

Transmitted light process refractometer for highly corrosive process conditions

For a wide range of applications in the field of chemistry

Sensor

Properties

- Inline process refractometer for temperature-compensated measurement of the refractive index and for the calculation of further physical quantities like concentration and percentage by mass (temperature measurement of the process fluid included)
- The patented transmitted light measuring method with integrated difference measurement ensures, due to its insensitivity to deposits, high precision and measurement stability over a wide refractive index range
- Wetted parts of the process refractometer are made of PTFE carbon-fiber reinforced material and offer therefore a high corrosion protection also in measurements with strong acids, lyes and other fluids
- Sapphire optics with high chemical resistance and mechanical durability
- Concealed FFKM gaskets, highly resistant against aggressive fluids
- Microcontrolled calibration of the sensor independent of the transmitter
- Internal sensor self diagnosis for demand-based control of cleaning intervals

Design

- Explosion-proof sensors for the use in explosive atmospheres: ATEX zone 0/1, 2
- Applicable for pressure stage PN10 and fluid temperature in the range of -20...+120 °C
- Type of construction M and L available
- Pressure-tight partition between connection compartment and electronics compartment

Measurement

- Extremely zero stable and drift-free due to patented transmitted light measuring method with integrated difference measurement
- Not sensitive to pressure and temperature fluctuations in the process
- Insensitive to deposits and bubbles
- No minimum flow required
- Independent of viscosity

Transmitter

- Provision of fluid data sets for each application
- Calculation of application-specific quantities, e.g., density, wt%, vol%, g/l, dry matter
- 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

Fields of Application

Concentration measurement and fluid detection of acids, lyes and other corrosive fluids (e.g. HCl, HNO₃, H₂SO₄, oleum, HF)



Sensor PIOX R400, type of construction MC



Sensor PIOX R400, type of construction LC



Transmitter PIOX R704



Transmitter PIOX R705

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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
- θ_i - angle of incidence
- n_t - refractive index of prism
- θ_t - angle of refraction

Measurement with refractometer PIOX R400

Sensor

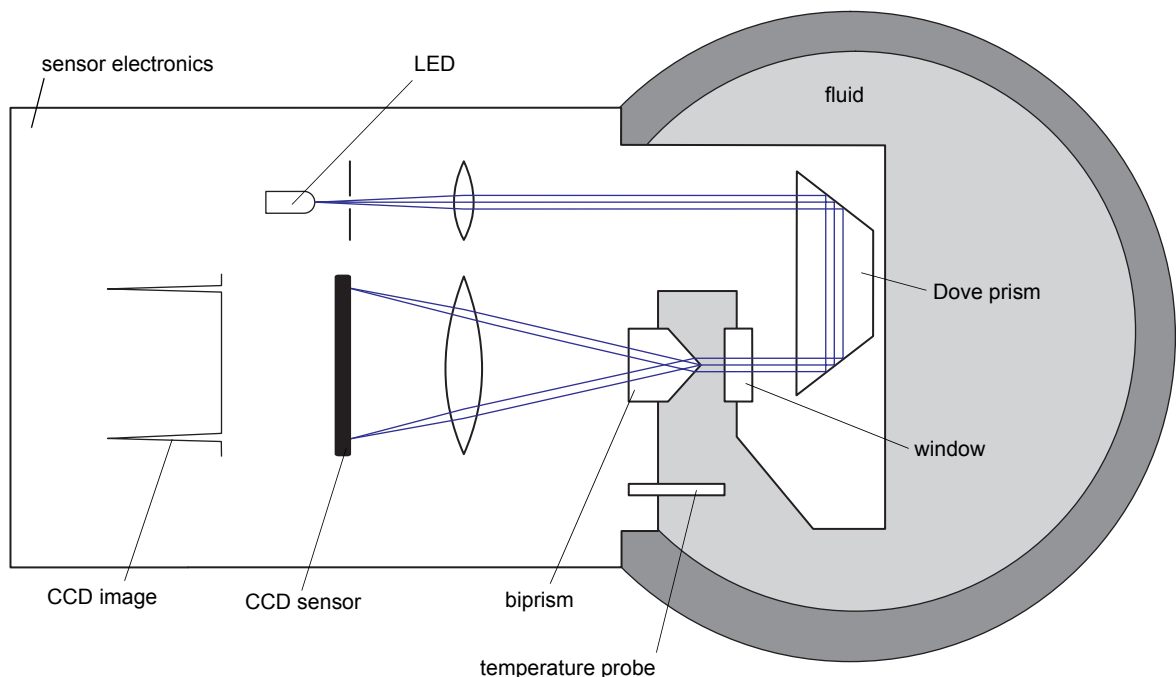
A special LED with a wave length $\lambda = 590$ nm (sodium D line) is used as the light source. The light passes through a slit, is parallelized by a lens and reversed by a Dove prism. Then it enters the fluid through a window in the sensor head. When the light beam re-enters the sensor, it is split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



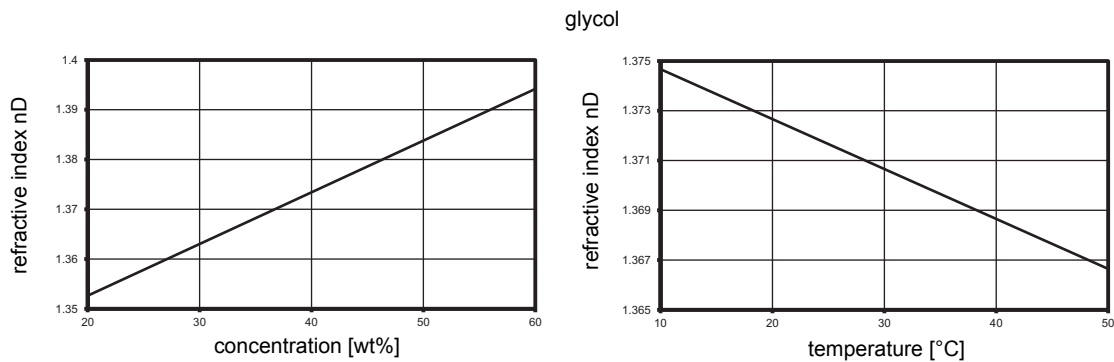
Processing in the transmitter

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 5).

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)

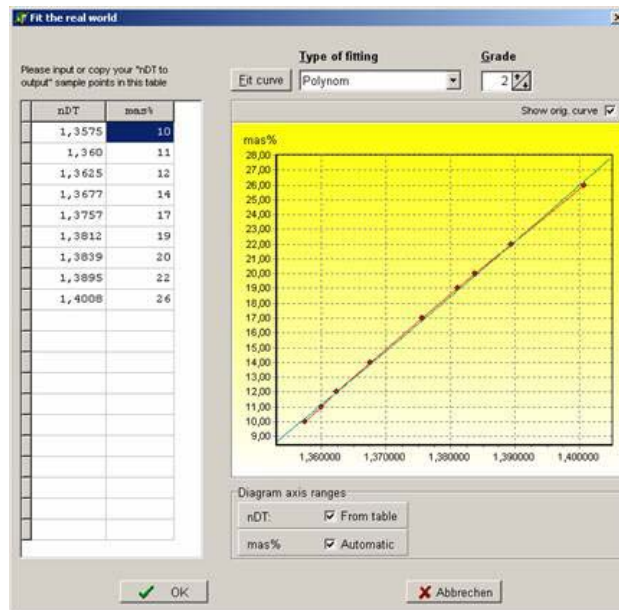
Program RMKoeff

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 wt%, g/l or mol/l.

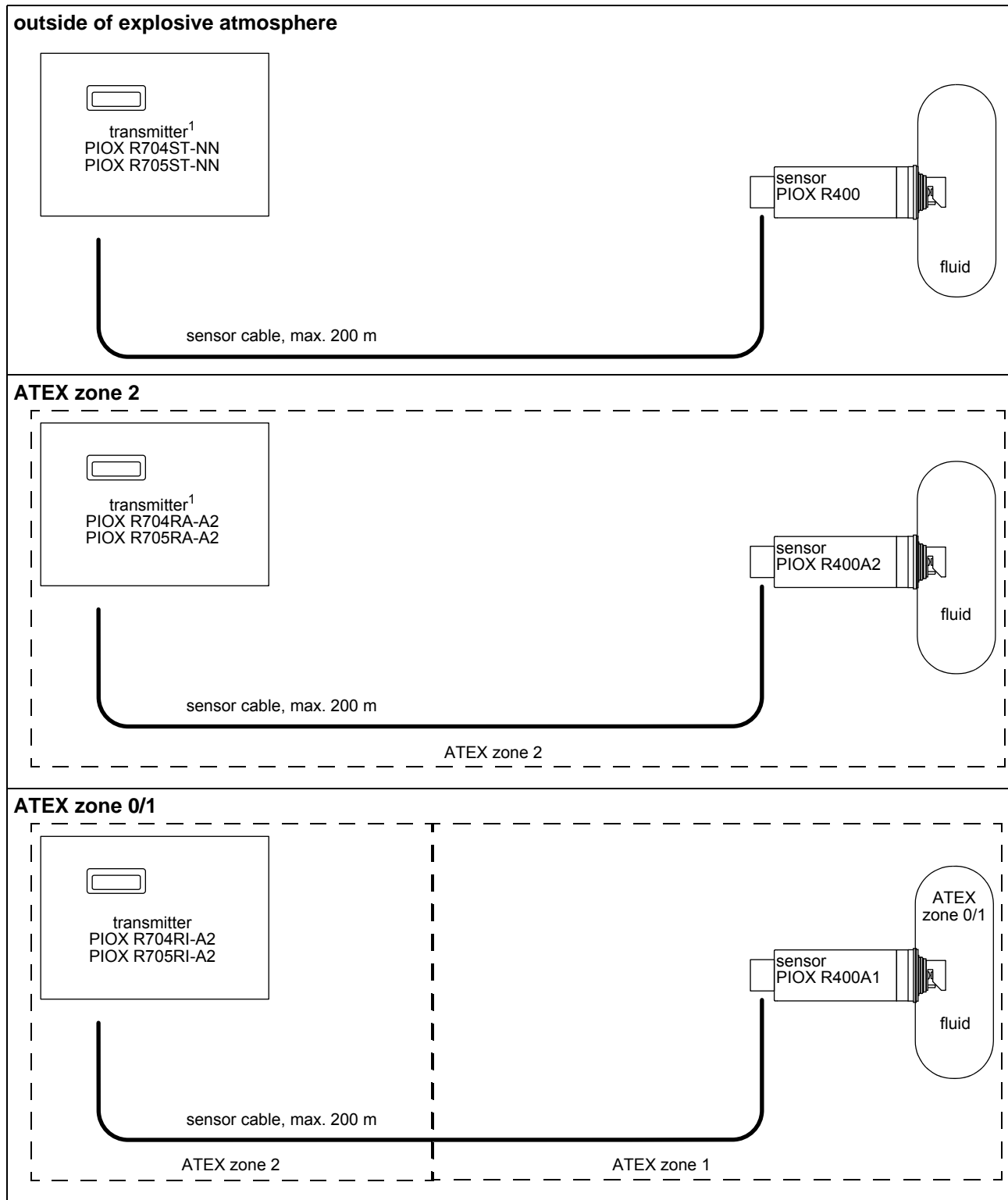
The customized data sets will be transferred between transmitter and PC via the serial interface RS232 or USB.

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



Program RMKoeff - generation of a concentration characteristics



Measuring setups



¹ optional: connection of 2 sensors

Transmitter

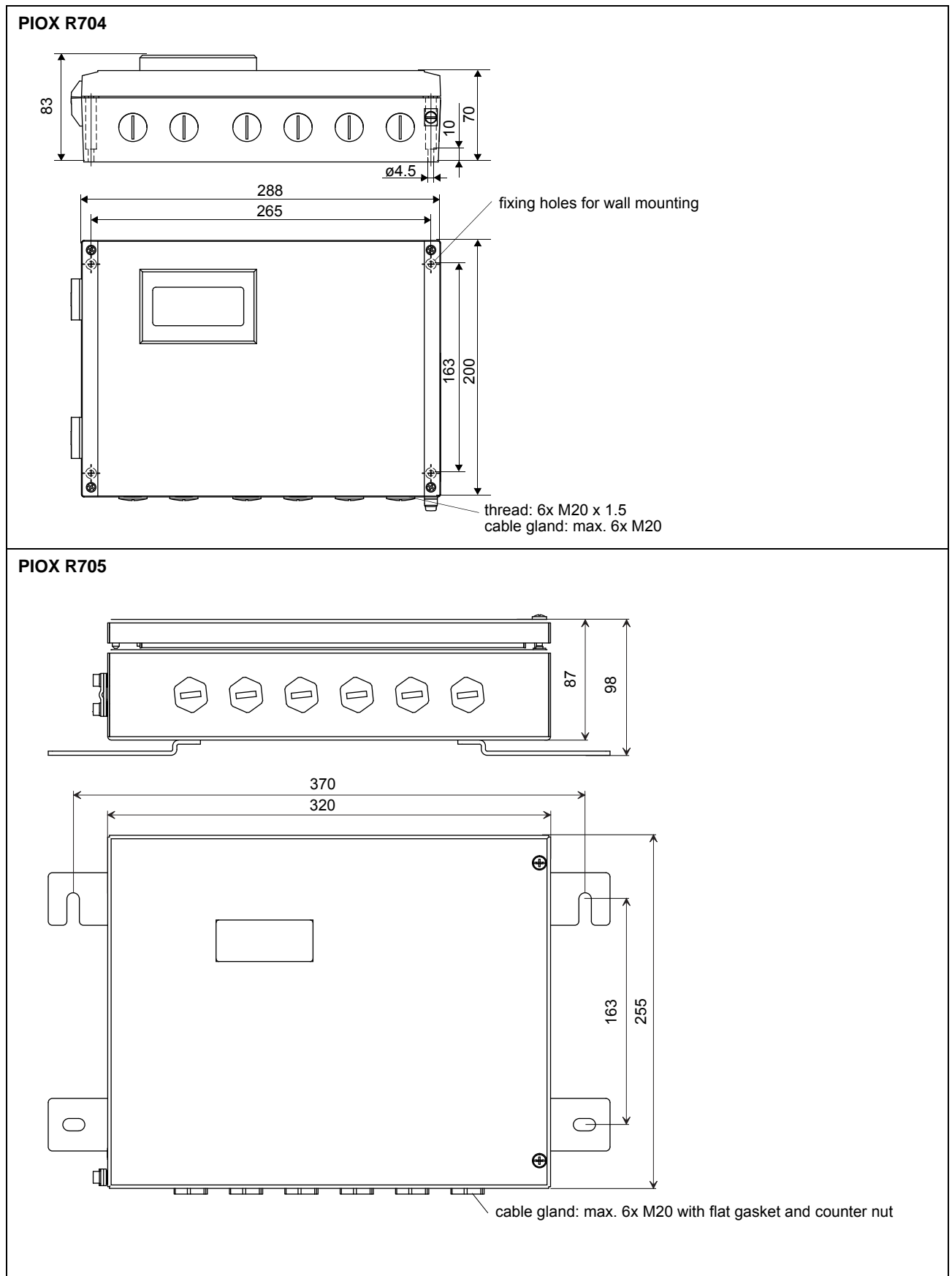
Technical data

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
damping	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 (< -20 °C without operation of the display)			
display	2 x 16 characters, dot matrix, backlight			
menu language	English, German			
explosion protection				
	R704RA-A2	R704RI-A2	R705RA-A2	R705RI-A2
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
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 _m = 250 V	-	U _m = 250 V
measuring functions				
physical quantities	refractive index, fluid temperature, more with application specific output parameters			
diagnostic functions	signal amplitude, sensor humidity, sensor temperature			
data logger				
type	SD card, removable			
capacity	min. 2 GB			
communication				
interface	- process integration: RS485 (optional) - diagnosis: RS232 ¹			
serial data kit				
software (all Windows™ versions)	RMKoeff: management of fluid data sets			
cable	RS232 ¹			
adapter	RS232 - USB ¹			

PIOX	R704ST-NN R704RA-A2	R704RI-A2	R705ST-NN R705RA-A2	R705RI-A2
outputs (optional)				
The outputs are galvanically isolated from the transmitter.				
number	on request			
current output				
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} $R_{ext} < 1 \text{ k}\Omega$			
voltage output				
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	$R_{int} = 500 \Omega$			
frequency output				
range	0...5 kHz			
open collector	24 V/4 mA, $R_{int} = 66.5 \Omega$			
binary output				
Reed relay	48 V/100 mA			
open collector	P1...P4: $R_{int} = 22 \Omega$			
optorelay	24 V/4 mA			
binary output as alarm output	P1...P4: $R_{int} = 22 \Omega$			
- functions	26 V/100 mA			
limit				
inputs (optional)				
The inputs are galvanically isolated from the transmitter.				
number	max. 4, on request			
current input				
accuracy	0.1 % of reading ± 10 µA			
active input	$U_{int} = 24 \text{ V}$, $R_{int} = 50 \Omega$, $P_{int} < 0.5 \text{ W}$, not short-circuit proof			
- range	0...20 mA			
passive input	$R_{int} = 50 \Omega$, $P_{int} < 0.3 \text{ W}$			
- range	-20...+20 mA			
voltage input				
range	0...1 V			
accuracy	0.1 % of reading ± 1 mV			
internal resistance	$R_{int} = 1 \text{ M}\Omega$			

¹ R70***-A2: connection of the interface RS232 outside of explosive atmosphere (housing cover open)

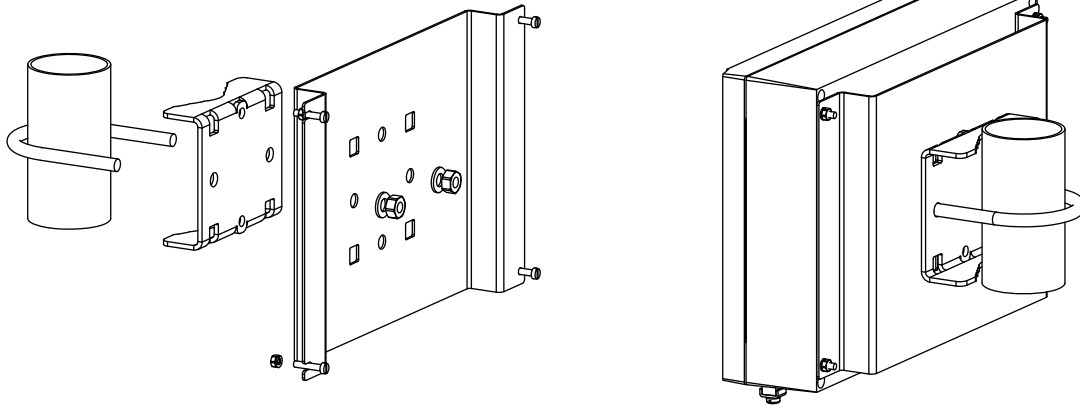
Dimensions



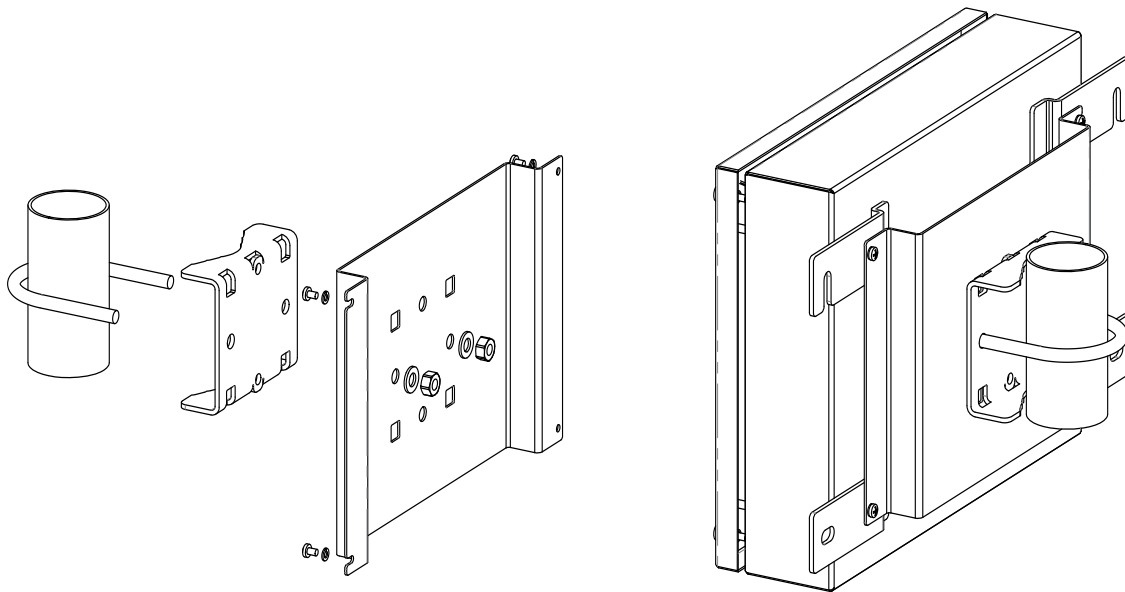
in mm

2" pipe mounting kit (optional)

PIOX R704

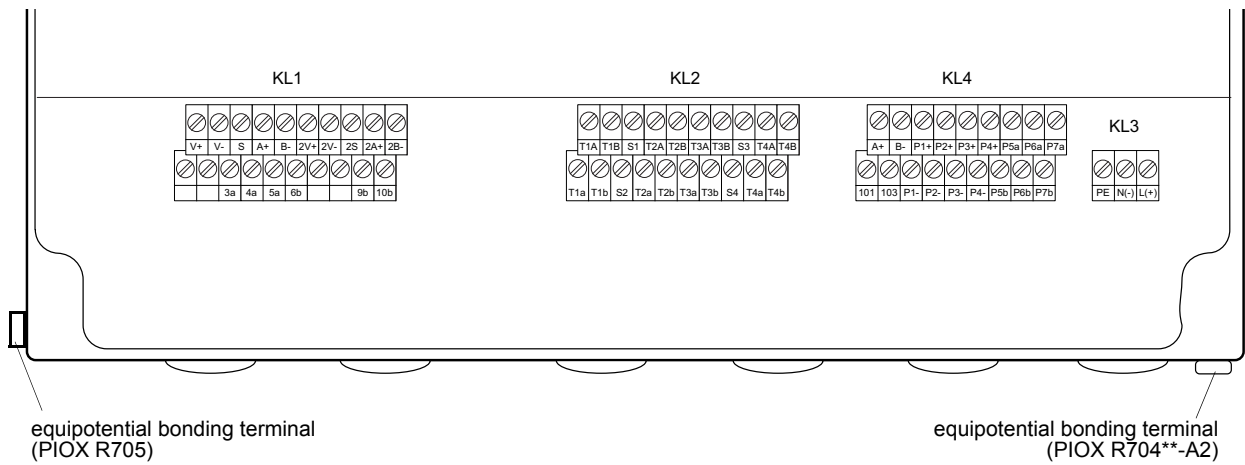


PIOX R705



Terminal assignment

PIOX R704, R705



power supply

terminal strip KL3

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

sensor

terminal strip KL1

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

outputs¹

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 (optorelay)

RS485 (optional)

terminal strip KL4

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

inputs¹

terminal strip KL2

	passive current source	active current source
terminal	connection of an active input	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

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

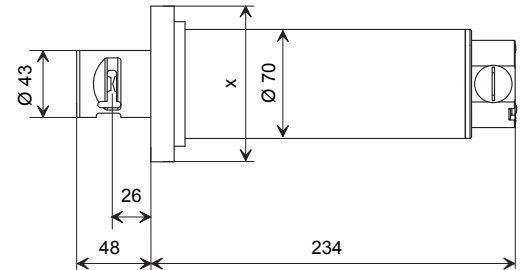
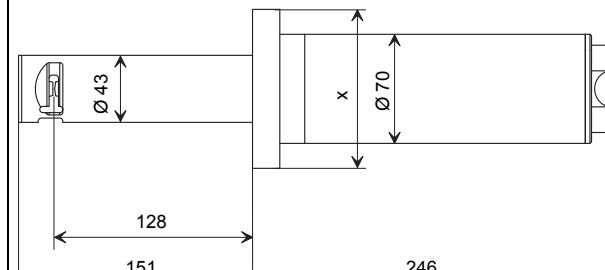
Sensor

Technical data

PIOX	R400	R400A2	R400A1	
process parameters				
fluid	all liquids with a turbidity < 10 000 FAU			
fluid temperature (depending on ambient temperature)	-20...+120 °C			
fluid pressure	PN 10			
measurement				
measurement principle	transmitted light refractometry			
measuring range	nD: 1.3... 1.7			
accuracy (absolute) ¹	nD: 0.000 2 (typical 0.1 wt%)			
repeatability	nD: 0.000 02 (typical 0.01 wt%)			
resolution (display)	nD: 0.000 001			
material				
housing	stainless steel 304 (1.4301), epoxy-powder coated			
wetted parts	PTFE/carbon 25 %			
gaskets	FFKM			
prism	sapphire, nD ≈ 1.76			
degree of protection according to IEC/EN 60529	IP67			
flange				
ambient temperature	-20...+60 °C			
explosion protection				
ATEX	zone	-	2	1
	marking	-	CE (Ex) II3G Ex nA op is IIC T4 Gc II3D Ex tc IIIC T 120 °C Dc Ta -40...+60 °C Tm -20...+120 °C	CE 0637 (Ex) 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...+120 °C
	certification ATEX	-	-	IBExU06ATEX1075 X
	type of protection	-	gas: non sparking dust: protection by enclosure	intrinsic safety, inherently safe optical radiation
temperature probe				
type	Pt1000			
resolution	0.01 K			
accuracy at 20 °C	0.15 K			
response time	20 s			

¹ R400-LCTF: dependent on temperature and flow:
 max. 2.5 m/s at 20 °C
 max. 1 m/s at 80 °C

Dimensions

<p>type of construction M</p>  <table border="1" style="margin-top: 10px; width: 100%; border-collapse: collapse;"> <thead> <tr> <th>pipe diameter</th> <th>x</th> </tr> </thead> <tbody> <tr> <td>DN 50, 2 "</td> <td>Ø100</td> </tr> <tr> <td>DN 80, 3 "</td> <td>Ø122</td> </tr> </tbody> </table>	pipe diameter	x	DN 50, 2 "	Ø100	DN 80, 3 "	Ø122	<p>type of construction L</p>  <table border="1" style="margin-top: 10px; width: 100%; border-collapse: collapse;"> <thead> <tr> <th>pipe diameter</th> <th>x</th> </tr> </thead> <tbody> <tr> <td>DN 50, 2 "</td> <td>Ø102</td> </tr> <tr> <td>DN 80, 3 "</td> <td>Ø124</td> </tr> </tbody> </table>	pipe diameter	x	DN 50, 2 "	Ø102	DN 80, 3 "	Ø124
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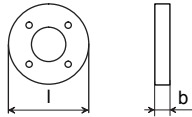
Sensor order code

1, 2	3...5	6, 7	6, 7	8, 9	10, 11	12, 13	14	15...17	18...20	no. of character	description
R	400	-	M								transmitted light refractometer
			L								standard sensor
				C							long sensor
					TF						chemistry design
						TF					PTFE
							KR				FFKM (Kalrez)
								A1			ATEX zone 1 (sensor head in zone 0) (R400A1)
								A2			ATEX zone 2 (R400A2)
								NN			not explosion proof (R400)
									D		direct flange
										H50	DN 50
										H80	DN 80
										H02	2 "
										H03	3 "
										XXX	in m, for max. cable length see page 15
example											
R	400	-	L	C	TF	KR	A1	D	H50	030	long sensor, chemistry design, wetted parts: PTFE, gaskets: FFKM, zone 1 (R400A1), direct flange DN 50, cable length 30 m
R	400	-									

Process connection

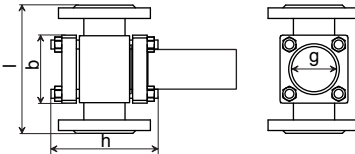
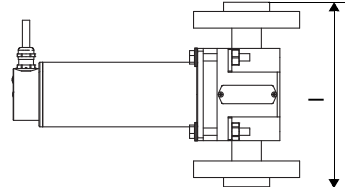
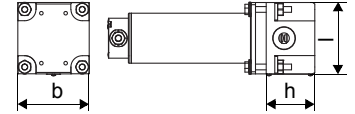
R400-LCTF

included in supply

description	sensor order code	process pressure	pipe diameter	dimensions [mm]		dimensional drawing
				l	b	
direct flange	R400-LCTFKR**DH50	PN 10	DN 50	166	19	
	R400-LCTFKR**DH80		DN 80	201	21	
	R400-LCTFKR**DH02		2"	166	19	
	R400-LCTFKR**DH03		3"	201	21	

R400-MCTFKR**D***

to be ordered separately

description	order code sensor order code	process pressure	pipe diameter	dimensions [mm]				dimensional drawing
				l	b	g	h	
flow chamber and sight glass fitting with PFA liner	PCR-FH050PFNN10 R400-MCTFKR**DH50	PN 10	DN 50	230	120	ø80	185	
	PCR-FH080PFNN10 R400-MCTFKR**DH80		DN 80	310	ø190	ø100	246	
	PCR-FH002PFNN10 R400-MCTFKR**DH50		2"	230	120	ø80	185	
	PCR-FH003PFNN10 R400-MCTFKR**DH80		3"	310	ø190	ø100	246	
flow chamber with flanges (PVDF) gasket: TR2644-SP ¹	PCR-PH025PVFE10 R400-MCTFKR**DH50	PN 10	DN 25	200				
	PCR-PH001PVFE10 R400-MCTFKR**DH50		1 "	200				
flow chamber with screwed connection (PVDF) gasket: TR2644-SP ¹	PCR-PHG38PVFE10 R400-MCTFKR**DH5	PN 10	NPT 3/8"	100	100		68	
	PCR-PHG12PVFE10 R400-MCTFKR**DH50		NPT 1/2"					
	PCR-PHG34PVFE101 R400-MCTFKR**DH50		NPT 3/4"					

¹ gasket TR2644-SP: 63.17 x 2.62 FEP (FPM)

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 grey	
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	
cable jacket				
material		PVC	PVC	
outer diameter	mm	8.9	8.5	
colour		blue	grey	
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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