



OKAZAKI
MANUFACTURING COMPANY
UK LIMITED

VortexWell

The Thermowell solution for when your design
fails the ASME PTC 19.3 TW Calculation



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We are Okazaki Manufacturing Company (OMC)

Temperature is our business

We design and manufacture market-leading temperature measurement products and heating systems.

In choosing us as your temperature partner, you will have access to an unrivalled range of the most highly accurate and advanced temperature-related products, designed to operate in some of the harshest environments.

Our temperature measurement assemblies cover the full range of process applications and temperatures from -269°C to +2,200°C.

Cutting Edge Technology

Since 1954, we have been at the forefront of our field - pushing the boundaries and actively pursuing new technologies to take our product development and the industry to new levels. Our history of innovation spans decades - from 1963 when we developed our metal sheathed MgO insulated resistance thermometer, RESIOPAK, which has since been replicated by manufacturers from around the world, right through to the present day and our most recent development of the smallest thermocouple at a diameter thinner than that of a human hair for which we now hold a world record.

At Okazaki, we are proud of our state-of-the-art production facilities where all our VortexWell Thermowells are machined to give accurate finished helical strakes on every product. Despite being a very difficult material to work with we can machine using Alloy 625, and we are amongst the most efficient companies in the world at doing this. We can also issue WPS and PQR which covers various exotic materials. Thermowell designs offered include welded and from one-piece forgings.

Quality Assurance

We are fully committed to quality management and the quality of our products and service is backed by numerous certifications and standards, including ISO 9001, ISO 14001 and JCSS 0079.

Bespoke Solutions

We appreciate that one size does not fit all and despite a large range of products, we are happy to develop customised products and solutions to solve specific issues or market needs.

Global Footprint, Local Specialists

With manufacturing sites in Japan, USA and Taiwan and offices around the globe, our world-wide footprint is coupled with local representatives who provide specialist instrumentation advice, guidance and technical support.



VortexWell

The Thermowell solution for when your design fails the ASME PTC 19.3 Thermowell calculation.

Having supplied standard thermowells to the Oil, Gas and Petrochemical industries for many years, we were continuously looking to develop a solution that would remove flow induced vibrations – to enable more accurate and reliable results.

The importance of this product development was brought to even greater urgency following the Japanese Monju nuclear power plant failure in 1995. This was caused by the failure of a thermowell which had passed a calculation based on the ASME PTC 19.3 1974 guidelines. Following this failure JSME wrote a guideline (JSME S 012) which mentioned several solutions which would prevent the Karman Vortex effect, one of these was 'Helical Strakes'.

Helical strakes are not an original idea, they have been used in other applications such as industrial cooling towers and car aerials, but it was discovered that this technology would also work on a thermowell to reduce vibrations.

The Okazaki VortexWell was developed in 2006 and has proven through various testing including CFD analysis to be the most reliable and accurate solution by massively reducing the effects of vibration induced vortices and has overcome the risk of thermowell failures.

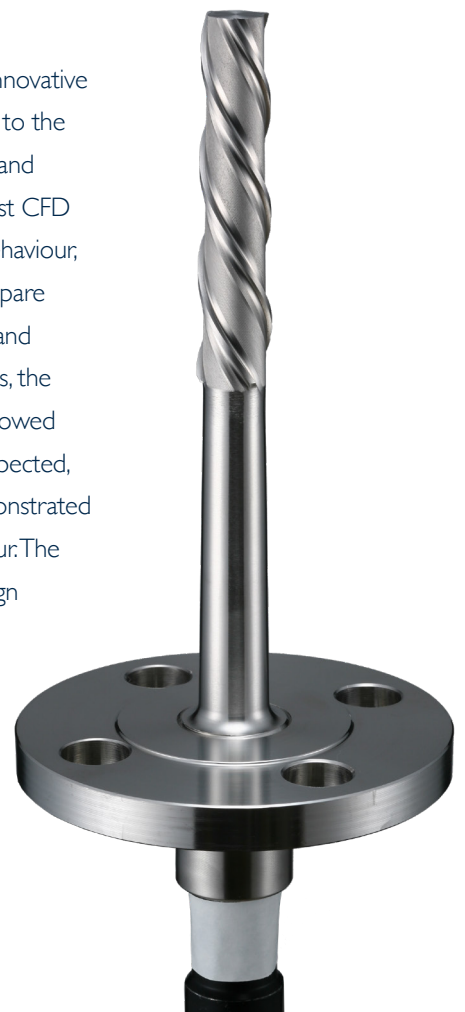


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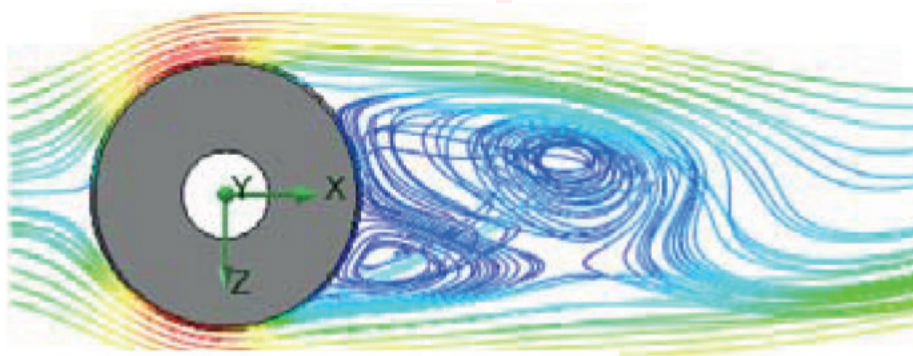
The VortexWell Thermowell

After extensive R&D and independent evaluation, we have developed a unique design of thermowell, the VortexWell®, which doesn't require a velocity collar and is cost effective for the end user in terms of purchase, installation and maintenance costs.

VortexWell® incorporates an innovative helical strake design, very similar to the helical strakes seen on columns and cooling towers. By using the latest CFD software to visualise the flow behaviour, we were able to accurately compare a standard tapered thermowell and its new VortexWell®. In the tests, the standard tapered thermowell showed classic shedding behaviour as expected, whereas the VortexWell® demonstrated no signs of regular flow behaviour. The VortexWell® helical strake design disturbed the flow sufficiently to interrupt the regular formation of vortices. Whilst a small vortex was observed in the wake of the VortexWell® this was a localised stagnation point and didn't shed.



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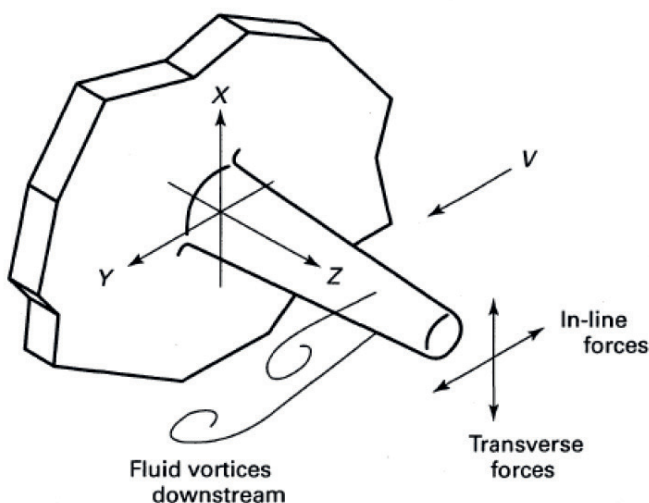
(T. Oakes, 8)

How the VortexWell works

Fluid flowing around a blunt object in its path, such as a standard thermowell, forms vortices downstream of the object – commonly known as vibration induced vortices and the implications this can have are huge, from inaccurate readings to complete failure of the thermowell.

As the vortex shedding frequency approaches the thermowell natural frequency, the tip displacement and stresses are greatly magnified and the thermowell can fail. Even when the thermowell has passed calculations to the ASME PTC 19.3 standard, failures are still known to have happened, Monju Power Plant being a prime example.

To solve this issue, we looked at several different ideas, from increasing damping to streamlined cross sections. It was found that the best solution was to incorporate a helical strake as a vortex suppression method which made our VortexWell the best performing and safest thermowell available.



(ASME PTC 19.3TW)



Testing & Results

In 2008 Okazaki UK commissioned a detailed CFD analysis of both a standard thermowell and the now branded VortexWell profile.

The following was shown within the report:

"It was found that the thermowell with helical strakes demonstrated no regular vortex shedding. While the flow behaviour varied significantly along the length of the thermowell it was observed that little or no time dependent changes occurred, and the results were considered dynamically stable in all cuts along the length. The plots showing flow streamlines provided an excellent visualisation of the influence of the helical strakes. It's suggested that the strakes sufficiently disturb the flow in the wake region such that no regular vortices can form. The strakes also encouraged cross plane flow behaviour (along the thermowell length) to an extent that was not observed with the standard thermowell. It's thought that this process also helps to interfere with vortex formation."





Their findings stated:

"A comparison of dynamic performance and mechanical stresses indicates that the VortexWell has significantly outperformed the standard thermowell in this project"

Evaluation International published its report E 1937 X 12 in December 2012 where a comparison trial had been carried out by TUV SUD NEL at their East Kilbride facility to validate the VortexWell.

Their conclusions from this report was:

"It should be noted that the VortexWell has significantly outperformed the standard thermowell in terms of dynamic performance and mechanical strength."

"A comparison of dynamic performance and mechanical stresses indicates that the VortexWell has significantly outperformed the standard thermowell in this project"

These findings confirm that the VortexWell designed and manufactured by Okazaki offers a credible solution to overcome increasing failures.



VortexWell

Report

The Thermowell solution for when your design fails the ASME PTC 19.3 TW calculation

Thermowell design is critical to the safe operation of today's many industrial applications. Failure of a relatively low cost Thermowell can have far reaching catastrophic consequences, and this can be highlighted in the 1995 failure at the Japanese Monju nuclear power plant.

Normally the Thermowell design and construction method is based around client instrument specifications and these in turn cross reference to industry standards such as API RP 551 and PIP PCCTE001, which in turn cross reference to ASME PTC 19.3 for design verification.

ASME PTC 19.3 was updated in 2010 to stand alone document ASME PTC 19.3TW and now incorporates several references to research papers from Japan.

ASME PTC 19.3 TW The object of this Standard

Is to establish a mechanical Design standard for reliable service of tapered, straight, and stepped-shank thermowells in a broad range of applications. This includes an evaluation of the forces caused by external pressure, and the combination of static and dynamic forces resulting from fluid impingement.

(ASME PTC 19.3 TW) SPECIFICATION OF A THERMOWELL

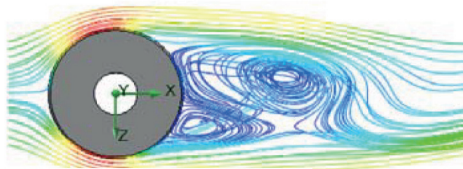
Specification of a thermowell, including details of its intended installation and all intended operating conditions, is the responsibility of the designer of the system that incorporates the thermowell. The designer of that system is also responsible for ensuring the thermowell is compatible with the process fluid and with the design of the thermowell installation in the system. The supplier of the thermowell should state that calculations to demonstrate compatibility of the thermowell with those operating conditions specified by the designer are in conformance with this Standard (ASME PTC 19.3TW)

Okazaki Manufacturing Company carries out calculations to ASME PTC 19.3TW and also takes into account JSME standard JSME S 012-1998: Guideline for Evaluation of Flow-Induced Vibration of a Cylindrical Structure in a Pipe.



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Fig 1



(T.Oakes , 8)

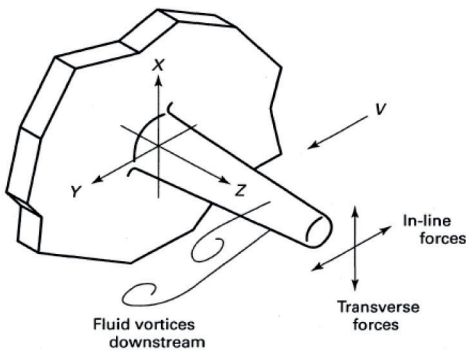
Theory:

The forces potentially causing harmful oscillations on a thermowell stem when immersed in a flowing fluid are associated with a vortex street development in the wake of the thermowell.

This is also referred to as vortex induced vibration (VIV). (Fig 1)

ASME PTC 19.3 TW now takes into account both the oscillating-lift force, transverse to the fluid flow at frequency f_s and the (T.Oakes , 8) Oscillating-drag force, in-line with the fluid flow at frequency $2f_s$ (Fig 2)

Fig 2



(ASME PTC 19.3 TW)

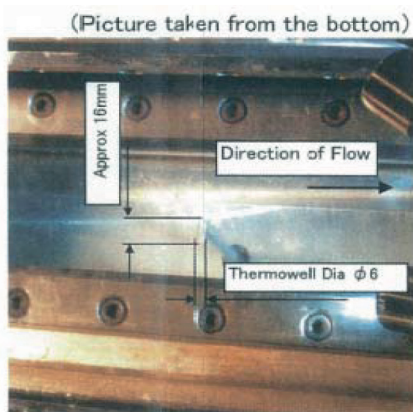
As the fluid velocity is increased, the rate of vortex shedding increases linearly while the magnitude of the forces increases with the square of the fluid velocity. The thermowell responds elastically according to the force distribution and its variation in time.

Should the vortex shedding rate coincide with the natural frequency of the thermowell, resonance occurs.

The fluid velocity at which this takes place is referred to as a velocity critical. There are a minimum of two critical velocities for each natural frequency of the thermowell (ASME PTC 19.3 TW) Since the in-line force fluctuates at twice the frequency of the lift excitation, the corresponding velocity critical is approximately onehalf that required for lift resonance.

For any given fluid velocity, both forces are acting on the thermowell with the result that the tip of the thermowell sweeps out an orbital (Lissajou figure) that changes shape as the fluid velocity is increased. (ASME PTC 19.3 TW)

Fig 3



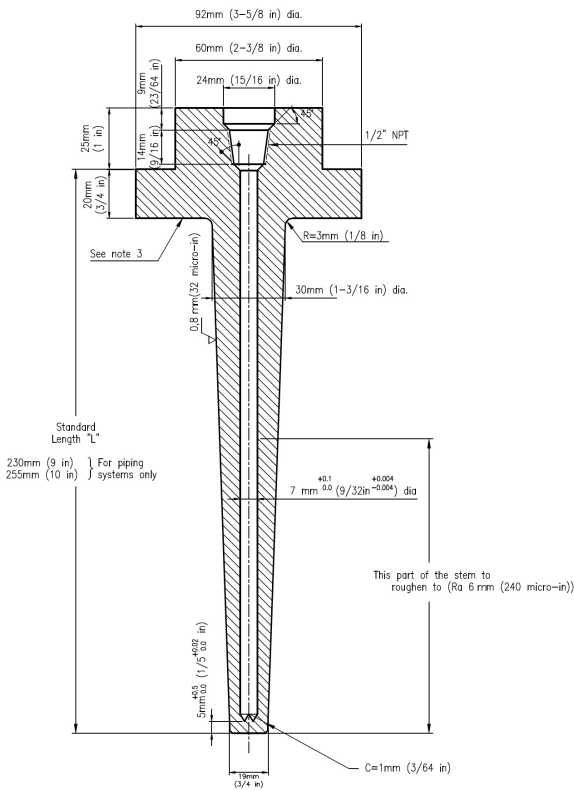
Thermowell design and validation should now take into account both these forces.

This movement can be seen in Okazaki video file on request and also partially on still photograph (Fig 3) shown in our test report AD-5274

Calculations:

ASME PTC 19.3 TW shows clear definition of when and how calculations should be carried out and the reader is referred to this document for a fuller understanding.

Fig 4



When a calculation is required

At very low fluid velocities, the risk of thermowell failure is greatly reduced. The calculations of natural frequency and corresponding frequency, steady-state stress and oscillating stress do not need to be performed provided the following criteria are met:

- The process fluid has a maximum velocity less than 0.64 m/s (2.1 ft/sec).
- The thermowell dimensions satisfy the limits
 - $A - d \geq 9.55 \text{ mm (0.376 in.)}$
 - $L \leq 0.61 \text{ m (24 in.)}$
 - $A \geq B \geq 12.7 \text{ mm (0.5 in.)}$
- The thermowell material satisfies $S \geq 69 \text{ MPa (10 ksi)}$ and $S_f \geq 21 \text{ MPa (3 ksi)}$.
- The thermowell material is not subject to stress corrosion or embrittlement.

The calculation of the external pressure rating shall still be performed.

Concern for Shell Design Thermowells

(Shell S38.113) This Standard applies to thermowells with an as-new surface finish of $0.81 \mu\text{m (32 } \mu\text{in.) Ra}$ or better. Stress limits given in subsection 6-12 are not valid for thermowells manufactured with rougher surfaces. (ASME PTC 19.3 TW)

Shell Drawings S38.113 and S38.114 shows for the last 120mm the surface is roughened to 6 Ra (Fig 4) so these designs are outside scope of the standard

What is Calculated?

Much attention has been focused on the frequency limit of the thermowell and how the natural frequency and wake frequency ratios compare and effect on the safe operation of the thermowell but in fact there are 4 criteria that the thermowell design must meet against the applicable process conditions.

Frequency Limit
Dynamic Stress Limit
Static Stress Limit
Hydrostatic Pressure Limit



Fig 5

If $N_{sc} > 2.5$ and $Re < 10^5$, in-line resonance is suppressed, and the installed natural frequency of the thermowell shall satisfy

$$f_s < 0.8 f_n^c$$

If the thermowell fails the cyclic stress condition for operation at the in-line resonance condition, the installed natural frequency,

$$f_s < 0.4 f_n^c$$

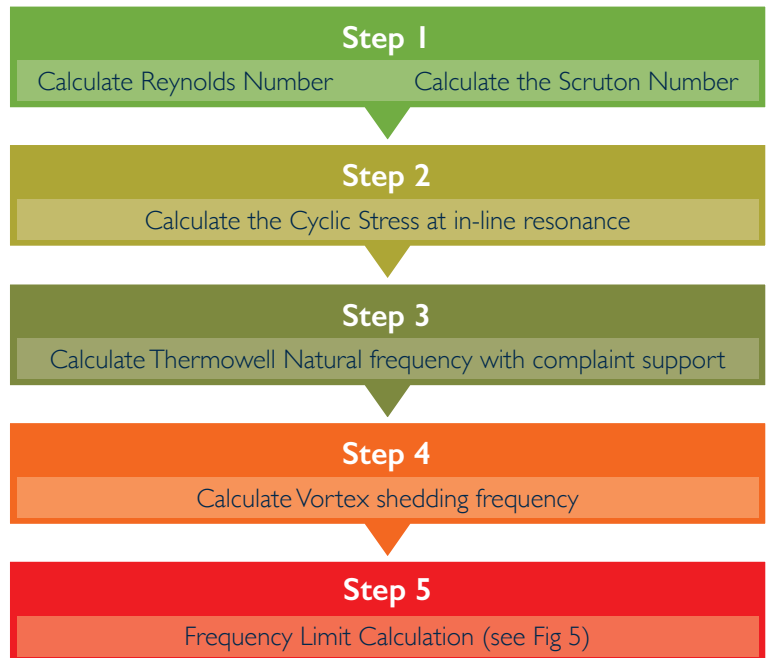
In cases where the thermowell passes the cyclic stress condition for operation at the inline resonance condition, care shall still be taken that in steady state the flow condition will not coincide with the thermowell resonance. The steady-state fluid velocity should meet one of the following conditions.

$$f_s(\text{steady state}) < 0.4 f_n^c$$

$$0.6 f_n^c < f_s(\text{steady state}) < 0.8 f_n^c$$

Frequency Limit Calculation

ASME PTC 19.3 TW now provides calculations and acceptance criteria based on the given process conditions and thermowell design. The reader is again referred to this standard for a full explanation and we will summarise for an overview understanding.



Dynamic Stress

Calculation carried out in line with ASME PTC 19.3 TW

Static Stress limit

Calculation carried out in line with ASME PTC 19.3 TW

Hydrostatic Pressure Stress and Limit

Calculation carried out in line with ASME PTC 19.3 TW For flanged thermowells note is taken to check thermowell flange rating against instrument data sheet due to thermowell material pressure ratings versus process pipe material pressure rating.

What happens when the thermowell fails the calculation?

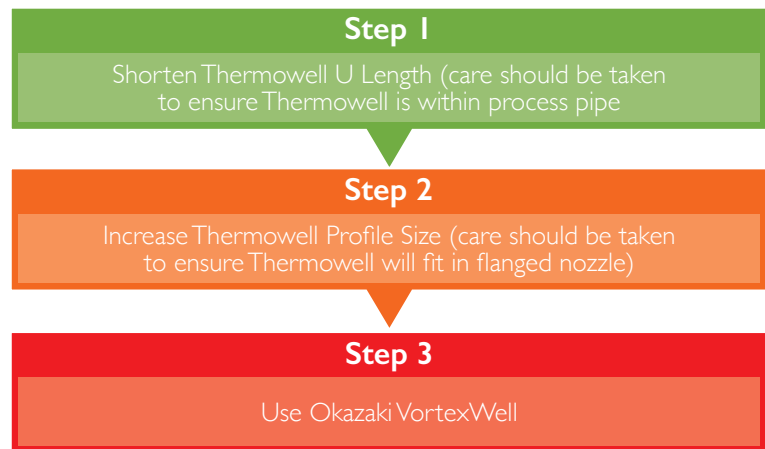
Nominal Pipe Size	Nozzle ID			
	40	80	160	XX Strong
1 1/2"	40.9	38.1	34.0	27.9
2"	52.5	49.3	42.9	38.2

Nominal Pipe Size	Maximum Well OD			
	40	80	150	XX Strong
1 1/2"	33	30	26	20
2"	45	41	35	30

ASME PTC 19.3 TW only defines the test criteria and offers no solution when the thermowell design fails the series of equations based on the operating conditions.

Okazaki has formulated a procedure drawing on over 50 years of engineering and manufacturing experience, this combined with a detailed understanding of client and international engineering standards and best practises give us a unique series of solutions to ensure correct thermowell design.

By following these detailed simple steps a solution can be found in a quickly and cost effective manner.



By decreasing the thermowell length this increases the natural frequency but with a flanged thermowell there is the increased length of the process connection and associated stub connection. The thermowell tip must be suitably positioned within the process pipe to ensure the sensor is also positioned in the correct position. There is much debate from engineer to engineer on the correct length into the process pipe and some guidance can be taken from API RP 551 which states the following.

“A thermowell installed perpendicular or at 45-degree angle to the pipe wall should have a minimum immersion length of 2 inches a a maximum distance of 5 inches from the wall of the pipe.”



Fig 7



Okazaki Manufacturing Vortexwell (Fig 7)

After the failure of a thermowell which had passed a calculation based on ASME PTC 19.3 1974 at the Japanese Monju nuclear power plant in 1995. Okazaki being one of Japan's largest manufacturers of temperature assemblies started its own research into how thermowell designs could be improved.

With the publication of JSME S 012-1998 and based on our own in house preliminary research we decided to look to industry for an alternative way to suppress the wake frequency, this would if successful remove the problem of and offer a real alternative solution.

JSME S 012-1998 shows the best methods to decrease the vibration caused by a Karman Vortex Street is as we discussed earlier to make the thermowell shorter or larger in diameter. When this is not possible then countermeasures to avoid the occurrence of the Karman Vortex Street should be used. There are several methods mentioned but after our initial R&D the Helical strake design was our choice due to the suitability on the Thermowell.

The use of Helical Strakes is referenced in many documents and patents Scruton, C., Walshe, D.E.: US3076533 (1963).

BS 4076 which recommend their use of Helical strakes for prevention of "Von Karman vortex shedding.

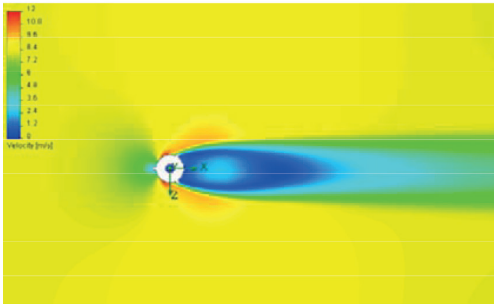
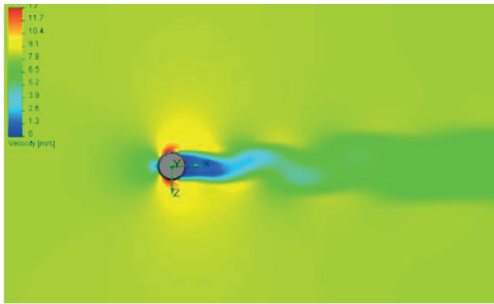
Okazaki Manufacturing Research

Once the technical research was carried out and the Helical Strake pitch, quantity and thickness was decided.

Tests carried out at Tamagawa University showed in a direct comparison between a standard thermowell profile and that fitted with Helical Strake profile then the latter showed no adverse effects from the various flow rates subjected on the test samples.

At the higher flow rate the standard thermowell showed signs of vibration and failed due to metal fatigue.

Fig 8



In 2008 Okazaki UK commissioned a detailed CFD analysis of both a standard thermowell and the now branded VortexWell profile. (Fig 8 shows comparison plots)

This report showed three clear findings firstly the shortcomings with the at time ASME PTC 19.3 1974 code and that our research information and Japan university test were correct.

The following was shown within the report

“It was found that the thermowell with helical strakes demonstrated no regular vortex shedding. While the flow behaviour varied significantly along the length of the thermowell it was observed that little or no time dependent changes occurred and the results were considered dynamically stable in all cuts along the length. The plots showing flow streamlines provided an excellent visualisation of the influence of the helical strakes. It's suggested that the strakes sufficiently disturb the flow in the wake region such that no regular vortices can form. The strakes also encouraged cross plane flow behaviour (along the thermowell length) to an extent that was not observed with the standard thermowell. It's thought that this process also helps to interfere with vortex formation.”

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“A comparison of dynamic performance and mechanical stresses indicates that the VortexWell has significantly outperformed the standard thermowell in this project”

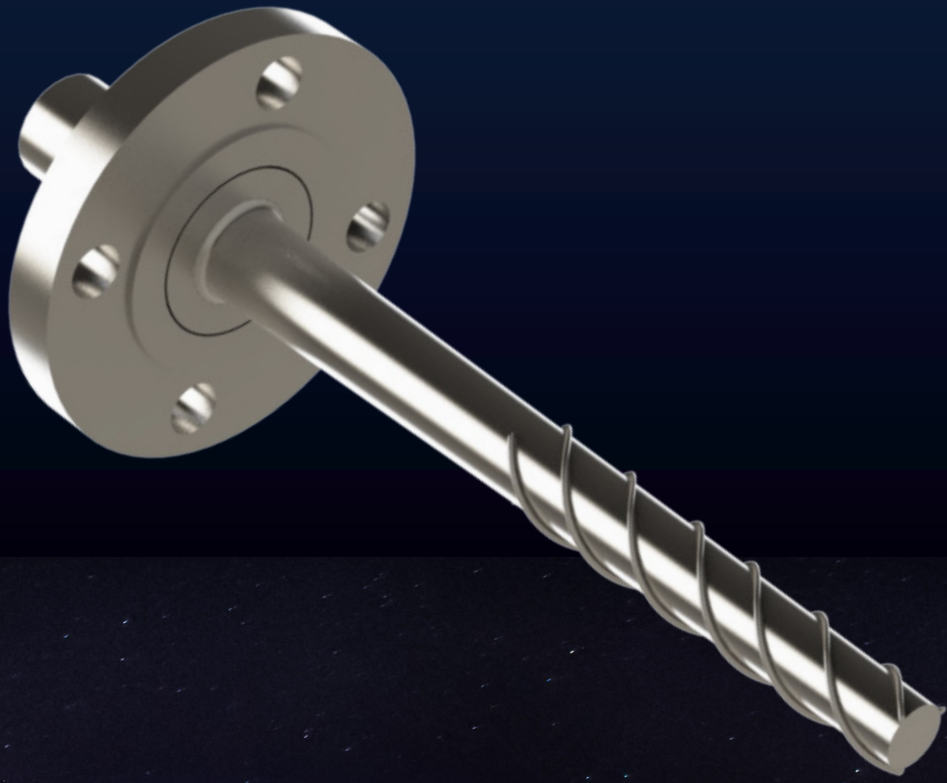
Conclusion

As end users, manufacturers and design engineers carry out thermowell calculations to ASME PTC 19.3 TW. Now with the inclusion of this requirement in the new version of ASME B31.1, published in 2014, it has been reported that the amount of thermowell calculation failures increased.

“By way of example, 2,571 thermowell calculations based on real data of thermowell calculations carried out in the past were evaluated. The comparison of the results shows that the probability of a thermowell calculation not passing the test with respect dynamic consideration in the examples under investigation increases by 27,9 %.”

The VortexWell designed and manufactured by Okazaki Manufacturing Company offers a credible solution to overcome increasing failures.







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