ULTRASONIC FLOW METER

AFLOWT UF

(with clamp-on converters)
VERSION UF-5xx d

INSTALLATION MANUAL

ISO 9001:2015

CONTENTS

The present manual covers procedures for on-site mounting and dismounting of AFLOWT UF ultrasonic flowmeters of UF-510 d, -520 d, -522 d models. In the course of work, also refer to manuals "ULTRASONIC FLOW METER AFLOWT UF (with clamp-on converters). Version UF-5xx d. Operation manual" part 1 and 2.

LIST OF ABBREVIATIONS

CS	- Secondary measuring converter
DN	- Nominal diameter
MC	- Measuring cut
PEA	- Electro-acoustic converter

NOTE. Words in the text marked in bold, for example, **Settings** correspond to the items displayed on the flowmeter's screen.

CAUTION! It is highly recommended to study the Operation Manual before starting to use the flowmeter.

1. SAFETY INSTRUCTIONS

1.1. The flowmeter should be mounted (dismounted) by the qualified technical staff:

- Certified for performing work of this type on the site where the flowmeter is installed and authorized by the manufacturer
- Authorized to work with electrical installations up to 1000 V
- Upon reading all the instructions for the flowmeter and the auxiliary equipment used for mounting and dismounting.

1.2. When working with the flowmeter, the dangerous factors are as follows:

- AC voltage (RMS value up to 264 V, frequency 50 Hz)
- Fluid temperature (up to 150 °C)
- Other installation site-specific factors.

1.3. Prior to performance of works, make sure with the use of appropriate equipment that no dangerous AC/DC voltage which may cause injury or death is applied to pipeline section to be worked on.

1.4. In the course of mounting, start-up, commissioning and dismounting works, it is strictly forbidden:

- To make connections to the flowmeter, switch over modes and replace electronic components when the flowmeter is powered up
- To use defective electronic devices and electric tools or use them without proper grounding.

1.5. Prior to connection of the flowmeter to the electric mains the CS module is to be connected to the protective earthing trunk line (neutral earthing).

CAUTION! Prior to connecting the protective earthing trunk line make sure that the voltage is off.

2. MOUNTING PREPARATION

2.1. For on-site mounting of the flowmeter the following conditions should be met:

- A free pipeline section should be available for mounting of the electroacoustic transducers (PEA)
- Availability of straight pipe runs of appropriate length upstream and downstream the PEAs.

2.2. The flowmeter should be transported packed in the manufacturer’s box.

After the flowmeter has been moved to the mounting location from a cold environment into a warm one (with ambient temperature above zero), it shall be left to stand in the manufacturer’s box for at least 3 hours to make sure that no condensation remains inside.

When unpacking the flowmeter, check that the delivery package contains all items specified in the Passport.

3. MOUNTING REQUIREMENTS

3.1. Requirements for Mounting the Electroacoustic Transducers

3.1.1. General Requirements.

3.1.1.1. The following requirements should be observed on-site of PEAs mounting:

- Liquid pressure in the pipeline and operation conditions must not be of values that may facilitate gas (air) release and/or accumulation
- When the flowmeter is operated, the pipeline should be fully filled with liquid
- Flow turbulence and pulsations are minimal.

The PEAs can be mounted into the pipeline horizontally, vertically, or obliquely (Fig.1). The PEAs should not be placed at the upper point of the pipeline or in the open-ended pipeline. The recommended location (if applicable) is at the lower or uprising pipeline section.

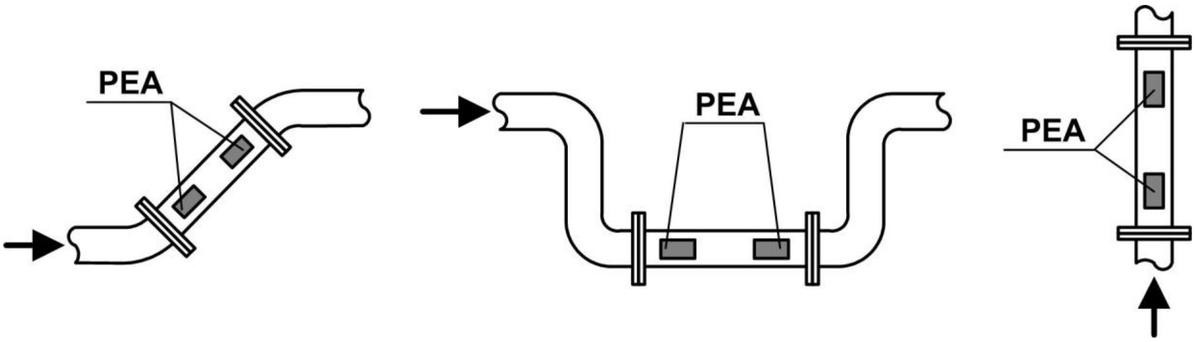


Fig.1. Recommended locations of the PEAs.

3.1.1.2. It is recommended not to install PEAs in the upper or in the lower circular points of the pipeline cross-section.

3.1.2. Placing the PEA pair for single-beam sounding

When mounting PEAs on the diameter, they should be placed so that the PEA longitudinal axis (the axis that runs through the PEA pair along the pipeline axis) would make an angle with the vertical of $\beta = 45°\pm10°$ (Fig.2). The PEAs can be mounted horizontally.

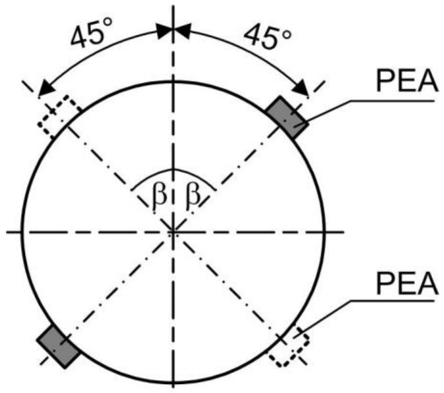
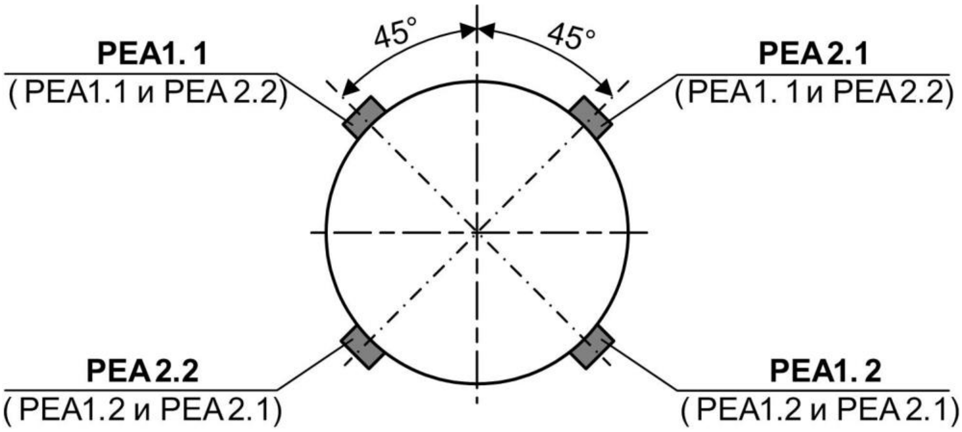


Fig.2. Recommended locations of the PEA pair when mounting “on the diameter” (single-beam sounding).

3.1.3. Placing the PEA pair for two-beam sounding

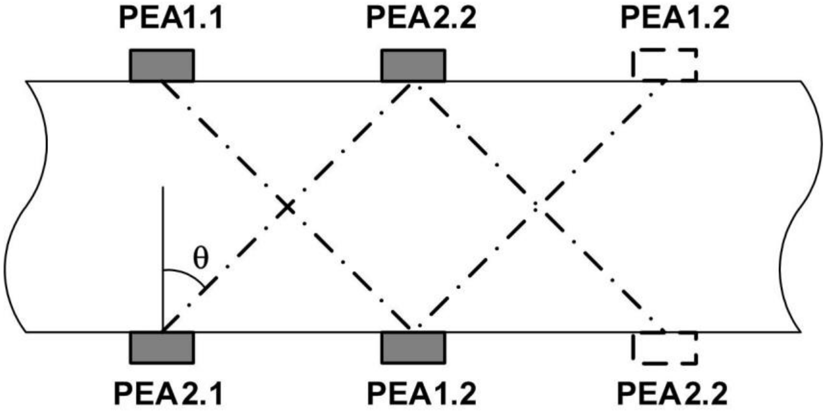
The clamp-on PEAs are mounted on the pipeline along the diameter (Fig.3). In this case, the PEA pairs for Z- and V-configurations can be placed either in different longitudinal planes or in the same plane. The symbols in brackets correspond to the PEA pairs placed in the same plane.



PEA1.1-PEA1.2 pair - 1st beam
PEA2.1-PEA2.2 pair - 2nd beam

Fig.3. Placing the PEA pairs “on the diameter” (two-beam sounding).

Fig.4 shows positioning of two PEA pairs in one plane.



for V-configuration the second PEA from a pair is shown in dashed line.

Fig.4. Location of PEA pairs for Z- and V-configuration in case of their placement in one longitudinal plane (double-beam sounding).

3.2. Length requirements for straight pipe runs

3.2.1. For proper flowmeter's operation, before the first and the last PEA with respect to the flow direction, there should be straight pipe runs of corresponding length with the DN equal to the DN of the pipeline. The "type" installation minimum values of relative length of the straight pipe runs for various PEA installation configurations and types of hydraulic resistance are shown in Table A.1 of Appendix A.

The length of the straight pipe run L (mm) is calculated as follows:

$$L = N \times DN,$$

where N is the relative length defined in the number of DNs and specified in Table. A.1.

DN is the pipeline nominal diameter at the mounting location of PEAs, mm.

CAUTION! While measuring the reverse flow, all the PEAs are in upstream position, and the length of the straight pipe runs shall be defined in view of this condition.

3.2.2. In case of mounting the straightening vane into the pipeline before the measuring section (Appendix D), reduction of straight pipe run length is possible at the inlet of the PEAs up to two times.

3.3. Requirements for placing the Secondary measuring converter

The following conditions should be observed at the site of CS location:

- Operation conditions in accordance with the requirements of the Operation Manual
- Option for connecting the CS to the protective earthing trunk line (neutral earthing)
- Free access to the CS.

4. MOUNTING THE FLOWMETER

4.1. Requirements for the pipeline at PEA mounting location

4.1.1. The pipeline at the PEA mounting location must meet the following requirements:

- Deviation of the pipeline inner diameter at the PEA mounting location must not exceed 0.015 of the average pipeline inner diameter
- The pipeline section should not have any junctions, dents or any other damages
- The straight pipe runs should not include devices or components upstream and downstream the PEA section that may disturb flow structure.

4.1.2. Prior to the flowmeter mounting operations, it is recommended to get details on the medium (fluid flow range, temperature and fluid viscosity) and get the pipeline certificate (standards for the pipe, material, dimensions, operational terms and conditions).

For the flowmeter with clamp-on PEAs, it is recommended to estimate the pipeline quality and PEA mounting location taking into consideration the following: how ultrasonic vibrations would be transmitted and whether the required level of received signal would be provided. For this purpose, you can use the handheld ultrasonic flowmeter "AFLOWT UFd PORT".

The inner pipeline surface at the PEA mounting location should be covered with acoustically transparent corrosion- and sediment-resistant protective coating.

4.2. Defining the parameters of the measuring cut

4.2.1. Prior to installation of PEAs on the active pipeline, it is necessary to determine characteristics of the measuring cut (MC) – the pipeline section intended for clamp-on PEA mounting.

4.2.2. To define the characteristics of the measuring cut, the measuring instruments and tools listed in Table 1 shall be used. Instead of the units given in Table 1, you may use alternative measuring instruments and tools provided that measurements of the corresponding parameters are performed with the required accuracy.

Table 1

Tool name and type	Basic metrological characteristics
Metal rule	Division value, 1 mm
Vernier caliper	Fundamental measurement error 0.1 mm
Measuring reel	Division value 1 mm
Ultrasonic Thickness Gauge	Measurement error no less than 0.1 mm
Snap Gage	Division value 1 mm

The measuring devices shall function properly and, in case of mounting the flowmeter at a metering station, they shall be timely calibrated and have the valid Calibration Certificates or corresponding marks in the Equipment Certificates.

In addition to the above-mentioned measuring tools, it is necessary to use the profiled angle, marking pencil for metal pipes and centre punch.

All measurement and calculation results are registered in the corresponding reports with 0.1 mm accuracy. The recommended form of the report is given in Appendix B.

4.2.3. Defining the average value of outer diameter of the MC

The average value of MC outer diameter is calculated by averaging measurements made on outer diameter (or outer circumference) for two PEA installation cross-sections normal to the MC axis.

The location of cross-sections is marked on the pipeline according to Fig.7.

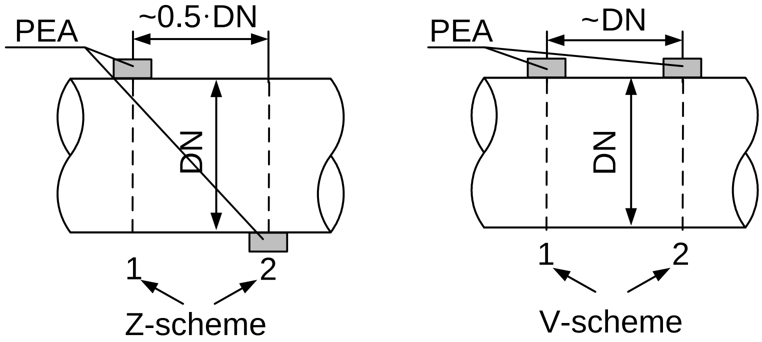


Fig.5. Position of cross-sections for placing PEAs on the MC.

4.2.3.1. Defining the average value of MC outer diameter by measuring outer circumference.

The MC is cinctured three times in each of the selected cross-sections. The average circumference value is calculated in cross-section 1 and 2:

$$L_{circ\ avg1,2} = \frac{\sum L_{circ\ ij}}{3},\ mm,$$

where $L_{circ\ avg1,2}$ is the average circumference value in cross-sections 1 and 2, mm;

$L_{circ\ ij}$ is the circumference value for the i-th measurement in the j-th cross-section, mm.

The average MC circumference value is calculated as follows: $L_{circ\ avg}$:

$$L_{circ\ avg} = \frac{L_{circ\ avg1} + L_{circ\ avg2}}{2},\ mm.$$

The average MC outer diameter value $D_{0\ avg}$ is defined as follows:

$$D_{0\ avg} = \frac{L_{circ\ avg}}{\pi},\ mm$$

The measurement and calculation results are registered in the report.

4.2.3.2. Defining the average value of MC outer diameter by direct diameter measurement.

Eight points are marked on each of the selected cross-sections of the MC. The points are equispaced along each cross-section (Fig.6).

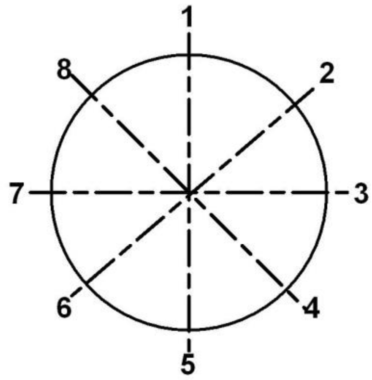


Fig.6. Location of points on the MC cross-sections.

Three measurements are made in the planes 1-5; 2-6; 3-7 and 4-8 of each cross-section. When measuring by a snap gauge, the fixed feeler is placed directly on the point marked on the MC, and the moving one is shifted to the facing point until the movable element achieves its maximum position towards the surface of the MC. The measurements can be carried out with the help of a vernier caliper and measuring reel.

The average value of MC outer diameter in cross-sections 1 and 2 is calculated as follows:

$$D_{0\ avg1,2} = \frac{\sum D_{0\ ij}}{12}, \text{ mm},$$

where $D_{0\ avg1,2}$ is the average value of MC outer diameter in cross-sections 1 and 2, mm;

$D_{0\ ij}$ is MC outer diameter for the i-th measurement on the j-th cross-section, mm.

The average MC outer diameter value is calculated as follows: $D_{0\ avg}$:

$$D_{0\ avg} = \frac{D_{0\ avg1} + D_{0\ avg2}}{2}, \text{ mm}.$$

The measurement and calculation results are registered in the report.

4.2.4. Defining the average value of MC outer diameter in the longitudinal plane if PEAs are installed “on the diameter”.

Measurement of MC outer diameter in the PEAs longitudinal plane running through the PEA installation points and the MC axis is performed with a snap gauge. In each of the selected cross-sections 1 and 2 on the MC (pipeline) the points intended for mounting of PEAs are marked. Three measurements of outer diameter are performed in these points for each cross-section. When measuring by the snap gauge, the fixed feeler is placed directly on the point marked on the MC, and the moving element is shifted to the facing point until the movable element is in its maximum position towards the surface of the MC. The measurements can be carried out with the help of a vernier caliper and measuring reel.

The average value of MC outer diameter at the selected points in cross-sections 1 and 2 is calculated as follows:

$$D_{tr\ avg1,2} = \frac{\sum D_{tr\ ij}}{3}, \text{ mm},$$

Where $D_{tr\ avg1,2}$ is the average value of MC outer diameter in the PEAs longitudinal plane for cross-sections 1 and 2, mm;

$D_{0\ ij}$ is MC outer diameter in the PEAs longitudinal plane for the i-th measurement on the j-th cross-section, mm.

The average MC outer diameter value in the PEAs longitudinal plane $D_{tr\ avg}$ is calculated as follows:

$$D_{tr\ avg} = \frac{D_{tr\ avg1} + D_{tr\ avg2}}{2}, \text{ mm}.$$

The measurement and calculation results are registered in the report.

4.2.5. Defining the distortion factor of the acoustic base.

Based on results of measuring MC parameters, the distortion factor of the flowmeter's acoustic base K_b is defined as follows:

$$K_b = \frac{D_{tr\ avg}}{D_{0\ avg}}.$$

The following condition is checked next:

$$0.985 \leq K_b \leq 1.015.$$

If the given condition is not satisfied, it is considered unsuitable to mount the PEAs on the selected pipeline section and to use it for commercial metering.

4.2.6. Measuring MC wall thickness.

Three measurements of MC wall thickness are performed with use of the thickness gauge in points 2, 4, 6, 8 (Fig.9) of each cross-section.

The average value of MC wall thickness in cross-sections 1 and 2 is calculated as follows:

$$h_{w\ avg1,2} = \frac{\sum h_{w\ ij}}{12}, \text{ mm},$$

where $h_{w\ avg1,2}$ is the average value of MC wall thickness in cross-sections 1 and 2, mm;

$h_{w\ ij}$ is the MC wall thickness for the i-th measurement on the j-th cross-section, mm.

The average value of MC wall thickness is calculated as follows:

$$h_{w\ avg} = \frac{h_{w\ avg1} + h_{w\ avg2}}{2}, \text{ mm}.$$

The measurement and calculation results are registered in the report.

4.2.7. Defining equivalent asperity of the MC.

The value of equivalent asperity of the MC inner surface **d** is defined as per Table 2 and then registered in the report.

Table 2

Material	Pipe type and condition of the inner surface		d, mm
Brass, copper, aluminum, plastics, glass, lead	New, without sediments		< 0.03
	New, joint-free:	- cold-drawn	< 0.03
		- hot-drawn	< 0.1
		- rolled	<0.1
	New, welded		< 0.1
	With a slight film of rust		< 0.2
	Rusty		< 0.3
	Oil-coated:	- new	< 0.05
		- used	< 0.2
	Galvanized:	- new	< 0.15
		- used	< 0.18
Cast iron	New		0.25
	Rusty		<1.2
	With sediments		< 1.5
	Oil-coated, new		< 0.05
Asbestos cement	With/without lining, new		< 0.03
	Without lining, in normal condition		0.05

4.2.8. Defining kinematic viscosity ratio.

The kinematic viscosity ratio for water is defined according to Appendix C. To do this, it is necessary to determine the water temperature range under operation conditions, calculate the average value of water temperature and find the kinematic viscosity ratio for this temperature in the table. The value is registered in the report.

For other liquids the value of the kinematic viscosity derived with use of the viscometer.

4.2.9. The values of other parameters required for flowmeter's operation are defined after PEAs are installed on the pipeline. The procedure for defining these parameters is described in the following sections of the present manual.

4.3. Mounting the Secondary Measuring Converter

Fixing the CS and Secondary power source in vertical plane is performed in accordance with the installation dimensions specified in the Operation Manual.

4.4. Procedures for mounting clamp-on PEAs

4.4.1. The section of outer MC surface on which MC parameters were defined is stripped to metal at cross-sections 1 and 2 (Fig.7). The stripped area shall be of value enough to move PEAs along the stripped surface at a distance equal to the PEA unit length in any direction.

When mounting PEAs according to Z- scheme, the stripped areas are located on the opposite walls of the MC (pipeline) at a distance of 0.5 DN between the mid-points of the areas (along the MC axis).

4.4.2. PEAs are attached to the connectors of the corresponding CS channel (Channel 1 – Channel 2) according to the flowmeter's connection scheme (Appendix B, part I of the Operation Manual) so that the corresponding PEA is placed first relative to the flow direction and connected to PEA1.1 and PEA1.2 terminals, and another one from the pair is the second regarding the flow direction and connected to PEA2.1 and PEA2.2 terminals.

4.4.3. The emitting surface of both PEA pairs is lubricated.

One unit from the PEA pair is mounted by seating it in the middle of the stripped area as shown in Fig.7 and fixed with the mount clip (which should be welded to the MC for the purpose) or by the clamp made of flexible steel band. The position of the mount marks on the side walls of this PEA is marked on the MC.

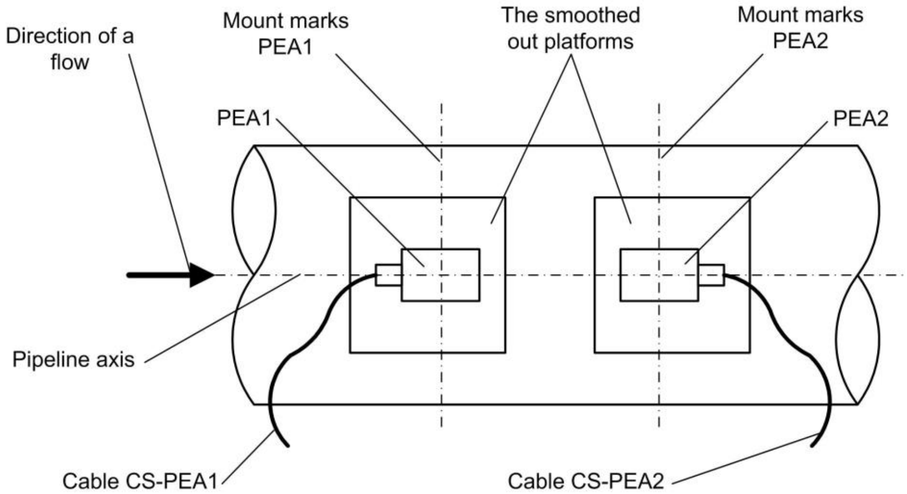


Fig.7. Positioning clamp-on PEAs on the pipeline (V-scheme mounting)

Another PEA from the pair is installed by seating it in the middle of the second stripped area and fixed on the MC by the mount clip welded to the pipeline or by the clamp made of steel band.

4.4.4. The datum axis of the device is measured – the distance between the acoustic centers of the PEAs in the pair (mount marks on the side walls) along the MC axis. When mounting according to Z-scheme, the MC is sequentially cinctured with a measuring reel through the PEA1 and PEA2 mount marks. At this time, it is necessary to draw the lines on the pipe surface along the measuring reel up to intersection with the generator going through the opposite PEA (a conventional line on the surface of the pipeline parallel to its axis). The distance between the half-arcs along the generator lines are measured with the measuring reel and the average value is calculated. The value is registered in the report.

The flowmeter automatically sets the required parameters of the received signal. Automatically adjusted range is designed to respond to considerable changes in both fluid characteristics (temperature, pressure, acoustic transparency, etc.) and flow conditions.

4.4.5. To install the PEAs for two-beam flow sounding, the procedures according to items 4.4.1-4.4.4 are performed for each PEA pair.

4.5. Wiring the Flowmeter

4.5.1. When connecting PEAs to the CS, it is necessary to provide that the elements of the measuring channel (PEAs and communications cables) be in correspondence with the characteristics of the channel.

PEA serial numbers with the measurement channel indicated are specified in the flowmeter's Passport.

The communications cable marking for the PEA pair is maintained in similar labels with one or two white transverse bars.

The label color denotes reference to the measurement channel:

- Black – channel 1
- Grey – channel 2

One white transverse bar denotes that the communications cable refers to PEA1, two white transverse bars denote that the communications cable refers to PEA2 from the pair of cables labeled in the same color.

The PEA cable connectors and mounting locations can be labelled "PEA1" and "PEA2", which will refer them to the corresponding PEA in the pair.

4.5.2. The flowmeter's power cable, CS-PEA connection cables, and CS-external devices connection cables (if applicable) are laid in accordance with flowmeter's operating conditions.

4.5.3. Communications and network cables are fixed on the wall wherever possible. The network cable is laid separately at a distance of 30 cm as a minimum from other cables. To avoid mechanical damages, it is recommended to place all cables in metal tubes or sleeves.

IT IS FORBIDDEN to lay CS-PEA cables and external signal cables within proximity to power circuits. With presence of high-level electromagnetic interference (for instance, from a thyristor controller), **IT IS FORBIDDEN** to lay the cables without putting them into properly grounded (neutrally earthed) metal tubes or sleeves.

The metal tubes or sleeves shall only be grounded on one side – on the CS side.

4.5.4. It is recommended not to coil the excessive cables.

4.5.5. Prior to connection, cut isolation from cable ends by 5 mm. The cables are directed via cable glands and attached to the connectors according to the Wiring diagram given in Appendix B of Part I of the Operation Manual.

4.5.6 To prevent polyethylene insulation of the CS-PEA communications cable from burning, the cable shall not be in contact with the heated pipeline. The pipeline shall be thermally insulated at the points of contact, or you may use another type of cable.

4.5.7. The RS-output of the flowmeter is connected to an external device. You can use the standard 15 m Null-Modem cable as an RS-232 communications cable.

4.5.8. The need for protective grounding is determined by power supply and environment conditions under which the flow meter is operated.

The protective grounding and earthing device should correspond to the rules on design of power electric installations. Do not use the lightning protection system for grounding since in could result in device's failure.

As a grounding wire, you must use a copper ground wire between the flowmeter and grounding device. If mechanically protected, its cross-section must be minimum 2.5 mm^2. Minimum 4 mm^2 cross-section is required for installations without protection.

The grounding conductor is connected to the earthing terminal of the CS.

5. START-UP PROCEDURE

5.1. Before start-up you should check that flowmeter's operation parameters specified in the Passport correspond to data entered in the flowmeter memory.

5.2. Parameters are entered according to the Operation Manual, Sections 2.1, Part II.

5.3. In case the flowmeter was supplied without the MS, and PEAs were mounted on site, flowmeter's zero offset **dT0** and additional delay **Padd** should be determined for each measurement channel or flowmeter beam according to the method specified in the Operation Manual, Sections 2.2 and 2.3, Part II.

CAUTION! In case of replacement of any component of measurement channel (CS, PEA, communications cables), parameters **dT0** and **Padd** should be determined anew.

5.4. Processing of measurement results is adjusted according to the Operation Manual, Section 2.4, Part II.

5.5. External devices (analog recorder, modem, etc.) are connected to the flowmeter, communication system and flowmeter outputs are adjusted according to the instructions given in Part II of the Operation Manual.

5.6. Current date and time are checked and set if necessary (see Section 2.5, Part II of the Operation Manual).

5.7. The device should be switched into the OPERATION mode (a jumper should be removed from terminal J4). Terminal J4 should be sealed. If necessary, two fixing screws are sealed from the front panel side.

If the parameters are set correctly, the flowmeter displays flowrate measurement results.

5.8. Requirements for mounting location and operating conditions specified in this operational documentation are based on the most typical factors affecting flowmeter performance.

The external factors that cannot be foreseen, evaluated or tested by the manufacturer during designing may exist or appear on site.

In this case such factors should be eliminated or flowmeter should be placed in other location.

6. DISMOUNTING

To dismount the flowmeter, do the following:

- Switch off the flowmeter
- Disconnect cables leading to the CS (PEAs)
- Dismount the PEAs and CS.

APPENDIX A. Relative length of straight pipe runs

Table A.1 shows minimum values of relative length of pipeline straight runs for installation of clamp-on PEAs depending on local hydraulic resistance types.

Table A.1

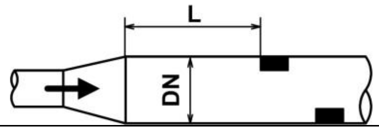
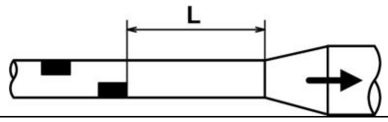
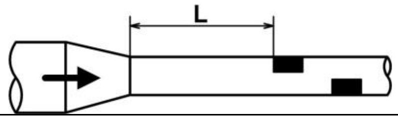
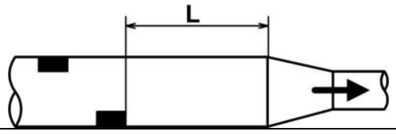
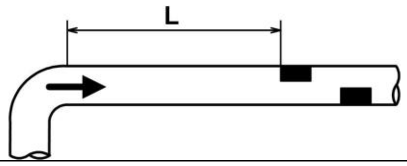
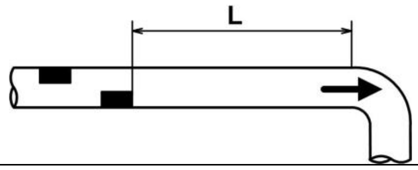
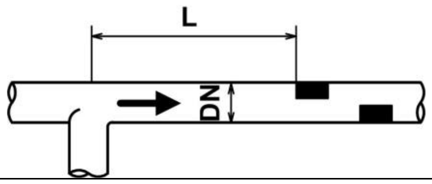
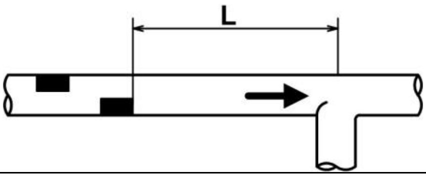
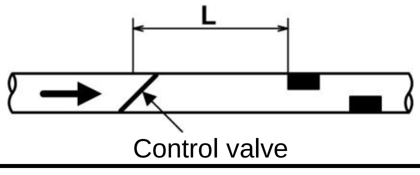
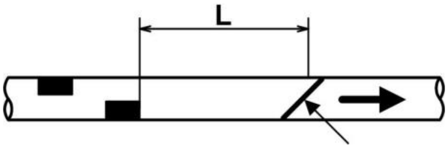
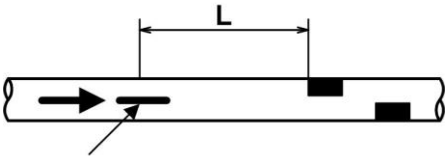
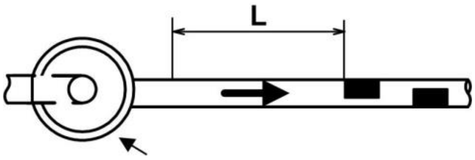
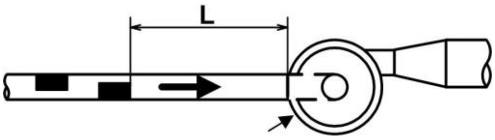
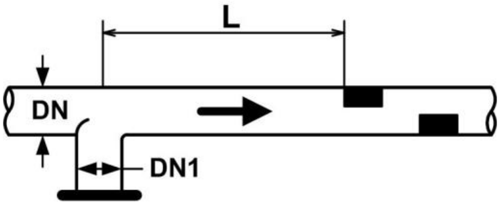
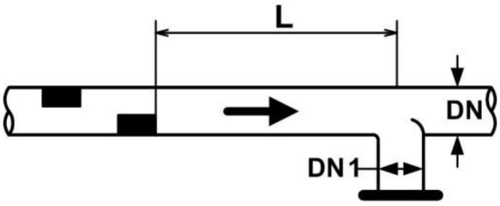
Type of local hydraulic resistance	Relative length of a straight run, N, minimum	
	V-scheme	Z-scheme
1	2	3
	10	15
	3	5
	10	15
	3	5
	10	15
	3	5
	10	15
	10	15
	30	40

Table A.1 (cont'd)

1	2	3
 Control valve	3	5
 Fully-open ball valve	10	15
 Pump	30	15
 Pump	3	5
 DN1 / DN > 0.1	10	15
 DN1 / DN > 0.1	3	5

In case of various types of hydraulic resistance in the pipeline, the length of a pipeline straight run related to the resistance nearest to the PEAs should be no less than the value specified in the table, and the distance from the PEAs to the other hydraulic resistances should be no less than the value specified in the table for hydraulic resistance of this type.

APPENDIX B. Report on mounting and start-up procedure

(recommended)

REPORT
on mounting and start-up procedure

for AFLOWT UF flowmeter, serial No. ________(sheet __ of ____)
UF-5__ d design version, channel No. _____

Beam 1 – PEA1.1 No. ______ / PEA1.2 No. _______ ;
Beam 2 – PEA2.1 No. ______ / PEA2.2 No. _______ ;

1. Site

____

organization name, postal address, tel/fax

____

2. Site characteristics: DN of measuring cut _______ mm;
PEA installation diagram ____________ ; negative flow ________
Type of sounding _________, beam

Table B.1

	Type of hydraulic resistance	Length of a straight run, m
To PEA1.1, 2.1		
After PEA1.2, 2.2		

3. MC outer diameter in the cross sections of PEA installation, $D_{0\ avg}$ (fill in table B.2 or B.3).

Table B.2

Circle perimeter		Cross section 1	Cross section 2
Measured value, $L_{circ\ ij}$, mm	1		
	2		
	3		
Average value in cross section, $L_{circ\ avg\ j}$, mm			
Average value, mm		$L_{circ\ avg}$ = ; $D_{0\ avg}$ = .	

Table B.3

Outer diameter		Cross section 1				Cross section 2			
		Measurement plane				Measurement plane			
		1-5	2-6	3-7	4-8	1-5	2-6	3-7	4-8
Measured value, $D_{0\,ij}$, mm	1								
	2								
	3								
Average value in cross section, $D_{0\,avg\,j}$, mm									
Average value, $D_{0\,avg}$, mm									

4. MC outer diameter in the longitudinal plane of PEA installation, $D_{tr\,avg}$ (determined in case of PEA installation on the diameter)

Table B.4

Outer diameter		Cross section 1	Cross section 2
Measured value, $D_{tr\,ij}$, mm	1		
	2		
	3		
Average value in cross section, $D_{tr\,avg\,j}$, mm			
Average value, $D_{tr\,avg}$, mm			

5. Acoustic base distortion factor

$$K_b = \frac{D_{tr\,avg}}{D_{0\,avg}} \text{------------} =$$

$$0.985 \leq K_b \leq 1.015$$

6. MC wall thickness, $h_{w\,avg}$

Table B.5

Outer diameter		Cross section 1				Cross section 2			
		Measurement points				Measurement points			
		2	4	6	8	2	4	6	8
Measured value, $h_{w\,ij}$, mm	1								
	2								
	3								
Average value in cross section, $p_{ц\,avg\,j}$, mm									
Average value, $h_{wr\,avg}$, mm									

7. Equivalent asperity of MC internal walls, d = ________ mm

8. Parameters of the medium.

8.1. Kind of liquid ____

8.2. Temperature of liquid: maximum _________ °C
minimum _________ °C
average 0.5 (t_{max} + t_{min}) = _________ °C

8.3. Kinematic viscosity ratio of liquid, ν = _________ m^2/s

9. Length of CS-PEA communications cables

Table B.6

Parameter	Parameter value in the channel with PEAs	
	PEA1.1- PEA1.2	PEA2.1- PEA2.2
Length of CS-PEA communications cables, m		

10. Measurement channel parameters

10.1. Zero offset, dT_0 = _________ ms

10.2. Additional delay, P_{add} = _________ ms

Note:

____

____

Representative of start-up organization

____________________ / ______________________ /
Signature name and initials

" ___ " ______________ 20__

Customer representative

____________________ / ______________________ /
Signature name and initials

" ___ " ______________ 20__

Calibrator

____________________ / ______________________ /
Signature name and initials

LS " ___ " ______________ 20__

APPENDIX C. Kinematic viscosity ratio of water

Table C.1

t, °C	$\nu \cdot 10^{-6}$	t, °C	$\nu \cdot 10^{-6}$	t, °C	$\nu \cdot 10^{-6}$	t, °C	$\nu \cdot 10^{-6}$	t, °C	$\nu \cdot 10^{-6}$
0.00	1.7905	35.00	0.7247	70.00	0.4137	105.0	0.2807	140.0	0.2125
1.00	1.7307	36.00	0.7107	71.00	0.4083	106.0	0.2781	141.0	0.2111
2.00	1.6738	37.00	0.6972	72.00	0.4030	107.0	0.2756	142.0	0.2097
3.00	1.6198	38.00	0.6841	73.00	0.3979	108.0	0.2731	143.0	0.2083
4.00	1.5684	39.00	0.6714	74.00	0.3929	109.0	0.2707	144.0	0.2070
5.00	1.5196	40.00	0.6591	75.00	0.3880	110.0	0.2683	145.0	0.2056
6.00	1.4731	41.00	0.6472	76.00	0.3832	111.0	0.2659	146.0	0.2043
7.00	1.4289	42.00	0.6356	77.00	0.3785	112.0	0.2636	147.0	0.2030
8.00	1.3867	43.00	0.6244	78.00	0.3740	113.0	0.2613	148.0	0.2017
9.00	1.3464	44.00	0.6135	79.00	0.3695	114.0	0.2591	149.0	0.2005
10.00	1.3080	45.00	0.6030	80.00	0.3651	115.0	0.2569	150.0	0.1992
11.00	1.2713	46.00	0.5927	81.00	0.3608	116.0	0.2547	151.0	0.1980
12.00	1.2363	47.00	0.5827	82.00	0.3566	117.0	0.2526	152.0	0.1968
13.00	1.2028	48.00	0.5730	83.00	0.3525	118.0	0.2505	153.0	0.1956
14.00	1.1708	49.00	0.5636	84.00	0.3485	119.0	0.2485	154.0	0.1945
15.00	1.1401	50.00	0.5544	85.00	0.3446	120.0	0.2465	155.0	0.1933
16.00	1.1107	51.00	0.5455	86.00	0.3407	121.0	0.2445	156.0	0.1922
17.00	1.0825	52.00	0.5368	87.00	0.3370	122.0	0.2425	157.0	0.1911
18.00	1.0555	53.00	0.5284	88.00	0.3333	123.0	0.2406	158.0	0.1900
19.00	1.0295	54.00	0.5201	89.00	0.3297	124.0	0.2387	159.0	0.1889
20.00	1.004	55.00	0.5121	90.00	0.3261	125.0	0.2369	160.0	0.1878
21.00	0.9807	56.00	0.5043	91.00	0.3227	126.0	0.2351	161.0	0.1868
22.00	0.9577	57.00	0.4967	92.00	0.3193	127.0	0.2333	162.0	0.1858
23.00	0.9356	58.00	0.4893	93.00	0.3159	128.0	0.2315	163.0	0.1847
24.00	0.9143	59.00	0.4821	94.00	0.3127	129.0	0.2298	164.0	0.1837
25.00	0.8938	60.00	0.4751	95.00	0.3095	130.0	0.2281	165.0	0.1828
26.00	0.8741	61.00	0.4683	96.00	0.3064	131.0	0.2264	166.0	0.1818
27.00	0.8551	62.00	0.4616	97.00	0.3033	132.0	0.2248	167.0	0.1808
28.00	0.8367	63.00	0.4551	98.00	0.3003	133.0	0.2232	168.0	0.1799
29.00	0.8190	64.00	0.4487	99.00	0.2973	134.0	0.2216		
30.00	0.8019	65.00	0.4425	100.0	0.2944	135.0	0.2200		
31.00	0.7854	66.00	0.4365	101.0	0.2916	136.0	0.2185		
32.00	0.7694	67.00	0.4305	102.0	0.2888	137.0	0.2169		
33.00	0.7540	68.00	0.4248	103.0	0.2861	138.0	0.2155		
34.00	0.7391	69.00	0.4191	104.0	0.2834	139.0	0.2140		

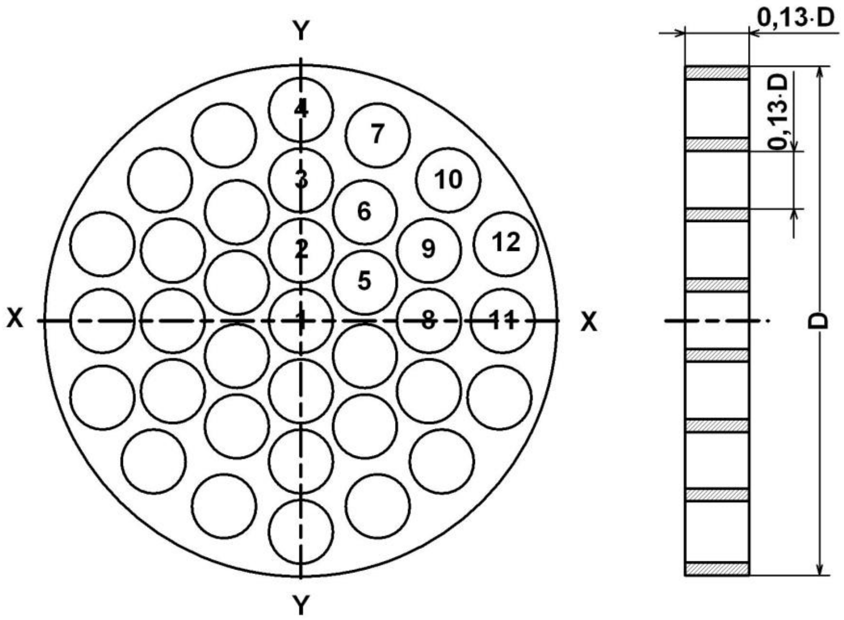
t – water temperature, °C

ν – kinematic viscosity ratio of water, m^2/s

$$1\ cSt = 1 \cdot 10^{-6}\ m^2/s$$

APPENDIX D. Straightening vane design

1. Fig.D.1 shows the design of type A straightening vane that is manufactured according to the following rules:
   a) straightening vane plate thickness is equal to the diameter of the holes; depending on material, the plate can be made of one or several sheets
   b) all the diameters of the holes in the plate are equal
   c) holes are spread more thickly in the center of the plate, and more rarely – at the periphery
   d) holes have chamfers from the flow inlet site.



D – internal diameter of the pipeline where the straightening vane is inserted.

Fig.D.1. Design of type A flow straightening vane.

2. To lower weight and material quantity a type B straightening vane (Fig. D.2) can be used, it is manufactured according to the following rules:
   a) tubes are inserted in the plate holes
   b) tube length is equal to tube diameter
   c) all the diameters of the holes in the plate are equal
   d) holes are spread more thickly in the center of the plate, and more rarely – at the periphery
   e) holes have chamfers from the flow inlet site.

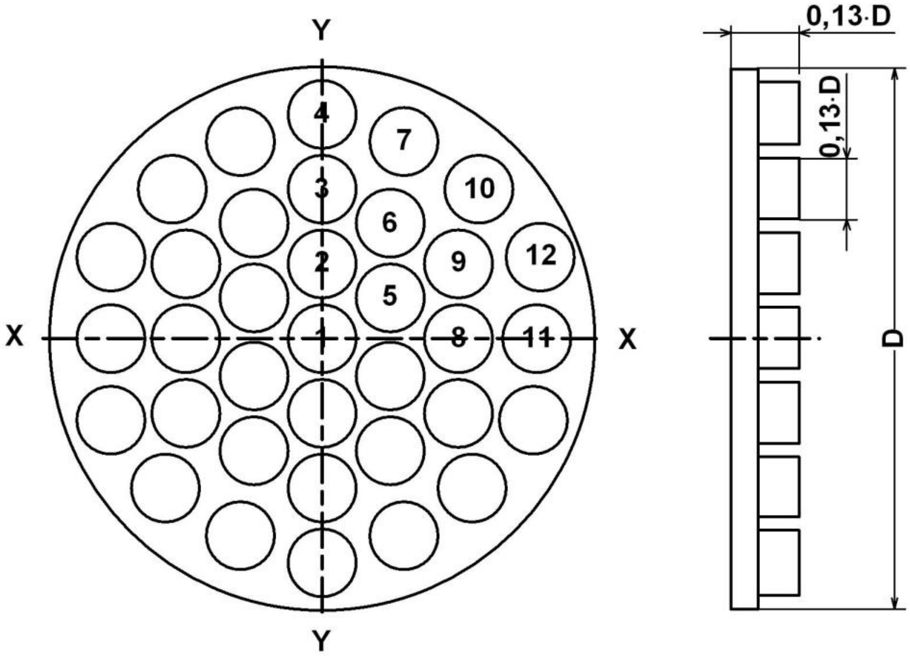


Fig.D.2. Design of type B flow straightening vane.

3. Hole marking in straightening vanes is shown in Table D.1.

Table D.1. Coordinates of the holes in straightening vanes of A and B type (D – pipeline internal diameter)

Item No.	X axis	Y axis
1	0	0
2	0	0.142·D
3	0	0.283·D
4	0	0.423·D
5	0.129·D	0.078·D
6	0.134·D	0.225·D
7	0.156·D	0.381·D
8	0.252·D	0
9	0.255·D	0.146·D
10	0.288·D	0.288·D
11	0.396·D	0
12	0.400·D	0.151·D

4. The straightening vane is installed in the pipeline at a distance of 1÷2 pipeline's DN from the last source of hydraulic resistance with respect to the flow direction. When installing the straightening vane, the length of a straight run before the PEA is determined as the distance from the source of hydraulic resistance to the PEA.