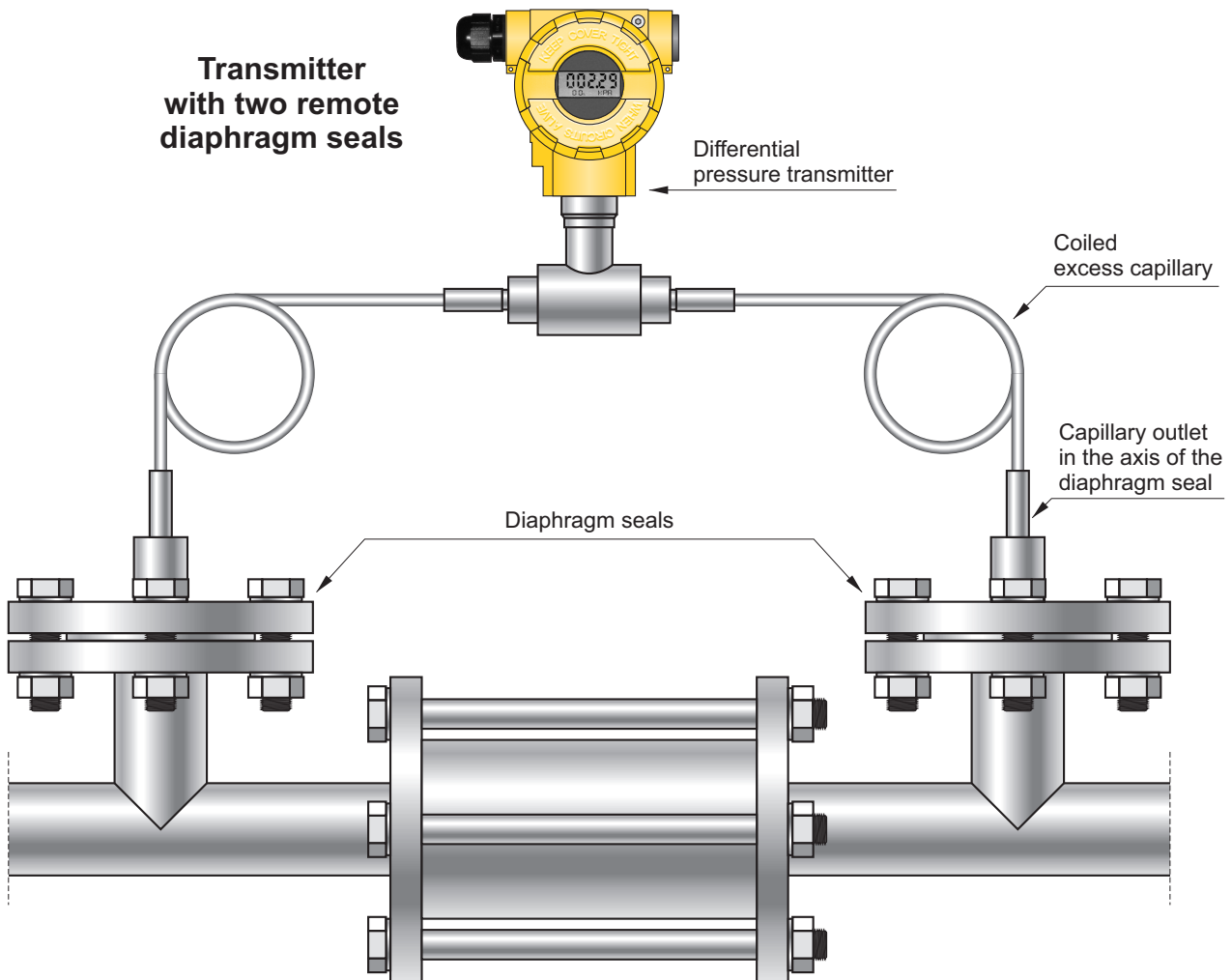APLISENS®

SMART DIFFERENTIAL PRESSURE TRANSMITTER WITH TWO DIAPHRAGM SEALS
MODEL APR-2000ALW (former APR-2200ALW)

✓ **4...20 mA output signal + HART 5 / HART 7 protocol**

✓ **Accuracy 0,1%**

HART
COMMUNICATION PROTOCOL

✓ **Safety version SIL2/SIL3**

SIL2/SIL3 safety version

✓ **Intrinsic safety certificate ATEX, IECEx, FM (USA, Canada), INMETRO, UKCA, KCS**

✓ **Explosion proof certificate ATEX, IECEx, FM (USA, Canada), INMETRO, UKCA, KCS**

✓ **Marine certificate – DNV, BV**

✓ **Fully welded sensor guarantees tightness of oil system for many years**

✓ **Ability to configure measuring range locally**

Transmitter with two remote diaphragm seals

Differential pressure transmitter

Coiled excess capillary

Capillary outlet in the axis of the diaphragm seal

Diaphragm seals

Example of a filter loss measurement

Recommendations

The version of the transmitter with two remote diaphragm seals is recommended for the measurement of pressure differences when the hydrostatic pressure of the manometric fluid in the capillaries (which depends on the vertical spacing of the seals) is significantly less than the measuring range of the transmitter. The best metrological results are obtained when the applied capillaries are identical, as short as possible, and terminated with identical seals. At such a configuration additional temperature errors, related to the remote sealing, affect both of the measurement chambers of the differential pressure transmitter in the same way, and thus cancel each other out.

Transmitter with two types of diaphragm seal: one – direct diaphragm seal and the other – remote diaphragm seal
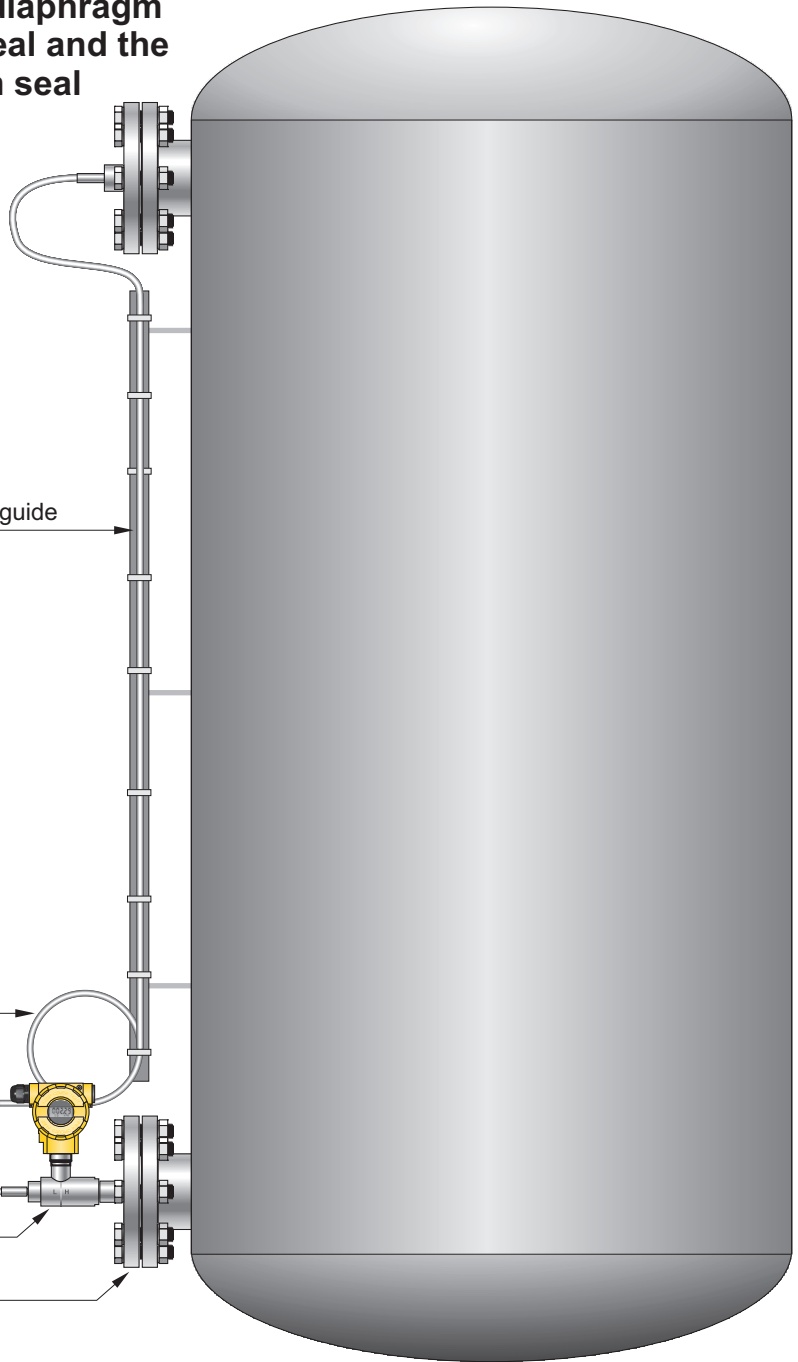

Upper remote diaphragm seal

Capillary fastened to a guide

Coiled excess of the capillary

Differential pressure transmitter

Lower direct seal

Example of measurement of the level in a pressure tank

Recommendations

The transmitter with a direct diaphragm seal (connected to the positive measurement chamber) and a remote diaphragm seal (connected to the negative chamber) is recommended for hydrostatic measurements of: levels, densities, phase boundaries and pressure differences (with differentiated height of pulse source points*).

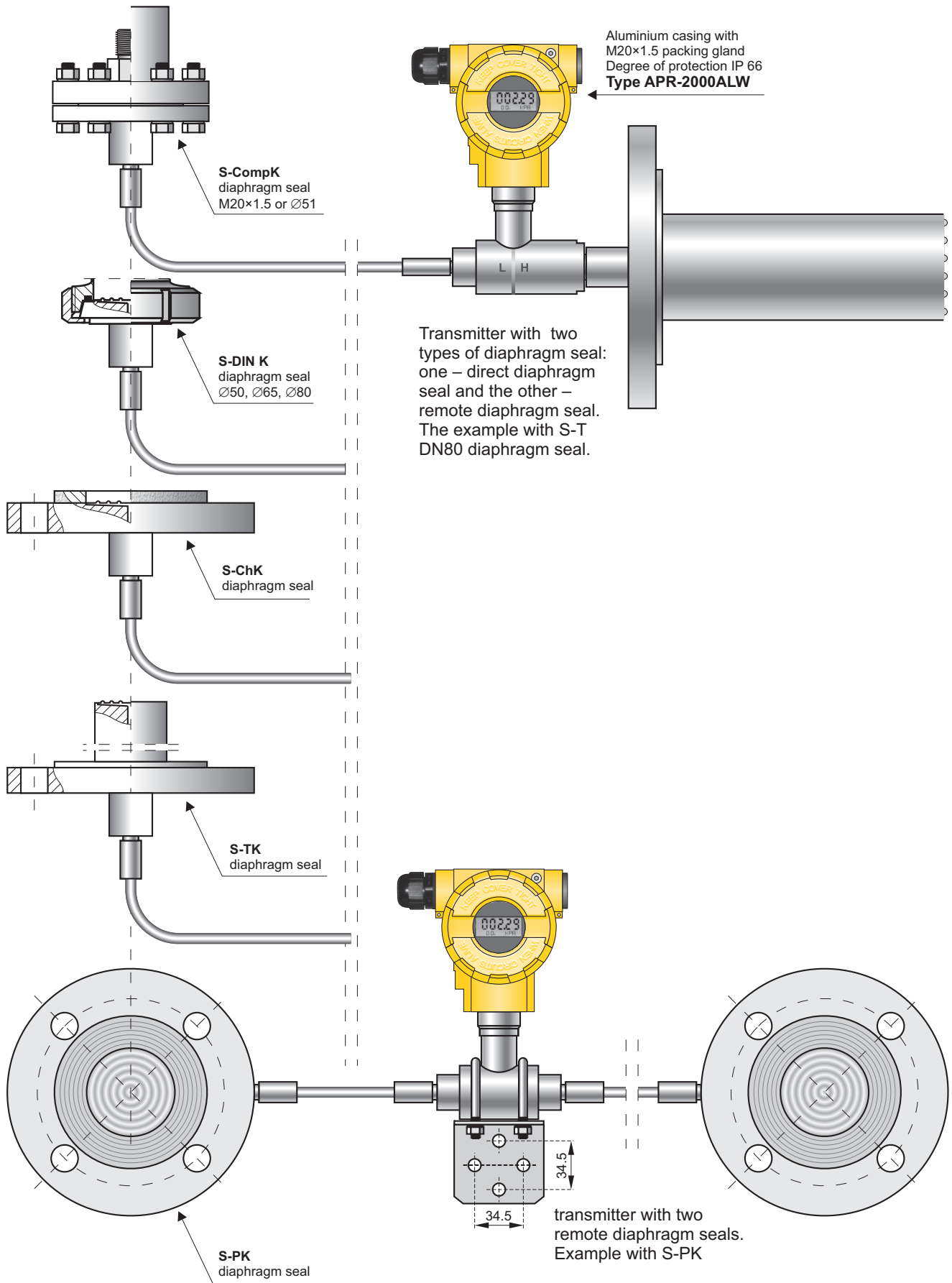In such a configuration, at ambient temperature changes, two opposite phenomena appear concurrently.

Thermal expansion causes the change in the volume (and hence also the change in density) of the manometric fluid in the capillary, which results in a change of the hydrostatic pressure related to the vertical spacing of the seals.

This phenomenon is counteracted by the elastic reaction of the diaphragm of the upper diaphragm seal, which is displaced by the change in volume of manometric fluid. Based on tests and experiments, the Aplisens transmitters are provided with carefully selected seal diaphragms, which guarantee compensation of the errors resulted from the ambient temperature changes.

The best metrological results are obtained using assembly, which include DN 80, DN 100, A 109 and S-Comp diaphragm seals or S-Mazut, S-DIN and S-Clamp diaphragm seals with a diameter of at least 65 mm, where the length of the capillary is (1...1.3) × (vertical spacing of seals). It is recommended using identical diaphragm seals at the both upper and lower connection points.

* The difference in height of pulse source points, at which the hydrostatic pressure of the manometric fluid is comparable to or greater than the range of the transmitter.

Example versions

Aluminium casing with
M20×1.5 packing gland
Degree of protection IP 66
Type APR-2000ALW

S-CompK
diaphragm seal
M20×1.5 or ⌀51

S-DIN K
diaphragm seal
⌀50, ⌀65, ⌀80

Transmitter with two
types of diaphragm seal:
one – direct diaphragm
seal and the other –
remote diaphragm seal.
The example with S-T
DN80 diaphragm seal.

S-ChK
diaphragm seal

S-TK
diaphragm seal

34.5

34.5

S-PK
diaphragm seal

transmitter with two
remote diaphragm seals.
Example with S-PK

Note: The appropriate configuration of the complete set of pressure transmitter, diaphragm seals and capillaries, as well as the proper selection of manometric fluid, depends on several factors, including the physical and chemical properties, temperature range of the medium, the vertical spacing of the diaphragm seals, the measuring range, static pressure range, range of ambient temperatures and the technical specifications for mechanical connection of the diaphragm seals to the pressure devices.

Application and construction

The differential pressure transmitter is applicable to the measurement of pressure differences of: gases, vapours and liquids in cases where it is necessary to use seals and the pressure pulse source points may be several metres apart. Typical applications include the hydrostatic measurement of: levels in closed tanks, densities and phase boundaries, and the measurement of a filter loss, pressure differences between media in pasteurisers etc. The available range of the diaphragm seals allows measurement at great majority of media. The active element is a piezoresistant silicon sensor separated from the medium by a distance sealing system. The special design of the measuring unit means that it can withstand pressure surges and overloads of up to 40 bar. The electronic circuits are enclosed in a casing with a degree of protection IP 65 or IP66.

Configuration

The settings of the following metrological parameters can be changed:
♦ the units of pressure in which the range is configured,
♦ start and end points of the range, time constant,
♦ inverted characteristic (output signal 20 ÷ 4 mA).

Communication

The transmitter is configured and calibrated using a KAP-03 communicator, some other communicators (HART) or a PC using an HART/USB converter and Aplisens RAPORT 2 configuration software.

The data interchange with the transmitter enables the users the transmitter identification, as well as reading of the currently measured differential pressure value, output current and percent of range width.

Measuring ranges

Nominal measuring range (FSO)	Minimum set range	Vertical spacing of diaphragm seals	Maximum set range width, considering the actual vertical spacing of the diaphragm seals (m)	Static pressure limit
-160…160 mbar	0,1 m H_2O	≤ 1,7 m	[1,6 + (vertical spacing of seals × 0,94)] m H_2O	40 bar
-0,5…0.5 bar	0,5 m H_2O	≤ 6 m	[5 + (vertical spacing of seals × 1,04)] m H_2O	40 bar
-1,6…2 bar	1,5 m H_2O	≤ 15 m	[20 + (vertical spacing of seals × 1,04)] m H_2O	40 bar
-1,6…16 bar	1 bar	≤ 15 m	16 bar	40 bar

CAUTION: The maximum vertical diaphragm seal spacing shown in the table applies to level measurement, ensuring that it is possible to set the zero point of the transmitter when the tank is empty. For measurements of density or phase boundaries (in the sugar, chemical or refinery industries) the vertical spacing of the diaphragm seals can be larger.

Metrological parameters

Accuracy   ≤ ±0.1% (FSO)
The other parameters as given in the sheet for the smart differential pressure transmitter APR-2000ALW.
Sealing effect errors – as given in the relevant diaphragm seal sheet in chapter III (Diaphragm Seals), concerning the distance seal.
 NOTE: The additional absolute zero error due to ambient temperature can be compensated by configuring the transmitter, seals and capillaries in accordance with the recommendations on pages II/ 20 and II/ 21.

Electrical parameters

As given in the sheet for the APR-2000ALW differential pressure transmitter.

Operating conditions

Operating temperature range (ambient temperature) -25...85°C
                                        Exia, IS version: -25...80°C
                                        Exd, XP version: -25...75°C

Medium temperature range – as given in the appropriate diaphragm seal sheet (remote seal)

Ordering procedure

Model	Code	Description
APR-2000		Smart differential pressure transmitter
Versions	/ALW……………...………………………………	With display, output 4-20mA + Hart
	/ALW/Safety..	With display, output 4-20mA + Hart Functional Safety certificate according to PN-EN 61508:2010 parts 1 ÷ 7, PN-EN 61511-1:2017 + PN-EN 61511-1:2017/A1:2018-03, PN-EN 62061:2008 + PN-EN 62061:2008/A1:2013-06 + PN-EN 62061:2008/A2:2016-01
Certificates, options *	/SS………………………………………………..	Stainless steel housing
	/Exia……………………………………………..	⟨Ex⟩ II 1/2G Ex ia IIC T4/T5 Ga/Gb IECEx Ex ia IIC T4/T5 Ga/Gb
	/Exia (Da)……………………………………………	⟨Ex⟩ II 1/2G Ex ia IIC T4/T5 Ga/Gb II 1D Ex ia IIIC T115°C Da I M1 Ex ia I Ma (version with SS housing) Ex ia IIC T4/T5 Ga/Gb IECEx Ex ia IIIC T115°C Da Ex ia I Ma (version with SS housing)
	/IS………………………………………………………	FM APPROVED IS Class I, Div 1, Groups A, B, C, D T4 IS Class II, Div 1, Groups E, F, G T5 IS Class III, Div 1, T5 Zone 0 AEx/Ex ia IIC T4 Ga Zone 20 AEx/Ex ia IIIC T105°C Da
	/ISB…………………………………………………	INMETRO Ex ia IIC T5/T4 Ga/Gb Ex ia IIIC T105°C Da Ex ia I Ma (version with SS housing)
See next page		

Code		Description	
/ISK……………………………………	[KCs]	Ex ia IIC T5/T4 Ga/Gb Ex ia IIIC T105°C Da	
/ISUK…………………………………	UKCA	II 1/2 G Ex ia IIC T5/T4 Ga/Gb II 1 D Ex ia IIIC T105°C Da I M1 Ex ia I Ma (version with SS housing)	
/Exd……………………………………	[Ex] IECEx	II 1/2G Ex ia/db IIC T6/T5 Ga/Gb II 1/2D Ex ia/tb IIIC T85°C/T100°C Da/Db I M2 Exd ia I Mb (version with SS housing) Ex ia/db IIC T6/T5 Ga/Gb Ex ia/tb IIIC T105°C Da/Db Ex db ia I Mb (version with SS housing)	Packing gland available on request
/Exd (2G)………………………………	[Ex] IECEx	II 2G Ex db ia IIC T6/T5 Gb II 2D Ex ia tb IIIC T105°C Db Ex db ia IIC T6/T5 Gb Ex ia tb IIIC T105°C Db	Packing gland available on request
/XP……………………………………	FM APPROVED	XP Class I, Div 1, Groups A, B, C, D T5 DIP Class II, Div 1, Groups E, F, G T5 DIP Class III, Div 1, T5 Zone 1 AEx db ia IIC T5 Gb Zone 21 AEx ia tb IIIC T105°C Db	Packing gland available on request
/XPC…………………………………..	c FM us APPROVED	XP Class I, Div 1, Groups B, C, D T5 DIP Class II, Div 1, Groups E, F, G T5 DIP Class III, Div 1, T5 Zone 1 AEx/Ex db ia IIC T5 Gb Zone 21 AEx/Ex ia tb IIIC T105°C Db	Packing gland available on request
/XPB……………………………………	INMETRO	Ex ia/db IIC T6/T5 Ga/Gb Ex ia/tb IIIC T105°C Da/Db Ex db ia I Mb (version with SS housing)	Packing gland available on request
/XPK……………………………………	[KCs]	Ex ia/db IIC T6/T5 Ga/Gb Ex ia/tb IIIC T105°C Da/Db	Packing gland available on request
/XPUK…………………………………	UKCA	II 1/2 G Ex ia/db IIC T6/T5 Ga/Gb II 1/2 D Ex ia/tb IIIC T105°C Da/Db I M2 Ex db ia I Mb (version with SS housing)	Packing gland available on request
/Exia(Da)/Exd…………………………		Dual certification Exia(Da) and Exd	
/Exia(Da)/Exd(2G)……………………		Dual certification Exia(Da) and Exd(2G)	
/IS/XP…………………………….......		Dual certification IS and XP for US	
/IS/XPC………………………………		Dual certification IS and XPC for US and Canada	
/ISB/XPB………………………………		Dual certification IS and XP and for Brazil	
/ISK/XPK………………………………		Dual certification IS and XP and for Korea	
/ISUK/XPUK…………………………		Dual certification IS and XP and for United Kingdom	
/SA……………………………………		Surge arrester for Exia version	
/MR……………………………………		Marine certificate – DNV, BV	
/250 bar..		Static pressure 250 bar (for transmitter with two remote diaphragm seal)	
/700 bar..		Static pressure 700 bar (for transmitter with two remote diaphragm seal)	
/IP67………………………………....		Protection class IP67	
/Hart 7………………………………..		Communication protocol HART in revision 7	

*- more than one option is available

Nominal measuring range		Range	Min. set range
	/-160÷160 mbar.....................................…	-160÷160 mbar (-16÷16 kPa)	0,1 mH2O
	/-0,5÷0,5 bar.........................…………...	-0,5÷0,5 bar (-50÷50 kPa)	0,5 mH2O
	/-1,6÷2 bar......................……...…….......	-1,6÷2 bar (-160÷200 kPa)	1,5 mH2O
	/-1,6÷16 bar.................……...……............	-1,6÷16 bar (-160÷1600 kPa)	1 bar

Measuring set range	/…÷… [required units]	Calibrated range in relation to 4mA and 20mA output

Process connections	/(+)……………………………	Direct diaphragm seal or remote diaphragm seal mounted on the (+) side of the transmitter- code as given in the relevant diaphragm seal sheet
	K=………………………………	Capillary length on (+) side of transmitter
	/(-)……………………………	Remote diaphragm seal mounted on the (-) side of the transmitter – code as given in the relevant diaphragm seal sheet
	K=………………………………	Capillary length on (-) side of transmitter

Electrical connection	(without marking)	Packing gland M20x1,5
	/US..............................	Thread 1/2"NPT Female

Accessories		/FI25………….	Mounting bracket for 1" pipe, mat. Stainless Steel

Other specification		/..............	Description of required parameters

Standard display configuration

	Std. version	Exia, Exia(Da), IS	Exd, XP	Exia(Da)/Exd, IS/XP	Safety
Backlight on	•	•	•		
Backlight off				•	•

Other configuration of display has to be marked upon placing order. User has no possibility of switching backlight on/off.

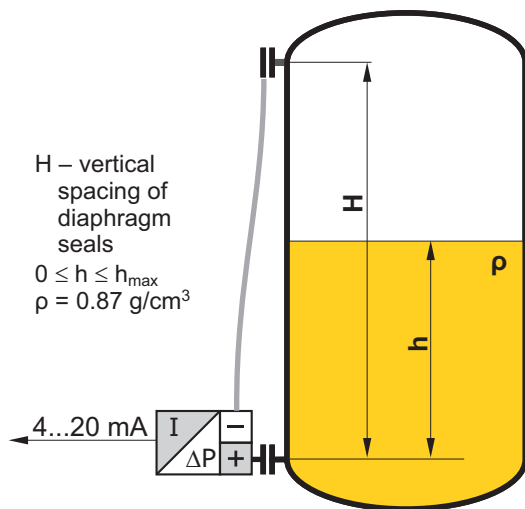To simplify the mathematical operations we introduce the density coefficient of the medium $X\rho$.

$$X\rho = \frac{\rho_{medium}\ [g/cm^3]}{\rho_{water\ at\ 4°C}\ [g/cm^3]}$$

Since the density of water at 4°C is 1 g/cm^3, the **density coefficient $X\rho$ is numerically equal to the density of the medium expressed in g/cm^3**. To determine the hydrostatic pressure of a column of liquid in mm H$_2$O, it is sufficient to multiply the height of the column h [mm] by the density coefficient of the liquid $X\rho$. Since it is easy to determine the hydrostatic pressure in mm H$_2$O and the transmitter can be configured in those units, in the descriptions of measurement methods given below we will make use of pressures expressed in mm H$_2$O and the density coefficient $X\rho$.

Configuration of the transmitter to measure the level of liquid in a tank

The measurement task:
To convert a variation in the level of a liquid with density $\rho = 0.87$ g/cm^3 between 0 and h$_{max}$ to a variation in the output signal from 4 to 20 mA.

H – vertical spacing of diaphragm seals
$0 \leq h \leq h_{max}$
$\rho = 0.87$ g/cm^3

4...20 mA

1. Install the transmitter in its working position on an empty tank.
2. Make the electrical connections of the transmitter, providing for the ability to use HART communication.
3. Connect the KAP-03 communicator, identify the transmitter and select the "configuration" function.

4. On the configuration menu select the "Reranging" procedure.
5. On the "Reranging" menu:
   a) change the units of measurement to mm H$_2$O at 4°C;
   b) enter the values for the start (Xń × h$_{min}$ [mm]) and end (Xρ × h$_{max}$ [mm]) of the measurement range, namely 0 and (0.87 h$_{max}$ [mm]) respectively;
   c) to compensate for the hydrostatic pressure of the manometric fluid, the start of the measurement range should be set using regulated pressure; when subject to the action of only the manometric fluid (empty tank) the transmitter will shift the start and end-points of the range, compensating for the value of that pressure.

When the transmitter has been configured in this way it is ready to be used to carry out the given measurement task.

If it is not possible to empty the tank to configure the transmitter, the hydrostatic pressure of the manometric fluid should be calculated by multiplying the vertical spacing of the diaphragm seals by the density coefficient of the oil in the capillaries. This pressure should be taken into account when entering the values for the start and end of the range:
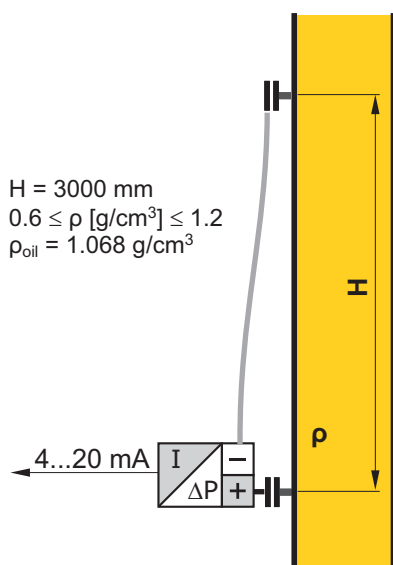
Start [mm H$_2$O] = $-$H [mm] × Xρ_{oil}

End [mm H$_2$O] =
= h$_{max}$ [mm] × X$\rho_{measured\ liquid}$ $-$ H [mm] × Xρ_{oil}

ρ_{oil} for DC-550 oil is equal to 1.068 g/cm^3
ρ_{oil} for AK-20 oil is equal to 0.945 g/cm^3

Configuration of the transmitter to measure density of liquids

H = 3000 mm
$0.6 \leq \rho$ [g/cm^3] ≤ 1.2
$\rho_{oil} = 1.068$ g/cm^3

4...20 mA

The measurement task:
To convert a variation in liquid density from $\rho_{min} = 0.6$ g/cm^3 to $\rho_{max} = 1.2$ g/cm^3 to a variation in the output signal from 4 to 20 mA, with the vertical spacing of the diaphragm seals equal to H = 3000 mm. The sealing system is filled with DC-550 oil with density $\rho_{oil} = 1.068$ g/cm^3.

1. Calculate the value of the start of the range as follows:
   H$_{[mm]}$ × (Xρ_{min} $-$ Xρ_{oil}) =
   = 3000 × (0.6 $-$ 1.068) = $-$1404 [mm H$_2$O]
2. Calculate the value of the end of the range as follows:
   H$_{[mm]}$ × (Xρ_{max} $-$ Xρ_{oil}) =
   = 3000 × (1.2 $-$ 1.068) = 396 [mm H$_2$O]
3. Set the zero point of the transmitter with the diaphragm seals positioned at the same level.
4. Install the transmitter in its working position.
5. Make the electrical connections to the transmitter, providing for the possibility of using HART communication.

6. Connect the KAP-03 communicator, identify the transmitter and select the "configuration" function.
7. On the configuration menu select "Reranging" procedure.
8. On the "Reranging" menu:
   a) change the measurement units to mm H_2O at 4°C;
   b) enter the calculated values for the start (−1404) and end (396) of the range.

When the transmitter has been configured in this way it is ready to be used to carry out the given measurement task.
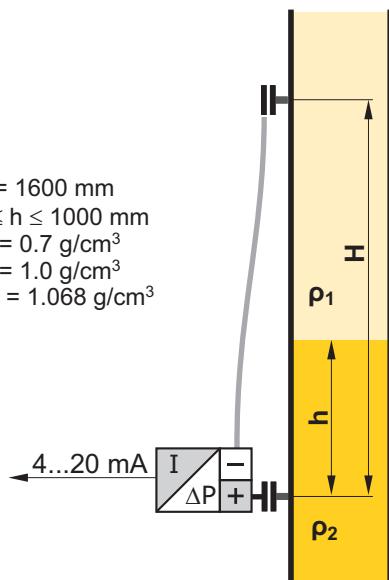
Note: If it is possible to fill the space between the seals with a liquid whose density corresponds to the start of the measurement range, the start of the range of the transmitter can be set using regulated pressure.

Measurement of phase boundary

The height of the phase boundary of liquids of different densities is determined by measuring the average density of the medium between the seals.

Example:
Calculate the measurement range start and end points for an APR-2000/ALW transmitter configured to measure phase boundary height in the range 0–1000 mm between liquids of density $\rho_1 = 0.7$ g/cm^3 and $\rho_2 = 1.0$ g/cm^3, where the vertical spacing of the seals H = 1600 mm. The sealing system uses DC-550 oil with a density of 1.068 g/cm^3.

H = 1600 mm
$0 \leq h \leq 1000$ mm
$\rho_1 = 0.7$ g/cm^3
$\rho_2 = 1.0$ g/cm^3
$\rho_{oil} = 1.068$ g/cm^3

To determine the start of the measurement range, calculate the pressure difference at the transmitter when the tank is filled with the lighter liquid only:

1600 [mm] × (0.7 − 1.068) = −588.8 [mm H_2O]

To determine the end-point of the range, add the increase in pressure resulting from the appearance of a 1 metre column of the heavier liquid:

−588.8 [mm H_2O] + (1.0 − 0.7) × 1000 [mm] =
= −288.8 [mm H_2O]

Additional remarks

The settings of the transmitter can be adjusted with reference to laboratory results from density measurements carried out on samples of the liquid being measured. This is most often necessary when the measurement takes place in a pipeline segment where the flow velocity of the measured liquid reaches several m/s.

Increasing the vertical spacing of the diaphragm seals widens the range and often improves measurement accuracy.

In planning the spacing of the diaphragm seals, ensure that the pressure difference at the transmitter lies within the basic range.

The maximum vertical spacing of the diaphragm seals (H) depends on the transmitter's basic range and the boundary values for the density of the measured liquid (ρ_{min}; ρ_{max}).

If $\rho_{min} < \rho_{oil} < \rho_{max}$, the seal spacing H should satisfy the following conditions:

$$H\,[mm] \leq \frac{\text{lower boundary of range [mm } H_2O]}{X\rho_{min} - X\rho_{oil}}$$

$$H\,[mm] \leq \frac{\text{upper boundary of range [mm } H_2O]}{X\rho_{max} - X\rho_{oil}}$$

Example:
Determine the maximum vertical spacing of the seals for the **APR-2000ALW/-10...10 kPa** transmitter when measuring the density of liquid between 0.6 and 1.2 g/cm^3. The sealing system uses AK-20 silicone oil with a density of 0.945 g/cm^3.

The lower boundary of the range of the transmitter is −10 kPa = −1020 mm H_2O

$$H\,[mm] \leq \frac{-1020}{0.6 - 0.945} \quad \Rightarrow \quad H\,[mm] \leq \frac{-1020}{-0.345} \quad \Rightarrow$$
$$H\,[mm] \leq 2957$$

The upper boundary of the range of the transmitter is +10 kPa = 1020 mm H_2O

$$H\,[mm] \leq \frac{1020}{1.2 - 0.945} \quad \Rightarrow \quad H\,[mm] \leq \frac{1020}{0.255} \quad \Rightarrow$$
$$H\,[mm] \leq 4000$$

In the example, both conditions are satisfied when the spacing of the seals is not more than 2957 mm.