(1)

Ashland Chemical

Drew Ameroid Marine Division

Ashland Chemical Company
Division of
Ashland Inc

Address Reply
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Miami, FL 33162
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7 PAGES

3 September, 1996

ATT.
CH ENG
S. HAMMERVOLD

Mr. Per Sopp
Norwegian Cruise Lines
95 Merrick Way
Coral Gables, FL 33134

Dear Mr. Sopp:

Drew has completed the analyses relative to the boiler tube and various deposit samples from the boiler of the SS NORWAY. We performed detailed chemical and metallurgical analyses of the tube and deposit samples.

Our conclusion is that the tube failed from the dual contributions of internal, stress-assisted corrosion damage and creep void and crack formation, which was related to long-term metal overheating. The deposits inside the tube were primarily iron and copper. Normal for a boiler of this age. The outside deposits were primarily vanadium and sulfur.

You may wish to consider adding a deposit modifier/combustion improver to the fuel when high sulfur or vanadium content is suspect. We suggest you consider Drew's new treatment, AMERGY 5800 PLUS. If you have any questions or comments, please do not hesitate to contact us.

Sincerely,

Kevin Gilbert
Senior Account Manager

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LCDR, LTJG, USCG p 1 of 7

E-0224
Also E-0116

(2)

Metallurgical Analysis

The S/S Norway - Marine Boiler #21 boiler tube section was examined in the Metallurgical Laboratory.

The OD surface exhibited fireside deposition (RFA# M4017), slight expansion, and longitudinally-oriented failures, characteristic of long-term, tube metal overheating and creep stress-rupture.

The ID surface had waterside deposits, and the analyses were reported under RFA# M4017. After removal of the deposits, the cleaned ID surface revealed pitting corrosion and cracks that can be described as stress-assisted corrosion or corrosion-fatigue. The stresses were likely associated with the tube bending, and the age of the boiler and the advanced, cyclical usage (numerous start-ups/shut-downs) were thought to have contributed to the pitting/cracking at the ID.

A metallographic examination indicated a thermally degraded metal microstructure, as the pearlite constituent exhibited spheroidized iron carbides. Creep voids were present near the OD surface, and they linked up to form cracks originating from the OD that were further oxidized.

In summary, the failure resulted from the dual contributions of internal, stress-assisted corrosion damage and creep void and crack formation, which was related to long-term metal overheating. The long service of the boiler tube in a high radiant heat section, the tube bending, cyclical nature of the boiler, and the presence of internal deposits were the likely root causes of the observed problems in the boiler tube.

TOTAL P.05

Drew Industrial Division/
Drew Ameroid® Marine Division
ASHLAND CHEMICAL COMPANY, DIV. ASHLAND OIL, INC.
One Drew Plaza, Boonton, New Jersey 07005

(3)

ANALYTICAL REPORT

DEPOSIT SAMPLE

SAMPLE FROM

NORWAY

RFA NUMBER M4017 -1
DATE SAMPLED 07/14/96
DATE RECEIVED 07/26/96
DATE REPORTED 08/01/96
DREW REPRESENTATIVE
GILBERT

****

SAMPLE NUMBER 05

SAMPLE DESCRIPTION OUTSIDE TUBES M BOILER #21

TEST DESCRIPTION	RESULTS
CALCIUM (AS CAO) PERCENT	< 1.0
MAGNESIUM (AS MGO) PERCENT	< 1.0
SILICON (AS SIO2) PERCENT	2.6
IRON (AS FE2O3) PERCENT	3.2
ZINC (AS ZNO) PERCENT	< 1.0
ALUMINUM (AS AL2O3) PERCENT	3.0
COPPER (AS CUO) PERCENT	< 1.0
SODIUM (AS NA2O) PERCENT	7.7
CARBONATE (AS CO2) PERCENT	< 1.0
SULFUR (AS SO3) PERCENT	45.2
PHOSPHORUS (AS P2O5), PERCENT	< 1.0
OIL AND GREASE, PERCENT	< 1.0
LOSS ON IGNITION, PERCENT	52.1

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(4)

ANALYTICAL REPORT

DEPOSIT SAMPLE

SAMPLE FROM

NORWAY

RFA NUMBER M4017 -1
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DREW REPRESENTATIVE
GILBERT

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SAMPLE NUMBER 02

SAMPLE DESCRIPTION GEN TUBES FURNACE SIDE MB21

TEST DESCRIPTION	RESULTS
CALCIUM (AS CAO) PERCENT	1.2
MAGNESIUM (AS MGO) PERCENT	< 1.0
SILICON (AS SIO2) PERCENT	1.6
IRON (AS FE2O3) PERCENT	3.8
ZINC (AS ZNO) PERCENT	< 1.0
ALUMINUM (AS AL2O3) PERCENT	< 1.0
COPPER (AS CUO) PERCENT	< 1.0
SODIUM (AS NA2O) PERCENT	2.1
CARBONATE (AS CO2) PERCENT	< 1.0
SULFUR (AS SO3) PERCENT	3.3
PHOSPHORUS (AS P2O5), PERCENT	1.1
VANADIUM (AS V2O5) PERCENT	85.1
OIL AND GREASE, PERCENT	< 1.0
LOSS ON IGNITION, PERCENT	4.4

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ANALYTICAL REPORT

DEPOSIT SAMPLE

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NORWAY

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DREW REPRESENTATIVE
GILBERT

****

SAMPLE NUMBER 03

SAMPLE DESCRIPTION GEN TUBES SCREEN TUBE SIDE

TEST DESCRIPTION	RESULTS
CALCIUM (AS CAO) PERCENT	1.8
MAGNESIUM (AS MGO) PERCENT	< 1.0
SILICON (AS SIO2) PERCENT	2.1
IRON (AS FE2O3) PERCENT	3.9
ZINC (AS ZNO) PERCENT	< 1.0
ALUMINUM (AS AL2O3) PERCENT	1.1
COPPER (AS CUO) PERCENT	< 1.0
SODIUM (AS NA2O) PERCENT	2.9
CARBONATE (AS CO2) PERCENT	< 1.0
SULFUR (AS SO3) PERCENT	10.0
PHOSPHORUS (AS P2O5), PERCENT	< 1.0
VANADIUM (AS V2O5) PERCENT	78.6
OIL AND GREASE, PERCENT	< 1.0
LOSS ON IGNITION, PERCENT	13.0

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One Drew Plaza, Boonton, New Jersey 07005

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ANALYTICAL REPORT

DEPOSIT SAMPLE

SAMPLE FROM

NORWAY

RFA NUMBER M4017 -1
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DREW REPRESENTATIVE
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SAMPLE NUMBER 04

SAMPLE DESCRIPTION PIPE SAMPLE

TEST DESCRIPTION	RESULTS
CALCIUM (AS CAO) PERCENT	3.9
MAGNESIUM (AS MGO) PERCENT	3.2
SILICON (AS SIO2) PERCENT	< 1.0
IRON (AS FE2O3) PERCENT	36.8
ZINC (AS ZNO) PERCENT	5.0
ALUMINUM (AS AL2O3) PERCENT	< 1.0
COPPER (AS CUO) PERCENT	19.5
SODIUM (AS NA2O) PERCENT	1.3
CARBONATE (AS CO2) PERCENT	4.3
SULFUR (AS SO3) PERCENT	6.5
PHOSPHORUS (AS P2O5), PERCENT	5.6
OIL AND GREASE, PERCENT	< 1.0
LOSS ON IGNITION, PERCENT	4.3

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ASHLAND CHEMICAL COMPANY,DIV. ASHLAND OIL,INC.
One Drew Plaza,Boonton,New Jersey 07005

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ANALYTICAL REPORT

DEPOSIT SAMPLE

SAMPLE FROM

NORWAY

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****

SAMPLE NUMBER 01

SAMPLE DESCRIPTION INSIDE DOWNCOMERS RISERS MB21

TEST DESCRIPTION	RESULTS
CALCIUM (AS CAO) PERCENT	6.4
MAGNESIUM (AS MGO) PERCENT	< 1.0
SILICON (AS SIO2) PERCENT	< 1.0
IRON (AS FE2O3) PERCENT	49.4
ZINC (AS ZNO) PERCENT	2.6
ALUMINUM (AS AL2O3) PERCENT	< 1.0
COPPER (AS CUO) PERCENT	8.0
SODIUM (AS NA2O) PERCENT	< 1.0
CARBONATE (AS CO2) PERCENT	< 1.0
SULFUR (AS SO3) PERCENT	< 1.0
PHOSPHORUS (AS P2O5), PERCENT	8.2

COMMENTS

INS. SAMPLE RECD FOR LOSS OF IGNITION AND OIL AND GREASE TEST.

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