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360° Coating & Engineering Experts

Cargo Tank Coatings: What can go wrong (and how to avoid it)

Presentation for IUMI
International Union of Marine Insurence
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Webinar

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About Safinah Group founded 1998*

360° Coating & Engineering Experts

*Danish TPO Holding acquired Safinah Ltd. UK in 2018

- **Safinah Group are world leading recognised independent coating and engineering experts.**
- Our expert coating consultants (12+) provides coating consultancy to the marine, yacht, energy and infrastructure markets.
- Our global technical service team (30+) manages annually 300 drydocking’s.
- Our naval architects (8+) handles FEED & design critique projects for oil majors.

Safinah Group provides accurate, unbiased and swift delivery of our expert witness services to insurance companies, law firms, loss adjusters, paint companies, ship owners, asset owners, ship builders, facility operators, manufacturers and charterers.

Agenda

- Introduction to tanker types, cargoes and cargo tank coatings
- What can go wrong with cargo tank coatings (risks and how to avoid it)
- New cargo tank coating technology – benefits and risks
- Conclusions - cargo tank coatings red flags and what to be wary of for Marine insurers

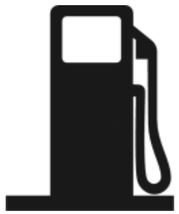
Introduction to tanker types, cargoes and cargo tank coatings

Crude oil tankers – Product carriers – Chemical tankers

- **Crude oil tankers** (75% of liquid seaborne trade is crude oil)
  - Transport crude oils from the oil field or exporting harbour to the oil refinery
  - Most uncoated or partly coated tanks
- **Product tankers** (19% of liquid seaborne trade is refined petroleum products)
  - Smaller than crude oil tankers, but more sophisticated. Handysize (30,000 to 50,000 dwt) is the workhorse of the industry.
  - Capable of carrying different types of petroleum product cargoes
  - Have coated cargo tanks that are easy to drain and clean and that protect the cargo from contamination
- **Chemical tankers** (6% of liquid seaborne trade is chemicals . Inorg./org.-4% & veg.oils-2%)
  - Carrying chapter 17 cargoes fine & aggressive chemicals, veg.oils. ,CPP etc. in coated or SS tanks
  - The IBC code defines ship types 3, 2 and 1 with increasing environment and safety hazard
    - Type 1: Products with very severe environmental and safety hazards which require maximum preventive measures to preclude an escape of such cargo
    - Type 2: Products with appreciably severe environmental and safety hazards which require significant preventive measures to preclude an escape of such cargo
    - Type 3: Products with sufficiently severe environmental and safety hazards which require a moderate degree of containment to increase survival capability in a damaged condition

”Big Movers” petroleum & crude cargoes carried

Refined white oil products



- clean petroleum products(CPP)
- white oils & aliphatic hydrocarbons
- methyl tert-butyl ether (MTBE)
- naphtha’s
- clean condensates
- jet fuels (paraffin)
- kerosene
- gasoline (contains alcohols)
- unleaded gasoline (contains MTBE)
- gas oils
- diesel
- dirty petroleum products(DPP)

Crude oil

- Sweet-low sulphur, 0 – 0,6 wt%
- Sour-sulphur 0,6 – 4 wt%
- Light, API > 35
- Medium, API 25 -35
- Heavy, API < 25
- Light Sweet
- Synthetic
- **Main traded grades:**
- WTI (West Texas Intermediate)
- Brent
- OPEC basket

API = American Petroleum Institute gravity scale

Chemicals & Veg oils (6%) – share and big mover development

organic chemicals (51%)

- **methanol**
- styrene
- **xylene**
- benzene
- alcohols
- **diols**
- esters
- phenols
- halogenated compounds
- ketones
- saturated hydrocarbons
- nitrogen compounds

inorganic chemicals (11%)

- inorganic acids (**H_2SO_4**, H_3PO_4)
- other acids (nitric acid)
- caustics (caustic soda)

	Product	Seaborne trade (MT mill.)			Average nautical miles			Tonne-miles (Billions)			Tonne-mile growth (%)			Trend 2019-21
		2016	2017	2018	2016	2017	2018	2016	2017	2018	2016	2017	2018	
Organic	Methanol	27.8	27.7	29.0	3,984	4,119	3,966	110.8	113.0	113.0	15%	3%	1%	↑
Organic	Para-xylene/Xylenes	19.4	20.8	22.6	1,858	1,788	1,907	36.0	34.3	34.3	13%	3%	16%	→
Organic	Ethylene Glycol	12.2	14.2	14.8	4,414	4,408	4,486	53.9	57.6	57.6	-4%	16%	6%	↑
Organic	Styrene	8.1	8.0	7.2	3,304	3,050	3,250	26.8	23.0	23.0	7%	-9%	-4%	↘
Organic	Benzene	6.9	7.8	8.2	3,055	2,577	2,963	21.1	17.4	17.4	-23%	-5%	21%	↗
Organic	MTBE	6.3	6.5	6.0	4,211	4,415	4,533	26.5	25.6	25.6	14%	8%	-5%	↘
Organic	Ethylene Dichloride	2.9	3.2	3.1	6,100	5,469	4,806	17.7	17.2	17.2	5%	-1%	-15%	↗
Organic	Toluene	2.9	2.9	2.9	1,926	1,690	1,655	5.6	4.8	4.8	6%	-12%	-2%	↘
Inorganic	Sulphuric Acid	12.6	14.1	15.0	2,575	2,709	3,127	32.4	34.4	34.4	-9%	18%	23%	↗
Inorganic	Caustic Soda	10.4	11.6	11.2	4,455	4,655	4,464	46.3	53.5	53.5	13%	16%	-7%	↑
Inorganic	Phosphoric Acid	5.1	5.4	5.4	4,926	4,815	4,778	25.1	23.4	23.4	20%	4%	-1%	→
Vegoil	Palm oil	40.4	48.5	51.8	3,608	3,433	3,618	145.8	151.7	151.7	-11%	1%	13%	↑
Vegoil	Soybean Oil	10.7	10.4	11.2	6,431	6,010	5,477	68.8	69.6	69.6	-4%	-11%	-2%	→
Vegoil	Sunflower Oil	8.4	9.8	9.0	3,670	3,694	3,644	30.8	38.9	38.9	19%	17%	-9%	→
Other	Ethanol	6.8	7.6	8.8	5,373	4,671	5,068	36.5	36.4	36.4	23%	-3%	26%	↑
Other	Molasses	5.2	5.0	5.0	3,069	2,960	2,880	16.0	17.8	17.8	-1%	-7%	-3%	→
	Others	47.2	47.2	49.9	3,359	3,483	3,454	158.6	164.3	172.2	-2%	4%	5%	↗
	Total	239.1	247.8	259.4	3,857	3,795	3,776	922.3	940.5	979.7	-2%	2%	4%	↑

GDP (+) ↑ GDP → GDP (-) ↘

Source: Odfjell, Drewry, ICIS, Customs data

50

vegetable & animal oils & fats (29%)

- **Palm oil**, **soybean oil**, sunflower, rape seed, coconut oil, tallow & grease (form fatty acids)

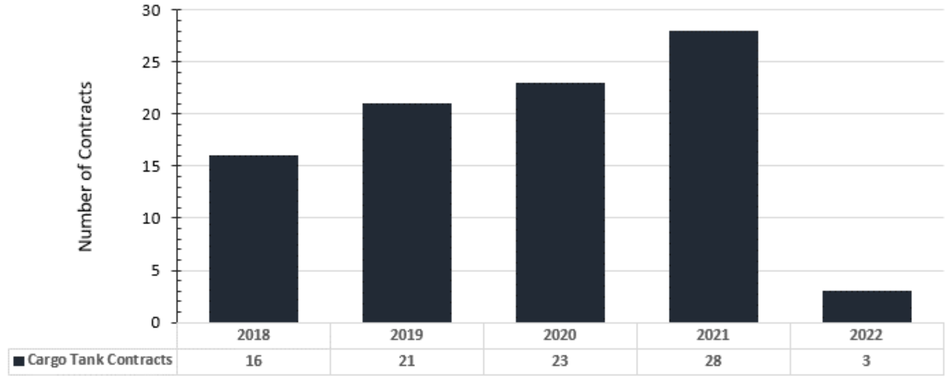
miscellaneous chemicals (9%)

- molasses
- lubrication oil

Introduction to cargo tank coatings

- Selection of cargo tank coating technology very much depends on vessel trade pattern, cargoes, durations and cleaning requirements.
- By moving up the technology ladder, you increase performance, cost, application difficulty, reduced system mechanical flexibility and risk.
- Cargo Tank Coating issues/failuers/claims are increasing (Safinah data, 2014 – 2017 range 5-10 cases, now > 25).
- Makers cargo tank coating guarantees are limited, full of excemptions and offer poor coverage to customer.
- Cargo tank coatings for chemical tankers is a complex subject so insurers need increased knowlegde and awareness of technology, risks and limitations of tank coatings.

Cargo Tank Coating failure investigations by Safinah Group



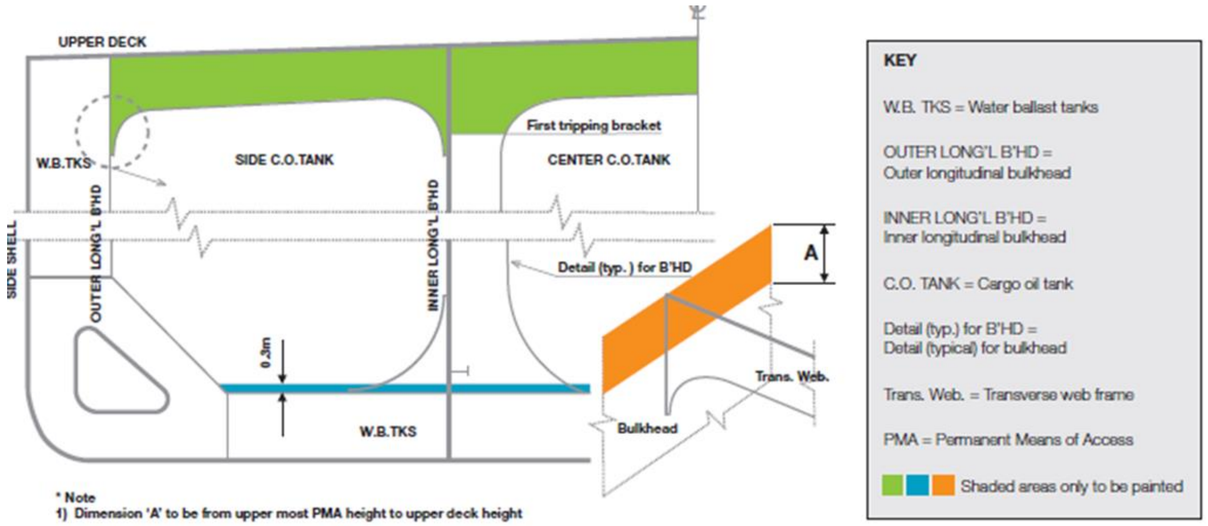
Crude oil tanker

Product tanker

Chemical tanker

Why do you need cargo tank coatings?

- Cargo tanks in commercial **product and chemical tankers** need coatings for three reasons
  - Protect the steel from corroding
  - Provide easy cleaning of the tank
  - Protect the next cargo from contamination
- Cargo tanks in **crude oil tankers** built after 1 January 2013 need to be coated in the tank top (bottom plating) and deck-head area
  - The standard requires that the tank deck-head with complete internal structure, longitudinal and transverse bulkheads must be coated to the upper most means of access level or 10% of the tank height at centreline. Also the flat inner bottom of the cargo tank (tanktop) and all the structure to a height of 0.3 m above the tank bottom must be coated.



Issues with corrosion in COT

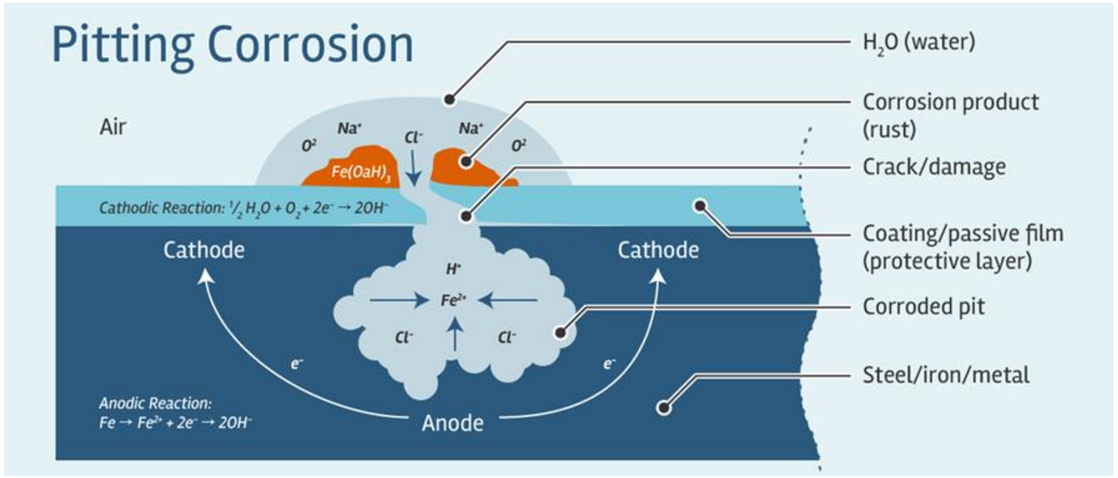
Deck-head:

Vapor space corrosion – acidic water condensate, H2S/Sulphur

Tanktop:

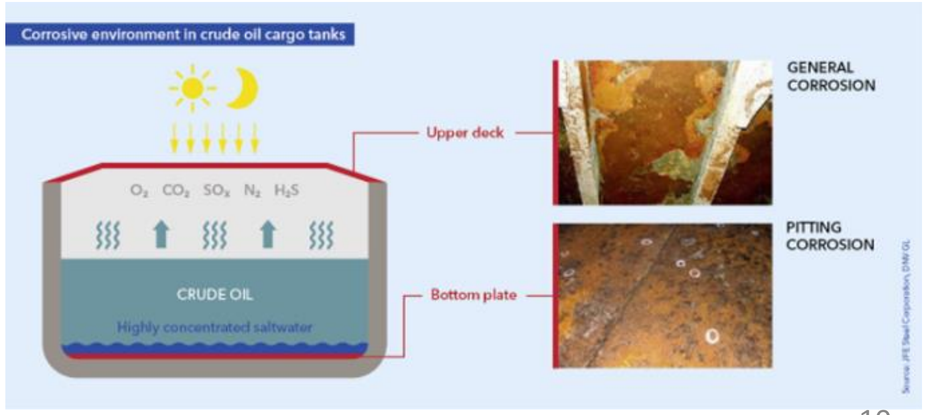
Tank bottom pitting corrosion - MIC / anaerobic bacteria

Pitting corrosion in Cargo Oil Tanks



Pitting corrosion occurs when a small hole, or cavity, forms in the metal, usually because of de-passivation of a small area. This area becomes anodic, while part of the remaining metal becomes cathodic, producing a localized galvanic reaction. The deterioration of this small area penetrates the metal and can lead to severe failures over a relative short period. Huge risk for older single hull ships. MIC – Microbiological Induced Corrosion could further aggravate the problems.

Corrosion types, mechanisms and how to detect them is a huge subject and maybe of interest for a separate webinar for IUMI?



Shipowners requirements for a cargo tank coating:

- Simple and economic application
- Maximum corrosion protection
- Minimal operational restrictions
- Chemical resistance to cargoes carried
- Low cargo absorption and retention
- Short conditioning/cleaning time
- Long service life with minimal maintenance

Epoxy coated cargo tank

Stainless steel cargo tank

Ship Type	Total	Coating Tank Indicator (Yes) Out of Total	%Coating Tank Indicator (Yes) Out of Total	Stainless Tank (Yes) Out of Total	%Stainless Tank (Yes) Out of Total
Product Tankers	9138	4419	0.484	NA	
Chemical Tankers	3899	3500	0.898	1366	0.350

Marine Tank Coating Technology Options

- **Zinc Silicate (1940s)**

  Excellent resistance to pure chemicals & solvents

  - Limited by range of pH (6-9)

  - Very rough surface, difficult to clean

- **Pure Epoxy (1950s)**

  Limited resistance due to low crosslinking density

  - Mainly for Clean Petroleum Products (CPP)

- **Phenolic Epoxy (Epoxy Novolac) (1960s)**

  Broadest chemical carriage capabilities, but

  - *Absorbs and retains cargoes*
  - *Cleaning headache*
  - *Contamination risk*
  - *Recovery time and cycling restrictions*

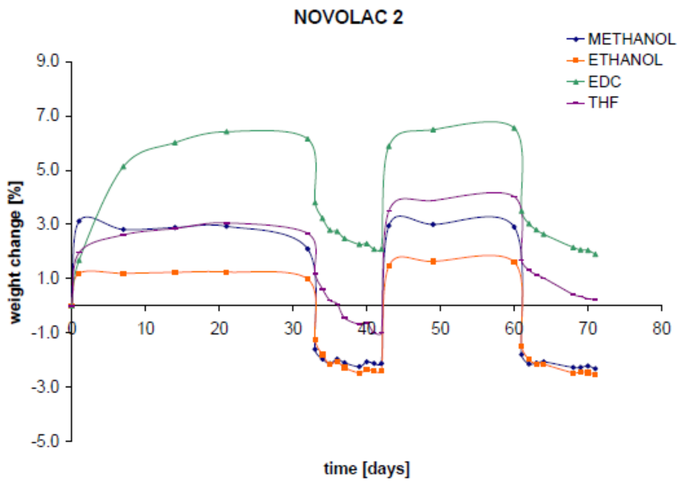
- **Low adsorption Resorsinol Epoxy (LA) (2000s)**

  Excellent resistance and very low cargo absorption

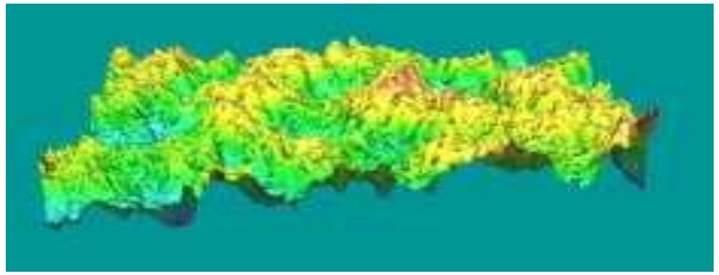
- **Alternative to coatings: Stainless Steel**

  Does not absorb or retain cargoes

  Expensive and uneconomical for many trades



Source Absorption-Retention in Tank Coatings – Jotun 2012



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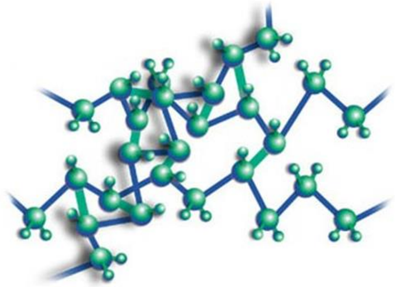
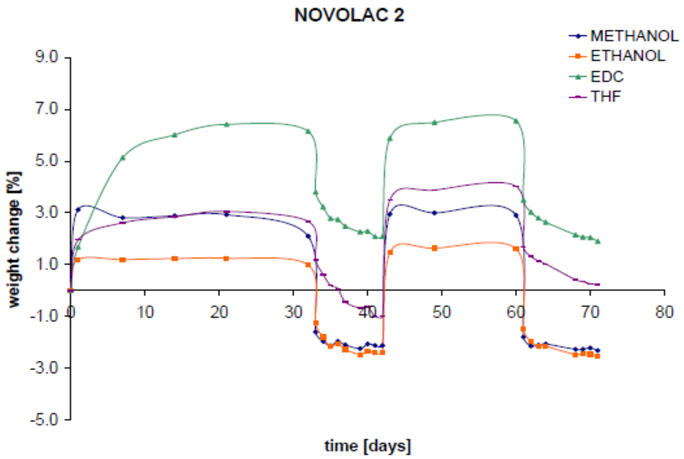


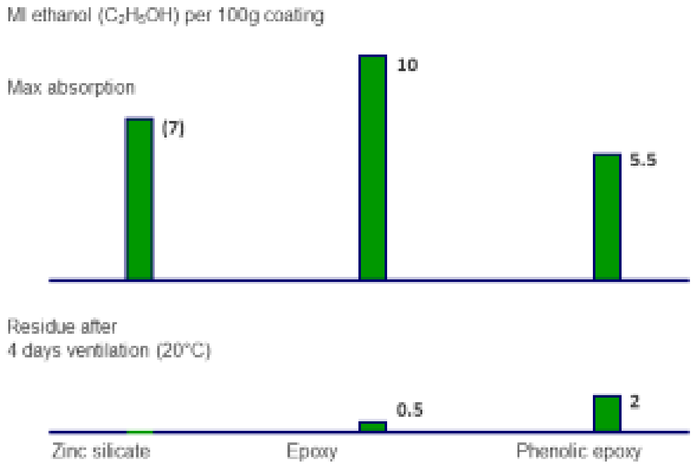
Other tank coating technologies:

- Vinyl Ester (1970s)
- Novolac vinyl ester (1980s)
- Solvent-free Epoxy (1990s)

Cargo absorption in tank coatings

- **Zinc silicates** has high absorption rate for solvents and alcohols but also desorbs fast, the rough porous surface is however a cleaning headache for CPP to MeOH.
- **Epoxy** has high absorption rate and desorbs slower than zinc silicate. Low molecular cargoes would either destroy the coating or soften and swell the coating leading to long recovery times.
- **Phenolic epoxy** has low absorption rate and far less than epoxy and zinc silicates. Low molecular cargoes needs longer time to desorb compared to low absorption tank coatings.
- **Low absorption tank coatings** absorbs very little (except for water/seawater) and in some cases zero cargo and desorbs fast, so it offers easier cleaning and fast turnaround time.
- In general retained cargoes are a cleaning headache, a contamination risk and impose recovery time and cycling restrictions.



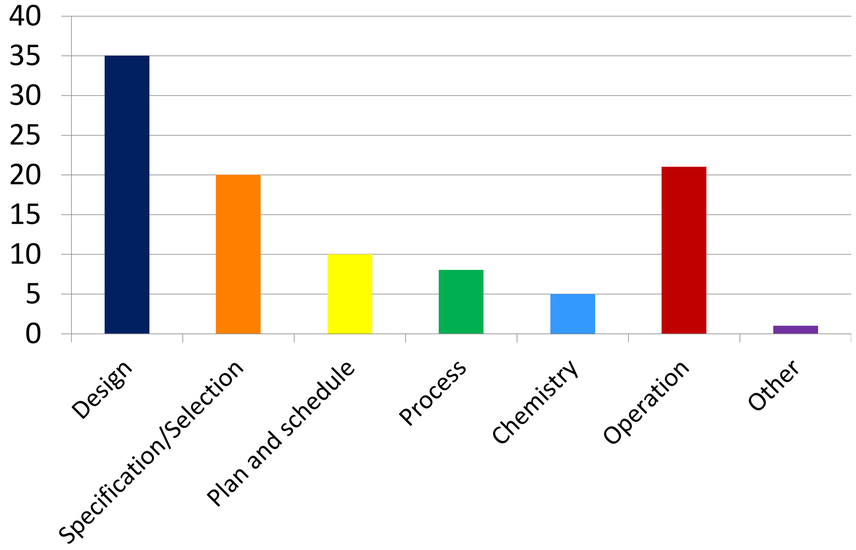


Source: Absorption-Retention in Tank Coatings – Jotun 2012

What can og wrong with cargo tank coatings?
(risks and how to avoid it)

Keep in mind 1: coatings are semi-fabricates

- Coatings are semi-fabricates and only work as specified if all surfaces are correctly designed and pre-treated prior to coating work commence and coatings are correctly specified for the operational conditions and applied to all surfaces and all coating is correctly dried/cured/post-cured in accordance with paint makers technical data sheets and application instructions.
- Coating makers claim that > 90% of all coating failuers are due to poor surface pre-treatment and/or poor coating application, while Safinah 22 years of collected coating failure data show process accounts for only 7-8% of coating failures. Our data show that >75% of coating failuers are due to poor design, wrong specification/selection and operational conditions.



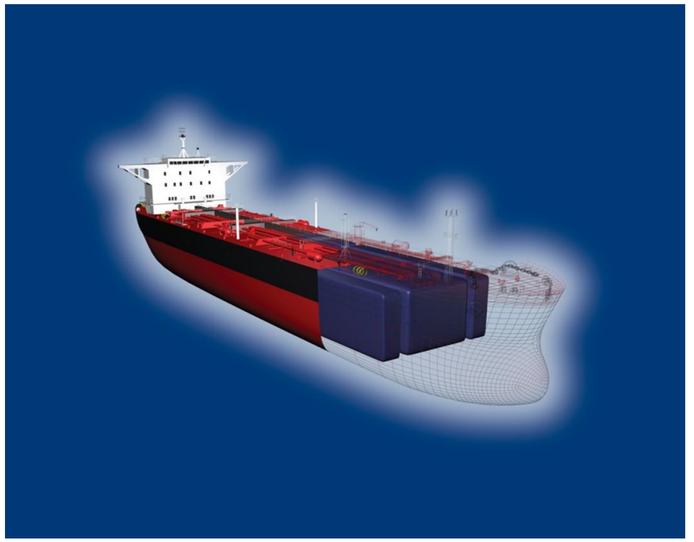
- Design
- Specification
- Product Selection
- Project management / application
- Chemistry – e.g. formulation change
- Operation / cargo carriage

What can owners influence?

Safinah can influence

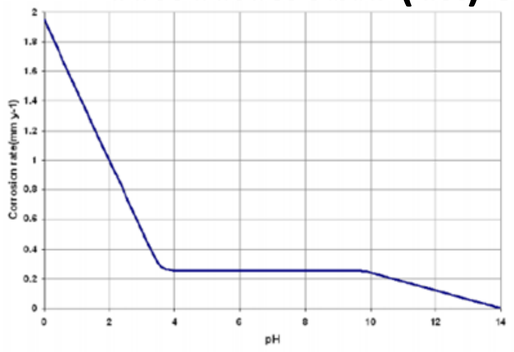
Keep in mind 2: exposure climate in a cargo tank is very tough on coatings

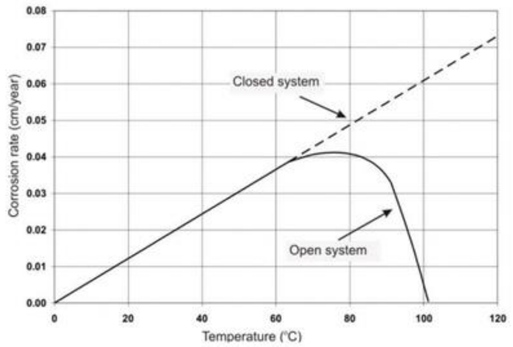
- Exposure to chemical active cargoes and cleaning chemicals
- Exposure to high temperatures
- Exposure to humidity from condensation and cleaning processes
- Exposure to seawater (central hold in ballast on backhaul voyage)
- Exposure to salts
- Exposure to oxygen
- Exposure to mechanical impact from falling tools, cleaning operations etc.
- In other words coatings in cargo tanks should protect against impact, abrasion, humidity, heat, corrosion and prevent chemical and cathodic reactions.

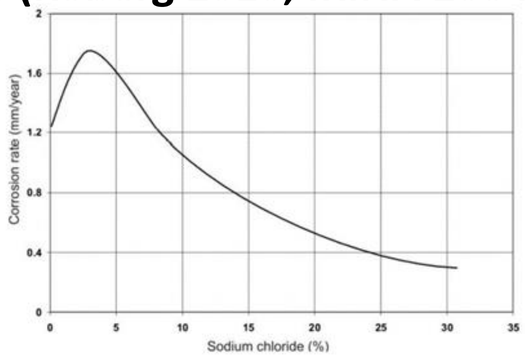


Some factors influencing corrosion rate;

Corrosion rate (CR) vs pH, temperature & salinity (Roberg 2010, IRINA 2004)







Keep in mind 3: cargo tank coating premature failures are increasing

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Documentation generally shows:

- Cargoes mostly carried according to manufacturers cargo resistance lists
- Applications were done according to guidelines – zero non conformances
- Tank cleaning processes appear OK

However what we often actually discover:

- Higher storage temperatures for extended periods.
- Grit inclusion and blistering associated with poor application
- Intercoat blistering and delamination (product/operational?)
- Cracking on welds/surface micro-cracking (design/application/product?)
- Questionable coating records (copied and pasted?)
- Incorrect cleaning procedures recorded

So what can go wrong with tank coatings in operation? (Coating failures)

- Insufficient surface pre-treatment or cleaning/removal of surface contaminants at NB or MR, leading to
  - Loss of adhesion, blistering and associated under film corrosion
- Lacking chemical resistance to cargo(s) carried, leading to
  - Blistering, cracking, discoloration, flaking and corrosion
- Lacking heat resistance to cargo(s) carried or peak temperatures reached during loading/offloading, leading to
  - Blistering
- Lacking water and/or seawater resistance, leading to
  - Hydroscopic stress induced cracking and blistering
- Lacking resistance to salts and oxygen will for all areas not properly coated, lead to
  - Possible osmotic blistering and corrosion under creep damages
- Lacking resistance to mechanical impact, leading to
  - Scratches and abrasion damages with following corrosion
- Coatings lacking resistance to internal stress/stress fatigue, leading to
  - Micro, mini and macro cracking with subsequent corrosion and flaking
- Not respecting makers conditioning time between cargoes and maximum cargo stowage time, leading to
  - Cargo contamination and chemical resistance issues (see first bullet point above)

Example: Application Management

Ship A

Ship B

Identical sister ships after 8 years operation

What was the same or different?

Specification	✓
Coating	✓
Operation	✓
Application	✘

Ship A

Surface profile 40µm

Dry Film Thickness 400 - 550µm

Grit contamination

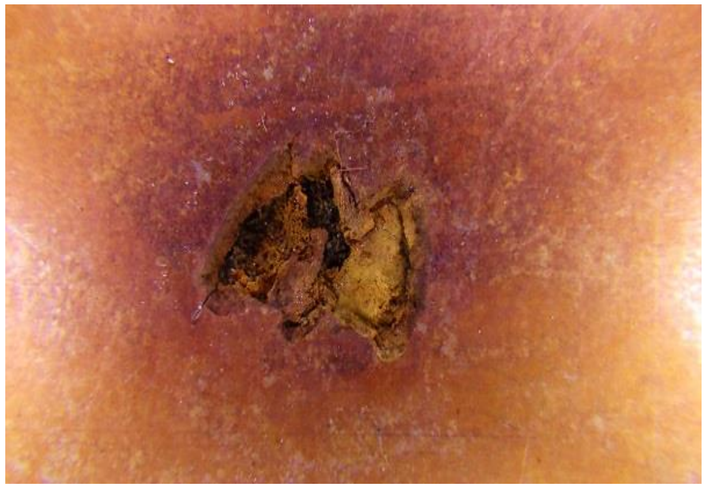
Poor adhesion resulting in osmotic blistering and cargo penetration

Catastrophic failure

Example: Application Management

- Cause of coating failure?
- Pattern follows scaffolding levels
- **Issue**: scaffolding too close to bulkheads during application risks poor cleaning and surface contamination

Example: Application Management



- >100 rust spots on the tank top after 6 months!
- Stainless steel heating coils
- Active corrosion/pitting when aqueous cargoes carried and during cleaning
- Cause?
- Tanks not tested for pinholes and holidays after curing in line with the application procedure
- All cargo tanks should be water tested or spark tested
  - “Faulty” areas repaired using vacuum blasting or bristle brush blasting

Example: Application Management

Corrosion due to insufficent steel preparation, P3

Blistering due to soluble salts on surface

- Steel surface cleanliness required on welds according to ISO 8501-3 should have undergone very thorough surface preparation – P3. This is difficult, time consuming and costly to achieve, so shipyards often do P1 or P2 lower surface cleanliness that can lead to pre-mature corrosion
- Lack of proper freshwater cleaning of carbon steel prior to surface-preparation can lead to insufficient removal of soluble salts on the surface, that would lead to osmotic blistering in the coating

More examples: Application Management

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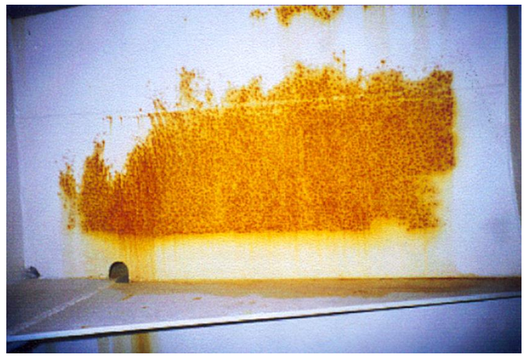
Some examples (corrosion, cracking, dry spray):

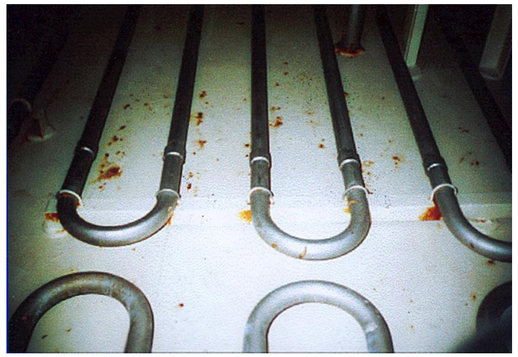
Corrosion due to incomplete stripe coating

Cracking due to too high DFT & stress



Corrosion due to incomplete filmformation

Mobile tank cleaning machine hits bulkhead



Corrosion due to incomplete cleaning before application

Dryspray not removed

Cracks due to too high DFT or solvent retention

Corrosion due to lacking stripecoat on welds/edges

Examples: Operational failures

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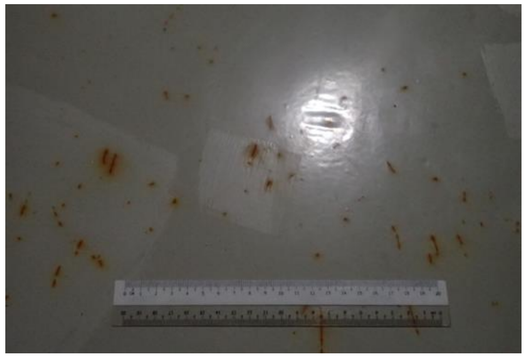
Some examples (softening/swelling, corrosion, flaking/delamination, impact, cracking) :

Softening & swelling due to acids/FFA

Corrosion/flaking due to insufficient resistance

Surface contamination due to insufficent cleaning

Mechanical damage from dropping tools from ladder



Macrocracking due to internal stress

Blistering/delamination due to stress fatigue

Cargo Tank Coating risks and how to avoid it?

- Independent third party review and functional cargo tank coating spesification tailored to vessels operational conditions.
- Controlled surface pretreatment and cargo tank coating application management at newbuilding and in drydock repair situations by experienced independent third party FROSIO or NACE III coating supervisors.
- Cargo tank coating awareness training of vessel owners commercial and technical teams with focus on risks.
- Good operational cargo tank coating house-keeping system for vessels. (cargo notes/chemical resistance, cargo storage time/temperatures, loading/offloading procedures, correct cleaning procedures, mopping, venting and conditioning of tanks, assessing cleanliness, carriage of aqueous cargoes or ballast water, onboard repairs, etc.)
- Frequent coating condition inspections.
- Perform major coating refurbishment based on expected life-time of coating.

New cargo tank technology – benefits and risks

Market Drivers for low absorption (LA) tank coatings

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Owner / Operator Perspective

Operational Flexibility/Efficiency

- Greater number of cargoes
- Fewer restrictions between cargoes
- Quicker cleaning

Tank Cleaning Level

- Better analytical techniques
- Tighter specifications
- More high specification cargoes

Tank cleaning options being removed

- In practice a banning of Methanol washing

Costs and emissions are key

- Maximize earnings and minimize downtime

LA tank Coatings

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Features

- **Low absorption coatings**

  Siloxirane – MarineLine 784 (2001)

  Bi-modal – Interline 9001(2011)

- **Low absorption and quick desorption coatings**

  Solvoxirane – Tankguard Flexline (2018)

Benefits

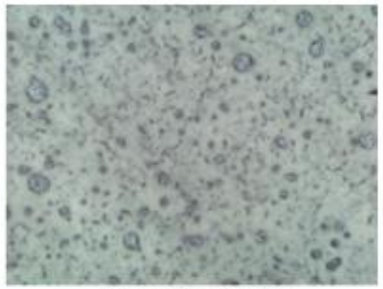
- Very high X-link density and tight network
- Extended chemical resistance
- Zero or very low cargo absorption
- Reduced conditioning/cycling restrictions
- Easy clean benefits & faster turnaround time

Challenges

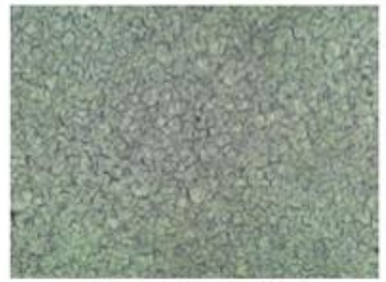
- Post / heat curing mandatory & expensive
- Application parameters complicated
- Lab versus field not the same
- Track record
- Cargo guide understanding / practicality
- Operational conditions
- Overcleaning
- Inherent high coating film stress leading to cracking

Microcracking in LA tank coatings

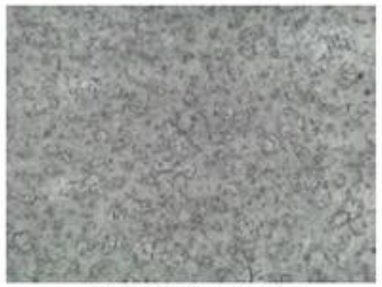
- Microcracking is related to coating internal stress and driven by “coating fatigue”
- Cracking sometimes not visible to naked eye
- Does not affect the vessel trading (tank Vetter's cannot see the defect)
- Does lead to further defects (macrocracking and intercoat delamination) that are visible and do affect the vessels trading
- Defects generally seems to become apparent in Y2 and Y3
- One LA coating lifetime is actually 5 years carrying mixture of CPP, veg oils and chemicals, not 10 years as marketed
- Coating stress increases with vessel sizes (40K & 50K dwt and above) where you have more steel flexing due to the size of the vessel.



Minor micro cracking



Major/full micro cracking



Medium micro cracking

Macrocracking and corrosion on welds for LA coatings

Conclusions - cargo tank coatings red flags and what to be wary of for Marine insurers

Risks with tank coatings and “red flags” to look for

Safinah Group
360° Coating & Engineering Experts

Safinah TC experts know the risks of coating failures and reasons for failures, but not the users

You as insurer and/or owners as TC users need to know that you have risks associated with;

- *Surface preparation, coating application and curing*
- *Cargo compatibility and reactivity*
- *Cargo contamination – cargo absorption and desorption*
- *Overcleaning (Styrene, Benzene, MtBE, EDC, Veg Oils, CPP)*
- *Carriage of aggressive cargoes (Methanol, Ethylene Dichloride)*
- *Cargo heating – the thermos bottle effect*
- *Makers cargo resistance guides containing overly optimistic resistance data or lacking data/notes*
- *New generation tank coatings (internal stress)*
- *Lack of coating maintenance*

What should insurance underwriters for TC insurance be wary of

- Coating failures are on the rise in particular for low absorption tank coatings.
- Expected life-time for tank coatings trading agressive chemicals can depending on trade and lack of maintenance be as low as 3-5 years, even if makers claim 10 years performance.
- Tanker owners and operators tend to blame NB yard for tank coating failuers, rather than maker for product issues or issues created by their own cargo tank operational conditions (cargo compatibility, towage temperatures, cargo sequencing, conditioning, tank cleaning etc.)
- Makers tank coating insurance provides owner poor coverage due to many exclusions and no indemnity coverage.
- When a tank coating failure occurs owners and operators tend to hold back on full operational history (cargo list for individual CT, heating/cleaning/cycling/ conditions etc.)
- Assure that you have copy of the vessels tank coating application log from NB and repair.
- Tank cleaning is a science and many tanker ship owners & operators are lacking knowledge or loosing knowledge in this area, so mistakes are done.
- The cost for full tank coating refurbishment on a chemical tanker can reach in excess of 3 M USD
- **Keep above in mind when evaluating and analyzing risks insuring tanker assets including cargo tank coatings.**

THANK YOU

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