Endurance test for vortex breakers

Extensive tests performed at the National Engineering Laboratory's (NEL) flow test facility in Glasgow, UK, have confirmed that thermowells with a ScrutonWell® design have no tendency to vibrate. Kai Grabenauer, product manager for WIKA's electrical temperature measurement business in Europe, presents the findings and the principles underpinning the ScrutonWell design.

No matter how stormy the weather, industrial chimneys with a helical structure stand firm. Numerous experiments at various times in the past have proven beyond all doubt that the helix solution patented by Scruton and Walshe prevents them from vibrating.

The helix diverts the wind flow upwards on one side of the chimney and downwards on the other, preventing the formation of Kármán vortex streets downwind of the chimney.

However, if this same principle is applied to other structures, mistrust quickly sets in. Like chimneys, traditional thermowells – the tubular fittings used to protect temperature sensors in industrial process piping – are at risk of flow-induced vibration and fatigue failure due to these same vortices that form behind the thermowell relative to the direction of process flow.

WIKA can now dispel all doubts: an endurance test has confirmed what has already been demonstrated in thousands of real applications: the ScrutonWell® design shows no tendency to vibrate.

Whenever there is flow around a thermowell, two rows of vortices rotating in opposite directions are formed behind it under certain conditions. These vortices can cause the thermowell to vibrate and subsequently fail under load. If the thermowell has a helix, on the other hand, this prevents the formation of these vortices. The tendency to vibrate is suppressed, as is the risk of dynamic fatigue failure.

In spring 2018, WIKA commissioned a behavioural comparison of a thermowell with a ScrutonWell® design and a standard thermowell at the flow testing facility of the internationally renowned National Engineering Laboratory (NEL) in Glasgow. The test comprised a total of 47 experimental runs in a pipe containing gasoil, a diesel-like medium, which flowed over the thermowell at room temperature at a velocity of between 0.5 m/s and 6.0 m/s, depending on the requirements.

Both thermowells were equipped with strain gauges for the duration of the test series in order to measure the dynamic load at the transition to the flange. An accelerometer in the thermowell hole served to record the velocity values at the thermowell tip. All tests were also recorded using a high-speed camera capable of producing 12 500 frames per second.

Prior to commencing the tests, the dimensions of the standard thermowell were adapted according to ASME PTC 19.3 TW-2016, the calculation standard, to ensure that vibration did in fact occur in the tested velocity range, both in the flow direction (in-line resonance) and at right angles to it (transverse resonance).

The ScrutonWell thermowell was then designed in the same way. The natural frequency of the standard TW10-F thermowell was calculated at 38.7 Hz, which deviated by only 4.1% from the frequency determined at the NEL during the experiments, testifying to the high reliability of the WIKA thermowell calculation software V2.7.1.

Test results

The maximum vibration measured at the tip of the standard thermowell was approximately 450 mm/s RMS at a flow velocity of around 1.8 m/s (in-line resonance) or approximately 2 480 mm/s RMS at a velocity of around 5.0 m/s (transverse resonance). No comparable maximum values were determined for the ScrutonWell® design. Instead, the vibration increased linearly with the flow but remained permanently low. Strain gauge measurements of the dynamic stress at the thermowell root produced a similar picture.

Thanks to the high-speed video, it was possible to measure the vibration amplitudes extremely precisely, which were recorded as deflection charts. Taking the transverse resonance for a 4.5 m/s flow speed as an example, the standard thermowell produced a deflection of 27 mm, while the ScrutonWell thermowell exhibited a maximum deflection of just 1.2 mm – about 96% less under identical conditions.

Damping

The damping of the ScrutonWell design was demonstrated in comparison to the standard thermowell in 47 experimental runs made up of several tens of thousands of measurements. A comparative factor was introduced to enable this damping to be quantified. It was decided that a damping factor greater than zero would identify the ScrutonWell as superior, while a value less than zero would make the standard thermowell the winner of the design comparison.

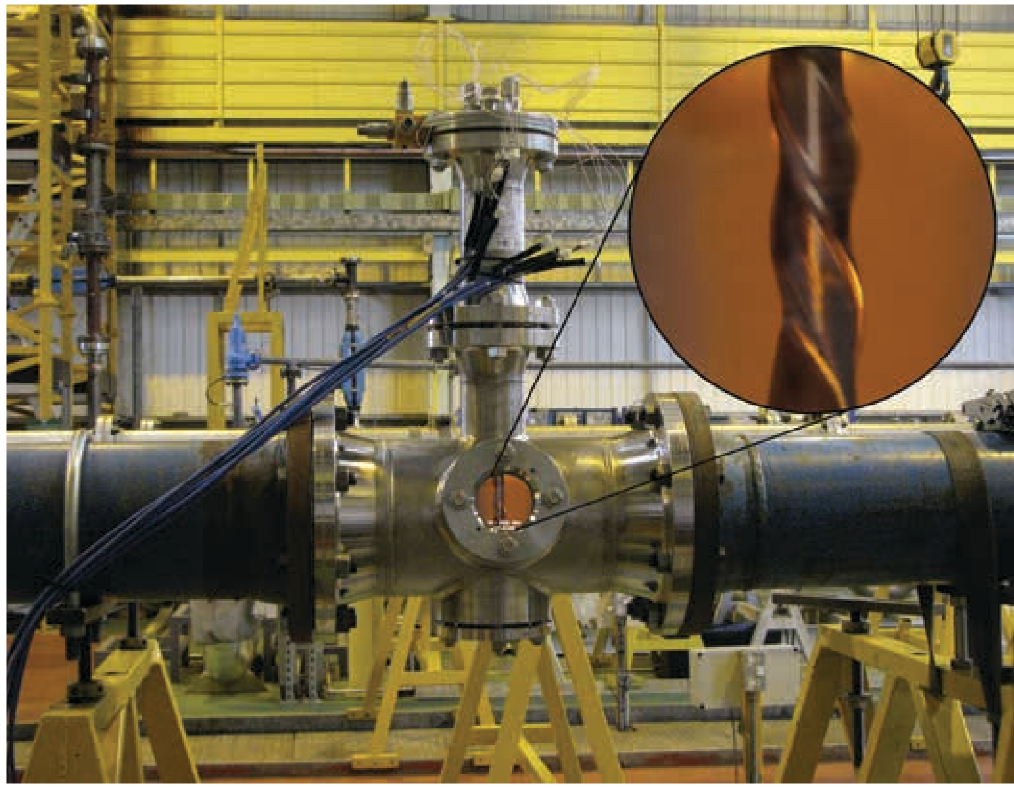
Industrial chimneys with a Scruton helix and (inset) a thermowell with a ScrutonWell® design. The helix diverts the wind or flow upwards on one side and downwards on the other, preventing the formation of vibration-causing vortices.

According to the test, the mean damping of the ScrutonWell thermowell in the in-line resonance range was 90.9% greater than that for the standard thermowell design and a mean damping of 92.8% better was recorded in the transverse resonance range. However, since the measured values exceeded the instrument measuring ranges in almost all of the transverse resonance tests, it can be assumed that the damping of the ScrutonWell design is actually much higher.

Response time measurements

Following the NEL flow test, the comparison of the two-thermowell types concluded with measurements of their response times. These times were measured in a water-glycol mixture in accordance with ASTM E644-09, the test standard for resistance thermometers.

The National Engineering Laboratory's (NEL) flow test facility in Glasgow, UK.



The ScrutonWell test stem mounted in the pipe.

The temperature change at the two thermowells was measured at an immersion depth of 150 mm. The result: based on the T90-time, the ScrutonWell design had a 17.6% faster response time compared to the standard thermowell.

Conclusion

Following on from the tests carried out at the Institute of Mechanics and Fluid Dynamics at TU Bergakademie Freiberg in 2014, these latest comprehensive tests by the NEL in Glasgow confirmed that thermowells with a ScrutonWell design live up to the expectations. They thus represent a good solution whenever thermowell calculations using the ASME PTC 19.3 TW-2016 standard are problematic.

The ASME standard is an excellent way to calculate the behaviour of thermowells in fluid processes, design them accordingly and make statements regarding critical process conditions. Conversely, if the thermowell fails the calculation, its design must be suitably modified, either by shortening the unsupported length or by increasing the diameter.

Very short or thick-walled thermowells may well meet the ASME requirements for mechanical strength. However, from the measurement perspective, they are a nightmare in terms of response time and precision. The need to strictly observe the interference-fit flange nozzle dimensions and the thermowell's mounting position only complicate matters further. If the thermowell is to be supported by a collar, this is of fundamental importance.

Experience shows that many modifications to the thermowell design as a result of a strength calculation are outside the scope of ASME PTC 19.3 TW-2016, so that considerable time, effort and costs are inevitable for mounting. In all such situations, thermowells with a ScrutonWell design are an attractive alternative, as has now been confirmed by several independent institutions.

The proven helix design unites the benefits of extremely effective suppression of vortex-induced vibration (VIV) with the hassle-free mounting of a standard thermowell. The static loads on the ScrutonWell due to the flow of medium and process pressure are calculated according to the relevant sections of ASME PTC 19.3 TW-2016. ☐