Belzona Polymerics Limited
Claro Road, Harrogate, HG1 4DS, England
Tel: +44 (0)1423 567641. Fax: +44 (0)1423 505967
Email: belzona@belzona.co.uk

COLD APPLIED VESSEL LININGS TAKE THE HEAT

Offshore process vessels operating at elevated temperatures and pressures represent one of the most arduous service environments and major challenges for asset owners and operators. These vessels, and in particular those involved in the separation of oil/water and gas as it enters the process stream, are constantly subjected to a wide variety of aggressive conditions which can ultimately lead to severe internal erosion and corrosion.

Dating back to the 1970s, organic epoxy linings, pioneered by Belzona, were used for the protection of process vessels operating at elevated temperatures. Since then considerable resources have been placed on material development leading to organic linings being widely used by most of the major oil companies worldwide. In 1994, linings resistant to explosive decompression and temperatures of up to 120°C were introduced for the protection of well test separators, production separators, knock-out drums and a variety of other types of process equipment.

Deeper wells – higher operating temperatures

With the sinking of increasingly deeper wells leading to higher operating temperatures and pressures, vessel operators are now faced with a difficult task to combat the problems associated with this kind of service environment. As a result, materials able to resist more arduous conditions had to be developed.

When designing systems for high temperature immersion, it was important to consider the reasons why conventional coatings tend to fail. Many such materials are solvent-based, and in these instances, apart from other limitations, problems are experienced due to solvent retention within the film. Eventually, this solvent leaves the now cured coating leaving behind a void which can then be filled by the process fluids causing blisters that in turn lead to premature failure. Furthermore, a desire for more environmentally friendly systems has made the use of volatile solvent based resin systems increasingly undesirable.

Even some 100% solids systems can present certain problems when operating at elevated temperatures. Systems with low cross-link density are susceptible to a high degree of permeation of both water and gases leading to corrosion. This phenomenon increases dramatically as the polymer system reaches its softening point, Heat Distortion Temperature, when movement of the polymer chains increases and permeation occurs more readily. Even conventional epoxy resins, which typically display good resistance to permeation at ambient temperatures, can only offer limited protection at elevated temperatures. Systems with high cross-link density, in turn, although exhibit excellent temperature resistance can be too rigid and crack during thermal cycling or flexing.

Novel solution to higher temperature immersion

The first step of Belzona's high temperature lining research project was the introduction of hand applied Belzona 1591 (Ceramic XHT) in 1998, and spray applied Belzona 1521 (HTS1) in 1999, following a successful field trial program. Over the following 16 years, Belzona's R&D department analysed data from the field and researched innovative technologies and filler systems that could enhance material characteristics and in-service performance that would allow for the coating to resist elevated temperatures, but at the same time, remain flexible to sufficiently minimise the risk of cracking. This research has culminated in the introduction of next generation HT vessel linings in March 2014, hand applied Belzona 1593 and spray applied Belzona 1523.

According to Belzona's Chief R&D Chemist, Richard Collett, "Belzona 1523 and Belzona 1593 are the culmination of 20 years of experience in formulating high temperature linings, starting in 1994. These linings are based on a combination of several 'state of the art' technologies and I believe they are our best high temperature linings yet."

Key aspects developed

Increased flexibility and toughness – enhanced performance

The high cross-link density required in coatings to achieve their high temperature immersion resistance leads to rigid coatings being susceptible to cracking during thermal cycling and substrate flexing. Belzona 1523 and Belzona 1593 have been formulated to exhibit toughness and flexibility with rubbery domains that inhibit crack propagation incorporated into the structure. With high tensile strength and elongation, these coatings are designed to withstand temperature and pressure cycles while preserving their integrity and maintaining adhesion, as well as providing corrosion and chemical resistance. Unlike rigid coatings, these next generation linings are less brittle and can tolerate high radial, circumferential and longitudinal stress, reducing material ruptures, breaks and fissures, moving in sympathy with the substrate.

Crack propagation in other coatings (left) and Belzona 1523 and Belzona 1593 (right)

Simplified application methodology and inspection

The next generation linings address an application issue previously experienced when applying a two coat system of HT linings - bypass the need for grit blasting between coats, provided the second coat is applied within a 24-hour overcoat window. In addition, their unique curing mechanism activated at ambient temperatures eliminates the need for separate post curing processes and the lining will post cure in service ensuring a faster turnaround.

High viscosity coatings are often over applied in an attempt to make the application easier and to improve the flow out, which can lead to over-thickness and have a big impact on cost but more importantly on performance. Improved rheology in this case allows a more uniform thickness can be achieved.

An important consideration for lining manufacturers is visual inspection during application. Dark coloured linings can make it very challenging due to poor lighting inside the vessel. Next generation linings have been formulated in light contrasting colours enabling quicker and more precise identification of potential problems at the application stage. They are also spark testable and with minimal bloom formation on the surface, false alarms due to surface tracking will be eliminated.

Put it to the test

In order to evaluate, determine and compare their performance under simulated service conditions to define their capabilities in service, Belzona 1523 and Belzona 1593 have been subjected to independent and in-house testing.

1. Explosive Decompression (NACE TM0185)

In July 2012, GL Industrial Services UK Ltd tested Belzona 1523 and Belzona 1593 according to NACE TM0185 international standards and passed at a temperature of 120°C (248°F) and 70 bar pressure. Test media comprised 33% sea water, 33% crude oil and 33% Gas (90% Methane and 10% CO_2).

2. Steam-out

Materials were tested by Det Norske Veritas, USA for resistance to pressurised steam-out conditions and after four days exposure to pressurised steam at 210°C no failure was reported and the successful outcome was confirmed by excellent retention of adhesion after exposure.

3. Atlas Cell Immersion (NACE TM0174)

This Atlas Cell test is designed to measure the maximum temperature resistance in continuous immersion and to evaluate the corrosion protection of a coating. The test method also evaluates a coating's ability to withstand the temperature gradient that exists between the internal and external surfaces of a coated substrate known as the cold wall effect.

Belzona 1523 and Belzona 1593 were tested in-house according to NACE TM0174 and in order to achieve the most severe conditions, the immersion equipment has not been insulated. Both materials passed six month testing without exhibiting any rusting or blistering, Belzona 1523 at 140°C (284°F) and Belzona 1593 at 160°C.

4. Three Point Bend Test

This flexure test method was designed by the manufacturer specifically to measure the behaviour of materials subjected to simple three point bend. The coated panel is flexed to the point where cracking occurs in the coating. Belzona 1523 and Belzona 1593 have exhibited comparable flexibility to other similar non-rigid coatings, such as Belzona 1391 (Ceramic HT), Belzona 1391S and Belzona 1391T. This indicates decreased risk of cracking during thermal cycling or impact.

5. Cathodic Disbondment (ASTM G95)

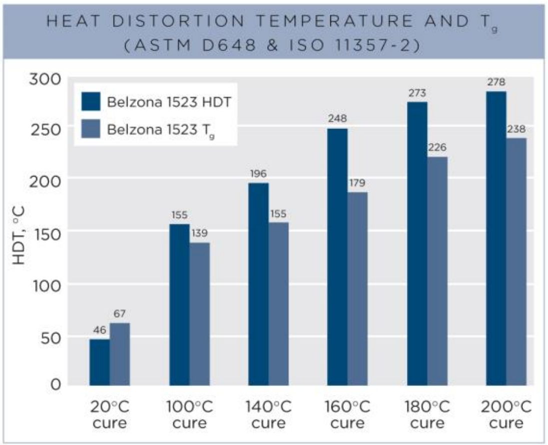
Belzona 1523 and Belzona 1593 have been tested to determine the coatings' suitability for use in conjunction with an installed cathodic protection system on 4 November 2013 by Exova (UK) Ltd according to ASTM G95 and both products passed 90°C for 30 days with 5mm average disbondment radius.

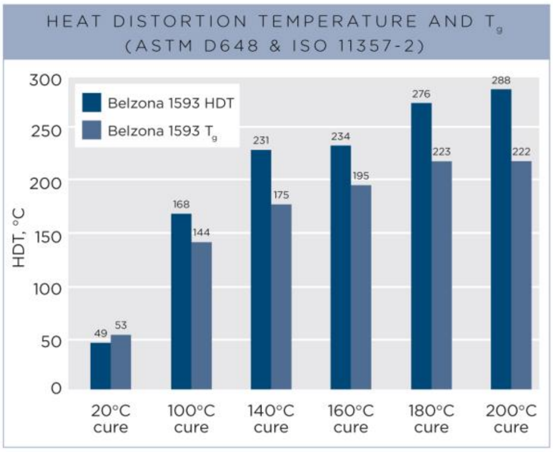
Laboratory testing, however, is not always 100% indicative of the in-service performance. Feedback received so far from the field concerning the use of the next generation HT linings has been positive, citing simplified application techniques and savings achieved as a result of greater coverage rates paired with decreased contractor expenses. Additionally, considering that newly released materials are the next generation versions of their predecessors, Belzona 1591 and Belzona 1521, field experience demonstrating longevity can be further effectively utilised to assist corrosion engineers and asset operators with the vessel corrosion protection material selection.

Material Technical Data

Property	Belzona 1593	Belzona 1523
Colours	Light grey, light green	Light grey, light green
Unit size	1 kg, 3 kg	10 ltr
Application method	Brush, applicator	Heated airless spray
Mixing ratios	11:1 PBW, 5.6:1 PBV	8:1 PBW, 4.5:1 PBV
Usable life	~45 mins (20ºC)	~45 mins (20°C)
Min/max total DFT	500 – 1000 microns	500 – 1000 microns
Theoretical coverage rate	1.10 m^2/kg	2 m^2/ltr

Inspection methods	Spark testing, sponge testing	Spark testing, sponge testing
Overcoat window	Up to 24 hours	Up to 24 hours
Maximum immersion temperature	160ºC (6 months, un-insulated)	140°C (6 months, un-insulated)
Steam-out resistance	210ºC (96 hours)	210°C (96 hours)
Maximum HDT	234ºC	196°C
Taber abrasion resistance	1042 mm^3 (H10/wet)	835 mm^3 (H10/wet)





- END -

<u>By-line (if applicable)</u>

Edited by Marina Silva, contributors: Richard Collett and Anna Michael
Belzona Polymerics Limited