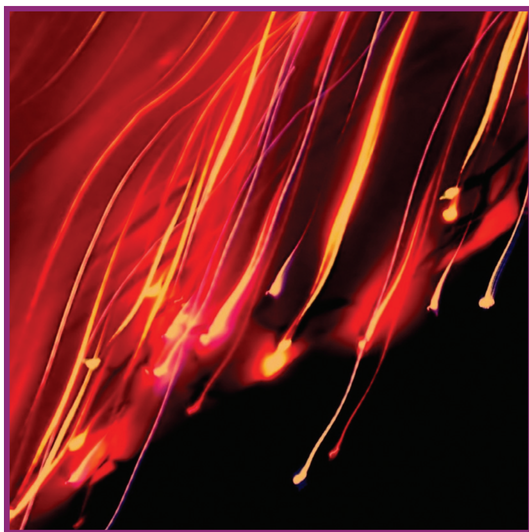

Why it Pays to be in the Know about Thermowells

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The thermowell may seem a fairly simple piece of equipment, designed to act as a barrier between a temperature sensor and the process medium. Yet it is fundamental to the safety of the process; a faulty thermowell can jeopardise the whole operation. Exacting standards, which the user needs to be aware of, govern the manufacture of thermowells.

Temperature is without question the most commonly measured variable in industry, being the simplest piece of information about the state of a process.

In many applications, particularly where the process medium is fast flowing or pressurised, the temperature sensor needs to be protected from direct contact with the medium by a metal structure known as a thermowell.

The integrity of the thermowell is essential to the process, as a leak or a structural failure will expose the contents of the pipeline to the atmosphere. For this reason, very strict standards govern the manufacture of thermowells.

Although the thermowell is a fairly simple piece of equipment, there is still scope for things to go wrong. The main risk comes from vortices forming in the process medium around the thermowell, which can cause vibrations. The stresses caused around the stem of the thermowell by these vibrations can, over time, lead to failure.

Incorrectly specifying pressure-retaining parts can have disastrous consequences, in the worst cases potentially leading to loss of life, loss of the plant and possible prosecution. Although the industry standards do not constitute law, deviation from them would be difficult to explain in court after an incident.

Follow the standards

The majority of thermowells are rated according to American system design standards. Good engineering practice is outlined by the ASME (American Society of Mechanical Engineers) VIII Pressure Vessel Code. This standard refers to other American standards from bodies such as ANSI (American National Standards Institute) or ASTM (American Society for Testing and Materials).

If a flange is specified as an ANSI X" 150 or greater, ANSI B16.5 is the standard it has to comply with. ANSI B16.5 in turn refers to other standards regarding materials and their form of manufacture, for example 'ASTM A182 Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges' and 'ASTM A105 Standard Specification for Carbon Steel forgings for Piping Applications'.

Any flanged device provided under the ASME codes will have the flange size and rating as well as the material specification stamped on it. The flange can be marked for example with 'ANSI 1" 150lb ASTM A 182', indicating that it complies to ANSI B 16.5 and is made from a forging in accordance with ASTM A 182. Additional markings from reputable manufacturers may also indicate the cast number of the material, tag number and the order against which it is supplied.

When specifying thermowells to European standards, P.D. (proposed document) 5500 (2006) is a harmonising document for the European Union. Although this has not yet been adopted as a European Directive, it is used as a unifying standard. Its standards and markings differ from the American standards but the principles remain the same.

Solid steel

Thermowells are made from single pieces of bar or forging. When forging a piece of metal, the internal grain of the metal deforms or 'upsets', aligning it with the shape of the part and producing a structure that is much stronger than an equivalent cast or machined part would be.

A high-quality forged thermowell is made from a single piece which is as close to the finished shape as possible and drilled without penetrating the end of the stem. If a forged thermowell is not required the flange is made either from a hot-worked forging or in some circumstances plate. Except for the weld seam that attaches the flange to the stem, the structure is made from single pieces of metal. Typical materials include but are not limited to 316, Duplex and Super Duplex stainless steels, along with specialist alloys such as Monel and Inconel.

The materials should be traceable all the way back to the mill and any reputable manufacturer should be able to produce verification upon request. The manufacturer needs to be in possession of supporting documentation in order to mark the equipment as compliant. Any raw materials used in the manufacturing must be inspected and measures taken to ensure traceability.

Manufacturing the thermowell

The design of the thermowell is important, but equally significant are the manufacture and test stages. Each part of the process interacts with the others to ensure a tough, reliable product suitable for demanding duty.

When drilling, the first step is to drill the barstock or forging with a specialised 'gun drill'. This ensures a straight hole through the material up to 1200mm long. This work piece is then marked for its centre and the rest of the process works from the drilled hole and not the external shape.

Profiling is then carried out to shape the thermowell stem to the measurements that it has been designed to, using state of the art CNC machines. At this point, a concentricity check is carried out.

All welding is carried out to detailed 'Welding Procedure Specifications'. The procedures are qualified to ASME requirements and all weld operators should have ASME certification. In addition, many operating companies have their own requirements and standards which the operators need to follow during manufacture.

Bolt holes should be machined as a final step. This prevents any deformation caused by the high temperatures generated in the welding process.

Quality control

Testing of the thermowell is an integral part of the manufacturing process. In addition, positive material identification (PMI) should be carried out by trained operators. Third party PMI is also commonly requested.

Dye penetrant inspection is frequently used to locate surface-breaking defects. This helps to detect casting, forging and welding surface defects such as hairline cracks. Penetrant fluid is applied to the piece and a developer is added, making invisible flaws detectable under ultraviolet or white light.

Ultrasonic weld inspection can also be carried out. This uses the principle that a gap in the weld changes the propagation of ultrasound through the metal. Bore concentricity is tested using an ultrasonic device. X-ray and gamma ray examination can also be carried out by accredited third parties.

Final dimensional checks are carried out by trained operators independent from the manufacturing process. All testing should be performed by operators who are qualified to spot defects.

Choose your sensor

Once the thermowell has been manufactured and tested, the heart of the assembly can be fitted. Sensors are calibrated traceable to national standards and fitted with terminal heads and transmitter extension pieces to suit requirements. As great care has been taken throughout the manufacturing of the thermowell, it is important to take equally great care of the sensor selection. The goal is to build a device capable of measuring temperature accurately over a long period of time, so high quality component parts should always be fitted.

The revised ASME PTC 19.3 TW-2010 standard

A new standard for thermowells was recently introduced to replace the existing ASME PTC 19.3-1974.

The latest revision of the ASME PTC19.3 standard makes use of significant new knowledge about the behaviour of thermowells, compared to the criteria laid out in 1974. The standard evaluates thermowell suitability with new and improved calculations for various thermowell designs and material properties. It also takes some detailed information about the process into account.

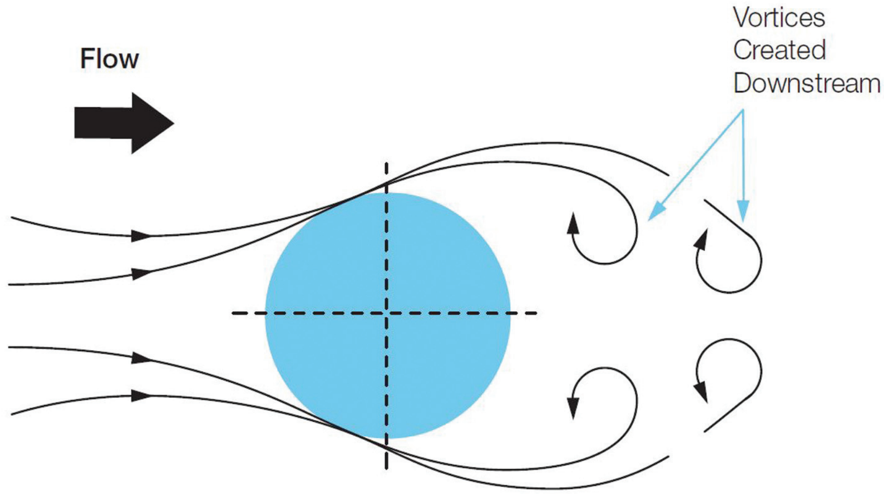

Fig. 3 Flow vortices from thermowell intrusion

In particular, the standard looks at the incidence of vortex shedding. This is the pheonomenon where vortices formed in the wake of the thermowell move from side to side; this is what causes vibrations in the thermowell. If this vortex shedding rate matches the natural frequency of the thermowell, resonance occurs, and dynamic bending stress on the thermowell increases.

Tighter design constraints

The frequency ratio is the ratio between the vortex shedding rate and the installed natural frequency. In the old standard, the frequency ratio limit was set to 0.8. The new standard stipulates that in some cases, the limit should be set to 0.4. The new possibility of having a much lower frequency ratio limit of 0.4 means tighter design constraints in many cases. As the majority of existing assets will have been designed to the 1974 standard, the new 0.4 frequency ratio means a lot of thermowells will not pass the new standard.

Re-evaluation and re-certification services are available. Operators will need to consider the implications when an existing thermowell fails the new calculation. If process conditions change, for example increased throughput for a part of plant, this should also be evaluated.

At a brownfield modification recently examined by ABB for new process conditions, 29 existing thermowells were evaluated under existing and new conditions. Only 6 passed the new standard under existing conditions. ABB subsequently assisted the operator by designing replacement thermowells.

Summary

ABB has a strong pedigree in the manufacture of temperature and primary flow elements, particularly for use in oil and gas applications. Its factory in Workington, Cumbria, is ABB's Centre of Excellence for temperature measurement in the oil and gas industry and specialises in the design, manufacture and testing of both standard and bespoke temperature instruments.

For more information about thermowells or ABB's temperature measurement capabilities, email moreinstrumentation@gb.abb.com or call 0870 600 6122 ref. 'Thermowells'.