Wake frequency calculation

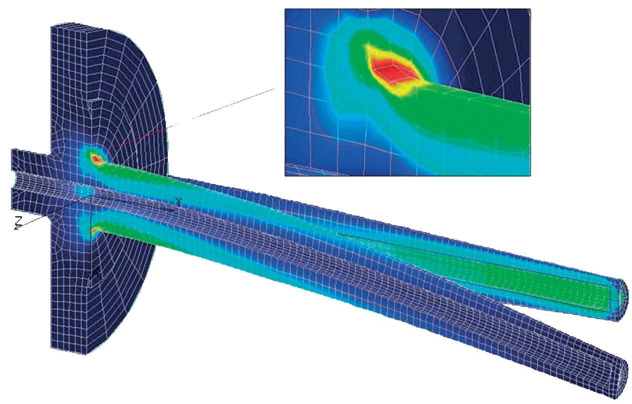
WIKA data sheet IN 00.15

Applications

- Minimisation of the risk of dynamic damage through vortex shedding of a Kármán vortex street (Vortex Induced Vibration; VIV)
- Calculation of the static loads due to inflow and process pressure
- Can be used in pipelines and process vessels

Special features

- Calculation of thermowells per ASME PTC 19.3 TW-2016
- Calculation of thermowells and protection tubes in accordance with Dittrich/Klotter
- If the permissible calculated load limits are exceeded, WIKA can, as an engineering service (subject to a charge), provide suggestions for modification of the thermowell design.



FEM representation of a thermowell within a flow with stress representation at the tip and in the root

Description

The wake frequency calculation in accordance with ASME PTC 19.3 TW-2016 is applicable for thermowells in tapered, straight or stepped design.

Protection tubes in accordance with DIN 43772 or comparable designs are calculated in accordance with Dittrich/Klotter.

All calculations are valid for non-corrosive or non-abrasive media, unless otherwise specified. The end users are responsible for the conformity of the process data with the calculation bases.

As a result of the pipeline design, a vibration excitation is also possible, which is not the subject of the wake frequency calculation.

A warranty by WIKA cannot be given.

Required process data for the wake frequency calculation

Process data	SI unit	Imperial	Others
Flow rate	m/s	ft/s	-
Medium density	kg/m^3	lb/ft^3	-
Temperature	°C	°F	-
Pressure	bar	psi	-
Dynamic viscosity 1)	mm^2/s	ft/1000s	cP

1) ASME PTC 19.3 TW-2016 selectable, not required for Dittrich/Klotter

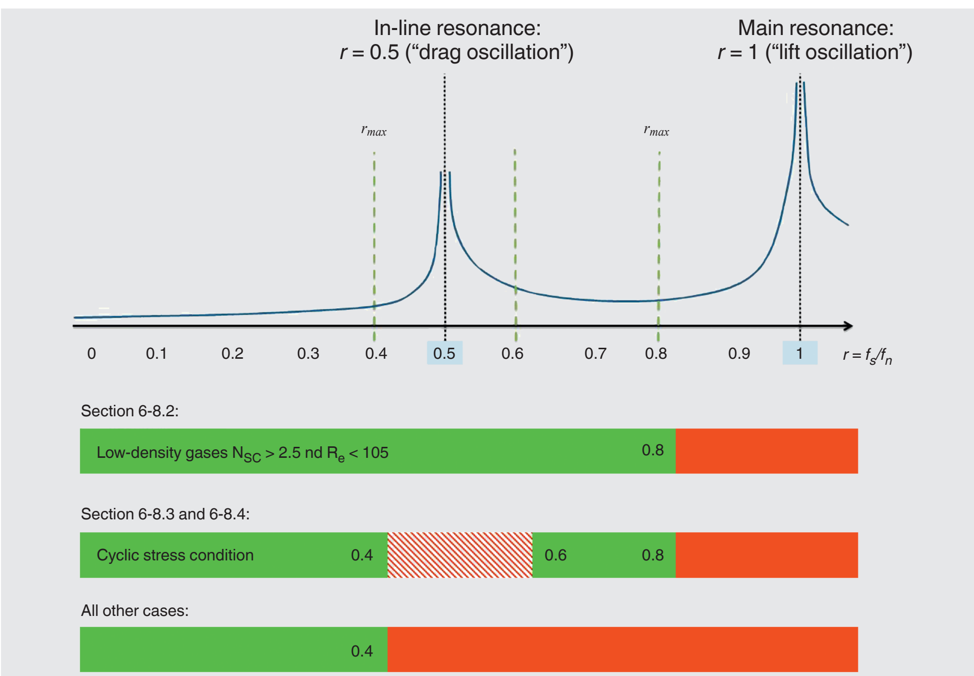
In accordance with ASME PTC 19.3 TW-2016, chapter 9-1, the designer of the system in which the thermowell is installed is responsible for specifying the process data used for the calculation (temperature, velocity, density, pressure).

If several process data are provided to WIKA (e.g. min. / process / max. / design), in accordance with 6-3.3 of the standard, the highest value is always used for the calculation.

This procedure is applied to each wake frequency calculation, regardless of the standard.

ASME PTC 19.3 TW-2016
ASME PTC 19.3 TW-2016 is divided into dynamic and static calculation results and is exclusively applicable to thermowells installed in pipes or process vessels. Applications in process or industrial furnaces are thus outside the scope of the calculation.

For low-density gases, the frequency limit is typically r_{max} = 0.8. With other gaseous media, constant operation in the range between r = 0.4 ... 0.6 around the in-line resonance is not permissible. For liquid media, in many applications, the limit frequency r_{max} = 0.4 for the in-line resonance is typically used.



The evaluation of the dynamic results is made using the damping factor N_{SC} (N_{SC}, the Scruton number, is directly related to the permissible frequency ratio r_{max} of the excitation frequency f_s to the natural frequency f_n)). In simplified terms, for gaseous media, a characteristic value is $N_{SC} > 2.5$; liquids typically have an $N_{SC} < 2.5$.
The values mentioned must not be considered as absolute in any calculation and are calculated individually by the program.

The Scruton number N_{SC} depends on the intrinsic damping factor, the density of the thermowell material, the process medium and the tip and bore diameter of the thermowell.

Whether the frequency ratio $r < 0.8$ can also be used as an evaluation limit for liquid process media is decided by considering the permissible stresses in the thermowell material compared to the actual stresses in the event of resonance. In addition, the strength of the thermowell material is evaluated with respect to the fatigue stress in the area of installation of the thermowell.
The static results of ASME PTC 19.3 TW-2016 are based on the maximum permissible process pressure (depending on the process temperature and the geometry data of the thermowell) and the bending stress in the area of the thermowell root.
The bending stress caused by the incident flow on the thermowell is, among other things, dependent on the shielded length resulting from the flange nozzle.

In addition to the VIV, vibration excitation of thermowells in all designs can be caused, for example, by the following factors:
- pulsating or turbulent flows
- Vibrations of the pipeline system (e.g. caused by pumps)
- Excitation through acoustic/flow-induced vibrations (AIV/FIV)
- The pipeline geometry itself (e.g. after T-pieces, dead legs or pipe elbows)
- Thermowell mounting with too little distance to interrupters or other thermowells (e.g. “2oo3 installation”), whereby other causes are also conceivable.

These vibration excitations cannot be calculated by the calculation methods in accordance with ASME, Dittrich/Klotter or using CFD (Computational Fluid Dynamics), but must also be evaluated by the end user in the design of the measuring location. The calculation results of the aforementioned methods are not directly comparable with each other.

Dittrich/Klotter
The static calculation of thermowells for thermometers is based on the formulae published by P. Dittrich in 1954 in the technical journal “Allgemeine Wärmetechnik” (“General Heating Technology”). These formulae were considered in DIN 43763, a predecessor standard of the current DIN 43772 from 2000.

Around 1990, WIKA supplemented the static calculation in accordance with Dittrich with the dynamic calculation in accordance with Klotter, which originates from the textbook “Das Ingenieurwesen - Hütte” (“Engineering - Metallurgy”) in the chapter “Kinetik der Schwinger” (“Kinetics of oscillators”). This combination enables the calculation of protection tubes and the estimation of the loads in the operating case, caused by the vortex shedding of the Kármán vortex street. The in-line resonance introduced in 2010 by ASME PTC 19.3-TW is not considered in the calculation in accordance with Dittrich/Klotter.

The static evaluation is made via the “comparative stress”. The pressure loading at the thinnest wall thickness near the tip of the thermowell is combined with the combined bending load at the root of the flow and axial pressure loading, whereby a representative stress value, $S_{comp} = max + min/3$, is formed. In addition, a safety number S is calculated via the quotient of S_{comp} with the permissible stress $0.7 \times Rp_{(T)}$.

For the dynamic consideration, the excitation frequency is calculated with the Strouhal number St = 0.21 and compared with the natural frequency in accordance with Klotter. The frequency ratio in accordance with ASME PTC 19.3-1974 should not exceed the limit value $r_{max} = 0.8$.

Solutions when the permissible frequency ratio r_{max} is exceeded due to design changes

If the maximum permissible limit frequency r_{max} for the in-line or main resonance is exceeded, the following design changes can be made:

a) Shortening of the insertion length
This is the most effective, and the design change recommended by all calculation methods, to improve the frequency ratio r.

b) Increasing the root diameter
By increasing the root diameter, the natural frequency f_n is reduced and thus the frequency ratio r is optimised.

c) Increasing the tip diameter
By increasing the tip diameter, the vortex shedding frequency f_s is reduced and thus the frequency ratio r is optimised

d) Support collar
Support Collars or other support devices are not included within the scope of ASME PTC 19.3 TW-2016 and are only offered on explicit customer request. The basics of the calculation in accordance with Dittrich/Klotter do not make any statements with regard to the support collar.

Supporting the thermowell with a support collar is not recommended, as a fixed support can only be achieved through an interference fit between the support collar and the flange nozzle (see ASME PTC 19.3 TW-2016, points 6-7-(e)).

The design of the thermowell below the support collar corresponds to the design and calculation criteria of ASME PTC 19.3 TW-2016 or Dittrich/Klotter.

Since each flange nozzle has individual dimensions, the support collar is delivered with an oversize. The operator is responsible for the interference fit of the collar in the nozzle, which makes it necessary to subsequently adapt the collar to the nozzle.

It should be noted that some nozzle designs are not suitable for use with support collars.
A warranty for support collars is not provided.

→ Further information is described in the technical information IN 00.26.

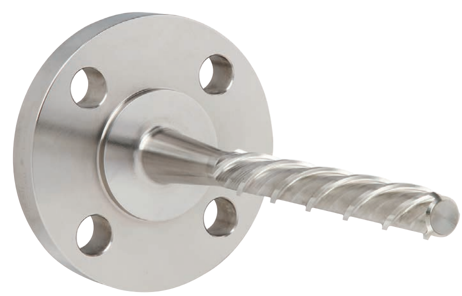
e) ScrutonWell® design
The ScrutonWell® design can be used for thermowells with flange connection, Vanstone design and also for welded or screwed process connections. This design enables the easy and quick mounting of the thermowell without the need for expensive and time-consuming adjustment on-site, as required for support collar.

The ScrutonWell® design reduces the vibration amplitude by more than 90 % with a vortex-induced excitation, which has been tested and proven by the independent laboratories TÜV SÜD NEL (Glasgow) and the Institute of Mechanics and Fluid Dynamics (Technische Universität Freiberg).

→ For further information, see data sheet SP 05.16

Strength calculation of the ScrutonWell® design using ASME PTC 19.3 TW-2016

- Maximum permissible pressure load with original stem dimensions
- Maximum permissible bending load with modified stem dimensions
- Due to the damping of the vibration amplitude by more than 90 %, no dynamic calculation is carried out



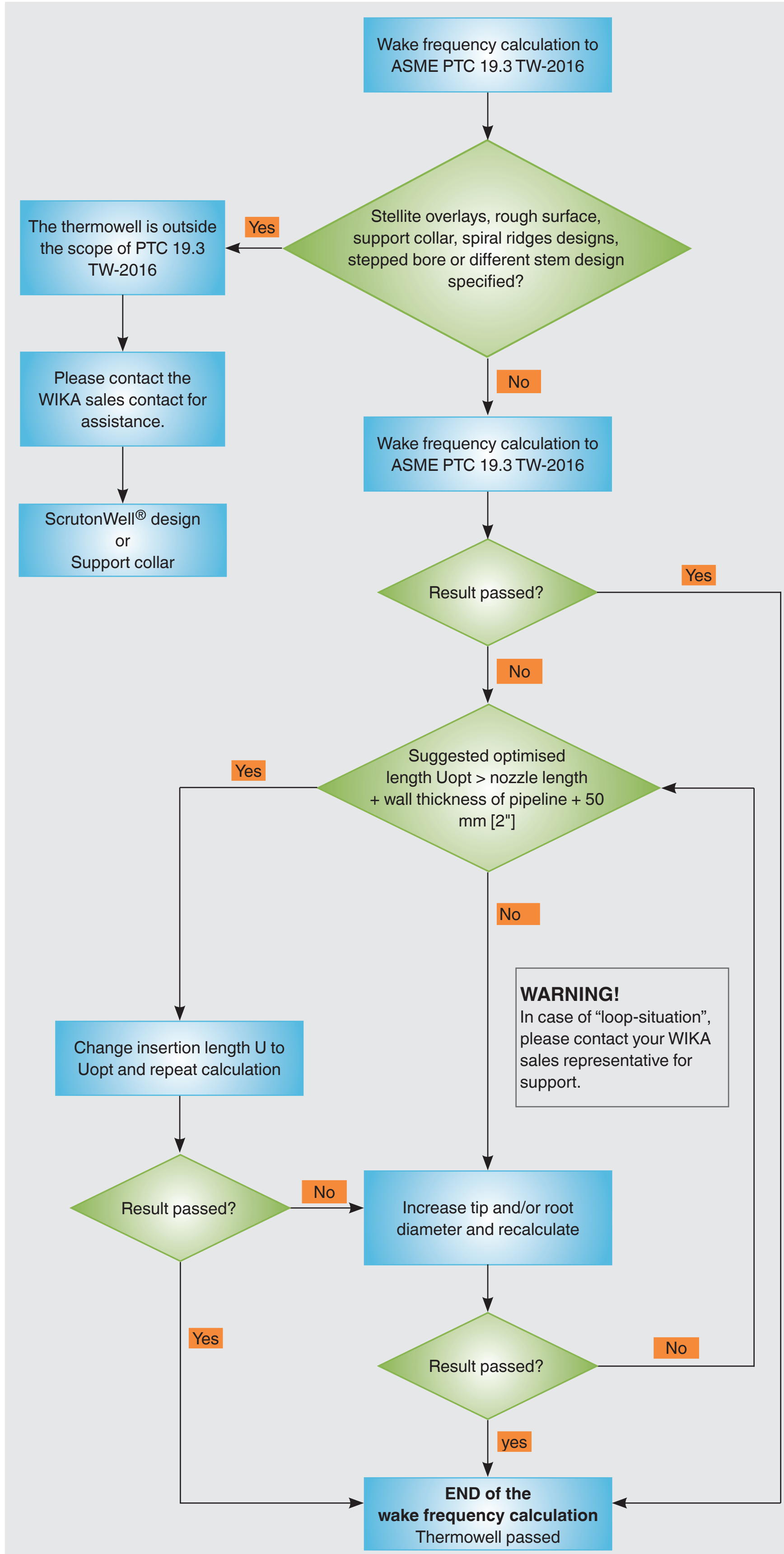
Thermowell model TW10 in ScrutonWell® design

Performing a standard wake frequency calculation in accordance with ASME PTC 19.3 TW-2016

This simplified flow diagram shows the procedure of performing a standard wake frequency calculation in accordance to ASME PTC 19.3 TW-2016 step-by-step. The diagram addresses a failed frequency ratio only.

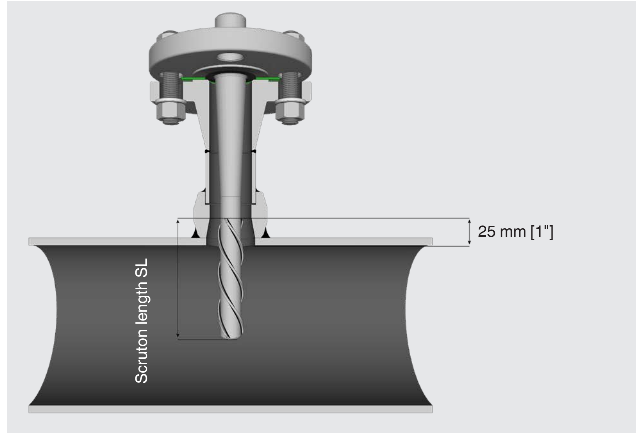
Because of variation in thermowell designs in combination with various process parameters not all wake frequency calculations can follow this standard procedure.

If the procedure shown does not provide a satisfactory result, contact the manufacturer to get support. A specific technical solution might be needed.



Design details

ScrutonWell®: Calculation of Scruton length SL
The length of the helixes, the so-called Scruton length SL, must be designed so that they reach 25 mm [1 in] into the shielded length of the nozzle.
→ For further information, see data sheet SP 05.16



Support collar

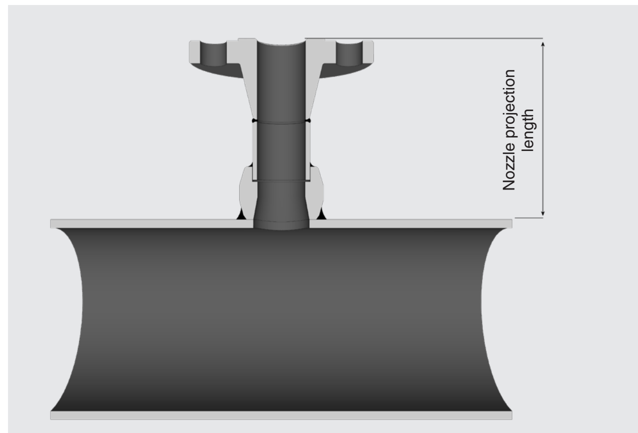
- Determine 1st support collar location

The position of the thermowell support collar is calculated as follows: Nozzle length - 25.4 mm [1 in]

- Example:

Nozzle length 356 mm [14 in]. The 1st support collar is located 330 mm [13 in] from the flange sealing face.

The nozzle length is defined as the length from the outer diameter of the pipe / pipeline / vessel wall to the height of the nozzle (flange sealing face, etc.).



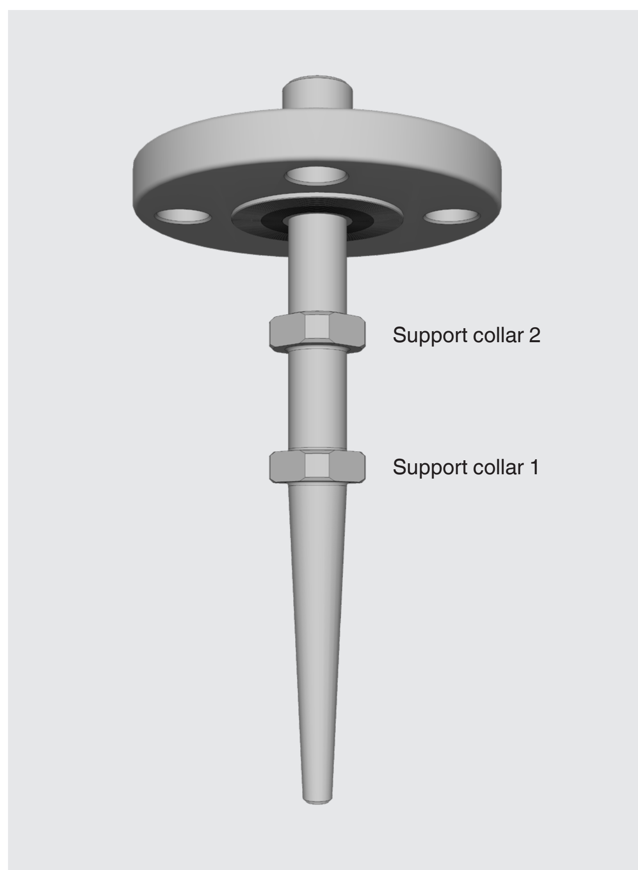
- Determine the number and position of the support collars

If the 1st support collar is less than 127 mm [5 in] from the flange sealing face, then only one support collar is required.

If the position of the 1st support collar is 127 mm [5 in] or more, then a 2nd support collar is required, at the point which is half the distance to the 1st support collar. For a nozzle projection length of more than 762 mm [30 in], please contact your WIKA sales representative.

- Example no. 1 – Two support collars

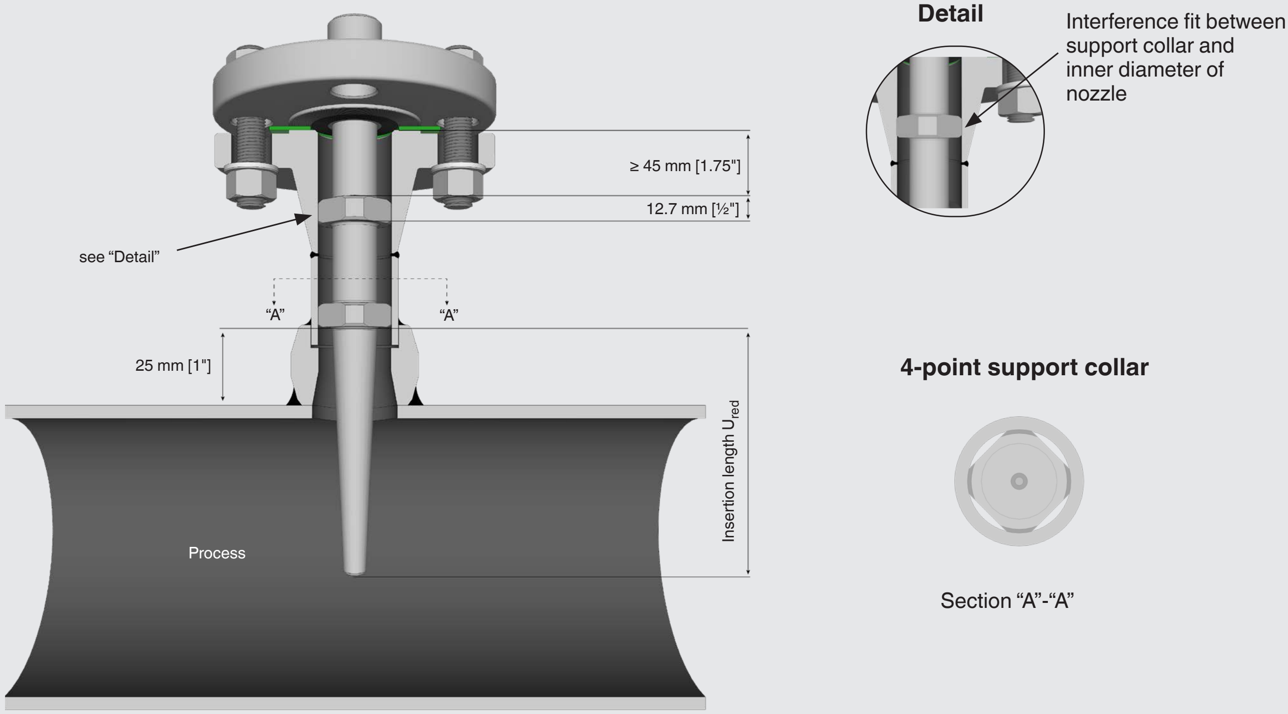
The nozzle length is 356 mm [14 in]. Support collar 1 is 356 mm [14 in] – 25.4 mm [1 in] = 330 mm [13 in]. Since this number is greater than 127 mm [5 in], two support collars are required. Thus, 330 mm [13 in] / 2 = 165 mm [6.5 in]. Support collar 2 is at 165 mm [6.5 in].



- Example no. 2 – One support collar

The nozzle length is 114 mm [4.5 in]. Support collar 1 is at 114 mm [4.5 in] – 25.4 mm [1 in] = 89 mm [3.5 in]. Since this number is smaller than 127 mm [5 in], a support collar is required.

Typical installation through a nozzle



Determine the support collar outer diameter from the pipe size and schedule

NPS	UOM	Outer diameter of the support collar						
		SCH.10	SCH.40	SCH.STD	SCH.80	SCH.XS	SCH.160	SCH.XXS
1"	in	1.107	1.059	1.059	0.967	0.967	0.825	0.609
	mm	28.1	26.9	26.9	24.6	24.6	21.0	15.5
1 ½"	in	1.692	1.620	1.620	1.510	1.510	1.348	1.110
	mm	43.0	41.1	41.1	38.4	38.4	34.2	28.2
2"	in	2.167	2.077	2.077	1.949	1.949	1.697	1.513
	mm	55.0	52.8	52.8	49.5	49.5	43.1	38.4

Determine the suggested maximum root diameter based on nozzle size and schedule

NPS	UOM	Suggested root diameter at the support collar						
		SCH.10	SCH.40	SCH.STD	SCH.80	SCH.XS	SCH.160	SCH.XXS
1"	in	0.938	0.875	0.875	0.813	0.813	0.688	0.500
	mm	23.8	22.2	22.2	20.6	20.6	17.5	12.7
1 ½"	in	1.500	1.375	1.375	1.250	1.250	1.125	1.000
	mm	38.1	34.9	34.9	31.8	31.8	28.6	25.4
2"	in	1.875	1.750	1.750	1.625	1.625	1.500	1.250
	mm	47.6	44.5	44.5	41.3	41.3	38.1	31.8

Design specifications in accordance with ASME PTC 19.3 TW-2016, Table 4-1-1, 4-2-1

Description	Tapered and straight designs		Stepped design	
	Minimum	Maximum	Minimum	Maximum
Insertion length L	63.5 mm [2.5 in]	609.6 mm [24 in] 1)	127 mm [5 in]	609.6 mm [24 in]
Bore diameter d	3.175 mm [0.125 in]	20.9 mm [0.825 in]	6.1 mm [0.24 in]	6.7 mm [0.265 in]
Tip diameter B	9.2 mm [0.36 in]	46.5 mm [1.83 in]	-	-
Taper ratio B/A	0.58	1	-	-
Step ratio B/A for B = 12.7 mm	-	-	0.5	0.8
Step ratio B/A for B = 22.2 mm	-	-	0.583	0.875
Bore ratio d/B	0.16	0.71	-	-
Aspect ratio L/B	2	-	2	-
Length ratio Ls/L	-	-	0	0.6
Min. wall thickness (B-d)/2	3 mm [0.12 in]	-	3 mm [0.12 in]	-

1) Insertion lengths > 609.6 mm (24 in) are permissible, as long as a one-piece design of the thermowell without weld seams is used.

Marking	per ASME PTC 19.3 TW-2016	in WIKA data sheets
Insertion length	L	U
Bore diameter	d	B
Tip diameter	B	V
Root diameter	A	Q

If the thermowell dimensions, based on customer requirements or for specific applications, lie outside the requirements of ASME PTC 19.3 TW-2016, the calculation results can only be used for informative purposes. For this reason, no warranty can be given by the manufacturer.

Provision of calculation data

The table shows how process and geometry data should be provided electronically as an Excel spreadsheet for a chargeable thermowell calculation by WIKA engineering services.

Example for 6 measuring points in metric units:

Legend

Tag no.	Tag number	Ø Q	Root diameter
T	Temperature	Ø V	Tip diameter
P	Pressure	T_t	Tip thickness
v	Flow rate	N_{ID}	Inner diameter of nozzle
rho	Density of the process medium	N_L	Nozzle projection length
U	Insertion length	Model	WIKA thermowell model
Ø d	Bore size		

Tag no.	T	P	v	rho	Dyn. viscosity in cP	Model	Dimensions in mm [in]							Material
	in °C [°F]	in bar [psi]	in m/s	in kg/m³			U	Ø d	Ø Q	Ø V	Tt	NID	NL	
TW-0301	220 [428]	1.5 [21.76]	23.6	2.4	0.013	TW10	250 [10.04]	8.5 [0.34]	25 [0.98]	19 [0.75]	6.4 [0.25]	38.3 [1.51]	220 [8.66]	1.4435
TW-0303	220 [428]	1.5 [21.76]	25.7	2.0	0.017	TW10	250 [10.04]	8.5 [0.34]	25 [0.98]	19 [0.75]	6.4 [0.25]	38.3 [1.51]	220 [8.66]	1.4435
TW-0305	235 [455]	10 [145.04]	19.6	6.1	0.015	TW10	250 [10.04]	8.5 [0.34]	25 [0.98]	19 [0.75]	6.4 [0.25]	38.3 [1.51]	220 [8.66]	1.4435
TW-0307	220 [428]	10 [145.04]	13	8.9	0.014	TW10	250 [10.04]	8.5 [0.34]	25 [0.98]	19 [0.75]	6.4 [0.25]	38.3 [1.51]	220 [8.66]	1.4571
TW-0309	235 [455]	30 [435.12]	8.9	28.3	0.013	TW10	250 [10.04]	8.5 [0.34]	25 [0.98]	19 [0.75]	6.4 [0.25]	38.3 [1.51]	220 [8.66]	1.4571
TW-0311	400 [752]	31.5 [456.88]	31.9	10.1	0.017	TW10	250 [10.04]	8.5 [0.34]	25 [0.98]	19 [0.75]	6.4 [0.25]	38.3 [1.51]	220 [8.66]	1.4571

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