Summary of Testing for Carriage of Food Grade Cargoes in Stainless Steel, Various Coatings and MarineLine®

TECHNICAL REPORT

The following tests illustrate the suitability of MarineLine® for the carriage of food grade products and illustrate its superior ability versus other types of coatings and stainless steel.

TEST #1 — Dr. Verwey Labs, Report dated 26 July 2005, Certificate No. 10556435

A) 2 MarineLine® test plates were exposed to 1,2 Dichloroethane (EDC) liquid during 30 days at ambient (24°C) lab temperature.

B) 2 MarineLine® test plates were exposed to styrene monomer liquid during 30 days at ambient lab temperature.
- All 4 test plates were washed with seawater, then freshwater and dried for 2 hours at ambient lab temperature.
- Panels from EDC immersion were immersed in sunflower seed oil.
- Panels from styrene immersion were immersed in sunflower seed oil and palm oil.

Results

A) Analysis of the sunflower seed oil used for the immersion test of the EDC exposed panels:
Ethylene Dichloride (EDC) content -- not detectable less than 0.01 mg/kg (<0.01 ppm)

B1) Analysis of sunflower seed oil used for the immersion test of the styrene monomer exposed panels:
Styrene Monomer content – not detectable less than 0.01 mg/kg (<0.01 pm)

B2) Analysis of palm oil used for the immersion test of the styrene monomer exposed panels:
Styrene Monomer content – not detectable less than 0.01 mg/kg (<0.01 ppm)

Coating area exposed panels equaled 14.6 m2 per ton.
Sunflower seed oil and palm oil were exposed to a surface area of over 15 times that seen onboard ship.

TEST #2 — MarinSpec Associates, Report dated October 2009, Project Reference: Marin 02/09 APC

This was a follow-on or continuation of a project for FOSFA International by MarinSpec Ref: Marin 02/08, FOSFA International dated December 2008

The 2008 project was carried out to investigate the influence of tank cleaning on the transmission of chemical cargoes retained in organic cargo tank coatings into vegetable oils.

The report concluded that the coating that performed the best (transmitted the lowest concentration of chemical cargoes into the vegetable oils) was the coating designated 'BA'. That coating was MarineLine®, produced by Advanced Polymer Coatings, Avon, Ohio, U.S.A. (APC).

As a consequence of the good results in the 02/08 project, APC commissioned MarinSpec Associates to carry out a continuation of this project. The primary objective was to compare the transmission characteristics of MarineLine® against a typical Zinc Silicate coating, a typical Phenolic Epoxy coating and Stainless Steel, as requested by FOSFA International.

The project evaluated the following surfaces:

- Mild steel with industry standard Ethyl Zinc Silicate coating
- Mild steel with industry standard Phenolic Epoxy coating
- Mild steel with MarineLine® coating
- Stainless Steel (Grade 304)

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The exact methodology used in the previous project (Marin 02/08 – FOSFA International), 28 sample panels 125 mm x 50 mm x 3 mm of each surface were used and these panels were pre-treated and post cured as follows:

1. Ethyl Zinc Silicate coating. Panels washed in fresh water at 25°C, dried, washed in toluene and then dried again.
2. Phenolic Epoxy coating. Post cured in accordance with manufacturers published specifications.
3. MarineLine® coating. Cured at 80°C for 6 hours.
4. Stainless Steel grade 304. Washed in toluene and dried before being passivated per ASTM A380.

Triplicate panels were exposed to Styrene Monomer (SM) or Ethylene Dichloride (EDC) for a period of 30 days at 30°C before being removed from the chemicals and cleaned.

Cold Washing Procedure		**Hot Washing Procedure**	
1 Hour	Cold Seawater Recirculation	1 Hour	Cold Seawater Recirculation
	Cold Freshwater	4 Hours	Hot (60°C) Seawater Recirculation
	Ventilation for 24 hours	2 Hours	Steaming (max. temp. 55°C)
			Ventilation for 24 hours

After cleaning, the test panels were individually, fully immersed, in the following vegetable oils:

1. Crude Sunflower Oil (CSFO) at 30°C.
2. Refined Bleach Deodorized Palm Stearin (PS) at 70°C.

The panels remained in the vegetable oils for 30 days in order to maximize the transmission of any retained chemical cargoes into the vegetable oils.

After all panels were removed from each individual vegetable oil, a sample of the oil was analyzed for the presence of the respective chemical cargoes by Gas Chromatography Mass Spectrometry (GC / MS) at an independent certified public analyst laboratory.

Results

The following table quantifies the transmission of SM and EDC into CSFO and PS after the “cold” and “hot” tank cleaning operations. These results are the average of the triplicate results that have been corrected to take into consideration a contact ratio of 1 m2 of coating to 1 m3 of vegetable oil cargo.

This is the same correlation used and reported in Marin 02/08 – FOSFA International and considered to be typical of the surface area to volume ratio that may exist on an IMO Type 2/3 chemical tanker.

Surface Type	**CSFO Cold clean Styrene (mg/kg)**	**CSFO Hot clean Styrene (mg/kg)**	**PS Cold clean Styrene (mg/kg)**	**PS Hot clean Styrene (mg/kg)**	**CSFO Cold clean EDC (mg/kg)**	**CSFO Hot clean EDC (mg/kg)**	**PS Cold clean EDC (mg/kg)**	**PS Hot clean EDC (mg/kg)**
MarineLine	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Stainless Steel	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Epoxy Phenolic	25.1	2.3	18.3	22.6	45.0	13.2	34.1	26.4
Zinc Silicate	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1

The surface posing the least threat to vegetable oils were MarineLine®, Stainless Steel, and standard Zinc Silicate, with results reported from the laboratory being below the detection limit (2 mg/kg) of the analytical equipment.

However, it is important to note at this point the stainless steel was newly passivated prior to exposure to the chemical cargoes. Similarly, the Zinc Silicate used was a newly applied coating that had been washed prior to being exposed to the chemical cargoes. As such, these two surfaces can be considered to be in new condition, had these two surfaces been in used condition their performance may have been different.

TEST #3 — Shipboard Testing

At the request of FOSFA International to have onboard real life testing, APC approached a customer to do immediate last cargo in MarineLine® coated tanks testing, and they agreed.

Both EDC and Styrene Monomer where tested as last cargoes prior to loading the next cargo.

1. Details of Ship:

Coating: MarineLine®, January 2008
Method of Tank Cleaning:
- Butterworth Saltwater (ambient) – 4 hours
- Butterworth Saltwater (hot) – 4 hours
- Re-circ with dye-out – 6 hours
- Butterworth with Saltwater (hot) – 6 hours
- Freshwater rinse

Date of Loading Styrene Monomer in 3P, 3S: 26th December 2009
Date of Discharge of Styrene Monomer: 17th January 2010
Name of cargo after Styrene Monomer in 3P, 3S was MTBE – Date of Loading: 06th March 2010
Date of Discharging: 25th March 2010

- An official sample (500 ml in dark sample bottle) of the cargo from tanks that carried Styrene Monomer as immediate last cargo, taken prior to discharge of cargo and signed by representative of the vessel and independent surveyor.
  - 1st set of sample bottles with ship's name, voyage, date and 3P, 3S was stamped with ship stamp.
  - 2nd set of sample bottles with ship's name, voyage, date and 3P, 3S was stamped by independent surveyor.

Analysis

Two set of sample bottles sealed and stamped containing MTBE from the vessel were given to SGS for analysis of any Styrene Monomer in the MTBE.

SGS' analysis report SOT10-01272.001 of 13th April 2010 stated cargo contained 11 mg/kg (11 ppm) of Styrene Monomer.

2. Details of Ship:

Coating: MarineLine®, April 2007
Method of Cleaning:
- Forced Ventilation
- Butterworth Saltwater (ambient) – 4 hours

Date of Loading EDC in 9P, 9S : 11th June 2010
Date of Discharge of EDC: 23rd July 2010
Name of cargo after EDC in 9P, 9S was 50% Caustic Soda Solution – Date of Loading: 14th August 2010

Date of Discharging: 21st September 2010

- Same procedure was followed pertaining to sample bottles of 50% Caustic Soda.

Analysis

Two sets of sample bottles sealed and stamped containing 50% Caustic Soda from the vessel were delivered to Polymer Diagnostics, Inc. for analysis of any EDC in the 50% Caustic Soda Solution.

Polymer Diagnostics' Project Number 26485 dated 7th December 2010 analysis of stated cargo contained no EDC below detection limit (2 mg/kg) of the analytical equipment.

TEST #4 — Real Time Testing on Stainless Steel Tanks

INTERTANKO with Odfjell, Stolt and Ino Line working with FOSFA in 2006 ran onboard testing of Stainless Steel tanks with respect to cleaning of immediate previous cargoes and subsequent contamination of vegetable oils.

"The overall premise of the proposal is, for Stainless Steel tanks only, if it is possible to demonstrate that the tank was absolutely clean, then it should be possible to load a vegetable oil into the tank following any previous cargo, including cargoes on the FOSFA banned list."

The services of Dr. Verwey Chemical Laboratories, who were experienced in this area of research and also a FOSFA DI Analyst and a member superintendent, were employed.

Dr. Verwey's Laboratories recommended three wall wash tests that would detect the majority of the cargoes on the FOSFA banned list.

Experimental Results

First test, Acetonytrile was the previous cargo and this was followed by a non-reactive cargo, Toluene. The results demonstrated that the wall wash test showed that the tanks were clean after their washing cycle and no contamination (above the limit of detection) except that the 1st foot sample in one of the tanks showed small level of Acetonytrile.

Second test, Styrene Monomer (SM) was selected as the previous cargo since this material is known to give problems when it is an immediate previous cargo. The non reactive cargo which followed the Styrene Monomer was Acetone.

Sample 5 is final sample in Rotterdam and was an average sample (top, middle, bottom).

Sample 6 is the pre-discharge sample which the group agreed showed an increase in Styrene content.

It was agreed that samples "5" and "6" showed an increase in Styrene contamination that was difficult to explain with the information available.

Verwey Laboratories' analysis of the wall wash test solvents showed levels of Styrene Monomer. This would indicate that there was some Styrene Monomer retained on the surface of the Stainless Steel tank.

Additional testing was undertaken in 2006 – results have not been published.

Note: Since completion of testing for FOSFA, MarineLine® has been recognized as safe (GRAS) for carriage of food grade products complying fully with the U.S. Federal Food, Drug and Cosmetic Act and all applicable food additive regulations.