BRITANNIA LOSS PREVENTION

INSIGHT

ISSUE 12 // AUGUST 2024

ESSENTIAL GUIDE TO TANKER SHIP COATINGS

TANKER SHIPS ARE DESIGNED TO TRANSPORT VARIOUS TYPES OF PRODUCTS AND CHEMICALS, AND THEIR ONBOARD TANKS REQUIRE SPECIALISED COATINGS TO ACCOMMODATE A WIDE RANGE OF CARGO TYPES.

A reliable and effective tank coating prevents water and corrosive agents from coming into direct contact with the metal surfaces, reducing the likelihood of structural damage and preventing cargo contamination during transportation. Therefore, it is essential to understand the significance of tank coatings and how they can impact claims and risk management.

This article outlines the primary types of tank coatings, their basic properties and their limitations.

Van Ameyde Marine

OUR PARTNER FOR THIS ISSUE

With over 70 marine surveyors and consultants worldwide, Van Ameyde Marine is one of the largest single service providers for the marine industry.

TYPES OF COATING

SEVERAL TYPES OF CARGO TANK COATINGS ARE AVAILABLE, EACH WITH THEIR OWN PROPERTIES AND ADVANTAGES FOR VARIOUS PRODUCT TYPES.

Stainless Steel Coating

STAINLESS STEEL

Stainless steel is technically not a coating. However, it is a common tank lining found on the majority of chemical tankers. Commonly used alloys in the tanker industry include: 316 and Duplex stainless steel. The 316L or LN-graded alloys are predominantly used where the surfaces in between cargo tanks are made of solid stainless steel and the surfaces between cargo tanks and adjacent ballast tanks or void spaces are cladded. “Cladded” implies a three-millimeter stainless steel layer has been applied to the construction steel of the vessel.

One distinctive property of stainless steel is the presence of a chromium-oxide layer, often known as the “passive layer”. This ultra-thin layer, measuring about three-nanometers in thickness, serves as a protective barrier between the stainless steel and the product carried in the tank. This passive layer may deteriorate over time when exposed to specific cargoes. Nevertheless, stainless steel has the natural capability to regenerate this passive layer when it interacts with oxygen. The integrity of the chromium-oxide layer is commonly referred to as “passivity”. To facilitate the complete restoration of the chromium-oxide layer in stainless steel, it is recommended that stainless steel cargo tanks are exposed to air for a duration of 24 to 72 hours after tank cleaning. However, this may not always be achievable due to quick turnarounds where discharging, tank cleaning and loading are carried out consecutively.

Following the repeated carriage of potentially aggressive cargoes, such as acids, the chromium-oxide layer may not be fully restored. This can be attributed to to the presence of contaminants, primarily consisting of free iron molecules originating from the stainless steel. To facilitate the steel to regenerate it's protective passive layer, a process known as “passivation” is conducted.

During this process, a solution of nitric acid or citric acid is circulated in the cargo tanks via the tank cleaning equipment. The acid effectively removes the free iron impurities. Subsequently, the tanks undergo thorough washing and are left exposed to air (oxygen) for some 72 hours. During this time, the chromium within the stainless steel alloy reacts with the oxygen to form the passive layer to its full extent. Ship crews can carry out passivation, but extreme caution and careful handling should be exercised.

Additionally, another process called “pickling” may also be carried out, although to a lesser extent compared to passivation. The process involves acid treatment and focuses on the removal of surface iron, impurities or oxides and the elimination of heat discolouration. Pickling is typically conducted by external specialised contractors.

Although stainless steel is highly resistant if compared to other steels, it may not avoid corrosion entirely. Pitting is the most common form of corrosion whereby small pits are created due to a chemical reaction of certain elements with the stainless steel (for instance cargo residues combined with chlorides). If left unattended, these pits may turn into larger crevices of multiple millimeters in depth and centimeters in width.

These pits create an irregular and uneven surface which makes it harder to clean. They can also retain cargo residues causing cross-contamination and can hamper the stainless steel in its ability to restore its passive layer. On cladded steel surfaces, pits and crevices may penetrate the three-nanometer stainless steel layer whereafter the underlying mild steel is exposed to the cargoes carried. In some extreme cases this may lead to a breach of the mild steel and result in cargo leakages into the adjacent ballast tanks and/or void spaces.

BEST PRACTICE

It is recommended to conduct a thorough inspection of the cargo tanks after each cleaning operation, not only for cleanliness, but also for a visual assessment of the steel's surface condition. Depending on the trade activities, the passivity of the steel should be measured periodically.

During these inspections special attention should be paid to the condition of stainless steel heating coils. Often, the presence of pitting can lead to the development of pinholes. Pinholes can result in cargo contamination by the heating medium - typically water (occasionally mixed with glycols) or thermal oil. To ensure the integrity of these coils, a regimen of pressure testing should be established before their utilisation, complementing the standard visual examination.

Additionally, special care should be taken prior, during and after the carriage of acid cargoes because they have the potential to form aggressive mixtures which react chemically with the stainless steel, causing corrosion damage. Depending on the severity of such damage, repairs may turn into costly affairs on account of labour, materials and operational delays.

PURE EPOXY
ORGANIC COATING

Intact coating

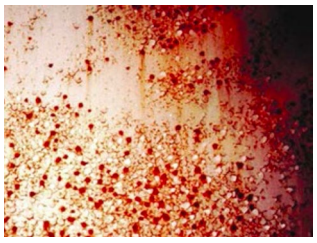
Typically used for vessels in the clean petroleum products (CPP) trade, pure epoxy has a low resistance and therefore limited flexibility among cargo types.

Poor corrective maintenance and failure to clean tanks properly after transporting cargoes can lead to the accumulation of particulate matter or retention of cargo and/or cleaning water residues, causing subsequent cargoes to be contaminated.

When subjected to improper cleaning methods or exposure to elevated temperatures, epoxy coatings may degrade faster, making them susceptible to accelerated deterioration and transforming them into potential sources of cargo contamination.

The binder within organic coatings can be chemically attacked by unsuitable or incompatible cargoes, such as palm fatty acid distillate and other vegetable acid oils in a pure epoxy-coated cargo tank. The cargo resistance list should always be consulted.

Unbroken coating blister



Cracked blister

BEST PRACTICE

Owing to the nature of trade, cargo tanks often undergo minimal cleaning or, at best, a freshwater bottom flush between cargoes. If an extended tank clean is required, then special attention should be given to the cleaning agent used and the temperature of the cleaning water. Certain cleaning agents are very effective in removing previous cargo residues but can be harmful to the epoxy coating too.

A routine inspection should be in place to periodically assess the condition of the coating. Localised coating breakdown may expand rapidly and should be addressed as soon as possible. Failure to do so may result in particulate matter contamination (coating flakes or rust particulates) or even cargo/moisture contamination.

When the coating has softened, sufficient time should be granted for the coating to harden. Exposure to additional heat should be avoided to prevent the top layer of the coating hardening, while the underlying layers remain soft.

Manufacturers' guidance should be followed in terms of cargo compatibility as well as exposure to heat and cleaning agents.

PHENOLIC EPOXY
ORGANIC COATING

Intact coating

Phenolic epoxy coating combines the properties of both phenolic and epoxy resins, offering resistance to a wider range of chemicals. This coating is commonly used as it offers more flexibility due to its exceptional resistant properties. However, the coating has the potential for cargo adsorption/desorption which makes it relatively difficult to clean. While it demonstrates limited or no-resistance to hydrocarbons such as aromatic (solvent) cargoes, ketones, alcohols and highly acidic cargoes, it is resilient against basic cargoes (alkalis) and suitable for the carriage of vegetable oils, CPP and mildly acidic cargoes.

CONTINUED ON NEXT PAGE

Blister

Patch breakdown

BEST PRACTICE

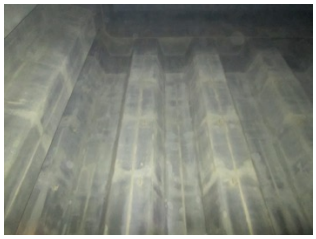
During tank cleaning, special attention should be given to the cleaning agent used and the temperature of the cleaning water. Certain cleaning agents are highly effective in removing previous cargo residues but can prove to be detrimental to the integrity of the phenolic epoxy coating.

It is important to be mindful that the properties of coating can adsorb and desorb cargo residues. The process of desorption is not immediate and the coating may need some time to swell and soften to be able to release the residues. Thorough ventilation at ambient temperatures after tank cleaning may assist in removing adsorbed (volatile) cargo residues. The application of additional heat to the coating may work counterproductively even though it increases the rate of evaporation of the residues in the coating. It may cause the top of the softened coating to harden, while the underlying layers remain soft. This could result in the "locking up" of previous cargo residues, which may consequently desorb at a later stage and contaminate the next cargo.

A routine inspection should be carried out to periodically assess the condition of the coating. Localised breakdown of coating may expand rapidly and should be addressed as soon as possible. Failure to do so may result in particulate matter contamination (coating flakes or rust particulate) or even cargo/moisture contamination.

Manufacturers' guidance should be followed.

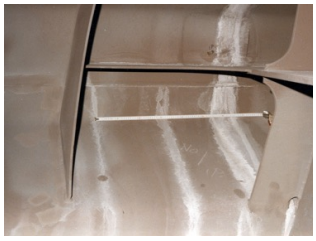
ZINC SILICATE
INORGANIC COATING



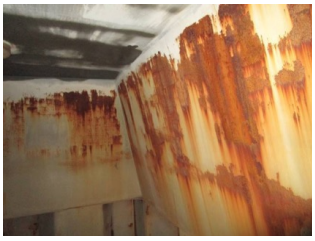
Coating intact condition (not as smooth as other coatings)

Zinc silicate coatings offer robust chemical resistance, especially for solvents and can be used as primers for other tank coatings. However, without proper surface preparation before applying zinc coatings, such as cleaning and blasting, it may lead to adhesion problems which can cause coating failure and increase contamination risks. When zinc coatings are used as primers, using an incompatible top coat can result in coating damage, potentially causing off-spec claims during cargo transportation.

Zinc salts are produced throughout the active lifespan of the coating and will appear as white patches. This provides a useful corrosion protection feature inherent to this type of coating. When zinc reacts with water at slightly elevated pH levels, it forms an insoluble layer of zinc hydroxide/zinc carbonate on the surface of the coating, which passivates it and protects the surface from further attack.



Damaged coating (Zinc salt)



Damaged coating

Zinc silicate coatings are particularly suitable for aromatic (solvent) cargoes, ketones and alcohols. They provide limited resistance to acidic/basic cargoes with a pH below 6 and higher than 9. This limited resistance also applies to cleaning agents (e.g. caustics), reactions of cargo residues with water and the formation of acids during carriage. Open structures and rough surfaces makes the coating somewhat difficult to clean. Zinc deposits can form and contaminate cargoes, such as jet fuel. Zinc coated cargo tanks are therefore not suitable for the carriage of cargoes destined for human consumption (such as edible oils).

BEST PRACTICE

During tank cleaning, special attention should be given to the cleaning agent used and the temperature of the cleaning water. Certain cleaning agents are very effective in removing previous cargo residues but harmful to the zinc coating.

Be mindful that vegetable oils can form Free Fatty Acid (FFA), which may accelerate when exposed to high heat and water. The FFA is acid by nature and may be harmful to the coating. Furthermore, be mindful that certain cargoes form into acids when mixed with water. The mixing of residues with water during tank cleaning may be harmful to the coating.

Similar to all coatings, a routine inspection should be carried out to periodically assess the condition of the coating. Localised breakdown of the coating may expand rapidly and should be addressed as soon as possible to avoid damage to the steel under the coating in the tanks as well as cargo claims.

MARINELINE
POLYMER COATING

MarineLine coatings provide high resistance to most CPP cargoes, vegetable oils and chemicals, including acids, caustics and various solvents.

Intact coating

It is a polymer coating and has a smooth surface, which makes it easier to clean. Due to its closed structure, the coating is not subject to adsorption and desorption of cargo.

Coating damaged

BEST PRACTICE

A routine inspection should be carried out to periodically assess the condition of the coating. Localised breakdown of coating may expand rapidly and should be addressed as soon as possible to avoid damage to the steel under the coating in the tanks and to avoid cargo claims.

Furthermore, while this applies to all coatings, crew members should be particularly careful when working in the cargo tank. The consequences of accidentally dropping a tool on the tank may not be immediately apparent, but this may cause microscopic cracks. Over time, these cracks may eventually lead to the breakdown of the coating system.

Manufacturers' guidance should be followed in terms of cargo compatibility, but also in respect of carrying out repairs if needed. Often the manufacturer provides a repair kit for touch up repairs. When the crew make repairs, the surface should be prepared and treated.

CHOOSING A COATING

THE DECISION REGARDING COATING TYPE IS MADE BEFORE THE CONSTRUCTION OF A VESSEL BEGINS. THE FOLLOWING SHOULD BE CONSIDERED WHEN DECIDING ON A COATING:

- **Intended trade of the vessel** (cargoes to be carried versus compatibility)
- **Costs to apply and maintain** the coating versus the expected proceeds
- **Expected lifespan of the coating** (typically 8 to 15 years, depending on the trade)
- **Ease of tank cleaning** and maintenance.

APPLICATION CONSIDERATIONS

It is important application guidelines are followed when applying coatings to tanks, specifically in terms of surface preparation, drying and curing.

For example, a common coating concern is when grit particles are not fully removed prior to the coating application. This causes miniscule spots where the coating adheres to 'loose' grit particles rather than directly to the steel. Although not initially conspicuous, these spots often form the foundation for accelerated coating deterioration which only becomes more apparent at a later stage.

Coating drying is a different process to curing.

Drying is often considered the first stage of curing and it refers to the evaporation of solvents added to the coating to enhance its application properties. These solvents improve the viscosity of the coating so it can be sprayed on to the tank walls.

Curing is a hardening process involving a chemical reaction, the nature of which depends on the type of coating. To support this process, a curing agent is added to the coating which induces or accelerates the chemical reaction.

To induce and accelerate drying and curing, exposure to high temperatures is normally required.

The curing of a coating after application is a time-consuming process which commonly takes place at the final stages of new building or a (dry) docking period. It is therefore tempting to cut corners in this process to bring the vessel into service as soon as possible.

However, incorrect application may lead to issues in the short- to medium term, or even a significant reduction in the coating lifespan.

To minimise the risk of coating failures caused by incorrect or incomplete application processes, it is recommended the application (including surface preparation, curing and post-curing testing and inspection) is performed under strict supervision of the owners' nominated coating specialist.

EXPOSURE OF COATING

CARGO TANK COATINGS ARE EXPOSED TO RAPIDLY CHANGING AND HARSH CONDITIONS DURING NORMAL VESSEL OPERATIONS, SUCH AS:

- A wide variety of chemical cargoes and cleaning agents in rapid succession
- Sea water
- Rapidly changing temperatures (cargo heating, tank cleaning, ballasting)
- Mechanical impact due to maintenance activities inside the tanks
- Dry/humid environments
- Tensions on the vessel following dynamic forces due to load/ballast conditions and sea conditions.

Although designed to withstand these factors, inevitably they will contribute to the deterioration of the coating over time. Deterioration, such as the formation of cracks, will normally start at microscopic levels. However, this deterioration will eventually become visible during routine operational inspections.

Deterioration of coating is therefore an ongoing process where eventually the coating will reach the end of its lifespan and require replacement. This lifespan is based on the (manufacturer's) assumption that the coating is good enough to carry the cargoes certified in their resistance list. However, it does not mean further deterioration (compared against the original specifications) will not take place during this time frame.

As a coating nears the end of its lifespan, it could be considered suitable to carry certain cargoes, but less suitable for others.

It is important to have a routine inspection regime in place to detect coating damages as early as possible. Smaller amounts of damage may be repairable, to a certain extent, by the ship's crew. However, they will need to have enough time to perform these repairs according to the instructions provided.

The coating manufacturer provides a resistance list which includes guidance to which cargoes are suitable for loading in the tanks. Furthermore, the manufacturer should provide guidance on temperature, exposure time and pH levels.

It is important to adhere to these guidelines and directives to minimise the risk of (premature) damage to coating.

Occasionally, products are selected for carriage which are not included in the coating manufacturer's guidelines. Consultation with a specialist is recommended in such cases, which will often entail in-depth analysis of the product to be carried.

CARGO TANK INSPECTION AND AREAS OF CONCERN

CARGO CONTAMINATIONS OR OFF-SPECIFICATIONS INVOLVING CARGOES CARRIED IN COATED CARGO TANKS ARE OFTEN ALLEGED TO BE ATTRIBUTABLE TO:

- **Previous cargoes trapped in coating blisters** (off-specifications on previous cargo)
- **Cleaning water trapped in coating blisters** (off- specifications on water)
- **Coating flakes due to damaged tank coating** (off- specifications on particular matter)
- **A prior cargo absorbed by the coating** (off- specifications on previous cargo)
- **Rust due to damaged coating exposing the underlying steel** (off-specifications on particulate matter or colour)

However, it should be noted that cargoes may also have an affect on coating. In such cases, coating disintegration or discolouration is most commonly seen. Discoloured cargo tanks are often rejected for loading since a visual inspection does not reveal if the discolouration is caused by the presence of previous cargoes or if it is only cosmetic.

Prior to loading, a cargo owner will appoint a cargo inspector to assess the cargo tank's suitability for loading of the nominated cargo.

The cargo inspector will assess the tank for cleanliness: water white standard is assessed visually whereas high purity standard is assessed by taking wall wash samples for laboratory testing.

CONTINUED ON NEXT PAGE

Additionally, a cargo inspector will assess the visual condition of the coating. Tank surfaces may have areas where the coating is damaged or disintegrated, particularly when nearing the end of its lifespan.

In practice, cargo inspectors may accept coating damages to an extent (often an estimated percentage of the total cargo tank surface). It is important to remember the percentage of the damaged surface is not a definitive number to accept or reject a cargo tank for loading. Instead, the risk for cargo contamination when loaded should be assessed considering the nature and appearance of coating damages. This criteria does not only apply to cargo inspectors when assessing the condition of a cargo tank for loading but also to owners when proposing the tanks.

Some vessels utilise spectrophotometers to assess cargo tank cleanliness and to reduce cargo tank entries (for efficiency and safety reasons). On such vessels, the need for monitoring of coating condition should be considered.

Be mindful that a visual inspection will not always reveal the presence of previous cargoes adsorbed by the coating.

Cargo claims have been brought forward involving the second, third, or even fourth last cargoes carried. In one case it was alleged a styrene contamination could be attributed back to a cargo of benzene four shipments previously. Further investigation revealed the benzene cargo adsorbed within the coating and non-solvent cargoes were carried during the subsequent three voyages. Due to its similar hydrocarbon properties, the styrene was able to pull the benzene from the coating, thereby rendering it out of specification.

In this case, the bulkheads were washed with a solvent (methanol) prior to loading and the resulting analysis did not reveal the presence of the benzene. Desorption is not an immediate process, as the coating needs time to soften and swell for trapped residues to gradually be released. In this case, the contact time of the methanol with the bulkheads was deemed too short to desorb detectable levels of the benzene into the wall-wash samples.

It is believed a typical chemical tanker could retain quantities from 0.5 to 2.0 kg of residues in the coating.

Thorough and prolonged ventilation (without the application of heat, which also softens the coating) after tank cleaning, normally removes any adsorbed cargo remnants and restores the hardness of softened coating. However, this does not always apply to cargoes of a less volatile nature.

GENERAL PREVENTATIVE MEASURES

THE FOLLOWING GENERAL PREVENTIVE MEASURES SHOULD BE CONSIDERED:

- **Clean tanks thoroughly after carrying cargoes** to avoid cross-contamination and off-spec claims during subsequent shipments
- **Conduct regular tank coating inspections and maintenance,** adhering to the coating manufacturer's guidelines and industry best practices
- **Conduct a compatibility test before loading new cargoes** to ensure the tank coatings used are compatible with the type of chemicals being transported
- **Provide training to crew members on tank cleaning procedures** and the handling of different types of cargoes to avoid cross-contamination
- **Maintain accurate and comprehensive records of tank coating maintenance,** inspections and cargo handling to provide evidence in case of disputes or insurance claims
- **Work with reputable contractors** experienced in marine tank coatings when applying or repairing coatings to ensure proper application and quality
- **Aim to understand the specific characteristics and limitations of each type of tank coating,** which will help tanker operators to proactively prevent claims, ensure cargo integrity and maintain a safe and efficient operation.

CONCLUSION

Overall, coating systems demand vigilant monitoring over time and are not to be neglected after application. The demanding environment and harsh conditions to which coatings are subjected to require a continuous and thorough monitoring regime to detect any issues at an early stage.

Owners and crews should have a clear understanding of the practical properties and constraints or limitations of the coating system applied. By treating the coating system with care, the risk for coating-related cargo contaminations and associated claims can be minimised. Furthermore, such attentive care contributes to extending the lifespan of the coating system and will therefore be cost effective.