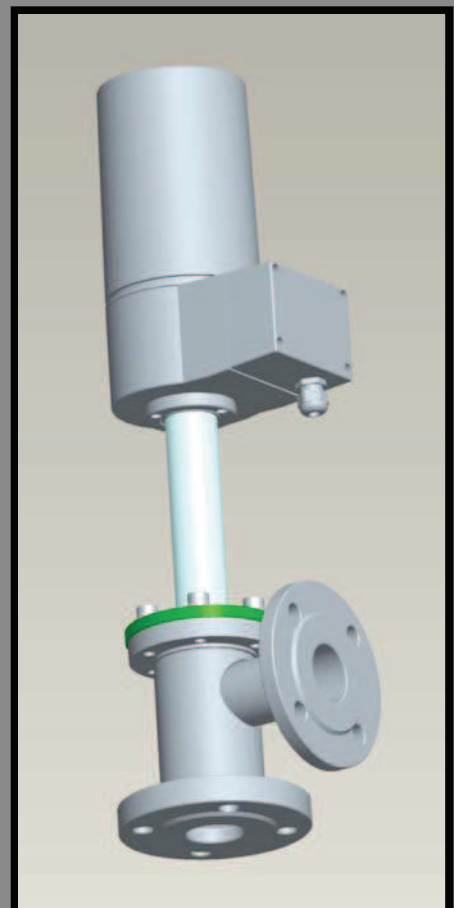
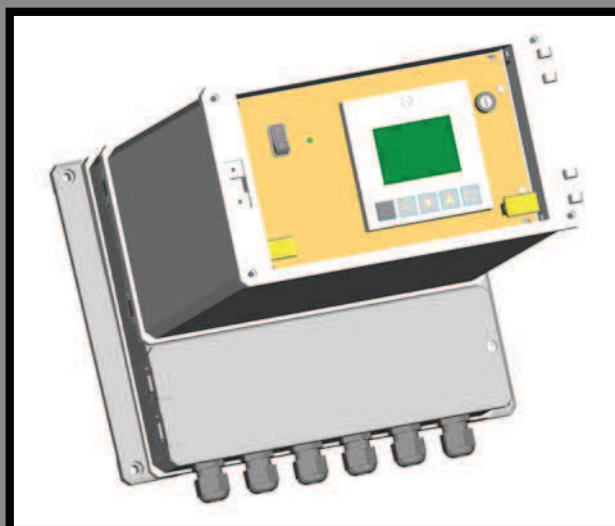


## Operating Manual

### Process Viscometer PV100

*versions PV100-DM and PV100-TM  
incl. control unit VC1*



## **Operating Manual for PV100 Process Viscometers**

Version 3.4 E

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Printed in Germany

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Revised 02/2008

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**Appendix 1: Pin assignment for PV100 / KS98 system (non-Ex conditions)**

**Appendix 2: Pin assignment for PV100 / KS98 system (Ex conditions)**

## **1. INTRODUCTION**

The Process Viscometers of the PV100 equipment system permit continuous measurement of the dynamic viscosity of newtonian fluids, its registration as a function of time, and its control in the process of mixing of multi-component systems. A specific control and evaluation unit serves to process all rheological data required for the process.

The equipment system comprises 2 basic variants: (Fig.1):

- PV100-TM Process Viscometer ♦ immersion-type measuring device
- PV100-DM Process Viscometer ♦ flow-through measuring device

The **PV100-TM Viscometer** is a working viscometer used to measure the viscosity of liquids in containers. It is mainly used in batch production processes and for the continuous viscosity control in storage containers.

The **PV100-DM Viscometer** is used for continuous measurement of the viscosity of flowing liquids in pipelines. PV100-DM Process Viscometers are supplied with different measuring cells, i.e. with or without terminal for substance temperature control, and with flange or Ermeto connections. The temperature of the substance is measured with a built-in resistance thermometer Pt100 installed right in the measuring location.

In all equipment versions the output signals are evaluated by an electronic unit whose programme processes the following values:

- viscosity
- shear rate
- shear stress
- temperature
- viscosity-temperature compensation
- upper limit

and represents them on the display. Output signals 4...20 mA for peripheral equipment are the original measuring signal and the calculated viscosity signal after a temperature compensation.

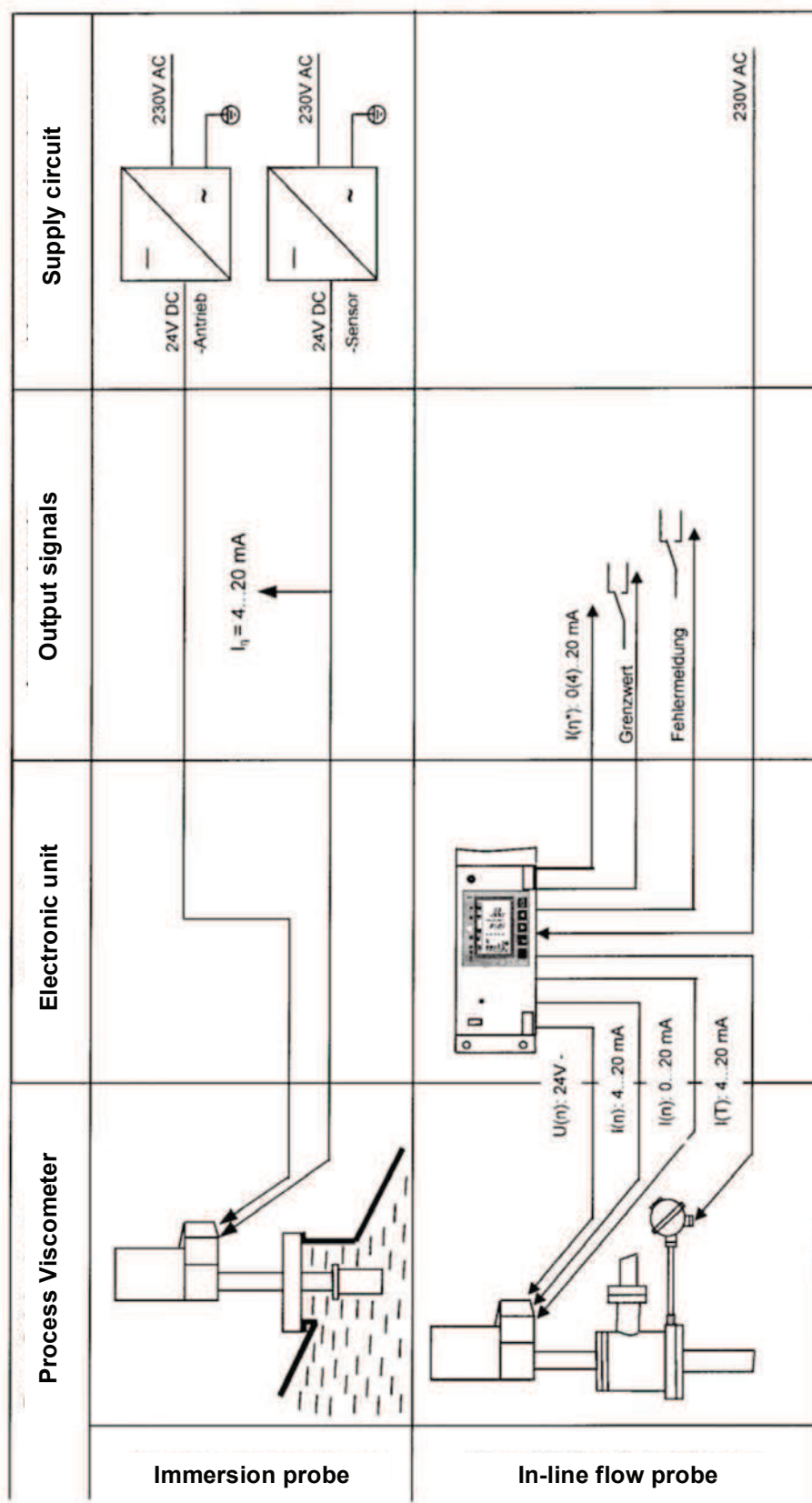


Fig. 1.: PV100 Process Viscometer as immersion-type or flow-through measuring device

## **2. TECHNICAL DATA**

### **2.1. Static parameters**

viscosity 2 ... 10<sup>7</sup> mPas (see table 1)

average shear rate see tables 2 and 3

average shear stress see table 4

interfaces

#### ***Viscometer***

- measuring transducer 4 ... 20 mA, analogue (two-wire)  
     auxiliary energy  $U_S = 14 \dots 24 \text{ V DC}$   
     apparent ohmic resistance  $R_B = (U_S - 14 \text{ V}) / 0.02 \text{ A}$
- drive 0...20 mA, analogue (speed control)  
     auxiliary energy  $U_S = 24 \text{ V DC} \pm 3\% / 0.5 \text{ A}$

#### ***Electronic unit***

- viscosity signal input INP1 4 ... 20 mA, analogue  
     resolution  $\leq 0.8 \mu\text{A}$   
     input resistance  $50 \Omega$   
     measuring circuit monitoring  $\leq 2 \text{ mA}$
- transducer supply 22 mA  $\geq 17.5 \text{ V}$
- temperature signal input INP6 4 ... 20 mA, analogue  
     resolution  $\leq 0.8 \mu\text{A}$   
     input resistance  $43 \Omega$   
     measuring circuit monitoring  $\leq 2 \text{ mA}$
- transducer supply 22 mA  $\geq 22.5 \text{ V}$

*Note: Inputs INP1 und INP6 are interconnected. If necessary they are to be electrically separated .*

- speed control current OUT1 without electrical contact to the inputs  
     0...20 mA, analog  
     resolution  $\leq 6 \mu\text{A}$   
     apparent ohmic resistance  $\leq 600 \Omega$
- viscosity signal output OUT2 without electrical contact to the inputs  
     4...20mA, analog  
     resolution  $\leq 6 \mu\text{A}$   
     apparent ohmic resistance  $\leq 600 \Omega$
- relay output OUT4 potential-free change-over contacts  
     contact rating  
      $12 \text{ V} \leq U \leq 32 \text{ V DC}$   
      $10 \cdot 10^{-3} \text{ A} \leq I \leq 2 \text{ A}$

|                                   |      |                                                                                                                                                     |
|-----------------------------------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| -relay output                     | OUT5 | potential-free change-over contacts<br>contact rating<br>$12\text{V} \leq U \leq 32\text{V DC}$<br>$10 \cdot 10^{-3}\text{A} \leq I \leq 2\text{A}$ |
| Temperature range of compensation |      | -25°C ... +300°C                                                                                                                                    |
| - safety                          |      | EN 61010-1<br>protection class I<br>overvoltage category 2<br>degree of pollution 2<br>operating voltage 264 V                                      |

## **2.2. Static error**

### **Basic error**

(relative to the respective partial measuring range and calibration fluid)

|                                                         |              |
|---------------------------------------------------------|--------------|
| viscometer with electronic unit                         | $\pm 2.5 \%$ |
| range of temperature compensation ( $\pm 5 \text{ K}$ ) | $\pm 5 \%$   |
| uncertainty of repeatability                            | 1 %          |

### **Additional error**

|                                         |                                          |
|-----------------------------------------|------------------------------------------|
| working pressure                        | 0.15 % / 1 MPa                           |
| flow                                    | 0.3 % / $\text{m}^3 \text{ h}^{-1}$      |
| temperature of substance to be measured | ca. 8 % / K (depending on the substance) |

**Table 1:** Measuring range of PV100 Process Viscometer with electronic unit

| Basic measur.<br>Range<br>in [mPas]                                                                                              | Speed<br>level | Partial measuring range<br>in [mPas]            |                            |                          |
|----------------------------------------------------------------------------------------------------------------------------------|----------------|-------------------------------------------------|----------------------------|--------------------------|
|                                                                                                                                  |                | Immersion-type and flow-<br>through viscometers | Immersion-type viscometers |                          |
|                                                                                                                                  |                |                                                 | with measuring tube        | without measuring tube   |
|                                                                                                                                  |                | TM64 / DM64                                     | TM06B                      | TM06                     |
| Measuring head<br><br><b>MH10</b><br><br>2...10 <sup>4</sup><br>or<br>30... 1.6x10 <sup>5</sup>                                  | 1              | 2 ..... 40                                      | 2 ..... 40                 | 30 ..... 640             |
|                                                                                                                                  | 2              | 5 ..... 100                                     | 5 ..... 100                | 75 ..... 1 600           |
|                                                                                                                                  | 3              | 10 ..... 200                                    | 10 ..... 200               | 150 ..... 3 200          |
|                                                                                                                                  | 4              | 20 ..... 400                                    | 20 ..... 400               | 300 ..... 6 400          |
|                                                                                                                                  | 5              | 50 ..... 1 000                                  | 50 ..... 1 000             | 750 ..... 16 000         |
|                                                                                                                                  | 6              | 100 ..... 2 000                                 | 100 ..... 2 000            | 1 500 ..... 32 000       |
|                                                                                                                                  | 7              | 200 ..... 4 000                                 | 200 ..... 4 000            | 3 000 ..... 64 000       |
|                                                                                                                                  | 8              | 500 ... 10 000                                  | 500 ... 10 000             | 7 500 ... 160 000        |
| Measuring head<br><br><b>MH16</b><br><br>20...10 <sup>5</sup><br>or<br>60...3.5x10 <sup>5</sup>                                  | 1              | 20 ..... 400                                    | 20 ..... 400               | 60 ..... 1 400           |
|                                                                                                                                  | 2              | 50 ..... 1 000                                  | 50 ..... 1 000             | 150 ..... 3 500          |
|                                                                                                                                  | 3              | 100 ..... 2 000                                 | 100 ..... 2 000            | 300 ..... 7 000          |
|                                                                                                                                  | 4              | 200 ..... 4 000                                 | 200 ..... 4 000            | 600 ..... 4 000          |
|                                                                                                                                  | 5              | 500 ..... 10 000                                | 500 ..... 10 000           | 1 500 ..... 35 000       |
|                                                                                                                                  | 6              | 1 000 ..... 20 000                              | 1 000 ..... 20 000         | 3 000 ..... 70 000       |
|                                                                                                                                  | 7              | 2 000 ..... 40 000                              | 2 000 ..... 40 000         | 7 500 ... 140 000        |
|                                                                                                                                  | 8              | 5 000 ... 100 000                               | 5 000 ... 100 000          | 15 000 ... 350 000       |
| Measuring head<br><br><b>MH16G</b><br><br>2x10 <sup>3</sup> ...10 <sup>7</sup><br>or<br>6x10 <sup>3</sup> ...3.5x10 <sup>7</sup> | 1              | 2 000 ..... 40 000                              | 2 000 ..... 40 000         | 6 000 ..... 140 000      |
|                                                                                                                                  | 2              | 5 000 ..... 100 000                             | 5 000 ..... 100 000        | 15 000 ..... 350 000     |
|                                                                                                                                  | 3              | 10 000 ..... 200 000                            | 10 000 ..... 200 000       | 30 000 ..... 700 000     |
|                                                                                                                                  | 4              | 20 000 ..... 400 000                            | 20 000 ..... 400 000       | 60 000 ..... 1 400 000   |
|                                                                                                                                  | 5              | 50 000 ..... 1 000 000                          | 50 000 ..... 1 000 000     | 150 000 ..... 3 500 000  |
|                                                                                                                                  | 6              | 100 000 ..... 2 000 000                         | 100 000 ..... 2 000 000    | 300 000 ..... 7 000 000  |
|                                                                                                                                  | 7              | 200 000 ... 4 000 000                           | 200 000 ... 4 000 000      | 600 000 ... 14 000 000   |
|                                                                                                                                  | 8              | 500 000 ... 10 000 000                          | 500 000 ... 10 000 000     | 1 500 000 ... 35 000 000 |

| Basic measur.<br>Range<br>in [mPas]                               | Speed<br>level | Torque range I     | Torque range II       |
|-------------------------------------------------------------------|----------------|--------------------|-----------------------|
|                                                                   |                | 7.5 mNm / 40°C     | 75 mNm / 20°C         |
| Measuring head<br><br><b>MHSZ</b><br><br>20...1.2x10 <sup>6</sup> | 1              | 20 ..... 480       | 480 ..... 4 800       |
|                                                                   | 2              | 50 ..... 1 200     | 1 200 ..... 12 000    |
|                                                                   | 3              | 100 ..... 2 400    | 2 400 ..... 24 000    |
|                                                                   | 4              | 200 ..... 4 800    | 4 800 ..... 48 000    |
|                                                                   | 5              | 500 ..... 12 000   | 12 000 ..... 120 000  |
|                                                                   | 6              | 1 000 ..... 24 000 | 24 000 ..... 240 000  |
|                                                                   | 7              | 2 000 ..... 48 000 | 48 000 ..... 480 000  |
|                                                                   | 8              | 5 000 ... 120 000  | 120 000 ... 1 200 000 |

Tolerance of the partial  
measuring range end value:

± 2.5 % at 20°C  
(calibrating liquid)

SI-units:  $1 \text{ mPas} = 10^{-3} \text{ Pas} = 10^{-3} \text{ Nsm}^{-2} = 10^{-3} \text{ kgm}^{-1}\text{s}^{-1}$

Conversion:  $10^{-1} \text{ Pas} = 1 \text{ P (Poise)}$   
 $1 \text{ mPas} = 1 \text{ cP}$

**Table 2:** Average shear rates  $D_m$  using MH10 and MH16 driving systems

|             | speed step no.           |                | 8     | 7     | 6     | 5    | 4    | 3     | 2    | 1    |
|-------------|--------------------------|----------------|-------|-------|-------|------|------|-------|------|------|
|             | measuring range [mPas]   | n [rpm]        | 1     | 2.5   | 5     | 10   | 25   | 50    | 100  | 250  |
| DM64 / TM64 | $10^4$ (MH10)            | $D_m [s^{-1}]$ | 4.4   | 11    | 22    | 44   | 110  | 220   | 440  | 1100 |
|             | $10^5$ (MH16)            | $D_m [s^{-1}]$ | 0.764 | 1.91  | 3.82  | 7.64 | 19.1 | 38.2  | 76.4 | 191  |
| TM06B       | $10^4$ (MH10)            | $D_m [s^{-1}]$ | 3.3   | 8.25  | 16.5  | 33   | 82.5 | 165   | 330  | 825  |
|             | $10^5$ (MH16)            | $D_m [s^{-1}]$ | 0.704 | 1.76  | 3.52  | 7.04 | 17.6 | 35.2  | 70.4 | 176  |
| TM06        | $1.6 \times 10^5$ (MH16) | $D_m [s^{-1}]$ | 0.208 | 0.52  | 1.04  | 2.08 | 5.2  | 10.4  | 20.8 | 52   |
|             | $3.5 \times 10^5$ (MH16) | $D_m [s^{-1}]$ | 0.201 | 0.518 | 1.036 | 2.07 | 5.18 | 10.36 | 20.7 | 51.8 |

**Table 3:** Average shear rates  $D_m$  using the MH16G driving system

|             | measuring range [mPas]    | n [min <sup>-1</sup> ] | 0.01    | 0.025   | 0.05    | 0.1    | 0.25   | 0.5    | 1     | 2.5   |
|-------------|---------------------------|------------------------|---------|---------|---------|--------|--------|--------|-------|-------|
| DM64 / TM64 | $10^7$ (MH16G)            | $D_m [s^{-1}]$         | 0.00764 | 0.0191  | 0.0302  | 0.0764 | 0.191  | 0.382  | 0.764 | 1.91  |
| TM06B       | $10^7$ (MH16G)            | $D_m [s^{-1}]$         | 0.00704 | 0.0176  | 0.0352  | 0.0704 | 0.176  | 0.352  | 0.704 | 1.76  |
| TM06        | $3.5 \times 10^7$ (MH16G) | $D_m [s^{-1}]$         | 0.00207 | 0.00518 | 0.01036 | 0.0207 | 0.0518 | 0.1036 | 0.201 | 0.518 |

**Table 4:** System factors for calculation of the average shear stress  $\diamond_m$ 

| Measuring probe | Meas. range [mPas]                                    | Z [mPa/mA] |
|-----------------|-------------------------------------------------------|------------|
| DM64 / TM64     | $10^4$ (MH10)                                         | 2765       |
|                 | $10^5$ (MH16)<br>$10^7$ (MH16G)                       | 4775       |
| TM06B           | $10^4$ (MH10)                                         | 2080       |
|                 | $10^5$ (MH16)<br>$10^7$ (MH16G)                       | 4400       |
| TM06            | $1.6 \times 10^5$ (MH10)                              | 2080       |
|                 | $3.5 \times 10^5$ (MH16)<br>$3.5 \times 10^7$ (MH16G) | 4397       |

$$\diamond_m = Z \cdot (I - 4)$$

with

Z ... system factor in mPa / mA  
I .... output signal in mA

## **2.3. Installation and operating conditions**

### **2.3.1. Assembly dimensions and terminal requirements**

#### **Viscometer**

|                                       |                       |                                                                                                                                                                                                            |
|---------------------------------------|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Type PV100-TM (pressure-proof, Fig.2) |                       | flange connection DN80; PN64 (with groove)                                                                                                                                                                 |
| Type PV100-TM (unpressurized, Fig.2)  |                       | flange connection DN80; PN6                                                                                                                                                                                |
| Type PV100-DM (pressure-proof, Fig.3) | <i>Substance:</i>     | flange connection DN40; PN64 (with groove)<br>or threaded boring M16x1.5 for screwed connection (Ermeto screw connection GE10-PSM-1.4571: special accessory)<br>(special connections available on request) |
|                                       | <i>Temp. control:</i> | threaded boring M16x1.5 for screwed connection (Ermeto screw connection GE10-PSM-1.4571: special accessory)                                                                                                |

Viscometers are preferably mounted in the reactor or pipeline in vertical position (measuring head at the top).

Permissible deviation of the fitting position from the vertical:

|                                                                                       |                                                                                                                         |
|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| Immersion-type and flow-through viscometers<br>PV100-TM; PV100-DM<br>(pressure-proof) | max. 30 angular degrees (or overhead operation)                                                                         |
| Immersion-type viscometer PV100-TM<br>(unpressurized)                                 | max. 10 angular degrees for measuring range $10^4$ mPas<br>max. 30 angular degrees for measuring range $10^5/10^7$ mPas |

#### **Electronic unit**

Electronics housing 3 HE/42 TE for wall mounting (Fig.4)

### **2.3.2. Auxiliary energy**

#### **Voltage**

|                                                |                                            |
|------------------------------------------------|--------------------------------------------|
| viscometer (operation without electronic unit) | 24 V DC (drive and signal each separately) |
| viscometer with electronic unit                | 90-253 V, 50/60 Hz                         |

#### **Power consumption**

|                                                |       |
|------------------------------------------------|-------|
| viscometer (operation without electronic unit) | 15 VA |
| viscometer with electronic unit                | 32 VA |

### **2.3.3. Technical stability**

#### **Nominal pressure**

|                              |                                                       |
|------------------------------|-------------------------------------------------------|
| PV100-TM and -DM viscometers | PN64 (64 bar)                                         |
| PV100-TM viscometer          | atmospheric pressure or PN6 (due to gas backpressure) |
| thermostatic liquid          | PN6 (6 bar)                                           |

#### **Temperature of measured substance**

|                                                                                                              |                                                                              |
|--------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| PV100-TM and -DM viscometers (pressure-proof)                                                                | -30°C ... +300°C                                                             |
| PV100-TM viscometer (low pressure)<br>(Protect measuring device from<br>vapours by means of protective gas!) | -30°C ... +150°C                                                             |
| overload limit of viscometer                                                                                 | 1.2 x viscosity end value of partial measuring range                         |
| compensation range of $\alpha$ -T function                                                                   | dependend from equation constants based on experimental<br>temperature range |

### **2.3.4. Climatic stability**

#### **Ambient temperature**

|                 |                                      |
|-----------------|--------------------------------------|
| viscometer      | -25°C ... +55°C                      |
| electronic unit | 0°C ... +40°C (surface-type housing) |

#### **Degree of protection**

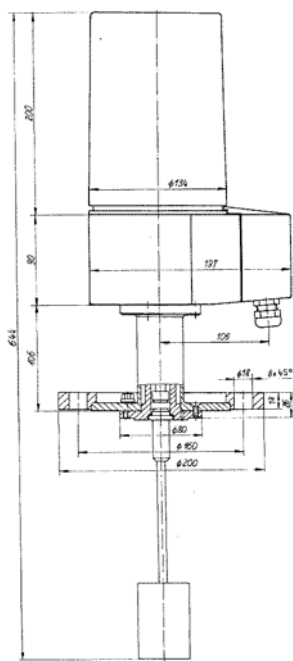
|                           |                              |
|---------------------------|------------------------------|
| PV100-TM; -DM viscometers | IP 54                        |
| electronic unit           | IP 54 - surface-type housing |

#### **Explosion protection**

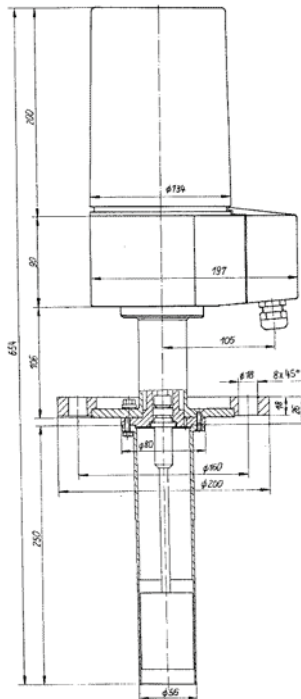
|                 |                                 |
|-----------------|---------------------------------|
| viscometer      | EExde IIB T6 EN 50018           |
| electronic unit | not protected against explosion |

### **2.3.5. Material and weight specifications**

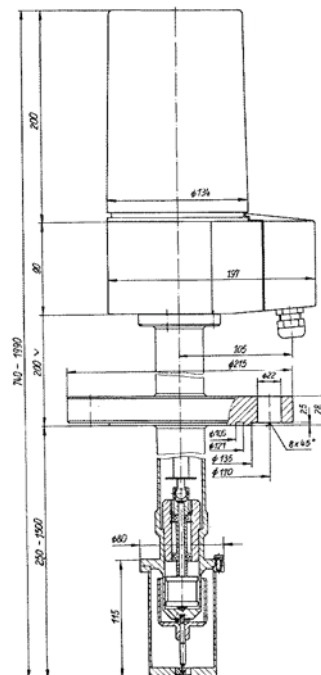
|                                                            |                                                                                                                 |
|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| viscometer parts in contact with the<br>measured substance | special steel 1.4571 according to DIN 17440<br>saphire according to DIN 8262<br>(bearings of measuring element) |
| PV100-TM viscometer (pressure-proof)                       | approx. 20 ... 25 kg (depending on length of immersion probe)                                                   |
| PV100-TM viscometer (low pressure)                         | approx. 7 kg                                                                                                    |
| PV100-DM viscometer                                        | approx. 20 kg                                                                                                   |
| electronic unit                                            | approx. 8 kg - surface-type housing                                                                             |

**PV100-TM06**

- free-rotating meas. element
- torque transmission via rigid shaft

**PV100-TM06B**

- coaxial cylind. meas. system
- torque transmission via rigid shaft

**PV100-TM64**

- coaxial cylind. meas. system (double gap)
- torque transmission via magnetic coupling

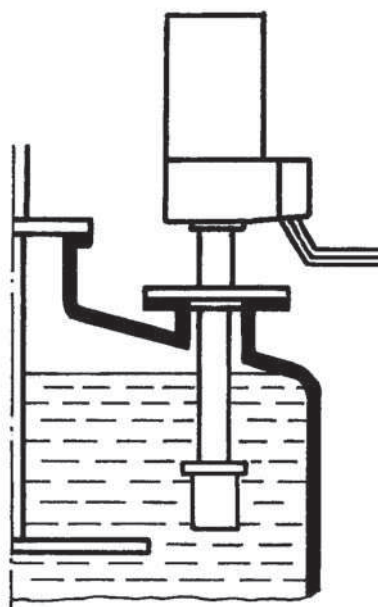


Fig. 2.: Immersion-type measuring devices for PV100 Process Viscometers

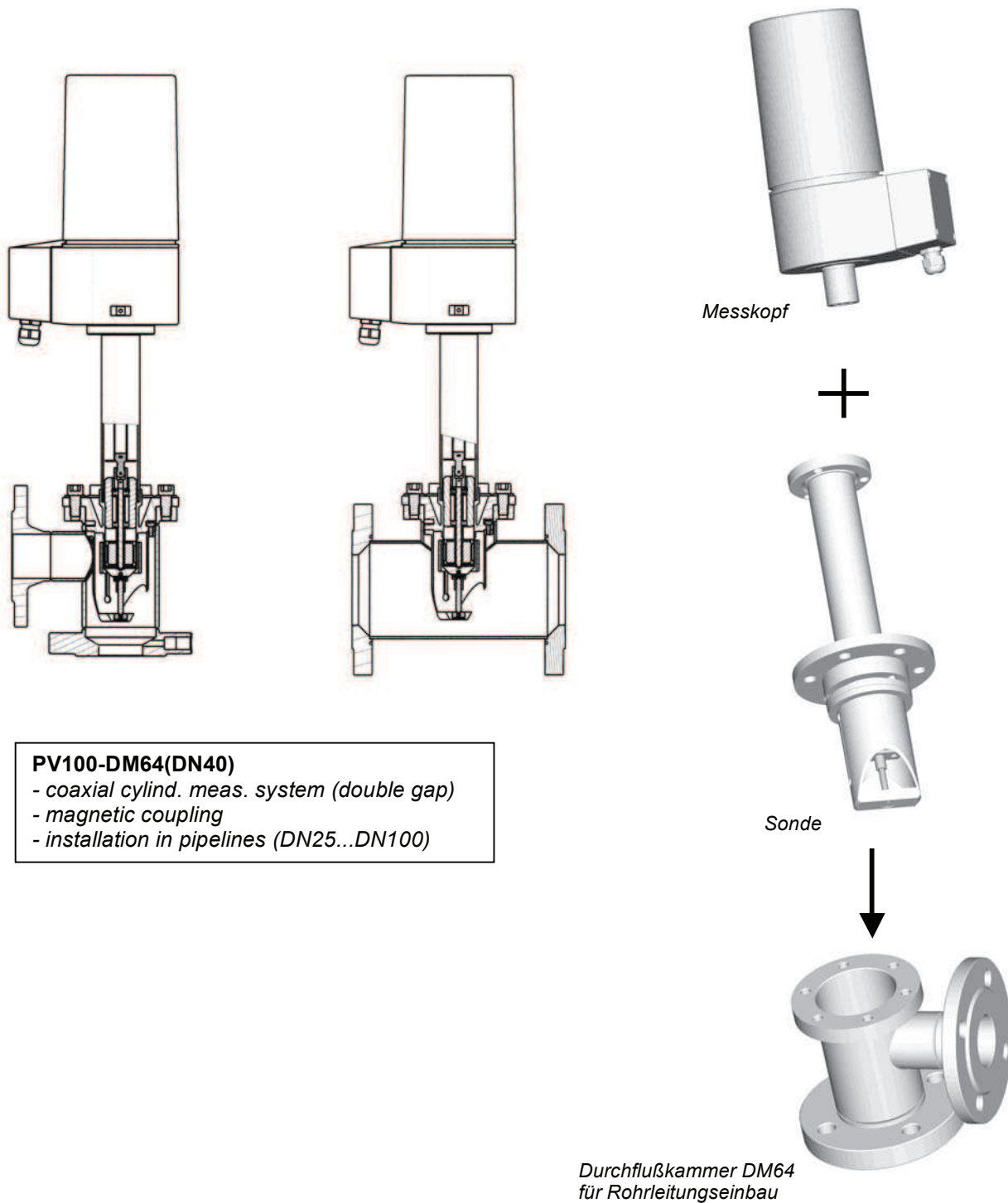


Abb. 3.: Flow-through measuring devices for PV100 Process Viscometers

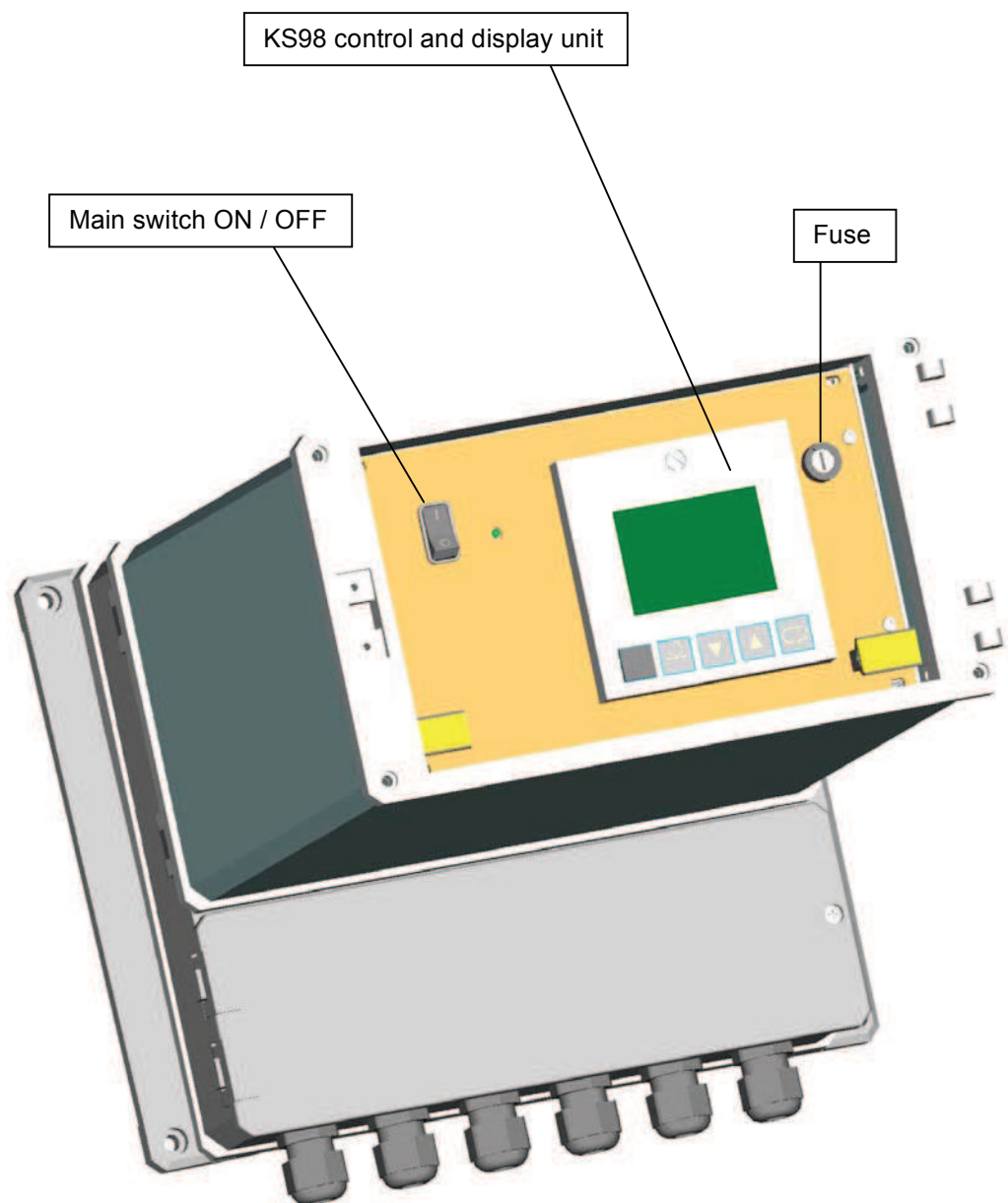


Fig. 4.: Electronic housing for wall mounting

### 3. PRINCIPLE OF MEASUREMENT

The Process Viscometers of the PV100 series are **rotational viscometers** (Fig. 5) with coaxial cylindrical measuring systems of different shapes. The measured substance is sheared in the ring gap of the cylinder system (measuring gap). The only exception is the free-rotation variant TM06 for measurement of apparent viscosity, where the measuring gap is "infinitely" large.

A constant angular velocity is transmitted from the viscometer drive (rotor) to the measuring element (through magnetic coupling or rigid arbor). The torque required to turn the measuring element in the measured substance is the measure for the viscosity of the substance. This torque is recorded by means of a torsion bar, i.e. it is converted into a proportionate angle deflection by the torsion dynamometer, detected by a capacitive transmitter and then converted into the output signal 4...20 mA by a measuring transducer.

The output signal 4...20 mA from the viscometer is used for direct indication, registration and control of viscosity or, through the electronic unit, for the formation of rheological parameters.

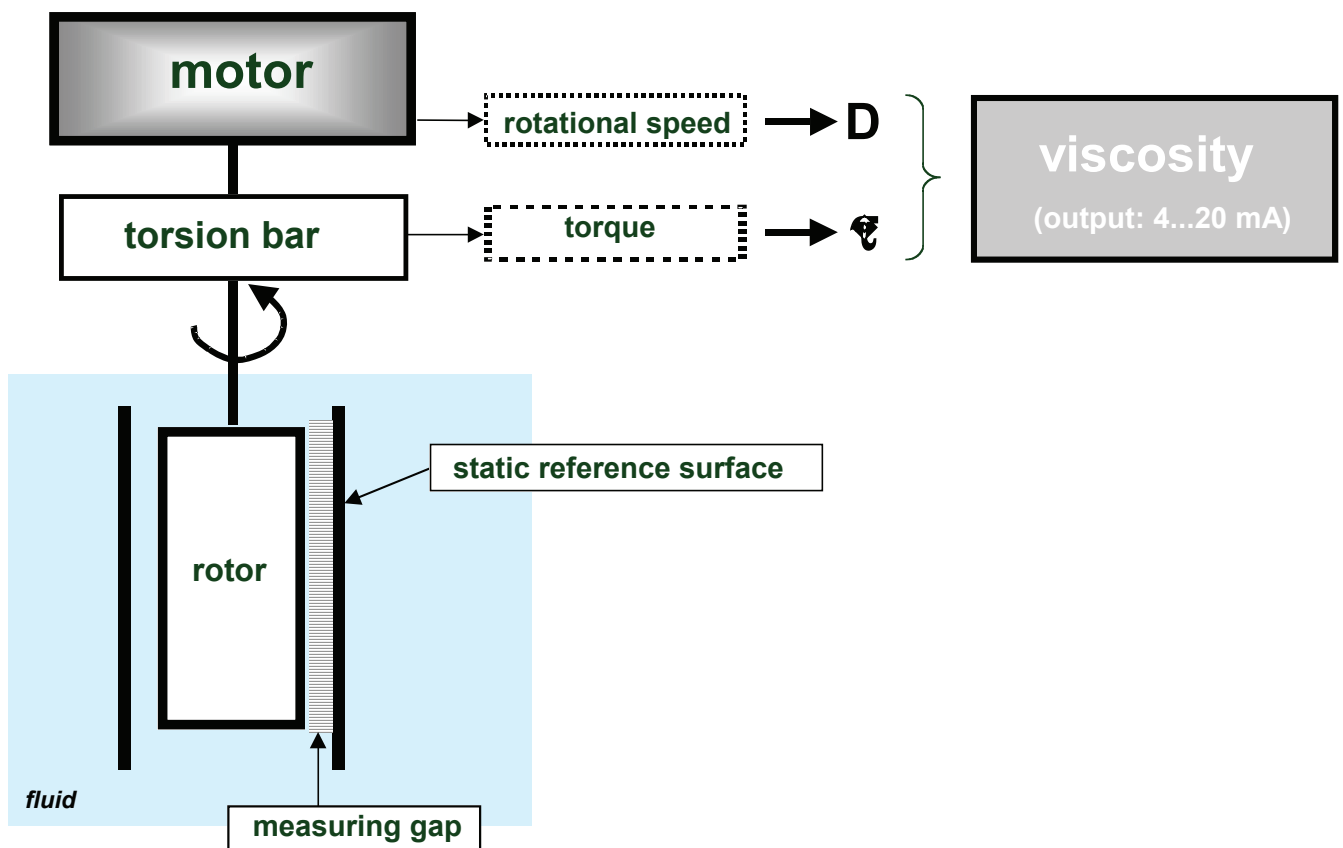


Fig. 5.: Measuring principle of the PV100 Process Viscometer

## 4. INSTRUMENT DESCRIPTION

### 4.1. Process Viscometer

The PV100 Process Viscometer (Fig. 6 and 7) consists of two basic components: **measuring head** (1) and **immersion-type measuring device TM** or **flow-through measuring device DM** (2). In Process Viscometers with pressure-proof immersion or flow-through measuring devices, the measured substance is sheared in the ring gap (7) of the cylinder system. It consists of a stationary inner cylinder - measuring sleeve (3) - and a hollow cylinder - measuring element (4) - and the stationary outer cylinder - measuring cup (5). A permanent-magnetic coupling transmits a constant angular velocity from the viscometer drive onto the measuring element in the pressure-tight measuring location.

The measuring head, which has optional speed steps for selecting the measuring range (drive with and without intermediate gear) and driving torques (10; 16 or 10/75 mNm), is designed to meet the explosion protection requirements of "Pressure-proof casing according to EN 50018". The casing holds the drive and the measuring device.

The drive creates a constant angular velocity. The measuring device measures the natural image signal, "torque", contactless and capacitively and converts it into a corresponding direct current 4...20 mA. A ball-jointed coupling serves to transmit the angular velocity and torque of measuring head and measuring device.

The measuring head is firmly connected to the measuring device (sensor) by means of a cylindrical guide and three screws M5x16. Depending on the model, the leads for motor supply and control as well as for the signal circuit are led into the "increased safety" connecting chamber through one or two gland bolt connections.

The measuring head version for the sugar boiling process permits, due to different torque curves, the representation of the entire measuring range in two successive partial measuring ranges. This variant can only be operated in combination with pressure-free immersion measuring devices.

The **immersion-type measuring device TM** is connected to the measuring head by means of a cylindrical guide. The ball joint of the connecting shaft for the pressure-proof TM engages into the catch shaft of the measuring head and transmits the rotation to the magnetic clutch in the rotor area. The magnetic clutch is separated from the pressure chamber by a partition. Measuring cup and measuring element are in coaxial position and form the "double ring gap" (7). Depending on the respective measuring range, measuring element and measuring cup have different dimensions. The flow resistance in the double ring gap of the coaxial cylinder measuring system is proportional to the rotor torque. Balance and cap jewel can easily be replaced. The continuous exchange of measured substance in the measuring cell is ensured by the slots in the measuring cup and the rotation of the measuring element.

In immersion-type measuring devices with freely rotating measuring elements, the rotation of the measuring element is effected through a shaft held by ball bearings. Threaded connection pieces M10x1 provide the possibility to lead protective gas (e.g. inert gas) through the immersion-type measuring device for pressure compensation. In this case the gas pressure should be slightly higher than the working pressure in the measuring cell, but it should not exceed 0.6 MPa. Through another threaded boring M10x1 in the connecting flange and an additional rinsing chamber the measuring element can be washed in fluid or vapour. This immersion variant can also be operated without measuring cup (note the change of the measuring range!).

The **flow-through measuring device DM** is of analogue design, but the measuring cup is contained in a flow-through cell. The measured substance flows through the cell from the substance inlet at the bottom to the substance outlet at the top. The flow-through cell can be integrated into the pipeline by means of DN40 flange connections or pipe connections.

The flow-through cell is available with an optional liquid temperature control shell (8). The flow direction of the thermostatic liquid in the temperature-controlled flow-through cell is also preferably from the bottom to the top. The measured substance is discharged by means of a screw plug (9), which can be replaced by a built-in resistance thermometer with or without measuring transducer for temperature control in the measured substance or as reference variable for the viscosity-temperature compensation function of the electronic unit. Socket head cap screws M12x20-8.8 connect the measuring cup with the flow-through measuring device. The threaded borings M6x12 in the upper flange can be used for attaching the flow-through measuring device.

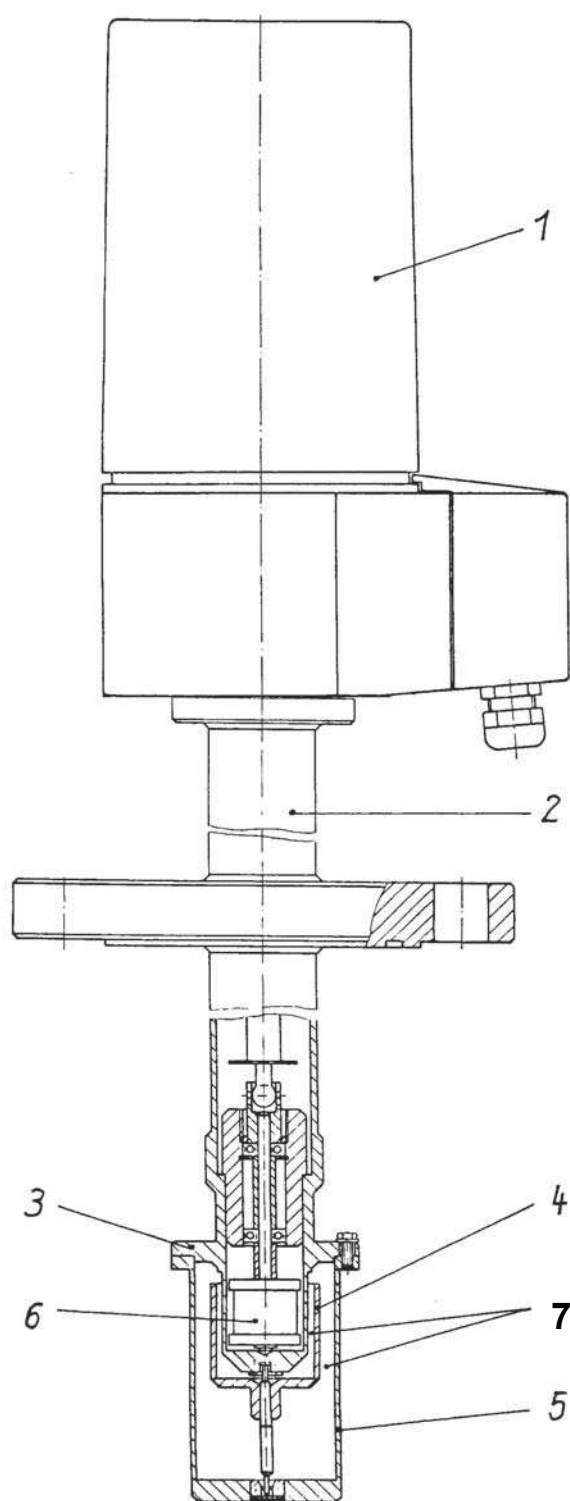


Fig. 6.: PV100-TM Process Viscometer (pressure-proof)

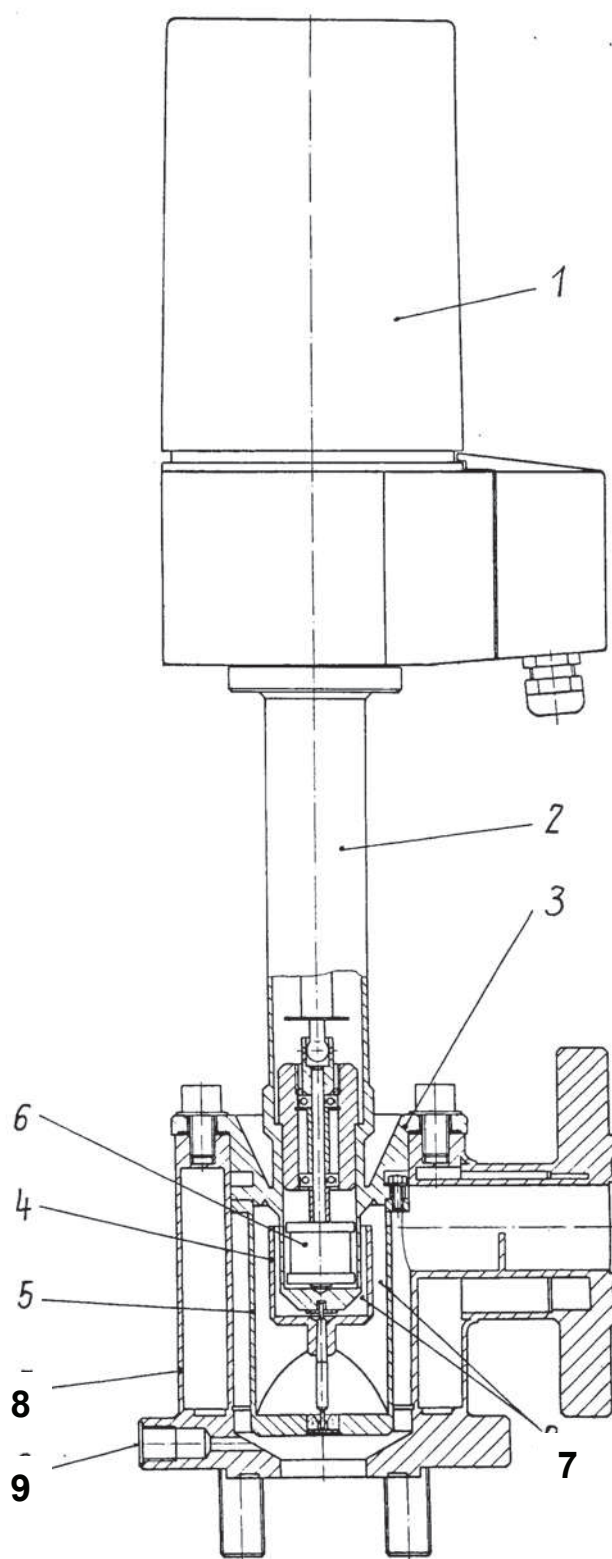


Fig. 7.: PV100-DM Process Viscometer

## 4.2. The electronic unit VC1

The electronic unit supplies the feed voltages for the viscometer and assumes all control and monitoring functions. Collection and processing of measured values make it possible to indicate

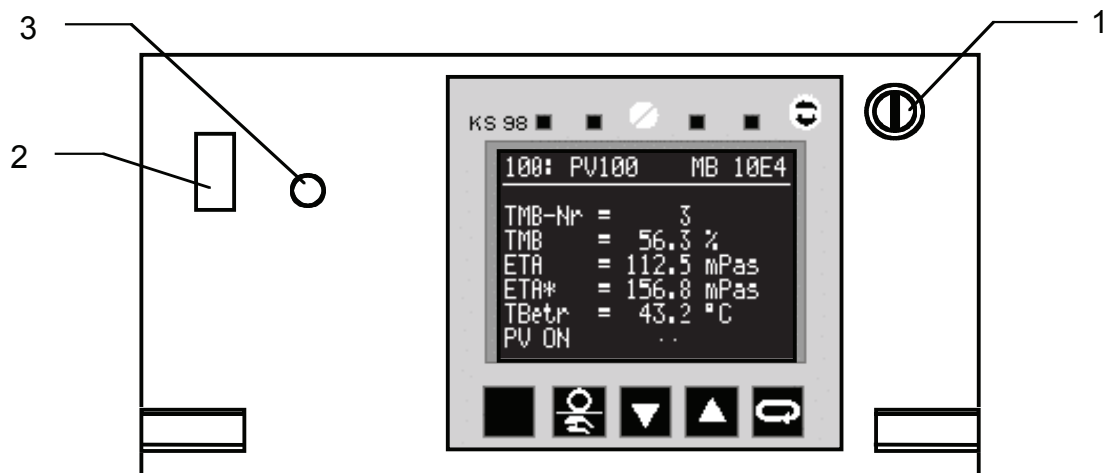
- viscosity
- shear rate
- shear stress
- actual temperature
- compensated viscosity
- percentage of the partial viscosity measuring range.

At the same time, a viscosity limit value is monitored and the viscometer speed controlled in accordance with the partial measuring range.

As an output signal is provided (4...20 mA), which is an image of the partial viscosity measuring range, it is possible to record and control viscosity. The indicated percentage is a standard value for viscosity in the respective partial viscosity measuring range.

The electronic unit VC1 is supplied in a surface-type housing (42 TE and 3 HE). The electronic unit consists of DC/DC printed circuit board, power unit and multifunctional display.

### VC1 cassette



The SV power unit and the DC/DC circuit board supply the feed voltages for the viscometer and the temperature sensor. The inlet from the supply circuit is protected by the fuse Si1 (1). The mains switch (2) serves to switch on the electronic unit. The LED (3) indicates the working order of the voltages.

| Voltage |               | relevant fuse |     |     |
|---------|---------------|---------------|-----|-----|
| 230 V ~ | mains voltage | Si 1          | 1.0 | A T |
| + 24 V  | converter (T) | Si 3          | 0.1 | A T |
| + 24 V  | drive         | Si 2          | 1.6 | A T |

### **4.2.1. Description of controller KS98**

The control unit KS98 is an operating and visualization unit. It is a main part of Viscometer Electronics Unit VC1.

The multifunctional unit, KS98, takes the mean of the analogue signal  $I_{(ETA)}$  (4...20mA) generated by the PV100 Process Viscometer and the analogue signal  $I_{(T)}$  (4...20mA) from the temperature measuring transducer, converts it and indicates it as a physical variable.

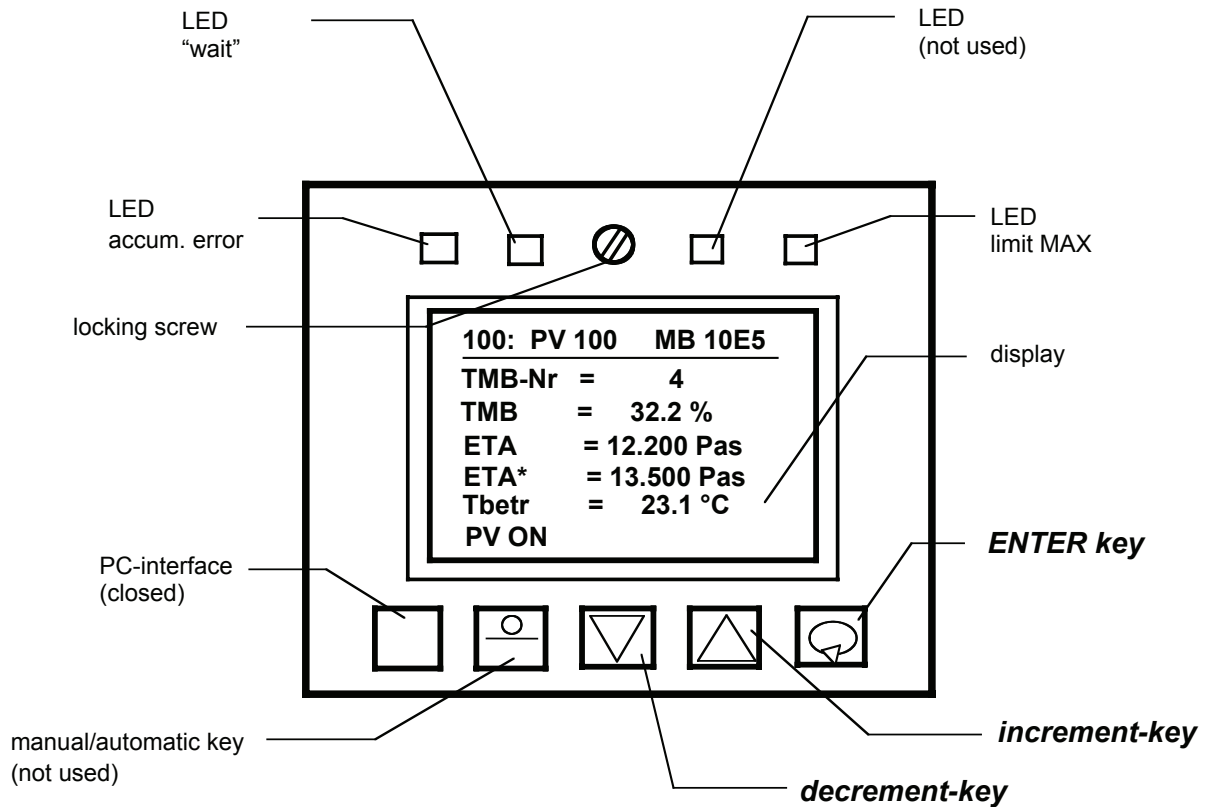
Through the output OUT1 of KS98 the process viscometer receives the control signal  $I_{(n)}$  for switching between the partial measuring ranges.

Either the unconverted viscosity signal (4...20 mA) or the analogue viscosity signal (4...20 mA), which was determined using a viscosity-temperature function, is available for further use at output OUT2.

The relay at output OUT4 indicates upper deviations from the limit set to a value lower than the parameter "Gzmax", and the relay at output OUT5 reports the accumulative error.

When the auxiliary energy is switched on, the PMA logo and the main menu will be displayed for a short time, followed by the operating pages **100: PV100 MB 10E4** or **5** or **7**.

**With the 35% partial measuring range monitoring in operation it is important that all components be supplied with auxiliary energy simultaneously. Otherwise, faults may occur in the switching between the partial measuring ranges!**

**Front view of KS98 unit in Viscometer Controller VC1**

LED ..... indicates the actual condition

attachment screw ..... serves to lock the plug-in unit in the housing

PC interface ..... for software transmission

display ..... LCD dot matrix

**Operating keys**

For adjustment of controller KS98 just three operating keys are necessary to use.

Pressing the **increment-key** or the **decrement-key** will scroll the active line (in reverse representation) to the start or end of the menu, respectively.

By pressing the **dial key**, in which an adjustable parameter will begin to blink in reverse representation, one can now alter the value with the increment-key or decrement-key.

When the required value is reached, the set value is confirmed with the dial key. Pressing the dial key while no line is shown in reverse representation one can chose from the operating pages described below.

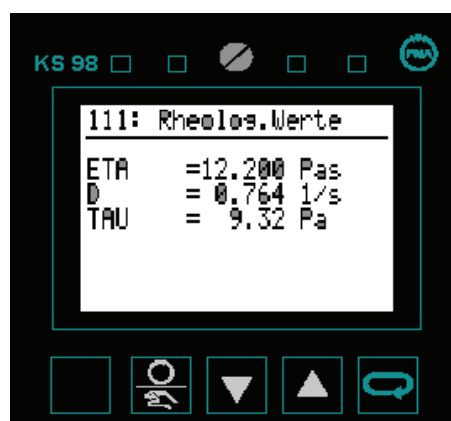
### 4.2.2. Operating pages

#### 100 : PV100 MB 10E4 or 5 or 7



- TMB-Nr** = indication and adjustable partial measuring range
- TMB** = indicates measured value ETA in % of the measuring range
- ETA** = indicates viscosity in mPas or Pas
- ETA\*** = indicates compensated viscosity in mPas or Pas relating to Tref
- T Betr** = indicates system temperature
- PV ON/OFF** = indication and adjustable status of PV100 drive  
(If the total measuring range is exceeded, the programme of KS98 will switch "OFF")

#### 111 : Rheolog. Werte



- ETA** = indicates viscosity in mPas or Pas
- D** = indicates shear rate in  $s^{-1}$
- TAU** = indicates shear stress in Pa

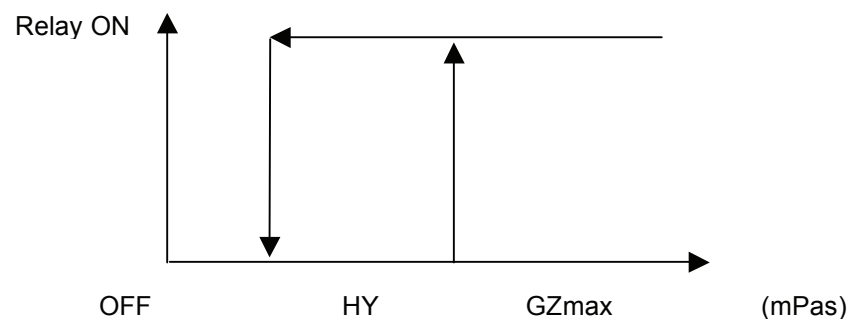
**118 : Konfiguration1****ON-TMB**

= adjustable initial measuring range which is functional after connection to the mains

**GZmax**

= adjustable limit in mPas or Pas

Control state at specification of **GZmax** and **HY**:

**HY****OUT2ETA\*/OUT2ETA**

= adjustable hysteresis of the switching point in mPas or Pas  
 = adjustable variant for output of the compensated viscosity signal or the uncompensated viscosity signal to terminal OUT2 (standard:OUT2/ETA\*)

**Tkpolyn.**

= Indication of variant for calculation of compensated viscosity by the equation:

$$\text{equation } y = 1 + ax + bx^2 + cx^3 \quad \text{with} \quad y = \eta(T=25^\circ\text{C}) / \eta(T_{\text{ref}})$$

Basic adjustment for reference temperature is  $T_{\text{ref}}=25^\circ\text{C}$ .

For recalculation of actual viscosity into a value to be expected for a special reference temperature:

$$\zeta^* = \zeta \frac{1 + a \cdot 10^{\text{EXP1}} (T_{\text{Betr}} - 25) + b \cdot 10^{\text{EXP2}} (T_{\text{Betr}} - 25)^2 + c \cdot 10^{\text{EXP3}} (T_{\text{Betr}} - 25)^3}{1 + a \cdot 10^{\text{EXP1}} (T_{\text{Ref}} - 25) + b \cdot 10^{\text{EXP2}} (T_{\text{Ref}} - 25)^2 + c \cdot 10^{\text{EXP3}} (T_{\text{Ref}} - 25)^3}$$

♦\* ... reference viscosity (ETA\*) at  $T_{\text{ref}}$

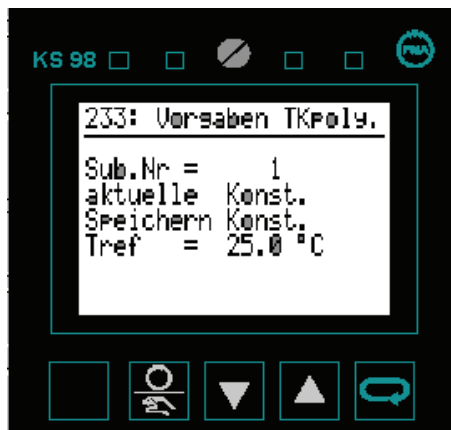
♦ .... actual viscosity (ETA) at  $T_{\text{Betr}}$

**CODE**

= For use by service personnel only !

**230 : aktuelle Konstanten**

|             |   |                                                     |
|-------------|---|-----------------------------------------------------|
| <b>a</b>    | = | indication and setting of constant 1                |
| <b>EXP1</b> | = | indication and setting of power of ten (constant a) |
| <b>b</b>    | = | indication and setting of constant 2                |
| <b>EXP2</b> | = | indication and setting of power of ten (constant b) |
| <b>c</b>    | = | indication and setting of constant 3                |
| <b>EXP3</b> | = | indication and setting of power of ten (constant c) |

**233 : Vorgaben Tkpoly**

|                                          |   |                                                                                             |
|------------------------------------------|---|---------------------------------------------------------------------------------------------|
| <b>Sub.Nr</b>                            | = | indication or setting of sample number (1...10)                                             |
| <b>akt. Konst. bzw. bearbeit. Konst.</b> | = | select whether operating page „230: aktuelle Konst.“ is displayed or modified (see 4.2.3.)  |
| <b>Speichern Konst. (ok)</b>             | = | after changing the data of choosen constant set, select „ok“ to save the modified constants |
| <b>Tref</b>                              | = | input reference temperature to be considered for calculation                                |

### **4.2.3. Input of equation constants**

To modify or enter a set of equation constants (e.g. for a new substance), proceed as follows:

1. set the appropriate **Sub.Nr** in the operating page „233: Vorgaben Tkpoly“
2. select **Bearbeit. Konst.**
3. go to operating page „230: aktuelle Konst.“
4. set or modify **coefficients** at the abovementioned page
5. go to operating page „233: Vorgaben Tkpoly“
6. go to **ok** under **Speichern Konst.** and confirm

Note: The order of inputs must be observed!

## **5. INSTRUMENT ASSEMBLY**

### **5.1. Process Viscometer**

Prior to the assembly of the viscometer, the measuring element must be carefully fitted into the measuring cell of the measuring device (Observe assembly instructions for measuring element!).

The PV100-TM viscometer is preferably installed in the container in vertical position (measuring head up!) by means of a flange (for permissible deviations, see Fig. 2.3.1).

The PV100-DM viscometer is also installed in vertical position, using either the threaded borings in the lateral connecting flange and the flange-flange connection, or the screw connections of the viscometer and the pipeline. With flow rates of  $Q \leq 6 \text{ m}^3/\text{h}$ , the mains for the measured substance can be integrated directly into the main flow (direction of substance flow from bottom to top).

The built-in resistance thermometer, which may be required for temperature registration or in function with the electronic unit, can be screwed in instead of the outlet screw plug. The supply voltage for the drive is applied directly (electronic drive 24 V DC, synchronous motor  $230 \text{ V} \pm 10 \%$ ) and for the signal circuit in 24 V DC or through a measuring transducer buffer amplifier with auxiliary power for intrinsically safe display circuits, depending on the application.

#### **Installing the measuring element in PV100-TM and -DM Process Viscometers (pressure-proof)**

Slide the cleaned measuring element over the flange sleeve and fit it into the upper bearing.

**Caution!** The magnetic clutch in viscometers with a nominal pressure of 6.4 MPa has a tendency to pull the measuring element over the flange sleeve and into the bearing abruptly. Do not let the measuring element jerk, for this might damage the bearings!

Fix the measuring cup with counter-bearing with 3 M5 screws without tilting it.

#### **Installing the measuring element in PV100-TM Process Viscometers (low pressure)**

The measuring element is fitted or removed directly by means of a lefthand-thread coupling.

**Attention!** The measuring element must be screwed in tight (hold measuring shaft with a size 9 spanner put through the measuring tube hole, screw the measuring element in by hand and screw it tight with a size 3 face spanner).

### **5.2. Electronic unit**

The electronic unit must be installed outside hazardous locations - preferably in measuring stations or similar locations.

The functioning of the electronic unit requires, apart from the electrical connection of the viscometer, the installation of a temperature sensor with transducer (4...20 mA). A suitable measuring transducer buffer amplifier with auxiliary energy must be installed to feed an intrinsically safe transducer. The length of the lead between the viscometer and the electronic unit, or between the electronic unit and the temperature measuring transducer, must not exceed 200 m, otherwise it must be limited by appropriate additional instruments.

To ensure intrinsically safe outputs it is necessary to insert suitable isolating amplifiers (Ex zone) or power supply units (Fig. 8). The leads on the viscometer should be long enough for the viscometer to be disassembled for maintenance purposes without detaching the connecting leads.

The protective conductor must be connected by the user according to the regulations, using the proper terminal in the surface-type housing and the M4 connecting bolt.

Cabling must follow the connecting drawing (Fig. 9 or 10) or the design diagramme (Fig. 11 or 12).

### **Safety instructions**

- Read the operating manual through carefully before installing, using or operating the instrument.
- **Warning!** After unpacking the instrument should be checked for mechanical damages and loose parts. In the event that a shipping damage is detected the supplier must be informed immediately. In this case the instrument must not be taken into operation.
- This instrument complies with VDE 411 / EN 61010-1 and is exclusively intended for use in technical systems as a measuring and control instrument.
- This instrument is intended for permanent connection according to the provisions of protection class I. It must be installed by qualified staff, observing all applicable VDE or regional regulations.
- Mains leads must be separated from signal or measuring lines.
- We recommend that twisted and screened measuring lines be used (screening and measuring earth connected).
- Exposure to external interference voltages (including high-frequency voltage) may result in malfunction of the instrument. A measuring earth must be connected in order to shunt the interference voltages and to increase the interference immunity of the instrument.  
A short line with earth potential must be connected to the measuring earth terminal.
- **Warning!** When instruments are opened or covers or components removed, live components may be exposed. Connection points may also be live. The instrument must be disconnected from all voltage sources before the commencement of such work.
- Whenever a fuse is blown, the cause must be found and eliminated. The replacement fuse must have the same parameters as the original one.

### **Explosion protection**

- The electronic unit is not explosion-protected und must therefore not be operated in explosion-endangered rooms. Moreover, the input and output circuits of the instrument must not lead into explosion-endangered rooms. Explosion protection must be guaranteed by means of the appropriate instruments, for which a certificate of explosion proofness is required. With respect to these explosion-proof instruments, the additional details in the respective certificate of conformity and the regulations of the respective country for the installation of electrical systems in explosion-endangered areas must be observed.

## **5.3. Assembly**

Particles of foreign solid matter in the substance (in particular ferrite particles) must be kept away from the probe by inserting suitable magnetic-mechanical filters.

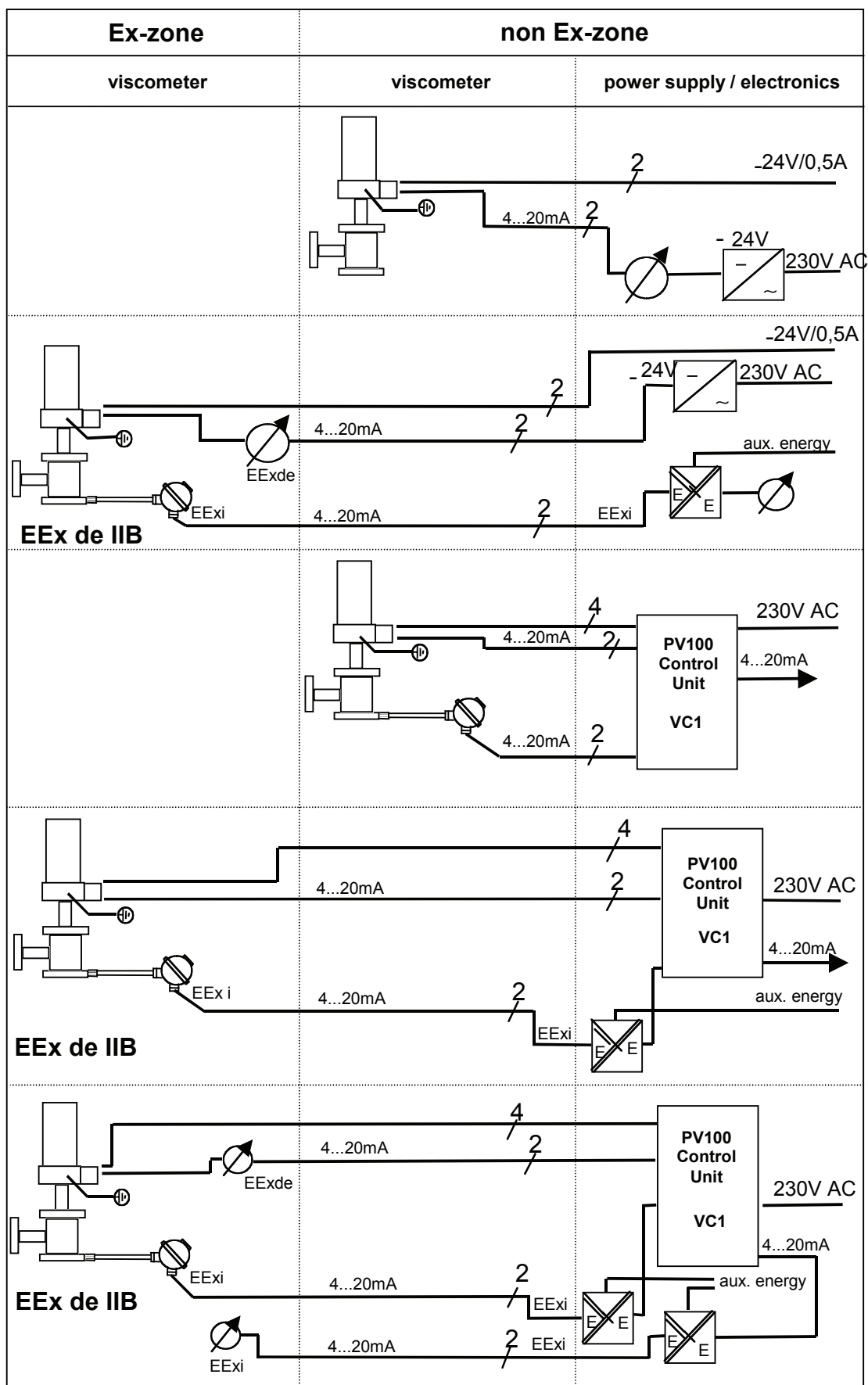


Fig. 8.: Design diagramme for Process Viscometers

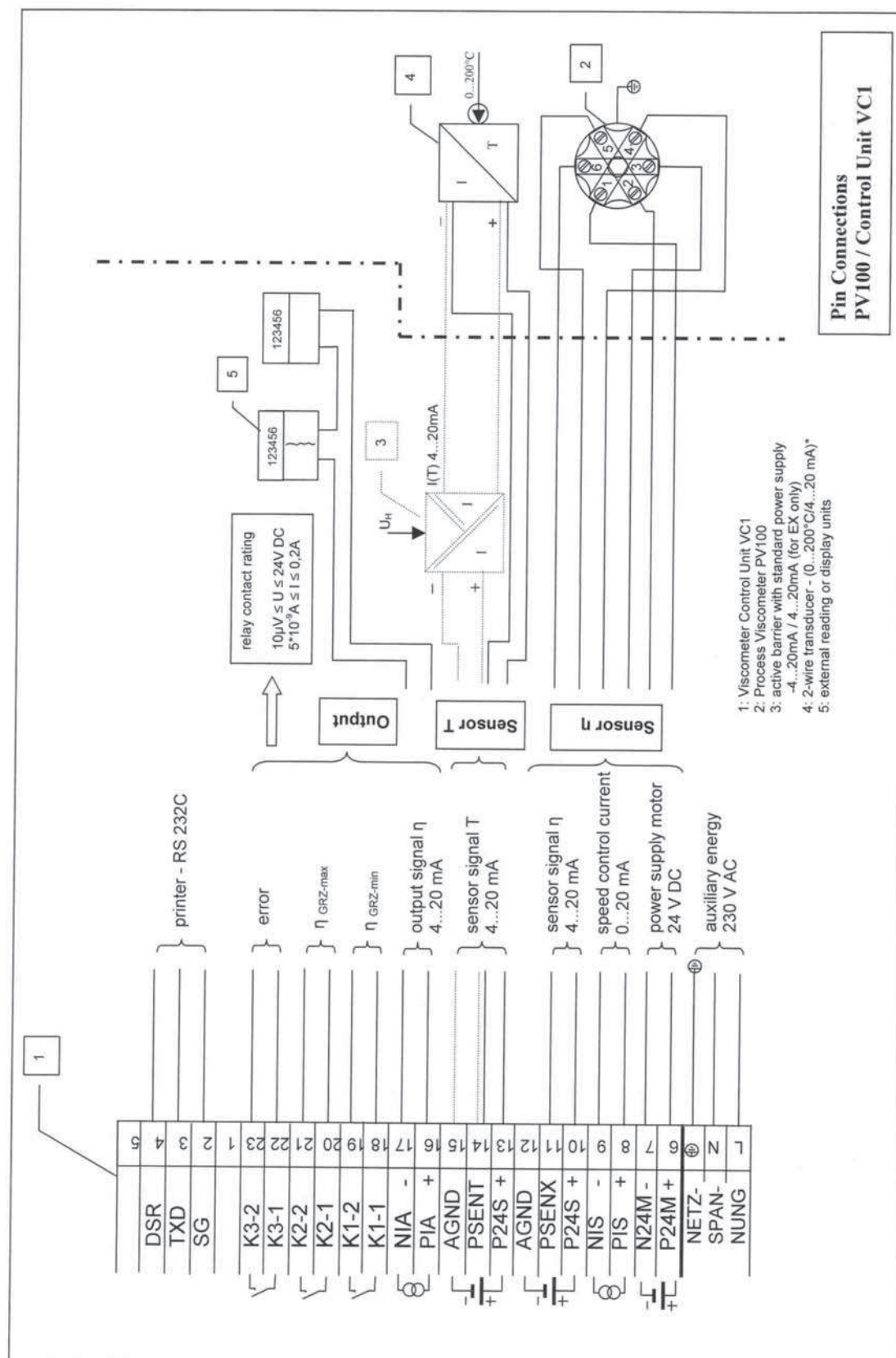


Fig. 9.: Terminal assignment electronic unit (surface-type housing)

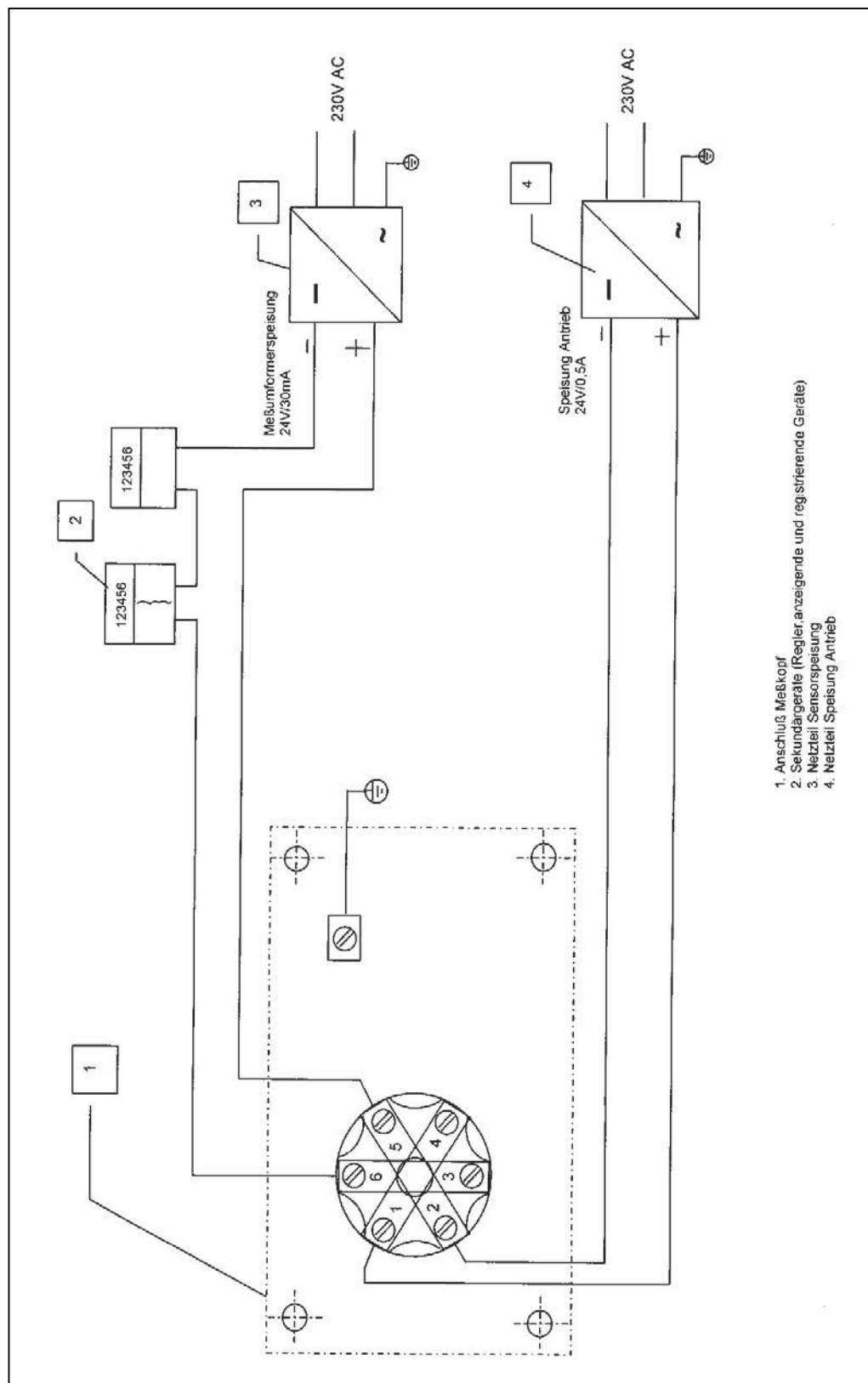


Fig. 10.: Connection of measuring head (without electronic unit VC1)

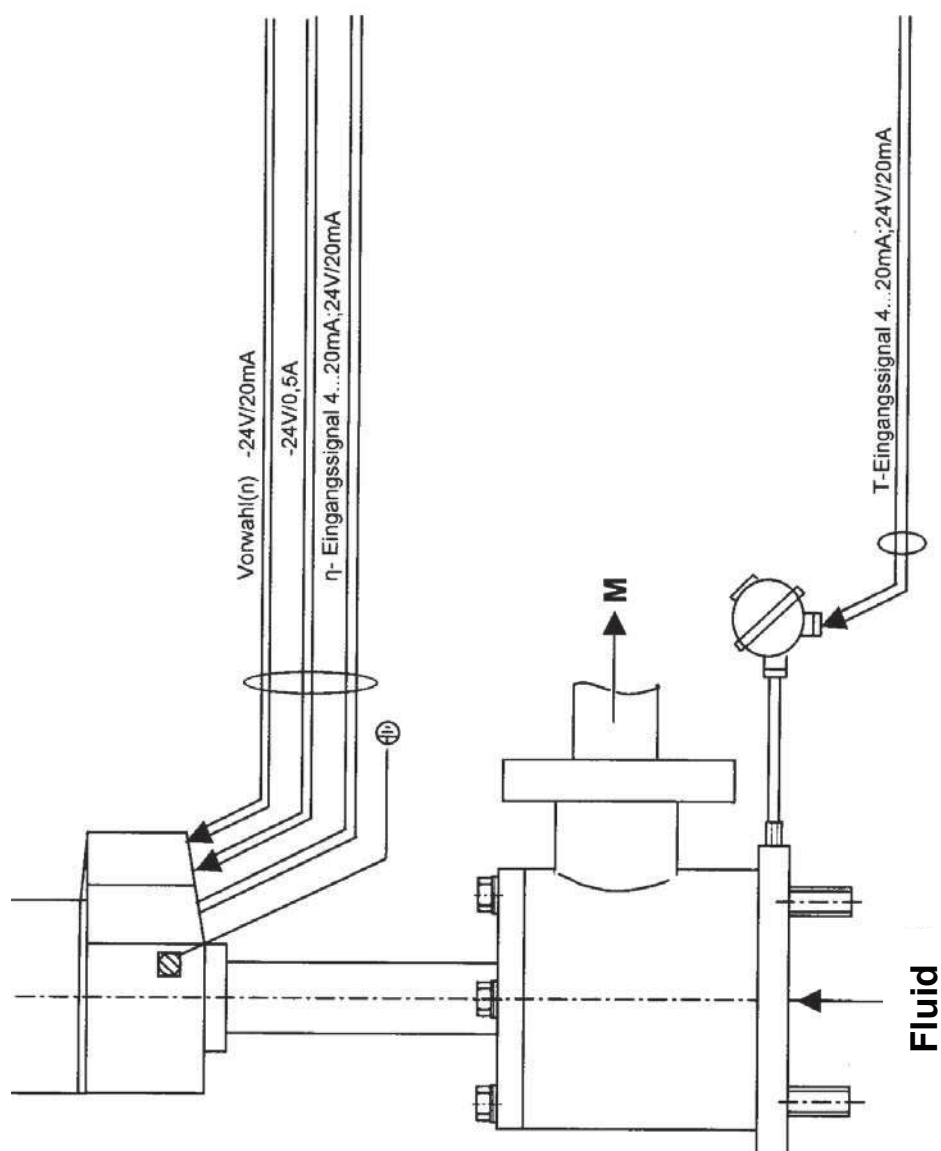


Abb. 11.: Design diagramme of PV100 Process Viscometer

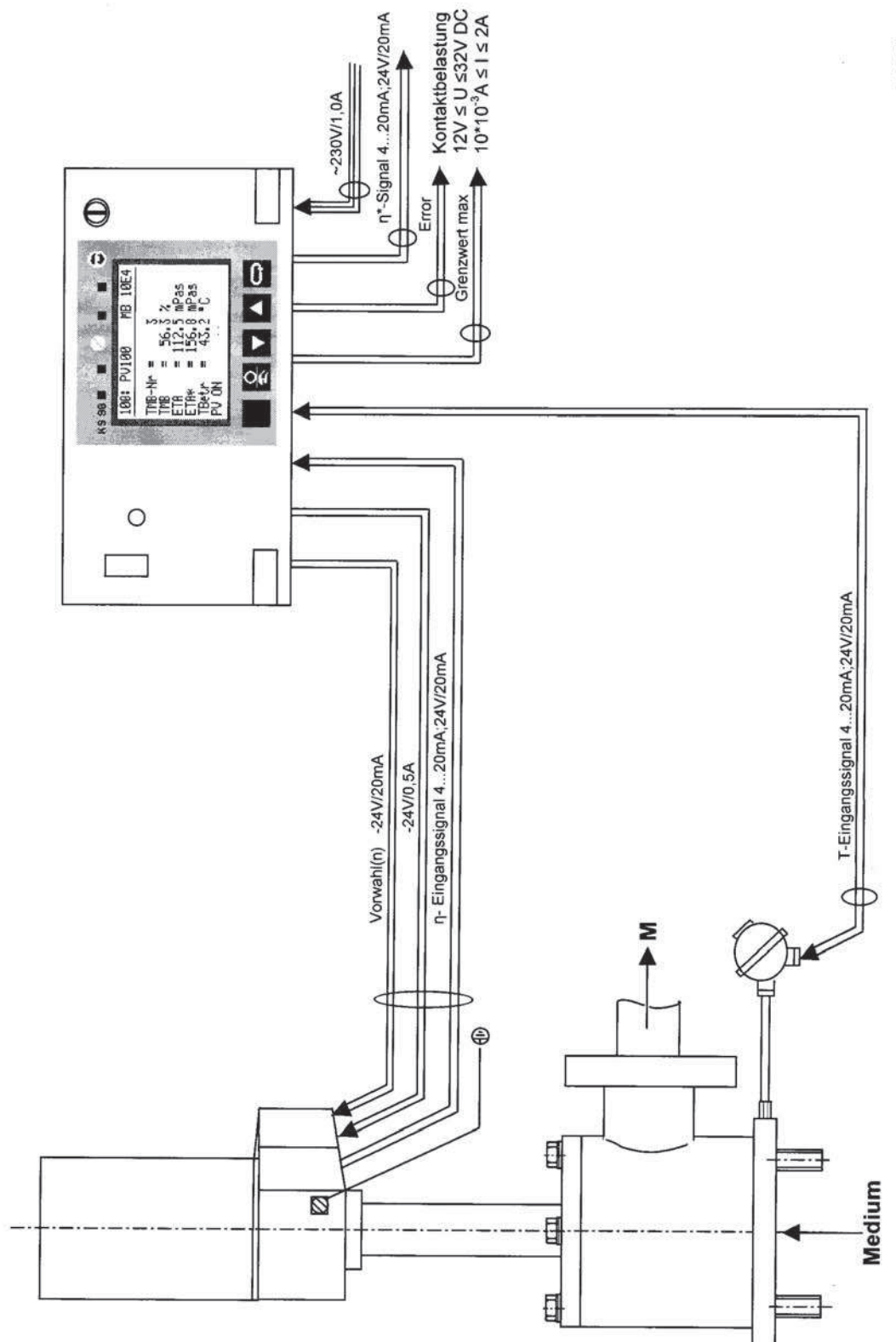


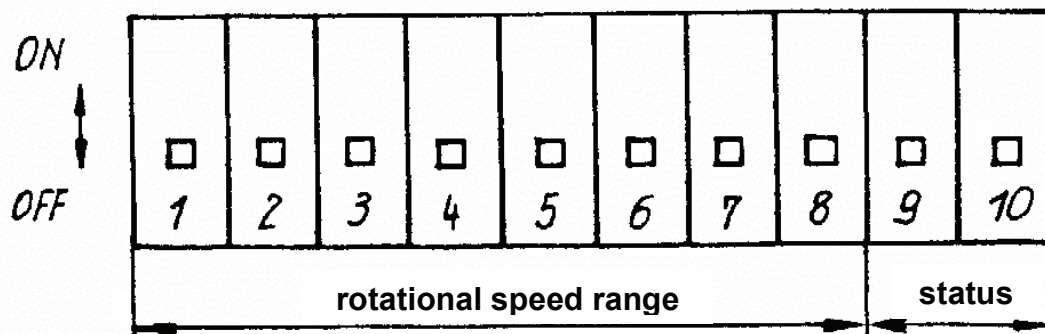
Fig. 12.: Design diagramme of PV100 Process Viscometer with electronic unit

## 6. INITIAL OPERATION

### 6.1. Process Viscometers

The Process Viscometers are calibrated in the factory in such a way that the measuring range or the partial measuring ranges are converted into the standard current signal 4...20 mA.

If the Process Viscometer is used with electronic unit, the required partial measuring range, and with that the speeds, are set by a control current (terminals 3 and 4) produced by the electronic unit. In this application the positions 1...10 at the DIL switch S1 are "OFF".



If the viscometer is operated without electronic unit, the speed is set by the switch position of S1.

| Speed<br>[rpm] | Switch position |     |     |     |     |     |     |     |    |    |
|----------------|-----------------|-----|-----|-----|-----|-----|-----|-----|----|----|
|                | 1               | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9  | 10 |
| 250            | ON              | OFF | OFF | OFF | OFF | OFF | OFF | OFF | ON | ON |
| 100            | OFF             | ON  | OFF | OFF | OFF | OFF | OFF | OFF | ON | ON |
| 50             | OFF             | OFF | ON  | OFF | OFF | OFF | OFF | OFF | ON | ON |
| 25             | OFF             | OFF | OFF | ON  | OFF | OFF | OFF | OFF | ON | ON |
| 10             | OFF             | OFF | OFF | OFF | ON  | OFF | OFF | OFF | ON | ON |
| 5              | OFF             | OFF | OFF | OFF | OFF | ON  | OFF | OFF | ON | ON |
| 2.5            | OFF             | OFF | OFF | OFF | OFF | OFF | ON  | OFF | ON | ON |
| 1              | OFF             | OFF | OFF | OFF | OFF | OFF | OFF | ON  | ON | ON |

Changes to the switch positions may only be made when the system is dead!

After applying the voltage for motor and measuring circuit the instrument is ready for operation without any further calibration.

## **6.2. Process Viscometer with electronic unit**

The cable connection between the viscometer and the electronic unit has to follow Fig. 9 or Fig. 12. After the supply circuit and the mains switch have been switched on, the instrument will display the logo and, for a few seconds, the main menu, followed by the first operating page (see 4.2.1).

### **Messages**

Messages appear in the top line of the display.

| <b>Message</b>  | <b>Probable cause</b>                                                                                                                                           | <b>Corrective action</b>                                                                               |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| Overflow MB8    | viscosity limit exceeded                                                                                                                                        | - viscosity of substance exceeds measuring range of viscometer<br>- viscometer rotor blocked           |
| PV OFF          | viscometer idle (rotational speed = 0 rpm)                                                                                                                      |                                                                                                        |
| Sensor ETA Fail | - viscometer not wired-up<br>- sensor signal < 2 mA                                                                                                             | check wiring                                                                                           |
| Sensor TEM Fail | - temperature sensor not wired-up<br>- sensor signal < 2 mA                                                                                                     | check wiring                                                                                           |
| ETA* Fail       | calculation of compensated viscosity outside of viscosity range                                                                                                 | - bring actual temperature into the respective temperature range<br>- check coefficients in the recipe |
| ...wait         | viscometer is in the process of switching between partial measuring ranges, with that the viscosity indication is updated and a new partial measuring range set |                                                                                                        |

## **7. MEASUREMENT AND EVALUATION**

### **7.1. Process Viscometers**

The partial measuring ranges of a Process Viscometer are given in the test certificate supplied with the instrument and realized by pre-selecting the corresponding speed. The overload limit of the partial measuring ranges depends on the magnetic clutch required for torque transmission or on the shearing pin of the coupling between measuring head and probe (in pressure-free probes). Normally it is 1.2 times the viscosity limit.

The measuring result is evaluated (see test certificate) by the following equation:

$$\diamond = F (I - 4)$$

with  $F$  = system factor [mPas/mA]

$I$  = output signal in [mA]

### **7.2. Process Viscometers with electronic unit**

All process-relevant rheological parameters (viscosity, temperature, corrected viscosity) are represented directly on the display of the electronic unit.

## **8. MAINTENANCE**

The viscometers are designed to withstand the hard conditions of the process and work largely maintenance-free.

Depending on the properties of the substance (non-homogeneity, soiling by particles of solid matter, deposits on the measuring surfaces), or in connection with a change of the measured substance, it may be necessary to clean the sensor. This can be done by immersion or rinsing the sensor in a suitable solvent or by thoroughly cleaning the sensor. The sensor must be disassembled beforehand!

The flow-through probe can be disassembled for the cleaning or maintenance of its cylinder system by unscrewing the 6 M12 hexagon bolts. In this way the cylinder system can be removed and reinserted without disconnecting the pipe connections from the feed line.

**The electronic unit requires no maintenance!**

## 9. CORRECTIVE ACTION

| No.                    | Disturbance                            | Probable cause                                                                                                                      | Corrective action                                                                                                   |
|------------------------|----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| <b>Viscometer</b>      |                                        |                                                                                                                                     |                                                                                                                     |
| 1                      | heavy fluctuation of reading           | measuring range exceeded                                                                                                            | change partial measuring range by reducing the speed                                                                |
|                        | magnetic coupling disconnects          | hardened substance residues                                                                                                         | cleaning (not mechanically)                                                                                         |
| 2                      | reading alternates                     | cracks in the bearing jewels;<br>shaft of measuring element<br>grooved by wear                                                      | replace                                                                                                             |
|                        |                                        | bearings not clean (incl. roller bearings)                                                                                          | clean bearings of measuring element; ball bearings in the instrument can only be replaced by manufacturer's service |
| 3                      | deviating viscosity values             | friction values too high:<br>- cracks in the bearing jewels<br>- shaft of measuring element<br>grooved by wear<br>- bearings soiled | replace bearings of measuring element;<br>replace shaft of measuring element                                        |
|                        |                                        | calibration misadjusted                                                                                                             | instrument must be calibrated by manufacturer's service                                                             |
|                        |                                        | deviating working temperatures                                                                                                      | thermostat                                                                                                          |
| 4                      | no reading                             | drive defective                                                                                                                     | replace                                                                                                             |
|                        |                                        | measuring transducer defective                                                                                                      | have it replaced by service                                                                                         |
| 5                      | 20 mA display                          | display circuit open                                                                                                                | make solid contact connection                                                                                       |
| <b>Electronic unit</b> |                                        |                                                                                                                                     |                                                                                                                     |
| 6                      | LED (11) without reading               | no mains voltage applied                                                                                                            | check power supply<br>check fusing instrument front<br>cartridge fuse (1.0 A T)                                     |
| 7                      | drive does not turn                    | no motor supply voltage applied                                                                                                     | check voltage                                                                                                       |
|                        |                                        | miniature fuse TRS-T<br>Si1 1.6 A T                                                                                                 | replace miniature fuse                                                                                              |
| 8                      | display Electronic unit Sensor XX Fail | viscometer cabling interrupted                                                                                                      | check cabling                                                                                                       |
|                        |                                        | miniature fuse TRS-T<br>Si3 0.1 A T                                                                                                 | replace miniature fuse                                                                                              |
| 9                      | display dark                           | no mains voltage                                                                                                                    | check power supply<br>check fusing instrument front<br>cartridge fuse (1.0 A T)                                     |