3. The TMU-W sensor

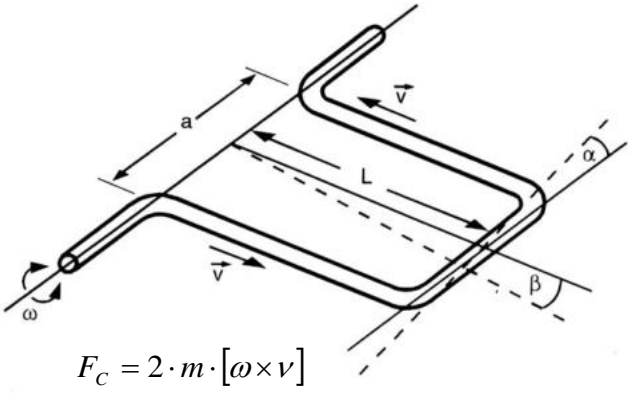
3.1 Application domain of the TMU-W sensor

The TMU-W sensor is intended solely for the direct and continuous mass flow measurement of liquids and gases under high pressure, irrespective of their conductivity, density, temperature, pressure, or viscosity. The sensor can be utilised for the direct and continuous mass flow measurement of chemical fluids, suspensions, molasses, paint, varnish, lacquer, pastes and similar materials.

3.2 Mode of operation

3.2.1 Measuring principle

The mass flowmeter is based on the Coriolis principle whereby in a rotating system a force (known as the Coriolis force) is exerted on a mass at a rotation point that is moving towards or away from this point.



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

3.2.2 System configuration

The flowmeter consists of a sensor mounted in to a piping system and a remote installed transmitter (see Section 4.1, “Application domain of the UMC4” on page 22), connected to the sensor via a special cable (e.g. on a wall or to a pipe).

The transmitter oscillates the flow tubes of the sensor by means of an excitation coil and captures, via pick-up coils, the measuring signal which is proportional to the mass flow. After temperature compensation, the measuring signal is converted into an analogue output signal that is consistent with the measuring range setting.

3.2.3 Acquisition

Measured variables: Mass flow,
Temperature.

3.3 Performance characteristics of the TMU-W sensor

3.3.1 Reference conditions

- Established flow profile
- Inlet section has to correspond to mounting length
- Control valves always positioned downstream
- Measurement is to be performed with a liquid containing no gas bubbles
- Flow tubes are to be kept clean at all times
- Process temperature is to be regulated as specified in Section 3.4.6, “Process conditions” on page 19
- Process pressure is to be regulated as specified in Section 3.4.8, “Process pressure range” on page 19
- Ambient temperature is to range from + 10 °C to + 30 °C (50 °F to 86 °F)
- Warm-up period: 15 minutes
- Standard calibration is to be performed at 20 %, 50 % and 100 % (two times each)
- High-frequency interference is to be regulated according to the EMC standards stated in section 9, “Declaration of Conformity” on page 115

3.3.2 TMU-W flow ranges

Model	Mass-flow		
	min. Measuring range	max. Measuring range	Zero point stability (of range)
	kg/min [lbs/min]	kg/min [lbs/min]	kg/min [lbs/min]
TMU-W004	0.13 [0.3]	4 [8.8]	0.0004 [0.0009]
TMU-W006	0.5 [1.1]	16 [35.3]	0.0016 [0.0035]
TMU-W012	2.5 [5.5]	25 [55.1]	0.0025 [0.0055]

Table 1: TMU-W flow ranges

Reference conditions: in conformity with IEC 770:
Temperature: 20 °C, relative humidity: 65 %, air pressure: 101.3 kPa
Fluid: water

3.3.3 Density measurement

Due to its constructive properties, a density calibration for the TMU-W family of sensors is not foreseen, thus also disabling the determination of volume flow.

3.3.4 Accuracy

Mass flow	Fluids
TMU-W004 and TMU-W006	± 0.1 % of actual flow ± zero point stability (1)
TMU-W012	± 0.15 % of actual flow ± zero point stability (1)
Repeatability error	± 0.05 % of actual flow (sensor with transmitter) ± ½ zero point stability (1)
Mass flow	**Gases**
TMU-W004, TMU-W006 and TMU-W012	± 0.5 % of actual flow ± zero point stability (1)
Repeatability error	± 0.25 % of actual flow (sensor with transmitter) ± ½ zero point stability (1)
Additional measured values	
Volume flow	Not available
Temperature	± 0.5 °C
Hysteresis	n/a
Settling time	1 to 15 seconds
Startup drift	15 minutes
Long-term drift	± 0.02 % of upper-range value per year
Influence of ambient temperature	± 0.005 % per K
Influence of fluid temperature	Compensated
Influence of fluid pressure	For fluids: too small to be relevant

(1) *Refer to section 3.3.2, "TMU-W flow ranges" for detailed information on flow ranges*

Table 2: Flow-Rate Accuracy

3.3.5 Pressure loss in Hydrogen dispensers

The pressure loss of gases with constant mass flow is highly dependent on the operating pressure in the mass meter and the resulting flow rate. The TMU-W is designed that its pressure lost will not exceed 30 bar during a standardized refuelling operation with hydrogen and an empty vehicle tank, as defined in the SAEJ2601. With an almost full vehicle tank, the pressure loss shall be much less than 20 bar.

3.3.6 Environmental Conditions

Ambient temperature

– 40 °C to + 60 °C (-40 °F to 140 °F)

Storage temperature

– 40 °C to + 80 °C (-40 °F to 176 °F)

Climatic category

In conformity with IEC 654-1. Unsheltered class D locations with direct open-air climate.

Ingress protection

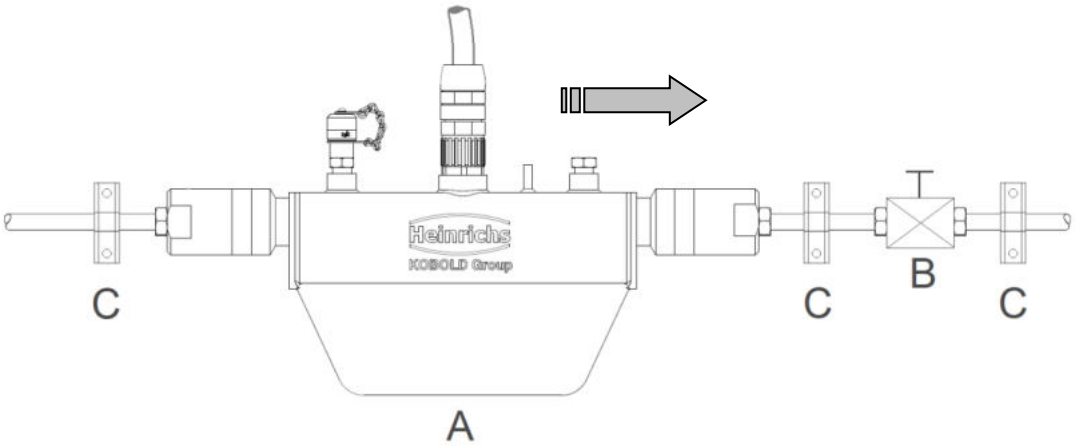
Sensor: IP 67 (NEMA 6), **Transmitter**: IP68 / 1 m for 24 hours (NEMA 6P) acc. to DIN EN 60529 with mounted and sufficiently tightened approved cable glands.

3.4 Operating conditions

3.4.1 Installation

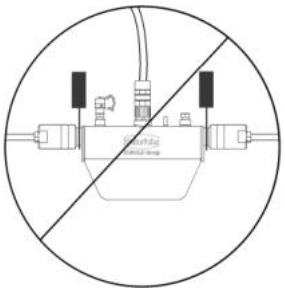
The sensor is to be protected, wherever possible, against valves, manifolds and similar fittings that generate turbulence. The sensor is to be installed in accordance with the following instructions.

Diagram showing flowmeter installation

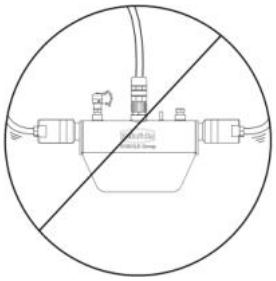


Flowmeter installation: A = sensor, B = valve, C = pipe clamps and supports

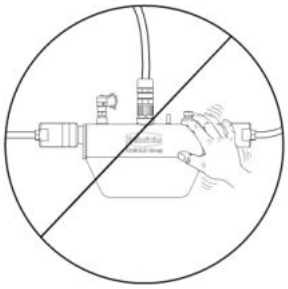
The sensor is not to be used to support a pipe or other pipe components.



Do not install the sensor in suspended pipes.

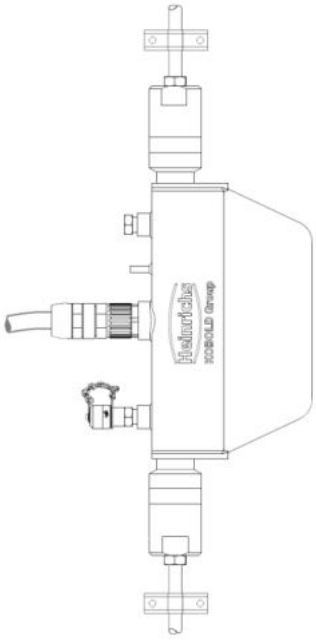
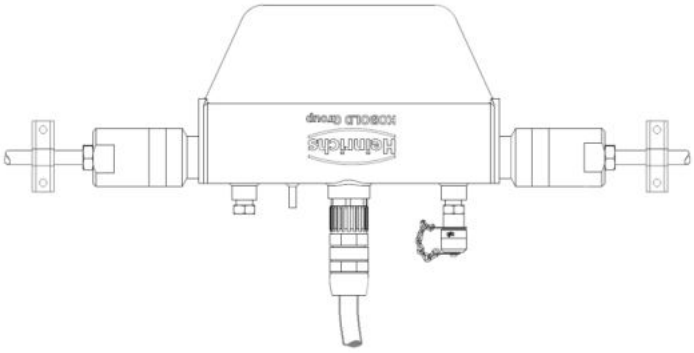
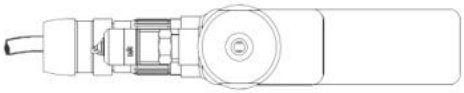
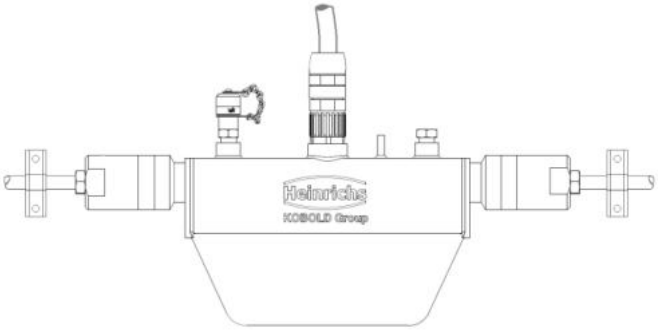


Do not adjust the position of a pipe by pulling or grasping the sensor.



3.4.2 Installation Orientation

Without compromising its accuracy, the TMU-W can be installed and operated in various orientations. The following representations show the most common installation positions and provide tips on how the operator can prevent installation-related influences on the measurement.

Standard installation position	
Installation position A	
Installation position B	
Installation position C	

Type of medium	Position	Assessment
Pure liquids	Standard installation position	Self-draining flow tubes
	Position A or B	OK
	Position C	Liquid residue remains in pipe
Liquids containing homogeneously dispersed gas	Standard installation position	Self-draining flow tubes, gas bubbles do not accumulate in flowmeter
	Position A	Not recommended owing to gas bubble accumulation in flowmeter
	Position B	Gas bubbles may accumulate in the presence of low flow velocities
	Position C	No gas bubble accumulation in flowmeter, liquid residues may remain in device after discharge
Liquids containing substances that could form deposits	Standard installation position	Self-draining flow tubes, no deposit formation
	Position A	OK
	Position B	Substances in the liquid could form deposits at low flow velocities
	Position C	Not recommended owing to presence in flowmeter of substances that could form deposits
Liquids containing homogeneously dispersed gas, which may contain substances that could form deposits	Standard installation position	Self-draining flow tubes, no accumulation of gases or substances that could form deposits
	Position A	Not recommended owing to gas bubble accumulation in flowmeter
	Position B	Gas bubbles or substances that could form deposits at low flow velocities
	Position C	Not recommended owing to presence in flowmeter of substances that could form deposits
Gases that do not form condensate	Standard installation position, Position A, B or C	Any of these installations positions can be used
Gas, condensate-forming gas/liquid, moisture	Standard installation position	Flow direction should be from top to bottom so that any condensate that forms can flow out efficiently
	Position A	OK
	Position B	Condensate might form in flowmeter
	Position C	Not recommended owing to condensate accumulation in flowmeter

Table 3: Sensor Installation Orientations

3.4.3 Pressure surges

Pressure surges in a pipe could be provoked by a sudden decrease in flow caused by rapid closing of a valve or similar factors. This change in pressure can lead to under-pressure downstream from a valve that has been closed rapidly, and to outgassing. If the valve is mounted directly on the inlet section of the flowmeter, a gas bubble can form in the flow tube that can cause a measuring signal disturbance that would shift the zero point of the output signal. In extreme cases, a pressure surge could cause mechanical damage to the sensors and/or flow tube.

Whenever possible, quick-closing valves should be mounted downstream from the sensor. If this is not feasible, such valves are to be mounted a minimum of 10 x DIA (Φ) from the nearest sensor. Alternatively, valve closing speed can be reduced.

3.4.4 Using the device with hazardous fluids

The sealing technology used in the TMU-W mass flowmeters connector plug renders the device unsuitable for use with hazardous fluids. Only sensors that meet the standards for safety instruments are suitable for use with hazardous fluids.

In the case of welded components, a coloured liquid penetration test can be performed on the welds, or the first seam of the weld can be x-rayed.

3.4.5 Vibration stability

The sensors are insensitive to vibration. Vibration stability has been validated in accordance with DIN IEC 68-2-6, for up to 1 g at 10 to 150 Hz.

If pipe vibration is greater than 1 g in the 5-2000 Hz range, additional supports shall be mounted such as depicted in the following images. Such supports will prevent vibration from affecting the device's mechanical configuration and/or measurement readings.

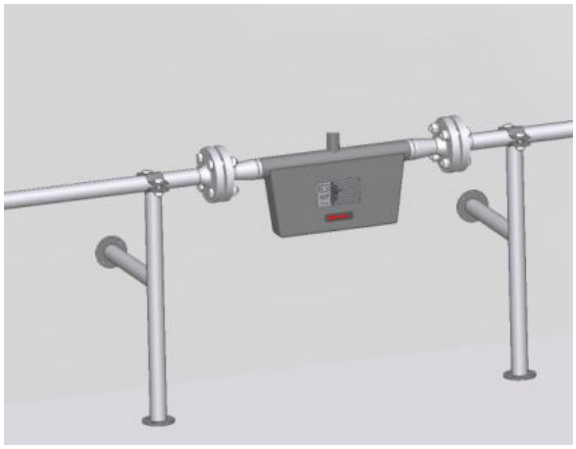


Image 1: Wall mounted supports

Image 2: Floor-mounted supports

3.4.6 Process conditions

Process temperature

– 40 °C to + 100 °C (-40 °F to 212 °F); rating plate inscription applies

Physical state

Liquid product	(maximum density 2 kg/l)
Gaseous product	(minimum density 0.002 kg/l in operating state)

Viscosity

0.3 up to 2,000 mPas (0.3 to 2,000 cP)

3.4.7 Gas content

The use of products containing gases is not permitted for custody transfer operations. In other applications, the presence of gas will increase false readings. For the readings of products containing gas to be valid, small gas bubbles must be homogeneously distributed in the fluid.
Large gas bubbles will automatically provoke extremely false readings and will shift the zero point. Thus, the extent to which readings are false is determined by the process conditions. A rule of thumb in this regard is as follows: A 1 % gas component will increase false readings by 1 %. The gas component is not to exceed 5 %.

3.4.8 Process pressure range

The applicable pressure range is dependent on the sensor and the selected process connections. It is essential that the correct process connections for the intended process pressure is selected during the ordering process.

TMU-W004	up to 1000 bar
TMU-W006	up to 500 bar
TMU-W012	up to 1000 bar

3.4.9 Outlet pressure

Outlet pressure must be greater than the vapour pressure ps of the measured product.

3.4.10 Connection to the transmitter

The sensors of the TMU-W family are only available as remote mount versions. The connection to the sensor is achieved via a special ten-cored cable by means of a detachable screw-on connector.
During installation, regulations and applicable legal standards are to be adhered to.
The maximum cable length is 200 m (approx. 650 ft). See Section 5.1.3 on page 36 for information regarding the connection and cable specifications.