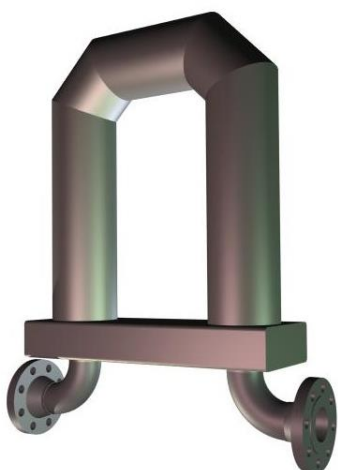

OPERATION INSTRUCTION MANUAL

CORIOLIS MASS FLOW METERS

Sensors

CMM series



March 2015

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1. DESIGNATION, FIELDS OF APPLICATION

At control of industrial processes, beside the knowledge of state parameters it is important to handle, measurement and control of material flows.

In many cases it is enough to measure volumetric flow, but in more and more cases the need of control of **mass proportions, mass balances** arises as well as **custody transfer based on mass**. The mass flow measurement built of traditional instruments based on volume measurement is called indirect measurement as the mass flow is calculated by correction for different state parameters (density, pressure, temperature, composition etc.) indirectly. This method contains several additional errors, which are eliminated by the CMM direct mass flow meter.

Some fields of application in most of which almost exclusively the direct mass flow measurement means the solution without problems are:

- batch control of aggressive mediums at chemical works
- measurement and control of mass balance of mixing proportions
- measurement, download and mass custody transfer of LPG
- direct mass measurement of high pressure gases and vapors (steam), the correction of volume measurement for pressure, temperature and composition is eliminated
- natural gas download station (custody transfer measurements)
- measurement of highly viscous materials

2. PRINCIPLE OF OPERATION

As it is known the Coriolis force F_C affecting at the mass m moving at a speed v in a system spinning with angular velocity of ω is proportional to the vectorial product of the angular velocity and the velocity of the mass:

$$F_C = 2 \cdot m \cdot \omega \times v$$

It is rather complicated to conduct a mass flowing in a pipeline through a spinning system, but if we construct a resonating pipe system instead of a pipe system performing a steady spinning movement, the mechanical construction of the instrument is essentially simplified and other advantages coming from the oscillation can be of use.

According to this the CMM contains also oscillating measuring tubes. The mass flow entering through the inlet conduit of the flow meter is distributed by the flow-splitter to the pipes (measuring tubes) bended parallels and symmetrically. The measured medium after flowing through the measuring tubes is collected in the meter body and is exiting the meter through the outlet pipe.

Due to an electromagnetic oscillating coil the symmetrical constructed pair of measuring tube is oscillating continuously and symmetrically at its momentary resonance frequency. Two sensor coils are fixed at the pipes symmetrically, sensing the symmetry of the oscillation. In zero-flow condition the electric signal of the two coils are sine wave signals identical in amplitude and in phase. In case a mass flow is started through the pipes, the Coriolis forces disturb the symmetry of the oscillation. Due to this the sine wave signal of the sensor at one side is shifted in phase from the sine wave signal of the sensor at the other side. The value of the phase shift is directly proportional to the mass flow

The completed mass flow metering system consists of two main parts:

CMM mass flow sensor

that contains the conduit arrangement described above, pipefittings, the driving and oscillation sensing elements, the resistance thermometer Pt100 sensing the temperature of the medium, cable connector, cover and its safety accessories.

MSP signal processing unit

receiving the signals of the two vibration sensors and the temperature sensor, provides the proper driving of the driver coil. (The signal-processing unit is described in details in separate manuals).

The calculation of mass flow from the time-shift of the signals of the sensors is performed by the following equation:

$$Mf = K \cdot dt$$

where:	Mf	mass flow	[kg/s]
	K	coefficient	[kg/s ²]
	dt	time shift	[s]

The **K** proportional coefficient is depending on the elastic modulus of the material of the oscillating pipes besides of the geometrical data. Due to this coefficient, though slightly, is temperature-dependent. The signal-processing unit continuously corrects this temperature-dependence by calculating the value of **K** by the following formula:

$$K = FF \cdot FA \cdot [1 + aT \cdot (T - TB)]$$

where:	FF	calibration constant	[kg/s ²]
	FA	multiplying factor if cal. constant	[-]
	aT	temperature coefficient	[1/°C]
	T	temperature of the medium	[°C]
	TB	reference temperature	[°C]

By measuring the resonance frequency the density of the medium can also be determined according to the following equation:

$$De = DeA + \frac{DeB}{fRe^2 \cdot [1 + DeC \cdot (T - T0D)]}$$

where:	De	momentary value of density	[kg/m ³]
	fRe	frequency of the oscillation	[Hz]
	T	temperature of the medium	[°C]
	T0D	reference temperature of density-calibration	[°C]
	DeC	temperature coefficient	[1/°C]
	DeA	calibration factor	[kg/m ³]
	DeB	calibration factor	[kg/m ³ /s ²]

Summed up, the CMM mass flow measuring system substantially contains three sensors that measure the following three parameters at the same time independently:

mass flow
density
temperature

MSP signal processing unit calculates further parameters using these three primary parameters. The most important of these are:

integrated mass	$M = \int_{t0}^t m' \cdot dt$
volumetric flow	$v' = \frac{m'}{D}$
integrated volume	$V = \int_{t0}^t v' \cdot dt$

The basic calculations mentioned above are available depending on the software version of signal processing unit, these are detailed in its instruction manual.

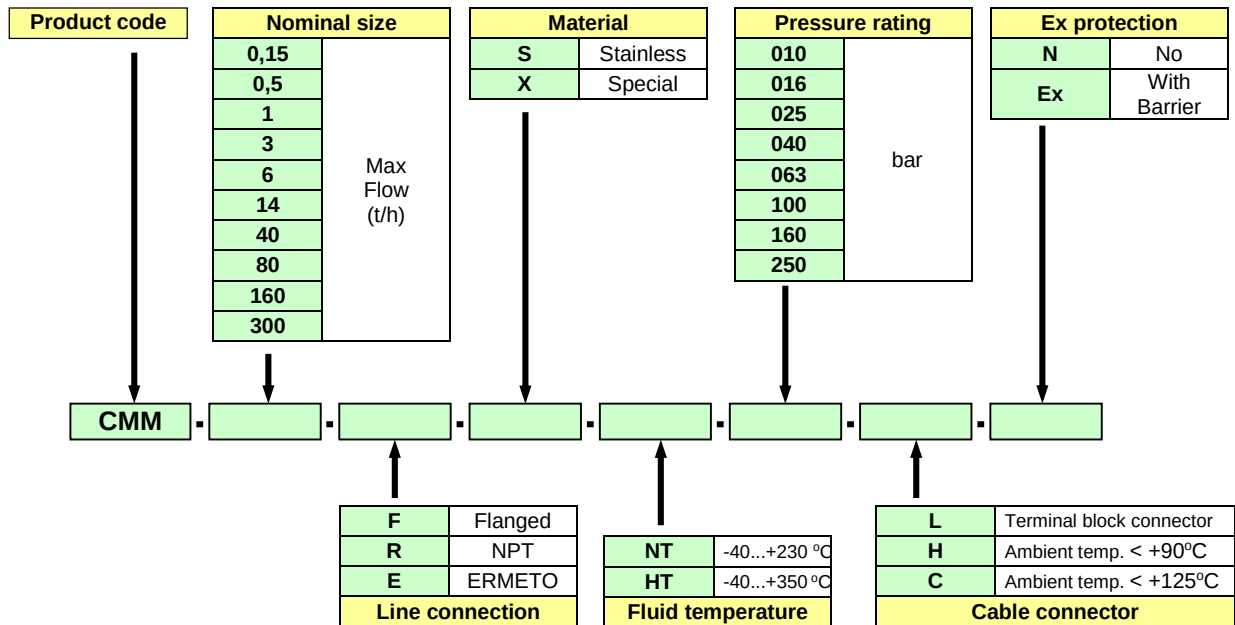
3. DESCRIPTION OF THE MECHANICAL CONSTRUCTION

The resonating conduits performing the principle described above are in a welded (not dismountable) cover made of stainless steel. On the front sides of it the connecting joints of the conduit are situated, and the connector of electrical signals and other fittings.

Figures 3 and 4 show the main mechanical sizes by types.

4. SPECIFICATION

4.1 Type selection



4.2 Quality of materials in contact with the measured medium

Measuring tubes: Stainless steel (1.4404)

Other wetted parts: Stainless steel (1.4541 and 1.4301)

X-Special materials (Hastelloy C22; Titanium) for custom-designed sensor

4.3 Expectable pressure drop

The diagrams on the Figures 4, 5 and show the pressure drop in function of mass flow rate with different viscosities.

Hereby we call the attention to the risk of cavitation which, when arising inside the measuring conduits, can make the measurement incorrect. Cavitation arises when the pressure of the liquid in a given place drops below the saturation value belonging to the temperature at the given place. This phenomenon can be avoided by using a pressure sustaining control valve at the outlet of the sensor. The minimal back-pressure to avoid the cavitation can be determined knowing exactly the type and temperature of the measured material, it is recommended to use the help of our experts.

4.4 Temperature limits

The limits of the temperature of the medium measured by the mass flow meter are:

NT	: normal execution	-40...+230 °C
HT	: high temperatur execution	-40...+350 °C

The ambient temperature range for the sensor unit:

H	with Hirschman cable connector:	-40... +90 °C
C	with Canon cavle connector:	-40...+125 °C

In case of intrinsically safe protection the temperatur range depends on the temperature class of the protection

Der Umgebungstemperaturbereich der Sensoreinheit:

4.5 Measurement errors

4.5.1 Error of mass flow measurement

The maximal error of the mass flow measurement consists of two components:

±0,2% related to the measured value

±0.05% related to the max flow

Described by equations:

$$h = 0.2 + \frac{5}{q}$$

$$q = \frac{m'}{m'_{\max}} \cdot 100$$

where:

h	max. error of the measurement related to measured value	[%]
q	flow rate	[%]
m'	mass flow to be measured	[kg/s]
m'_{max}	maximal mass flow of the sensor	[kg/s]

4.5.2 Limits and error of density measurement

The table below contains the maximal error of density measurement related to the measured value in the measuring range of 0,7 – 1,3 g/cc at the temperature of 20 °C and pressure of 1 bar depending on the size:

Size	Error of density measurement [g/cc]
CMM 0,15	±0,015
CMM 0,5	±0,005
CMM 1	±0,0015
CMM 3	±0,001
CMM 6	±0,001
CMM 14	±0,0008
CMM 40	±0,0008
CMM 80-300	±0.0005

By a special calibration method the densities of media out of the range of 700 - 1300 kg/m³ is also possible, or, in a narrower range within the given range the error can be reduced. The possibilities for this must be discussed according to the special needs on an expert consultation.

4.5.3 Error of temperature measurement

Within the temperature range of the medium specified in chapter 4.1 the maximal error of the temperature measurement is ±1 °C at the display of the signal processing unit.

4.6 Mechanical dimensions, connection, masses

The mechanical and connection dimensions are illustrated on Figures 3 and 4. Masses of the mass flow meter sensors are listed in the table below:

<i>Size</i>	<i>Mass [kg]</i>
CMM 0,15	6,5
CMM 0,5	6,8
CMM 1	7,5
CMM 3	11,0
CMM 6	14,0
CMM 14	18,0
CMM 40	25,5
CMM 80	52,0
CMM 160	120-155
CMM 300	240-320

4.7 Overloadability

The pressure drop limits the flow overloadability of the mass flow sensors. Overload can cause a cavitation erosion inside the sensor, in this range the specified accuracy data are not valid.

5. PRELIMINARY INSTRUCTIONS

- At unpacking care must be taken that the mass flow sensor e.g. its cover is not hit against anything, because the sensors could be crashed and it results in the device becoming out of operation.
- In case the piping is undergoing operationally to oscillation, insert the meter between elastic pipe sections for isolating the oscillation, and the meter should be fixed at its connecting ends to oscillation-free fittings.
- Care must be taken to the direction of flow. It's indicated on the cover.
- For regular zeroing of the meter cutoff fittings (for instance ball valves) should be installed in the upstream and downstream pipe section. Care must be taken for the perfect cutoff, else in case of leakage zeroing will be erroneous.

6. INSTRUCTIONS FOR USE

6.1. Safety instructions

CMM mass flow meters are explosion proof constructions in case they are connected to the signal-processing unit through the Zener Barrier Unit (ZBU) type 3691-1-901-0. In this case the protection mode of the measuring system is according to the regulations of standards EN 50014, EN 50020:

[EEx ib] IIB, EEx ib IIB T3/T6

At applications of intrinsically safe systems not keeping the instructions in this manual or any intrusion in the sensor box can make the safety invalid, therefore the responsibility of the manufacturer according to this ceases. Optionally, for increased safety the cover of the meter can be equipped with a bracket disc. It serves for the purpose that in case of the possible damage of the measuring pipe inside the box the pressure in the measuring system breaks the bracket disc this way the cover remains unhurt. In this case a drainpipe can be connected from outside to the fitting holding the bracket disc.

6.2. Electric connections

Electric connection of the sensor and the signal-processing unit is shown on the Figure 1 and 2.

At the construction of intrinsically safe protection measuring circuits the following must be by all means kept:

- Electric connection must be provided only after the rigid installation.
- Only cable with the insulation strength of minimum 500 Veff. should be applied
- The allowed values for energy storing for cabling between the sensor and the electronic unit in the intrinsically safe measuring system are:

Cmax: 1,8 μ F;

Lmax: 2 mH.

6.3. Preliminary setting, setup

The sensor must be filled up completely free of air bubbles with the medium to be measured. It can be performed the easiest way by driving the medium at minimum 20% flow rate through the meter for about a few minutes.

Close the cutoff fittings at the outlet then at the inlet of the meter. Wait for 10 -15 seconds, then perform zeroing procedure according to the instruction manual of the signal processing unit. According to the possibilities given by the technology check the zero by cutting off flow and if necessary perform zeroing.

After performing the above the sensor unit is ready for measurement. Further settings according to the measuring system must be performed according to the Instruction Manual of the signal-processing unit.

7. MAINTENANCE, REPAIR

The mass flowmeter sensor needs no maintenance.

As the sensor is placed in a welded box, no reparation can be performed on the site. Even the experts of the manufacturer can repair it after transporting it back to the authorized workshop.

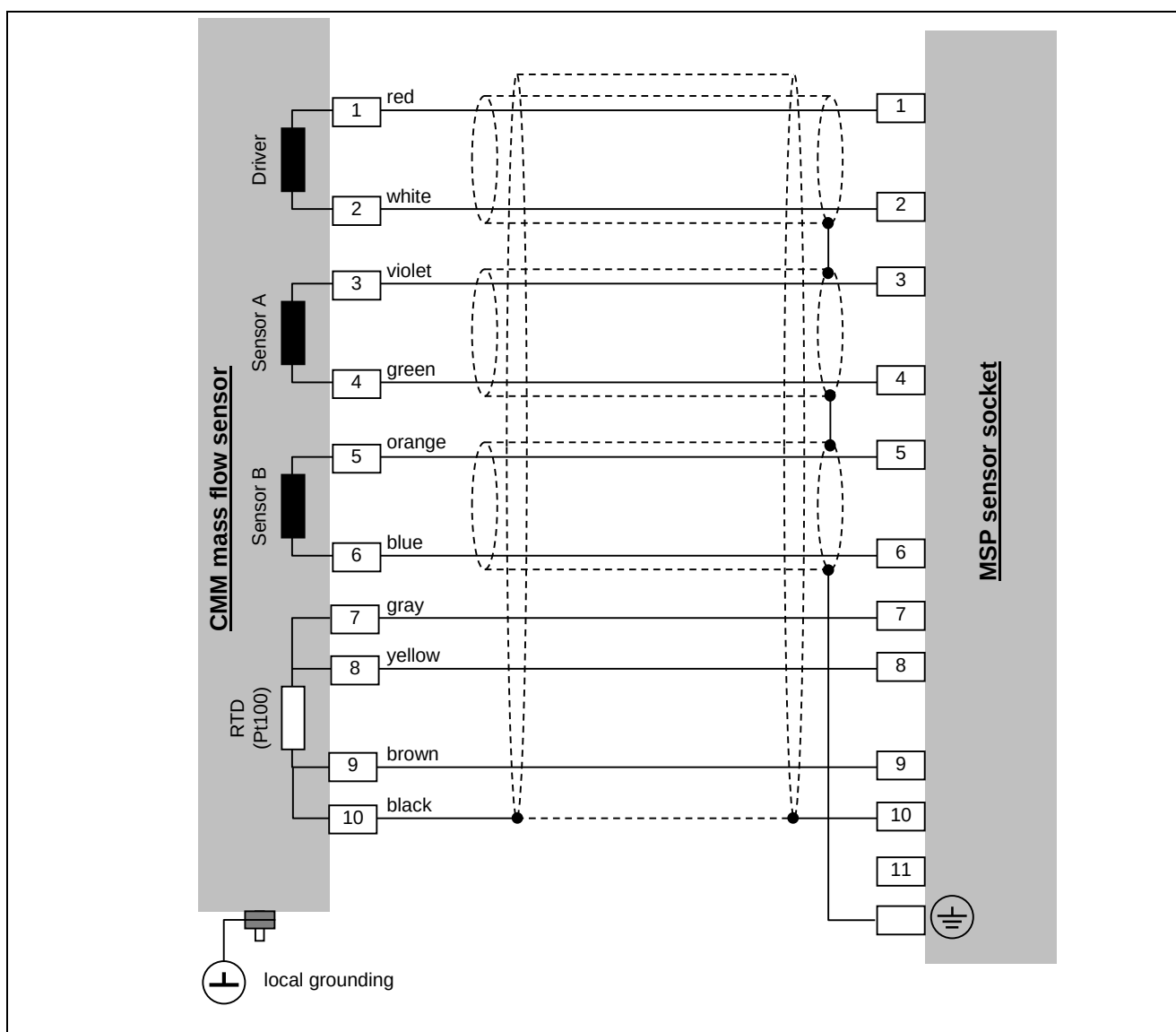


Fig. 1 Electrical connection in normal (non hazardous) application

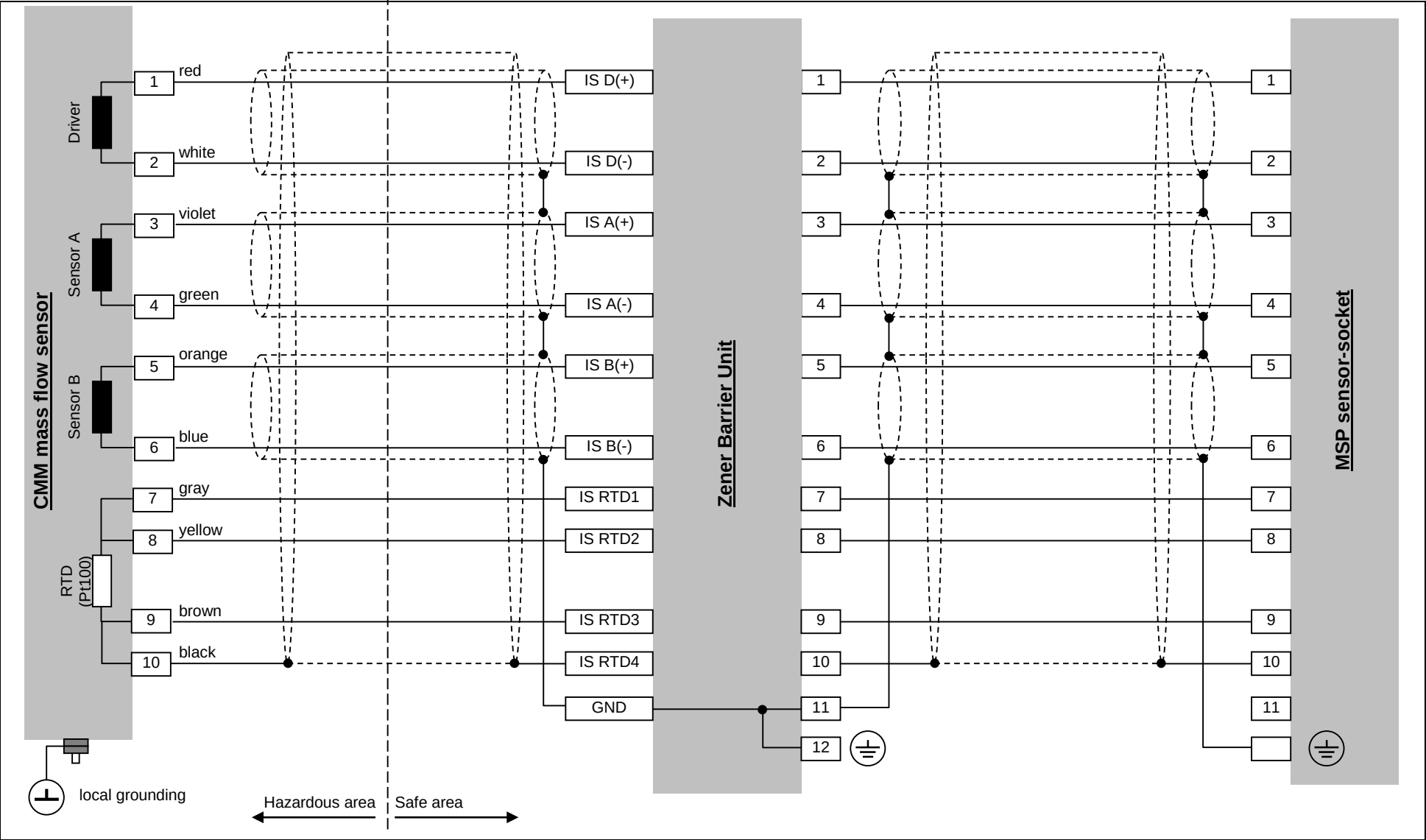
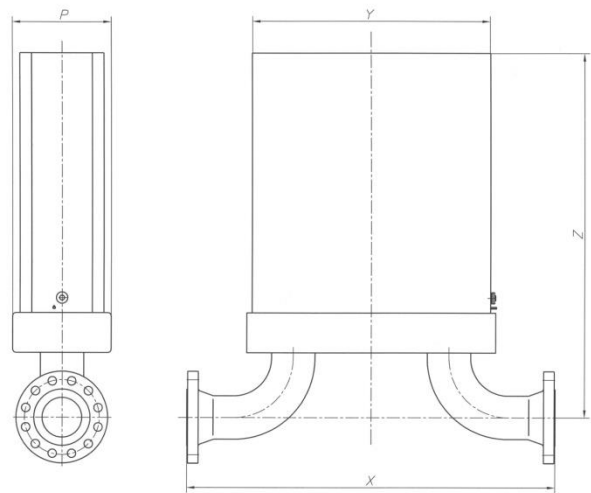


Fig. 2 Electrical connection in hazardous application



CMM	X	Y	Z	P	Connection		Max. pressure
	(mm)	(mm)	(mm)	(mm)	Threaded	Flanged MSZ EN 1092-1	(bar)
0,5	346	180	217	110	NPT 1/2"	DN15	250
1	406	228	253	110			
3	470	332	489	140	NPT 1/2"	DN15/25	160
6	470	274	405	128	NPT 3/4"	DN25	160
14	590	405	706	160	NPT 1"	DN25	160
40	670	442	734	200	NPT 1 1/2" / 2"	DN40/50	100
80	1040	728	1023	240	-	DN80/100	100
160	1185	788	1222	300	-	DN100/150	160
300	1420	960	1430	380	-	DN150	160

CMM-0,150:

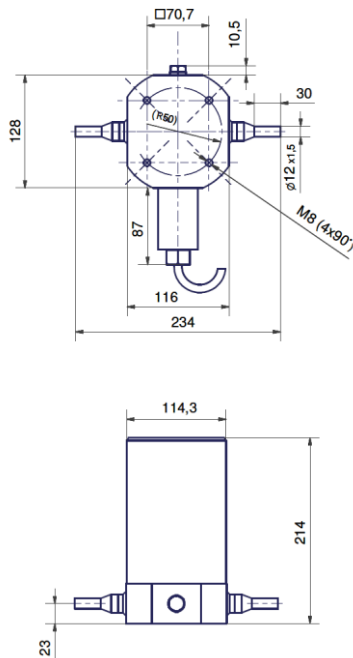
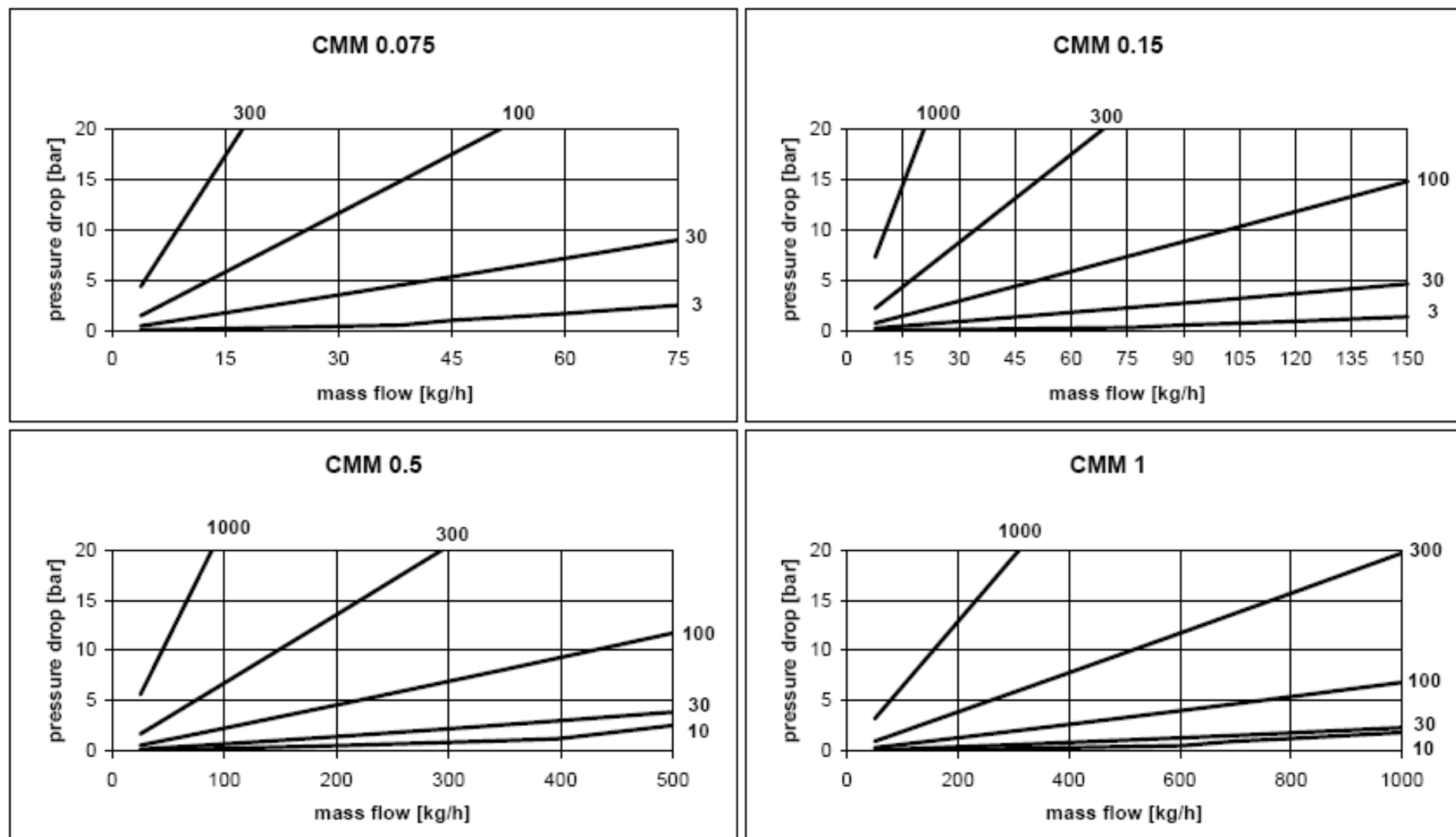
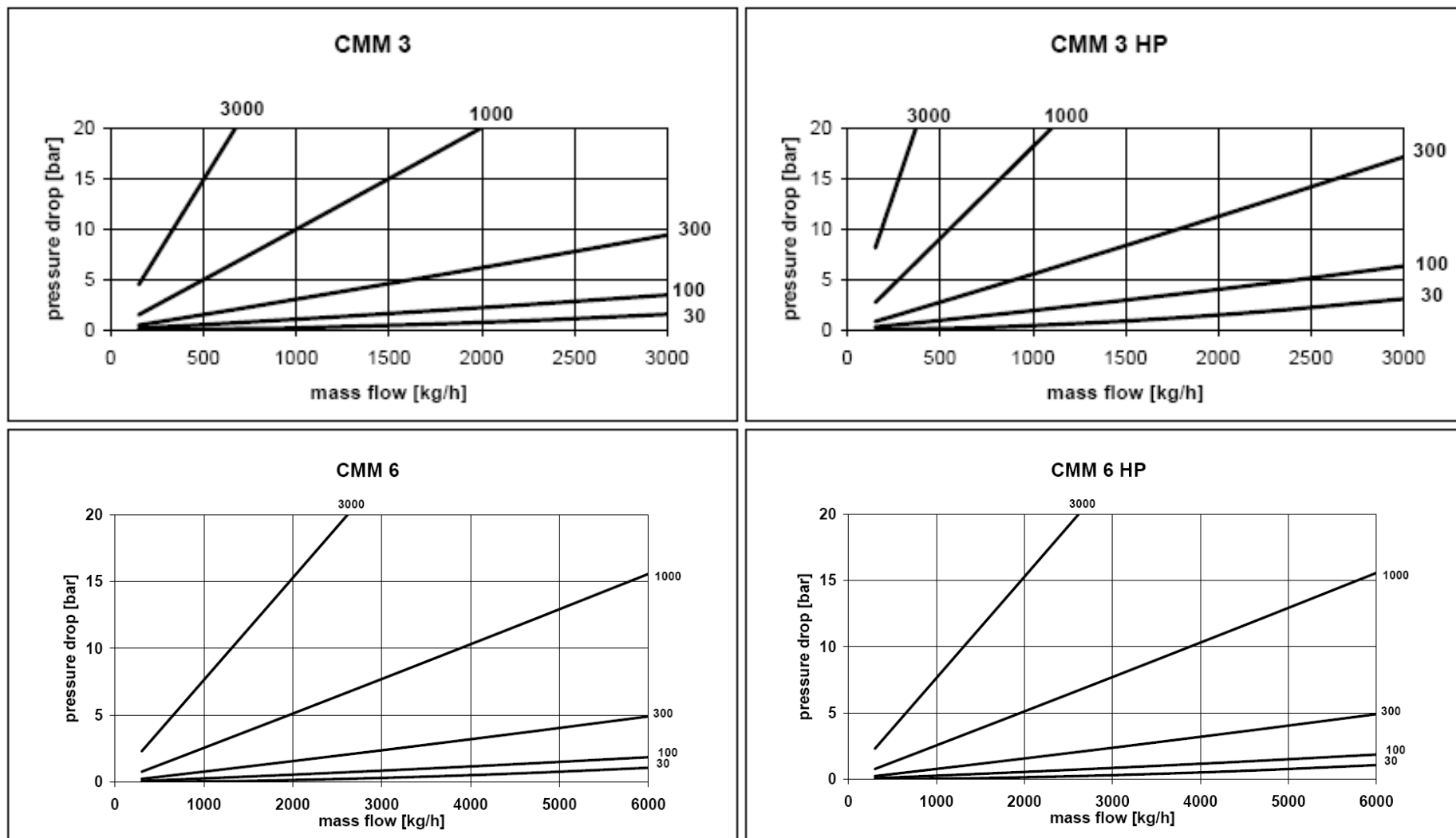


Fig. 4 Mechanical sizes



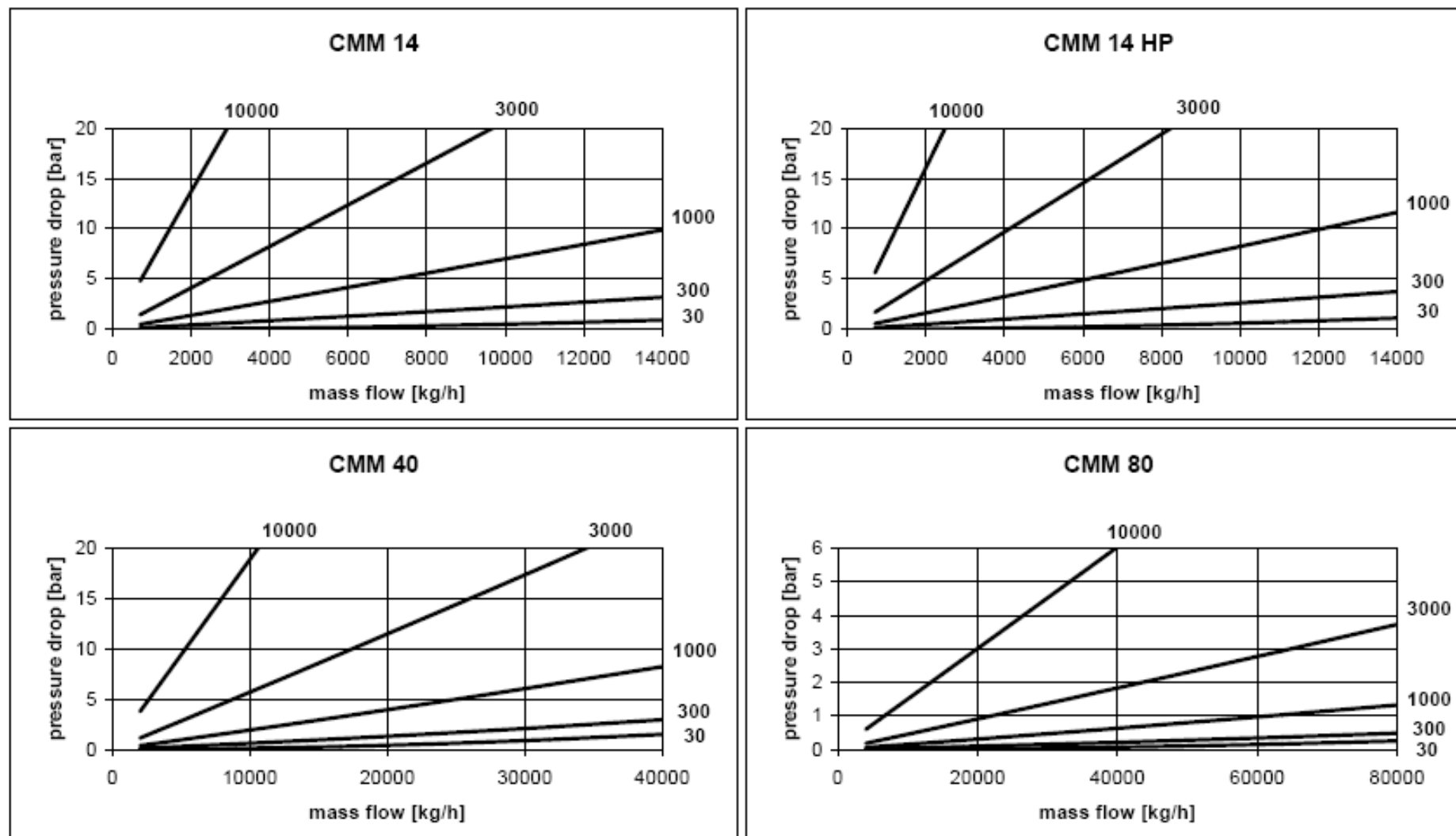
Parameter: Viscosity in mm²/s

Fig. 3 Pressure drop diagrams (CMM 0,075-1)



Parameter: Viscosity in mm²/s

Fig. 4 Pressure drop diagrams (CMM 3-6)



Parameter: Viscosity in mm²/s

Fig. 5 Pressure drop diagrams (CMM14-80)