

Non-invasive ultrasonic mass flow rate and volumetric flow rate measurement of saturated steam

Features

- Non-invasive measurement of saturated steam up to 356 °F without fluid contact – no need to open the pipe
- Temperature-compensated mass flow rate calculation via saturated steam curve possible
- Very high measuring dynamics of 0.33 to 197 ft/s – no need to reduce pipe diameters
- Cost-efficient due to start-up during ongoing operation and without pressure/energy loss in the steam network
- Drift-free and maintenance-free, as no wear and tear
- Compact transducers that are easy to insulate – no energy loss at the measuring point
- 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

For the following measuring tasks in pharmaceutical, food and manufacturing industries, building technology and hospitals:

- Energy management and energy efficiency
- Quantity balancing and cost distribution
- Consumption metering
- Process/boiler optimization



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Errors excepted.
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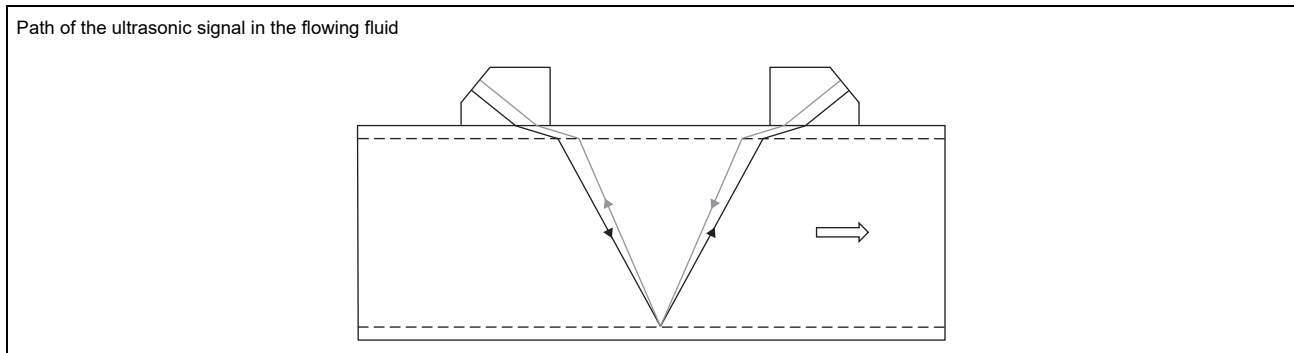
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Function

Measurement principle

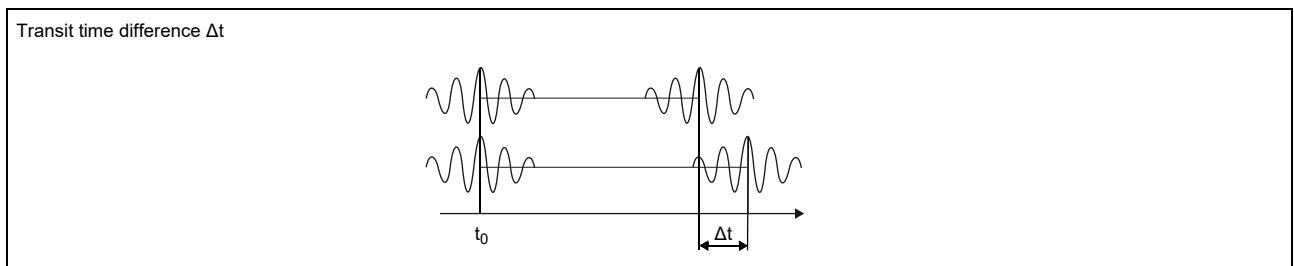
The transducers are mounted on the pipe which is completely filled with the fluid. The ultrasonic signals are emitted alternately by a transducer and received by the other. The physical quantities are determined from the transit times of the ultrasonic signals.



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.



Calculation of volumetric flow rate

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

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_y - average of transit times in the fluid

Calculation of mass flow rate

The mass flow rate is calculated from the operating density and the volumetric flow rate:

$$\dot{m} = \rho \cdot \dot{V}$$

The operating density of the fluid is calculated as the function of pressure and temperature of the fluid:

$$\rho = f(p, T)$$

where

- ρ - operating density
- p - fluid pressure
- T - fluid temperature
- \dot{m} - mass flow rate
- \dot{V} - volumetric flow rate

Temperature-compensated mass flow rate calculation via the saturated steam curve is possible.

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.

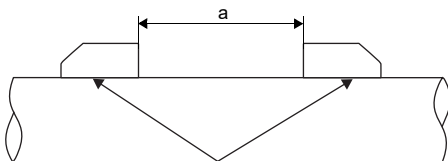
- **direct mode**

Diagonal arrangement with 1 sound path. This should be used in the case of a high signal attenuation by the fluid, pipe or coatings.

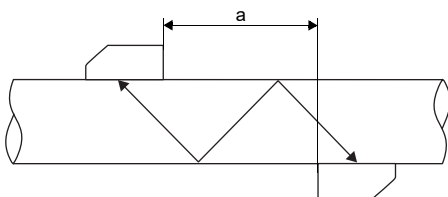
The preferred method of installation depends on the application. While increasing the number of sound paths increases the accuracy of the measurement, signal attenuation increases as well. The optimum number of sound paths for the parameters of the application will be determined automatically by the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

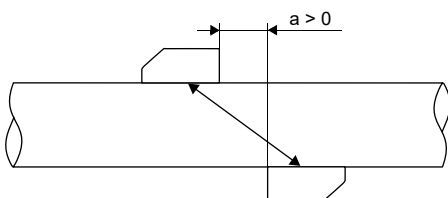
Reflect arrangement, number of sound paths: 2



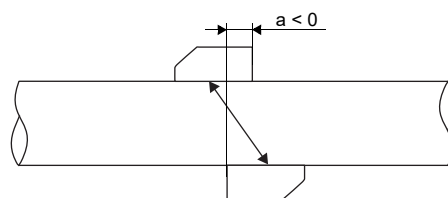
Diagonal arrangement, number of sound paths: 3



Direct mode, number of sound paths: 1



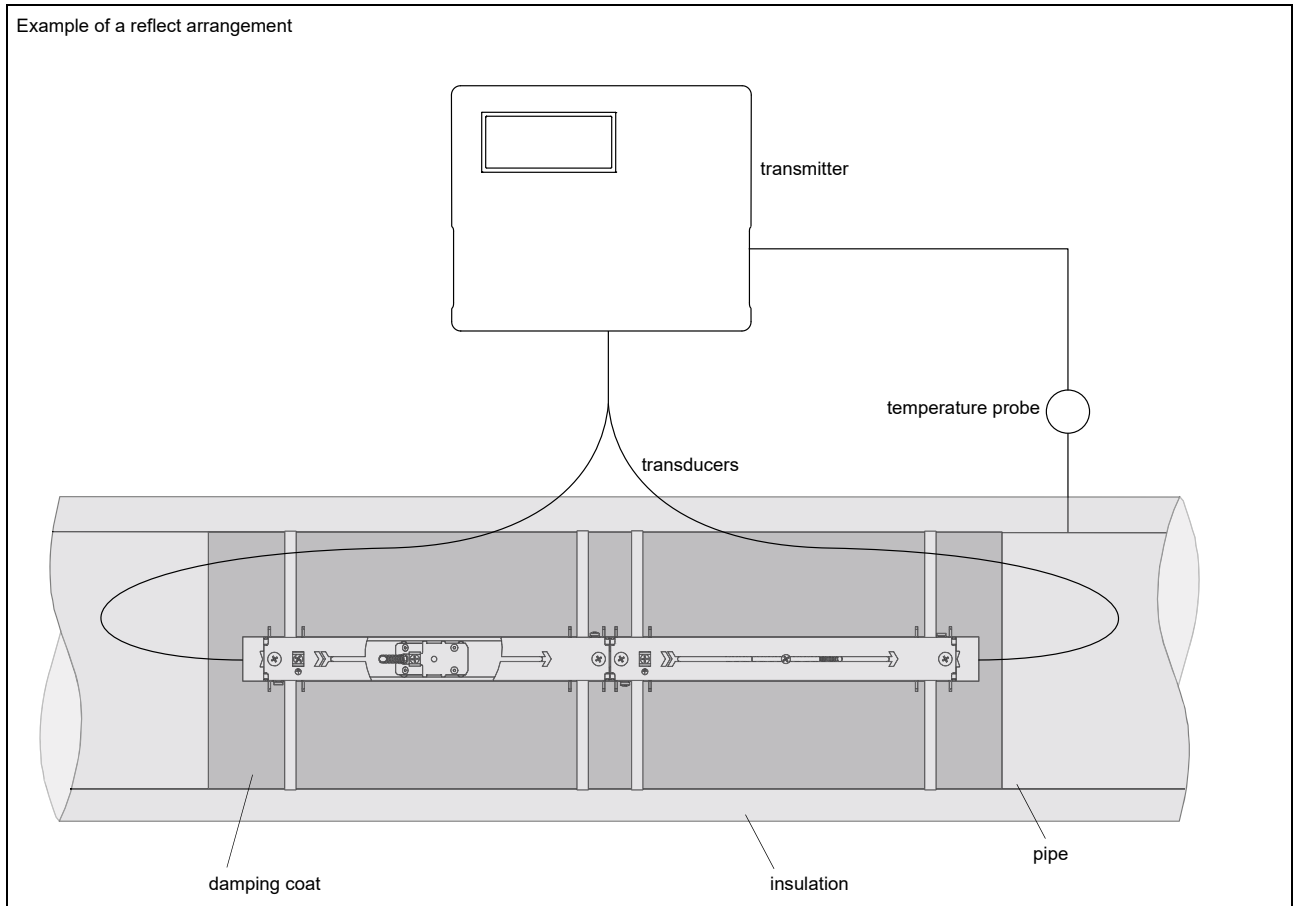
Direct mode, number of sound paths: 1, negative transducer distance



a - transducer distance


Typical measurement setup

Example of a reflect arrangement



Transmitter

Technical data

		FLUXUS G532ST-LT (analog outputs)	FLUXUS G532ST-LT (process interface)
			
design		field device with 1 measuring channel	
application		steam measurement ²	
measurement			
measurement principle		transit time difference correlation principle	
flow velocity		depending on pipe diameter and transducer, see diagrams	
repeatability		0.15 % MV ±0.02 ft/s	
fluid		saturated steam, superheated steam	
fluid pressure	psia	44 to 145	
fluid temperature	°F	275 to 356	
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 3 % MV ±0.02 ft/s, depending on the application	
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	
measuring functions			
physical quantities		operating 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		-	• Modbus RTU or • BACnet MS/TP or • Modbus TCP or • 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	
outputs			
		The outputs are galvanically isolated from the transmitter.	
• switchable current output			
		configurable according to NAMUR NE43	
number		1	-
range	mA	4 to 20 (3.2 to 24)	-
accuracy		0.04 % MV ±3 µA	-
active output		R _{ext} < 530 Ω	-
passive output		U _{ext} = 9 to 30 V, depending on R _{ext} (R _{ext} < 458 Ω at 20 V)	-

¹ with aperture calibration of the transducers

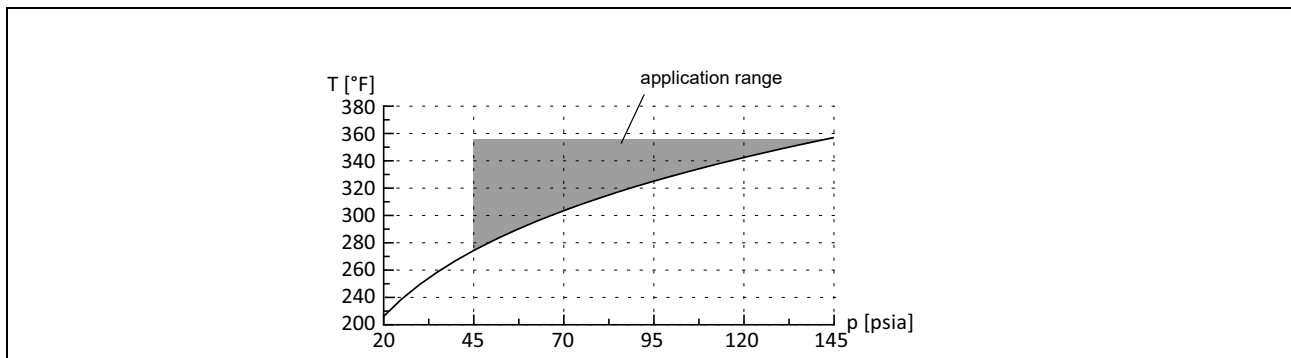
² test measurement to validate the application required in advance

		FLUXUS G532ST-LT (analog outputs)	FLUXUS G532ST-LT (process interface)
• digital output			
number		2	-
functions		<ul style="list-style-type: none">• frequency output• binary output• pulse output	-
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	

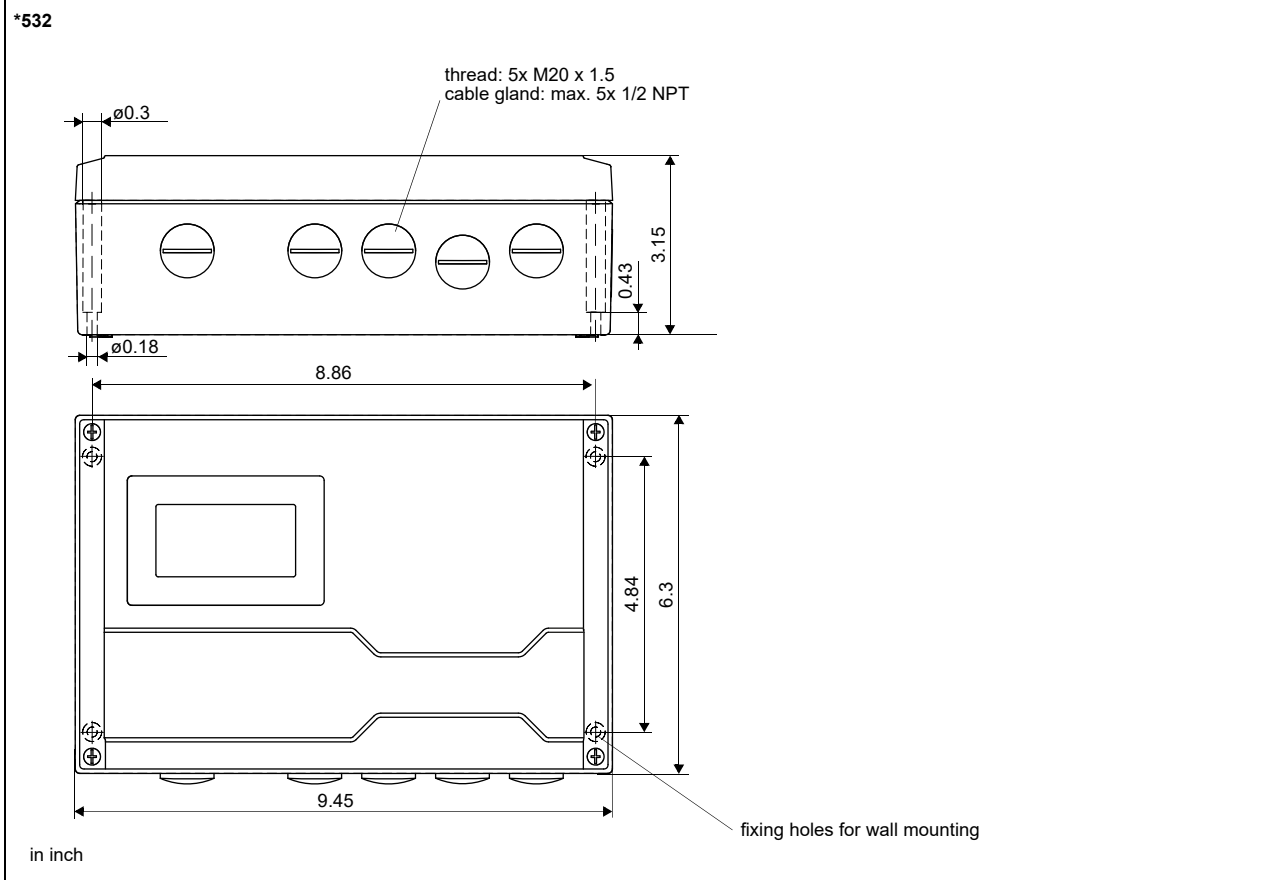
¹ with aperture calibration of the transducers

² test measurement to validate the application required in advance

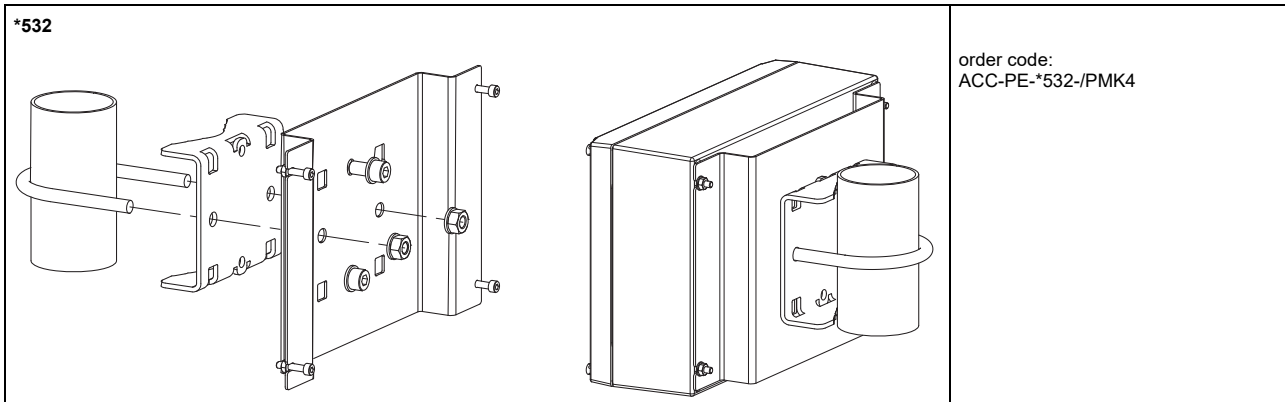
Saturated steam pressure curve



Dimensions



2" pipe mounting kit (optional)



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 supply¹

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

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
1, 2, 3, 4	temperature 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

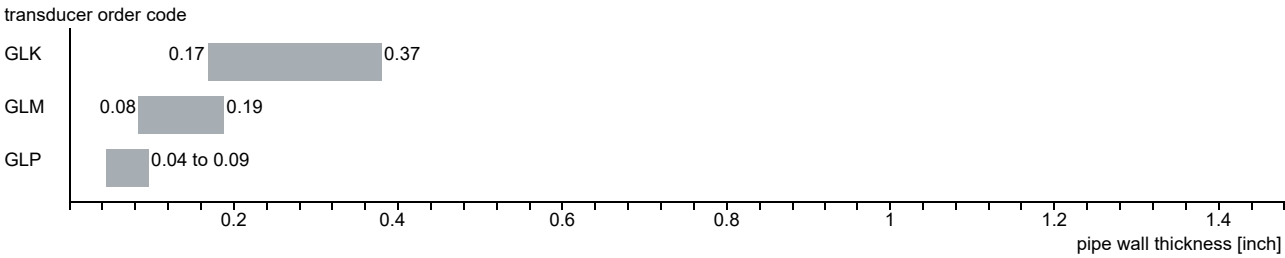
² The number, type and terminal assignment are customized.

Transducers

Transducer selection

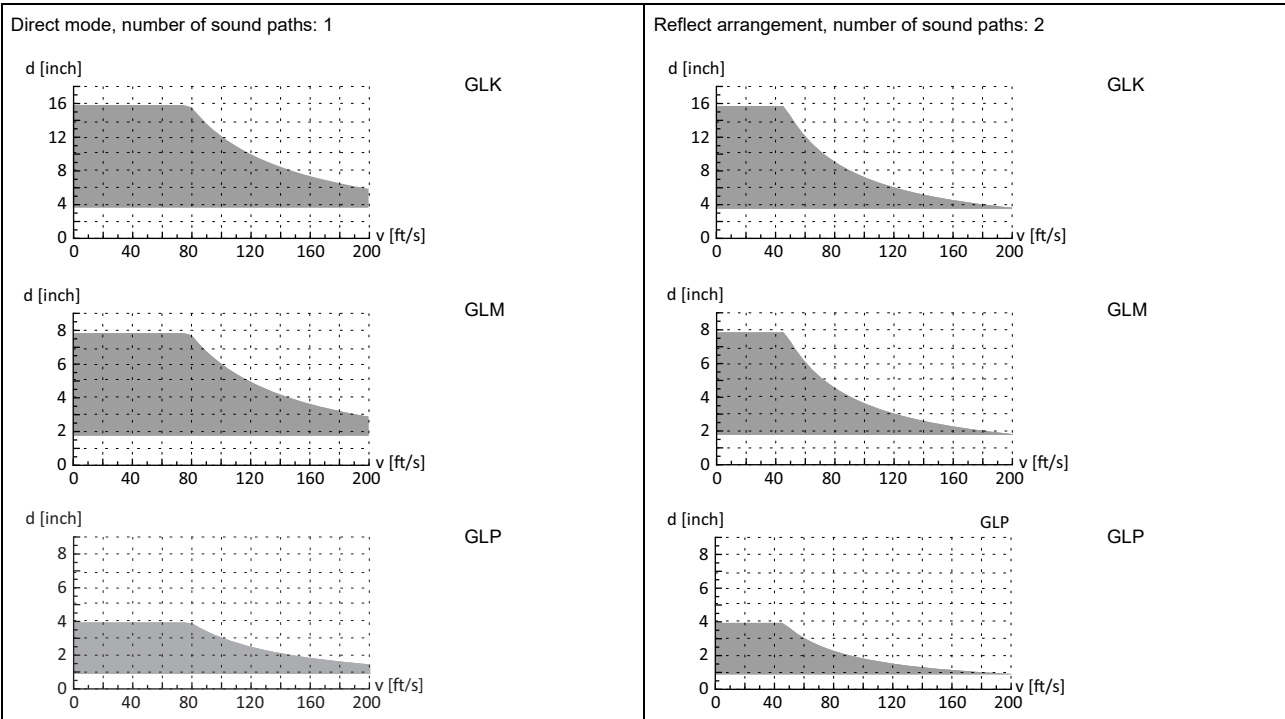
Step 1

pipe wall thickness



Step 2

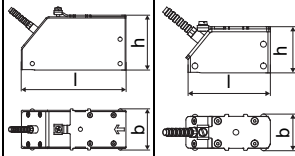
inner pipe diameter d dependent on the flow velocity v of the fluid in the pipe



inner pipe diameter and max. flow velocity for a steam application

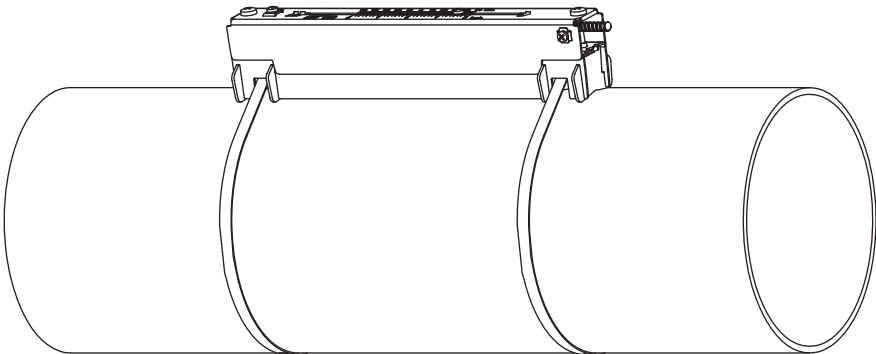
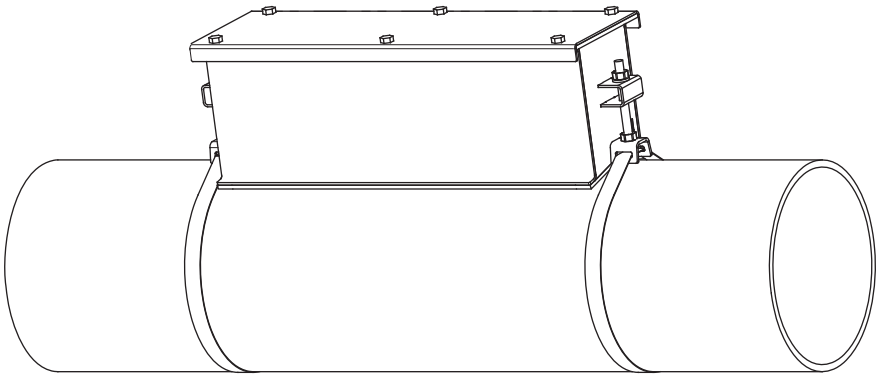
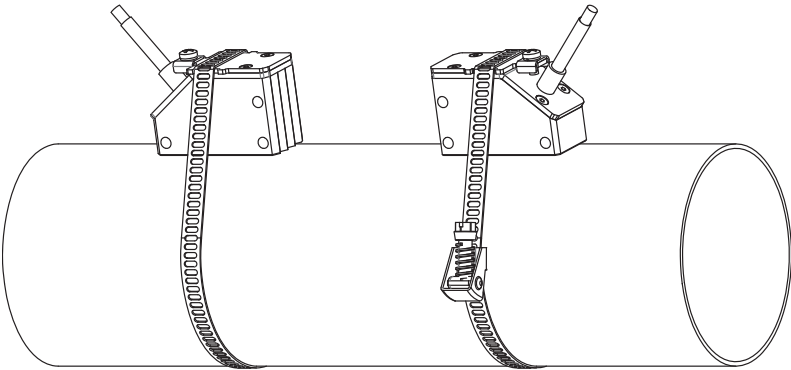
Technical data

Lamb wave transducers

order code		GLK-SNNT1/**	GLM-SNNT1/**	GLP-SNNT1/**
technical type		G(RT)K1S53	G(RT)M1S53	G(RT)P1S53
transducer frequency	MHz	0.5	1	2
fluid pressure		see saturated steam pressure curve		
inner pipe diameter d				
min.	inch	3.5	1.8	0.91
max.	inch	15.7	7.9	3.9
pipe wall thickness				
min.	inch	0.17	0.08	0.04
max.	inch	0.37	0.19	0.09
material				
housing		PPSU with stainless steel cover 316Ti		
contact surface		PPSU		
degree of protection		IP65		
transducer cable				
type		1699		
length	ft	16	13	
length (***-****/LC)	ft	29	29	
dimensions				
length l	inch	5.06	2.91	
width b	inch	2.01	1.3	
height h	inch	2.66	1.59	
dimensional drawing				
weight (without cable)	lb	1.8	0.35	
storing temperature				
storing temperature	°F	-40 to +356		
operating temperature	°F	212 to 356		
warm-up time	h	3	1	
temperature compensation		x		

completely thermally insulated transducer installation necessary

Transducer mounting fixture

<div>PermaRail (VLK, VLM)</div> 	<div>material: stainless steel 304, 301, 410 option OS: 316Ti, 316L, 17-7PH inner length: VLK: 13.7 inch, VLM: 9.2 inch dimensions: VLK: 16.65 x 3.54 x 3.66 inch VLM: 12.17 x 2.24 x 2.48 inch</div>
<div>PermaLok PL</div> 	<div>material: stainless steel 316 dimensions: PLK-RL: 19.25 x 3.9 x 3.95 inch PLK-DS: 13.25 x 3.85 x 3.95 inch PLM: 25.25 x 3.08 x 3.15 inch weight: PLK-RL: 6 lb PLK-DS: 4.2 lb PLM: 6.6 lb</div>
<div>quick release clasps and tension straps</div> 	<div>material: stainless steel 410, 200</div>

Coupling materials for transducers

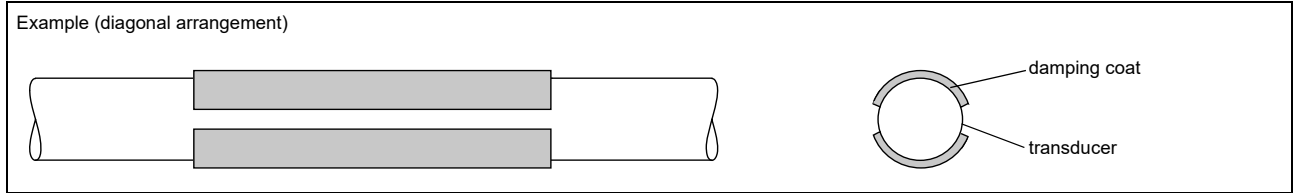
type	ambient temperature °F
coupling pad type VT ¹	14 to +392
coupling compound type E ²	-22 to +392

¹ fluid temperature 392 °F: min. 2 years

² in combination with type VT only

Damping coat

The damping coat will be used to reduce acoustic noise influences on the measurement.



Technical data

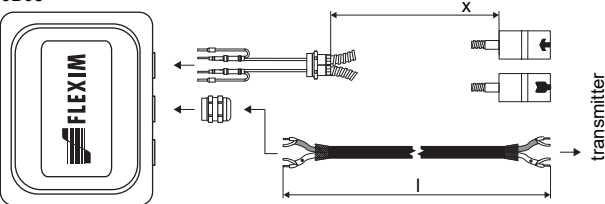
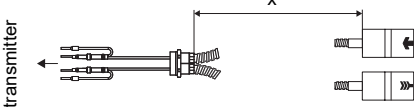
order code		ACC-PE-GNNN-/DPL1
material		multipolymeric matrix/inorganic ceramic coating
packing drum	gal	1
properties		heat-resistant, inert
fluid temperature when applying	°F	50 to 392
drying time (example)		approx. 3 h at 68 °F approx. 15 min at 302 °F
temperature resistance in dry state	°F	max. 1202
durability of the packing drum (unopened)		2 years

Observe installation instructions (TI_DampingCoat).

Dimensioning

transducer frequency	number of packing drums	
	outer pipe diameter	
	≤11.8	≤19.7
	inch	
K	1	1
M	1	-
P	1	-

Connection systems

connection system T1		
connection with extension cable	direct connection	transducers technical type
<div><div>JB05</div></div>	<div></div>	*****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 304 option OS: 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

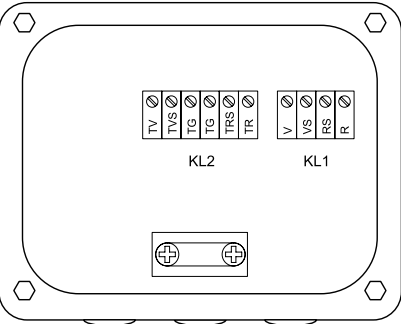
Cable length

transducer frequency		K		M, P	
transducers technical type		x	l	x	l
*R***5*	ft	16	≤ 984	13	≤ 984
option LC: *T***5*	ft	29	≤ 984	29	≤ 984

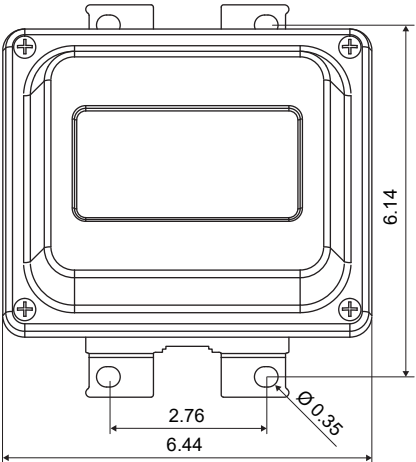
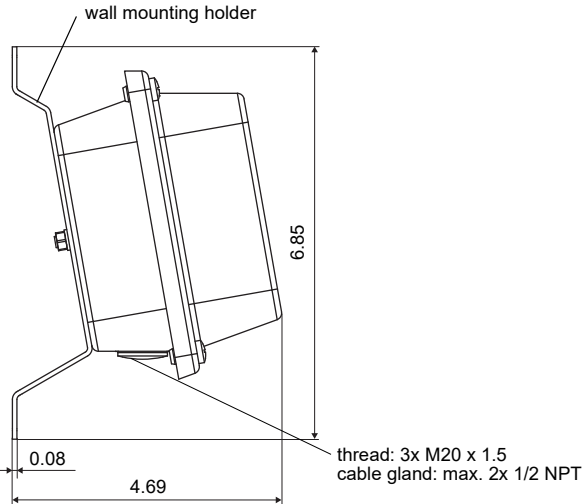
x = transducer cable length
l = max. length of extension cable (depending on the application)

Junction box

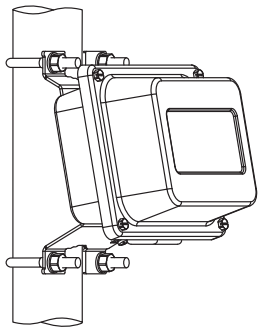
Technical data

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

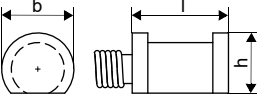
JB0*, JBP*	
	
in inch	

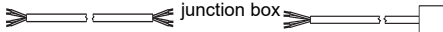

2" pipe mounting kit

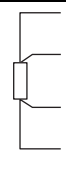
<p>JB**</p> 	<p>order code: ACC-PE-GNNN-/JBPMK4</p>
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Clamp-on temperature probe (optional)

Technical data

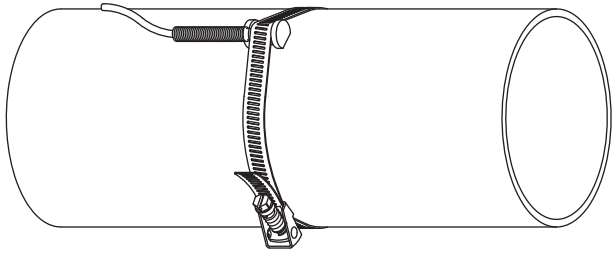
PT13N		
design		clamp-on
type		Pt1000
connection		4-wire
measuring range	°F	-40 to +392
accuracy T		±(0.27 °F + 2 · 10 ⁻³ · (T [°F] - 32 °F)) class A
housing material		360 brass alloy
degree of protection		NEMA 4
dimensions		
length l	inch	0.79
width b	inch	0.59
height h	inch	0.49
dimensional drawing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

Connection system	
connection with extension cable	direct connection
extension cable 	

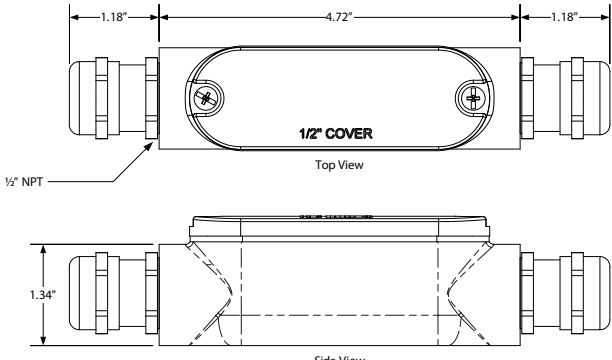
Connection	
	temperature probe
	red
	red
	white
	white

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

	Connection <table> <tr> <th>temperature probe</th><th>extension cable</th></tr> <tr> <td>red</td><td>white</td></tr> <tr> <td>red</td><td>black</td></tr> <tr> <td>white</td><td>green</td></tr> <tr> <td>white</td><td>red</td></tr> </table>	temperature probe	extension cable	red	white	red	black	white	green	white	red
temperature probe	extension cable										
red	white										
red	black										
white	green										
white	red										