MULTICHANNEL ULTRASONIC
FLOW METER

AFLOWT UF

VERSION
UF-5xx d

INSTALLATION MANUAL

9001:2008

Saint-Petersburg, Russia

CONTENTS

The present manual covers procedures for on-site mounting and dismounting of AFLOWT UF multichannel ultrasonic flowmeters of UF-510 d, -520 d, -522 d, -530 d, -540 d, -542 d, -544 d models. In the course of work, also refer to manuals "MULTICHANNEL ULTRASONIC FLOW METER AFLOWT UF. Version UF-5xx d. Operation manual" part 1 and 2.

LIST OF ABBREVIATIONS

CS	- Secondary measuring converter
DN	- Nominal diameter
MC	- Measuring cut
CP	- Primary converter
PEA	- Electro-acoustic converter (transducer)
SC	- Service centre.

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 160 °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 flow sensor (CP) or electroacoustic transducers (PEA)
- Availability of straight pipe runs of appropriate length upstream and downstream the flow sensor
- A free pipeline section for mounting of the secondary measuring converter (CS).

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 Equipment Certificate.

3. MOUNTING REQUIREMENTS

3.1. Requirements for Mounting the Primary converter and Electroacoustic Transducers

3.1.1. General Requirements.

3.1.1.1. The following requirements should be observed on-site of CP (PEA) 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 CP (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.

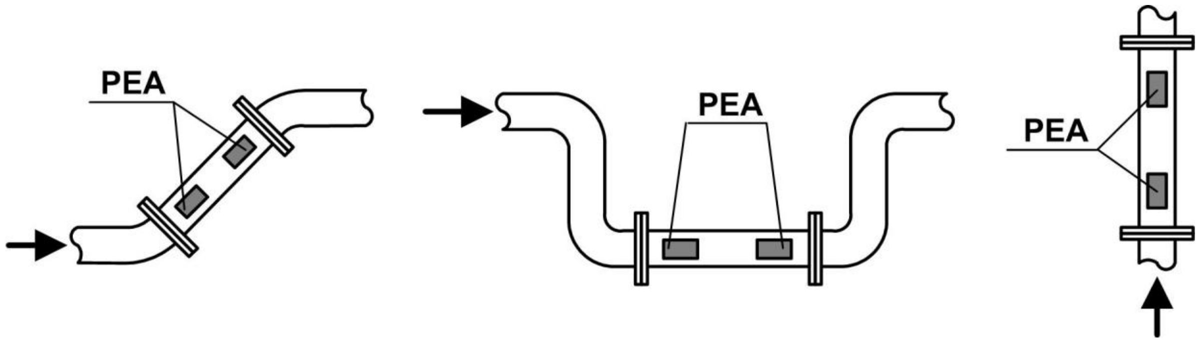


Fig. 1. Recommended locations of the CP.

3.1.1.2. The difference in the internal diameters of the pipeline and a measuring cut (MS) of the CP at a link up point should not exceed 0.05 DN for straight measuring cuts and 0.1 DN for CPs of U-elbow type.

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

3.1.1.4. For wetted PEAs installed in the straight CP, the longitudinal installation angle θ can range from 20° to 70° (the recommended value is ~ 45°). The longitudinal installation angle of wetted PEAs θ is the angle between the axis of the wetted PEA (ultrasonic beam travel direction) and the plane normal to the pipeline centerline (see Fig.5).

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 β = 45°±10° (Fig.2). The PEAs can be mounted horizontally.

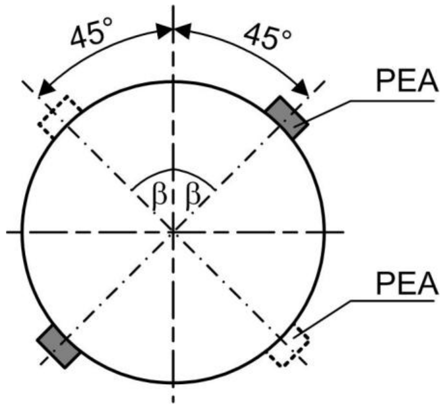
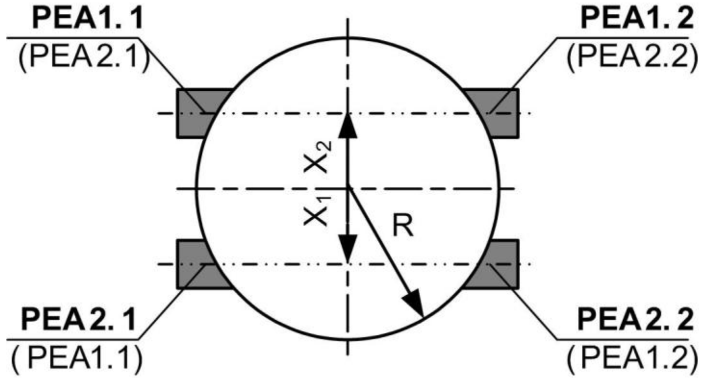


Fig. 2. Recommended locations of the PEA pair when mounting "on the diameter" (single-beam sounding).

3.1.3. Placing the PEA pair for two-beam sounding

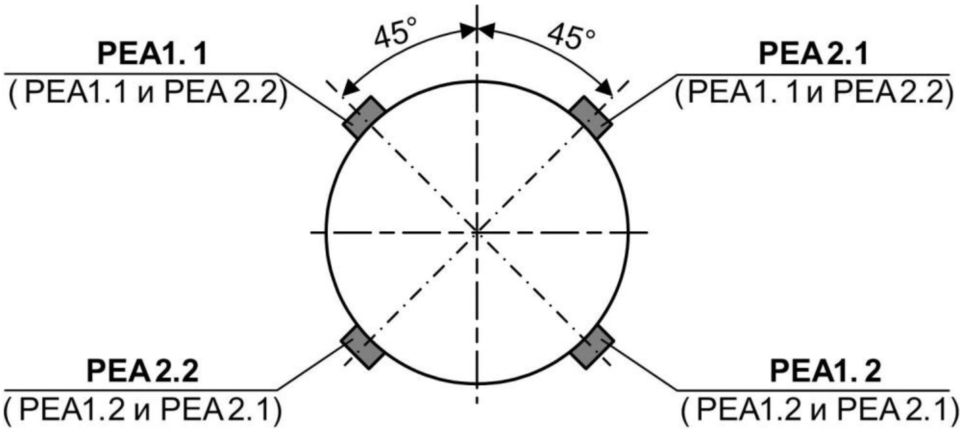
In case of two-beam scanning, the wetted PEAs should be mounted on the CP along two chords. The CP should be mounted so that the chords are directed horizontally (Fig.3).



X_1, X_2 = (0,48÷0,52)·R
PEA1.1-PEA1.2 pair - 1st beam
PEA1.1-PEA1.2 pair - 2nd beam

Fig. 3. Placing the wetted PEA pairs "on chords" (single-beam sounding).

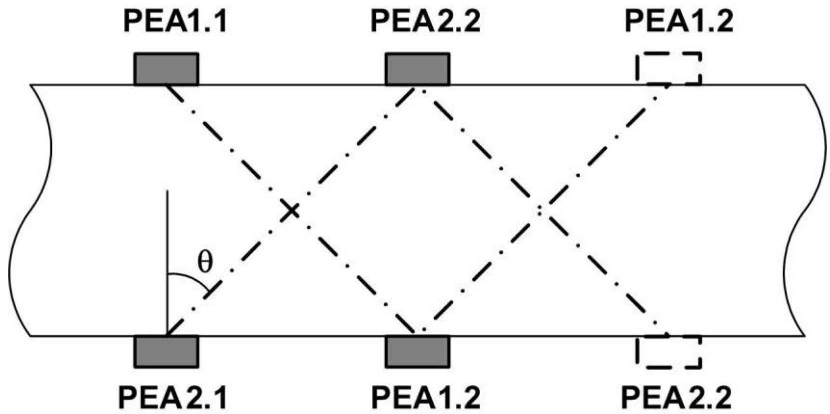
The wetted and clamp-on PEAs can be mounted on the CP along the diameter (Fig.4). In this case, the PEA pairs for Z- and V-configurations can be placed either in different longitudinal planes or in the same plane. The symbols in brackets correspond to the PEA pairs placed in the same plane.



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

Fig. 4. Placing the wetted and clamp-on PEA pairs "on the diameter" (two-beam sounding).

Fig.5 shows positioning of two PEA pairs in one plane.

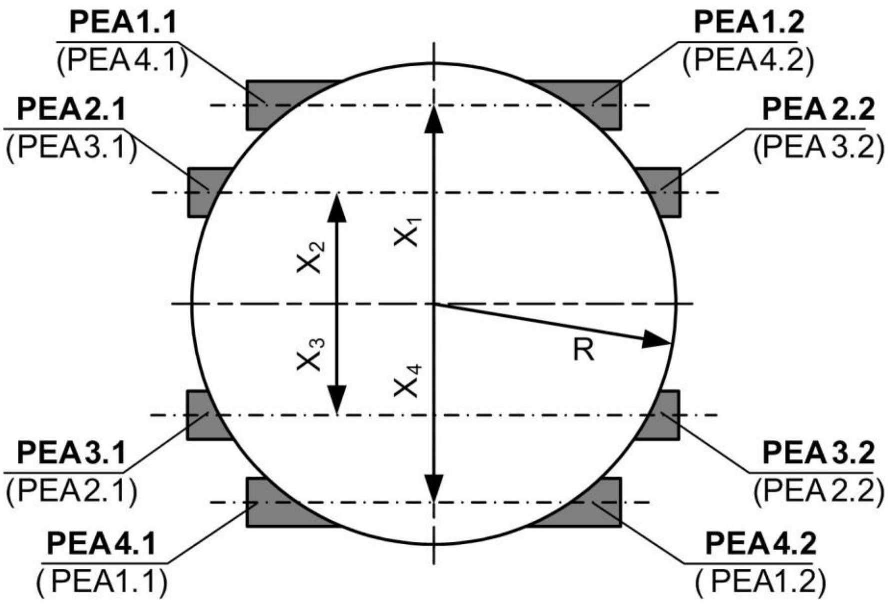


for V-configuration the second PEA from a pair is shown in dashed line.

Fig. 5. Location of PEA pairs for Z- and V-configuration in case of their placement in one longitudinal plane (double-beam sounding).

3.1.4. Placing the PEA for four-beam scanning

In case of four-beam scanning, the wetted PEA pairs are mounted on the CP along four chords placed horizontally (Fig.6). The order of beams can be reverse.



X_1=X_4= 0.809·R
X_2=X_3= 0.309·R
PEA1.1-PEA1.2 pair - 1st beam
PEA2.1-PEA2.2 pair - 2nd beam
PEA3.1-PEA3.3 pair – 3rd beam
PEA4.1-PEA4.2 pair– 4th beam

Fig. 6. Placing the wetted PEA pairs "on chords" (four-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 CP. 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. Allowable variations from the type installation requirements for the two-beam scanning scheme are shown in Table A.2.

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

$$L = N \times DN, \quad (1)$$

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

DN is the CP or 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.

If the required lengths of straight pipe runs cannot be provided at the estimated PEA location as per Appendix A, the on-site survey is needed to specify the opportunities for individual measuring procedure based on the measurement conditions at the particular site.

3.2.2. The lengths of straight pipe runs for the hydraulic resistance of “thermal transducer in a protection sleeve” type can be defined in accordance with the two bottom lines of the table in Appendix A (for plugged tappings) provided that the following condition is observed:

$$D_t / D_v > 0.1, \quad (2)$$

where D_t is the diameter of the protection sleeve of the thermal transducer, mm;

D_v is the internal diameter of the pipeline, mm.

If the condition $D_t / D_v < 0.1$ is fulfilled, the thermal transducer’s hydraulic resistance may be neglected.

3.2.3. Diaphragm or venturi type structure, as well as any valve, refer to the type of hydraulic resistance specified in Appendix A as “control valve”.

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

3.2.5. For the flowmeter with PEAs mounted along the axis of the straight CP of U-elbow type, the requirements for the length of the straight pipe runs before and after the CP are not specified. The required technical and metrological characteristics of the flowmeter are provided by the CP design of U-elbow type.

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 WITH PRIMARY CONVERTERS

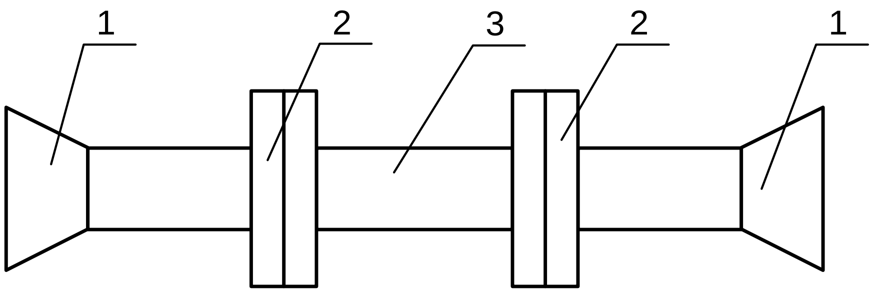
4.1. Mounting the Primary Converter

4.1.1. In order to install the CP into the pipeline the following fittings are to be delivered: companion flanges, pipe adaptors, taper adaptors (if the DN of the primary converter is less than the DN of the pipeline intended for mounting the CP).

4.1.2. Before working on the pipeline at the CP mounting location, fix the pipe sections that may tip out of their axes after cutting the pipeline.

4.1.3. To mount the flanged CP and companion flanges with the welded adaptors in the pipeline, the piping shall be assembled into a single construction. If necessary, the tapered adaptors are welded to the pipe adaptors (Fig.7).

If the hub diameter of the tapered adapter is wider than the mating pipeline diameter, the adapter hub is cut to match the diameter of the pipeline.



1 – taper adaptor; 2 – companion flange with the pipe adaptor; 3 – CP (MC)

Fig. 7. Assembly-welded structure for mounting the flanged CP (MC) into the pipeline.

When mounting the non-flanged (welded-in) CP, the crossings can be welded directly to the measuring cut provided that the lengths of straight pipe runs are observed.

4.1.4. A pipe run of the required length is cut at the selected liquid-free pipeline section, and a structure with a flanged CP or welded CP is welded instead. The arrow on the CP shall point to the flow direction or forward flow direction in case of bidirectional measurements.

CAUTION! It is **STRICTLY FORBIDDEN** to throw the CP and hit it while mounting. This can cause damage to the PEAs installed on it.

For the welded CP with PEAs installed on it, the welding temperature at the PEA section shall be lower than 100 °C.

4.1.5. Components of the assembly-welded structure are welded together and then welded to the pipeline where the flow meter will be installed in compliance with local rules and regulations in force. Alignment of the whole unit and flatness/parallel alignment of the flanges for the CP to be mounted between them must be provided.

4.2. Mounting the Secondary Measuring Converter

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

4.3. Wiring the Flowmeter

4.3.1. 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 Equipment Certificate.

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
- Blue – channel 3
- Dark blue – channel 4;

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.

4.3.2. 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.

4.3.3. 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.

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

4.3.5. 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.

4.3.6 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.

4.3.7. 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.

4.3.8. 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. MOUNTING ELECTRO-ACOUSTIC CONVERTERS ON THE ACTIVE PIPELINE

5.1. Requirements for the pipeline at PEA mounting location

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

- Deflexion 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.

5.1.2. 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 portable multichannel flowmeter "AFLOWT UF-Port".

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

5.1.3. If clogging of the inside of the pipeline with DN $>$ 300 mm is possible, it is recommended to use the structures listed in Appendix K. Mounting of such structures makes it possible to regularly control the state of the inner pipeline surface and cleanse is, if necessary. The clamp-on PEAs should be installed on top of these structures.

The following conditions must be observed when preparing and mounting the structure:

a) curve radius of the plate for mounting of PEAs should not differ from the pipeline radius for more than $\pm$ 0.2 %

b) after mounting, the plate with a PEA installed on it should not project either inside or outside with respect to the pipeline inner surface for more than 0.002 DN

c) clearance between the PEA installation plate and the wall of the outer sleeve shall not exceed 5 mm.

5.2. Defining the parameters of the measuring cut

5.2.1. Prior to installation of PEAs on the active pipeline, it is necessary to determine characteristics of the measuring cut – the pipeline section intended for PEA mounting.

5.2.2. 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	Identification	Basic metrological characteristics
Metal rule		Division value, 1 mm
Vernier caliper		Fundamental measurement error 0.1 mm
Measuring reel		Division value 1 mm
Angle measurer		Fundamental measurement error less than 5 ′
Ultrasonic Thickness Gauge	AFLOWT TG	Measurement error no less than 0.1 mm
Snap Gage		Division value 1 mm
Crossbar with mount hubs	Ind. manufacture	-
Tool for measuring slope angle	Ind. manufacture	-

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.

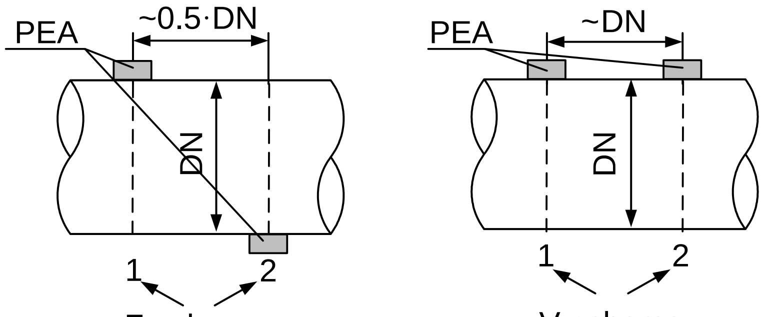
If a multichannel flowmeter is installed, the reports are issued for each channel.

If installation is performed in several steps, the separate report can be issued and verified by signatures for each step. In such reports, the sections related to the completed works are filled, and the sections related to the works not carried out at this step are left blank and marked by dashed line.

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

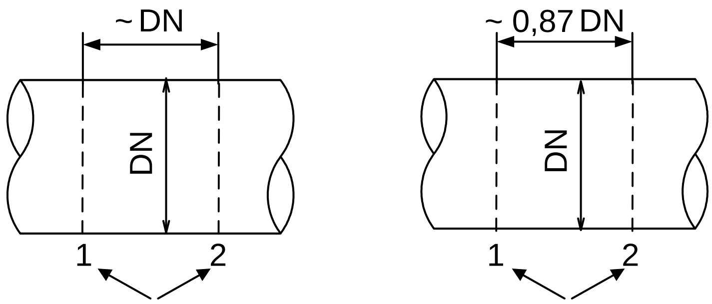
The average value of MC outer diameter is calculated by averaging measurements made on outer diameter (or outer circumference) for two PEA installation cross-sections normal to the MC axis.

The location of cross-sections is marked on the pipeline according to Fig.8.



Z-scheme V-scheme

a) measurement cross-sections for mounting clamp-on PEAs



on diameter (Z-scheme) on chord (Z-scheme)

b) measurement cross-sections for mounting wetted PEAs (at the PEA installation longitudinal angle $\theta \approx 45°$).

Fig. 8. Position of cross-sections for placing PEAs on the MC.

5.2.3.1. 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:

$$L_{circ\ avg1,2} = \frac{\sum L_{circ\ ij}}{3}, \text{ mm}, \qquad (3)$$

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: $L_{circ\ avg}$:

$$L_{circ\ avg} = \frac{L_{circ\ avg1} + L_{circ\ avg2}}{2}, \text{ mm}. \qquad (4)$$

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

$$D_{0\ avg} = \frac{L_{circ\ avg}}{\pi}, \text{mm.} \tag{5}$$

The measurement and calculation results are registered in the report.

5.2.3.2. 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.9).

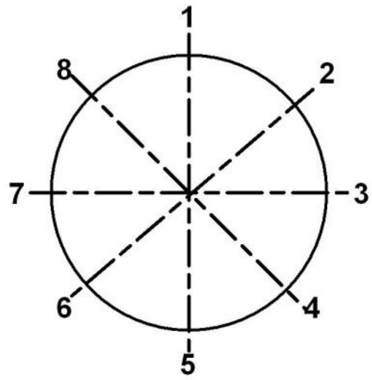


Fig. 9. Location of points on the MC cross-sections.

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:

$$D_{0\ avg1,2} = \frac{\sum D_{0\ ij}}{12}, \text{ mm,} \tag{6}$$

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: $D_{0\ avg}$:

$$D_{0\ avg} = \frac{D_{0\ avg1} + D_{0\ avg2}}{2}, \text{ mm.} \tag{7}$$

The measurement and calculation results are registered in the report.

5.2.4. 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:

$$D_{tr\ avg1,2} = \frac{\sum D_{tr\ ij}}{3}\text{, mm,} \tag{8}$$

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:

$$D_{tr\ avg} = \frac{D_{tr\ avg1} + D_{tr\ avg2}}{2}\text{, mm.} \tag{9}$$

The measurement and calculation results are registered in the report.

5.2.5. 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:

$$K_b = \frac{D_{tr\ avg}}{D_{0\ avg}}. \tag{10}$$

The following condition is checked next:

$$0.985 \le K_b \le 1.015.$$

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.

5.2.6. Measuring MC wall thicknes.

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:

$$h_{w\ avg1,2} = \frac{\sum h_{w\ ij}}{12}\text{, mm,} \tag{11}$$

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:

$$h_{w\ avg} = \frac{h_{w\ avg1} + h_{w\ avg2}}{2}, \text{ mm.} \quad (12)$$

The measurement and calculation results are registered in the report.

5.2.7. 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 MC 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

5.2.8. Defining kinematic viscosity ratio.

The given parameter is defined and entered in the flowmeter only if PEAs are installed “on the diameter” or along the flow axis (U-elbow).

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.

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

5.3. Procedures for mounting clamp-on PEAs

5.3.1. The section of outer MC surface on which MC parameters were defined is stripped to metal at cross-sections 1 and 2 (Fig.10). 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).

5.3.2. PEAs are attached to the connectors of the corresponding CS channel (Channel 1 – Channel 4) according to the flowmeter's connection scheme (Appendix B, part II 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.

5.3.3. The emitting surface of both PEA pairs is lubricated with couplant. The recommendations for preparation and application of the couplant are provided in Appendix L.

One unit from the PEA pair is mounted by seating it in the middle of the stripped area as shown in Fig.10 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.

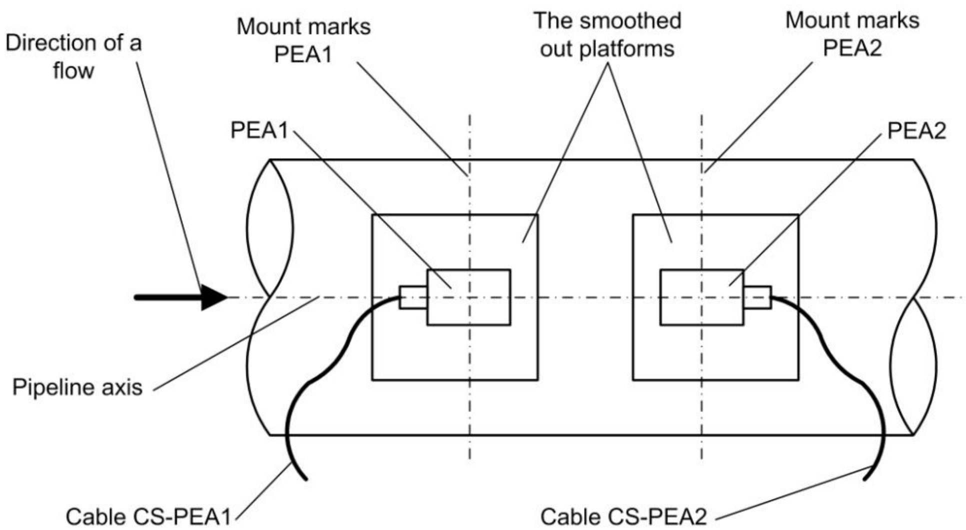


Fig. 10. Positioning clamp-on PEAs on the pipeline (V-scheme mounting)

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.

5.3.4. 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.

According to the Operation Manual (Section 2.2, Part II), the configuration settings are entered in the CS.

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.

There may be factors on the site or such factors may appear during operation that lead to the situation when the adjustment range appear to be insufficient to provide the required characteristics of ultrasonic signal (at **Kg** = **63**, **P** < **3000**, menu **PROSESS, DATA**). Such factors include sediment on inner walls of the pipeline, high concentration of gas or mechanical impurities (suspensions) in liquid, high level of flow pulsation, etc. Such factors can result both in increasing flowrate measurement error and termination of measurements.

5.3.5. To install the clamp-on PEAs for two-beam flow sounding, the procedures according to items 5.3.1-5.3.4 are performed for each PEA pair.

5.4. Procedure for wetted PEA mounting

5.4.1. Circle lines of cross sections 1 and 2 should be plotted on the MS outer surface at the locations where MS parameters have been determined (Fig.11a):

- At a distance of 0.87 $D_{0\ avg}$ – for PEA installation by chords
- At a distance of $D_{0\ avg}$ – for PEA installation by diameter.

The angle of PEA longitudinal installation is $\theta \approx 45°$.

5.4.2. PEA positioning by chords.

5.4.2.1. In order to specify locations for PEA installation, support (upper) point A should be determined on the MS outer surface in cross section 1 (Fig.11b). Arcs should be marked off point A along the circle line of cross section 1 in both directions:

$$AB = AC = \frac{1{,}047\,D_{0\ avg} + h_{w\ avg}}{2}. \qquad (13)$$

Points B and C should be punched.

From points B and C lines should be drawn with a ruler or rigid profile (angle, U-section, etc) — that are parallel to MS axis — up to intersection with the circle line of cross section 2 — points D and E respectively (Fig.11a).

To verify accuracy of the procedures performed, arcs with the length of (1.047 $D_{0\ avg}$ + $h_{w\ avg}$) and (2.094 $D_{0\ avg}$ – $h_{w\ avg}$) should be marked off points B and D along the circle lines of the cross sections in different directions. Ends of the arcs should concur.

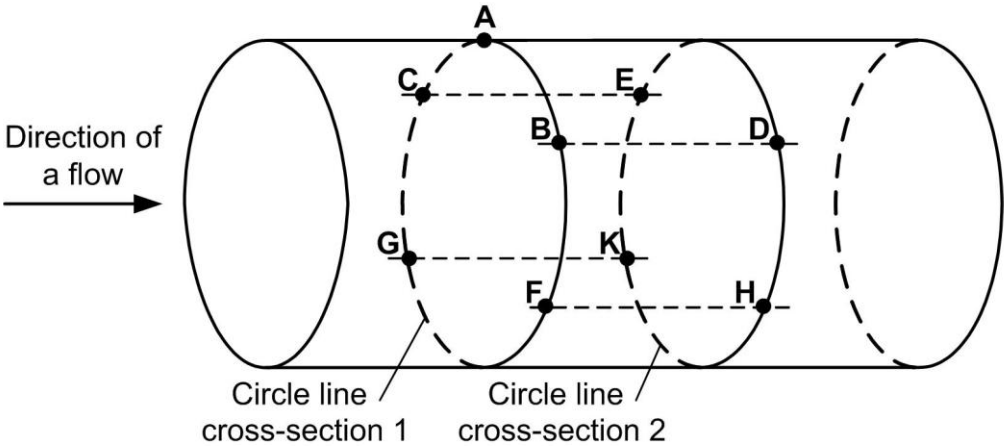
5.4.2.2. In case of two-beam flow sounding and when the first beam is above the second one, points B and E or points C and D can be used for PEA1.1 / PEA1.2 pair installation.

To mark the second beam down along the circle line of cross section 1, arc BF = (0.524 $D_{0\,avg}$ – $h_{w\,avg}$) should be marked off point B, and arc FG = (1.047 $D_{0\,avg}$ + $h_{w\,avg}$) – from point F. Points F and G should be punched. The same marking procedure is performed for point D. Points H and K should be punched.

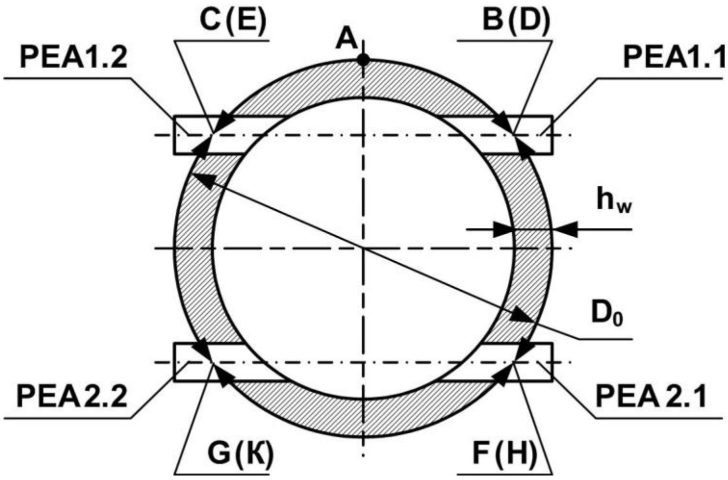
To verify accuracy of the procedures performed, arcs with the length of (1.047 $D_{0\,avg}$ + $h_{w\,avg}$) and (2.094 $D_{0\,avg}$ – $h_{w\,avg}$) should be marked off points F and H along the circle lines of the cross sections in different directions. Ends of the arcs should concur.

If point B is chosen for PEA1.1, and point E – for PEA1.2, points F and K should be used as locations for PEA2.1 / PEA2.2 pair installation for the second beam.

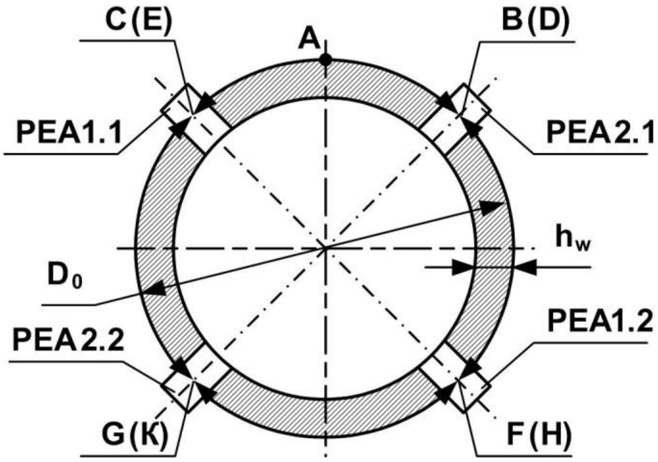
if point C is chosen for PEA1.1, and point D – for PEA1.2, point G is used for PEA2.1, and point H – for PEA2.2.



a) marking points location on the MS



b) view in flow direction when installing PEA pairs by chords



c) view in flow direction when installing PEA pairs by diameters

Fig. 11. Diagram for marking the pipeline surface for wetted PEA pair installation.

NOTE. In figures 11b and 11c, point designation in the circle line of cross section 2 is specified in brackets.

5.4.3. PEA location by diameter.

5.4.3.1. In order to specify locations for PEA installation, support (upper) point A should be determined on the MS surface on the circle line in cross section 1 (Fig.11c). Arc AB = 0.393 $D_{0\ avg}$ should be marked off point A along the circle line, point B should be punched.

Arc BG = 1.571 $D_{0\ avg}$ should be marked off point B in any direction along the circle line of section 1, point G should be punched.

From points B and G lines should be drawn with a ruler or rigid profile (angle, U-section, etc) – that are parallel to MS axis – up to intersection with the circle line of cross section 2 – points D and K (Fig.11c).

To verify accuracy of the procedures performed, arcs with the length of 1.571 $D_{0\ avg}$ should be marked off points B and D along the circle lines of the cross sections in different directions. Ends of the arcs should concur.

Points B and K or points G and D can be used as locations for PEA1.1 / PEA1.2 pair installation.

5.4.3.2. To mark the second beam (in case of two-beam flow sounding) down along the circle line of cross section 1, arc BF = 0.785 $D_{0\ avg}$ should be marked off point B, and arc FGC = 1.571 $D_{0\ avg}$ – from point F. Points F and C should be punched. The same marking procedure is performed for point D. Points H and E should be punched.

To verify accuracy of the procedures performed, arcs with the length of 1.571 $D_{0\ avg}$ should be marked off points F and H along the circle lines of the cross sections in different directions. Ends of the arcs should concur.

If point B is chosen for PEA1.1, and point K – for PEA1.2, points C and H should be used as locations for PEA2.1 / PEA2.2 pair installation for the second beam.

If point G is chosen for PEA1.1, and point D – for PEA1.2, point F is used for PEA2.1, and point E – for PEA2.2.

Dimensions for marking in case of different schemes of sounding are shown in Table 3.

Table 3

Sounding scheme	Arc length				Distance btw cross sections 1 and 2
by chords	AB; AC	BAC; DE; FG; HK	BFGC; DHKE; FBACG; HDEK	BF; CG; DH; EK	$0.87\ D_{0\ avg}$
	$\frac{1{,}047\,D_{0\ avg} + h_{w\ avg}}{2}$	$1.047\ D_{0\ avg} + h_{w\ avg}$	$2.094\ D_{0\ avg} + h_{w\ avg}$	$0.524\ D_{0\ avg} - h_{w\ avg}$	
by diameter	AB; AC	BFG; BACG; DEK; DHK	FBAC; FGC; HDE; HKE	BF; CG; DH; EK	$D_{0\ avg}$
	$0.393\ D_{0\ avg}$	$1.571\ D_{0\ avg}$	$1.571\ D_{0\ avg}$	$0.785\ D_{0\ avg}$	

5.4.4. Installation of PEA pipe mount adaptors onto the MS.

The template of the future elliptical hole should be cut out of rigid material (cardboard, whatman paper, etc) according to the hole profile in the flat end (adjacent to the pipeline) of a PEA pipe mount adaptor. Then its axes and center are marked.

The template center is alternatively aligned with the centers of the future holes for PEA installation (by two punched points located in cross sections 1 and 2 respectively on the opposite walls of the pipeline). The longitudinal axis of the sample should be parallel to the pipeline axis.

Profiles of the future holes are drawn out on the surface of the pipeline wall. According to the marked ellipses holes are cut (drilled) in the pipeline wall. Overlaps, burrs and scales at hole edges are eliminated.

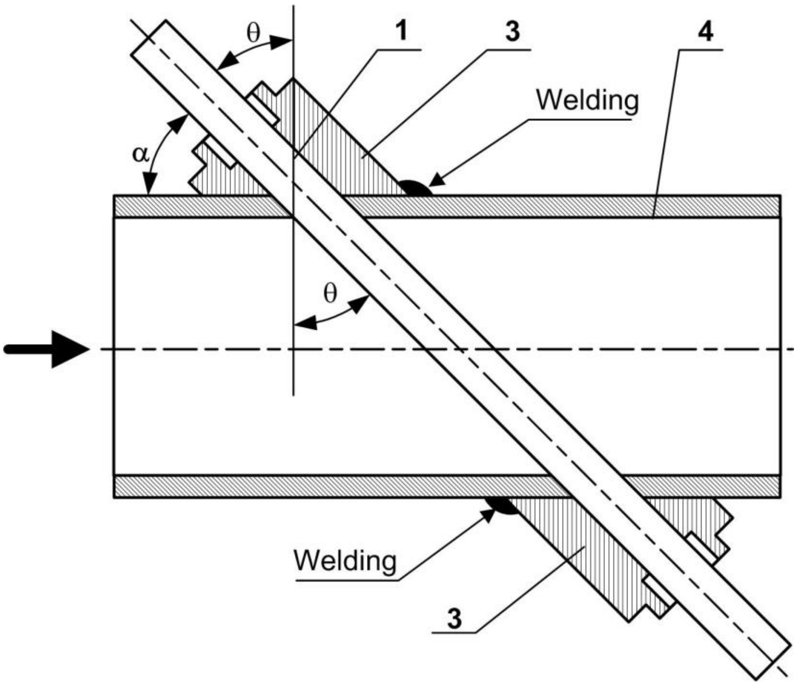
PEA pipe mount adaptors are welded to the pipeline (welding procedure is according to the requirements of Appendix G or special requirements of the authority that operates the pipeline). To complete the procedure (see Fig.12a):

- Pass the crossbar through the holes in the pipeline walls after removing of mount hubs
- Put a PEA pipe mount adaptor onto one end of the crossbar
- Tack weld the adaptor to the MS in 2-3 spots
- Put the second PEA pipe mount adaptor onto the other end of the crossbar and tack weld it to the MS
- Ensure that crossbar slip fit in the adaptors is preserved, then weld them while preserving the slip fit.

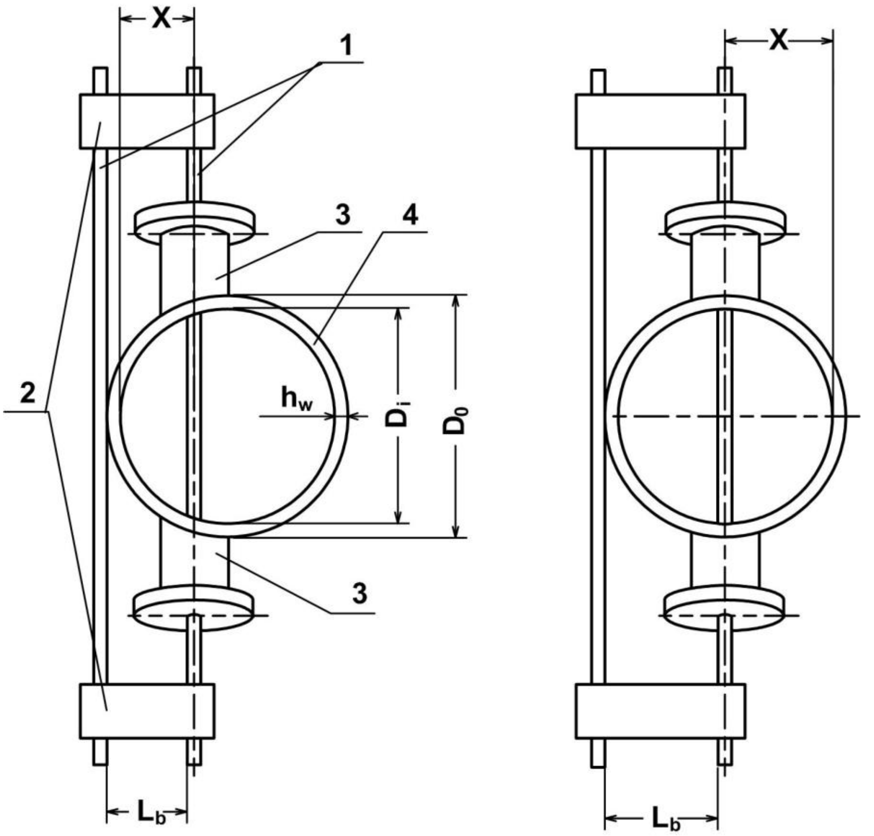
PEA adaptors are welded to the MS in such a manner that to ensure coincidence of the holes in the adaptors and MS. The first upstream adaptor is welded, and the PEA inside it should be installed in the flow direction, and the second one – against the flow (Fig.12a).

Internal thread of the adaptors should not be damaged when welding.

CAUTION! ***NEVER*** weld pipe mount adaptors with PEA installed inside them.



a) position of PEA pipe mount adaptors on the MS



when installing PEA on chords when installing PEA on the diameter

1 – crossbar; 2 – tie; 3 – PEA pipe mount adaptor; 4 – MS

b) determining offset of the acoustic channel axis

Fig. 12. Determining parameters for PEA installation onto MS

5.4.5. Device base L (distance between PEA emitting surfaces) is determined with either method.

5.4.5.1. Method 1.

A PEA is installed in a pipe mount adaptor. The crossbar is inserted in the opposite adaptor to thrust against emitting surface of the installed PEA. A mount hub is put on the protruding end of the crossbar and fixed on the crossbar in the PEA mounting bore in the adaptor. Then the crossbar is taken out and the distance between the crossbar flat end and the mount hub flat end is measured with a vernier caliper, measuring reel or snap gauge. Also the length of the PEA submerged section is measured with the vernier caliper L_{SP} – the distance from the emitting surface to the supporting ring plane (Fig.13).

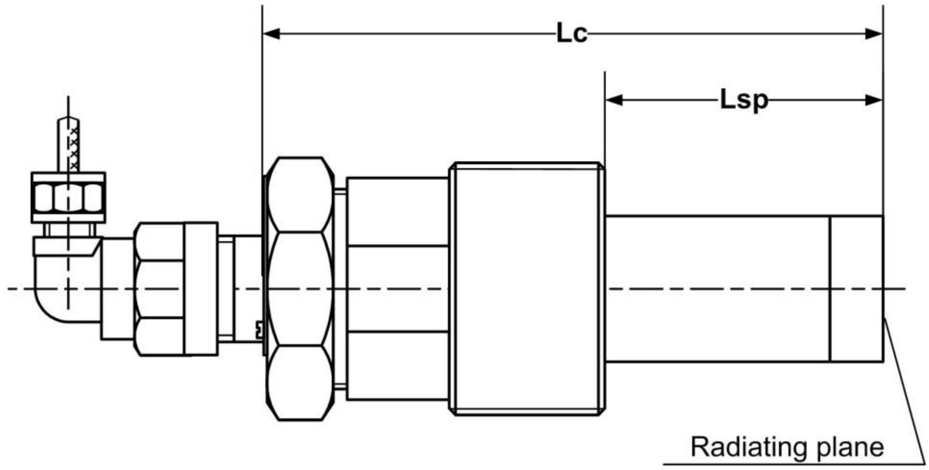


Fig. 13. View of the wetted PEA

Distance L between emitting surfaces of PEAs in the pair is calculated with:

$$L = L_{FF} – L_{SP}, \text{ mm}, \quad (14)$$

where L_{FF} – distance between the crossbar flat end and mount hub flat end, mm;

L_{SP} – length of the PEA submerged section, mm.

5.4.5.2. Method 2.

Case length of both sensors is measured – the distance from the emitting surface to the opposite plane of PEA hex nut that secures the cable through (Fig.13). Then both PEA pairs are installed into adaptors and the distance between the specified PEA nut planes is measured. L is calculated with:

$$L = L_{PP} – L_{C1} – L_{C2}, \text{ mm}, \quad (15)$$

where L_{PP} – distance between PEA nut planes, mm;

$L_{C1,2}$ – PEA1, PEA2 case length, mm.

The distance between emitting surfaces of PEAs can be determined with another method that ensures error of linear measurements of no more than 0.1 mm.

The result is recorded in the report.

5.4.6. Determining axis base of the device L_x (distances between centers of emitting surfaces of the PEA pair along the MS axis).

Determining the axis base requires measurement of acoustic channel slope angle α. Acoustic channel slope angle α is an angle that complements longitudinal angle of wetted PEA installation θ to 90° (see Fig.12a).

The angle α is determined with use of the crossbar and an angle measurer (protractor). For this purpose, the crossbar is installed into pipe mount adaptors and the angle between protruding ends of the crossbar and the outer surface of the MS is measured with the protractor. The angle should be measured at least 11 times on each side of the pipeline.

If there is no protractor at hand, acoustic channel axis slope angle is measured according to the method specified in Appendix E.

Axis base L_x between the centers of emitting surfaces of the PEA pair along the MS axis is calculated with:

- PEA installation by diameter:

$$L_x = D_i \operatorname{ctg} \alpha, \text{ if } L \geq L_{calc}; \tag{16}$$

$$L_x = L \cos \alpha, \text{ if } L < L_{calc}; \tag{17}$$

- PEA installation by chords.

$$L_x = 0.866\, D_i \operatorname{ctg} \alpha, \text{ if } L \geq L_{calc}; \tag{18}$$

$$L_x = L \cos \alpha, \text{ if } L < L_{calc}, \tag{19}$$

where $D_i = D_0 - 2h_w$ – MS internal diameter;

$$L_{calc} = \frac{D_i}{\sin\alpha} \text{ – PEA installation by diameter;} \tag{20}$$

$$L_{calc} = \frac{0{,}866\, D_i}{\sin\alpha} \text{ – PEA installation by chords.} \tag{21}$$

For MS DN ≥ 150 mm the distance L_x can be determined without measuring acoustic channel slope angle with the following method:

- Determine the middle (along the MS axis) between the end points of PEA pipe mount adaptor welding and mark it on the MS surface (for each pipe mount adaptor from the PEA pair)
- Draw circle lines through the marks on the outer surface perpendicular to the MS axis with a metal reel or a rigid steel tape
- Measure the distance between the circle lines in 11 points equally spaced along the circles with a measuring reel, snap gauge or caliper and calculate average $L_{0\,avg}$ with the accuracy of 0.1 mm
- Calculate the value of the axis base with:

$$L_x = L_{0\,avg} - 2h_w. \tag{22}$$

The result is recorded in the report.

Monitoring of accuracy of the procedures performed implies checking of the following conditions:

$0.95\, D_i \leq L_x \leq 1.05\, D_i$ – when installing PEA by diameter;

$0.82\, D_i \leq L_x \leq 0.91\, D_i$ – when installing PEA by chord;

5.4.7. Measurement of acoustic channel axis offset.

Acoustic channel axis offset in relation to the MS inner wall is determined with two crossbars with ties of equal length according to Fig.12b. One crossbar should be passed through pipe mounting adaptors and the other one is placed outside the MS and the contact point should be the center of the crossbar. Then crossbar ends are fixed with ties equally spaced in order to keep them in parallel. Distance between the crossbars L_b is measured with a caliper. Offset X is determined with:

$$X = L_b + \frac{D_b}{2} - h_w \text{, mm,} \tag{23}$$

where D_b – diameter of the crossbar passed through the pipe mount adaptors, mm;

h_w – MS wall thickness, mm.

After that the following condition is checked:

$0.48\ (D_{PEA\ avg} – 2\ h_w) \leq X \leq 0.52\ (D_{PEA\ avg} – 2\ h_w)$ – PEA installation by diameter;

$0.24\ (D_{PEA\ avg} – 2\ h_w) \leq X \leq 0.26\ (D_{PEA\ avg} – 2\ h_w)$ – PEA installation by chords;

where $D_{PEA\ avg}$ – average value of the MS outer diameter in the longitudinal plane of PEA installation.

In case there is no appropriate equipment to determine acoustic channel axis offset, length of arcs between two lines drawn along the MS axis through the centers of adaptors welded to MS is measured.

When PEAs are installed on the diameter in points B and K (Fig. 11a) the length of arcs between lines BD and GK is measured. In this case the following condition should be ensured:

$$0{,}96 \leq \frac{L_1}{L_2} \leq 1{,}04, \tag{24}$$

where L_1 – length of arc BFG (DHK), L_2 – length of arc BACG (DEK).

When PEAs are installed on chord in points B and E (Fig.11a) the length of arcs between lines BD and CE is measured. In this case the following condition should be ensured:

$$0{,}48 \leq \frac{L_1}{L_2} \leq 0{,}52, \tag{25}$$

where L_1 – length of arc BAC (DE), L_2 – length of arc BFGC (DHKE).

5.4.8. PEAs are installed in pipe mount adaptors on the pipeline, and then this pipeline is filled with liquid. PEA pairs are connected to the connectors of the appropriate CS channel (Channel 1 – Channel 4) according to the flowmeter wiring diagram (Operation Manual, Appendix B, Part I): the corresponding PEAs should be placed first relative to the flow direction and connected to terminals PEA1.1, PEA1.2, and the other units from the pairs should be in the second place relative to the flow direction and connected to terminals PEA2.1, PEA2.2.

Configuration settings are entered in the CS according to the instructions given in the Operation Manual (Section 2.2, Part II).

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.

There may be factors on the site or such factors may appear during operation that lead to the situation when the adjustment range appear to be insufficient to provide the required characteristics of ultrasonic signal (at **Kg** = **63**, **P** < **3000**, **PROSESS. DATA** menu). These factors include sediment on inner walls of the pipeline, high concentration of gas or mechanical impurities (suspensions) in liquid, high level of flow pulsation, etc. Such factors can result both in increasing flowrate measure error and complete stop in measurement.

6. START-UP PROCEDURE

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

6.2. Parameters are entered according to the Operation Manual, Sections 2.1 and 2.2, Part II, depending on type of PEAs used (clamp-on or wetted).

6.3. 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 2.3 and 2.4, 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.

6.4. Processing of measurement results is adjusted according to the Operation Manual, Section 2.5, Part II.

6.5. 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.

6.6. Current date and time are checked and set if necessary (see Section 2.6, Part II of the Operation Manual).

6.7. 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.

6.8. 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.

7. DISMOUNTING

7.1. To dismount the flowmeter, do the following:

- Switch off the flowmeter
- Before dismounting the CP or wetted PEAs, cut off liquid flow in the pipeline section where they are located, ensure there is no pressure in the pipeline and drain the liquid
- Disconnect cables leading to the CS (PEAs)
- Dismount the CP (PEAs) and CS.

7.2. Before dispatching the flowmeter with the CP for calibration or repair, clean the measuring cuts and emitting surfaces of wetted PEAs from sediment and liquid residues after dismounting.

APPENDIX A. Relative length of straight pipe runs

Table A.1 shows minimum values of relative length of pipeline straight runs for type installation, four-beam scheme of sounding and installation of clamp-on PEAs according to Z-configuration depending on local hydraulic resistance types.

Table A.1

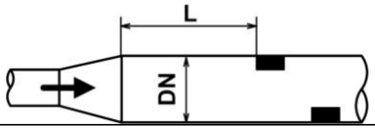
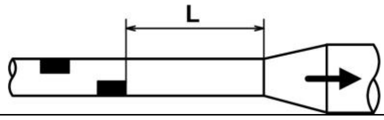
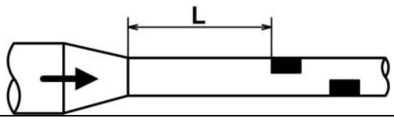
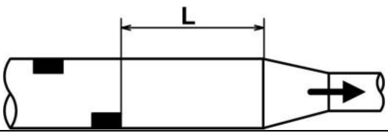
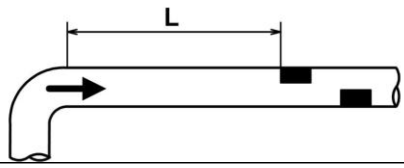
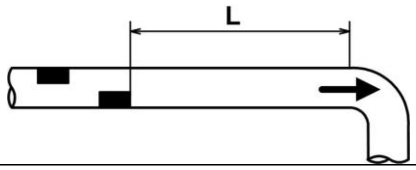
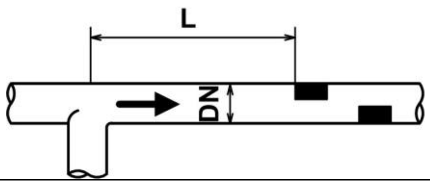
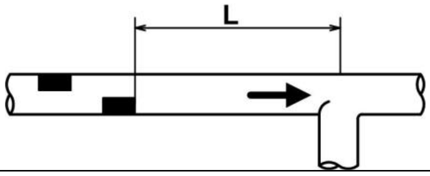
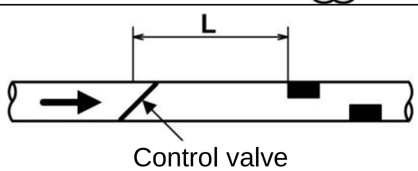
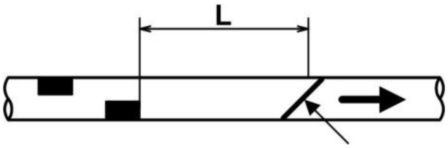
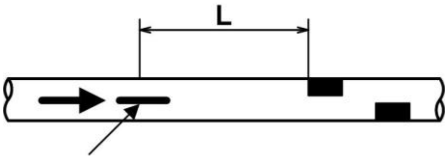
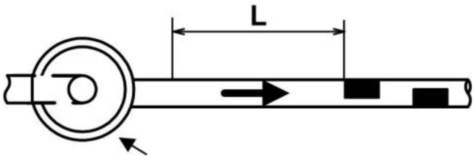
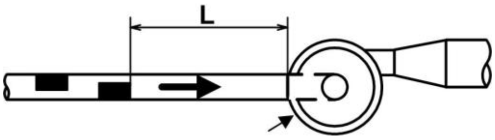
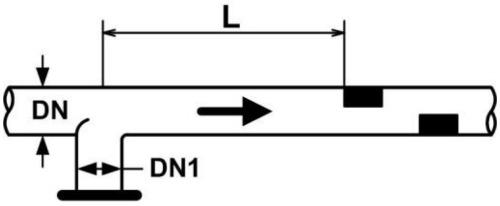
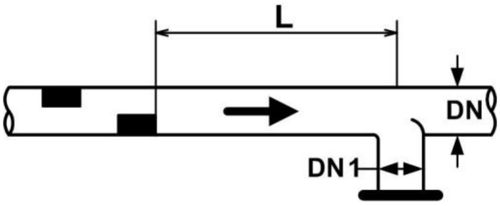
Type of local hydraulic resistance	Relative length of a straight run, N, minimum
1	2
	10
	3
	10
	3
	10
	3
	10
	10
	30

Table A.1 (cont'd)

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

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. _______ ;
Beam 3 – PEA3.1 No. ______ / PEA3.2 No. _______ ;
Beam 4 – PEA4.1 No. ______ / PEA4.2 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, 3.1, 4.1		
After PEA1.2, 2.2, 3.2, 4.2		

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

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

$$0.985 \le K_b \le 1.015$$

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, $p_{u\ avg\ j}$, mm									
Average value, $h_{wr\ avg}$, mm									

7. Position of wetted PEAs on the MS (determined in case of on-site mounting of PEAs on the MS).

7.1 Acoustic channel slope angle, α

Table B.6

Acoustic channel Slope angle	PEA1.1		PEA1.2		PEA2.1		PEA2.2		PEA3.1		PEA3.2		PEA4.1		PEA4.2	
Measured value, α_i, deg.																
Average value, α, deg.																

7.2. Acoustic channel offset X_1 / X_2 / X_3 / X_4 = ___/ ___/ ___/ ___ mm

8. Device axis base, L_x (distance between the centers of emitting surfaces of the PEA pair along the MC axis)

$L_{x\ 1.1\text{-}1.2}$ = _________ mm; $L_{x\ 3.1\text{-}3.2}$ = _________ mm;
$L_{x\ 2.1\text{-}2.2}$ = _________ mm; $L_{x\ 4.1\text{-}4.2}$ = _________ mm

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

10. Parameters of the medium.

10.1. Kind of liquid ____

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

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

11. 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	PEA3.1-PEA3.2	PEA4.1-PEA4.2
Length of CS-PEA communications cables, m				

12. Measurement channel parameters

12.1. Zero offset, dT_0 = _________ ms

12.2. 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. Ultrasound velocity in water

1. Ultrasound velocity depends on temperature and pressure in the pipeline. Ultrasound velocity at different temperatures and atmospheric pressures is specified in Table D.1.

Table D.1

t, °C	c, m/s	t, °C	c, m/s	t, °C	c, m/s	t, °C	c, m/s	t, °C	c, m/s
0	1402.7	20.0	1482.7	40.0	1528.9	60.0	1551.0	80.0	1554.5
0.5	1405.2	20.5	1484.2	40.5	1529.7	60.5	1551.3	80.5	1554.4
1.0	1407.7	21.0	1485.7	41.0	1530.5	61.0	1551.6	81.0	1554.2
1.5	1410.1	21.5	1487.1	41.5	1531.3	61.5	1551.8	81.5	1554.1
2.0	1412.6	22.0	1488.6	42.0	1532.1	62.0	1552.1	82.0	1553.9
2.5	1415.0	22.5	1490.0	42.5	1532.9	62.5	1552.4	82.5	1553.8
3.0	1417.3	23.0	1491.4	43.0	1533.7	63.0	1552.7	83.0	1553.6
3.5	1419.7	23.5	1492.8	43.5	1534.5	63.5	1552.9	83.5	1553.5
4.0	1422.0	24.0	1494.2	44.0	1535.0	64.0	1553.0	84.0	1553.3
4.5	1424.2	24.5	1495.6	44.5	1536.1	64.5	1553.5	84.5	1553.2
5.0	1426.5	25.0	1496.9	45.0	1536.9	65.0	1553.8	85.0	1553.0
5.5	1428.7	25.5	1498.3	45.5	1537.7	65.5	1554.0	85.5	1552.9
6.0	1430.9	26.0	1499.6	46.0	1537.8	66.0	1553.8	86.0	1552.5
6.5	1433.1	26.5	1500.9	46.5	1539.3	66.5	1554.6	86.5	1552.6
7.0	1435.2	27.0	1502.2	47.0	1540.1	67.0	1554.9	87.0	1552.4
7.5	1437.4	27.5	1503.4	47.5	1540.9	67.5	1555.1	87.5	1552.3
8.0	1439.5	28.0	1504.7	48.0	1540.3	68.0	1554.4	88.0	1551.5
8.5	1441.5	28.5	1505.9	48.5	1542.5	68.5	1555.7	88.5	1552.0
9.0	1443.6	29.0	1507.1	49.0	1543.3	69.0	1556.0	89.0	1551.8
9.5	1445.6	29.5	1508.2	49.5	1544.1	69.5	1556.2	89.5	1551.7
10.0	1447.6	30.0	1509.4	50.0	1542.6	70.0	1554.8	90.0	1550.5
10.5	1449.5	30.5	1510.5	50.5	1543.1	70.5	1554.9	90.5	1550.2
11.0	1451.5	31.0	1511.7	51.0	1543.6	71.0	1554.9	91.0	1549.9
11.5	1453.4	31.5	1512.8	51.5	1544.1	71.5	1555.0	91.5	1549.6
12.0	1455.3	32.0	1513.9	52.0	1544.6	72.0	1555.0	92.0	1549.3
12.5	1457.2	32.5	1515.0	52.5	1545.1	72.5	1555.1	92.5	1549.0
13.0	1459.0	33.0	1516.0	53.0	1545.6	73.0	1555.1	93.0	1548.7
13.5	1460.9	33.5	1517.1	53.5	1546.1	73.5	1555.2	93.5	1548.4
14.0	1462.7	34.0	1518.1	54.0	1546.5	74.0	1555.1	94.0	1547.9
14.5	1464.5	34.5	1519.1	54.5	1547.1	74.5	1555.3	94.5	1547.8
15.0	1466.2	35.0	1520.1	55.0	1547.6	75.0	1555.3	95.0	1547.5
15.5	1468.0	35.5	1521.1	55.5	1548.1	75.5	1555.4	95.5	1547.2
16.0	1469.7	36.0	1522.1	56.0	1548.2	76.0	1555.0	96.0	1546.5
16.5	1471.4	36.5	1523.0	56.5	1549.1	76.5	1555.5	96.5	1546.6
17.0	1473.1	37.0	1523.9	57.0	1549.6	77.0	1555.5	97.0	1546.3
17.5	1474.7	37.5	1524.8	57.5	1550.1	77.5	1555.6	97.5	1546.0
18.0	1476.4	38.0	1525.7	58.0	1549.7	78.0	1554.8	98.0	1544.9
18.5	1478.0	38.5	1526.6	58.5	1551.1	78.5	1555.7	98.5	1545.4
19.0	1479.6	39.0	1527.5	59.0	1551.6	79.0	1555.7	99.0	1545.1
19.5	1481.1	39.5	1528.3	59.5	1552.1	79.5	1555.8	99.5	1544.8

2. When the flowmeter is used to measure water flowrate and volume in water and heat supply systems, ultrasound velocity is determined according to data in Table D.2 with the method of proportional parts by temperature and pressure with the following formula:

$$c(t,P) = c(t_1) + \left(\frac{c(t_2) - c(t_1)}{t_2 - t_1}\right) \cdot (t - t_1) + \left(\frac{c(P_2) - c(P_1)}{P_2 - P_1}\right) \cdot (P - P_1)$$

where c(t,P) – ultrasound velocity in liquid passing through the pipeline, m/s

$c(t_1)$ – table value of ultrasound velocity at temperature lower than the measured values, m/s

$c(t_2)$ – table value of ultrasound velocity at temperature and pressure higher than the measured values, m/s

$c(P_1)$ – table value of ultrasound velocity at pressure lower than the measured values, m/s

$c(P_2)$ – table value of ultrasound velocity at pressure lower than the measured values, m/s

t – water temperature in the pipeline, °C

P – water pressure in the pipeline, MPa

t_1, t_2 – table value of temperature, °C

P_1, P_2 – table value of pressure, MPa

NOTE:

1. Water temperature and pressure in the pipeline should be measured with the measurement error of no more than ± 0.5 °C and ± 0.5 MPa respectively.
2. Values $c(t_1)$ and $c(t_2)$ are determined by table D.1. Values $c(P_1)$ and $c(P_2)$ are determined by table D.2 at a temperature, the closest to water temperature in the pipeline.

Table D.2

t = 2 °C		t = 4 °C		t = 5 °C		t = 10 °C		t = 20 °C		t = 30 °C	
P, MPa	c, m/s	P, MPa	c, m/s	P, MPa	c, m/s	P, MPa	c, m/s	P, MPa	c, m/s	P, MPa	c, m/s
30.458	1461.06	30.459	1470.64	30.458	1475.28	30.458	1496.75	30.461	1532.53	30.459	1560.07
25.561	1452.85	25.561	1462.37	25.561	1467.06	25.560	1488.55	25.565	1524.31	24.582	1550.20
15.765	1436.75	15.765	1446.29	20.663	1458.99	20.663	1480.49	20.667	1516.20	19.683	1541.98
10.867	1428.95	10.867	1438.46	15.765	1450.97	15.764	1472.41	15.768	1508.10	14.787	1533.78
5.092	1419.95	5.0918	1429.41	10.867	1443.15	10.867	1464.43	10.870	1500.03	9.888	1525.56
0.0969	1412.33	0.09435	1421.71	5.0929	1434.04	5.0923	1455.22	5.0958	1490.53	5.0931	1517.54
				0.09586	1426.31	0.09494	1447.32	0.0986	1482.40	0.09585	1509.18

t = 75 °C		t = 100 °C		t = 130 °C		t = 150 °C		t = 200 °C	
P, MPa	c, m/s	P, MPa	c, m/s	P, MPa	c, m/s	P, MPa	c, m/s	P, MPa	c, m/s
30.463	1612.39	30.465	1605.84	30.463	1574.59	30.462	1542.26	30.460	1428.27
25.565	1603.35	25.566	1596.04	25.566	1563.58	25.565	1530.23	25.563	1412.88
20.668	1594.26	20.668	1586.10	20.668	1552.43	20.667	1518.06	20.666	1397.12
15.769	1585.05	15.769	1576.07	15.770	1541.03	15.769	1505.58	15.777	1380.84
10.871	1575.77	10.872	1565.92	10.872	1529.49	10.871	1492.80	10.870	1364.02
5.0978	1564.72	5.0968	1553.73	5.0973	1515.53	5.0968	1477.39	5.0961	1343.47
0.09843	1555.06	0.09936	1543.07	0.2731	1503.63	0.4915	1464.80	1.5891	1330.47

3. If there are no ultrasound velocity vs liquid temperature tables at hand, ultrasound velocity can be determined with the device shown in Fig. D.1. Just before ultrasound velocity measurement the device's sensor (steel bracket) is submerged into the liquid, and the thickness gauge is adjusted to measure ultrasonic velocity. Then ultrasound velocity is measured with the ultrasonic thickness gauge.

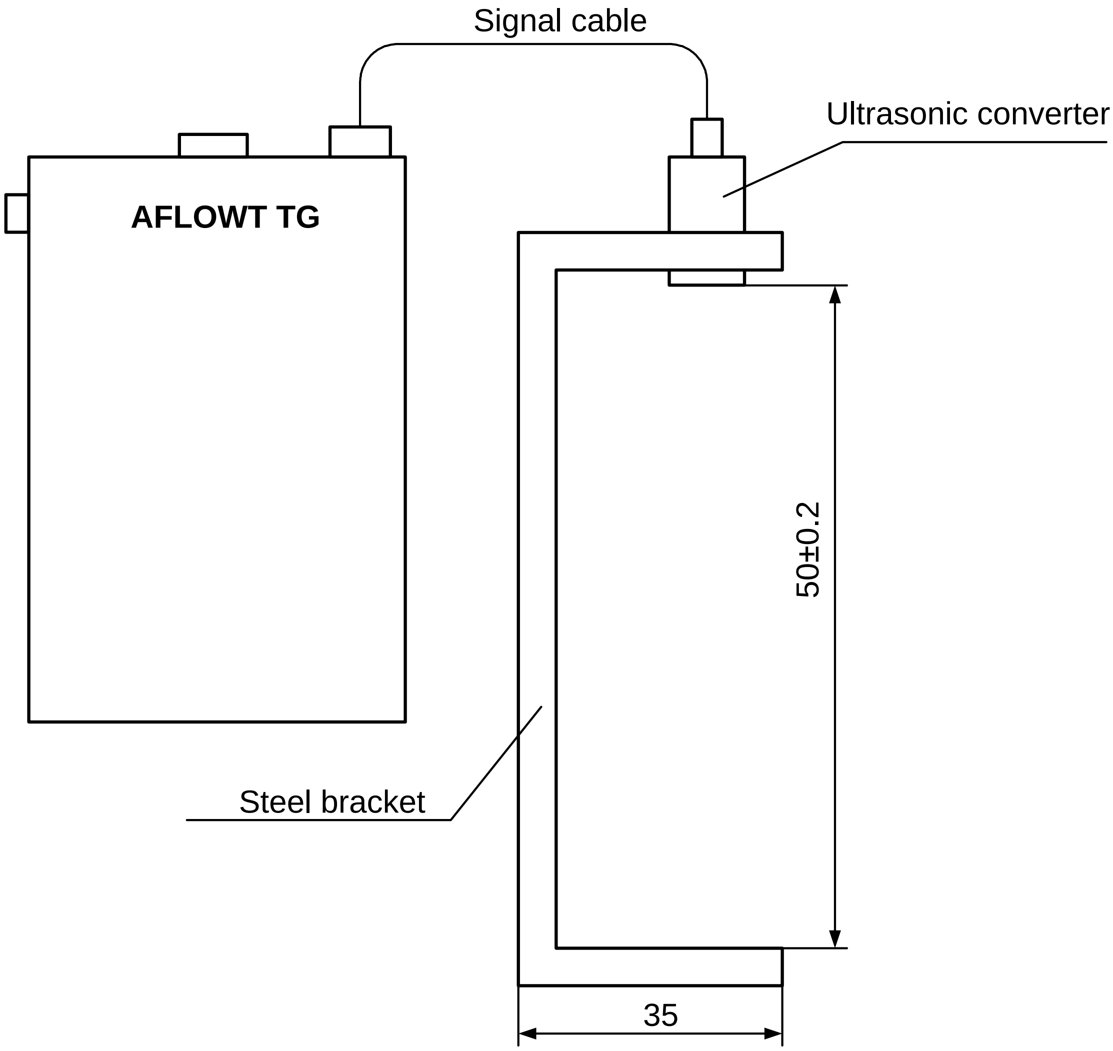
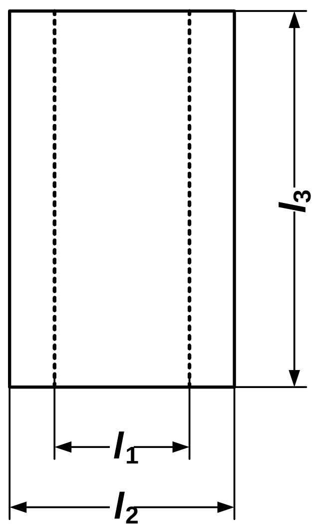


Fig. D.1. Gauge for measuring ultrasound velocity in liquid

APPENDIX E. Measuring acoustic channel slope angle

1. If there is no protractor at hand, acoustic channel slope angle can be measured with an auxiliary tool. The tool is a rectangle with sides of 150 $\times$ 300 mm made of rigid sheet material (glass fiber plastic, steel, etc.) with markings. Markings are two parallel lines spaced from each other for no less than 100 mm and perpendicular to the base. The base is the smaller side of the rectangle (Fig.E.1).
2. To carry out measurements, the tool is installed onto the pipeline in such a manner: its base should tightly adjoin the pipeline's outer surface and be in parallel with the line drawn along the pipeline axis (see Section 5.4.2), and rectangle's flat surface should adjoin the outer surface of the crossbar passed through the adaptors.

   A line parallel to the crossbar axis is drawn on the tool. A perpendicular is drawn from the point of intersection of this line with one of the parallel lines to the other parallel line. Intersection points of these lines and parallel lines of the tool are marked (Fig.E.2).
3. Length of sections |OA|, |OB|, |AB| is measured with a caliper. $\sin\alpha = \frac{|OB|}{|AB|}$, $\operatorname{ctg}\alpha = \frac{|OA|}{OB}$, $\cos\alpha = \frac{|OA|}{|AB|}$ are calculated and used to get the value of "Axis base" parameter with the formulae specified in Section 5.4.6 of this manual.



$l_1 \geq 100$ mm; $l_2 \geq 150$ mm; $l_3 \geq 300$ mm

Fig. E.1.

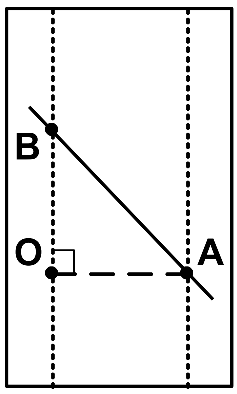


Fig. E.2.

APPENDIX F. Determining dT0 zero offset and Padd additional delay on the test bench

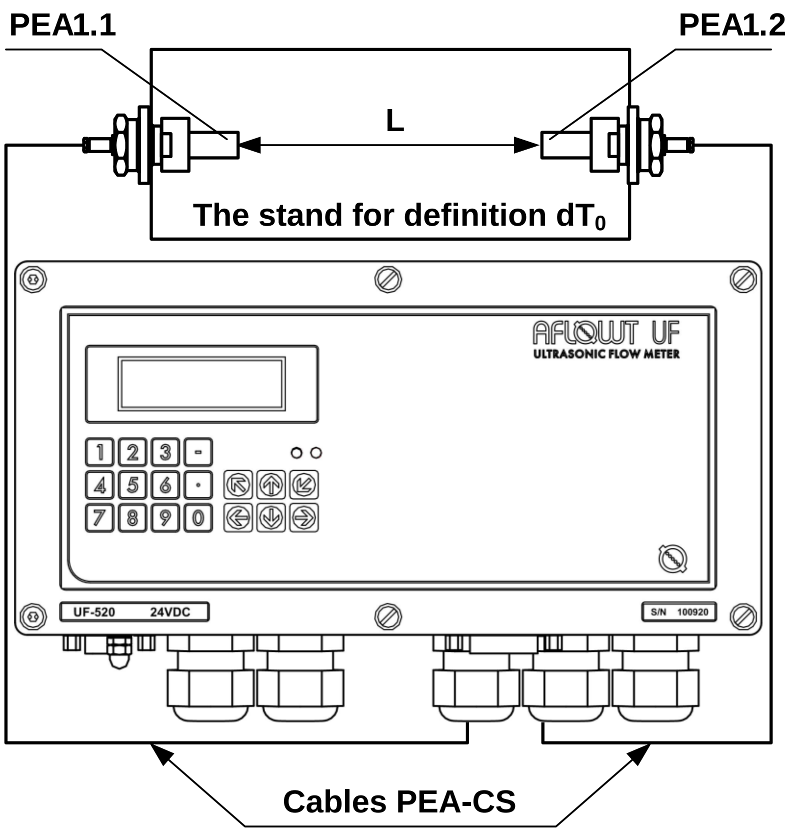


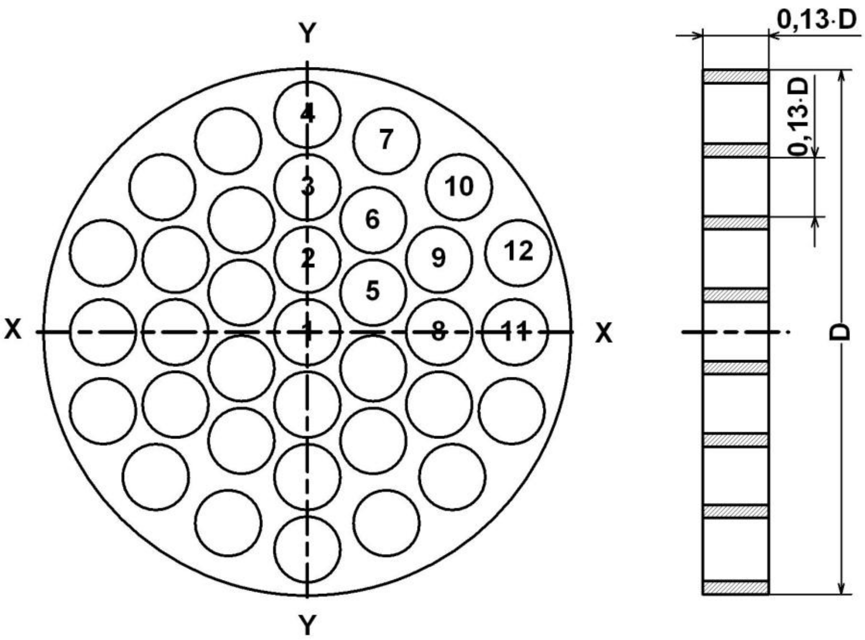
Fig. F.1. Determining dT0 zero offset with the test bench.

1. To determine **dT0** and **Padd,** you should use the appropriate CS measurement channel and PEA pair along with CS-PEA communications cables that will be mounted on site for the given measurement channel.
2. PEA pair is installed on the bench and the distance between emitting surfaces should be **L** (device base).

   The bench is filled with medium (water).
3. Open **SETTINGS / Main settings / Install. setting** menu and set the site-specific parameters:
   - **Lcirc** (circle perimeter defined for pipeline outer diameter)
   - **hw** (wall thickness)
   - **L** (device base)
   - **Lx** (axis base).
4. The flowmeter is adjusted according to the parameters of the received signal.
5. dT0 zero offset of the flowmeter should be measured according to the method specified in the Operation Manual, Section 2.3, Part II.
6. The value of ultrasound velocity in liquid (water) that fills the test bench should be determined and entered in the flowmeter. Padd additional delay should be measured according to the method specified in the Operation Manual, Section 2.4, Part II.

APPENDIX G. Straightening vane design

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

2. To lower weight and material quantity a type B straightening vane (Fig. G.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.

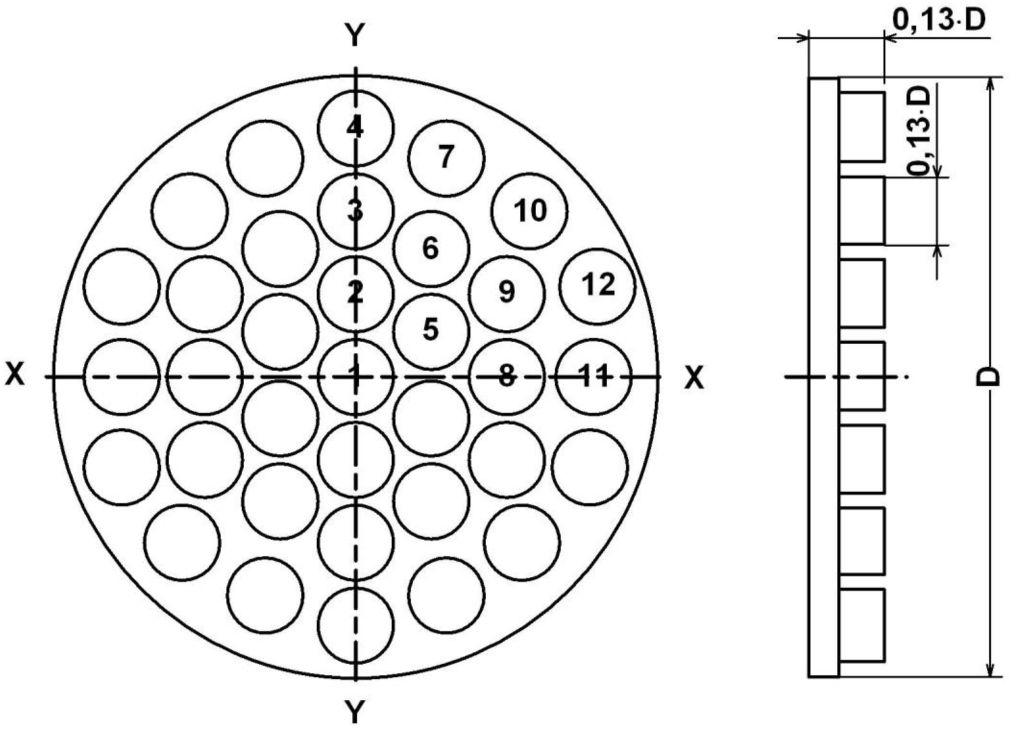


Fig. G.2. Design of type B flow straightening vane.

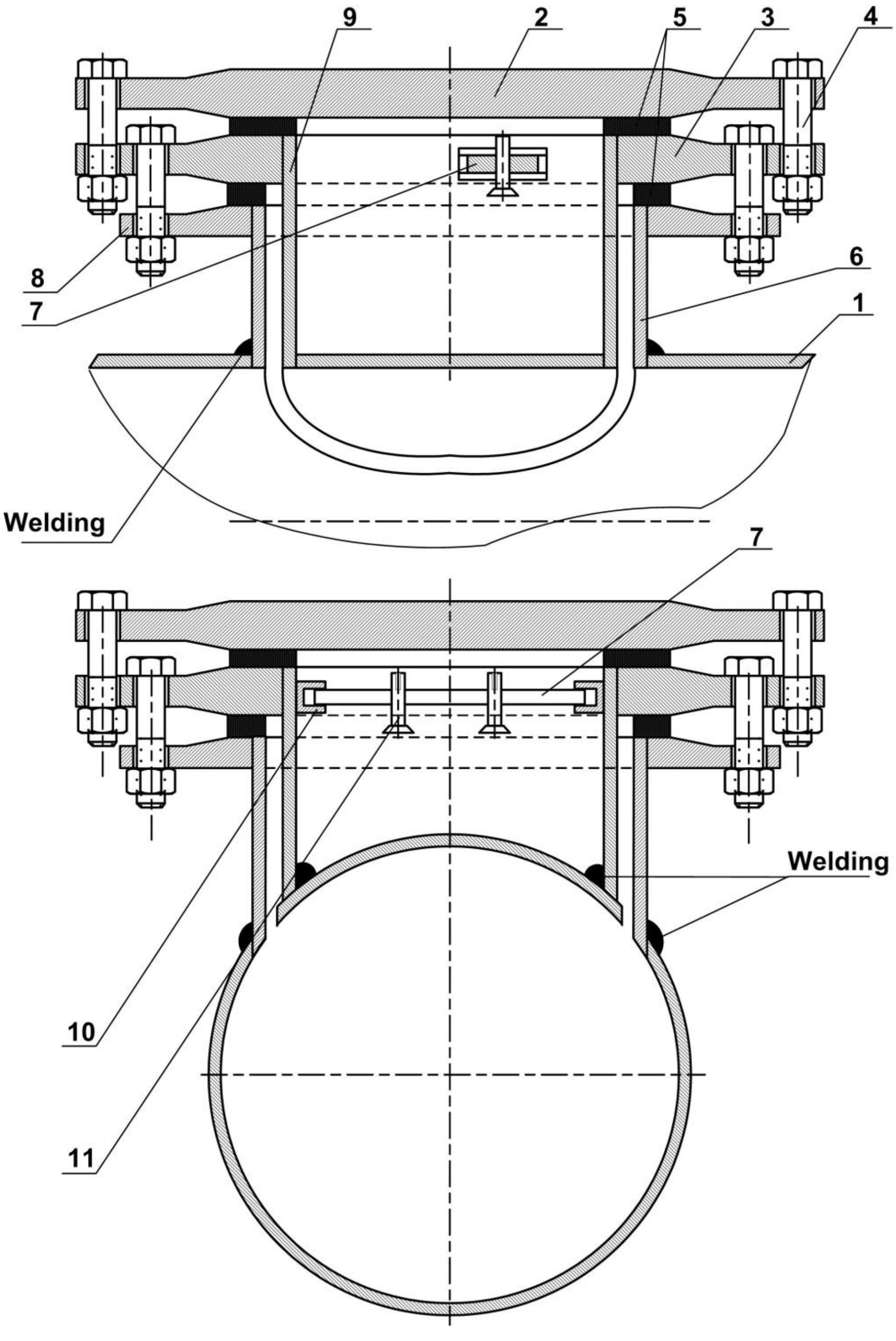
3. Hole marking in straightening vanes is shown in Table G.1.

Table G.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.

APPENDIX H. Design of the structure support used for clamp-on PEA installation



1 – pipeline; 2 – inner shell cap; 3 – inner shell flange; 4 – fixing bolt; 5 – ring gasket; 6 – outer shell; 7 – PEA fixing strip; 8 – outer shell flange; 9 – inner shell; 10 – PEA strip holder; 11 – PEA fixing screw.

Fig. H.1.

APPENDIX K. Recommendations on greasing used during PEA installation

1. "Litol-24" grease is recommended for application if temperature of the medium is no more than 110°C.
2. If the temperature of the medium is more than 110 °C, it is recommended to apply heat treated greases.

   The list of greases that can be subjected to heat treatment, heat treatment modes and grease applications are specified in Table L.1.

Table K.1

Grease name	Temperature of the medium, °C, maximum	PEA type	Parameters of heat treatment mode	
			cure temperature, °C	cure time, hour, at least
Litol-24	160	clamp-on	150	5
Loctite 8102	160	clamp-on	180	3

3. Heat treatment is performed as follows: grease is applied to the dry metal (not copper) surface with the layer thickness of 1 mm as a maximum and preserved at appropriate temperature during the specified period.

   After completion of heat treatment, the grease is packed into dry boxes with a tightly closed lid. It is recommended to place a bag with silica gel into the box to store grease.