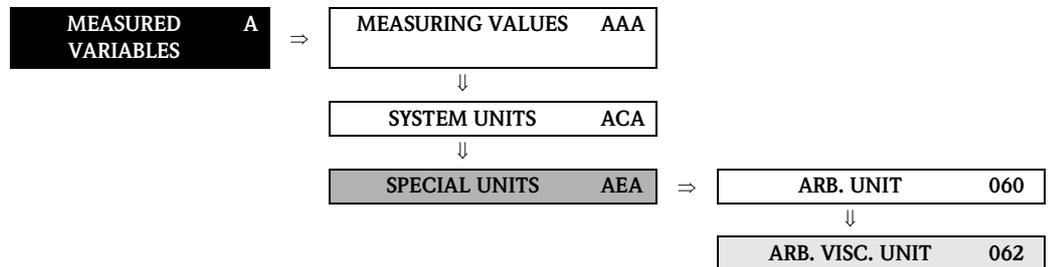
2.2.1 Function group ADDITIONAL CONFIGURATION



Functional description	
MEASURED VARIABLES → SYSTEM UNITS → ADDITIONAL CONFIGURATION	
UNIT DYNAMIC VISCOSITY (0427)	Use this function to select the desired unit displayed for the dynamic viscosity measurement. Options: <ul style="list-style-type: none"> ■ Pa·s ■ mPa·s ■ P ■ cP Factory setting: cP
UNIT KINEMATIC VISCOSITY (0428)	Use this function to select the desired unit displayed for the kinematic viscosity measurement. Options: <ul style="list-style-type: none"> ■ m²/s ■ mm²/s ■ St ■ cSt Factory setting: cSt

2.3 Group SPECIAL UNITS

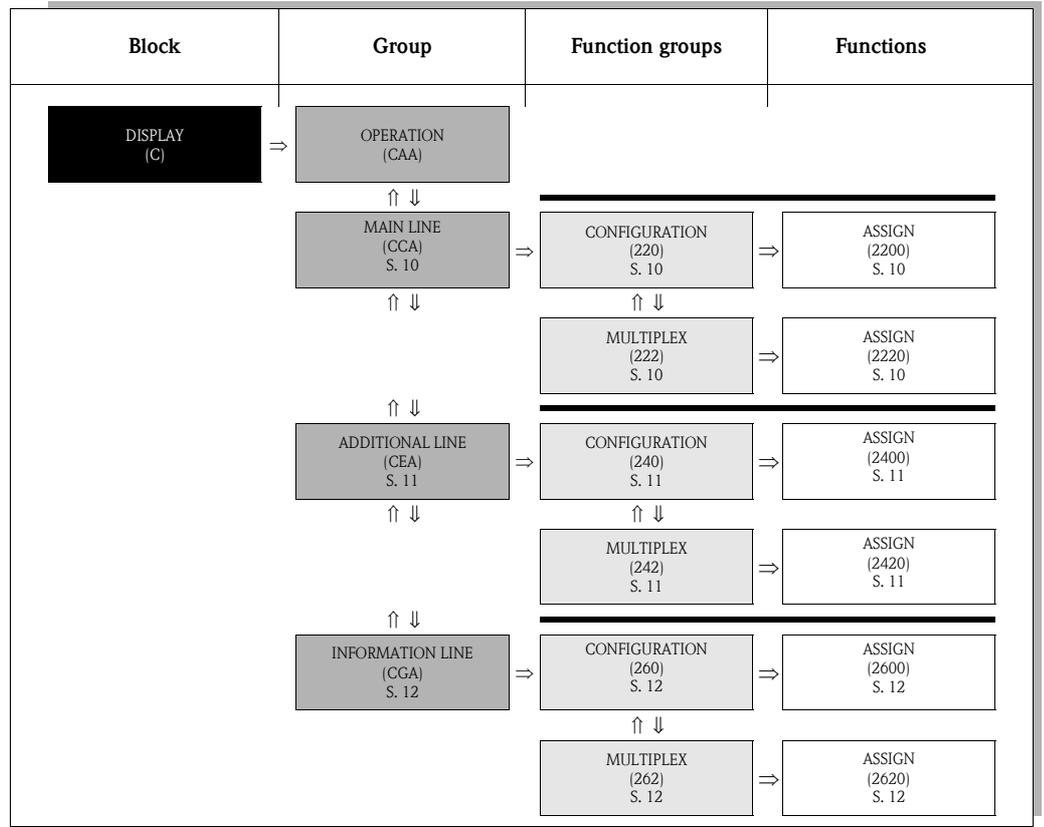
2.3.1 Function group ARB. UNIT



Functional description MEASURED VARIABLES → SPECIAL UNITS → ARB. VISC. UNIT	
TEXT ARBITRARY UNIT FOR DYNAMIC VISCOSITY (0620)	<p>Use this function to select the arbitrary unit for dynamic viscosity.</p> <p>Input: xxxx (max. 4 digits) Every one of the digit spaces can be assigned A-Z, 0-9, +, -, period, space or underscore</p> <p>Factory setting: “----” (no text)</p>
FACTOR ARBITRARY UNIT FOR DYNAMIC VISCOSITY (0621)	<p>Use this function to select the quantity factor for the arbitrary unit for dynamic viscosity.</p> <p>Input: 7-digit floating-point number</p> <p>Factory setting: 1</p> <p>Reference value: This factor refers to a dynamic viscosity of 1 Pa·s.</p>
OFFSET ARBITRARY UNIT FOR DYNAMIC VISCOSITY (0622)	<p>Use this function to add or subtract an offset value to/from the measured value of the dynamic viscosity.</p> <p>Input: 7-digit floating-point number</p> <p>Factory setting: 0</p> <p>Reference value: This offset refers to a dynamic viscosity of 1 Pa·s.</p>
TEXT ARBITRARY UNIT FOR KINEMATIC VISCOSITY (0623)	<p>Use this function to select a text for the arbitrary unit for kinematic viscosity.</p> <p>Input: xxxx (max. 4 digits) Every one of the digit spaces can be assigned A-Z, 0-9, +, -, period, space or underscore</p> <p>Factory setting: “----” (no text)</p>

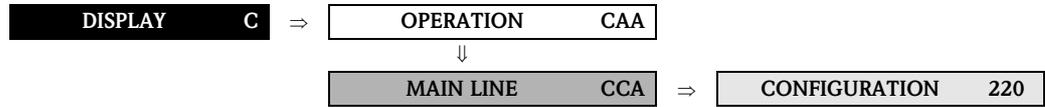
Functional description	
MEASURED VARIABLES → SPECIAL UNITS → ARB. VISC. UNIT	
FACTOR ARBITRARY UNIT FOR KINEMATIC VISCOSITY (0624)	<p>Use this function to select a quantity factor for the arbitrary unit for kinematic viscosity.</p> <p>Input: 7-digit floating-point number</p> <p>Factory setting: 1</p> <p>Reference value: This factor refers to a kinematic viscosity of 1 m²/s.</p>
OFFSET ARBITRARY UNIT FOR KINEMATIC VISCOSITY (0625)	<p>Use this function to add or subtract an offset value to/from the measured value of the kinematic viscosity.</p> <p>Input: 7-digit floating-point number</p> <p>Factory setting: 0</p> <p>Reference value: This offset refers to a kinematic viscosity of 1 m²/s.</p>

3 Block DISPLAY



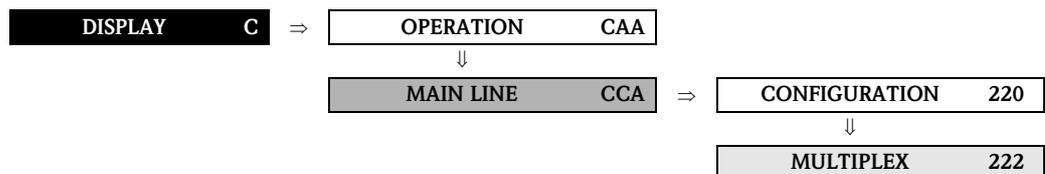
3.1 Group MAIN LINE

3.1.1 Function group CONFIGURATION



Functional description DISPLAY → MAIN LINE → CONFIGURATION	
<p>1 = main line, 2 = additional line, 3 = information line</p> <p style="text-align: right;">A0001253</p>	
ASSIGN (2200)	<p>Use this function to assign a display value to the main line (top line of the onsite display). This value is displayed during normal operation.</p> <p>Extended options with the optional VISCOSITY software package: DYNAMIC VISCOSITY KINEMATIC VISCOSITY TEMPERATURE COMPENSATED DYNAMIC VISCOSITY TEMPERATURE COMPENSATED KINEMATIC VISCOSITY</p> <p> Note! The options in the VISCOSITY software package are an addition to: Display Block → Main Line Group → Configuration Function Group → Assign Function (see “Proline Promass 83, Description of Device Functions” manual, (BA060D/06/en/)).</p>

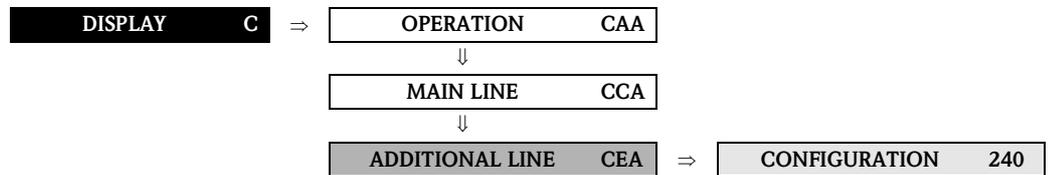
3.1.2 Function group MULTIPLEX



Functional description DISPLAY → MAIN LINE → MULTIPLEX	
ASSIGN (2220)	<p>Use this function to define a second display value that is displayed on the main line, alternating (every 10 seconds) with the display value from the ASSIGN (2200) function.</p> <p>Extended options with the optional VISCOSITY software package: DYNAMIC VISCOSITY KINEMATIC VISCOSITY TEMPERATURE COMPENSATED DYNAMIC VISCOSITY TEMPERATURE COMPENSATED KINEMATIC VISCOSITY</p> <p> Note! The options in the VISCOSITY software package are an addition to: Display Block → Main Line Group → Multiplex Function Group → Assign Function (see “Proline Promass 83, Description of Device Functions” manual, (BA060D/06/en/)).</p>

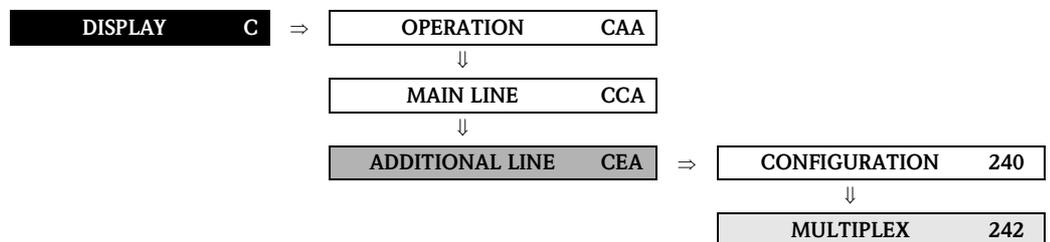
3.2 Group ADDITIONAL LINE

3.2.1 Function group CONFIGURATION



Functional description	
DISPLAY → ADDITIONAL LINE → CONFIGURATION	
ASSIGN (2400)	<p>Use this function to assign a display value to the additional line (middle line of the onsite display). This value is displayed during normal operation.</p> <p>Extended options with the optional VISCOSITY software package: DYNAMIC VISCOSITY KINEMATIC VISCOSITY TEMPERATURE COMPENSATED DYNAMIC VISCOSITY TEMPERATURE COMPENSATED KINEMATIC VISCOSITY</p> <p> Note! The options in the VISCOSITY software package are an addition to: Display Block → Additional Line Group → Configuration Function Group → Assign Function (see “Proline Promass 83, Description of Device Functions” manual, (BA060D/06/en/)).</p>

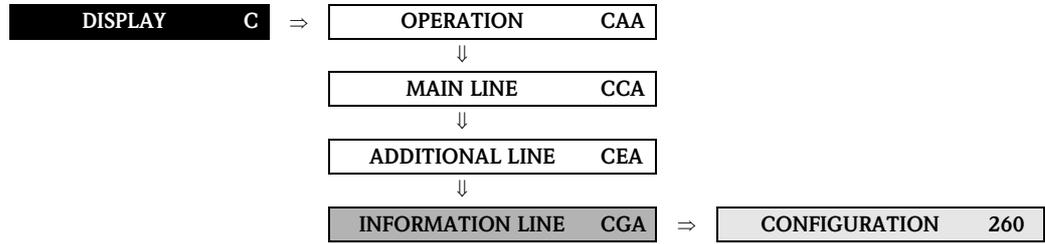
3.2.2 Function group MULTIPLEX



Functional description	
DISPLAY → ADDITIONAL LINE → MULTIPLEX	
ASSIGN (2420)	<p>Use this function to define a second display value that is displayed on the additional line, alternating (every 10 seconds) with the display value from the ASSIGN (2400) function.</p> <p>Extended options with the optional VISCOSITY software package: LIMIT VALUE DYNAMIC VISCOSITY LIMIT VALUE KINEMATIC VISCOSITY LIMIT VALUE TEMPERATURE COMPENSATED DYNAMIC VISCOSITY LIMIT VALUE TEMPERATURE COMPENSATED KINEMATIC VISCOSITY</p> <p> Note! The options in the VISCOSITY software package are an addition to: Display Block → Additional Line Group → Multiplex Function Group → Assign Function (see “Proline Promass 83, Description of Device Functions” manual, (BA060D/06/en/)).</p>

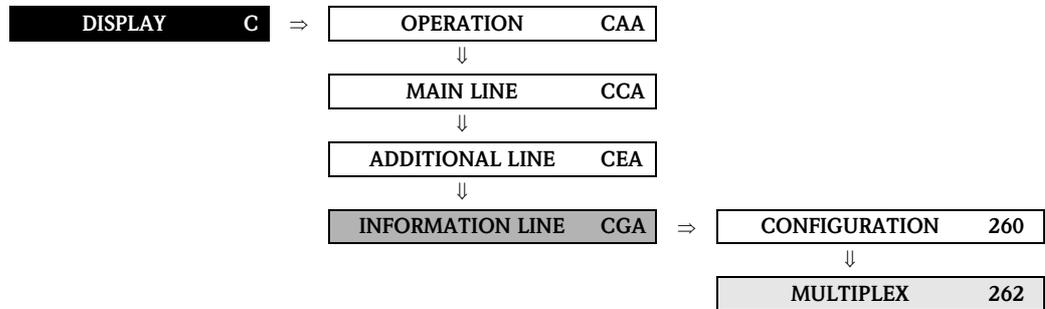
3.3 Group INFORMATION LINE

3.3.1 Function group CONFIGURATION



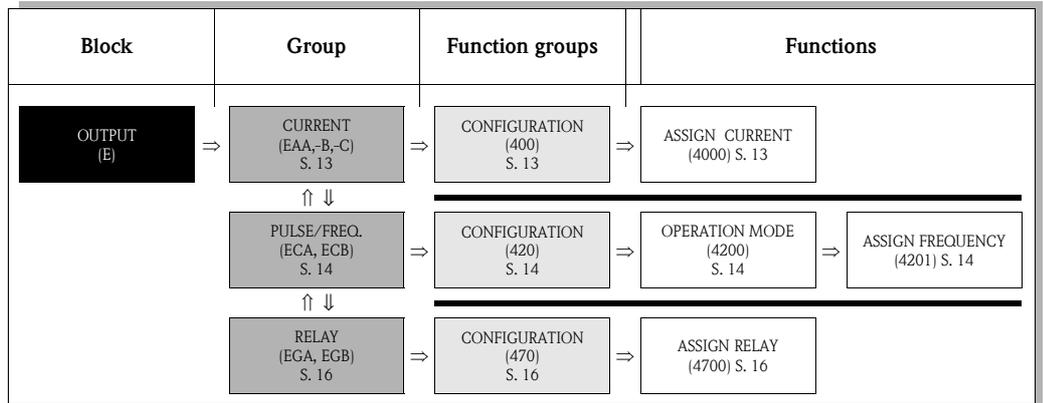
Functional description	
DISPLAY → INFORMATION LINE → CONFIGURATION	
ASSIGN (2600)	<p>Use this function to assign a display value to the information line (bottom line of the onsite display). This value is displayed during normal operation.</p> <p>Extended options with the optional VISCOSITY software package: DYNAMIC VISCOSITY KINEMATIC VISCOSITY TEMPERATURE COMPENSATED DYNAMIC VISCOSITY TEMPERATURE COMPENSATED KINEMATIC VISCOSITY</p> <p> Note! The options in the VISCOSITY software package are an addition to: Display Block → Information Line Group → Configuration Function Group → Assign Function (see “Proline Promass 83, Description of Device Functions” manual, (BA060D/06/en/)).</p>

3.3.2 Function group MULTIPLEX



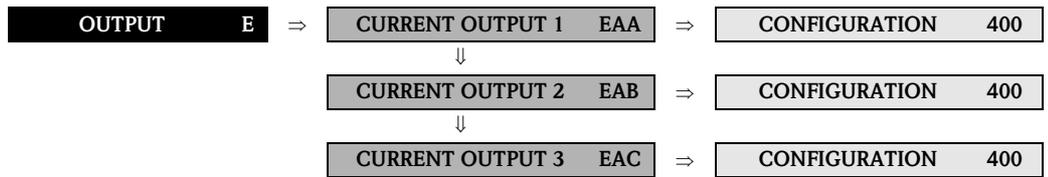
Functional description	
DISPLAY → INFORMATION LINE → MULTIPLEX	
ASSIGN (2620)	<p>Use this function to define a second display value that is displayed on the information line, alternating (every 10 seconds) with the display value from the ASSIGN (2600) function.</p> <p>Extended options with the optional VISCOSITY software package: DYNAMIC VISCOSITY KINEMATIC VISCOSITY TEMPERATURE COMPENSATED DYNAMIC VISCOSITY TEMPERATURE COMPENSATED KINEMATIC VISCOSITY</p> <p> Note! The options in the VISCOSITY software package are an addition to: Display Block → Information Line Group → Multiplex Function Group → Assign Function (see “Proline Promass 83, Description of Device Functions” manual, (BA060D/06/en/)).</p>

4 Block OUTPUT



4.1 Group CURRENT OUTPUT (1...3)

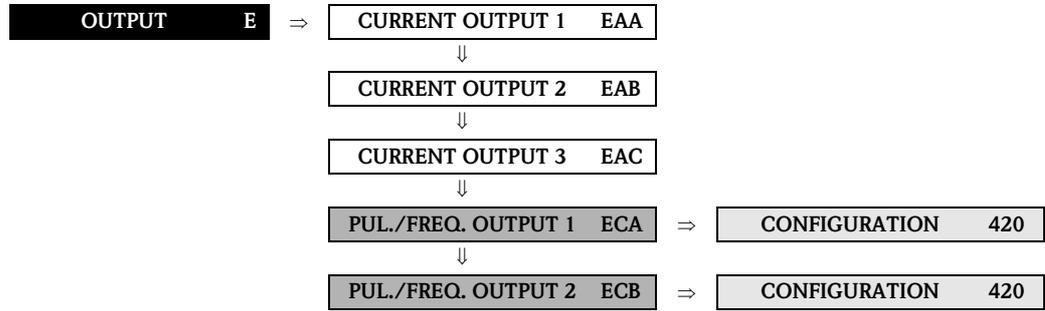
4.1.1 Function group CONFIGURATION



Functional description	
OUTPUT → CURRENT OUTPUT (1...3) → CONFIGURATION	
ASSIGN CURRENT OUTPUT (4000)	<p>Use this function to assign a measured variable to the current output.</p> <p>Extended options with the optional VISCOSITY software package: DYNAMIC VISCOSITY KINEMATIC VISCOSITY TEMPERATURE COMPENSATED DYNAMIC VISCOSITY TEMPERATURE COMPENSATED KINEMATIC VISCOSITY</p> <p> Note! The options in the VISCOSITY software package are an addition to: Output Block → Current Output (1...3) Group → Configuration Function Group → Assign Current Output Function (see “Proline Promass 83, Description of Device Functions” manual, (BA060D/06/en/)).</p>

4.2 Group PULSE/FREQUENCY OUTPUT (1...2)

4.2.1 Function group CONFIGURATION

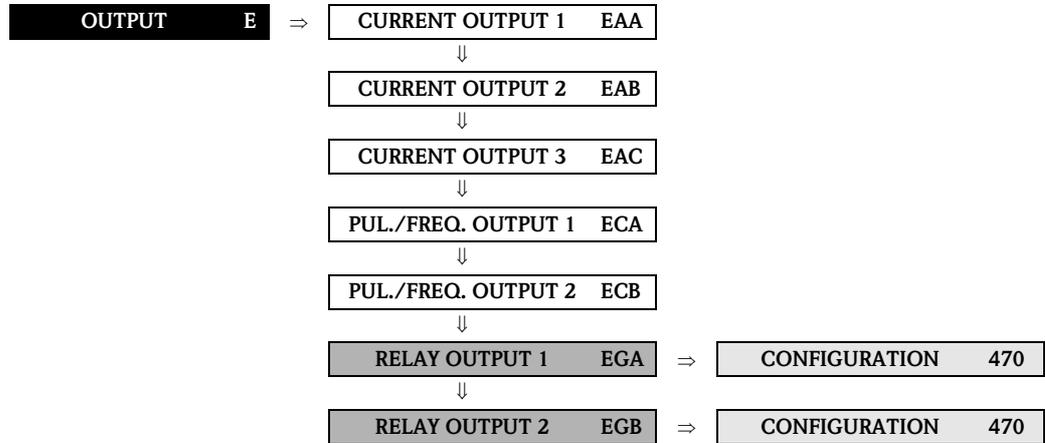


Functional description	
OUTPUT → PULSE/FREQUENCY OUTPUT (1...2) → CONFIGURATION (GENERAL)	
OPERATION MODE (4200)	<p>Use this function to configure the output as a pulse, frequency or status output. Depending on the option selected here, different functions are available in this function group.</p> <p>Options: PULSE FREQUENCY STATUS</p> <p>Factory setting: PULSE</p>
ASSIGN FREQUENCY (4201)	<p> Note! This function is not available unless the FREQUENCY option was selected in the OPERATION MODE function (4200).</p> <p>Use this function to assign a measured variable to the frequency output.</p> <p>Extended options with the optional VISCOSITY software package: DYNAMIC VISCOSITY KINEMATIC VISCOSITY TEMPERATURE COMPENSATED DYNAMIC VISCOSITY TEMPERATURE COMPENSATED KINEMATIC VISCOSITY</p> <p> Note!</p> <ul style="list-style-type: none"> ■ If OFF is selected, the CONFIGURATION function group only displays this function, ASSIGN FREQUENCY (4201). ■ The options in the VISCOSITY software package are an addition to: Output Block → Pulse/Frequency Output Group → Configuration Function Group → Assign Frequency Function (see “Proline Promass 83, Description of Device Functions” manual, (BA060D/06/en/)).

Functional description	
OUTPUT → PULSE/FREQUENCY OUTPUT (1...2) → CONFIGURATION (GENERAL)	
ASSIGN STATUS (4241)	<p> Note! This function is not available unless the STATUS option was selected in the OPERATION MODE function (4200).</p> <p>Use this function to assign a switch function to the status output.</p> <p>Extended options with the optional VISCOSITY software package: LIMIT VALUE DYNAMIC VISCOSITY LIMIT VALUE KINEMATIC VISCOSITY LIMIT VALUE TEMPERATURE COMPENSATED DYNAMIC VISCOSITY LIMIT VALUE TEMPERATURE COMPENSATED KINEMATIC VISCOSITY</p> <p> Note!</p> <ul style="list-style-type: none"> ■ The switching behavior options for this function in the VISCOSITY software package are an addition to: Output Block → Pulse/Frequency Output Group → Configuration Function Group → Assign Status Function (see “Proline Promass 83, Description of Device Functions” manual, (BA060D/06/en/)). ■ The behaviour of the status output is a normally closed behaviour, in other words the output is closed (transistor conductive) when normal, error-free measuring is in progress. <ul style="list-style-type: none"> – “normal, error-free” operation: Flow direction = forwards; limit values = not exceeded; no empty or partially filled measuring tube (EPD/OED); no fault or notice message present. – Switching response like relay output, see “Proline Promass 83, Description of Device Functions” manual, (BA060D/06/en/) ■ If you select OFF, the only function shown in the CONFIGURATION function group is this function, in other words, ASSIGN STATUS (4241).

4.3 Group RELAY OUTPUT (1...2)

4.3.1 Function group CONFIGURATION



Functional description	
OUTPUT → RELAY OUTPUT (1...2) → CONFIGURATION	
ASSIGN RELAY (4700)	<p>Use this function to assign a switch function to the relay output.</p> <p>Extended options with the optional VISCOSITY software package: LIMIT VALUE DYNAMIC VISCOSITY LIMIT VALUE KINEMATIC VISCOSITY LIMIT VALUE TEMPERATURE COMPENSATED DYNAMIC VISCOSITY LIMIT VALUE TEMPERATURE COMPENSATED KINEMATIC VISCOSITY</p> <p> Note!</p> <ul style="list-style-type: none"> ■ The switching behavior options for this function in the VISCOSITY software package are an addition to: Output Block → Relay Output (1...2) Group → Configuration Function Group → Assign Relay Function (see “Proline Promass 83, Description of Device Functions” manual, (BA060D/06/en/)). ■ It is advisable to configure at least one relay output as a fault output and define the outputs' response to error. ■ The relay output is configured as a normally open (NO or make) contact by default. It can be reconfigured as a normally closed (NC or break) contact by means of a jumper on the relay module (see Operating Instructions “Proline Promass 83”, (BA 059D/06/en/)). ■ If OFF or ON is selected, the CONFIGURATION function group only displays this function, ASSIGN RELAY (4700).

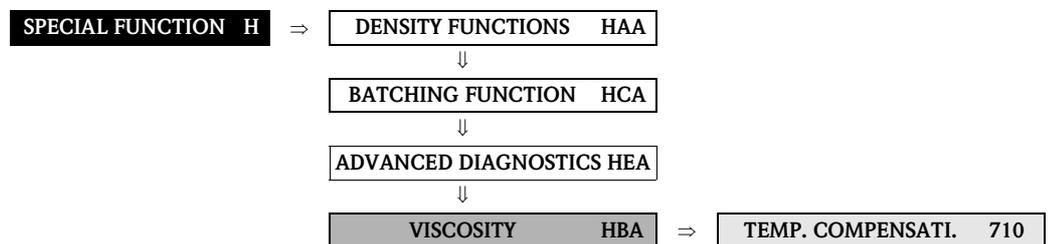
5 Block SPECIAL FUNCTION

Block	Group	Function groups	Functions	
SPECIAL FUNCTION (H)	DENSITY FUNCTIONS* (HCA)			
	BATCHING FUNCTION* (HCA)			
	ADVANCED DIAGNOSTICS* (HEA)			
	VISCOSITY (HBA) S. 17	TEMP. COMPENSATI. (710) S. 17	MODEL (7100) S. 17	VALUE REF-TEMP. (7101) S. 17
			X1 (7102) S. 18	X2 (7103) S. 18

* Software packages that can be ordered as an additional option

5.1 Group VISCOSITY

5.1.1 Function group CONFIGURATION



Functional description	
SPECIAL FUNCTION → VISCOSITY → TEMP. COMPENSATI.	
MODEL (7100)	Use this function to select a formula (→ page 26) for temperature compensation. Depending on the temperature behavior of the fluid, you can select the model that best fits the temperature curve. Options: Power law Exponential Polynomial Factory setting: Polynomial
VALUE REFERENCE TEMPERATURE (7101)	Use this function to enter the reference temperature that should be used for the calculation of temperature compensated viscosity. Input: 7-digit floating-point number Factory setting: 0 Reference value: °C

Functional description SPECIAL FUNCTION → VISCOSITY → TEMP. COMPENSATI.	
X1 (7102)	Use this function to enter the compensation coefficient X1 (calculation → page 26) Input: 7-digit floating-point number Factory setting: 0
X2 (7103)	Use this function to enter the compensation coefficient X2 (calculation → page 26) Input: 7-digit floating-point number Factory setting: 0

6 Technical data for viscosity measurement

6.1 Application

With the “VISCOSITY” software package, the measuring device can be used to measure the dynamic and kinematic viscosity of Newtonian and non-Newtonian liquids (e.g. slurry, mineral oils etc.).

6.2 Input

Measuring range

Nominal diameter		Viscosity measurement in non-Ex area	Viscosity measurement in Ex area
[mm]	[inch]		
DN8	5/16"	5600 mPa·s	5600 mPa·s
DN15	1/2"	10300 mPa·s	10300 mPa·s
DN25 / DN15 “FB”	1"	20000 mPa·s	20000 Pa·s
DN40 / DN25 “FB”	1 1/2"	20000 mPa·s	5500 Pa·s (20000 mPa·s [*])
DN50 / DN40 “FB”	2"	20000 mPa·s	5200 Pa·s (20000 mPa·s [*])
DN80 / DN50 “FB”	3"	20000 mPa·s	2700 Pa·s (14100 mPa·s [*])

* Reducing the measuring amplitude by 50 % will increase the upper limit value for viscosity measurement in hazardous area applications (see values in brackets).

6.3 Performance characteristics

Maximum measured error Accuracy for Newtonian liquids:
 $\pm 5\% \pm 0.5 \text{ mPa}\cdot\text{s}$ of reading

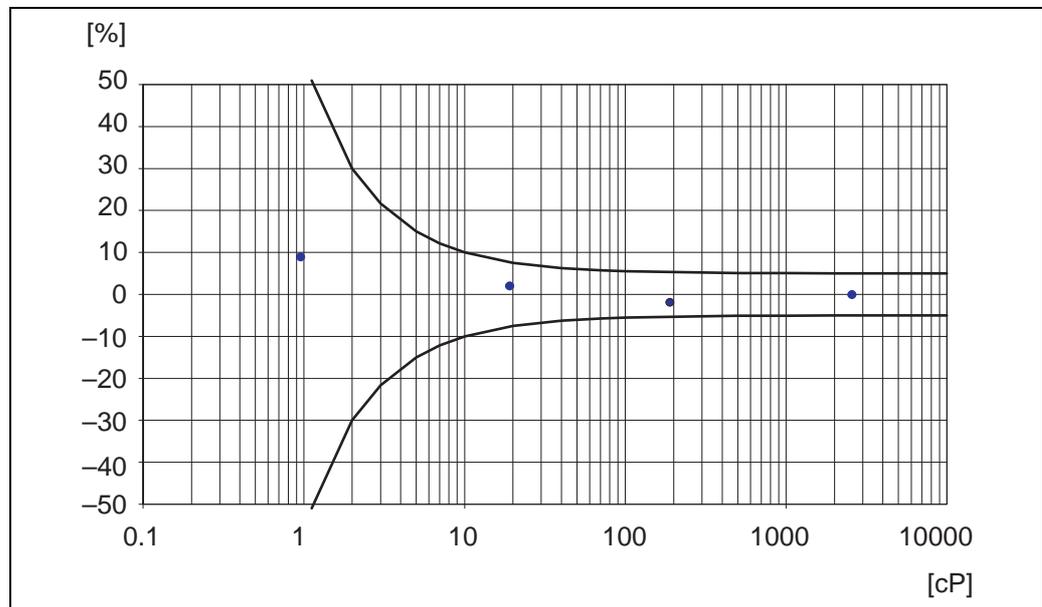


Fig. 1: Error diagram

Repeatability $\pm 0.5\%$ of reading

6.4 Operating conditions: Installation

Installation instructions No additional requirements when using the device for viscosity measurement

7 Viscosity fundamentals

Viscosity describes the flow properties of fluids (liquid and gas). This property depends on forces acting between the molecules. The more viscous a fluid, the stronger these intermolecular forces. As a result, a larger internal resistance has to be overcome to move through the fluid or apply a force to it.

7.1 Definitions of viscosity (general)

Consider a liquid between two parallel plates. If you slide one of the plates parallel against the other in a horizontal direction (→ Fig. 2), a certain force F (shear force) is needed as the liquid acts against the flow movement in the form of an internal resistance.

The relationship between the moving surface A and the shear force F is known as **shear stress τ** .

$$\tau = \frac{F}{A} \quad \left[\frac{\text{N}}{\text{m}^2} \equiv \text{Pa} \right]$$

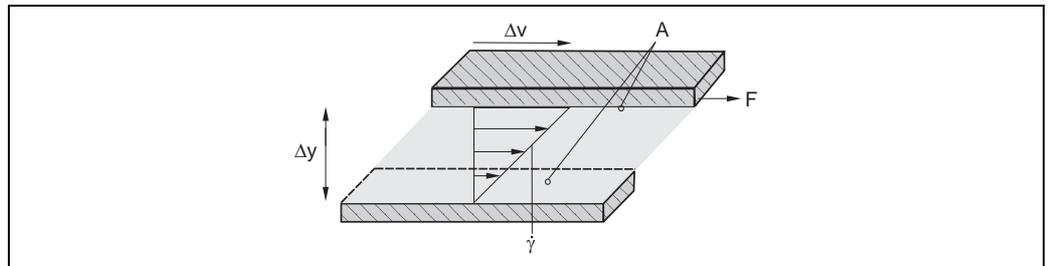


Fig. 2: Shear rate

- A Friction surface
- F Shear force
- $\dot{\gamma}$ Shear rate
- Δv Change in velocity
- Δy Plate distance or layer thickness

The relationship between the change in velocity Δv and layer thickness Δy (distance between the plates) is known as the **shear rate $\dot{\gamma}$** .

$$\dot{\gamma} = \frac{\Delta v}{\Delta y} \quad [1/\text{s}]$$

The **dynamic viscosity (μ)** is calculated from the ratio of the shear stress τ to the shear rate $\dot{\gamma}$.

$$\mu = \frac{\tau}{\dot{\gamma}} = \frac{F/A}{(\Delta v)/(\Delta y)} = \frac{F \cdot \Delta y}{A \cdot \Delta v} \quad \left(\frac{\text{N}/\text{m}^2}{(\text{m}/\text{s})/\text{m}} = \frac{\text{N} \cdot \text{m}}{\text{m}^2 \cdot (\text{m}/\text{s})} = \frac{\text{N} \cdot \text{s}}{\text{m}^2} = \text{Pa} \cdot \text{s} \right)$$

The SI unit for dynamic viscosity is the pascal second [$\text{Pa} \cdot \text{s}$].

The poise [P] unit is also widely used, where:

$$1 [\text{mPa} \cdot \text{s}] = 1 [\text{cP}]$$

$$1 [\text{Pa} \cdot \text{s}] = 10 [\text{P}]$$

Kinematic viscosity (ν) is the quotient from the dynamic viscosity μ of a liquid and its density ρ .

$$\nu = \frac{\mu}{\rho} \quad \left(\frac{(\text{N} \cdot \text{s})/\text{m}^2}{\text{kg}/\text{m}^3} = \frac{(\text{kg} \cdot \text{m}/\text{s}^2 \cdot \text{s})/\text{m}^2}{\text{kg}/\text{m}^3} = \frac{\text{m}^2}{\text{s}} \right)$$

The SI unit of kinematic viscosity is $[\text{m}^2/\text{s}]$. The stokes [St] unit is also widely used, where:

$$1 [\text{m}^2/\text{s}] = 1,000,000 [\text{cSt}]$$

$$1 [\text{mm}^2/\text{s}] = 1 [\text{cSt}] [\text{centistokes}]$$

A selection of the most common units of viscosity is provided in the “Comparison table for viscosities” (→ page 27).

7.2 Differentiating viscous behavior

A distinction is made between Newtonian liquids and non-Newtonian liquids based on their viscosity behavior at different shear rates. In Newtonian liquids, the viscosity behavior remains constant at different shear rates. In non-Newtonian liquids, the viscosity behavior changes at different shear rates.

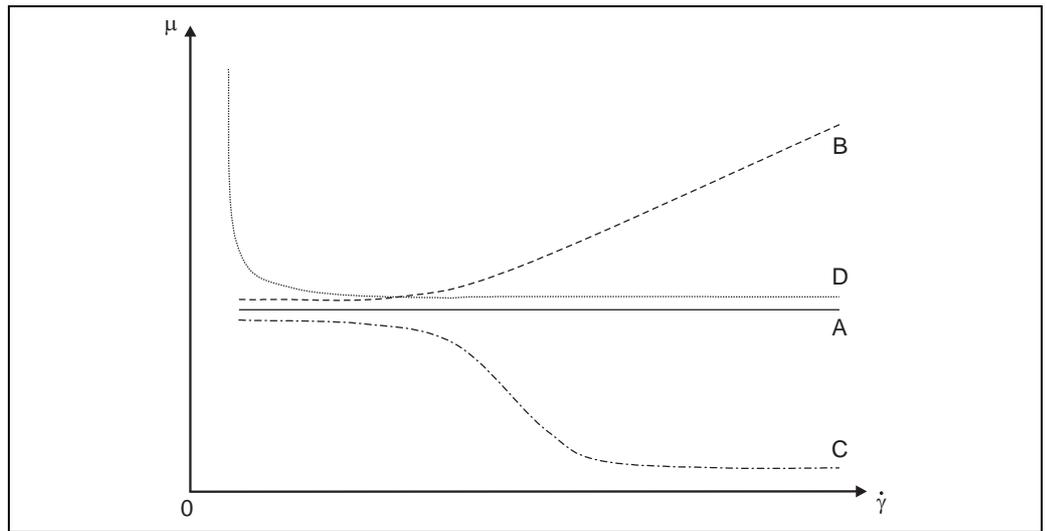
Newtonian liquids

	Example	Viscosity behavior with increasing shear rate
Feature	<ul style="list-style-type: none"> – Water – Lube oils 	No effect

Non-Newtonian liquids

		Example	Viscosity behavior with increasing shear rate
Time-independent behavior	Dilatant liquid	<ul style="list-style-type: none"> – Concentrated solutions of sugar and water – Aqueous suspensions of rice starch – Wet sand 	Increases
	Pseudoplastic liquid	<ul style="list-style-type: none"> – Gelatine – Clay – Milk – Cream – Fruit juice concentrate – Salad dressings 	Decreases
	Bingham-plastic liquid	<ul style="list-style-type: none"> – Certain emulsions – Oil paint 	Decreases but acts like a Newtonian liquid as of a certain shear rate
Time-dependent behavior	Thixotropic liquid	<ul style="list-style-type: none"> – Yoghurt – Mayonnaise – Margarine – Ice cream – Paints 	Decreases but assumes the original state when in quiescent state
	Rheopectic liquid	<ul style="list-style-type: none"> – Gypsum in water – Printer ink 	Increases but drops again when in quiescent state

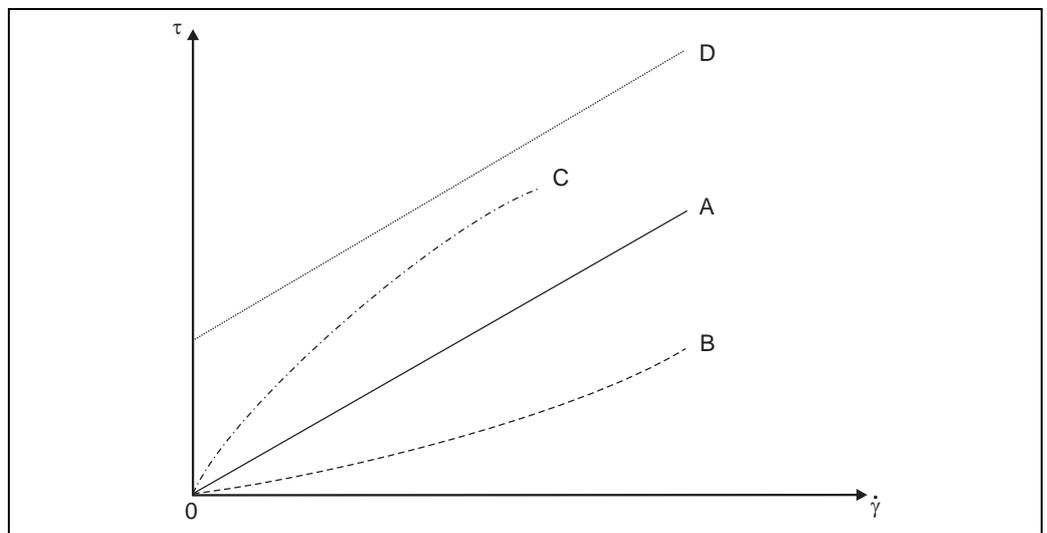
Viscosity and flow curves



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Fig. 3: Viscosity curves

- A Viscosity curve of a Newtonian liquid
- B Viscosity curve of a dilatant liquid
- C Viscosity curve of a pseudoplastic liquid
- D Viscosity curve of a Bingham-plastic liquid
- $\dot{\gamma}$ Shear rate
- μ Dynamic viscosity



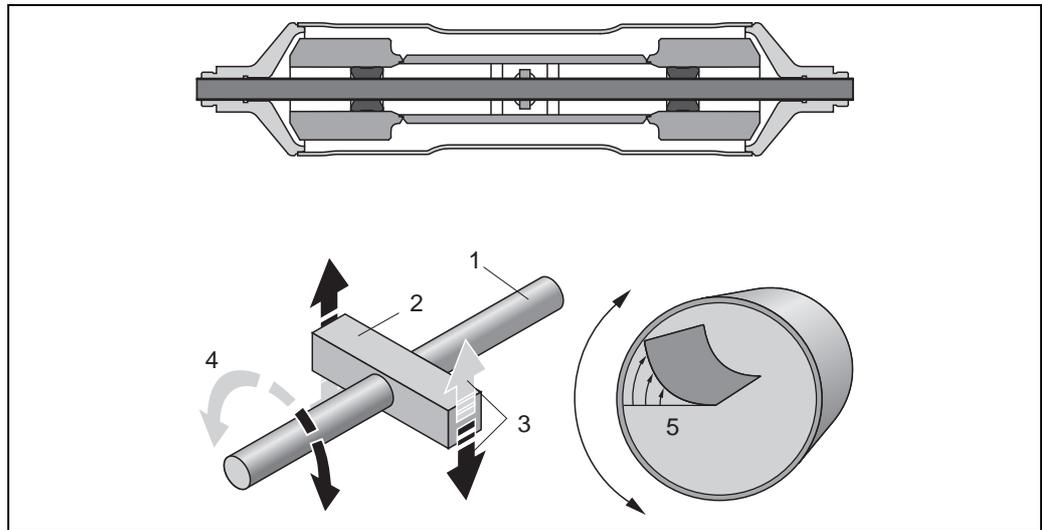
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Fig. 4: Flow curves

- A Flow curve of a Newtonian liquid
- B Flow curve of a dilatant liquid
- C Flow curve of a pseudoplastic liquid
- D Flow curve of a Bingham-plastic liquid
- $\dot{\gamma}$ Shear rate
- τ Shear stress

7.3 Promass 83I measuring principle

The patented measuring principle is based on torsional movement of the measuring tube:



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Fig. 5: Principle of viscosity measurement with Promass 83I

- 1 Torsion bar
- 2 Measuring tube
- 3 Velocity profile
- 4 Rotational movement of the measuring tube
- 5 Rotational movement of the torsion bar

A torsion bar (1) fitted to the measuring tube (2) imposes a torsional movement (oscillation of the tube) which is used to measure the viscosity of the fluid. The torsional movement creates a velocity profile in the liquid (3) across the pipe cross-section. The velocity profile is thus an expression of the fluid viscosity. The viscosity of the fluid dampens the torsional oscillation of the measuring tube so if viscosity is high, more excitation current (power, in other words) is needed to sustain the torsional oscillation. Thus, dynamic viscosity is determined by measuring the required excitation power. Fluid density is measured independently and simultaneously, so the kinematical viscosity can be determined as well.

7.4 Temperature correction of the viscosity value

The viscosity of a liquid depends on the medium temperature. Usually, the viscosity decreases with increasing temperatures.

The temperature effect becomes clear when laboratory and process measurements are compared. The process and laboratory temperatures normally deviate from one another. To be able to compare both measurements, the measuring device can calculate the process viscosity back to a reference temperature using various models. Three calculation models are available for this purpose (→ page 26). The model selected should be the one for which the viscosity behavior exhibits the lowest error deviations (→ Fig. 6).

The device calculates the temperature correction of the viscosity value based on the compensation coefficients X_1 and X_2 (→ page 17 ff.).

Example:

The following example illustrates the correction of the viscosity to 20 °C:

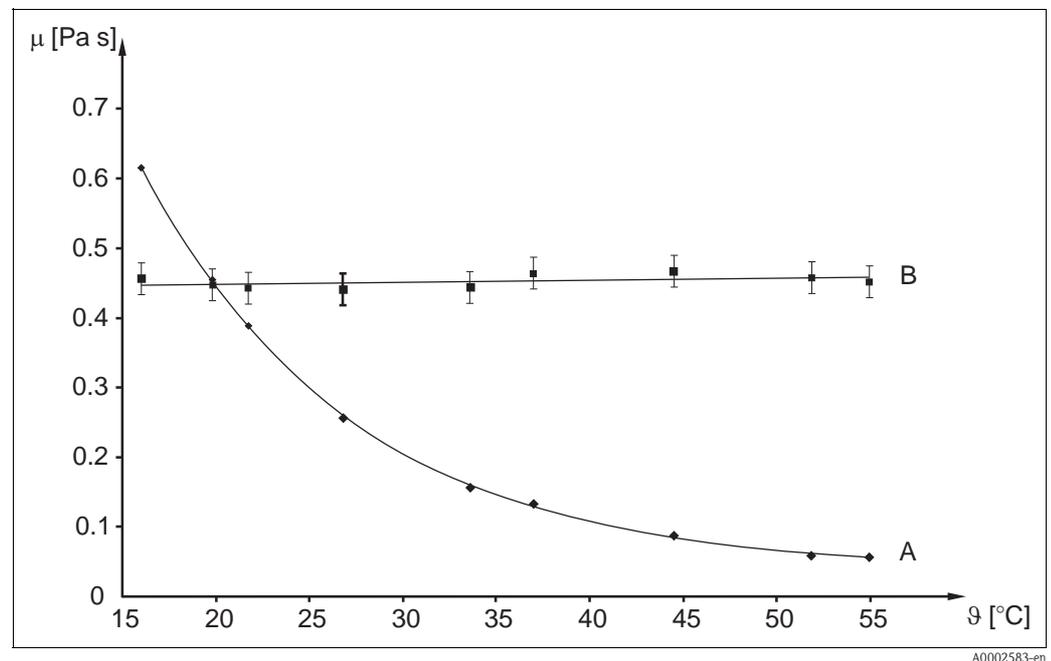


Fig. 6: Temperature correction of viscosity of glycerin to 20 °C

μ Dynamic viscosity

θ Temperature

A Measured value under process conditions

B Calculated standard viscosity referenced to 20 °C

7.5 Formula models for temperature correction

The measuring device calculates the temperature correction of the viscosity value on the basis of the following formulas:

Models	Dynamic viscosity μ
Power law	$\mu_N = \mu \cdot X_1 \cdot \left(\frac{\vartheta}{\vartheta_{ref}}\right)^{X_2}$
Exponential	$\mu_N = \mu \cdot X_1 \cdot e^{X_2 \cdot (\vartheta - \vartheta_{ref})}$
Polynomial	$\mu_N = \mu \cdot [1 + X_1 \cdot (\vartheta - \vartheta_{ref}) + X_2 \cdot (\vartheta - \vartheta_{ref})^2]$

Model	Kinematic viscosity ν
General	$\nu_N = \frac{\mu_N}{\rho_N}$

- μ_N Dynamic viscosity under normal/laboratory conditions
 μ Dynamic viscosity at process temperature
 X_1 Compensation coefficient X_1
 X_2 Compensation coefficient X_2
 ϑ Process temperature
 ϑ_{ref} Reference temperature
 ν_N Kinematic viscosity under normal/laboratory conditions
 ρ_N Reference density



Note!

- In the event of large temperature differences between the liquid and the environment, pipe heating or insulation can help avoid cooling effects of the liquid.
- If more than one liquid should be measured with temperature correction the calculation should take place externally (e.g. in a PCS).

8 Comparison tables for viscosities

Centipoise [cP] [mPa·s]*	Poise [P]	DIN cup 4 [s]**	Pascal second [Pa·s]***	°Engler	Ford cup 4 [s]**
10	0.1	10	0.01	1.83	5
15	0.15	11	0.015	2.32	8
20	0.2	12	0.02	2.87	10
25	0.25	13	0.025	3.46	12
30	0.3	14	0.03	4.07	14
40	0.4	15	0.04	5.33	18
50	0.5	16	0.05	6.62	22
60	0.6	18	0.06	7.93	25
70	0.7	21	0.07	9.23	28
80	0.8	23	0.08	10.54	32
90	0.9	25	0.09	11.86	34
100	1	27	0.1	13.17	37
120	1.2	31	0.12	15.8	43
140	1.4	34	0.14	18.43	48
160	1.6	38	0.16	21.06	54
180	1.8	43	0.18	23.69	58
200	2	46	0.2	26.3	64
220	2.2	51	0.22	28.9	70
240	2.4	55	0.24	31.6	75
260	2.6	58	0.26	34.2	80
280	2.8	63	0.28	36.8	86
300	3	68	0.3	39.4	93
320	3.2	72	0.32	42.1	100
340	3.4	76	0.34	44.7	107
360	3.6	82	0.36	47.4	112
380	3.8	86	0.38	50	119
400	4	90	0.4	52	124
420	4.2	95	0.42	55.1	130
440	4.4	100	0.44	57.6	138
460	4.6	104	0.46	60.4	142
480	4.8	109	0.48	63.0	150
500	5.0	112	0.50	65.8	155
550	5.5	124	0.55	72.4	170
600	6.0	135	0.60	79.0	185
700	7.0	160	0.70	92.1	220
800	8.0	172	0.80	105.2	249
900	9.0	195	0.90	117.8	280
1000	10.0	218	1	131.6	310

* [mPa·s] = Milli pascal second

** [s] = Second

*** [Pa·s] = Pascal second

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