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# Special Documentation
# Proline Promass I 300 FOUNDATION Fieldbus

Viscosity Measurement application package

FOUNDATION

Endress+Hauser
People for Process Automation

# Table of contents

# 1 Document information

## 1.1 Document function

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

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

## 1.2 Using this document

### 1.2.1 Information on the document structure

For the arrangement of the parameters as per the **Operation** menu, **Setup** menu, **Diagnostics** menu, along with a short description, see the Operating Instructions for the device

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

## 1.3 Symbols used

### 1.3.1 Symbols for certain types of information

| Symbol | Meaning |
|---|---|
| | **Tip**<br>Indicates additional information. |
| | Reference to documentation |
| | Reference to page |
| | Reference to graphic |
| ▶ | Notice or individual step to be observed |
| 1., 2., 3.... | Series of steps |
| ↳ | Result of a step |
| | Operation via local display |
| | Operation via operating tool |
| | Write-protected parameter |

### 1.3.2 Symbols in graphics

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

## 1.4 Documentation

This manual is Special Documentation. It is not a substitute for the Operating Instructions supplied with the device.

For detailed information, refer to the Operating Instructions and other documentation on the CD-ROM provided or visit "www.endress.com/deviceviewer".

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

| Measuring device | Documentation code |
|---|---|
| Promass I 300 | BA01520D |

This Special Documentation is available:
- On the CD-ROM supplied with the device (depending on the device version ordered)
- In the Download Area of the Endress+Hauser Internet site:
  www.endress.com → Download

### 1.4.1 Content and scope

This Special Documentation contains a description of the additional parameters and technical data that are provided with the Viscosity application package. All the parameters that are not relevant to viscosity measurement are described in the Operating Instructions.

For general information on viscosity and viscosity measurement, see the "Viscosity fundamentals" section → 📄 14

# 2 System integration

## 2.1 Input

### 2.1.1 Measuring range

#### Measuring ranges for liquids

| DN | | Measuring range full scale values $\dot{m}_{min(F)}$ to $\dot{m}_{max(F)}$ | |
|---|---|---|---|
| [mm] | [in] | [kg/h] | [lb/min] |
| 8 | ⅜ | 0 to 2 000 | 0 to 73.50 |
| 15 | ½ | 0 to 6 500 | 0 to 238.9 |
| 15 FB | ½ FB | 0 to 18 000 | 0 to 661.5 |
| 25 | 1 | 0 to 18 000 | 0 to 661.5 |
| 25 FB | 1 FB | 0 to 45 000 | 0 to 1 654 |
| 40 | 1½ | 0 to 45 000 | 0 to 1 654 |
| 40 FB | 1½ FB | 0 to 70 000 | 0 to 2 573 |
| 50 | 2 | 0 to 70 000 | 0 to 2 573 |
| 50 FB | 2 FB | 0 to 180 000 | 0 to 6 615 |
| 80 | 3 | 0 to 180 000 | 0 to 6 615 |
| FB = Full bore | | | |

#### Measuring ranges for gases

The full scale values depend on the density of the gas and can be calculated with the formula below:
$\dot{m}_{max(G)} = \dot{m}_{max(F)} \cdot \rho_G : x$

| | |
|---|---|
| $\dot{m}_{max(G)}$ | Maximum full scale value for gas [kg/h] |
| $\dot{m}_{max(F)}$ | Maximum full scale value for liquid [kg/h] |
| $\dot{m}_{max(G)} < \dot{m}_{max(F)}$ | $\dot{m}_{max(G)}$ can never be greater than $\dot{m}_{max(F)}$ |
| $\rho_G$ | Gas density in [kg/m³] at operating conditions |
| x | Constant dependent on nominal diameter |

| DN | | x |
|---|---|---|
| [mm] | [in] | [kg/m³] |
| 8 | ⅜ | 60 |
| 15 | ½ | 80 |
| 15 FB | ½ FB | 90 |
| 25 | 1 | 90 |
| 25 FB | 1 FB | 90 |
| 40 | 1½ | 90 |
| 40 FB | 1½ FB | 90 |
| 50 | 2 | 90 |
| 50 FB | 2 FB | 110 |

| DN | | x |
|---|---|---|
| [mm] | [in] | [kg/m³] |
| 80 | 3 | 110 |
| FB = Full bore | | |

**Calculation example for gas**

- Sensor: Promass I, DN 50
- Gas: Air with a density of 60.3 kg/m³ (at 20 °C and 50 bar)
- Measuring range (liquid): 70 000 kg/h
- x = 90 kg/m³ (for Promass I, DN 50)

Maximum possible full scale value:

$\dot{m}_{max(G)} = \dot{m}_{max(F)} \cdot \rho_G : x = 70\,000$ kg/h · 60.3 kg/m³ : 90 kg/m³ = 46 900 kg/h

## 2.2 Output

Extended options if the viscosity application package is used

| | |
|---|---|
| **Output values**<br>(from measuring device to automation system) | **Analog Input modules (slot 1 to 14)**<br>▪ Dynamic viscosity<br>▪ Kinematic viscosity<br>▪ Temp. compensated dynamic viscosity<br>▪ Temp. compensated kinematic viscosity<br>The range of options increases if the measuring device has one or more application packages. |

*Administration of software options*

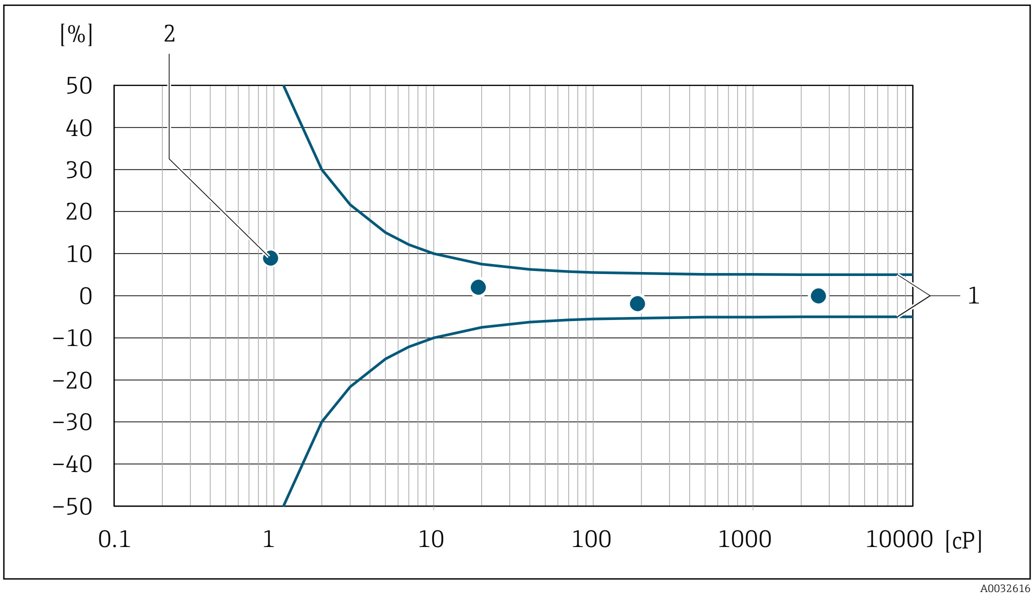
| Input/output value | Process variable | Category | Permitted in slots |
|---|---|---|---|
| Output value | Dynamic viscosity | Viscosity [1] | 1…14 |
| | Kinematic viscosity | | |
| | Temp. compensated dynamic viscosity | | |
| | Temp. compensated kinematic viscosity | | |

1) Only available with the "Viscosity" application package.

# 2.3 Performance characteristics

## 2.3.1 Maximum measured error

| | |
|---|---|
| **Accuracy for Newtonian liquids** | ±5% ± 0.5 mPa·s (cP) of reading |




*1 Error curve indicating the relative error as a % for dynamic viscosity in cP*

1 *Maximum measured error*
2 *Typical measuring points of viscosity calibration*

## 2.3.2 Repeatability

±0.5% of reading

# 3 Commissioning

## 3.1 Availability

If the optional **Viscosity Measurement** package was ordered for the flowmeter ex works, the function is available when the measuring device is delivered from the factory. The function is accessed via the operating interfaces of the measuring device, via the Web server or Endress+Hauser's FieldCare asset management software. No particular measures are required to put the function into operation.

Ways to check function availability in the measuring device:
- Using the serial number:
  W@M Device viewer [1] → Order code option **EG** "Viscosity measurement"
- In the operating menu:
  Check whether the function appears in the operating menu: Diagnostics → Measured values → Process variables → Viscosity
  If the "Viscosity" option is available the function is activated.

If the function cannot be accessed in the measuring device, the optional package was not selected. It is then possible to upgrade to this function during the life cycle of the measuring device. On most flowmeters it is possible to activate the function without having to upgrade the firmware.

### 3.1.1 Activation without firmware upgrade

If the viscosity option is retrofitted during the flowmeter's life cycle, viscosity calibration must be performed. The device must be returned to the factory for this.

Activation without firmware upgrade is possible as of the following firmware versions: FOUNDATION Fieldbus H1: 01.00.zz

### 3.1.2 Firmware upgrade before activation

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

This function requires service-level access to the device.

A firmware upgrade is required for measuring devices with earlier firmware versions (see "3.1.1 Activation without firmware upgrade"). In addition the reference condition of the sensor must be recorded and selected during commissioning.

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

## 3.2 Advanced settings

**Navigation**
"Setup" menu → Advanced setup → Viscosity

| | | |
|---|---|---|
| ▶ **Viscosity** | | |
| | ▶ **Temperature compensation** | → 10 |

1) www.endress.com/deviceviewer

| | |
|---|---|
| ▶ Dynamic viscosity | → 📖 10 |
| ▶ Kinematic viscosity | → 📖 11 |

### 3.2.1 Temperature compensation

**Navigation**
"Setup" menu → Advanced setup → Viscosity → Temperature compensation

| | |
|---|---|
| ▶ **Temperature compensation** | |
| Calculation model | → 📖 10 |
| Reference temperature | → 📖 10 |
| Compensation coefficient X 1 | → 📖 10 |
| Compensation coefficient X 2 | → 📖 10 |

#### Parameter overview with brief description

| Parameter | Description | Selection / User entry | Factory setting |
|---|---|---|---|
| Calculation model | Select a formula for the temperature compensation of viscosity. | ■ Power law<br>■ Exponential<br>■ Polynomial | Polynomial |
| Reference temperature | Enter reference temperature used to calculate the temperature compensated viscosity. | −273.15 to 99 999 °C | 0 °C |
| Compensation coefficient X 1 | Enter compensation coefficient used to calculate the temperature compensated viscosity. | Signed floating-point number | 0 |
| Compensation coefficient X 2 | Enter compensation coefficient used to calculate the temperature compensated viscosity. | Signed floating-point number | 0 |

### 3.2.2 Dynamic viscosity

**Navigation**
"Setup" menu → Advanced setup → Viscosity → Dynamic viscosity

| | |
|---|---|
| ▶ **Dynamic viscosity** | |
| Dynamic viscosity unit | → 📖 11 |

**Parameter overview with brief description**

| Parameter | Description | Selection / User entry | Factory setting |
|---|---|---|---|
| Dynamic viscosity unit | Select dynamic viscosity unit.<br>*Result*<br>The selected unit applies for:<br>▪ **Dynamic viscosity** parameter (gases)<br>▪ **Dynamic viscosity** parameter (liquids) | Unit choose list | Pa s |
| User dynamic viscosity text | Enter text for the user specific unit of the dynamic viscosity. | | UserDynVis |
| User dynamic viscosity factor | With user-specific unit: Enter a factor which is multiplicated with the measured dynamic viscosity value. | Signed floating-point number | 1.0 |
| User dynamic viscosity offset | With user-specific unit: Enter zero point shift which is added or subtracted to/from the measured value of the dynamic viscosity. | Signed floating-point number | 0 |

### 3.2.3 Kinematic viscosity

**Navigation**
"Setup" menu → Advanced setup → Viscosity → Kinematic viscosity

| ▶ Kinematic viscosity | |
|---|---|
| Kinematic viscosity unit | → 11 |

**Parameter overview with brief description**

| Parameter | Description | Selection / User entry | Factory setting |
|---|---|---|---|
| Kinematic viscosity unit | Select kinematic viscosity unit. | Unit choose list | cSt |
| User kinematic viscosity text | Enter text for the user specific unit of the kinematic viscosity. | | UserKinVis |
| User kinematic viscosity factor | With user-specific unit: Enter a factor which is multiplicated with the measured kinematic viscosity value. | Signed floating-point number | 1.0 |
| User kinematic viscosity offset | With user-specific unit: Enter zero point shift which is added or subtracted to/from the measured value of the kinematic viscosity. | Signed floating-point number | 0 |

## 3.3 Simulation

**Navigation**
"Diagnostics" menu → Simulation → Assign simulation process variable

| ▶ Simulation | |
|---|---|
| Assign simulation process variable | → 12 |

### Parameter overview with brief description

| Parameter | Description | Selection | Factory setting |
|---|---|---|---|
| Assign simulation process variable | Select a process variable for the simulation process that is activated. | ▪ Off<br>▪ Mass flow<br>▪ Volume flow<br>▪ Corrected volume flow<br>▪ Density<br>▪ Reference density<br>▪ Temperature<br>▪ Dynamic viscosity<br>▪ Kinematic viscosity<br>▪ Temp. compensated dynamic viscosity<br>▪ Temp. compensated kinematic viscosity<br>▪ Concentration<br>▪ Target mass flow<br>▪ Carrier mass flow | Off |

# 4 Operation

## 4.1 Reading measured values

### Navigation

"Diagnostics" menu → Measured values → Process variables

| ▶ Process variables | |
|---|---|
| Dynamic viscosity | → 📄 13 |
| Kinematic viscosity | → 📄 13 |
| Temp. compensated dynamic viscosity | → 📄 13 |
| Temp. compensated kinematic viscosity | → 📄 13 |

### Parameter overview with brief description

| Parameter | Prerequisite | Description | User interface |
|---|---|---|---|
| Dynamic viscosity | For the following order code:<br>"Application package", option **EG** "Viscosity"<br>ℹ The software options currently enabled are displayed in the **Software option overview** parameter. | Displays the dynamic viscosity currently calculated.<br>*Dependency*<br>The unit is taken from the **Dynamic viscosity unit** parameter (→ 📄 11). | Signed floating-point number |
| Kinematic viscosity | For the following order code:<br>"Application package", option **EG** "Viscosity"<br>ℹ The software options currently enabled are displayed in the **Software option overview** parameter. | Displays the kinematic viscosity currently calculated.<br>*Dependency*<br>The unit is taken from the **Kinematic viscosity unit** parameter (→ 📄 11). | Signed floating-point number |
| Temp. compensated dynamic viscosity | For the following order code:<br>"Application package", option **EG** "Viscosity"<br>ℹ The software options currently enabled are displayed in the **Software option overview** parameter. | Displays the temperature compensation currently calculated for the viscosity.<br>*Dependency*<br>The unit is taken from the **Dynamic viscosity unit** parameter (→ 📄 11). | Signed floating-point number |
| Temp. compensated kinematic viscosity | For the following order code:<br>"Application package", option **EG** "Viscosity"<br>ℹ The software options currently enabled are displayed in the **Software option overview** parameter. | Displays the temperature compensation currently calculated for the kinetic viscosity.<br>*Dependency*<br>The unit is taken from the **Kinematic viscosity unit** parameter (0578) (→ 📄 11). | Signed floating-point number |

# 5 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.

## 5.1 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,→ 2, 14 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.

$$\tau = \frac{F}{A} \qquad Pa = \frac{N}{m^2}$$

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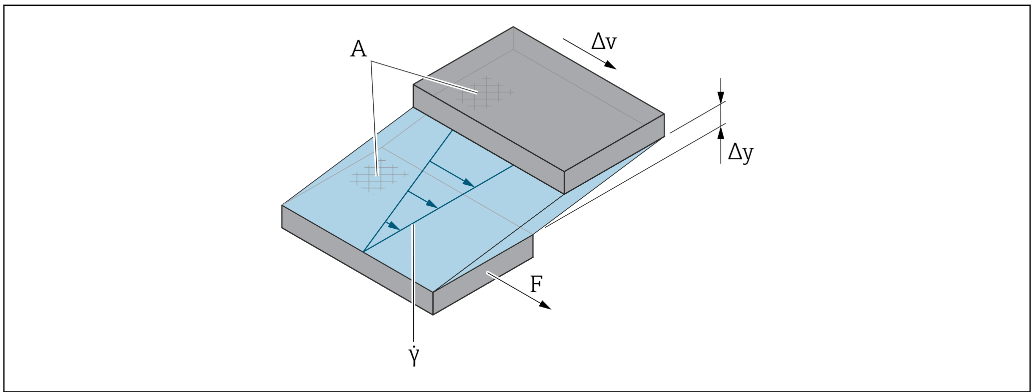


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2 *Shear rate*

| | |
|---|---|
| A | Friction surface |
| F | Shear force |
| $\dot{\gamma}$ | Shear rate |
| Δv | Change in velocity |
| Δy | Distance between plates 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 $\dot{\gamma}$.

$$\dot{\gamma} = \frac{\Delta y}{\Delta v} \qquad \frac{m}{m \cdot s} = \frac{1}{s}$$

A0019948

### 5.1.1 Dynamic viscosity

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

$$\eta = \frac{\tau}{\dot{\gamma}} = \frac{F/A}{\Delta v/\Delta y} = \frac{F \cdot \Delta y}{A \cdot \Delta v} \qquad \frac{N/m^2}{(m/s)/m} = \frac{N \cdot m}{(m/s) \cdot m^2} = \frac{N \cdot s}{m^2} = Pa \cdot s$$

A0019947

The SI unit for dynamic viscosity η is the pascal second (Pa · s). The poise (P) unit is also widely used, where:

1 mPa · s = 1 cP

1 Pa · s = 10 P

A selection of the most common used viscosity units: → 22.

### 5.1.2 Kinematic viscosity

The kinematic viscosity v is the quotient from the dynamic viscosity η of the liquid and its density ρ.

$$\nu = \frac{\eta}{\rho} \qquad \frac{(N \cdot s)/m^2}{kg/m^3} = \frac{(kg \cdot m/s^2 \cdot s)/m^2}{kg/m^3} = \frac{m^2}{s}$$

A0019950

The SI unit of kinematic viscosity is $m^2/s$. However, the stokes (St) unit is also widely used, where:

1 $m^2/s$ = 1 000 000 cSt

1 $mm^2/s$ = 1 cSt (centistokes)

A selection of the most commonly used viscosity units: → 22.

## 5.2 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.

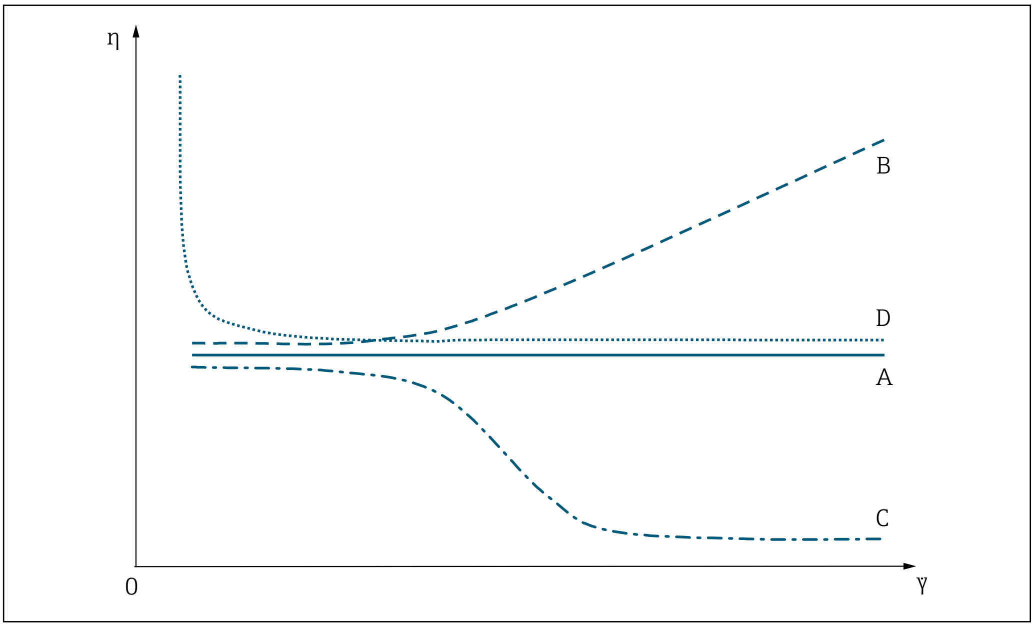
### 5.2.1 Newtonian liquid

| | Example | Viscosity behavior with increasing shear rate |
|---|---|---|
| **Feature** | ▪ Water<br>▪ Lube oils | No effect |

### 5.2.2 Non-Newtonian liquid

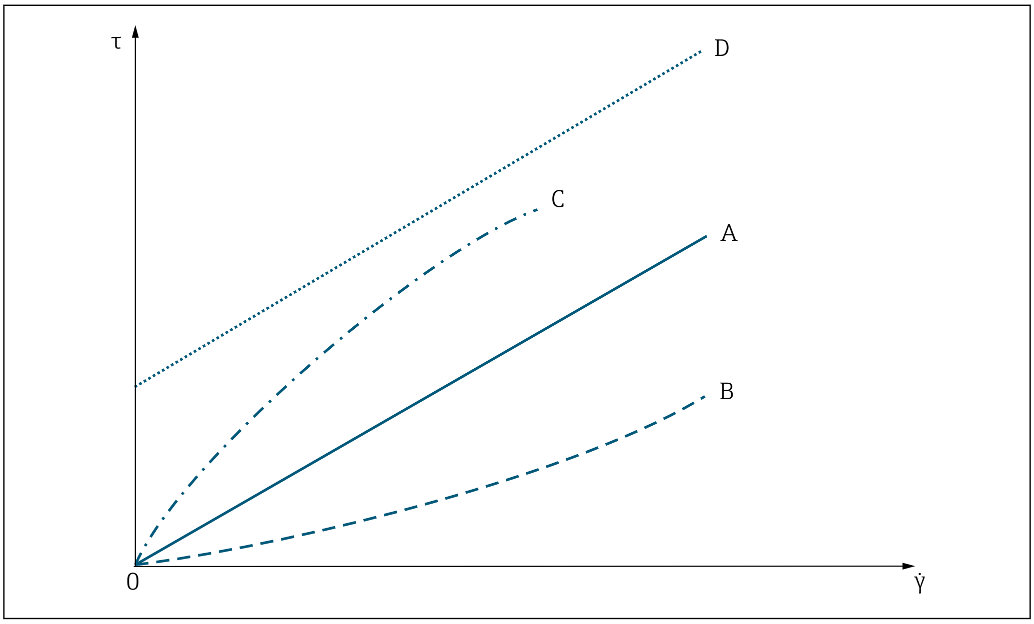
| | | Example | Viscosity behavior with increasing shear rate |
|---|---|---|---|
| **Time-independent behavior** | **Dilatant liquid** | ▪ Concentrated solutions of sugar and water<br>▪ Aqueous suspensions of rice starch<br>▪ Wet sand | Increases |
| | **Pseudoplastic liquid** | ▪ Gelatine<br>▪ Clay<br>▪ Milk<br>▪ Cream<br>▪ Fruit juice concentrate<br>▪ Salad dressings | Increases |
| | **Bingham liquid** | ▪ Certain emulsions<br>▪ Oil paint | Decreases but acts like a Newtonian liquid as of a certain shear rate |
| **Time-dependent behavior** | **Thixotropic liquid** | ▪ Yogurt<br>▪ Mayonnaise<br>▪ Margarine<br>▪ Ice cream<br>▪ Paints | Decreases but assumes the original state when in quiescent state |
| | **Rheopectic liquid** | ▪ Gypsum in water<br>▪ Printer ink | Increases but drops again when in quiescent state |

### 5.2.3 Viscosity and flow curves




*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 |
| η | Dynamic viscosity |

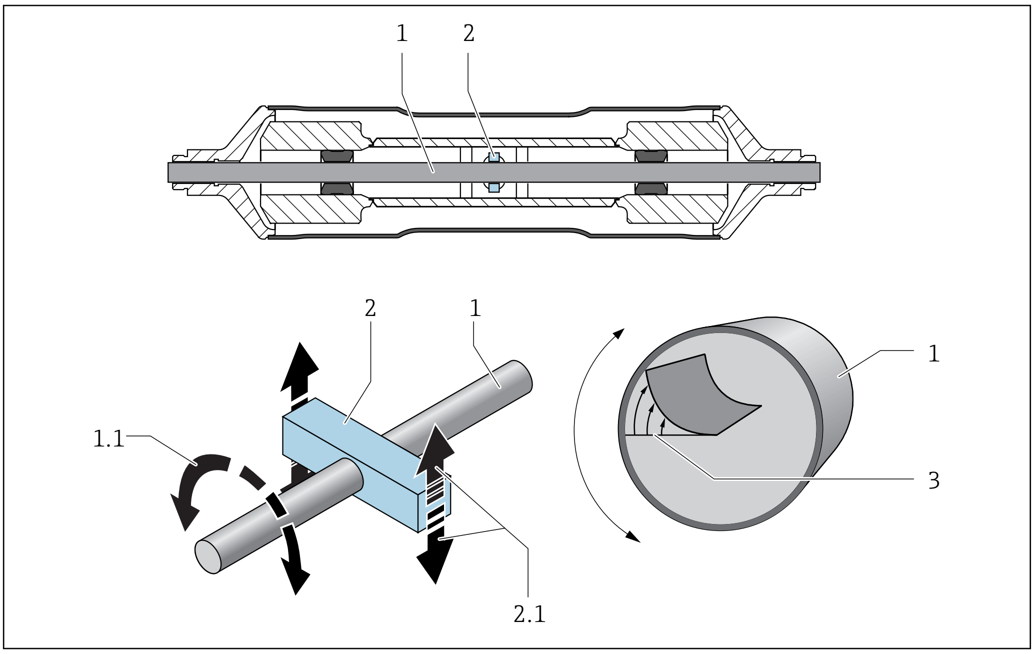



*4 Flow curves*

| | |
|---|---|
| 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 |
| $\tau$ | Shear stress |

## 5.3 Principle of viscosity measurement with Promass I

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




*1 Measuring tube*
*1.1 Rotational movement of the measuring tube*
*2 Torsion bar*
*2.1 Rotational movement of the torsion bar*
*3 Velocity profile in the medium*

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

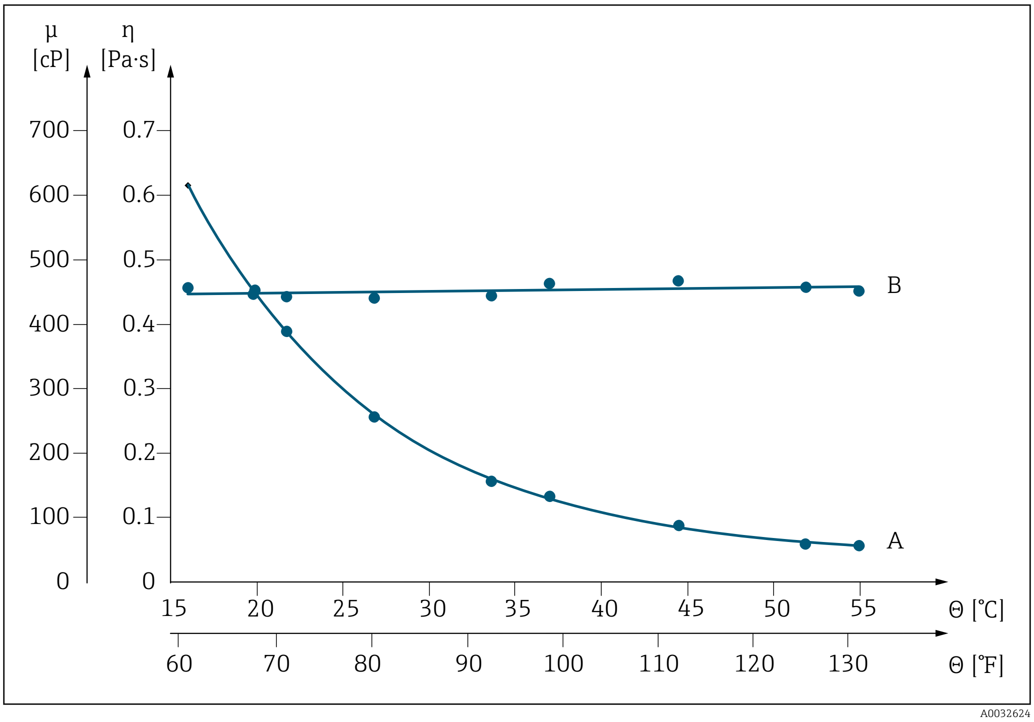
## 5.4 Temperature correction of the viscosity value

The viscosity of a liquid depends on the temperature of the medium. 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. → 📄 21. The model selected should be the one for which the viscosity behavior has the lowest error deviations.→ 🖼 5, 📄 20.

The device calculates the temperature correction of the viscosity value based on the compensation coefficients X1 and X2 . → 📄 9.

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




🖼 5 *Temperature correction of viscosity of glycerin to 20 °C*

| | |
|---|---|
| μ, η | Dynamic viscosity |
| θ | Temperature |
| A | Measured value under process conditions |
| B | Calculated standard viscosity referenced to 20°C |

## 5.5 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 η |
|---|---|
| Power law | $\eta_N = \eta \cdot x_1 \cdot (\theta/\theta_{ref})^{x_2}$ |
| Exponential | $\eta_N = \eta \cdot x_1 \cdot e^{x_2 \cdot (\theta - \theta ref)}$ |
| Polynomial | $\eta_N = \eta \cdot [1 + x_1 \cdot (\theta - \theta_{ref}) + x_2 \cdot (\theta - \theta_{ref})^2$ |

| Models | Kinematic viscosity η |
|---|---|
| General | $v_N = \eta_N / \rho_N$ |

| | |
|---|---|
| **$\eta_N$** | Dynamic viscosity under standard/laboratory conditions |
| **η** | Dynamic viscosity at process temperature |
| **$x_1$** | Compensation coefficient $X_1$ |
| **$x_2$** | Compensation coefficient $X_2$ |
| **θ** | Process temperature |
| **θref** | Reference temperature |
| **$v_N$** | Kinematic viscosity under standard/laboratory conditions |
| **$\rho_N$** | Reference density |

- 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 PLC).

# 6 Comparison tables for viscosities

| Centipoise (cP) (mPa · s) 1) | Poise (P) | DIN cup 4 (s) 2) | Pascal second (Pa · s) 3) | °Engler | Ford cup 4 (s) 2) |
|---|---|---|---|---|---|
| 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 |

1) Milli Pascal second
2) Second
3) Pascal second

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