Ultrasonic Flow Meters

SONOELIS SE4041
MID Certification
TCM 142-16/5353

Content

1. APPLICATION

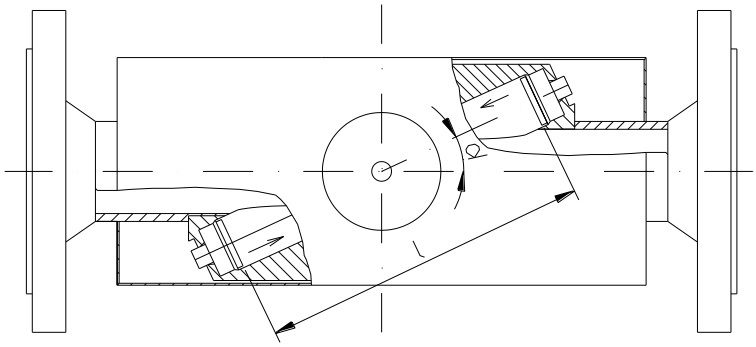
Ultrasonic flow meters SONOELIS - model SE4041 can be used to measure instantaneous flow rate of water passing through the meter sensor over a given period of time. The measurement method used allows application of the SONOELIS flow meters for measurement of heat/cold energy mainly. The meters are equipped with pulse output for connection with any calorimetric counters for measurement of heat/cold energy, which are equipped a pulse input. The flow meter includes a single beam sensor (UC 3.0).

2. FUNCTION

The SONOELIS flow meter utilizes the impulse-wave transit-time method where the fluid flow velocity is determined from the flight time of the ultrasonic signal between two ultrasonic transducers. The flight times are measured for both directions of the signal wave propagation (upstream and downstream), whereby any asymmetry in the transducer positions are effectively eliminated.

The flight time of an ultrasonic wave travelling downstream the fluid flow can be determined as follows:

$$t_1 = \frac{l}{c + v.\cos\alpha} + \frac{l_1}{c_1} \qquad [s]$$



where l is the distance between the head parts of the ultrasonic transducers [m]
c is the ultrasonic signal propagation velocity [m/s] in the flowing fluid
v is the fluid flow velocity [m/s]
l_1 is the aggregate thickness of the bottom parts of the transducers [m]
c_1 is the ultrasonic signal propagation velocity [m/s] in the transducer body material.

The flight time of an ultrasonic wave travelling upstream/downstream the fluid flow is defined by the following formula; the difference between the “downstream “ (t_1) and “upstream” (t_2) flight times is given by the different signs of the fluid flow velocity term in the fraction denominator.

$$t_2 = \frac{l}{c - v \cdot \cos\alpha} + \frac{l_1}{c_1} \qquad [s]$$

For a given transducer, l_1 and c_1 are known constants.
The ultrasonic signal propagation velocity can be expressed as:

$v_1 = c + v.\cos\alpha$ for the case of downstream measurement, and

$v_2 = c - v.\cos\alpha$ for the case of upstream measurement.

Therefore, the difference between the velocities of ultrasonic signals travelling downstream and upstream is proportional to the fluid flow velocity v [m/s].

$$v = \frac{v_1 - v_2}{2.\cos\alpha}$$

The instantaneous fluid flow rate q is defined by the following formula:

$$q = v \cdot s \cdot k(v) \qquad \left[m^3 / s\right]$$

where v is the fluid velocity [m/s]
s is the effective cross-section of the flow meter sensor [m^2], and
k(v) is a correction coefficient the magnitude of which depends on the fluid velocity.

This coefficient reflects the varying fluid velocity profile in the hydraulic section of the flow meter.

3. DESCRIPTION

3.1. Basic information

Ultrasonic flow meter SONOELIS SE4041 is electronic device designed for measurement of fluid flow parameters in a piping completely filled with the flowing fluid. The meter consists of a fluid flow sensor UC 3.0 and an evaluation electronic unit. These two parts are in remote version only. The sensor UC 3.0 includes two ultrasonic transducers. The application of this sensor extends the range of measured values, allows for shorter fluid-flow stabilization piping sections at the meter input and output and generally increases the measurement accuracy.
The sensor is connected to the electronic unit by two co-axial cables of adequate length. The type SONOELIS SE4041 is delivered with blind electronics only, which is equipped with pulse output only.

Regarding function, the evaluation electronic unit of the flow meter can be divided into the following sections:

- sensor isolation circuits
- sensor output switches
- ultrasonic transducer
- ultrasonic receiver including sensitivity control circuits
- interface circuits to the signal evaluation processor
- signal evaluation processor
- circuits for isolated pulse output
- power supply circuits.

The basic configuration of the evaluation electronic unit includes pulse output only. Output signal is isolated from the rest of the meter circuits.

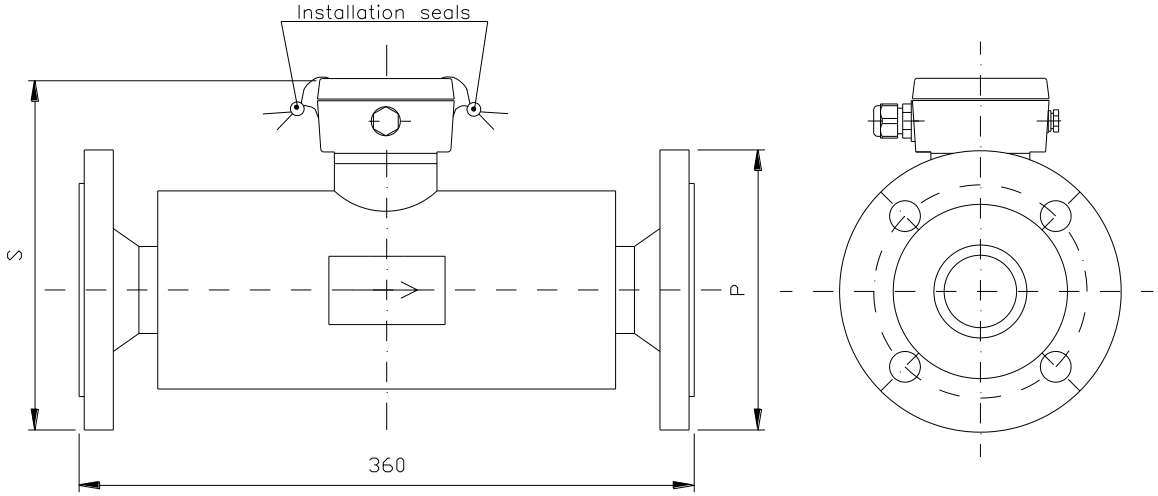
An adaptive filter included in the signal processing circuits suppresses short-term fluctuations of the measured flow-rate values due to pulsation of the fluid in the piping, flow disturbances following action of the flow control devices or other external interferences. In the standard meter configuration, the filter causes the signal output.

3.2. Flow meter design

3.2.1. Ultrasonic sensor including terminal box

The principle difference consists in the number and arrangement of the incorporated ultrasonic transducers. Sensor UC 3.0 includes two ultrasonic transducers.
The sensor body is a stainless-steel welded structure consisting of inner pipe with welded-on ultrasonic transducer holders. The flanges (made of high-quality steel or stainless steel, according to the customer requirements) are welded to the ends of the inner pipe. The transducers are provided with hermetic covers made of high-quality steel or stainless steel. The electric terminal board is accommodated in an aluminum box with a thermal insulation insert between it and the sensor body. The electrical connections are led through two PG 9 coaxial leadthrough. A special valve prevents water condensation inside the terminal box. The surface finish of the sensor assembly is a powder-paint coating, hue RAL 7035 for the sensor body, and RAL 7016 for the terminal box. The sensor assembly dimensions are shown in the following table:

Dimensional sketch of the sensor assembly:



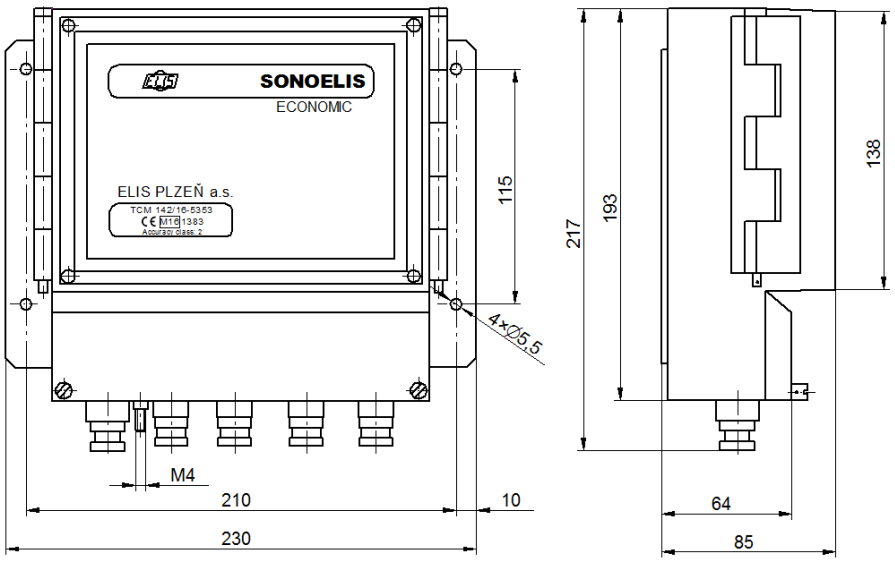
PN	Nominal dim.	DN 32	DN 40	DN 50	DN 65	DN 80
16/40	∅ P [mm]	140	150	165	185	200
16/40	S [mm]	181	191	206	220	237
16/40	L [mm]	360	360	360	360	360

PN	Nominal dim.	DN 100	DN 125	DN 150	DN 200	DN 250	DN 300
16	∅ P [mm]	220	250	285	340	405	460
16	S [mm]	256	285	314	361	419	471
40	∅ P [mm]	235	270	300	375	450	515
40	S [mm]	263	296	321	379	441	499
16/40	L [mm]	360	360	360	450	450	450

Weight of the UC 3.0 ultrasonic sensors [kg]		
DN	**PN 16**	**PN 40**
32	**9**	**9**
40	**9**	**9**
50	**11**	**11**
65	**12**	**12**
80	**15**	**15**
100	**17**	**17**
125	**18**	**20**
150	**19**	**21**
200	**28**	**37**
250	**45**	**70**
300	**58**	**84**

3.2.2. Evaluation electronic unit

The evaluation electronic unit of the flow meter is located in a plastic box with a metal sheet base to be mounted on a vertical support plate. At the front panel of the box there are the flow meter trade name, the manufacturer's trade name and logo. A terminal strip is located at the bottom part of the box. To access the terminals it is necessary to remove a plastic cover under seals. Fitted at the bottom wall of the box there are a grounding bolt and at least five plastic leadthrough (one PG 9 and four PG 7) for cables of circular cross-section. A leadthrough size PG 9 will accommodate (and provide for air-tight assembly of) a cable of external diameter 6 to 8 mm, a PG 7 for a cable of external diameter 4 to 6 mm.



Dimensional sketch of the electronic unit of type UP2.10

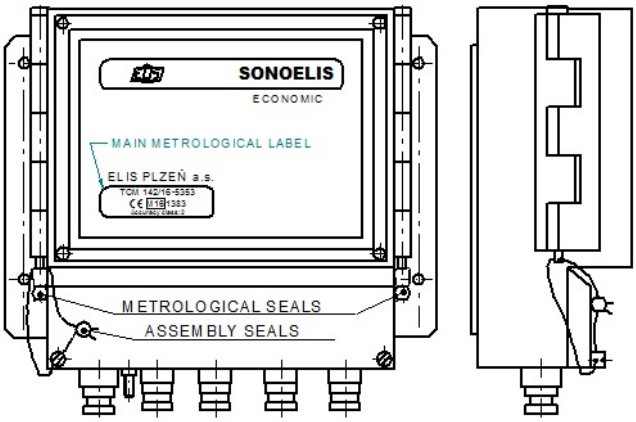
3.2.3. Commercial (invoicing) meters

Calibrated meters used for commercial purposes need be provided with officially certified seals to ensure that no unauthorized modification of the meter functions or readings may take place. The official certification and meter protection consist of:

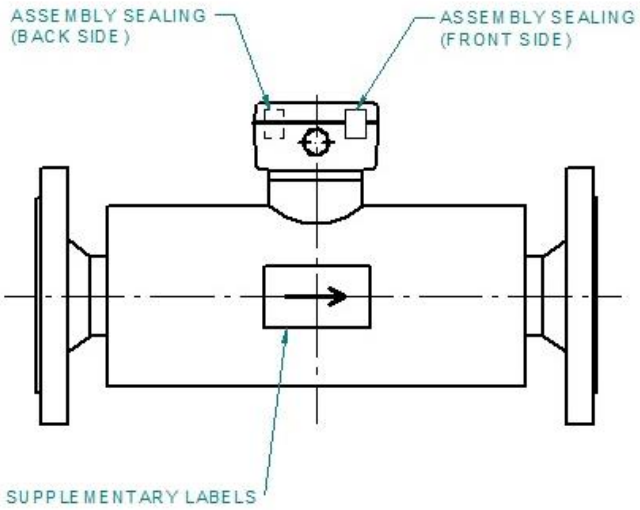
- Stick-on labels with official seals of the responsible organization to be attached on top of the meter type plate on the evaluation electronic unit box;
- Two official seals on the covers of the electronic unit box to prevent any unauthorized meter setting action.

Further protective measures shall be adopted after the meter has been installed by a duly authorized technical organization:

- Two installation seals with official symbols imprinted thereon to prevent unauthorized opening of the cover of the sensor terminal box ;
- Two installation seals with official symbols imprinted thereon to prevent unauthorized opening of the terminal cover on the evaluation electronic unit box.



Sealing of evaluating electronics UP2.10



Sealing of sensor UC3.0

4. SPECIFICATIONS

4.1. Ultrasonic sensors: nominal ID, rated and limit flow rates

For a given size of the flow meter sensor (UC 3.0), the maximum flow rate and other sensor parameters can be found in the following table.

Flow meter model SE4041

DN	32	40	50	65	80	100	125	150	200	250	300
q_s [m³/h]	20	32	50	80	150	240	350	500	900	1400	2000
q_p [m³/h]	10	16	25	40	75	120	175	250	450	700	1000
q_i [m³/h]	0.2	0.32	0.5	0.8	1.5	2.4	3.5	5.0	9.0	14	20
q_{NEC} [m³/h]	0.07	0.09	0.14	0.22	0.37	0.6	0.9	1.2	2.2	3.5	5

where
q_s is the overload (maximum) fluid flow rate,
q_p is the steady-state (rated) fluid flow rate,
q_i is the minimum flow rate for specified measurement accuracy, and
q_{NEC} is the sensitivity threshold (flow rate) level of the sensor concerned.

The minimum flow rate at which the flow meter starts to measure and deliver measured data is set by the manufacturer at the value of q_{NEC}. On customer's request this threshold level can be reset within the range of $q_{NEC} = 0 \div 0{,}25q_s$.

4.2. Flow meters: basic technical specifications

Type of sensor	UC3.0
Rated pressure of the measured fluid (PN) [bar]	40 or 16
Type of evaluating electronics	UP 2.10
Accuracy class	2
Temperature of the measured fluid	0 to +150 °C (on request 180 °C)
Ratio q_p/q_i	50
Ratio q_s/q_p	2
Ambient temperature	+0 to +50 °C
Maximum ambient relative humidity	80 %
Storage temperature	-10° C to +70° C
- evaluation electronic unit	IP 65
- ultrasonic sensors UC 3.0	IP 67
Sensor installed in piping	Flanges ČSN EN 1092-1
Connecting cables for sensors	Standard length 5 m, maximum length 100 m
Max. difference in cable lengths	0,1 m
Max pressure loss classes at q_p]bar]	Δ 0,10
Electronic unit - weight - power supply - stand-by power supply - power requirement - mains fuse - protection against electric shock, ČSN 332000-4-41	1.5 kg 90 to 260 V, 50/60 Hz 3 V, Li battery (Lifetime 5 years) 6 VA T 250 mA, 250 V automated disconnection from power supply in the TN-S network
Outputs (optoelectronically isolated)	pulse, 0.1 to 1,000 l/imp (pulse length 50 ms)
Optional equipment	modification for extended range of fluid temperature measurements; from - 20°C to +180°C
	pipe-end flanges, flange packing pieces, bolts and nuts
	sensors protection IP 68
	two direction flow measurement and direction indication
	Different types of flanges (ANSI, JIS, BS, AS)
	Material of flanges from stainless steel

4.3. Sensor selection

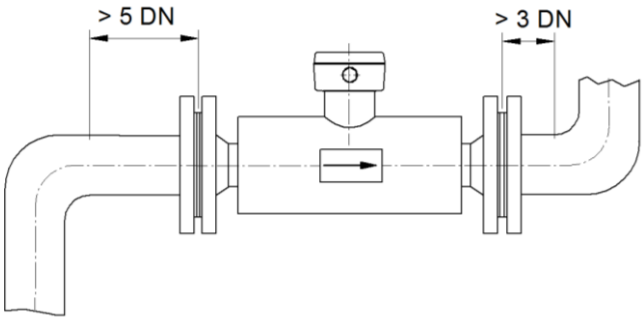
The meter sensor shall be selected with respect to the fluid flow parameters at the measuring location. The normal steady-state flow rate should be as close as possible to the q_p value (the rated flow rate) of the sensor (see the table in section 4.1 above). Attention shall be also paid to the pressure loss value of the sensor which, although it is generally very low, adds up to the total losses of the fluid piping, in particular at high flow velocities.

5. METER INSTALLATION AND APPLICATION; BASIC RULES

When using an ultrasonic flow meter in a piping containing a particular fluid, certain conditions need be met to ensure correct measurements. The limiting operational parameters of the fluid (i.e. temperature, pressure and flow velocity) as well as the mechanical design and properties of the meter sensor (flow stabilisation piping sections before and after sensor, complete flooding of the sensor cavity at all times, elimination of cavitation effects and fluid foaming) must comply with the requirement for steady fluid flow with no gas bubbles or foam appearing in the piping. Such conditions are different for various types of fluid and need be correctly identified for each specific measuring spot and/or technological piping system.

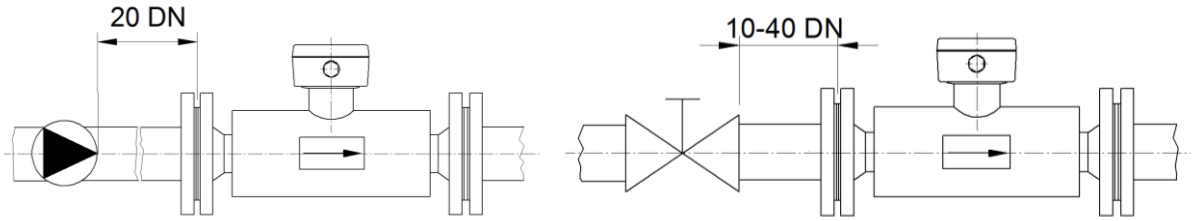
CAUTION: Ultrasonic flow meter of a specific DN must not be used in piping of lesser sizes (smaller DN).

The ultrasonic flow meter shall be applied/installed in observance of certain rules concerning meter placement in the fluid piping so as to ensure that the measurement accuracy complies with the meter specifications. Thus sensor UC 3.0 requires flow-stabilization straight sections of piping of the length of 5D (D = sensor ID) at the input and 3D at the output where such arrangement effectively eliminates any flow disturbances due to 90° pipe bends, changes in the piping diameter or similar simple flow-interference factors.



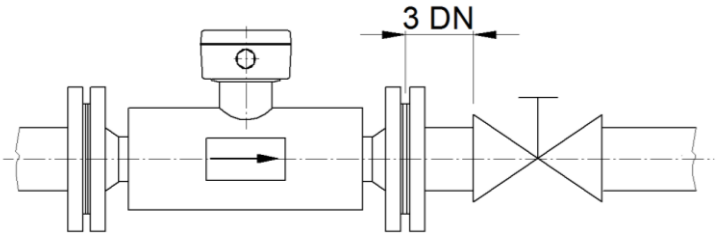
Required straight piping sections to stabilize the fluid flow through the sensor

If there is a pump located in the piping on the input side of the flow sensor, the required length of the stabilization piping is 20 D. If there is a valve or similar flow control element at the sensor input, the required stabilization length is 40 D. If such control element is fully open, the stabilization length is 10 D.



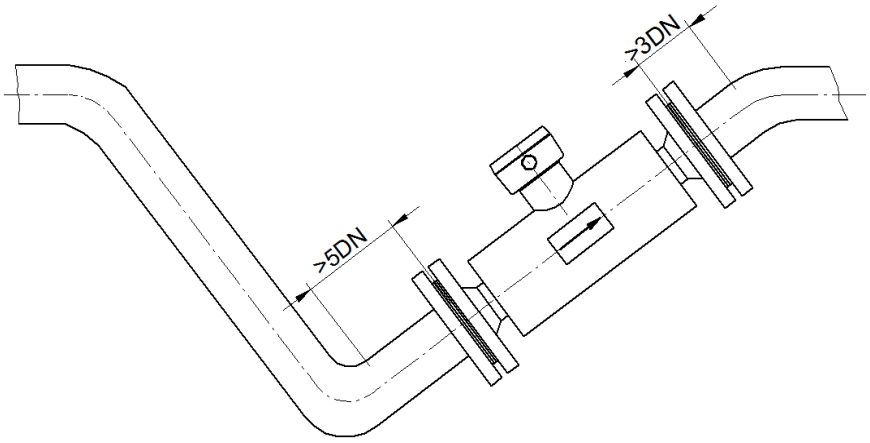
Straight piping sections to stabilize the fluid flow after a "disturbance" in the piping

If any fluid-flow control element is located in the piping on the sensor output side, the sufficient length of the flow stabilization piping is 3 D.



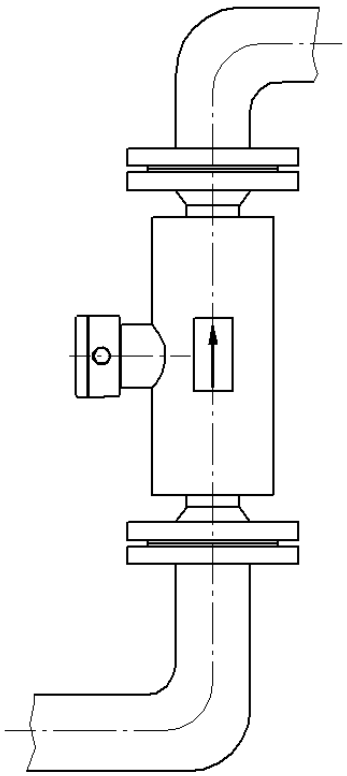
Required straight piping section for a "disturbance" located at the sensor output

In the cases where, in the periods of low flow rate, the fluid level in various parts of the piping may sink, the flow meter sensor shall be located at a bottom pocket of the piping to ensure full flooding of the sensor at all times.



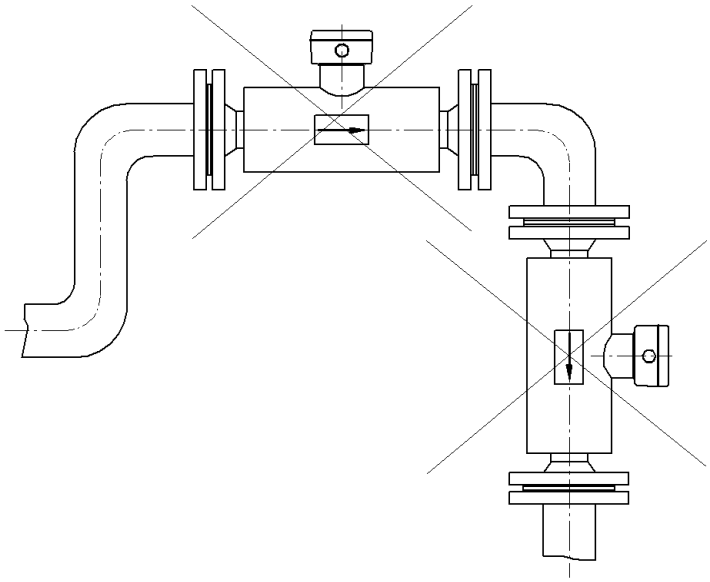
Flow sensor location at the "bottom pocket" of the fluid piping

If a flow sensor is to be installed in a vertical section of the fluid piping, the fluid flow direction shall always be upwards.



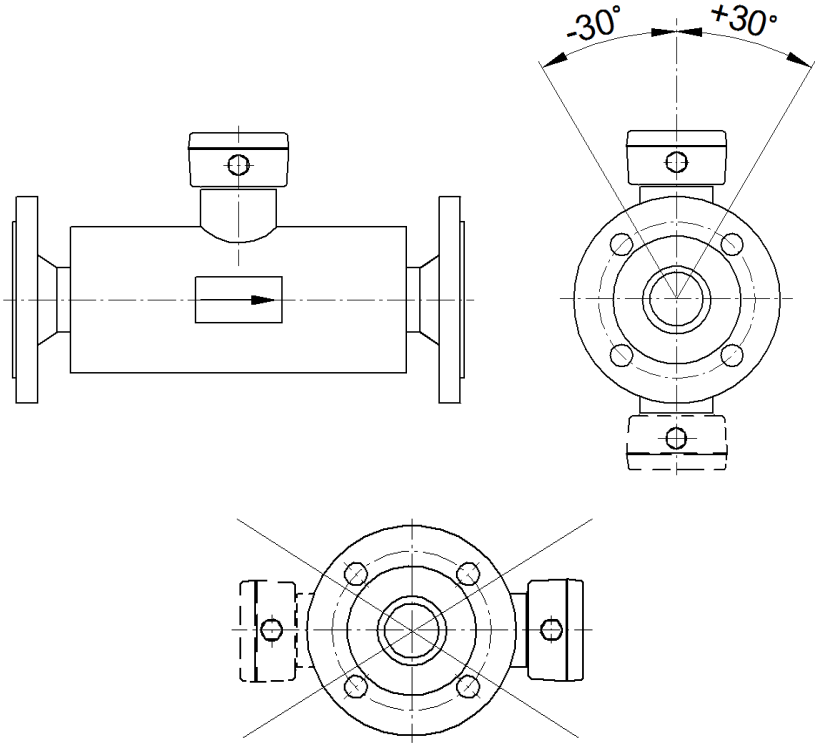
Sensor installed in a vertical section of the fluid piping

To ensure correct flow rate measurement, the internal section of the meter sensor shall always be filled with the flowing fluid. Therefore the basic rule to follow regarding the meter sensor placement is to avoid top pockets in the fluid piping and, in the cases where the sensor is located in a vertical section of the piping and/or near the place where the fluid leaves the piping system, the flow direction in the sensor should not be downwards.



Examples of incorrect sensor placement

The following pictures show correct and incorrect ways of the sensor installation in a horizontal piping section with respect to the possible positioning of the meter display unit.



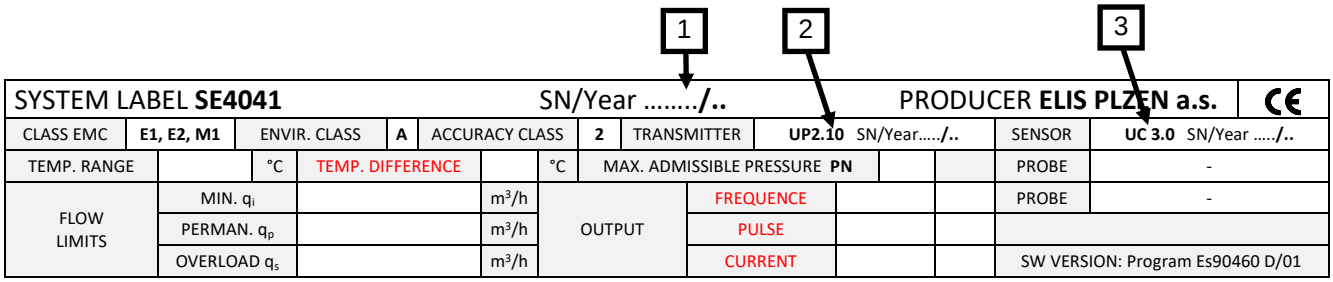
The measured fluid shall be free of larger solid particles and air bubbles either coming into the fluid through leaks in the piping or originating by the cavitation process in the sensor or other piping components. If cavitation is suspected to appear in the sensor or piping, the fluid pressure in the sensor or the respective piping section needs be increased.
In the cases of commercial (invoicing) meters, the evaluation electronic unit of the meter shall be supplied from the mains (230 V, 50 Hz) by a separate power line with an overcurrent circuit breaker to be sealed at the ON position, where the switching-off actions shall be reserved to duly authorized staff only. The recommended power supply cable is CYKY 3x1.5 mm^2 with the external diameter 10.5 mm, and the associated overcurrent circuit breaker should be rated at 6 A.

6. METER INSTALLATION GUIDE

6.1 Rules for the connection of the electronics UP 2.10 to the sensor UC3.0

6.1.1 The matching of the electronics UP 2.10 to the sensor UC3.0

Main series label with system series number is placed at the side of the evaluating electronics.

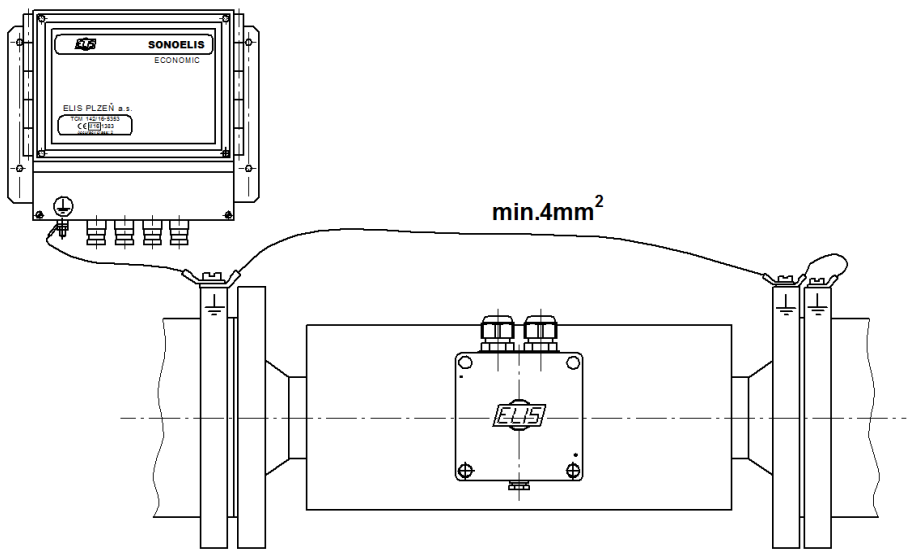


Important warning:
It is important to keep the correct serial numbers of all parts of one system.
Mark 1 - S/N of the system
Mark 2 - S/N of the evaluating electronics UP2.10
Mark 3 - S/N of the sensor UC3.0

6.1.2 Installation rules

The meter assembly and installation directions given in this manual shall be strictly observed.
To prevent undesirable interference between the power and signal devices, the power cables shall be placed at least 25 cm away from all signal cables (the coaxial cables connecting the sensor with the signal processing electronic circuits.
Sensor must be grounded properly. For grounding use a conductor with minimum cross section area 4 mm^2 and connect the conductor to grounding bolts of evaluation electronic and flow sensor (see figure here below).

Grounding connection between the sensor and the electronic unit

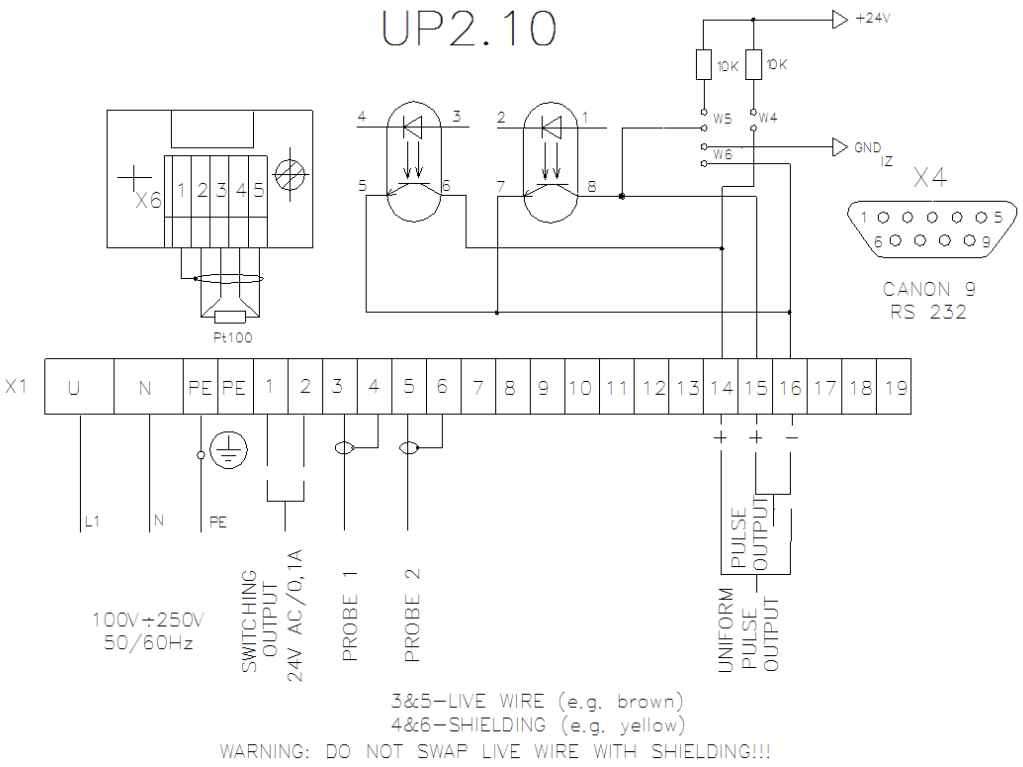


6.2. Electronic circuits

The electronic signal processing unit shall be mounted in a vertical position on an installation frame. The interconnection between the electronic unit and the meter sensor UC 3.0 is described in section 6.2 below. The connecting coaxial cables should not differ in length by more than 0.1 m.

6.3. Electrical connections

Schematic drawing of connections to the SE4041 ultrasonic flow meter

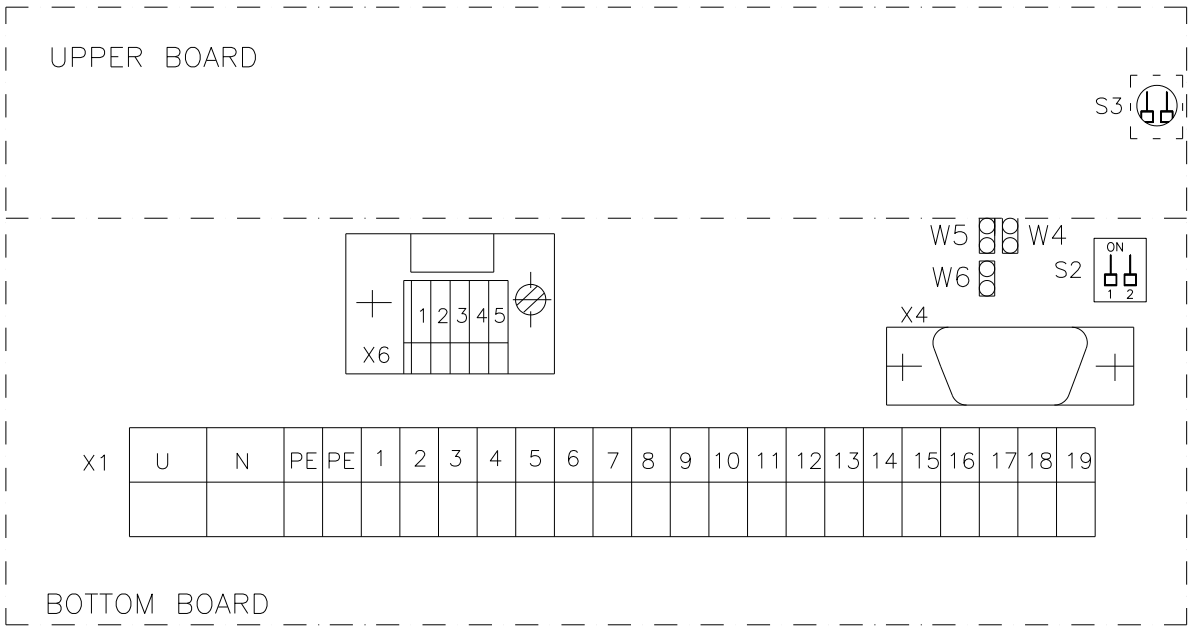


Connected to terminal strip X1 are, apart from the ultrasonic transductors, the feeding power lines, signal output - the pulse.
By connection the jumpers W4 and W6 the pulse output will be activated; the same action on jumpers W5 and W6 activates the pulse output (uniform pulses for the connection with calorimetric counter). If the pulse output is used in the passive mode of operation (jumpers W4 through to W6 disconnected), the optron current shall not exceed 20mA. To indicate the fluid flow direction, connect to terminals 1 and 2 on terminal strip X1 a relay coil in series with external alternating voltage source 24 V/100 mA.

Note:

a) Connection transductors to terminals: terminals 3 and 5 = live wires (e.g. brown), terminals 4 and 6 = shielding (e.g. yellow)
b) Terminals X1 14 and 15 are used for standard pulses
b) Terminals X1 14 and 16 are used for uniform pulses (for connection with a calorimetric counter)
c) Connector X4 is used for services purposes which can be done from a Producer's Authorized Service center only.

Switches S2 and S3 – location and functions



Flow meter mode of operation		***Combination of switch positions***
Measurement	Instantaneous flow rate	S2 ON 1 2 S3 ON 1 2

6.4. Ultrasonic sensor

Ultrasonic sensors shall not be covered with thermal insulation. The connecting coaxial cables shall not be attached to piping containing warm fluid. The sensors shall be installed in the piping in such a way as to ensure the terminal box is facing up or down.
The position of the sensor in the piping shall be such that the hydraulic part of the sensor is fully flooded by the measured fluid at all times. If the sensor is installed in a vertical section of the piping, the measured fluid shall only flow in the upward direction. Disregarding these or other sensor installation rules (see section 5) may result in incorrect flow rate.

6.5. Mechanical assembly and installation

Ultrasonic sensors shall be fitted into the piping by means of end flanges (size 11, ČSN EN 1092-1) with suitable counterparts at the piping ends. The internal diameters of the pipe flanges and the piping itself shall be the same as that of the sensor. The pipe flange faces shall be perpendicular to the piping axis. The piping sections including sealing rings at the sensor input and output shall be co-axial with no protruding edges in the flow channel.
The separate box with electronic circuits shall be attached to a suitable vertical support plate by means of four bolts of diameter 5 mm.

7. METER COMMISSIONING AND CONTROL

7.1. The electronics configuration

After the meter has been installed in the piping (which implies installation of the flow sensor in the piping and connecting it to a separate signal processing unit) the meter can be energized. Very soon (within a few seconds) the meter will adopt the measuring mode and pulse output will be operative. The pulse output can be used either in the passive mode (where the function is essentially that of a transistor switch with power supplied from the associated equipment) or in the active mode where the output circuits are powered from an internal isolated source. The selection of the output mode of operation is done by connecting or disconnecting the respective W pins (see section 6.3 above).

8. SERVICE ACTIVITIES

8.1. Warranty services

The product warranty services are understood to include any repair work executed free of charge either on site or at the manufacturer's premises during the product warranty period. Warranty repairs shall concern product defects due to the use of non-standard materials, parts or design errors. Should such defects prove irreparable, the product shall be replaced at no costs to the customer.
Any warranty repairs shall be performed either by the manufacturer (ELIS PLZEŇ a. s.) or other duly authorized distribution agents or service centers.

The manufacturer's warranty shall not cover

- products where the installation and/or metrological seals have been removed
- product defects due to incorrect installation
- product defects due to non-standard product use
- product pilferage
- product defects due to circumstances classified as force majeure.

Any requirement for warranty repair shall be submitted in writing (using fax, electronic mail or registered letter) to the official address of the manufacturer. Should the manufacturer establish that the subject product repair does not fall within the warranty conditions, this fact will be made known to the customer in writing and the respective repair costs will be invoiced to the customer. In the case of a commercial meter, the parameters of a repaired product shall be verified at a duly authorized metrological center.

8.2. Post-warranty services

The post-warranty services are understood to include any repair work necessitated by the product defects or deficiencies identified after the warranty period. All such repair work, whether executed at the manufacturer's plant or on site, shall be invoiced and paid for by the customer. In the case of a commercial meter, the parameters of a repaired product shall be verified at a duly authorized metrological center. Any requirement for post-warranty repair shall be submitted in writing (using fax, electronic mail or registered letter) to the official address of the manufacturer.

9. STANDARD TESTS

Each finished product is thoroughly checked to establish the product completeness and compliance with the manufacturer's quality assurance standards. Subsequently the product functions are tested according to the specifications of the approved test directions and subject to at least 15-hour burn-in operation cycle.

10. VERIFICATION TESTS

In the case of a commercial (invoicing) meter, the manufacturer shall provide for initial product testing at a duly authorized Metrological Centre. There the meter functions and accuracy are verified under three different operational conditions within the specified range of the fluid flow rate. Upon agreement with the customer and/or in the cases of higher accuracy requirements, the scope of tests can be extended up to nine verification tests under different operational conditions.

Important notice: The verification tests on the flow meters SE4041 are recommended to be executed on a running-start testing facility.

11. PRODUCT MARKING

11.1 Main metrological label

- Manufacturer's mark or label
- The "CE" marking and metrological marking
- Number of EC-type examination certificate

11.2 Supplementary labels (shields) - (located on the electronic unit box):

- Year of Manufacture
- Measuring device type
- The serial number
- Accuracy class 2
- Then maximum admissible pressure PN
- Limits of flow parameters
- Limits of temperature range
- Place of the flow sensor installation (flow or return)
- Direction of flow arrow on the meter body
- Environmental and mechanical classes E1, M1
- SW identification
-

12. PACKAGING

The product packaging shall meet the requirements regarding safe domestic and international transport or other conditions agreed to with the customer. In that, the manufacturer uses its own in-company packaging directions and standards.

13. PRODUCT ACCEPTANCE PROCEDURE

The product acceptance procedure consists of visual inspection and check on the completeness of the delivered items with reference to the delivery note. Each shipment of flow meters SE4041 shall include a delivery note, operation and maintenance manuals and a statement on the product compliance with the respective standards.

14. WARRANTY CONDITIONS

Unless agreed otherwise between the manufacturer and the customer, the warranty period for the SONOELIS flow meters is 12 months from the delivery date. Within the warranty period, the manufacturer shall repair, free of charge, any product defects due to faulty materials or parts. In the case of a warranty repair, the warranty period shall be extended by the time the flow meter was inoperative because of such repair. Manufacturer's warranty shall not cover product defects or malfunctions due to incorrect product installation, operation, intentional damage, pilferage or damage due to force majeure circumstances.

15. PRODUCT ORDERING

Address of manufacturer:

ELIS PLZEŇ a. s.
Luční 425/15
301 00 Plzeň
Czech Republic Tel.: +420/377 517 711
Fax: +420/377 517 722
E-mail: sales@elis.cz
http://www.elis.cz ELIS PLZEŇ a. s.

Issue: 1