

Thermowells in LNG Carrier Liquid Lines

Background

Over the last few years there has been a small but steady occurrence of failures of thermowells fitted into LNG cargo liquid lines. Whilst a simple component, the cost of repair far exceeds the cost of the component, particularly if off-hire is incurred.

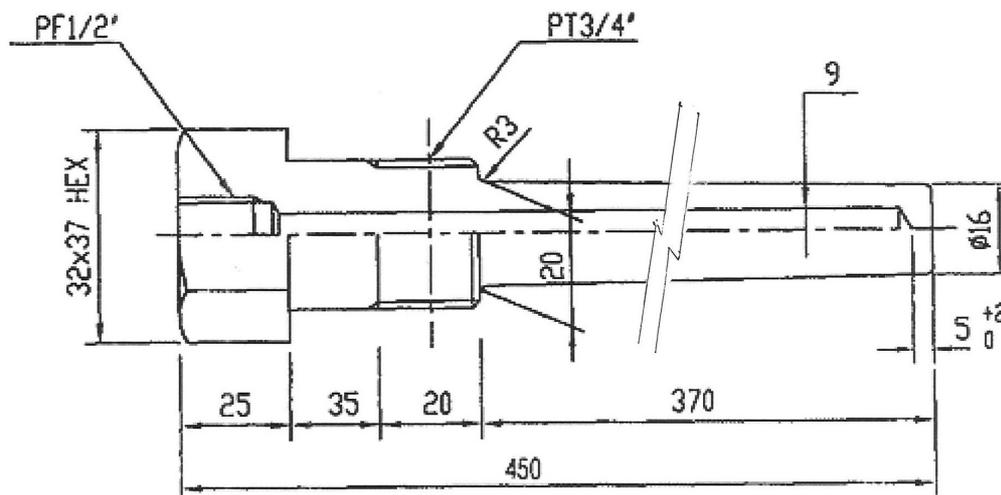
These failures may be discovered when the broken off section is found in the manifold strainers at the discharge port, in a cargo tank at refit, or in some cases, a leak has developed leading, in at least one instance, to a cryogenic fracture of the deck.

These failures have been discussed in SIGTTO meetings, however, the fact that they continue to occur indicates a need for a wider discussion.

Definition

A thermowell, also known as a thermometer pocket, is a closed pocket inserted into the liquid line through a boss welded to the pipe with a screw threaded aperture. The thermowell is screwed into the boss and the temperature sensing element is inserted inside the thermowell. (Note: the sensing element inserted should be sealed into the thermowell so that failure of the thermowell does not inevitably lead to leakage, however, there is no practical way to prove the tightness of the sealing arrangements.)

Thermowells are commonly found in processing plants and ships, but the ones where problems have arisen are installed into LNG liquid cargo lines. The overall length is typically about 450 mm, which is much longer than a normal thermometer pocket (typically about 100mm long).



TYPE : DRILLED BAR STOCK, TAPER

MATERIAL : Carbon Steel SUS304

SUS316L OTHERS _____

Failure Description

A review of the failures indicates a clean brittle fracture across the tubular section near the threaded portion of the thermowell. (See photographs.) The fracture surface indicates a fatigue failure mechanism.

The likely mechanism of cyclic loading leading to a fatigue failure is thought to be a combination of a phenomenon called "vortex shedding" off the thermowell in the flowing liquid and natural resonance of the thermowell. The combination leads to work hardening of the material making it more susceptible to fatigue failure.



Commentary

There appears to be three factors at play in the increasing incidence of these failures;

1. In 1998, the world fleet of LNG ships passed 100, at the time of writing (April 2011) the fleet is over 360. Some of the increase in incidence of thermowell failures may be purely down to a larger world fleet.
2. Vessels built about 20 years ago typically had in total 3 or 4 thermowells on liquid lines, vessels built in the last 10 years may have as many as 16. (There seems no logical justification for this – the older ships have operated perfectly satisfactorily with a small number of thermowells.)
3. There is a suggestion that the design liquid line velocities have increased. (The drive for this is reduced pipeline diameter, hence reduced pipe costs.) However, higher velocities do lead to a greater chance of vortex shedding and, if this coincides with the natural frequency of the thermowell, a greater chance of failure.

Operational Requirements and Proposed Remedy

It is understood that these temperature probes are installed for the benefit of operators to monitor the cargo transfer operations. They have no role in the custody transfer process. In most cases, the interest is whether the pipeline is 'hot' (at ambient temperature), 'cold' (at LNG temperature), or somewhere in between (cooling down or warming up). There is no necessity for a high degree of accuracy, experience has shown that the level required can be met perfectly satisfactorily by attaching the temperature sensing element to the outside of the pipe beneath the thermal insulation. So long as the temperature sensing element is in direct contact with the pipe wall, and covered by thermal insulation, then satisfactory performance should result.

If this remedy is adopted, the thermowell should be unscrewed and removed from the pipe boss, and the hole plugged with a suitable threaded stainless steel plug and seal welded. (Note: We suggest you discuss this with the ship's Classification Society but we understand that, providing the plug and its thread are to a recognised standard, they are not likely to request a pressure test since this weld is not affecting the overall strength of the pipe.)

Suggestions

- 1) If you have already suffered such a failure, we suggest that you do not simply replace with an identical thermowell. There are some so-called "modified" designs of thermowell, usually with less penetration into the pipe, or changes in shoulder profile. We have received reports of cracks in these as well. We suggest you review carefully the need and, if appropriate follow the remedy set out above.
- 2) If you have not had this problem on your ships, we nevertheless suggest during normal, full rate loading or discharge operations you inspect each thermowell for signs of resonance – a low pitched hum or buzz. If you find this, we suggest you consider removing the affected thermowells as above.
- 3) If you are involved in the design and construction of LNG vessels, we suggest that you carefully assess with experienced operational staff how many temperature measurement points you really need on the liquid line system – don't get drawn into putting extra ones in simply because the monitoring system has enormous capacity and can handle them. Also, for the points you have decided upon, consider not using thermowells in the first place, i.e. placing the sensing element directly onto the outside of the pipe. The cost saving will be minimal, but the potential problems avoided may have significant value!

Notwithstanding the foregoing, if it is felt necessary to use thermowells, the following guide is proffered.

- 1) The length of the thermowell is restricted to a maximum of 100 mm penetration into the pipe. (Note, for LNG flows, velocities above about 2 m/s are turbulent and the boundary layer is not more than 10 mm in depth. i.e. providing the sensing element is more than 10 mm into the line, a true reading should be obtainable.)
- 2) Wake frequency calculations for the thermowell are conducted as per ASME Performance Test Code PTC 19.3. This is a procedure used in process plant design.
- 3) The sensing element is screwed into the thermowell with an effective sealing arrangement.
- 4) The external parts of the thermowell and sensor are insulated.

SIGTTO
April 2011