The internal coating of a ship’s cargo tanks is a common and necessary way to protect steel surfaces against corrosion, to avoid cargo contamination, and to facilitate cleaning. In product and light chemical carriers, for example, full coating of internal tank surfaces is necessary to avoid corrosion damage and possible cargo contamination, since a smooth coating facilitates tank cleaning between cargoes and helps prevent contamination from rust or leftover cargo deposits. Therefore, proper tank coating is essential for effective and profitable ship management.

Applying coatings in cargo tanks is more complex and difficult than most other painting operations. For satisfactory and durable results, every step must be carried out properly, including choice of coating system, planning, work scheduling, staging, surface preparation, ventilation, dehumidification, paint application, inspections, water testing (i.e., filling the cargo tanks with sea water for at least 24 hours to detect possible defective spots in the coating), and final touch-up.

A faulty coating job or improper cargo handling can shorten the service life of the coating, resulting in expensive early renewal and lay-off time. Although tank coating jobs are generally covered by a guarantee of one or more years, the cost of ship lay-off during repair work is not included. This could mean a considerable loss of money to the ship owner.

The first step in a tank coating job—and the scope of this article—is the correct choice of a coating system, which depends mainly on the type of tanker and the possible cargo range.

Liquid Cargo Tankers

Liquid cargo carriers can be divided into four categories: crude oil tankers, product carriers, light chemical carriers, and chemical carriers.

Crude Oil Tankers

These vessels usually have a dead-weight capacity of more than 50,000 tonnes and are dedicated to transportation of crude and refined oil. They are constructed of carbon
steel with specified mechanical properties. If the tanks are coated, the coating is usually limited to horizontal surfaces (bottoms and ceilings), which are more affected by corrosion than other surfaces. The main causes of fast and dangerous corrosion (pitting), especially on bottom areas, are sulphur compounds in cargoes reacting with water to form acidic solutions. Hydrogen sulphide may also develop and form corrosive water droplets on tank ceilings. In addition, inert gas such as CO₂, which is used to purge empty tanks and hence avoid explosion hazards, may contain sulphur compounds.

Product Carriers
These vessels usually have a dead-weight capacity of less than 50,000 tonnes and are dedicated to transportation of refined petroleum products. They are constructed of carbon steel, and the tank structure is similar to that of crude oil tankers. All cargo tanks receive a chemically resistant coating system to protect the steel surfaces from corrosion and to prevent cargo contamination. In bare steel tanks, liquid cargo can impregnate rust scales and pitted areas. While it can be impossible to clean these surfaces with pressure water washing, a smooth-coated surface usually requires only high-pressure washing. Cleaning problems may arise with high viscosity cargoes, and so most product carriers are outfitted with heating coils, which can reduce the viscosity of the cargo for easier removal and also heat water in the tank for better cleaning.

Light Chemical Carriers
These carriers, usually with less than 15,000 tonnes dead-weight capacity, carry refined petroleum products as well as aggressive organic chemical products. Light chemical carriers are required to have a double-hull structure and comply with tight regulations regarding tank equipment and outfitting. For instance, internal piping, if located in the tanks, must have welded flanges. All cargo tanks are protected with a chemically resistant coating, which should fulfill the same requirements as for product carriers but with a broader resistance range.

Chemical Carriers
True chemical carriers are vessels with up to 15,000 tonnes dead-weight capacity that carry aggressive organic products as well as certain inorganic acids. These vessels are required to have a double-hull structure and cargo tanks made of stainless steel. Stainless steel cargo tanks should not be coated, because the coating probably would not withstand the aggressive chemicals carried. Before entering service, however, stainless steel tanks must be thoroughly cleaned and passivated in order to avoid possible corrosion problems. Cargo handling and tank washing require special care, since the stainless steel is corrosion resistant only if certain conditions are met.

Table 1: Coating Systems for Cargo Tanks

<table>
<thead>
<tr>
<th>Surface Preparation</th>
<th>Coating System</th>
<th>Minimum DFT</th>
<th>Number of stripe coats</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 8501-1</td>
<td>Epoxy primer</td>
<td>100 microns</td>
<td>2</td>
</tr>
<tr>
<td>Sa 2 1/2</td>
<td>Epoxy undercoat</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Epoxy finish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISO 8501-1</td>
<td>Epoxy phenolic primer</td>
<td>100 microns</td>
<td>2</td>
</tr>
<tr>
<td>Sa 2 1/2</td>
<td>Epoxy phenolic undercoat</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Epoxy phenolic finish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISO 8501-1</td>
<td>Epoxy isocyanate primer</td>
<td>90 microns</td>
<td>2</td>
</tr>
<tr>
<td>Sa 2 1/2</td>
<td>Epoxy isocyanate undercoat</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Epoxy isocyanate finish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISO 8501-1</td>
<td>Zinc silicate</td>
<td>80 microns</td>
<td>1</td>
</tr>
<tr>
<td>Sa 2 1/2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISO 8501-1</td>
<td>Cyclosilicon epoxy</td>
<td>150 microns</td>
<td>1–2</td>
</tr>
<tr>
<td>Sa 2 1/2</td>
<td>Cyclosilicon epoxy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ISO 8501-1: Preparation of Steel Substrates Before Application of Paints and Related Products—Visual Assessment of Surface Cleanliness

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cargo tank structures, since the reinforcing framework is placed in ballast tanks, double bottoms, and sometimes on the upper side of the main deck. Figure 2 shows schematically the structure of a modern double-hull tanker where the required reinforcing of bulkheads is obtained by using corrugated plates, a design which makes coating operations much easier.

**Liquid Cargoes and Cargo Handling**

**Crude Oil**

Raw crude oil is pumped directly from a holding tank into a ship’s cargo tanks. It varies widely in chemical composition, sulphur, and water content. Depending on its chemical composition, the prevailing components of crude oil are naphthenic, paraffinic, or aromatic hydrocarbons. Crude oils are carried in bare steel tanks and tanks coated with epoxy coal tar or epoxy paints.

**White Oil**

This group of liquid cargoes consists mainly of aliphatic hydrocarbon products and includes gasoline, diesel oils, kerosene, virgin stock, aviation fuels, heating oils, etc. These cargoes are not very aggressive, and they usually are shipped in conventional epoxy-coated tanks. However, some unleaded gasolines may require a modified epoxy or zinc silicate coating system.

**Solvents and Chemicals**

This complex group of liquid cargoes includes alcohols, ketones, glycols, esters, ethers, aromatic hydrocarbons, chlorinated hydrocarbons, etc. These cargoes vary from mild to very aggressive. They are shipped in tanks coated with epoxy, modified epoxy, and zinc silicate. Some of these products require extreme care in the choice of coating and cargo handling.

**Vegetable and Animal Oils**

Vegetable and animal oils may vary in composition. The most important factor is their free fatty acid content, which greatly affects the suitability of coatings. Refined vegetable oils with low acid value are usually acceptable for carriage in conventional epoxy-coated tanks. Those with a higher acid value are more aggressive and may require a more resistant coating system. Crude vegetable oils, fatty acids, and by-products (fatty acid distillates and acid oils) may pose serious problems for carriage in coated tanks. Water content and loading/unloading temperatures can make these cargoes even more aggressive.

**Lube Oils and Additives**

This group of cargoes (excluding halogenated, phosphated, and ester types) usually poses no problems for carriage in coated cargo tanks, but contamination of cargo may be a problem, requiring thorough cleaning and drying of tanks before loading. These products usually can be carried in tanks coated with conventional epoxy.

**How Cargoes Affect Coating Selection**

For the right choice of coating system and proper handling of cargoes, a basic knowledge of the chemical properties of the most common cargoes is advisable, since the behaviour of products within the same groups of organic compounds may vary to a great extent. For instance, methanol will soften most organic coatings, but alcohols with higher molecular weight are far less aggressive.

In most groups of organic compounds (i.e., alcohols, esters, ketones, etc.), individual compounds differ in their effect on coatings. Compounds of lower molecular weight usually are more aggressive than their higher homologues. For instance, pure epoxy coatings are not suitable for long-term contact with acetone, other lower ketones (e.g., methyl ethyl ketone), or the lower esters such as methylacetate. They are, however, suitable for higher homologues such as methyl isobutyl.
ketone and dibutylphalate.

This difference in behaviour toward coatings depends mainly on the steric hindrance (three-dimensional structure) of individual molecules. It is easier for smaller molecules to penetrate the polymeric structures, solvating or encapsulating the polymer chains in solvent. Steric hindrance also depends on the number of chain branches. Linear chains have more penetrating power than chains with lateral branches.

Other factors influencing the solvent power of non-hydrocarbon compounds on polymers are functional groups (such as –OH for alcohols, –NH₂ for amines, –O– for ethers, etc.), polarity of molecules, and hydrogen bonds.

All of today's organic coatings for cargo tanks are two-component types, resulting in a chemically crosslinked film that cannot be redissolved. However, strong solvents can soften cured coatings, causing swelling and, in some cases, even scaling from the substrate. For instance, methylene chloride is such a strong solvent for organic coatings that it is used as a paint remover. Therefore, it should not be carried in tanks coated with organic coatings.

An additional factor affecting coating suitability is the water solubility of solvents. Most organic coatings used for cargo tank protection can tolerate a certain degree of softening from solvent absorption, provided they are given sufficient time for the absorbed solvent to evaporate and to regain their original hardness. However, if the retained solvent is water-soluble and tanks are washed with water or loaded with an aqueous cargo before the film has completely dried, blistering due to osmosis may occur.

Zinc silicate coatings are based on inorganic binders and, therefore, they have none of these disadvantages. They are very resistant to strong solvents but, on the other hand, very sensitive to the acidity (below pH 6) and alkalinity (above pH 9) of cargoes. For this reason, they are not suitable for cargoes such as most vegetable oils, highly alkaline crude oils, caustic alkalines, etc. Furthermore, hydrolisable cargoes such as esters and chlorinated hydrocarbons must be carried dry in perfectly dry tanks.

Proper cargo handling is not always an easy task. Although paint manufacturers furnish resistance lists for their tank coating systems, some resistance lists may contain up to 4,000 sea-trade products. These lists must be consulted for each cargo. More aggressive cargoes are marked with one or more restriction notations, which must be read and understood in order to avoid mistakes. Failing to comply with restrictions or cargo handling instructions may cause severe damage to coatings.

Protective Coatings for Cargo Tanks

During the last 30 years, several types of coatings have been used for tank lining service in the sea trade: vinyls, polyesters, epoxies, epoxy phenolics, epoxy isocyanates, polyurethanes, alkaline zinc silicates, and ethyl zinc silicates.

Some of these coating materials have stopped being used for tank linings. Vinyls, being thermoplastic, had limited solvent resistance. Glass-reinforced polyesters, used for transportation of acid cargoes, were replaced by stainless steel tanks. Polyurethanes, loudly advertised in the 1980s for their wide resistance to different types of cargoes, showed some application problems and unsatisfactory resistance to ballast water.

Today's state-of-the-art coatings basically fall into the following categories: pure epoxy, epoxy phenolic, epoxy isocyanate, alkaline zinc silicate, ethyl zinc silicate, and cyclosilicon epoxy. Typical systems based on these coatings are shown in Table 1.

Pure Epoxies

Pure epoxy coatings are based on bisphenol A/epichlorhydrin resins reacting, through their terminal epoxide (oxirane) groups, with hardeners having polyfunctional –NH₂ groups (polyamines or polyamides).

Chemical resistance and mechanical properties of epoxy coatings may vary to a great extent, depending on the formulation of individual paints. Factors influencing these properties are the molecular weight of resins, the type of hardener, and, to a lesser degree, pigmentation and solvent mixture.

Low molecular weight epoxy resins result in coating films with a higher density of three-dimensional crosslinkings as well as a lower number of hydroxyl groups. Therefore, low molecular weight epoxy resins offer better chemical
and water resistance than medium molecular weight epoxy resins, which, on the other hand, offer better mechanical resistance and flexibility.

Amine hardeners confer good chemical resistance on epoxy coatings, while polyamide-cured epoxies show more surface tolerance and better mechanical properties. For tank linings, polyamine hardeners are preferred because of their superior solvent resistance. This resistance is also related to the type of polyamine hardeners, which are mostly aliphatic polyamine adducts.

Epoxy coatings are the most widely used linings for cargo tanks because of their versatility, resistance range, and application properties. A properly formulated pure epoxy coating can be applied by airless spraying at medium to high dry film thickness (DFT) without sagging, with little overspray, and without problems such as cracking or pinholing. However, maximum overcoating intervals are relatively short (three to five days), requiring a tight application schedule, and chemical resistance to strong solvents is limited. Pure epoxies, for instance, are not recommended for transportation of methanol, ethanol, methyl ethyl ketone, or some unleaded gasolines.

**Epoxy Phenolics**

Epoxy phenolics are multifunctional epoxy resins, such as epoxy phenol novolacs, prepared by the epoxidation of phenolic resins with epichlorhydrin. Aliphatic amine-cured resins of this type result in polymers with very high crosslink density and, therefore, outstanding chemical resistance. However, most epoxy phenolic coatings require heating to 50–60°C for about one week to reach their full resistance range.

Chemical resistance of heat-cured epoxy phenolics against strong solvents and fatty acids is better than pure epoxies. From a practical point of view, however, heat post-curing poses several problems. To keep the cargo tanks at the required temperature, they must be loaded with an inert cargo (e.g., lube oil) and heated with heating coils. This procedure is usually insufficient to reach 50–60°C in areas such as deck-heads and external bulkheads, requiring the use of auxiliary heaters in the double-skin compartments as well as the construction and heating of provisional air casings (void spaces made of stag and tarp into which hot air is blown) on the deck areas above tank ceilings. Besides being expensive and time consuming, heat post-curing is subject to some risk, since it is quite difficult to ensure that all tank areas are kept constantly and uniformly at the required temperature for long periods.

Without heat treatment, the chemical resistance of epoxy phenolics improves after a service time of at least three months if only moderately aggressive cargoes are carried, but it does not acquire the full resistance range of heat-cured coatings. In this case, carriage of products such as methanol and ethanol is not recommended.

Properly formulated epoxy phenolic coatings have application properties similar to pure epoxies but usually longer overcoating times, making recoating less critical. On the other hand, they may create more overspray due to their stronger (faster evaporating) solvents, and they may be sensitive to overthickness. A coating system with a DFT of more than 700–800 microns, which may occur in critical areas such as angular welding seams on bottoms and ceilings, may cause cracking through the whole coating film. Usually this phenomenon appears only after a salt water test and cannot be detected during application.

**Epoxy Isocyanates**

Higher molecular weight epoxy resins can be crosslinked with polyisocyanate compounds. This reaction occurs at room temperature, and the isocyanate reacts with the hydroxyl groups of the epoxy resin. A densely crosslinked (epoxy urethane linkage) structure with excellent chemical resistance is obtained. Overcoating intervals are similar to those of epoxy phenolics.

Cured epoxy isocyanates offer a resistance range similar to heat-cured epoxy phenolics, the only exception being alkaline cargoes, which can be carried only at lower concentrations. Most cargoes can be carried after a curing time of 10 days. Very aggressive products such as methanol can be carried after a three-month service period. No heat post-curing is required.

On the other hand, epoxy isocyanates are more difficult to apply than pure epoxies or epoxy phenolics, or they at least have more critical application properties. For instance, due to their strong solvents, overspray may be a problem. Also, epoxy isocyanates are very sensitive to overthickness.

While, unlike epoxy phenolics, the DFT of the whole system is usually not significant, too heavy single coats can crack at 150–180
microns DFT. In most cases, the cracking after drying can be detected by the naked eye, although sometimes it is visible only with a magnifying lens. The cracking usually does not split the whole coating film. Therefore, it will not result in rusty spots during a salt water test. Unrepaired cracks, however, will propagate during cargo service and cause rusting and/or scaling of the coating.

Areas usually affected by cracking are angular welding seams and corroded spots (pitting). Stripe-coated areas, if overcoated before completely dry, can cause cracking or blistering. To eliminate this problem, each coat must be inspected for cracking, and defective areas must be repaired by sanding and touch-up painting. Paint defects such as sagging and orange peel must also be eliminated, because they are nearly always associated with cracking.

These application problems, besides the well known health problems of isocyanates, are the main reasons for the reduced usage of epoxy isocyanates. However, if they are used anyway, epoxy isocyanates offer an excellent tank coating system for aggressive cargoes, especially in the case of newbuildings. When considering repainting of in-service ships, epoxy isocyanates might not be recommended if the tank plates are already heavily corroded, since it may be difficult to avoid overthickness on pitted areas.

**Alkaline Zinc Silicates**

Alkaline zinc silicates may be composed of water-dissolved sodium silicate, potassium silicate, or lithium silicate. The chemistry of these inorganic silicates is very different from organic compounds such as epoxies, since curing occurs by a reaction between the pigment (zinc powder) and the binder (silica gel). The binder is supposed to react also with the steel substrate, forming a chemical bond that results in outstanding adhesion. This chemical bonding to steel surfaces avoids undercutting, which can occur on substrates protected with organic coatings because their adhesion is created mainly by physical forces.

The curing mechanism of inorganic zinc silicates is very complex. Today, only self-curing zinc silicates are used as linings for cargo tanks, and the polymerisation is supposed to occur in three stages:

1. Initial reaction involves concentration of the components by water evaporation. This brings the zinc and the silica gel into close contact, providing a moist coating on the substrate. During this stage, wetting agents in the paint enhance contact of the coating film with the steel surface.

2. During the second stage, which occurs shortly after application, insolubilisation of the coating film, caused by the reaction of zinc ions with the silicic acid, forms the initial zinc silicate. After this reaction, a solid, insoluble coating on the metal substrate has formed. This coating has nearly the full range of chemical resistance. Mechanical resistance is acceptable but not complete, and the coating film has a porous structure subject to water diffusion.

3. The third stage of the reaction occurs over a long period of time, usually several months, and requires the action of carbonic acid formed by carbon dioxide and moisture. The carbonic acid, when penetrating the coating film, reacts with free zinc particles, completing the formation of a dense zinc silicate matrix. Contact with ballast (sea) water contributes to this reaction, forming zinc hydroxide. When this reaction is completed, a very hard and dense coating film has formed.

The first alkaline zinc silicates had to be post-cured by spraying an acid solution on the coating surface. These types of inorganic zinc silicates had a silica to alkali ratio of about 2:1, providing an insufficient amount of free silicic acid for self-curing. Today’s self-curing zinc silicates have ratios from 3:1–5:1. The higher the silica-to-alkali ratio, the faster the curing reaction occurs once the water has evaporated. The curing speed also depends on the type of alkaline metal, with lithium silicates offering the earliest insolubilisation. Fast curing has some advantages, since insolubilisation and metallic hardness occur within a few hours, but it can cause frequent plugging of the spray gun nozzle. Fast-curing inorganic zinc silicates are advantageous for application on outside structures, while zinc silicates with medium curing speed are preferable for cargo tanks.

Another important factor influencing the curing characteristics of alkaline zinc silicates is the zinc dust grade. Suitable zinc powder should have a main particle range from 6–10 microns. Finer particle mixtures are less suitable, since they may cause sagging or cracking at low DFT.

The corrosion resistance of inorganic zinc silicates is related to the percentage by weight of zinc in the dried film. Top grade zinc
silicates contain more than 90% zinc.

Small amounts of additional pigments such as iron oxide or chromium oxide are also used to change the colour from the light grey of zinc. This helps a lot when spraying and inspecting the coating, since the abrasive-blasted surface is also grey. For application in cargo tanks, coloured zinc silicates make avoiding holidays and stripe coat defects much easier.

Application of alkaline zinc silicates is more difficult than that of organic coatings for the following reasons.

• Because of their high content of metallic zinc powder, alkaline zinc silicates cannot be applied by airless spraying but only with low-pressure air spray equipment. Hence, the application rate is lower and specialised sprayers are needed.

• Dehumidification and ventilation during the drying and curing periods (stages 1 and 2) are critical. If dead air pockets due to poor air circulation occur in the tank during this period, the coating will not “metallise” in those areas. Once the maximum drying time has expired without proper curing, the reaction cannot be resumed, and reblasting is required.

• Inorganic zinc silicates are sensitive to overthickness. Depending on the formulation, a single coat may start cracking at a DFT from 150–250 microns. However, cracking is usually macroscopic (mud cracking) and can be easily detected and repaired.

• Inorganic zinc silicates are applied in a single coat at 75–125 microns DFT and one stripe coat only. Therefore, possible coating defects are not readjusted by subsequent coats.

Hence, the application of inorganic zinc silicate coatings in cargo tanks requires a contractor with specialised equipment as well as operators and coating inspectors familiar with this type of material. However, if the coating is applied properly, it provides a tank lining with outstanding corrosion protection, superior solvent resistance, and excellent mechanical resistance. The duration may equal the service life of the tanker, compared to a duration of 10–15 years for organic coatings. Possible disadvantages are unsuitability to cargoes with a pH lower than 6 and higher than 9 as well as the risk of contamination when transporting sensitive products such as aircraft fuels.

**Ethyl Zinc Silicates**

Ethyl zinc silicates are solvent-borne paints consisting of ethyl silicate and zinc powder. To be self-curing, the silicate binder must be partially hydrolysed. Essentially, the curing reaction is similar to the reaction that occurs in water-borne, self-curing products.

1. During the initial reaction, solvent evaporation occurs, bringing the zinc particles and the silicate into close contact and forming a loose coating film on the steel substrate.

2. Shortly after application of the coating, moisture from the air continues to hydrolyse the organic silicate, freeing more silicic acid, which reacts with the zinc particles and the steel substrate. Organic zinc silicates show a faster resistance to water and to solvents than their inorganic counterparts. After completion of the second reaction, a coating film with nearly full chemical resistance and acceptable mechanical resistance has formed.

3. In the third stage, the polysilicic acid further polymerises, reacting with the zinc particles until a dense and hard coating film has formed. Carbonic acid and ballast sea water may also react with the zinc particles, creating an even denser zinc silicate matrix. The final chemical and mechanical properties are essentially the same as those of water-borne zinc silicate coatings.

The application procedure of organic zinc silicates differs in some steps from that of inorganic zinc silicates.

• Application can be carried out by airless spraying, since organic zinc silicates have a lower content of zinc powder.

• Dehumidification and ventilation conditions during the drying and curing period are far less critical than for water-borne zinc silicates. However, the relative humidity of the tank should not fall below 60%, because otherwise insufficient moisture for curing is available. Areas where the coating has not metallised can be cured by raising the relative humidity or by spraying atomised water.

• A serious problem with ethyl zinc silicate coatings is the difficulty of respraying low DFT areas, since intercoat adhesion problems may occur. Once curing has taken place, a second coat of ethyl zinc silicate will not always react properly with the first coat. This fact may also cause stripe coat adhesion problems. These problems do not exist with water-borne zinc silicates.

Inorganic and ethyl zinc silicate coatings were very popular as tank linings until the end of the
1970s. Today, their market share is greatly reduced, since most ship owners prefer tank linings that are suitable for carrying vegetable oil as well as aviation fuel without contaminating the cargo. (Both inorganic and ethyl zinc silicates pose the risk of contamination from the zinc.)

**Cyclosilicon Epoxies**

These coatings are based on a completely new resin, which is essentially a cyclic silicon structure with five phenol glycidyl ether groups (epoxidised phenol groups) that are cured by means of a catalyst to give a highly crosslinked homopolymer. Polymerisation occurs through etherification of the epoxy groups, resulting—after curing—in strong ether (oxygen to carbon) linkages without hydroxyl or ester groups, which are subject to acid attack or hydrolysis.

The combination of a very densely crosslinked structure and strong primary chemical bonds makes the resin impervious to penetration by the most aggressive solvents and resistant to acid and alkaline attack. Cyclosilicon coatings are said by their manufacturers to resist, without restrictions, 98% of all common sea-trade cargoes, including products unsuitable for stainless steel, and to have very low adsorption values. As a result, they offer significant advantages over conventional coatings regarding cargo range, cargo handling, and tank cleaning operations, especially in the case of light chemical tankers.

The coating is furnished as a two-component paint. It can be applied like a conventional organic coating with partial curing taking place at room temperature. Maximum overcoating time is limited to four to five days at 20 C. A two-coat system with one or two stripe coats usually is specified. However, for the full chemical resistance range, heat curing at 80 C for at least eight hours with hot air or steam is necessary.

Moreover, the coating system is sensitive to overthickness. Maximum DFT should not exceed 500 microns because of the risk of solvent entrapment or cracking. Overthickness could be a problem when recoating older tankers with corroded structures, since it may be difficult to avoid a DFT of more than 500 microns on pitted areas. Another disadvantage is the need of a heating device for possible touch-up repairs during service.

The first cargo tanks were coated with cyclosilicon epoxy systems in 1993. To date, about 30 tankers, mainly for the methanol trade, have been coated. The results are said to be very satisfactory with some minor exceptions.

**References**