Non-invasive ultrasonic volumetric flow rate measurement of compressed air

Features
• Non-invasive ultrasonic measurement of compressed air, technical and medical gases
• Integrated standard volumetric flow rate calculation, temperature and pressure compensated via process inputs
• Bidirectional measurement with flow direction detection and separate totalizers
• Drift- and maintenance-free, since there is no measurement impairment due to moisture, dirt or oil
• Perfectly suitable for leakage monitoring by detecting the smallest flow velocities from 0.03 ft/s
• Smart meter/IoT ready via Ethernet interface with corresponding IP data protocols (e.g. Modbus TCP)
• Sophisticated support software for parameterization, remote control, recording and automatic state diagnosis (FluxDiagReader, FluxDiag, Advanced Meter Verification)

Applications
• Energy management and leakage monitoring in compressed air networks
• Monitoring and consumption measurement of medical, pharmaceutical and technical clean gas
• Balancing and cost distribution
• Process optimization

Function

Measurement principle

The transducers are mounted on the pipe which is completely filled with the fluid. The ultrasonic signals are emitted alternately by a transducer and received by the other. The physical quantities are determined from the transit times of the ultrasonic signals.

Path of the ultrasonic signal in the flowing fluid
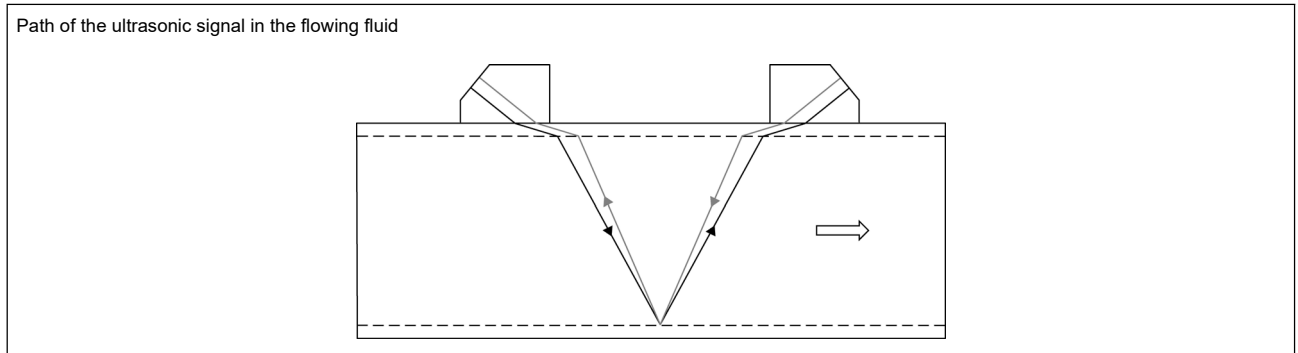
As the fluid where the ultrasound propagates is flowing, the transit time of the ultrasonic signal in flow direction is shorter than the one against the flow direction.

The transit time difference Δt is measured and allows the flowmeter to determine the average flow velocity along the propagation path of the ultrasonic signals. A flow profile correction is then performed in order to obtain the area averaged flow velocity, which is proportional to the volumetric flow rate.

The integrated microprocessors control the entire measuring cycle. The received ultrasonic signals are checked for measurement usability and evaluated for their reliability. Noise signals are eliminated.

Transit time difference Δt
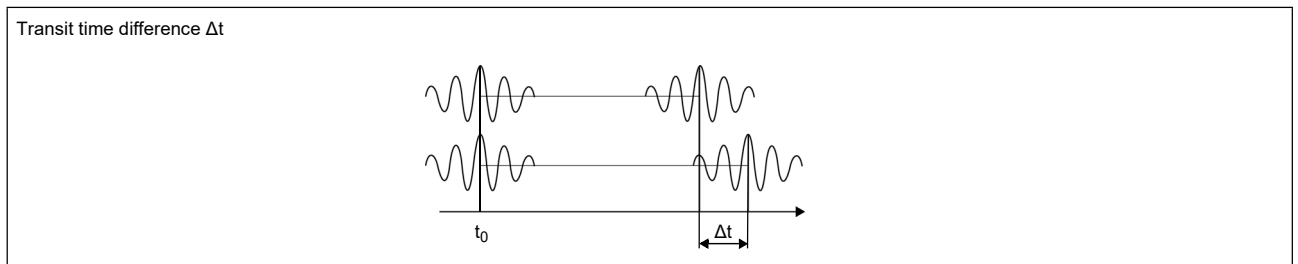
Calculation of volumetric flow rate

$$\dot{V} = k_{Re} \cdot A \cdot k_a \cdot \frac{\Delta t}{2 \cdot t_\gamma}$$

where

$\dot{V}$ -   volumetric flow rate

k_{Re} -   fluid mechanic calibration factor

A -   cross-sectional pipe area

k_a -   acoustic calibration factor

Δt -   transit time difference

t_γ -   average of transit times in the fluid

Calculation of standard volumetric flow rate

The standard volumetric flow rate can be selected as physical quantity. It is calculated with the following formula:

$$\dot{V}_N = \dot{V} \cdot \frac{p}{p_N} \cdot \frac{T_N}{T} \cdot \frac{1}{K}$$

where

$\dot{V}_N$ -   standard volumetric flow rate

$\dot{V}$ -   operating volumetric flow rate

p_N -   standard pressure (absolute value)

p -   operating pressure (absolute value)

T_N -   standard temperature in K

T -   operating temperature in K

K compressibility coefficient of gas: ratio of the compressibility factors of the gas at operating conditions and at standard conditions Z/Z_N
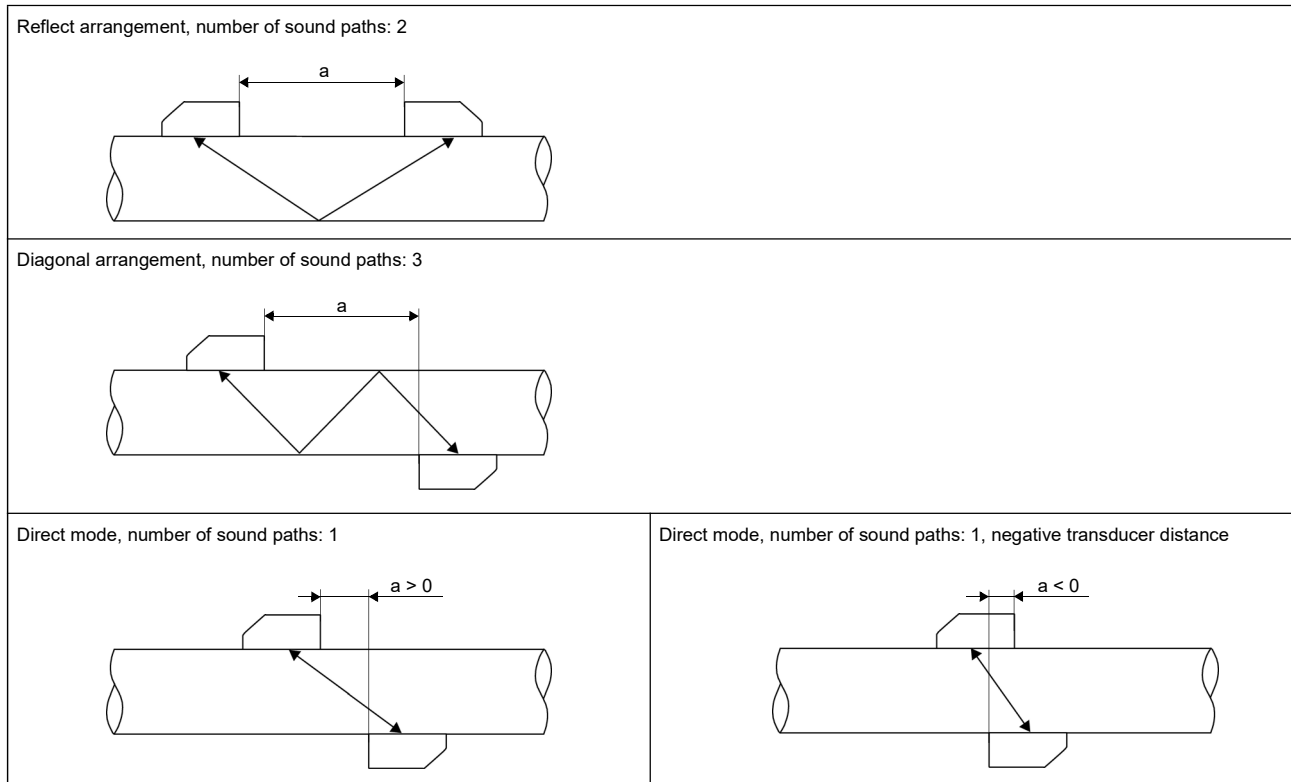
Number of sound paths

The number of sound paths is the number of transits of the ultrasonic signal through the fluid in the pipe. Depending on the number of sound paths, the following methods of installation exist:

- **reflect arrangement**
  The number of sound paths is even. The transducers are mounted on the same side of the pipe. Correct positioning of the transducers is easy.
- **diagonal arrangement**
  The number of sound paths is odd. The transducers are mounted on opposite sides of the pipe.
- **direct mode**
  Diagonal arrangement with 1 sound path. This should be used in the case of a high signal attenuation by the fluid, pipe or coatings.

The preferred method of installation depends on the application. While increasing the number of sound paths increases the accuracy of the measurement, signal attenuation increases as well. The optimum number of sound paths for the parameters of the application will be determined automatically by the transmitter.

As the transducers can be mounted with the transducer mounting fixture in reflect arrangement or diagonal arrangement, the number of sound paths can be adjusted optimally for the application.

Reflect arrangement, number of sound paths: 2

Diagonal arrangement, number of sound paths: 3

Direct mode, number of sound paths: 1

Direct mode, number of sound paths: 1, negative transducer distance

a - transducer distance

Typical measurement setup

Example of a reflect arrangement with connection of the inputs to an external process pressure and temperature measurement for standard volumetric flow rate calculation

transducers

damping mat

transmitter

e.g., external pressure sensor

temperature probe

inputs
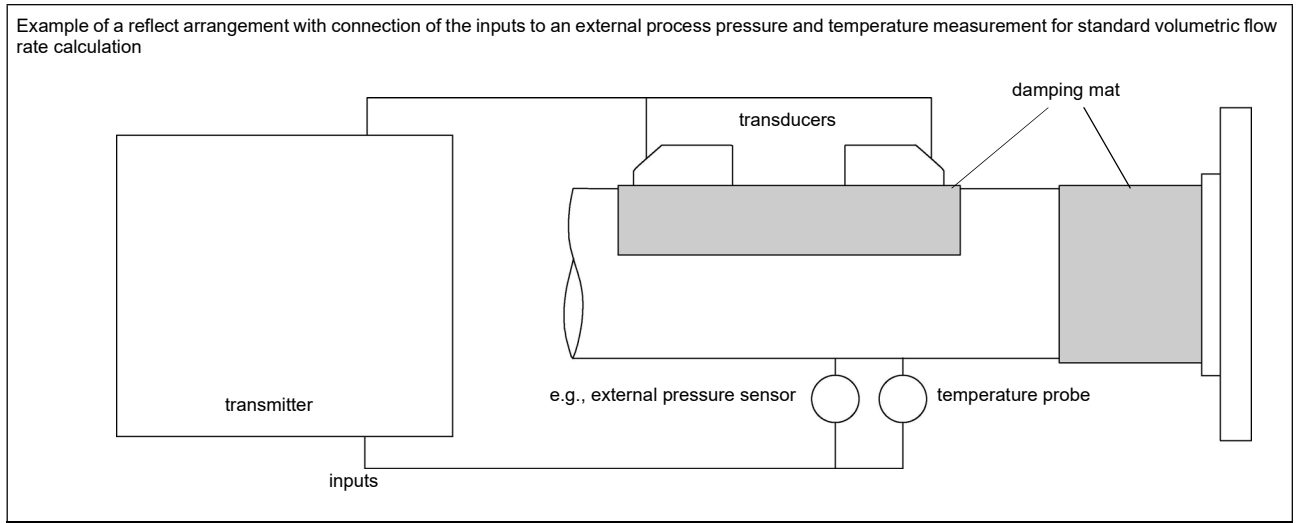
Transmitter

Technical data

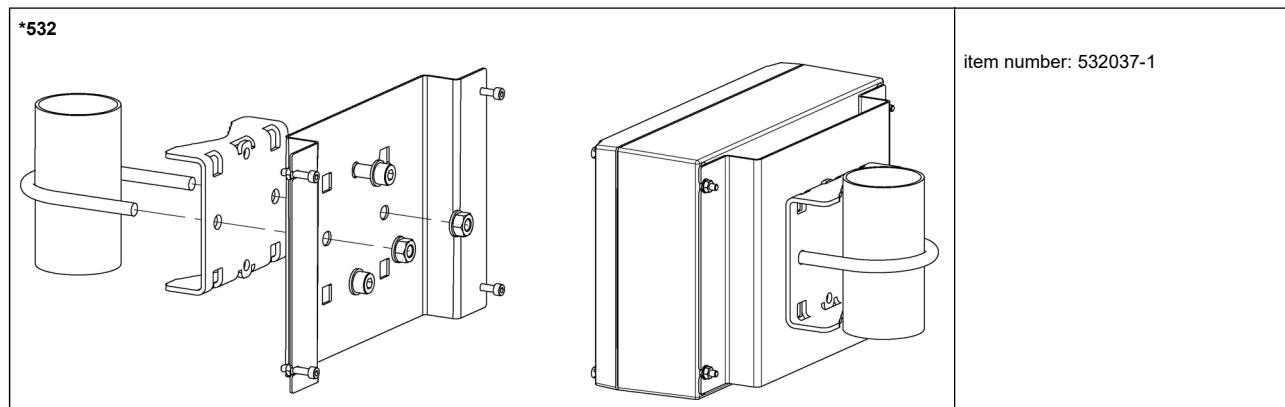|		FLUXUS G532CA (analog outputs)	FLUXUS G532CA (process interface)
design		field device with 1 measuring channel	
application		flow measurement of compressed air, industrial, pharmaceutical and clean gases	
measurement			
measurement principle		transit time difference correlation principle	
flow direction		bidirectional	
flow velocity	ft/s	0.03 to 115, depending on pipe diameter	
repeatability		0.15 % MV ±0.02 ft/s	
fluid		compressed air, oxygen, nitrogen, argon, helium	
temperature compensation		corresponding to the recommendations in ANSI/ASME MFC-5.1-2011	
measurement uncertainty (volumetric flow rate)			
measurement uncertainty of the measuring system[1]		±0.3 % MV ±0.02 ft/s includes calibration certificate traceable to NIST	
measurement uncertainty at the measuring point		±1 to 2 % MV ±0.02 ft/s, contact FLEXIM for an application specific uncertainty evaluation	
transmitter			
power supply		• 90 to 250 V/50 to 60 Hz or • 11 to 32 V DC	
power consumption	W	< 10	
number of measuring channels		1	
damping	s	0 to 100 (adjustable)	
measuring cycle	Hz	100 to 1000	
response time	s	1	
housing material		aluminum, powder coated	
degree of protection		IP66	
dimensions	inch	see dimensional drawing	
weight	lb	7	
fixation		wall mounting, optional: 2" pipe mounting	
ambient temperature	°F	-4 to +140	
display		128 x 64 pixels, backlight	
menu language		English, German, French, Spanish, Dutch, Russian, Polish, Turkish, Italian, Chinese	
certificates			
use in unclassified (ordinary) locations		optional: FM23NUS0010 FM23NCA0007	
measuring functions			
physical quantities		operating volumetric flow rate, standard volumetric flow rate, mass flow rate, flow velocity	
totalizer		volume, mass	
diagnostic functions		sound speed, signal amplitude, SNR, SCNR, standard deviation of amplitudes and transit times	
communication interfaces			
service interfaces		measured value transmission, parametrization of the transmitter: • USB • LAN	measured value transmission, parametrization of the transmitter: • USB • LAN
process interfaces		-	1 option: • Modbus RTU • BACnet MS/TP • HART • Modbus TCP • BACnet IP
accessories			
data transmission kit		USB cable	
software		• FluxDiagReader: reading of measured values and parameters, graphical representation • FluxDiag (optional): reading of measurement data, graphical representation, report generation, parametrization of the transmitter	
data logger			
loggable values		all physical quantities and totalized physical quantities	
capacity		max. 800 000 measured values	

[1] with aperture calibration of the transducers

		FLUXUS G532CA (analog outputs)	FLUXUS G532CA (process interface)
outputs			
		The outputs are galvanically isolated from the transmitter.	
• switchable current output			
		configurable according to NAMUR NE 43	
number		1	optional: 1 (HART)
range	mA	4 to 20 (alarm current: 3.2 to 3.99, 20.01 to 24, hardware fault current: 3.2)	4 to 20 (alarm current: 3.2 to 3.99, 20.01 to 24, hardware fault current: 3.2)
uncertainty		0.04 % of output value ±3 µA	0.04 % of output value ±3 µA
active output		R_{ext} = 250 to 530 Ω, $U_{opencircuit}$ = 28 V DC	R_{ext} = 250 to 530 Ω, $U_{opencircuit}$ = 28 V DC
passive output		U_{ext} = 9 to 30 V DC, depending on R_{ext} (R_{ext} < 458 Ω at 20 V)	U_{ext} = 9 to 30 V DC, depending on R_{ext} (R_{ext} < 458 Ω at 20 V)
current output in HART mode • range	mA	-	4 to 20 (alarm current: 3.5 to 3.99, 20.01 to 22, hardware fault current: 3.2)
• active output		-	R_{ext} = 250 to 530 Ω, $U_{opencircuit}$ = 28 V DC
• passive output		-	U_{ext} = 9 to 30 V DC, depending on R_{ext} (R_{ext} = 250 to 458 Ω at 20 V)
• digital output			
functions		• frequency output • binary output • pulse output	-
number		2	-
operating parameters		U_{ext} = (8.2 ±0.1) V DC	-
frequency output • range	kHz	0 to 10	-
binary output • binary output as alarm output		limit, change of flow direction or error	-
pulse output • pulse value	units	0.01 to 1000	-
• pulse width	ms	0.05 to 1000	-
inputs			
		The inputs are galvanically isolated from the transmitter.	
• temperature input			
number		1	
type		Pt100/Pt1000	
connection		4-wire	
range	°F	-238 to +1040	
resolution	K	0.01	
accuracy		±0.01 % MV ±0.03 K	
• switchable current input			
number		1	
accuracy		±0.1 % MV ±0.01 mA	
active input • range	mA	U_{out} = max. 28 V, R_{int} = 75 Ω 0 to 24	
passive input • range	mA	R_{int} = 35 Ω, U_{out} = 26 V, I_{max} ≤ 24 mA 0 to 20	

[1] with aperture calibration of the transducers

Dimensions

thread: 5x M20 x 1.5
cable gland: max. 5x 1/2 NPT

ø0.3

3.15

0.43

ø0.18

8.86

4.84

6.3

9.45

fixing holes for wall mounting

in inch

*532
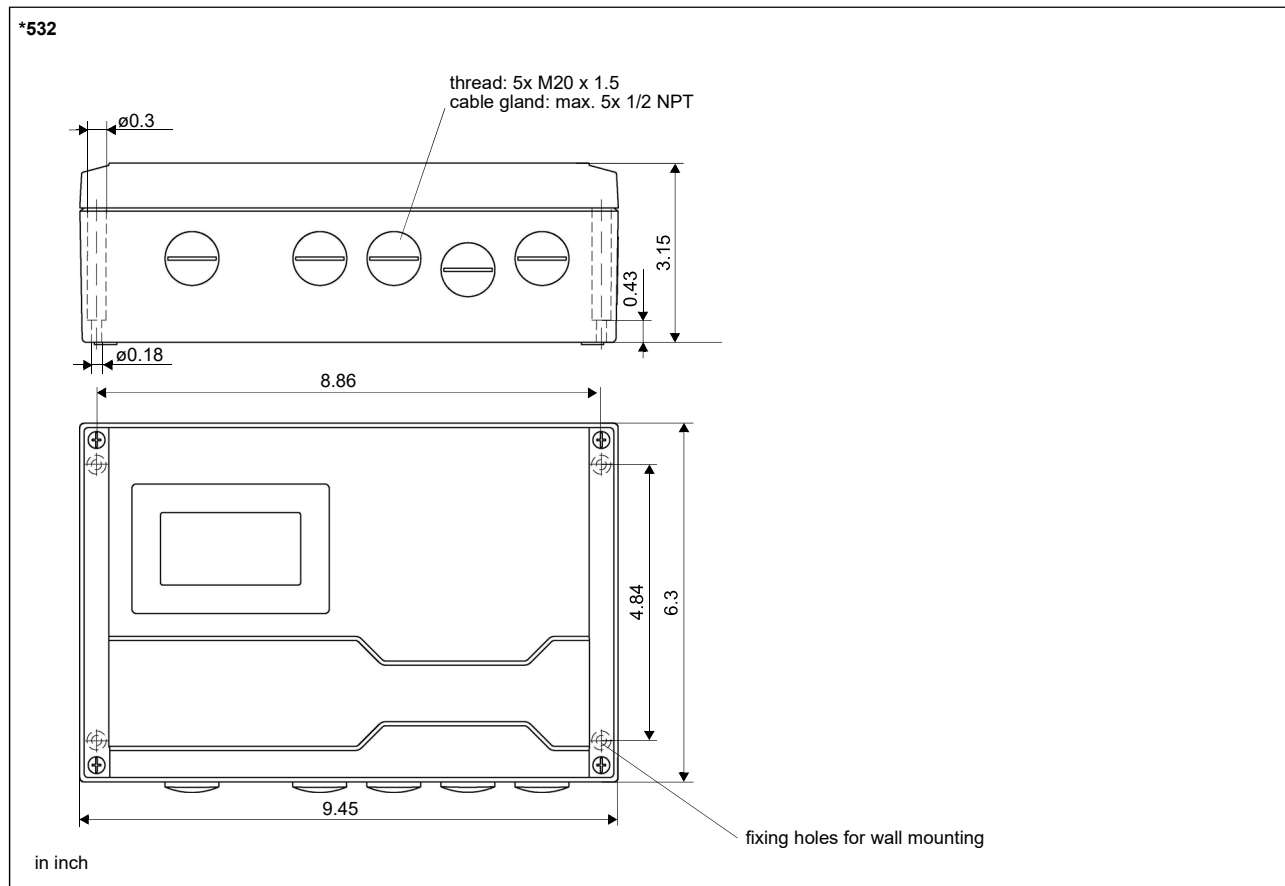
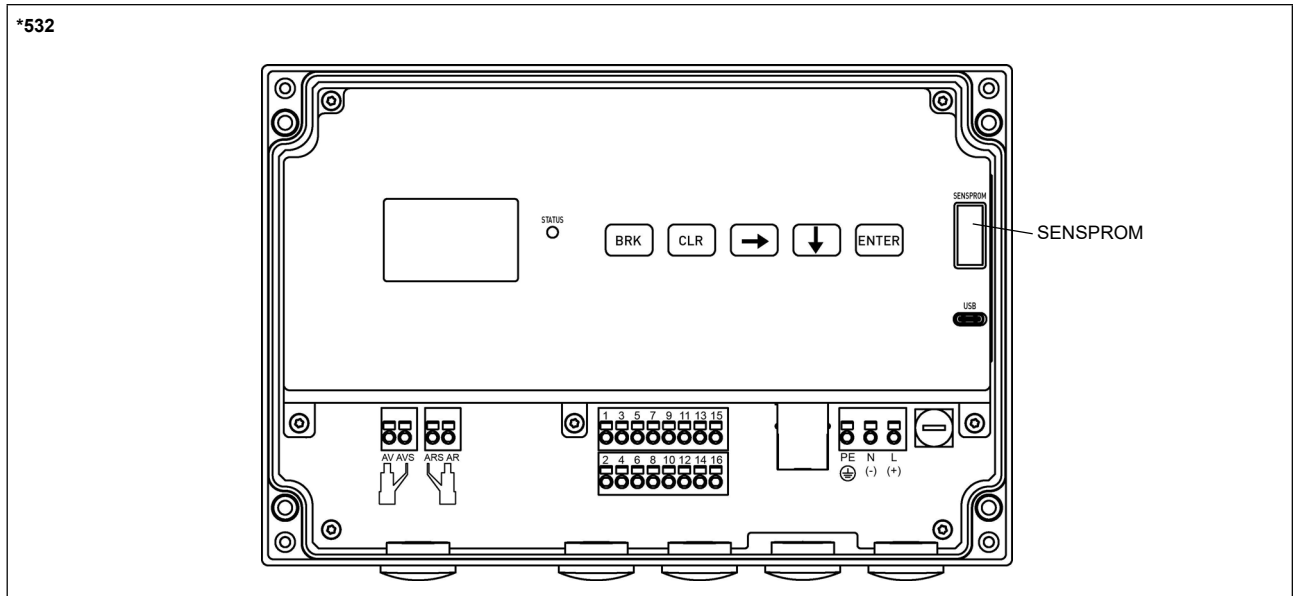## 2" pipe mounting kit (optional)

*532

item number: 532037-1

Storage

• do not store outdoors
• store within the original package
• store in a dry and dust-free place
• protect against sunlight
• keep all openings closed
• storing temperature: -4…+140 °F

Terminal assignment

*532

power supply[1]

terminal	connection (AC)	terminal	connection (DC)
PE	protective conductor	PE	protective conductor
N	neutral conductor	(-)	-
L	outer conductor	(+)	+

transducers

terminal	connection	transducer
AV	signal	⬆
AVS	internal shield	
ARS	internal shield	⬆
AR	signal	
cable gland	external shield	⬆ ⬆

outputs, inputs[1, 2]

terminal	connection
13+, 14-	passive current output
13-, 14+	active current output
9+, 10- 11+, 12-	digital output
15+, 16-	passive current output/HART
15-, 16+	active current output/HART
1, 2, 3, 4	temperature input
5+, 6-	passive current input
5-, 6+	active current input

temperature probe

terminal	direct connection	connection with extension cable
1	red	white
2	white	red
3	red	black
4	white	green

communication interfaces

terminal	connection	communication interface
15	signal +	• Modbus RTU[1]
16	signal -	• BACnet MS/TP[1]
USB	type C Hi-Speed USB 2.0 Device	service (FluxDiag/FluxDiagReader)
LAN	RJ45 10/100 Mbps Ethernet	• service (FluxDiag/FluxDiagReader) • Modbus TCP • BACnet IP

[1] cable (by customer): e.g., flexible wires, with insulated wire ferrules, wire cross-section: AWG14 to 24

[2] The number, type and terminal assignment are customized.

Transducers

Technical data

Lamb wave transducers

order code		GLK-NNNN-**TS	GLM-NNNN-**TS	GLP-NNNN-**TS	GLQ-NNNN-**TS
technical type		G(RT)K1N52	G(RT)M1N52	G(RT)P1N52	G(RT)Q1N52
transducer frequency	MHz	0.5	1	2	4
fluid pressure[1]					
min. extended	psi	metal pipe: 145 (d > 4.7 inch) 44 (d < 4.7 inch)	metal pipe: 44 (d < 2.4 inch)	metal pipe: 44 (d < 1.4 inch)	metal pipe: 44 (d < 0.59 inch)
min.	psi	metal pipe: 218 (d > 4.7 inch) 145 (d < 4.7 inch) plastic pipe: 15	metal pipe: 145 (d > 2.4 inch) 73 (d < 2.4 inch) plastic pipe: 15	metal pipe: 145 (d > 1.4 inch) 73 (d < 1.4 inch) plastic pipe: 15	metal pipe: 145 (d > 0.59 inch) 73 (d < 0.59 inch) plastic pipe: 15
inner pipe diameter d[2]					
min. extended	inch	2.4	1.2	0.59	0.28
min. recommended	inch	3.1	1.6	0.79	0.39
max. recommended	inch	11.8	5.9	2	0.87
max. extended	inch	14.2	7.1	2.4	1.2
pipe wall thickness					
min.	inch	0.2	0.1	0.05	0.02
max.	inch	0.39	0.2	0.12	0.05
material					
housing		PPSU with stainless steel cover 304, ***-*****/OS: 316L			
contact surface		PPSU			
degree of protection		IP66			
transducer cable					
type		1699			
length	ft	16	13		9
length (***-*****/LC)	ft	29			
dimensions					
length l	inch	5.06	2.91		1.65
width b	inch	2.01	1.26		0.87
height h	inch	2.66	1.59		1
dimensional drawing					
weight (without cable)	lb	1	0.17		0.04
pipe surface temperature	°F	-40 to +266			
ambient temperature	°F	-40 to +266			
temperature compensation		x			

[1] depending on the application, typical absolute value for natural gas, nitrogen, compressed air

[2] Lamb wave transducer:
typical values for natural gas, nitrogen, oxygen; pipe diameters for other fluids on request
inner pipe diameter max. recommended: in reflect arrangement (diagonal arrangement) and for a flow velocity of 49 ft/s (98 ft/s)
inner pipe diameter max. extended: in reflect arrangement (diagonal arrangement) and for a flow velocity of 39 ft/s (82 ft/s)
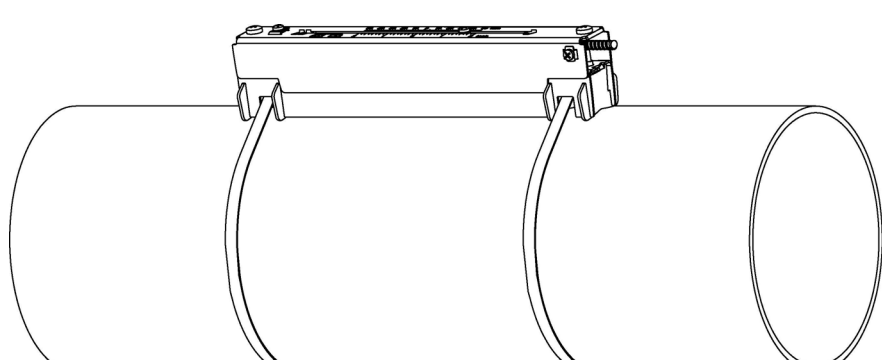
Shear wave transducers (optional)

order code		GSK-NNNN-**TS	GSM-NNNN-**TS	GSP-NNNN-**TS	GSQ-NNNN-**TS
technical type		G(DL)K1N52	G(DL)M2N52	G(DL)P2N52	G(DL)Q2N52
transducer frequency	MHz	0.5	1	2	4
fluid pressure[1]					
min. extended	psi	metal pipe: 290			
min.	psi	metal pipe: 435, plastic pipe: 15			
inner pipe diameter d[2]					
min. extended	inch	2.4	1.2	0.59	0.28
min. recommended	inch	3.1	1.6	0.79	0.39
max. recommended	inch	11.8	5.9	2	0.87
max. extended	inch	14.2	7.1	2.4	1.2
pipe wall thickness					
min.	inch	0.2	0.1	0.05	0.02
material					
housing		PEEK with stainless steel cover 304, ***-*****/OS: 316L			
contact surface		PEEK			
degree of protection		IP66	IP66/IP67		
transducer cable					
type		1699			
length	ft	16	13		9
length (***-*****/LC)	ft	29			
dimensions					
length l	inch	4.98	2.52		1.57
width b	inch	2.01	1.26		0.87
height h	inch	2.66	1.59		1
dimensional drawing					
weight (without cable)	lb	0.79	0.15		0.04
pipe surface temperature	°F	-40 to +266			
ambient temperature	°F	-40 to +266			
temperature compensation		x			

[1] depending on the application, typical absolute value for natural gas, nitrogen, compressed air

[2] shear wave transducer:
typical values for natural gas, nitrogen, oxygen; pipe diameters for other fluids on request
inner pipe diameter max. recommended/max. extended: in reflect arrangement and for a flow velocity of 49 ft/s

Transducer mounting fixture

PermaRail (VL)

material: stainless steel 316Ti, 316L, 17-7PH
inner length:
VLK: 13.7 inch
VL(MP): 9.2 inch
VLQ: 6.9 inch
dimensions:
VLK: 16.65 x 3.54 x 3.66 inch
VL(MP): 12.17 x 2.24 x 2.48 inch
VLQ: 9.72 x 1.69 x 1.85 inch

Coupling materials for transducers

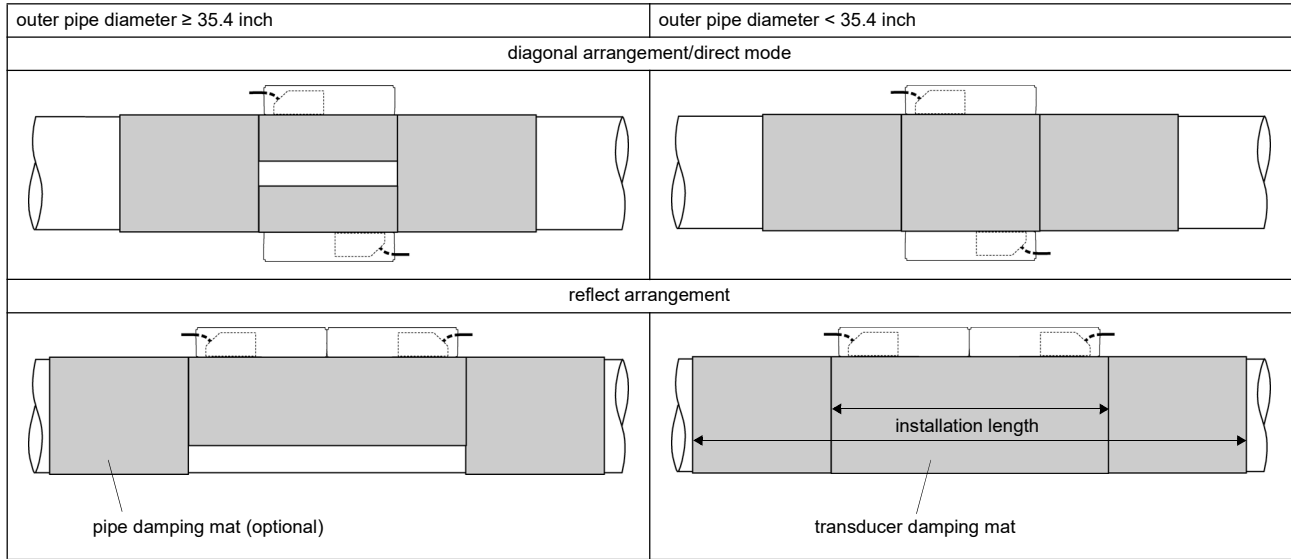| type	ambient temperature °F
coupling compound type N	-22 to +266
coupling pad type VT	14 to +392

Damping mats

Damping mats will be used for the gas measurement to reduce acoustic noise influences on the measurement.

transducer damping mat
Transducer damping mats will be installed below the transducers.

pipe damping mat
Pipe damping mats will be installed if the sound propagation is disturbed at reflection points (e.g., flange, weld). Depending on the noise, the pipe damping mats will be installed at one or both sides of the transducer damping mat. If the local conditions are unknown, pipe damping mats should be installed.

outer pipe diameter ≥ 35.4 inch	outer pipe diameter < 35.4 inch
diagonal arrangement/direct mode	
reflect arrangement	
pipe damping mat (optional)	installation length / transducer damping mat

Technical data

type		E30R4	E30R3
item number		992080-11	992080-10
width	inch	8.9	2
thickness	inch	0.03	
length (per roll)	ft	32	
weight	lb/ft^2	2.2	
ambient temperature	°F	-22 to +176	
properties		self-adhesive	

Dimensioning

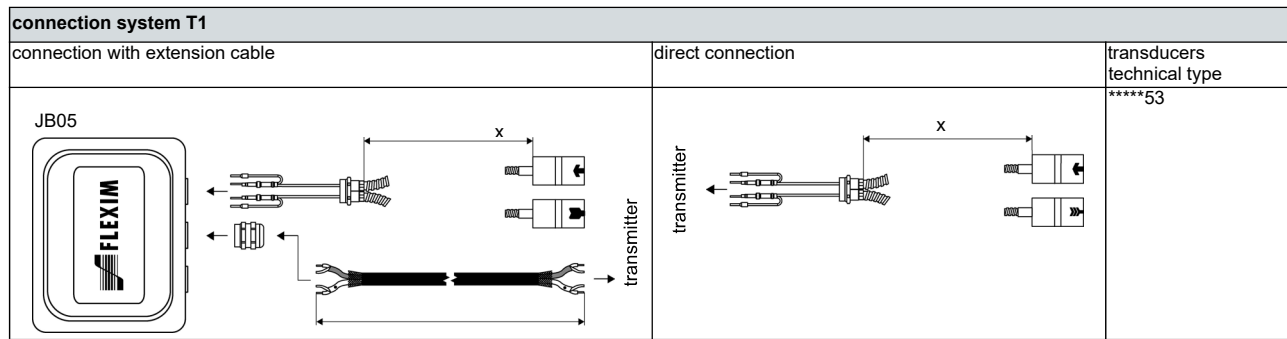| transducer		damping mat						
transducer mounting fixture	order code	type	number of layers	transducer damping mat			transducer damping mat + 2x pipe damping mat		
				max. installation length [inch]	number of rolls[1] standard[2]	extended[2]	max. installation length [inch]	number of rolls[1] standard	extended
PermaRail									
VLK	GLK	E30R4	1	35	1	1	72	2	2
VLM	GLM	E30R3	1	26	1	1	53.5	2	2
	GLP		1		1	1		1	1
VLQ	GLQ	E30R3	1	21.3	1	1	44.1	1	1

[1] calculation on the base of:
    max. installation length (installation of one transducer mounting fixture per transducer in reflect arrangement) and
    max. recommended pipe diameter (standard) or max. extended pipe diameter (extended)

[2] calculation of the number of rolls when both transducers are mounted in one transducer mounting fixture (reflect arrangement) or in diagonal arrangement/direct mode: number of rolls/2 and round up to the nearest integer

Connection systems

connection system T1		
connection with extension cable	direct connection	transducers technical type
JB05	transmitter	*****53

Cable

transducer cable		
type		**1699**
weight	lb/ft	0.06
ambient temperature	°F	-67 to +392
cable jacket		
material		PTFE
outer diameter	inch	0.11
thickness	inch	0.01
color		brown
shield		x
sheath		
material		stainless steel 316Ti
outer diameter	inch	0.31

extension cable		
type		**2615**
weight	lb/ft	0.12
ambient temperature	°F	-22 to +158
properties		halogen-free
		fire propagation test according to IEC 60332-1
		combustion test according to IEC 60754-2
cable jacket		
material		PUR
outer diameter	inch	0.47
thickness	inch	0.08
color		black
shield		x

Cable length

transducer frequency		K		M, P		Q	
transducers technical type		x	l	x	l	x	l
*(DR)***5*	ft	16	≤ 984	13	≤ 984	9	≤ 295
*(LT)***5*	ft	29	≤ 984	29	≤ 984	29	≤ 295

x = transducer cable length

l = max. length of extension cable (depending on the application)

Junction box

Technical data

JB05					
weight	lb	2.6 lb			
fixation		wall mounting optional: 2" pipe mounting			
material					
housing		stainless steel 316L			
gasket		silicone			
degree of protection		IP66/IP67			
ambient temperature	°F	-40 to +176			

Connection

Transducers

terminal strip	terminal	connection	transducer
KL1	V	signal	⬆
	VS	internal shield	
	RS	internal shield	⬆
	R	signal	

Extension cable

terminal strip	terminal	connection
KL2	TV	signal
	TVS	internal shield
	TRS	internal shield
	TR	signal

Dimensions

JB0*, JBP*

wall mounting holder

6.14

6.85

2.76

Ø 0.35

6.44

0.08

4.69

thread: 3x M20 x 1.5
cable gland: max. 2x 1/2 NPT

in inch
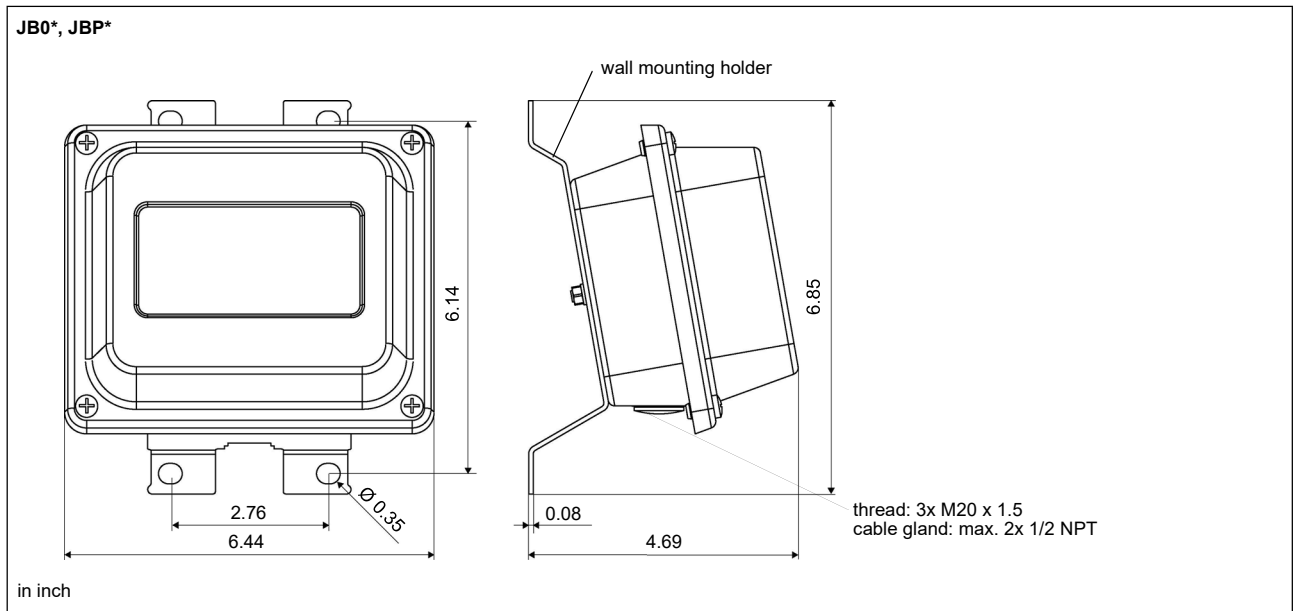
2" pipe mounting kit
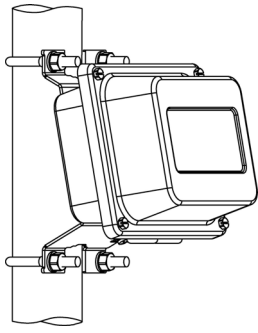
JB**	item number: 751035-2

Temperature probes

Technical data

PT13N		
design		clamp-on
type		Pt1000
connection		4-wire
measuring range	°F	-40 to +392
accuracy T		$\pm(0.27\ °F + 2 \cdot 10^{-3} \cdot (|T\ [°F]| - 32\ °F))$ class A
housing material		360 brass alloy
degree of protection		NEMA 4
dimensions		
length l	inch	0.79
width b	inch	0.59
height h	inch	0.49
dimensional drawing		
weight	lb	0.437
accessories		
thermal conductivity foil 482 °F		x

Connection system

connection with extension cable	direct connection
extension cable	

Connection

temperature probe
red
red
white
white

Cable

		temperature probe	extension cable
type		4 x 24 AWG	4 x 18 AWG
standard length	ft	20	-
max. length	ft	-	656
cable jacket		PTFE	LS PVC

Fixation

tension strap PT13N	
	material: stainless steel 301, 410 thermal insulation necessary

Junction box

½" NPT
1.18″   4.72″   1.18″
1.34″
1/2″ COVER
Top View
Side View

Connection

temperature probe	extension cable
red	white
red	black
white	green
white	red