

### Transmitted Light Process Refractometer

For a wide range of applications in the field of chemistry

#### Sensor

##### Properties

- unique transmitted light process refractometer
- one sensor type applicable for all relevant process medium as the accuracy is constant in a wide range of refractive indices
- integrated temperature measurement of the process medium
- sapphire optics with high chemical resistance and mechanical hardness
- optical system insensitive to deposits
- concealed FFKM gaskets, highly resistant against aggressive media
- calibration of the sensor using microcontrollers, independent of the transmitter
- digital data transmission
- internal self diagnosis for rapid error detection

##### Design

- compact design
- access to the pipe from one side
- pressure-tight partition between connection compartment and electronics compartment
- process connections for a wide range of pipe and vessel dimensions
- ATEX: zone 0/1, 2, mining approved sensors for hazardous areas available

##### Measurement

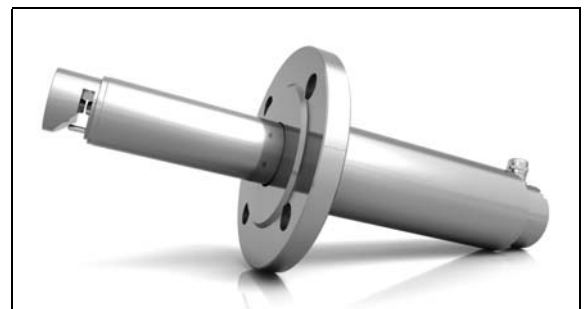
- stable zero point and no drift due to difference measurement
- not sensitive to pressure and temperature fluctuations in the process
- insensitive to bubbles
- no minimum flow required
- independent of viscosity

##### Transmitter

- processing of media data sets for each application
- calculation of application-specific source quantities, e.g., density, M%, Vol%, g/l, dry mass
- measurement of mixtures containing three or more components using additional external quantities (e.g., sound speed, density, conductance)
- integrated inputs and outputs as well as a data logger (SD card)
- transmitter for ATEX zone 2 available



Sensor PIOX R400, type of construction MC



Sensor PIOX R400, type of construction LC



PIOX R704



PIOX R705

# Table of Contents

**Fields of Application** ..... 3

**Measurement Principle** ..... 4  
 Measurement with Refractometer PIOX R400 ..... 4

**Program RMKoeff** ..... 6

**Measuring Setups** ..... 7

**Transmitter** ..... 8  
 Technical Data ..... 8  
 Dimensions ..... 10  
 2 " Pipe Mounting Kit (optional) ..... 11  
 Terminal Assignment ..... 12

**Sensor** ..... 13  
 Technical Data ..... 13  
 Dimensions ..... 14  
 Mounting Positions of Sensor ..... 14  
 Transducer Order Code ..... 15

**Process Connection** ..... 16  
 Sensor PIOX R400-LC\*\*\*\*\*D ..... 16  
 Sensor PIOX R400-MC\*\*\*\*\*F ..... 16

**Connection Systems** ..... 19

## Fields of Application

- concentration measurement, e.g. during distillation, rectification, solvent recovery
- process and quality control
- incoming goods inspection (medium detection)

## Refinery

- quality control of lubricating oils

## Chemical Industry

- acids, e.g. sulfuric acid, oleum, hydrochloric acid, acetic acid, hydrogen peroxide
- solvents of metal salts, e.g. chlorides, phosphates, sulfates
- organic solvents, e.g.,
  - alcohols, glycols
  - amines, e.g. MEA, DEA, EDA
  - pyrrolidones, e.g. NMP, PVP
  - acetone
- fungicides
- urea, urea ammonium nitrate solution (UAN)

## Polymer Chemistry, Fiber Production

- caprolactam
- cellulose spinning solution
- N-Methyl-2-pyrrolidone (NMP)
- dimethylformamide (DMF)
- dimethylacetamide (DMAC)

## Aircraft De-icing

- Dosing and recycling of de-icing fluids

## Mining, Hydraulics

- HFA fluids/concentration control

## Metal Industry

- cutting fluids
- rolling oil
- solvents

## Paper and Glue Production

- starch concentration
- solids content in starch- and casein-based glues

## Pharmaceutical Industry

- vitamin C production
- ascorbic acid, ketogulonic acid

### Measurement Principle

The refractive index  $n$  of a solution is determined using transmitted light refractometry. A light beam propagates through the solution and is refracted at the interface of a prism. The angle of refraction is measured by a detector. The refractive index  $n$  of the solution is calculated from the angle of refraction using Snell's law of refraction:

$$n_i \cdot \sin\theta_i = n_t \cdot \sin\theta_t$$

where

- $n_i$  - refractive index of fluid
- $\theta_i$  - angle of incidence
- $n_t$  - refractive index of prism
- $\theta_t$  - angle of refraction

### Measurement with Refractometer PIOX R400

#### Sensor

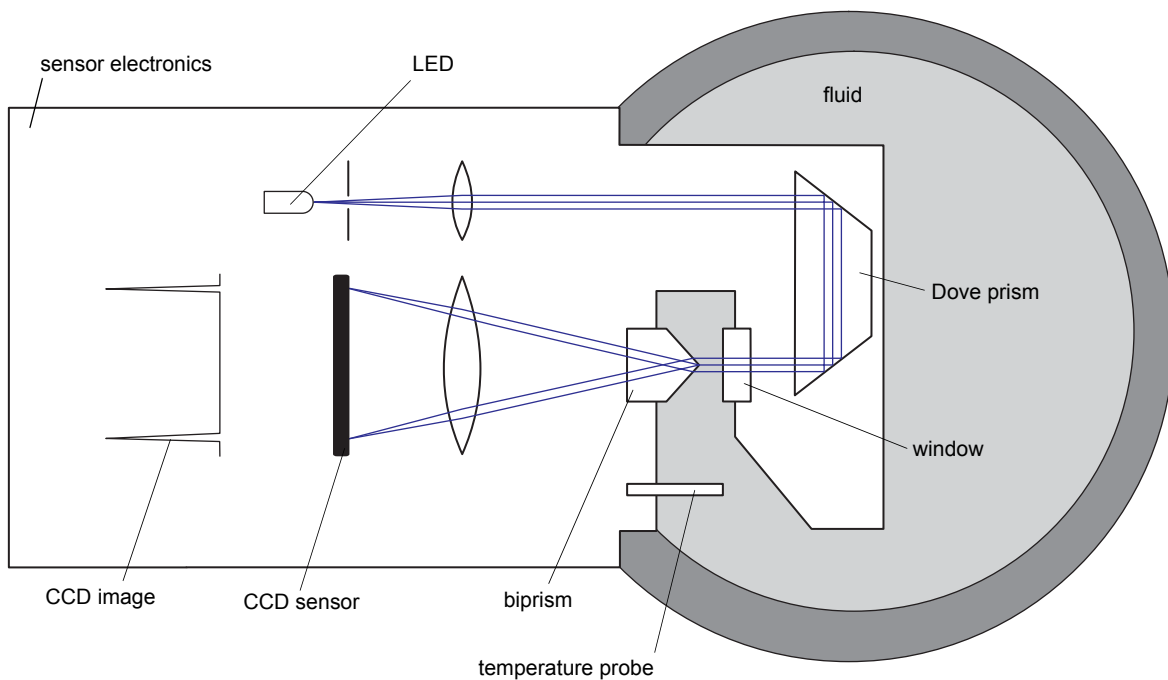
A special LED with a wave length  $\lambda = 590 \text{ nm}$  (sodium D line) is used as the light source. The light passes through a slit, is parallelized by a lens and reversed by a Dove prism. Then it enters the fluid through a window in the sensor head. When the light beam re-enters the sensor, it is split at the apex of a biprism and refracted at its lateral surfaces.

The two resulting measuring beams are focused by a lens, generating sharp images of the slit on the detector, a CCD sensor with 2048 pixels.

The angle of refraction is determined from the difference between the two images of the slit. The zero point is calculated continuously in order to compensate for the influences of the process pressure and temperature.

The following quantities are measured/calculated in the sensor and sent to the transmitter:

- refractive index  $n_D$  (= matched to the sodium D line), calculated from the angle of refraction
- fluid temperature measured by the integrated temperature probe Pt1000
- signal amplitude, calculated from the CCD signals
- internal sensor temperature
- relative humidity, measured in the sensor electronics



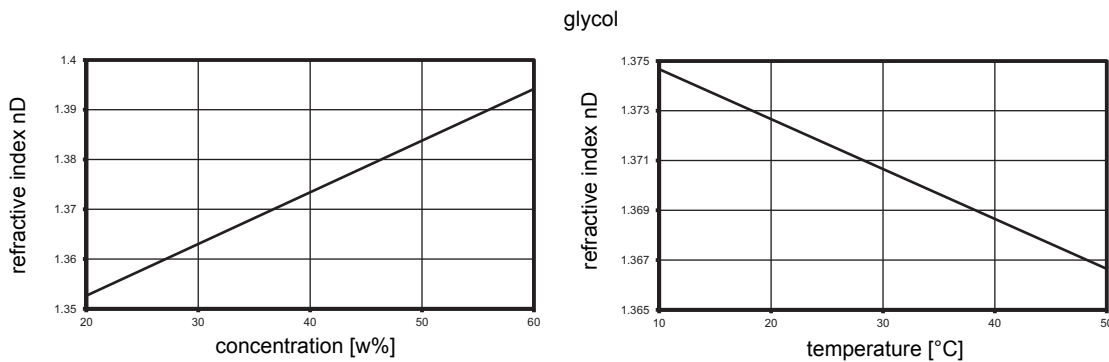
### Processing in the Transmitter

The refractive index and the fluid temperature sent by the sensor are used for the calculation of process parameters, e.g., the temperature-compensated refractive index  $n_{DT}$ , the ° Brix value or the concentration in mass or volume percent. Additional process parameters can be configured by means of the program RMKoeff (see page 6).

The transmitter can be equipped with electrical inputs, allowing for the input of additional available fluid quantities, e.g. sound speed, density or conductance, and using them for the measurement of three-component mixtures.

### Temperature Dependence

As the refractive index depends on the fluid temperature, the process parameters can often only be calculated if the fluid temperature is known. The temperature measured by the integrated temperature probe is used for the calculation of the temperature-compensated refractive index  $n_{DT}$ .



Dependence of the refractive index on the concentration (temperature = constant)

Dependence of the refractive index on the temperature (concentration = constant)

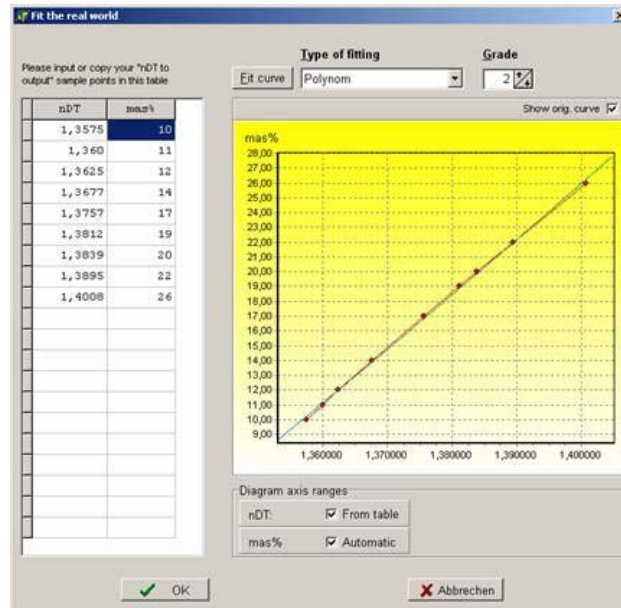
### Program RMKoeff

The transmitter has an internal database for storing the data sets of commonly used fluids. Data sets for additional fluids can be easily added and managed on a PC using the program RMKoeff.

The characteristics is generated by polynomials of grade 1...3 from a data table or from a test series. The X axis quantity is the refractive index nDT related to a standard temperature. The Y axis quantity is the required process parameter and its unit of measurement are user defined, e.g. concentration in w%, g/l or mol/l.

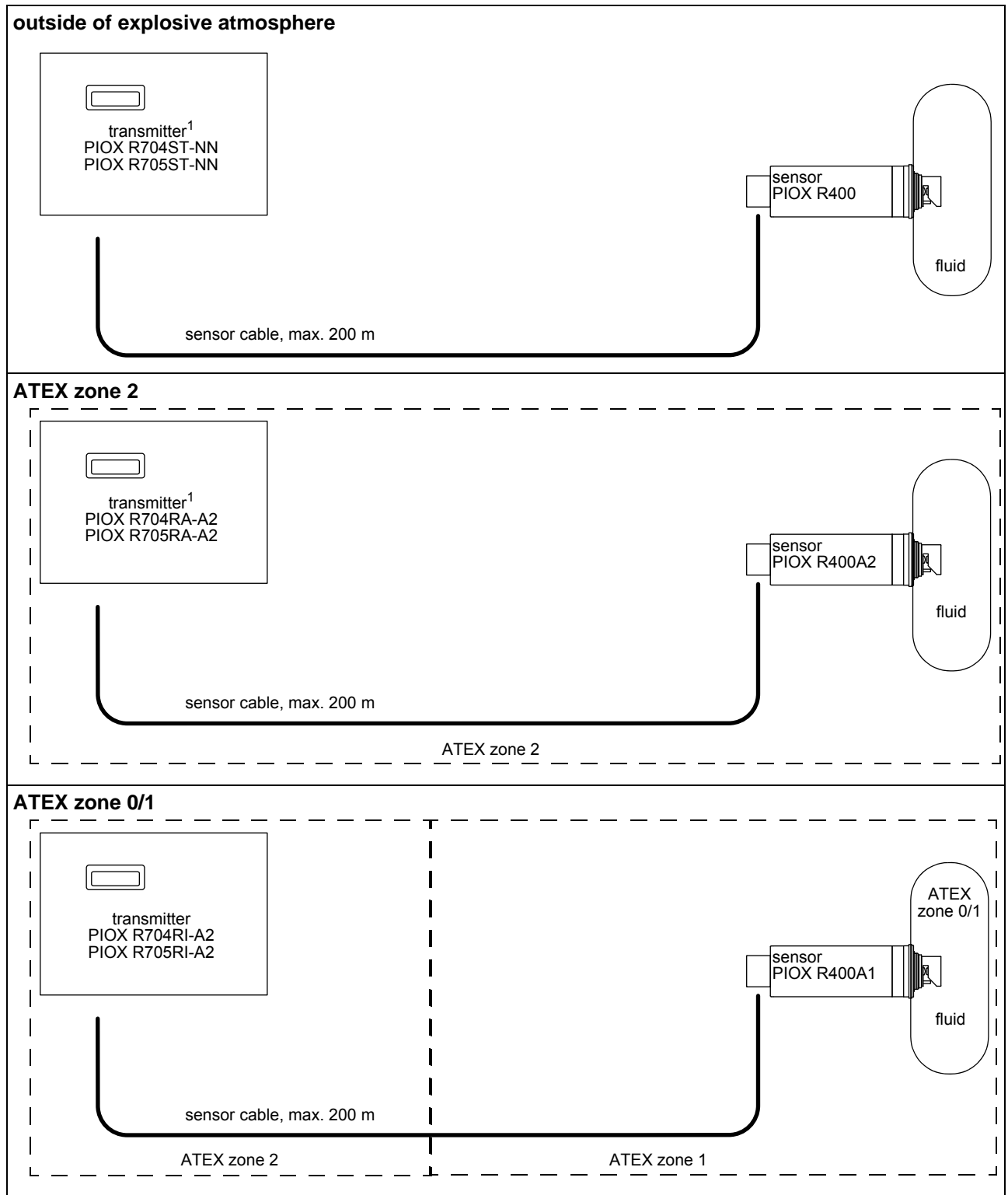
The customized data sets will be transferred between transmitter and PC via the serial interface RS232 or USB.

Data sets, even with high complexity, can also be generated in the FLEXIM laboratory.



Program RMKoeff - generation of a concentration characteristics



## Measuring Setups



<sup>1</sup> optional: connection of 2 sensors

# Transmitter

## Technical Data

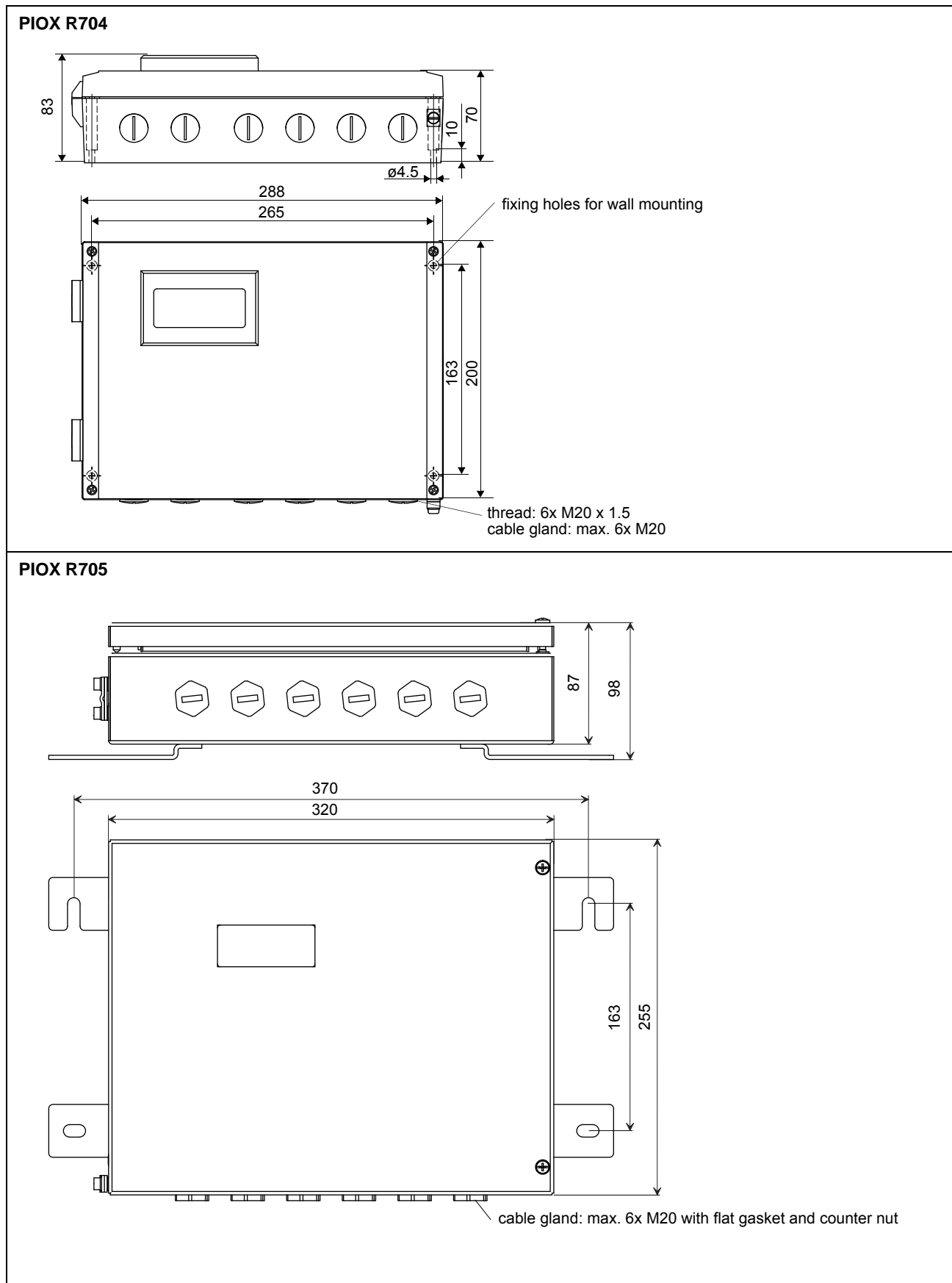
PIOX	R704ST-NN R704RA-A2	R704RI-A2	R705ST-NN R705RA-A2	R705RI-A2		
	standard field device		field device with stainless steel housing			
						
power supply	100...230 V/50...60 Hz or 20...32 V DC					
power consumption	< 15 W					
number of measuring channels	1, optional (on request): 2	1	1, optional (on request): 2	1		
attenuation	0...100 s, adjustable					
response time	1 s					
housing material	aluminum, powder coated		stainless steel 316L (1.4404)			
degree of protection according to IEC/EN 60529	IP65		IP66			
dimensions	see dimensional drawing					
weight	2.8 kg		4.76 kg			
fixation	wall mounting, optional: 2 " pipe mounting					
ambient temperature	-40...+60 °C (-40...-20 °C without operation of the display)					
display	2 x 16 characters, dot matrix, backlight					
menu language	English, German					
<b>explosion protection</b>						
ATEX	transmitter	R704RA-A2	R704RI-A2	R705RA-A2	R705RI-A2	
	zone	2	2	2	2	
	marking	CE Ex II3G Ex nA nC ic IIC T4 Gc II3D Ex tc IIIC T 120 °C Dc Ta -40...+60 °C	CE 0637 Ex II(2)3G Ex nA [ib Gb] IIC T4 Gc I (M2) [Ex ib Mb] I II2D Ex tb [ib] IIIC T 120 °C Db Ta -40...+60 °C	CE Ex II3G Ex nA nC ic IIC T4 Gc II3D Ex tc IIIC T 120 °C Dc Ta -40...+60 °C	CE 0637 Ex II(2)3G Ex nA [ib Gb] IIC T4 Gc I (M2) [Ex ib Mb] I II2D Ex tb [ib] IIIC T 120 °C Db Ta -40...+60 °C	CE 0637 Ex II(2)3G Ex nA [ib Gb] IIC T4 Gc I (M2) [Ex ib Mb] I II2D Ex tb [ib] IIIC T 120 °C Db Ta -40...+60 °C
	certification ATEX	-	IBExU06ATEX1075 X	-	IBExU06ATEX1075 X	
	type of protection	gas: non sparking dust: protection by enclosure	gas: non sparking dust: protection by enclosure	gas: non sparking dust: protection by enclosure	gas: non sparking dust: protection by enclosure	
intrinsic safety parameters	-	U <sub>m</sub> = 250 V intrinsically safe power supply for zone 1 sensors: P <sub>o</sub> = 1.1 W U <sub>o</sub> = 13.2 V I <sub>o</sub> = 84 mA C <sub>o</sub> = 0.24 µF RS485 (intrinsic safety): P <sub>o</sub> = 0.2 W U <sub>o</sub> = 6 V I <sub>o</sub> = 76 mA C <sub>o</sub> = 39.3 µF	-	U <sub>m</sub> = 250 V intrinsically safe power supply for zone 1 sensors: P <sub>o</sub> = 1.1 W U <sub>o</sub> = 13.2 V I <sub>o</sub> = 84 mA C <sub>o</sub> = 0.24 µF RS485 (intrinsic safety): P <sub>o</sub> = 0.2 W U <sub>o</sub> = 6 V I <sub>o</sub> = 76 mA C <sub>o</sub> = 39.3 µF	U <sub>m</sub> = 250 V intrinsically safe power supply for zone 1 sensors: P <sub>o</sub> = 1.1 W U <sub>o</sub> = 13.2 V I <sub>o</sub> = 84 mA C <sub>o</sub> = 0.24 µF RS485 (intrinsic safety): P <sub>o</sub> = 0.2 W U <sub>o</sub> = 6 V I <sub>o</sub> = 76 mA C <sub>o</sub> = 39.3 µF	



PIOX	R704ST-NN R704RA-A2	R704RI-A2	R705ST-NN R705RA-A2	R705RI-A2
<b>measuring functions</b>				
physical quantities	refractive index, fluid temperature, more with application specific output parameters			
diagnostic functions	signal amplitude, sensor humidity, sensor temperature			
<b>data logger</b>				
type	SD card, removable			
capacity	min. 2 GB			
<b>communication</b>				
interface	- process integration: RS485 (optional) - diagnosis: RS232 <sup>1</sup>			
<b>serial data kit</b>				
software (all Windows™ versions)	RMKoeff: management of fluid data sets			
cable	RS232 <sup>1</sup>			
adapter	RS232 - USB <sup>1</sup>			
<b>outputs (optional)</b>				
	The outputs are galvanically isolated from the transmitter.			
number	on request			
<b>current output</b>				
range	0/4...20 mA			
accuracy	0.1 % of reading ± 15 µA			
active output	$R_{ext} < 500 \Omega$			
passive output	$U_{ext} = 4...24 \text{ V}$ , depending on $R_{ext}$ $R_{ext} < 1 \text{ k}\Omega$			
<b>voltage output</b>				
range	0...1 V or 0...10 V			
accuracy	0...1 V: 0.1 % of reading ± 1 mV 0...10 V: 0.1 % of reading ± 10 mV			
internal resistance	$R_i = 500 \Omega$			
<b>frequency output</b>				
range	0...5 kHz			
open collector	24 V/4 mA, $R_i = 66.5 \Omega$			
<b>binary output</b>				
Reed relay	48 V/100 mA P1...P4: $R_i = 22 \Omega$			
open collector	24 V/4 mA P1...P4: $R_i = 22 \Omega$			
optorelay	26 V/100 mA			
binary output as alarm output - functions	limit			
<b>inputs (optional)</b>				
	The inputs are galvanically isolated from the transmitter.			
number	max. 4, on request			
<b>current input</b>				
accuracy	0.1 % of reading ± 10 µA			
active input	$U_i = 24 \text{ V}$ , $R_i = 50 \Omega$ , $P_i < 0.5 \text{ W}$ , not short-circuit proof			
- range	0...20 mA			
passive input	$R_i = 50 \Omega$ , $P_i < 0.3 \text{ W}$			
- range	-20...+20 mA			
<b>voltage input</b>				
range	0...1 V			
accuracy	0.1 % of reading ± 1 mV			
internal resistance	$R_i = 1 \text{ M}\Omega$			

<sup>1</sup> R70\*\*\*-A2: connection of the interface RS232 outside of explosive atmosphere (housing cover open)

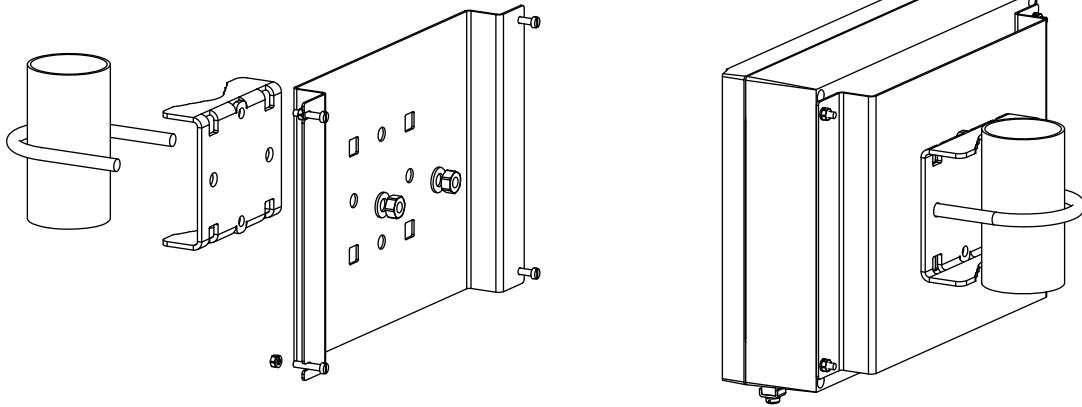
### Dimensions



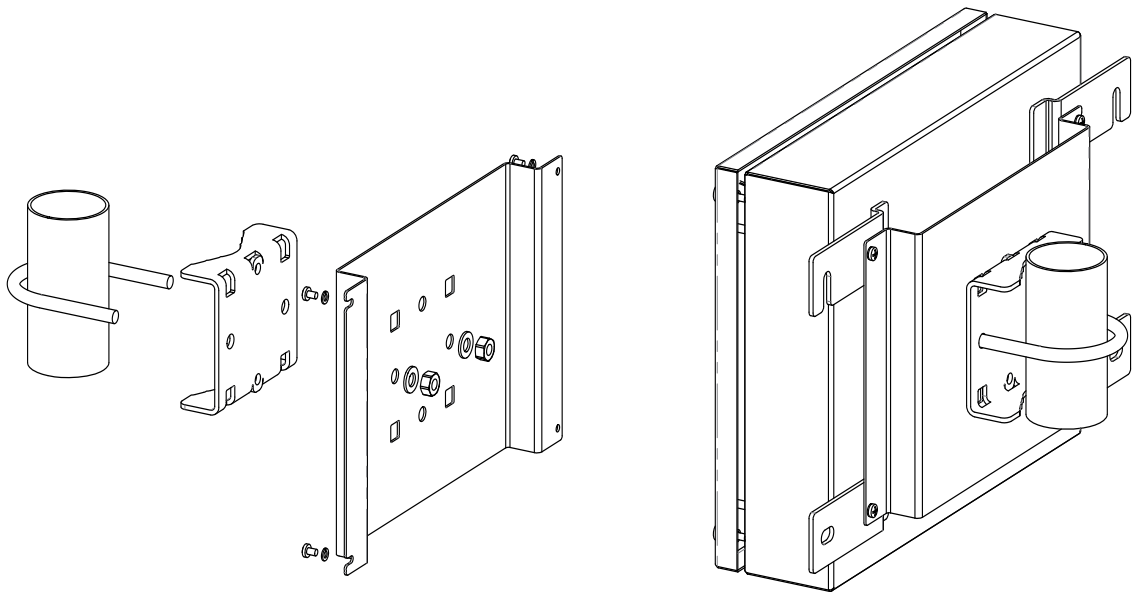
in mm

## 2 " Pipe Mounting Kit (optional)

PIOX R704

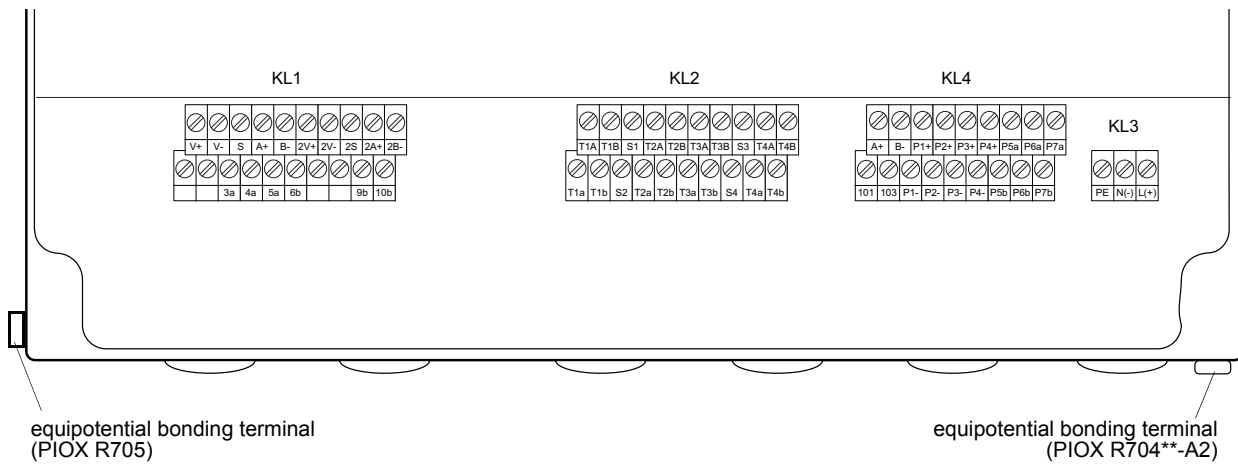


PIOX R705



## Terminal Assignment

### PIOX R704, R705



#### power supply

terminal strip KL3

terminal	connection (AC)	connection (DC)
PE	earth	earth
N(-)	neutral	-
L(+)	phase	+

#### transducers

terminal strip KL1

terminal measuring channel A	terminal measuring channel B	transducer cable	extension cable
V+	2V+	yellow	yellow
V-	2V-	green	green
A+	2A+	brown	brown
B-	2B-	white	white

#### outputs<sup>1</sup>

terminal strip KL4

terminal	connection
P1+...P4+, P1-...P4-	current output, voltage output, frequency output or binary output (Reed relay, open collector)
P5a...P7a, P5b...P7b	binary output

#### RS485 (optional)

terminal strip KL4

terminal	connection
A+	signal +
B-	signal -
101	shield

#### inputs<sup>1</sup>



terminal strip KL2

terminal	passive current source connection of an active input	active current source connection of a passive input
T1a...T4a	not connected	not connected
T1A...T4A	-	+
T1b...T4b	+	not connected
T1B...T4B	not connected	-
S1...S4	not connected	not connected

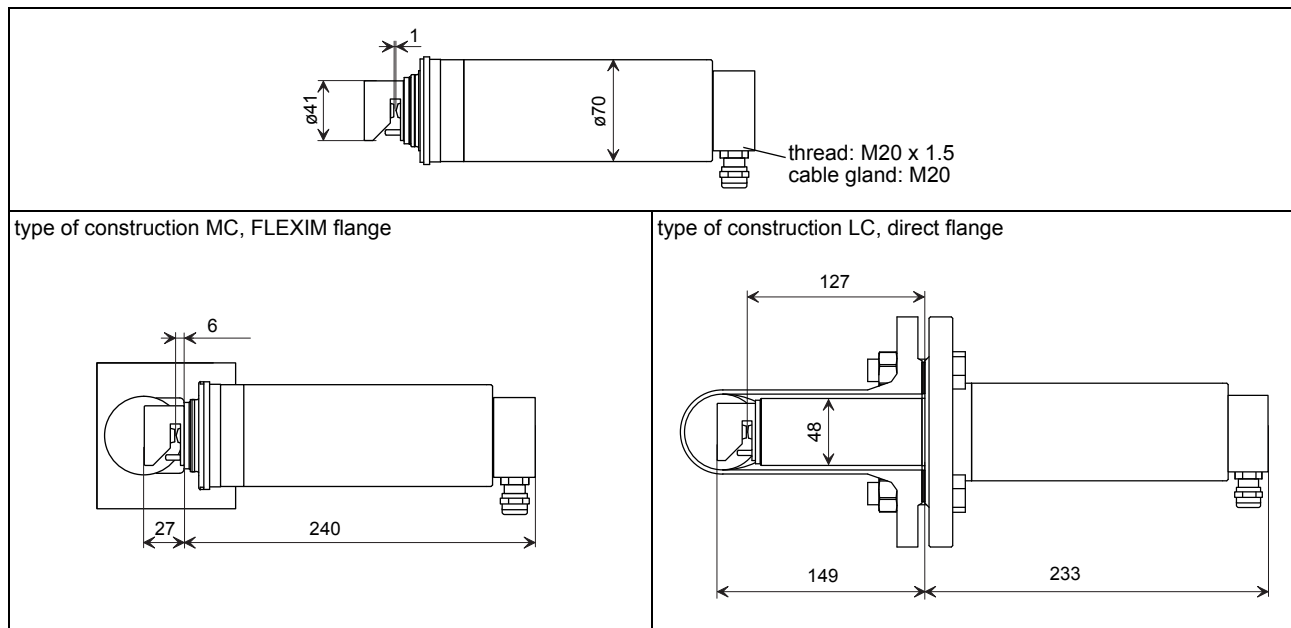
<sup>1</sup> The number, type and terminal assignment of the outputs and inputs will be customized.

## Sensor

### Technical Data

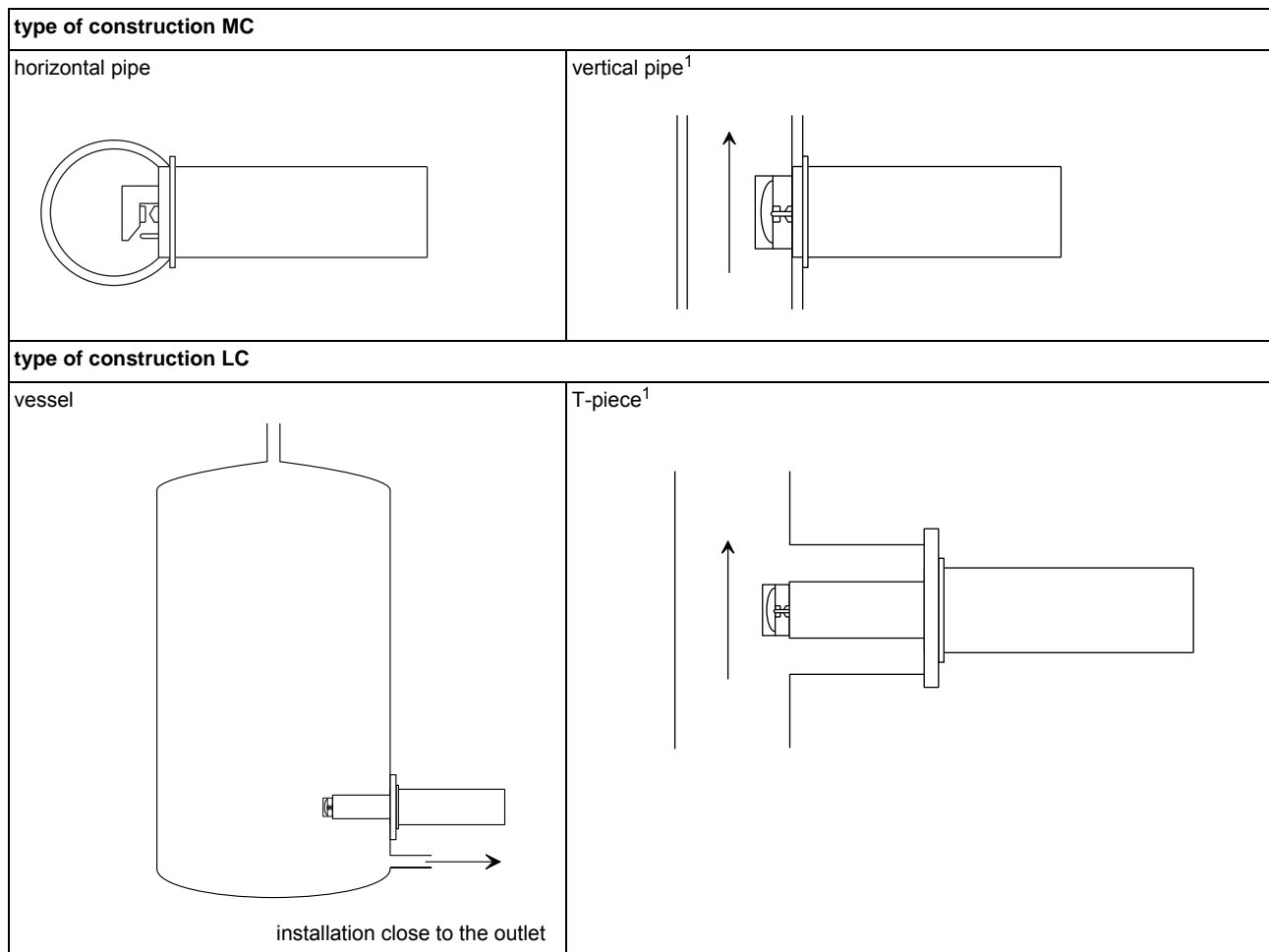
PIOX	R400	R400A2	R400A1
<b>process parameters</b>			
medium	all liquids with a turbidity < 10 000 FAU		
fluid temperature (depending on ambient temperature)	-20...+150 °C (150 °C at an ambient temperature of 20 °C)	-20...+130 °C	
fluid pressure	PN 10, PN 16, PN 40 (on request, depending on process connection)		
<b>measurement</b>			
measurement principle	transmitted light refractometry		
measuring range	nD: 1.3...1.7		
accuracy (absolute)	nD: 0.000 2 (typical 0.1 w%)		
repeatability	nD: 0.000 02 (typical 0.01 w%)		
resolution (display)	nD: 0.000 001		
<b>material</b>			
housing	stainless steel 304 (1.4301)		
wetted parts	stainless steel 316Ti (1.4571) (others see sensor order code, page 15)		
gaskets	FFKM		
prism	sapphire, nD ≈ 1.76		
degree of protection according to IEC/EN 60529	IP67		
flange	dependent on the type of construction (see sensor order code, page 15)		
dimensions with flange	see dimensional drawing		
weight	min. 2 kg		
ambient temperature	-20...+60 °C		
<b>explosion protection</b>			
A T E X	zone	-	2
	marking	-	CE  II3G Ex nA op is IIC T4 Gc II3D Ex tc IIIC T 120 °C Dc Ta -40...+60 °C Tm -20...+130 °C
	certification ATEX	-	CE 0637  II1/2G Ex ib op is IIC T4 Ga/Gb I M2 Ex ib op is I Mb II2D Ex ib IIIC T 120 °C Db Ta -40...+60 °C Tm -20...+130 °C
	type of protection	-	gas: non sparking dust: protection by enclosure
	intrinsic safety parameters	-	intrinsic safety, inherently safe optical radiation power supply: Ci = 141.6 nF Li = 0 µH data: Ci = 22.7 nF Li = 0 µH
<b>temperature probe</b>			
type	Pt1000		
resolution	0.01 K		
accuracy at 20 °C	0.15 K		
response time	5 s		

### Dimensions



in mm

### Mounting Positions of Sensor



<sup>1</sup> The pipe always has to be completely filled. The preferred flow direction is upward, in exceptional cases downward.

### Transducer Order Code

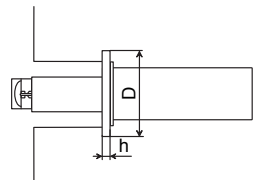
1, 2	3...5	6, 7	6, 7	8, 9	10, 11	12, 13	14	15...17	18...20	no. of character	
measurement principle	type	-	type of construction	design	material (wetted parts)	gaskets	explosion protection	flange	flange size (flange = D)	cable length	description
R	400										transmitted light refractometer
			M								standard sensor
			L								long sensor
				C							chemistry design
					S4						stainless steel 316Ti (1.4571)
					S5						stainless steel 904L (1.4539)
					C2						Hastelloy
					SO						special materials (on request)
						KR					FFKM (Kalrez)
							A1				ATEX zone 1 (sensor head in zone 0) (R400A1)
							A2				ATEX zone 2 (R400A2)
							NN				not explosion proof (R400)
								F			FLEXIM flange (R400-MC) (for process connection see page 16)
								D			direct flange (R400-LC)
									050		DN 50
									065		DN 65
									080		DN 80
									100		DN 100
									125		DN 125
									002		2 "
									003		3 "
									004		4 "
										XXX	in m, for max. length of cable length see page 19
example											
R	400	-	M	C	S4	KR	A1	F		030	standard sensor, chemistry design, wetted parts; stainless steel 316Ti, gaskets: FFKM, zone 1 (R400A1), FLEXIM flange, cable length 30 m
R	400	-									

## Process Connection

### Sensor PIOX R400-LC\*\*\*\*\*D

The sensor is welded to the direct flange (DIN 2527 or ASME B16.5 150 lbs).

### Technical Data

sensor order code	process pressure	material	pipe diameter	dimensions [mm]		dimensional drawing
				D	h	
R400-LC*****D050	PN 16 optional: PN 40	stainless steel 316Ti (1.4571), special materials (on request)	DN 50	ø165	18	
R400-LC*****D065			DN 65	ø185	18	
R400-LC*****D080			DN 80	ø200	20	
R400-LC*****D100			DN 100	ø220	20	
R400-LC*****D125			DN 125	ø250	22	
R400-LC*****D002			2 "	ø 6 "	19.1	
R400-LC*****D003	3 "	ø 7.5 "	23.9			
R400-LC*****D004	4 "	ø 9 "	23.9			

### Sensor PIOX R400-MC\*\*\*\*\*F

### Order Code

process connection	-	connection type	pipe diameter <sup>1</sup>	material <sup>1</sup>	gaskets	process pressure <sup>1</sup>	/	option	description
PCR									process connection of refractometer
		FD FA FT FW WR WS							flow chamber with flanges according to DIN 2633 flow chamber with flanges according to ASME B 16.5 150 lbs flow chamber with screwed connection flow chamber with welded connection to the process pipe round welding plate for vessel installation square welding plate for vessel installation
			xxx						DN xxx (xxx = 010, 015, 020, 025, 040, 050, 080, 100) 1 " (xxx = 001), 2 " (xxx = 002), 3 " (xxx = 003), 4 " (xxx = 004), 3/8 " (xxx = G38), 1/2 " (xxx = G12), 3/4 " (xxx = G34)
				S4 TI SO					stainless steel 316Ti (1.4571) titanium special materials
					FE NN				FPM with FEP coating (PCR-F*) without gasket, process connection welded to sensor (PCR-D*)
						yy			pressure stage PN yy in bar (yy = 10, 16, on request: 40) 150 lbs (yy = 10)
								CL	cleaning line (PCR-F*)
example									
PCR	-	FD	050	S4	FE	16			process connection of refractometer with flow chamber and flanges according to DIN 2633, pipe diameter: DN50, material: stainless steel 316Ti, gaskets: FPM with FEP coating, process pressure: PN16
PCR	-								

<sup>1</sup> possible pipe diameters/materials/process pressures to be selected from table on page 17. Observe national regulations when selecting the flange size depending on the process pressure.



**Technical Data**

description	order code	process pressure yy	pipe diameter xxx	dimensions [mm]			dimensional drawing
				l	b	h	
flow chamber with flanges accessories: blind cover, sensor mounting kit (see page 18) optional: cleaning line <sup>1</sup>	PCR-FDxxxS4FEyy PCR-FDxxxTIFEyy PCR-FDxxxSOFEyy	PN 16	DN 10	170	∅90	58	
			DN 15	170	∅95	58	
			DN 20	176	∅105	58	
			DN 25	176	∅115	58	
			DN 50	190	∅165	80	
			DN 65	190	∅185	95.8	
			DN 80	200	∅200	107	
	PCR-FAxxxS4FE10 PCR-FAxxxTIFE10 PCR-FAxxxSOFE10	150 lbs	ANSI 1 "	8.4 "	∅4.25 "	2.3 "	
			ANSI 2 "	9 "	∅6 "	3.15 "	
flow chamber with screwed connection accessories: blind cover, sensor mounting kit (see page 18) optional: cleaning line <sup>1</sup>	PCR-FTxxxS4FEyy PCR-FTxxxTIFEyy PCR-FTxxxSOFEyy	PN 16	G 3/8 "	100	100	56	
			G 1/2 "				
			G 3/4 "				
flow chamber with welded connection to the process pipe accessories: blind cover, sensor mounting kit (see page 18) optional: cleaning line <sup>1</sup>	PCR-FWxxxS4FEyy PCR-FWxxxTIFEyy PCR-FWxxxSOFEyy	PN 16	DN 25	100	100	58	
			DN 40	100	100	70	
			DN 50	100	100	80	
			DN 65	100	100	95.8	
			DN 80	100	100	107	
			1 "	3.94 "	3.94 "	2.3 "	
			2 "	3.94 "	3.94 "	3.15 "	
3 "	3.94 "	3.94 "	4.21 "				
round welding plate for vessel installation accessories: blind cover, sensor mounting kit (see page 18)	PCR-WRT00S4FEyy PCR-WRT00TIFEyy PCR-WRT00SOFEyy	PN 16			∅100 <sup>2</sup>	20	
square welding plate for vessel installation accessories: blind cover, sensor mounting kit (see page 18)	PCR-WST00S4FEyy PCR-WST00TIFEyy PCR-WST00SOFEyy	PN 16		100	100	20	

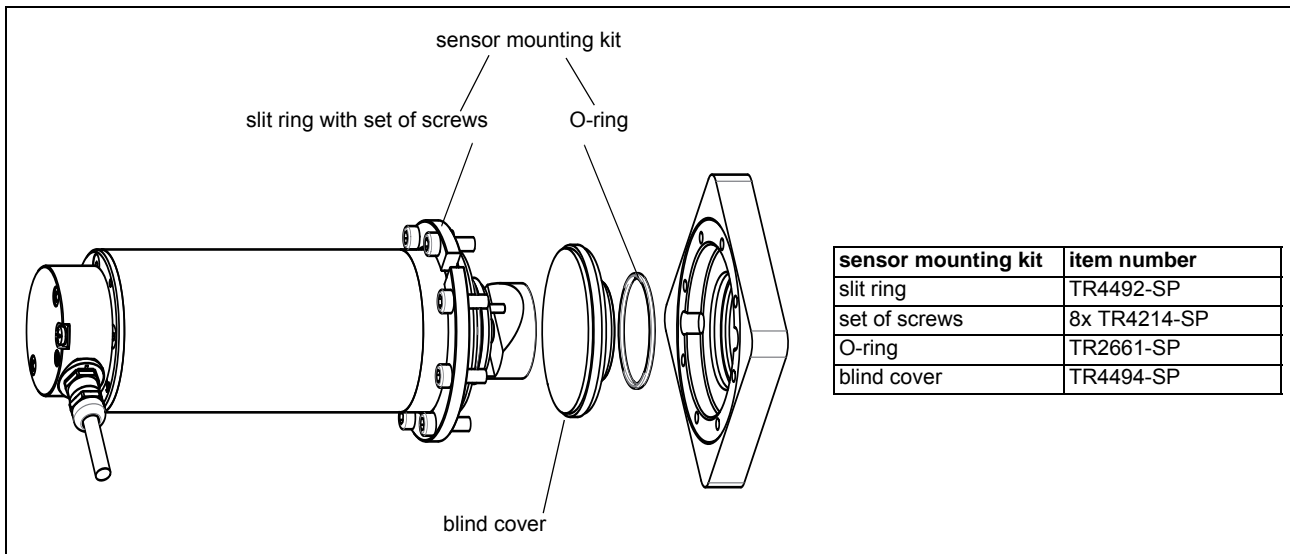
xxx, yy - see order code

PN 40 on request

<sup>1</sup> cleaning connection: G1/2 ", internal thread

<sup>2</sup> other diameters on request

**Accessories for PCR-F, PCR-W**



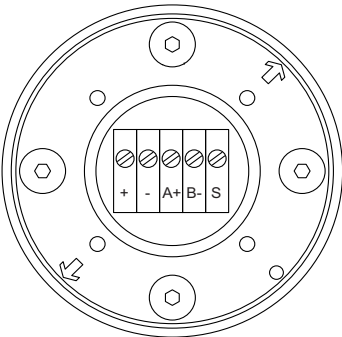
sensor mounting kit	item number
slit ring	TR4492-SP
set of screws	8x TR4214-SP
O-ring	TR2661-SP
blind cover	TR4494-SP

## Connection Systems

### Sensor Cable

PIOX		R400A1	R400A2	R400
item number		TR10125	TR10126	
type		LIYCY 2 x 2 x 0.75 blue	LIYCY 2 x 2 x 0.75 gray	
max. length	m	200	200	
weight (approx.)	kg/m	0.112	0.106	
ambient temperature	°C	-10...+80	-40...+80	
properties		flame-retardant according to DIN VDE 0482, part 265-2-1 self-extinguishing	flame-retardant according to IEC 60332-1-2	
<b>cable jacket</b>				
material		PVC	PVC	
outer diameter	mm	8.9	8.5	
color		blue	gray	
shield		x	x	

### Terminal Assignment



terminal	connection
+	yellow
-	green
A+	brown
B-	white
S	shield

equipotential bonding terminal on housing cover



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