Marine Engine Damage due to Catalytic Fines in Fuel

A Joint Hull Committee paper in conjunction with Braemar (The Salvage Association)

September 2013

Joint Hull committee

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Executive Summary

Catalytic fines (cat fines) have been a feature of residual fuel oil for over five decades, with engineers and surveyors increasingly aware of the potential damage caused by high cat fine content.

There is strong evidence that hull underwriters are experiencing a significant increase in frequency of engine damage as a result of excessive component wear – a substantial number of these claims have been attributable to poor fuel quality and in particular high levels of cat fines present in the fuel.

With increasing demand through environmental legislation that requires the burning of cleaner fuel, low sulphur bunkers containing a higher cat fine content are mandatory for use in vessels trading in emission controlled areas, increasing the requirement for careful fuel management.

In summary:

- There is real evidence that the quality of heavy fuel oil bunkers has declined in recent years with resultant impact on the frequency of engine damage,
- Individual claims arising from cat fines are likely to exceed $1 million,
- High density cat fines can dramatically increase the rate of wear on critical machinery parts,
- Data demonstrates an increase in cat fine levels corresponding with demand for low sulphur fuel and a notable increase in the frequency of cat fine damage cases,
- A discrepancy exists between ISO standards for cat fine content and the recommended content by engine manufacturers, requiring effective filtration, purification and fuel management,
- Contributory factors can include:
    - insufficient capacity and poor efficiency of purifiers,
    - lack of knowledge of current fuel quality on board,
    - absence of effective maintenance practices

The attached paper, drafted by a working group of the Joint Hull Committee in association with Braemar (The Salvage Association) focuses on key issues and provides underwriters with the technical background to the issue of cat fines. More specifically:

Part 1: detailed assessment of the cause and consequences of cat fine related machinery damage, and

Part 2: supplement highlighting risk assessment and mitigation factors for consideration during the underwriting process.

In addition, included is an amended version of the JHC Machinery Space technical audit wording which now includes specific reference to bunker fuel management.

Marine Engine Damage due to Catalytic Fines in Fuel

Part I: Technical Analysis

Demand for low sulphur fuels and poor on board fuel management add up to a million dollar headache for insurers

Catalytic (cat) fines have been a hot topic in the news recently as the insurance market has witnessed a dramatic increase in claims for engine damage as a result of excessive component wear. A substantial amount of these claims have been attributable to poor fuel quality and in particular high levels of cat fines present in the fuel.

Cat fines are small, very hard particles of aluminium-silica based material that can be found in residual fuels. Cat fines may enter the engine combustion space when the fuel is injected, where they can become embedded on the surface of the cast iron cylinder liner, piston grooves and rings. Once in the engine these very hard particles act as an abrasive, rapidly wearing the sliding components. Wear rates depend on the quantity and size of the cat fine particles. In certain circumstances, wear beyond the maximum limits can occur in as little as a few weeks. The problem is mainly affecting large two stroke engines but cases involving four stroke engines are also reported.
The costs of these claims can be in excess of one million USD, especially if the wrong actions are taken by ship owners after the problem has been diagnosed.

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Lloyd's List

lloydslist.com | No. 60,876 | Wednesday March 6th, 2013
Leading maritime commerce since 1734

BALTIC EXCHANGE'S LPG FREIGHT RATE, PREVIOUS SIX MONTHS

Source: Baltic Exchange

Catalyst fines drive growth in claims for engine damage

Commercial pressures and demand for low-sulphur fuel add up to $1m headache

Liz McMahon

THERE has been a spike in cases of engine damage caused by catalyst fines as a result of commercial pressure and the ever-increasing demand for low sulphur fuel, according to Braemar marine engineer Paul Hill.

Mr Hill said the industry should be concerned about this problem as engine damage claims can be very expensive, costing anything up to $1m.

Cat fine damage occurs mainly in large, slow-speed crosshead main engines, Mr Hill said. Large abrasive particles can pass through fuel injection equipment and into the cylinder liners, where they embed themselves onto the cylinder wall surfaces.

Cat fine damage is less common in medium- or high-speed engines, although it can occur, Mr Hill said.

"This is mainly due to the smaller gaps between fuel injection equipment, and the method of cylinder liner lubrication, which washes the walls of the cylinders with more frequency, lessening the chance of cat fines being embedded."

Mr Hill said that cat fines were not necessarily a new problem as they had existed in fuel oil since the 1950s, when diesel engines were made to burn this type of fuel instead of the more expensive diesel and gas oil distillate fuels.

"Back in the late 1950s and 1960s, fuel was relatively cheap so the refineries were not interested in squeezing the last drop of distillates from the fuel, so less cat fines were carried over into the residual fuel oil," he said.

"The result of the 1970s oil crisis precipitated by the 1973 Middle East war was crude oil prices rising by around 300%.

"This price increase and the higher demands for distillate fuels forced refiners to implement improved refining techniques, to enable higher-end distillates to be extracted from the crude stock.

"Unfortunately, these techniques such as thermal and catalytic cracking were to have a major impact on the quality of marine fuels."

In the 1980s engine problems relating to cat fines started to be reported. Mr Hill said that since the mid-1980s the quality of residual fuel oil had decreased steadily, but this has had little significant impact on the number of cat fine-related damage that Braemar has surveyed, until now.

Mr Hill said the main changes that contributed to the recent rise were environmental legislation for the use of ever-decreasing levels of low-sulphur fuels and commercial demand for cheaper fuel.

Braemar has charted its reported cases of engine damage due to cat fines against regulatory sulphur limits and it seems to illustrate this worrying trend.

For several years, DNVPS has been compiling data on worldwide bunker fuel quality and its study revealed that the average levels of cat fines found in worldwide bunker fuels were steadily increasing, with levels in 2011 around 30 mg/kg.

This comes at a time when the North Sea and North American emission control areas are already set at 1% sulphur. In 2015 this is to drop much further, to 0.1% sulphur.

Since 1982, the International Organisation for Standards has published a specification for marine bunker fuels. It is on its fourth edition, published in 2010, which sets cat fine limits at 60mg/kg.

Mr Hill raised the question why this limit has not fallen further, when leading enginemakers specify a maximum of 15mg/kg cat fines.

He explained: "The answer to this question is purely commercial, with refiners saying, 'Yes we can produce 15 ppm fuel oil, but it will cost you, the consumer, more'. Furthermore, all ships are built with a fuel treatment system that is capable of removing the cat fines to a level below the 15mg/kg stated by enginemakers."

Mr Hill said that the problem stemmed from poor efficiency of purifiers; lack of knowledge of the current bunker fuel quality by the ships' engineers; lack of good maintenance practices, such as

CAT FINE ENGINE DAMAGE CASES

Number of cases

Source: Braemar

A WORRYING TREND

Sulphur %

Number of cases

MARINE SULPHUR LIMITS

Sulphur %

HOW SMALL ARE CAT FINES?

Human hair

1 micron = 0.001 mm

PM2.5

PM10

Fine beach sand

Source: Braemar

What are cat fines?

PARTICLES composed of highly abrasive aluminium and silicon oxides almost as hard as diamonds, catalyst fines are particles, mostly spherical, that originate from catalytic cracking units in refineries.

Entering the engine with the fuel, catalyst fine particles that are larger than five microns and which are present in sufficient quantities can quickly wear down piston rings, ring grooves, liners and fuel pumps.

Engine experts say particles in the 10-25 micron range are especially harmful to machine components. ■

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NEWS HIGHLIGHTS

UK cruise passengers grow
UK passenger embarkations increased 10%, with 78,000 extra British and 6,000 additional overseas passengers, according to the Passenger Shipping Association.

Carriers discuss round-trips
Container lines operating in the transpacific trades will have the opportunity to discuss round-trip economics for the first time when the two existing carrier groups become a single entity next month.

Emma Maersk docks at Palern
Maersk Line's flagship *Emma Maersk* is alongside at Fincantieri Palermo facilities and work is abo to begin on pumping floodwater o of the engine room.

Cuts will delay box inspectio
US Customs and Border Protectio is warning of major delays for incoming containers and other cargoes at seaports because of sequestration, but early reports suggest that business is operating normally on arterial waterfronts a least for now.

Shell invests in LNG corridor
Energy group Shell has made a fi investment decision on two small scale liquefaction units in North America that will create liquefied natural gas fuel corridors in the Great Lakes and US Gulf regions.

STX OSV renamed Vard
Offshore specialist STX OSV has been renamed Vard after its takeover earlier this year by Italia cruiseship builder Fincantieri, vi its wholly owned subsidiary Fincantieri Oil & Gas.

North Pole transits on the wa
Vessel transits over the North Pol could be physically possible a lot sooner than the industry believes

Front page of Lloyd's List, 6 March 2013

The increased trend has been largely due to the global environmental legislation curtailing the levels of sulphur in ships fuel, and with these limits reducing further in the coming years, the instances of engine damage are expected to correspondingly increase.

There are however solutions and preventative measures that can be taken to assist in minimising the risk of problems, and with the cooperation of legislative and technical bodies, ship owners, charterers and classification societies the number of these occurrences can be reduced.

INTRODUCTION

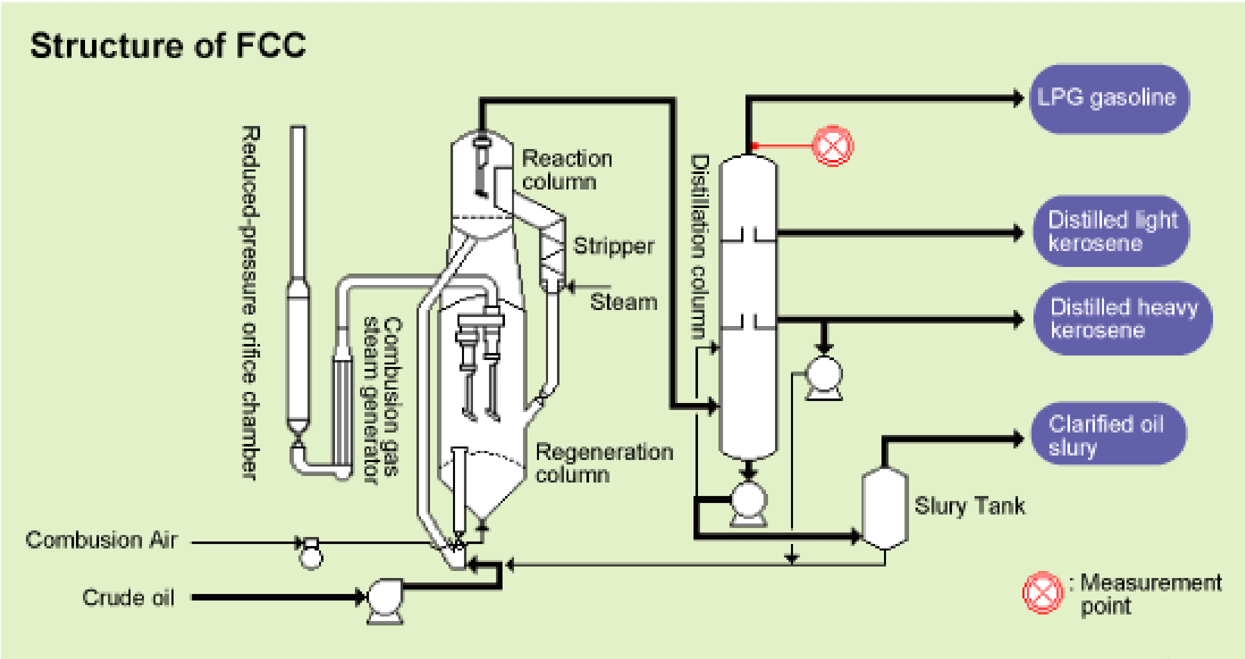
In recent years, the quality of heavy fuel oil bunkers has declined. This has had a dramatic impact on fuel related engine damage, with the consequential increase in losses for ship owners, charterers and insurers.

Environmental policies and the ever increasing cost of fossil fuels have played a major part in this decline; as more valuable distillate fuels are squeezed out of the crude oil stock and exhaust emission laws limit the sulphur content, the results are dangerously increased levels of catalytic fines remaining in the end product that is delivered on board the ship.

In the past bunker fuels were refined to suit their intended purpose, which is to burn efficiently in the engine; density and viscosity were the important factors in producing suitable fuel. These days the refineries are concentrating their efforts on producing low sulphur fuels for use in sulphur emission controlled areas (ECAs). These areas were originally limited to the Baltic, North Sea and English Channel, until August 2012 when the North American ECA came into force.

In order to achieve the low sulphur limits required for vessels that operate in these areas the oil refineries have to blend residual fuel with higher levels of cutter stocks such as slurry oil which comes from the catalytic cracking process. The catalysts used in this complex process are oxides of aluminium and silicon, which breakdown as they react with the fuel becoming increasingly smaller. These catalysts are expensive and are largely recycled by the refinery, however some of the smaller particles, known as cat fines, find their way into the slurry oil which is a by product of the process.

Slurry oil (shown at the bottom of the distillation column in figure 1) is a highly aromatic fluid which has a relatively high density and viscosity but low sulphur content, when mixed with high sulphur residual fuel, the result is a low sulphur fuel with increased density and potentially increased levels of cat fines.



Source: Yakogawa

Figure 1 Structure of the fluid catalytic cracker

If cat fines find their way into the engine, these hard particles usually get embedded in the softer metal surfaces of cylinder liners and piston rings, and may also affect the operation of fuel pumps and injectors, components which are intolerant to any abrasive compounds. Figure 2 shows these particles under the microscope.

These embedded particles can act like an abrasive paste between the moving components. Vertical lines are scored into the surface of the cylinder liner, which reduces the surface lubrication properties and accelerates the rate of wear.

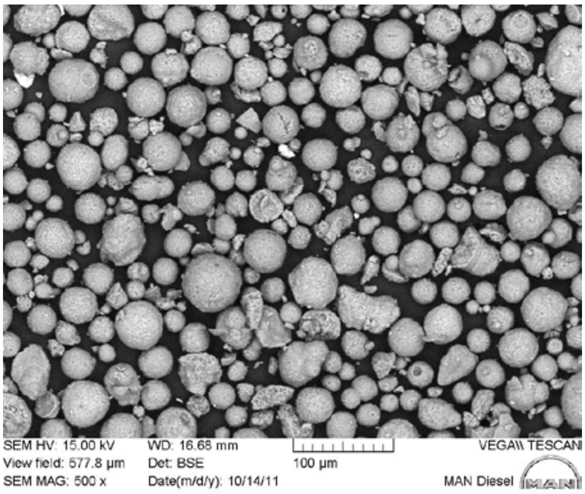


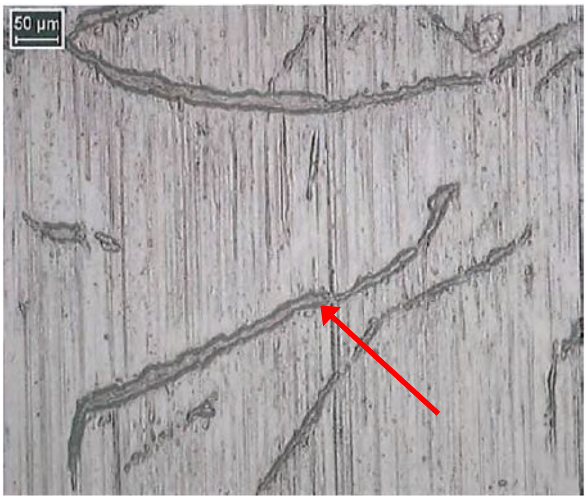
Figure 2 Microscope photograph of cat fines used in the refinery

In cases that involve high levels of cat fines the rate of wear that normally takes place over a year can occur in a matter of weeks.

Cat fine damage is mainly reported in large slow speed crosshead main engines; this is due to the action of large abrasive particles passing through the fuel injection equipment and into the cylinder liners, where they can embed themselves onto the soft cast iron cylinder wall surfaces. It is less likely to find cat fine damage in medium or high speed engines, although it can occur. This is largely due to the splash method of cylinder liner lubrication which washes the walls of the cylinders with more frequency, lessening the chance of cat fines being embedded.

Contrary to popular belief, the surface of a cylinder liner is not polished and smooth; it is precisely honed to give an open graphite structure, which may be considered to be rough in texture. This is to enable an adequate film of lubricating oil to adhere to the surface to minimise the metal to metal contact with the piston rings.

The dark areas shown in figure 3 are known as open graphite lamellae. These lamellae are made of a slightly softer material than

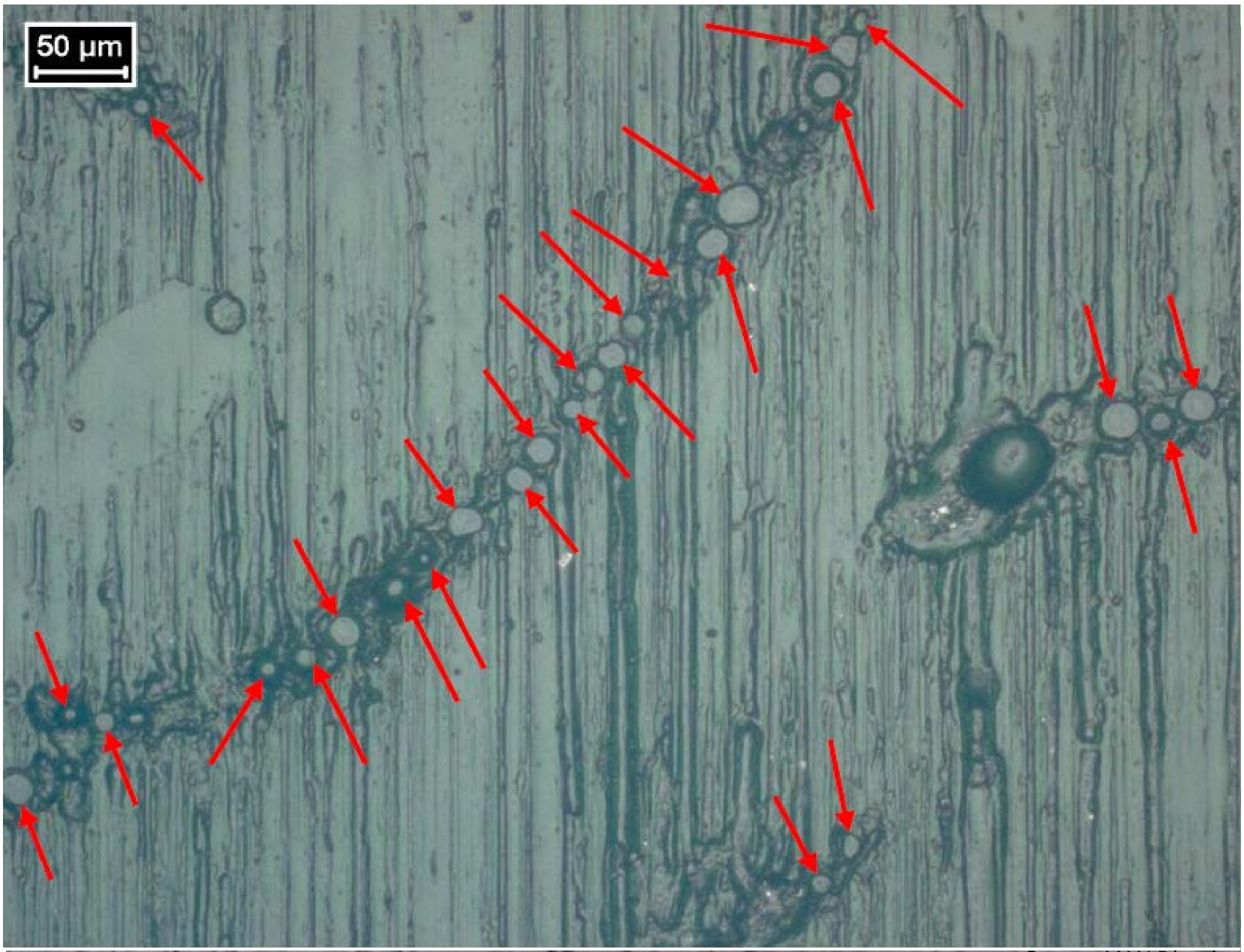


Source: MAN Diesel

Figure 3 Microscope view of a cast iron cylinder liner

that of the surrounding cast iron, and as such they tend to entrap the cat fine particles. The microscope photograph in figure 4, shows cat fine particles embedded into these graphite lamellae and the surrounding cast iron structure has become closed or polished due to scuffing.

This polishing inevitably reduces the cylinder lubricating oil's ability to stick to the liner surface and increase the metal to metal contact of the piston rings. This will result in rapid wear of both piston ring and cylinder liner.



Source: MAN Diesel

Figure 4 - Red arrows show cat fines embedded in the lamellae of the cast iron cylinder liner

THE SIZE OF THE PROBLEM

Cat fine particles can vary in physical size between 1 micron and 75 microns.

A micron is more properly known as a micro metre and is equivalent to 0.001 millimetres. By comparison, a human hair is 50 to 70 microns, and a fine grain of sand is around 90 microns.

Engine experts suggest that particles in the 10 to 25 micron range are especially harmful to machinery components, as they are able to get into the gaps between sliding components. Figure 5 shows a microscope view of the mesh of a 50 micron fuel oil filter, with two cat fine particles trapped within.

Source: MAN Diesel

Figure 5 - Microscope photograph of cat fines entrapped in the mesh of a fuel filter

Although the size of the particles is important, the quantity of catfines present in the fuel is the most important factor in the extent of damage that they can cause.

Engine makers and their experts state that from experience, quantities of less than 200 cat fines per square cm (CF/cm²) found imbedded in the cylinder liner surface are harmless and quite normal. More than 200 CF/cm² may increase liner and piston ring wear rates. If the quantity reaches or exceeds 1000 CF/cm², excessive liner and piston ring wear will take place within just a few days. In extereme cases quantities of more than 5000 CF/cm² have been recorded.

HISTORY OF THE PROBLEM

Cat fines have existed in residual fuel oil since the 1950's, when diesel engines were converted to burn this type of fuel instead of the more expensive diesel and gas oil distillate fuels.

Back in the late 1950s and 60s residual fuel was relatively cheap. As such, the refineries were not overly interested in squeezing the last drop of distillates from the crude oil stock. Less vigorous refining meant fewer cat fines carried over into the residual fuel oil product.

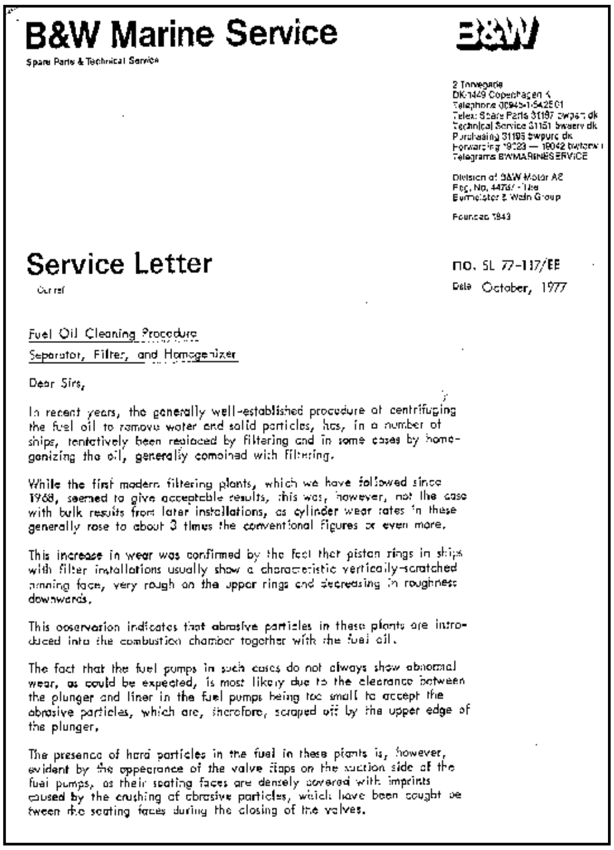
Crude oil prices rapidly increased by around 300% during the 1970's as a direct result of the Middle East War in 1973. This price increase, and the higher demands for distillate fuels, forced refiners to implement improved refining techniques to enable higher end distillates to be extracted from the crude stock.

Unfortunately, the techniques such as thermal and catalytic cracking were to have a major impact on the quality of marine fuels.

The first half of the 1980's saw constant modifications and improvements to ships' main engines by the major manufacturers, with equal improvements and modifications to purifiers and the onboard fuel treatment process.

Around this time fuel related engine damages were beginning to be reported, with catalytic fines being a predominant cause.

Figure 6 shows a service bulletin from engine makers B&W dated October 1977, warning owners about the problems and solutions to the decreasing quality of residual fuel oil. Particular emphasis was made to the onboard fuel oil treatment plant, filters, heaters and purifiers, and how important the correct operation and maintenance of this plant was to reduce the quantity of cat fines in the fuel before it reached the engine.



B&W Marine Service

Spare Parts & Technical Service

2 Torvegade
DK-1449 Copenhagen K
Telephone 00945-1-542501
Telex: Spare Parts 31197 bwpart dk
Technical Service 31151 bwserv dk
Purchasing 31195 bwpurc dk
Forwarding 19123 — 19042 bwforw
Telegrams BWMARINESERVICE

Division of B&W Motor AS
Reg. No. 44767 - The Burmeister & Wain Group

Founded 1843

Service Letter

Our ref

no. SL 77-117/EE

Date October, 1977

Fuel Oil Cleaning Procedure

Separator, Filter, and Homogenizer

Dear Sirs,

In recent years, the generally well-established procedure of centrifuging the fuel oil to remove water and solid particles, has, in a number of ships, tentatively been replaced by filtering and in some cases by homogenizing the oil, generally combined with filtering.

While the first modern filtering plants, which we have followed since 1968, seemed to give acceptable results, this was, however, not the case with bulk results from later installations, as cylinder wear rates in these generally rose to about 3 times the conventional figures or even more.

This increase in wear was confirmed by the fact that piston rings in ships with filter installations usually show a characteristic vertically-scratched running face, very rough on the upper rings and decreasing in roughness downwards.

This observation indicates that abrasive particles in these plants are introduced into the combustion chamber together with the fuel oil.

The fact that the fuel pumps in such cases do not always show abnormal wear, as could be expected, is most likely due to the clearance between the plunger and liner in the fuel pumps being too small to accept the abrasive particles, which are, therefore, scraped off by the upper edge of the plunger.

The presence of hard particles in the fuel in these plants is, however, evident by the appearance of the valve flaps on the suction side of the fuel pumps, as their seating faces are densely covered with imprints caused by the crushing of abrasive particles, which have been caught between the seating faces during the closing of the valves.

Figure 6 - B&W Service letter from 1977 warning about cat fines

THE INCREASES IN CAT FINE DAMAGE CASES

Over the last 12 years Braemar (inc The Salvage Association) has seen many cases of engine damage due solely or partially to Cat Fines in bunker fuel.

The graph shown in figure 7 shows the number of cases that Braemar (inc The Salvage Association) has dealt with over the past 12 years, and shows a large increase in cases during 2012. The first 8 months of 2013 has already seen nine confirmed cases of cat fine damages.

The rise in cases numbers since 2009 and in particular the large increase in 2012 are considered to be due to the environmental legislation for the reduction in sulpur content of fuel oil used on ships. These case numbers only represent Braemars experience, combined with results from the many other survey companies worldwide they will be much larger.

MARPOL Annex VI on "Regulations for the Prevention of Air Pollution from Ships"

In 2008 a global cap of 4.5% sulphur content for residual fuels was introduced. In 2012 the global cap was reduced further to 3.5%. The plan is to further reduce this cap to 0.5% sulphur content in 2020.

In 2008 the Baltic Sea and North Sea, including the English Channel, was designated as a Sulphur Emission Control Area (ECA), this is shown in Figure 8. Vessels operating in this area were required to use fuel with a maximum of 1.5% sulphur. In 2010 this cap was reduced to 1.0% and is planned to be further reduced to 0.1% in 2015. Additionally, vessels that are in port or anchored close to port are required to use gas oil with a cap of 0.1%.

In August 2012 the USA and Canada enforced the North American ECA which requires vessels operating within 200 nautical miles of the coast to use less

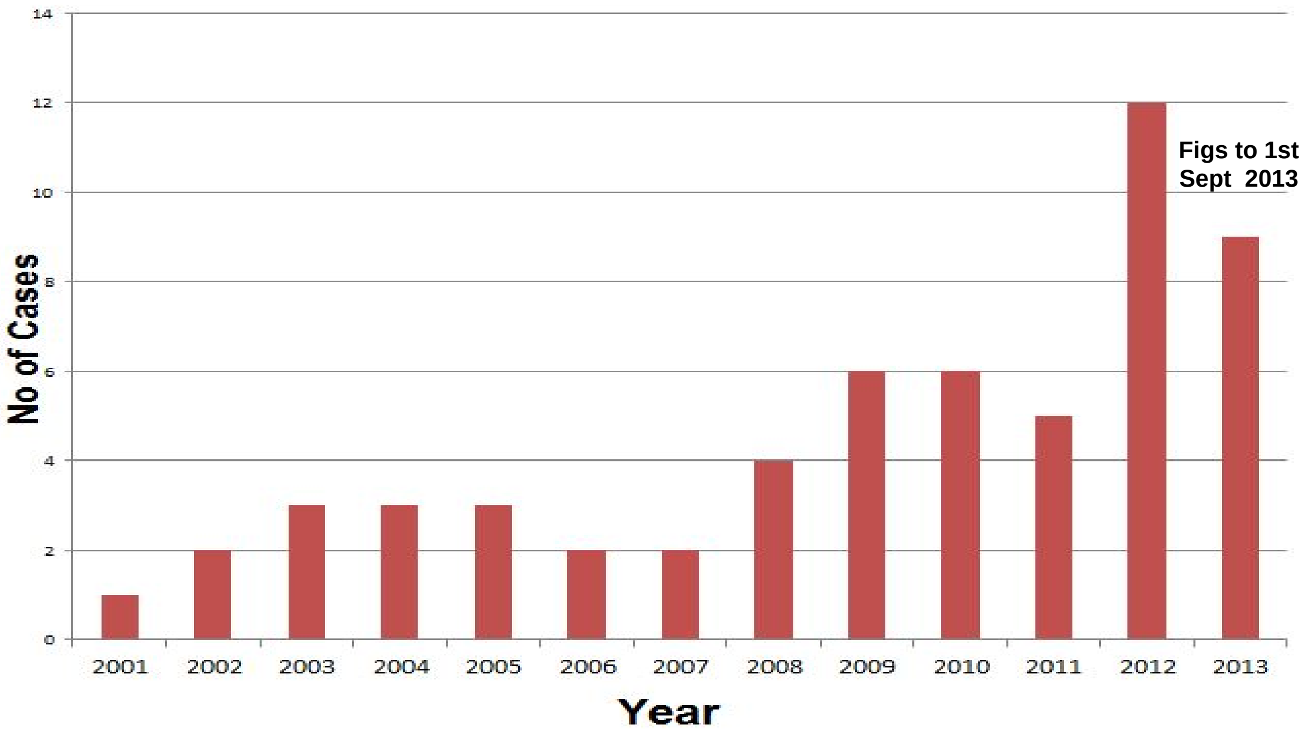


Figure 7 - Number of cases of confirmed cat fine engine damage seen by Braemar (inc The Salvage Association) over the last 12 years

than 1.0% sulphur as required in the Baltic & North Sea ECA, with the corresponding cap drop to 0.1% in 2015.

No plans so far exist for expanding the ECA areas to the Mediterranean Sea, South America or Asia.

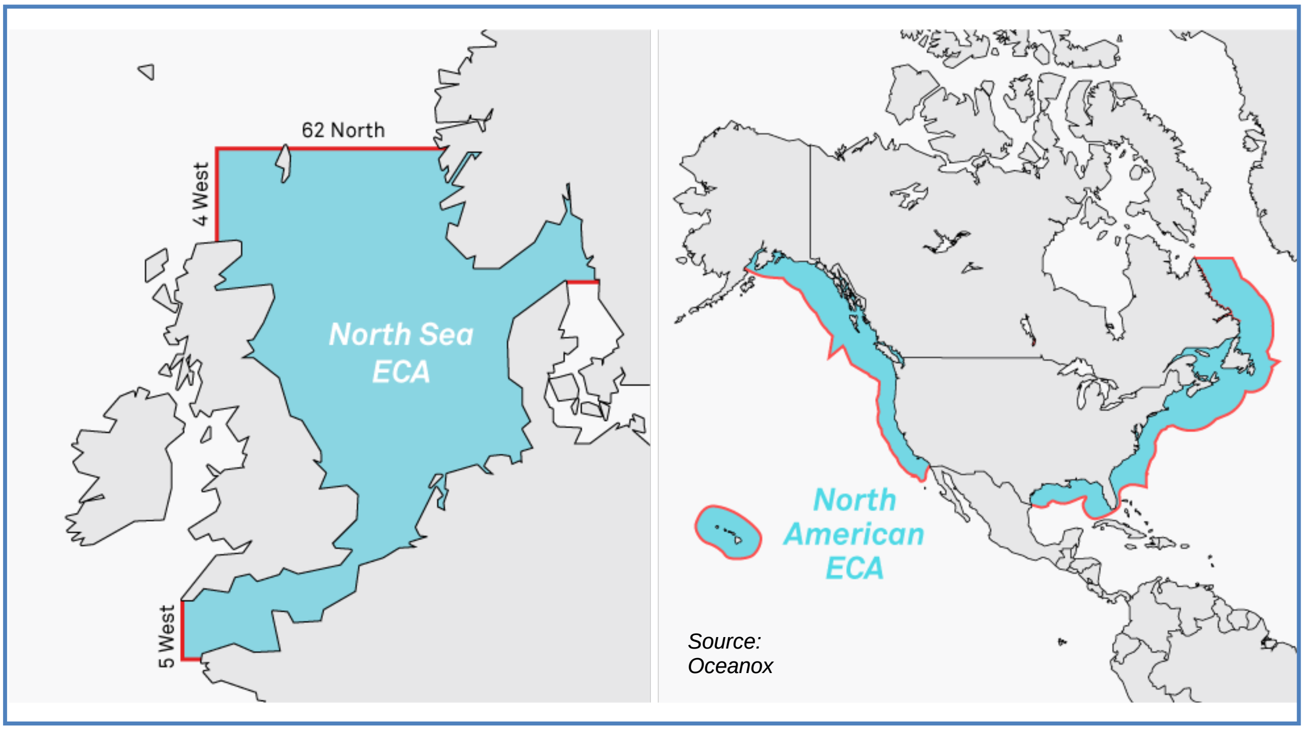


Figure 8 – The Baltic Sea and North Sea ECA zone, and the North American ECA introduced in August 2012

At this point ships will no longer be able to use residual fuel oil in these areas as, unless the vessel uses an appropriate exhaust gas scrubber, only gas oils will meet the sulphur content limits.

Some bodies suggest that cat fine problems will cease at this time as distillate fuel is not likely to contain cat fines, however for oil refiners to meet this massive new demand for distillate fuels more intensive use of Catalytic crackers will be necessary, increasing the levels of cat fines in the residual fuel used by shipping in the rest of the world.

Even more of a concern is the 0.5% Global Cap planned to be imposed in 2020, although IMO have now suggested that this deadline may be delayed.

It is further planned to enforce a Caribbean and Mexican Coast ECA in January 2014.

FUTURE LEGISLATION

Shipping analysts forecast that the 2012 global sulphur cap of 3.5% would require 11% of global high sulphur fuel oil to be blended to meet the new limit.

Since August 2012 with the North American ECA in force, the worldwide demand for low sulphur fuel oil has doubled, leading to further, more complex blending. The consequence of this has been an inevitable increase in the levels of cat fines.

Figure 9 shows the Braemar (inc The Salvage Association) cat fine engine damage confirmed case files overlaid with a chart showing the MARPOL Annex VI on "Regulations for the Prevention of Air Pollution from Ships" sulphur limit timeline.

The resultant chart clearly shows the relationship between decreasing low sulphur legislation and the increase in cat fine engine damage cases.

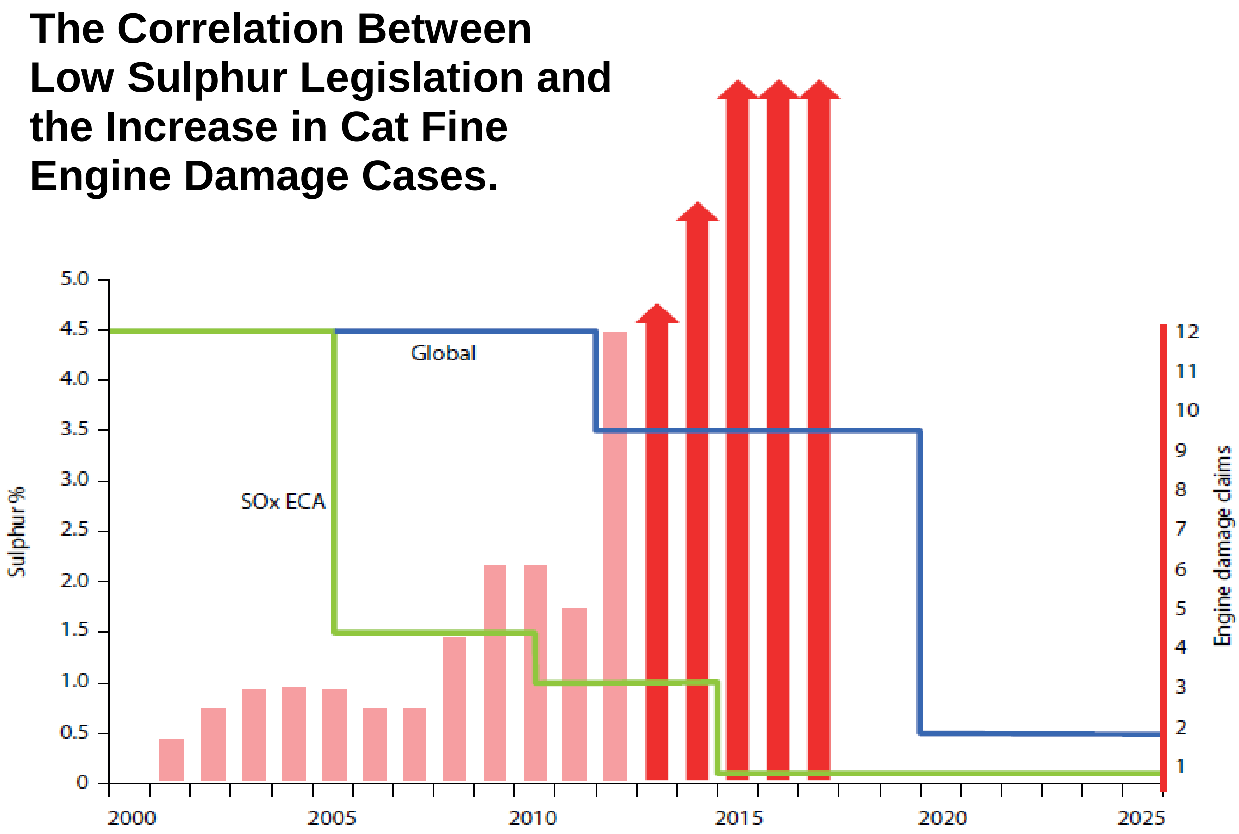


Figure 9 – Salvage Association case numbers plotted against the MARPOL sulphur limits, the red arrows suggest that an increase may be inevitable

REGIONAL DIFFERENCES IN RESIDUAL FUEL OIL CAT FINE LEVELS

During recent years Det Norske Veritas Petroleum Services (DNVPS) have been compiling data on worldwide bunker fuel quality and issuing alerts notices to ship owners who subscribe to the service.

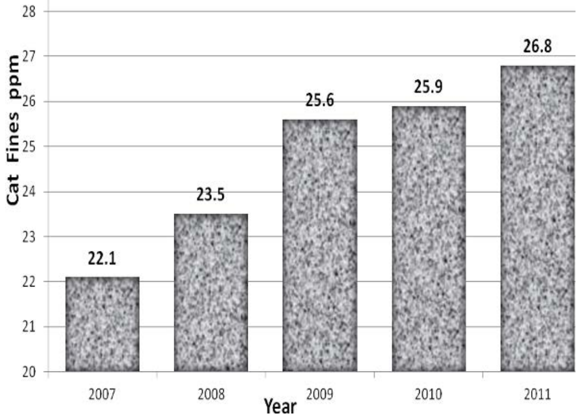


Figure 10 – DNVPS statistics showing the increase in ppm cat fines year by year

The data shows that the average levels of cat fines found in worldwide bunker fuels to be steadily increasing with the levels in 2011 on average 26.8 ppm. This is shown in the graph in Figure 10.

The data is collected from bunker fuel samples taken for analysis by vessels around the world and also shows specific cat fine levels by country or area. Some of the highest levels of 48 ppm are found in the US Gulf bunker fuel which is a concern following the introduction of the North American ECA last year.

Another concerning trend is the rising density of fuels, which is considered in part to be another result of refineries blending to achieve low sulphur products. In addition to affecting the ignition quality of fuel, increasing density may also affect the ability of the vessel's fuel purifiers to deal with cat fines, which will be explained later in this paper.

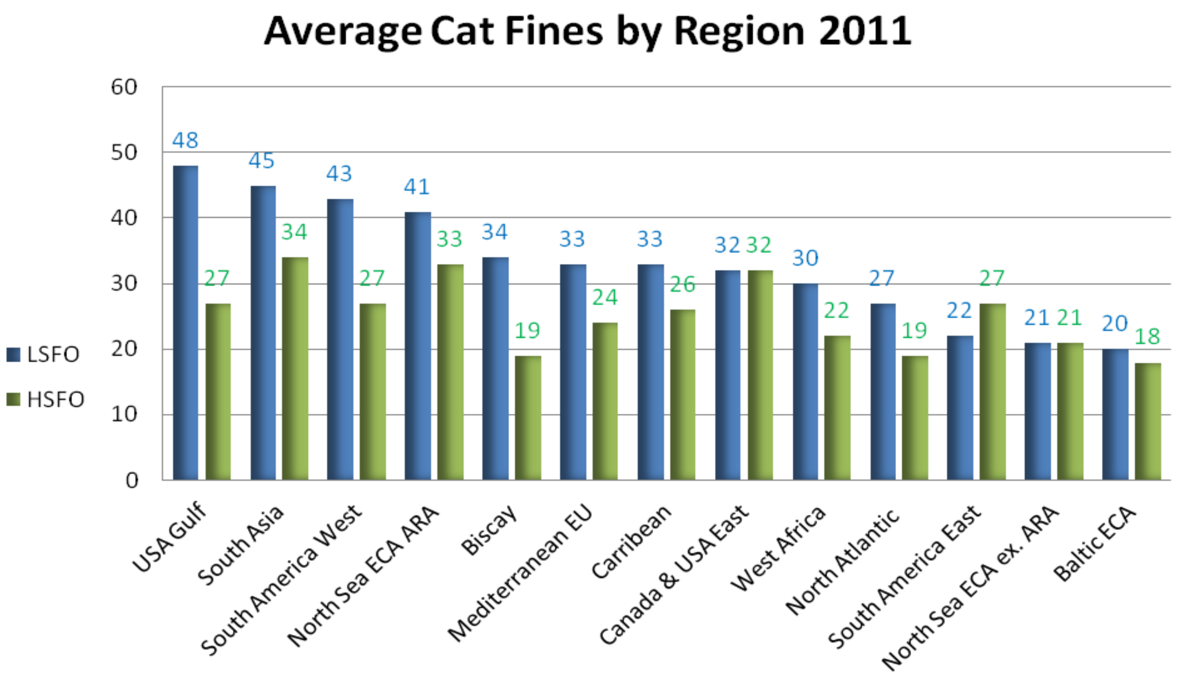


Figure 11 – DNVPS fuel analysis reports show regional differences in the ppm of cat fines in both high and low sulphur fuels

PREVENTION OF CAT FINE DAMAGE

Since 1982 the International Standards Organisation (ISO) has published a specification for the quality of marine bunker fuels, specifying the maximum limits of various characteristics, components and contaminants. The standard is known as ISO 8217 and the current edition, the fifth revision, is ISO 8217: 2012

The table in figure 12 shows the five editions of the standard and the maximum limits of cat fines allowed for RMG 380 grade fuel oil.

It can be seen from this table that the latest version of the standard, which came into effect in August 2012, specifies a maximum level of 60 parts per million cat fines.

Interestingly the major engine makers specify a maximum of 15 parts per million as a safe maximum level to use in their engines after the necessary pre-treatment onboard. This however was a notional measure of filter efficiency, not a scientifically established standard.

Date		Version	Cat Fine Limits
1982	BS MA 100	First published	Not specified
1986	ISO 8217	Published as BS MA 100:1986	Not specified
1996	ISO 8217	2nd edition	Max 80mg/kg
2005	ISO 8217	3rd edition	Max 80mg/kg
2010	ISO 8217	4th edition	Max 60mg/kg
2012	ISO 8217	5th edition	Max 60mg/kg

Figure 12

Many different characteristics and components are specified within the standard with each being given a maximum allowed value. Of relevance here is the level of cat fines, which are measured as the sum of aluminium and silicon particles in mg per kg or parts per million. Figure 13 shows the ISO 8217:2010 standard, the column headed RMG includes limits for RMG 380 grade fuel oil which is arguably the most common grade of marine residual fuel oil.

The leading main engine makers MAN B&W and Wartsila specify fuel with a maximum of 15 ppm cat fines at the point of injection to be used in their engines. It may be surprising to the layman therefore that the ISO limit remains as high as it does. The reason is purely commercial, with refiners saying “yes we can produce 15ppm fuel oil, but it will cost you the consumer more”.
It is generally accepted that the correct pre-treatment of fuel oil onboard the vessel should reduce cat fine levels by 75%

However there are many problems faced by ship-owners such as:

- Poor efficiency of purifiers, an essential part of the onboard fuel treatment system.
- In certain circumstances, the lack of knowledge about the current bunker fuel quality by the ships engineers
- Consequently, a lack of awareness of other potentially contributing fuel quality parameters such as water content and used lube oil content prior to using the fuel
- Lack of good maintenance practices, such as regular cleaning of fuel oil service tanks
- Minimal and insufficient capacity of purifiers provided by the shipyard during the building process

			Category ISO-F-											
			RMA	RMB	RMD	RME	RMG				RMK			Test method reference
Characteristic	Unit	Limit	10	30	80	180	180	380	500	700	380	500	700	
Kinematic viscosity at 50 °C	mm²/s	max.	10,00	30,00	80,00	180,0	180,0	380,0	500,0	700,0	380,0	500,0	700,0	ISO 3104
Density at 15 °C	kg/m³	max.	920,0	960,0	975,0	991,0	991,0				1010,0			ISO 3675 or ISO 12185
CCAI		max.	850	860	860	860	870				870			Annex B
Sulphur	mass %	max.	Statutory requirements											ISO 8754 ISO14596
Flash point	°C	min.	60,0	60,0	60,0	60,0	60,0				60,0			ISO 2719
Hydrogen sulphide	mg/kg	max.	2,00	2,00	2,00	2,00	2,00				2,00			IP 570
Acid Number	mg KOH/g	max.	2,5	2,5	2,5	2,5	2,5				2,5			ASTM D664
Total Sediment Aged	mass %	max.	0,10	0,10	0,10	0,10	0,10				0,10			ISO 10307-2 Procedure B
Carbon residue, micro method	mass %	max.	2,50	10,00	14,00	15,00	18,00				20,00			ISO 10370
Pour point (upper) –winter quality –summer quality	°C	max. max.	0 6	0 6	30 30	30 30	30 30				30 30			ISO 3016 ISO 3016
Water	Volume %	max.	0,30	0,50	0,50	0,50	0,50				0,50			ISO 3733
Ash	mass %	max.	0,040	0,070	0,070	0,070	0,100				0,150			ISO 6245
Vanadium	mg/kg	max.	50	150	150	150	350				450			IP 501, 470 or ISO14597
Sodium	mg/kg	max.	50	100	100	50	100				100			IP 501 or 470
Aluminium plus silicon	mg/kg	max.	25	40	40	50	60				60			IP 501, 470 or ISO10478
Used lubricating oils (ULO)	mg/kg	-	The fuel shall be free from ULO. A fuel shall be considered to contain ULO when either one of the following conditions is met: Calcium > 30 and Zinc > 15; or Calcium > 30 and Phosphorus > 15											IP 501, 470 or 500

- New Grade
- New Parameters
- Same as 2005
- Changed Values

Figure 13 – ISO 8217:2010 Standard for marine fuel oil

FUEL OIL TREATMENT ONBOARD THE VESSEL

All vessels are built with an onboard fuel treatment plant, which consists of settling tanks, service tanks, purifiers, pumps, heaters and filters. The components are standard on all vessels but the size and quantity of equipment can vary. Figure 14 shows a standard layout approved by Wartsila.

temperature of the fuel to 98 degrees C before being fed through to the purifiers. This is the optimum temperature for efficient separation of contaminants in the purifiers.

The purifiers are constructed with a bowl that spins at very high speed. Fuel is delivered into the bowl and the action of centrifugal force throws the heavy particles and contaminants outwards to the edges of

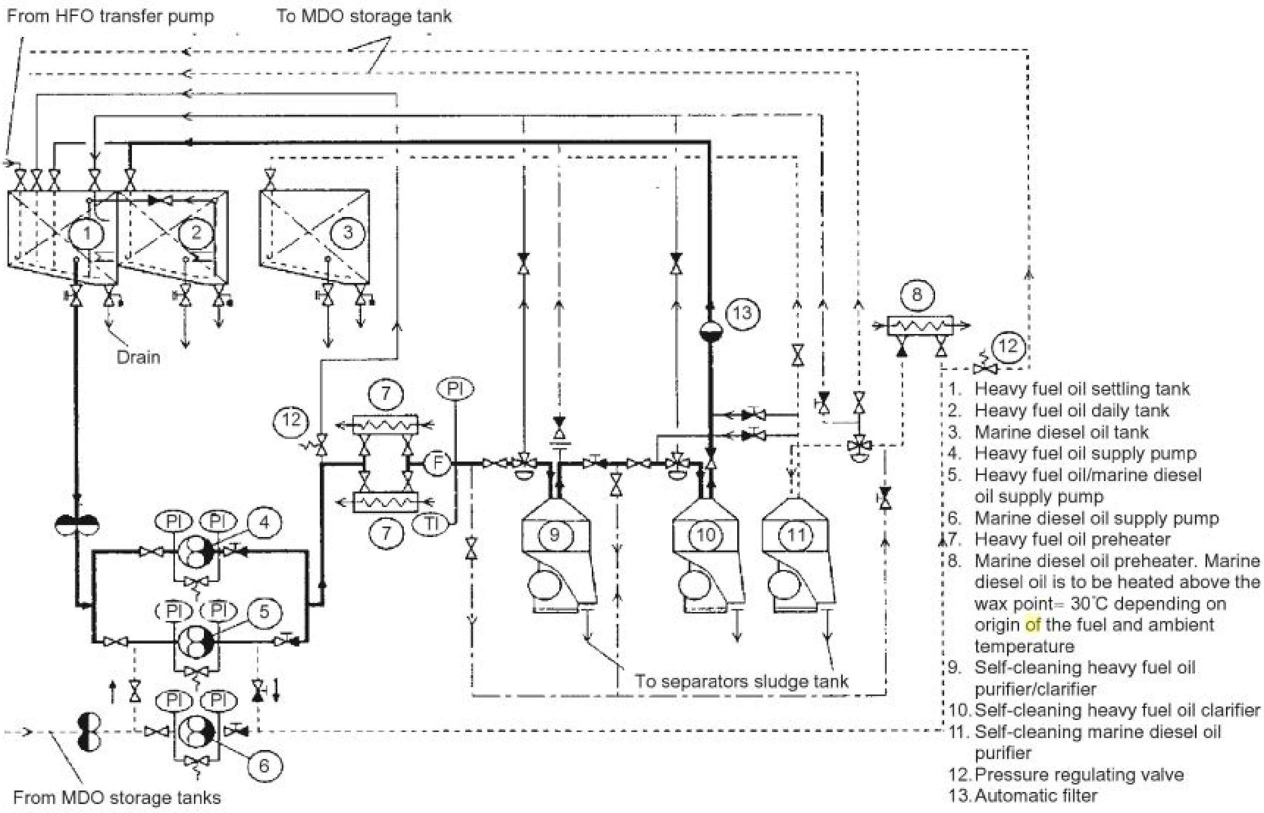


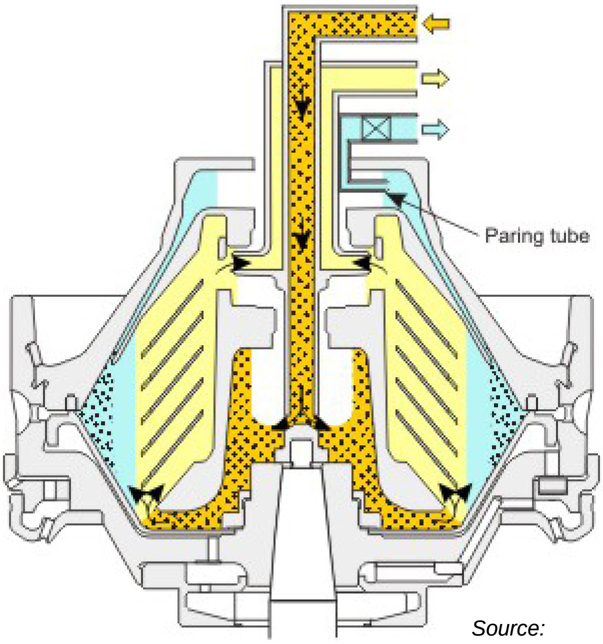
Figure 14 – Fuel oil treatment plant layout approved by Wartsila for its low speed engines

Fuel is transferred by the vessel's engineers from double bottom or wing storage tanks to the FO settling tank, which is constructed with an inclined bottom so that heavy particles, sludge and water can be drained off at the lowest point. The fuel remains in this tank as long as possible and is preheated by heating coils in the tank, before being transferred to the FO service tank via the purifiers. The settled and heated fuel is then pumped through filters and in line heaters which raise the

the bowl, where they are discharged on a regular cycle to the sludge tank.

The purifiers are set up with a throughput of fuel sufficient to fill the service tank with just the right amount of fuel according to the engines consumption. Ideally the through put should be adjusted so that engine consumption plus 10% is delivered to the service tank with the excess being overflowed back to the settling tank.

Figure 15 shows a purifier bowl with fuel from the settling tank entering from a central pipe. After separating the heavy contaminants, the purified oil is discharged (shown as yellow in the diagram). Water is discharged by means of a valve in the discharge pipe and the sludge is discharged when the bowl is momentarily opened during a specifically timed cycle.



Source: Alfa Laval

Figure 15 - Operation of a fuel oil purifier

Although the operation of the purifier is normally automatically controlled by microprocessor, manual maintenance is essential for efficient operation. Fuel oil varies considerably in density, viscosity and contaminant levels, so the purifier has to be closely monitored to ensure that the sludge cycle is frequent enough to remove the sludge that builds up in the bowl. If this sludge cycle is not optimal, sludge can fill the bowl and carry over with the clean fuel. This effectively results in the purifier acting purely as a pump and not removing any contaminants, as it should.

Figure 16 and 17 show excess sludge build up in a purifier bowl.

As well as maintaining the purifiers with a regular planned maintenance system, the other components of the system should be regularly checked and adjusted as necessary. Fuel filters should be removed cleaned and inspected for holes, whilst heaters should be regularly opened and cleaned to ensure that the maximum temperature of the fuel can be obtained prior to purification.

Daily draining of the settling and service tanks should be carried out by the watch keeping engineers and excess amounts of sludge and water drained from these tanks recorded and reported.

Figure 16 - excess sludge build up in the purifier casing

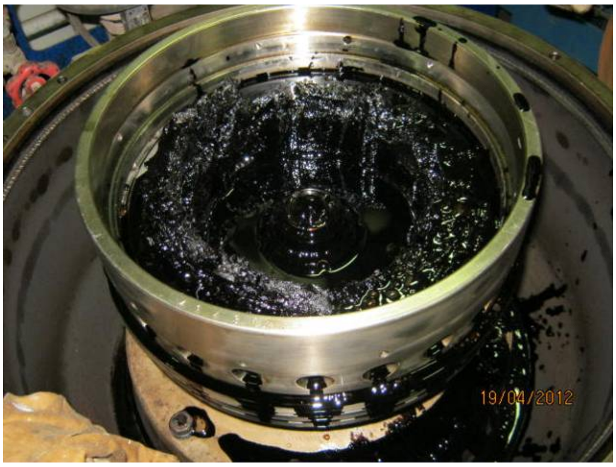


Figure 17 - excess sludge build up in the purifier bowl

CASE STUDY 1

54,000 DWT bulk carrier, built in 2005

Main Engine: MAN B&W 6S50MC-C slow speed direct reversing two-stroke diesel engine.
Bore: 500 mm
Stroke: 2,000 mm

6 September 2009 to 5 October 2009
Main Engine Operational Problems

On 30 July 2009 the vessels chief engineer noticed that the diesel generators were running erratically, and that excessive sludge was building up in the fuel oil purifiers and filters. At the next port the engineers made an inspection of the six main engine cylinder units. While all piston rings were noted intact, the pistons and rings were found to be abnormally dirty.

On the next passage a rise in the exhaust gas temperatures of the No.2 main engine unit was noted. Consequently the unit was overhauled on 6 September 2009, at which time the piston rings were found broken and severely worn. By this time the chief engineer suspected that the quality of the fuel oil on board was poor. After discussions with the engineers he discovered that the previous chief engineer had been using the No. 1 & 3 fuel oil double bottom tanks for dumping excess sludge.

In anticipation of stemming new bunkers for the next voyage, the chief engineer ordered the remaining fuel in No. 1, 2 & 3 double bottom tanks be consolidated into No. 4 port tank. A large quantity of water and sludge was noted to be carried over to this tank during the transfer. New bunkers were then loaded into the empty tanks.
During passage on 15 September the chief engineer noted rising exhaust gas temperatures in Nos. 1, 3, 4, 5, and 6 units of the main engine. The engine was stopped and inspection found that all piston rings had excessive wear and many were broken. The piston crowns had evidence of blow by and large deposits of sludge and scrapings were noted in the scavenging manifold.

The Owners were duly advised of the problem, and in view of a planned long ocean passage, the vessel was diverted to the nearest suitable port to carry out overhaul of the main engine and repairs to the generator fuel pumps, as these continued to give running problems. While en route to this port, the problems with the generators worsened, and eventually the chief engineer switched over to running on diesel oil. The No. 5 cylinder cover on the No. 2 generator had to be replaced at this time due to burning of the exhaust valve.

During the overhaul of the main engine the following damage was found:

No.1 cylinder liner found cracked.
All six piston crowns heavily fouled, and with slight scuffing marks on the skirts.
All ring sets appeared worn and with the compression ring stuck in a number of cases.
All remaining cylinder liners worn to some extent, with ridges on the exhaust side about 100 mm below the top landing on nos. 1, 4, and 6 units.
Two main engine piston rods were found to have excessive wear and sent to MAN authorised repair facilities for grinding undersize. Two undersize stuffing boxes were provided.

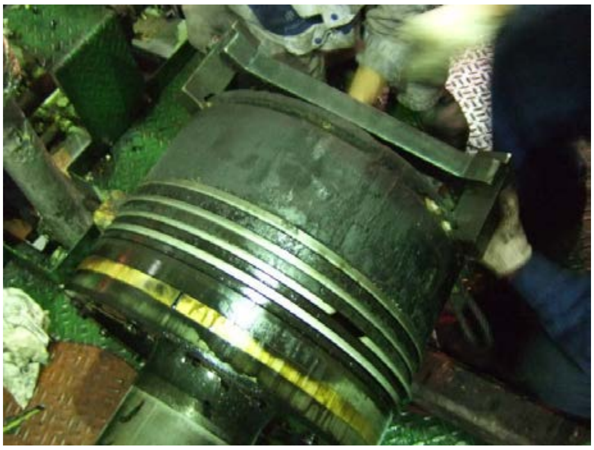
Fuel Oil Tanks

The vessel had a total of four double bottom fuel oil tanks, and two engine room side tanks, plus settling and service tanks for heavy fuel oil, totalling about 2,200 m^3.

Owners arranged for all fuel oil tanks to be cleaned of sludge, and for all contaminated fuel oil to be disposed of.

No. 1 Unit ME Piston (after only 240 running hours)

No. 4 Unit piston – note broken 2nd ring



No. 3 Unit piston after removal

Main engine with all pistons removed

The alleged cause of the damage was the supply of poor fuel oil bunkers with excessive levels of cat fines.

The cost of repairs was in the region of USD 1,500,000.

CASE STUDY 2

302,986 DWT Crude oil tanker
Built in 2002
Main Engine: Sulzer 8RTA84T slow speed direct reversing two-stroke diesel engine.
Bore: 840 mm
Stroke: 3,150 mm

21 November 2006 main engine damage

At 0830 hrs on 21 November 2006 while on a loaded passage the double hulled crude oil carrier experienced main engine failure. Upon inspection it was found six of the eight main engine cylinders had suffered extensive inexplicable wear.

Fuel Oil

The vessel had a fuel oil consumption, when fully loaded and running at 90% of its maximum continuous rating, of about 120 tonnes per day. The fuel oil bunker capacity was some 10 500 tonnes in four bunker tanks, two settling tanks and a service tanks.

The fuel in use at the time of the main engine failure was bunkered on 9 September 2006, when 7280 tonnes were loaded.

The samples of this stem, which were collected by drip feed throughout the bunkering process, numbered four; one for MARPOL purposes, one for the bunker suppliers, one for the vessel and one to be despatched to VISWA.

Two sets of analysis results were received back from the test laboratory for this fuel oil. The first, received on 14 September 2006, did not give the fuels silicon or aluminium content, the tests for which were being re-run, the report advised.
These figures were however included the second report received on 15 September.

Two things of note emerged from the analysis of this fuel oil. One being that the silicon and aluminium content was high and the other being that the sulphur content was low. Each of these factors generated remarks from the lab. A transcript of the report is given below.…

Fuel Oil Analysis

Grade Conformance

The fuel sample tested conforms to grade RMG 380.

Comments

High iron noted. High iron can cause damage to fuel pump and fuel nozzle.
Ensure purification and filtration systems are functioning efficiently.

Catfines

Observation: Catfines content (Aluminium +Silicon) in fuel is high.
Catfines cause high wear in rubbing surfaces of cylinder and fuel system.
If the catfines content is less than 15 ppm, wear and tear for the engine will be minimal.
Increased catfines content will increase the wear rate.
Purify continuously and recirculate the fuel several times to bring down the catfines content.

Damage Found and Recommendations Made

With the fitting of three replacement liners it was anticipated that a further five liners would require replacement in conjunction with associated consumable spares.
It was recommended that the main engine piston crowns be calibrated and replaced if found to be outside the Maker's recommended levels of wear.

All of the fuel injectors in service prior to the engine failure required removal from the engine for examination with the recommendation that they be replaced if showing unacceptable signs of wear (three injectors are fitted to each unit).
It was also recommended that a number of fuel pump spill valves be examined and assessed for cavitation, another symptom indicating the presence of cat fines. Should cavitation be evident, all valves should be replaced.

The cost of repairs was in the region of USD 900,000

Marine Engine Damage due to Catalytic Fines in Fuel

Part II: Guidance Notes (JH2013/006)

JHC Guidance Notes (JH2013/006)
Mitigation of Engine Damage due to Catalytic Fines

1 - Prior to Bunker Fuel Delivery

The Vessel should:

- Ensure that there are sufficient empty tanks to store the newly purchased fuel.
- Ensure that the empty tanks are clean.
- Be aware of the analysis statistics on fuel quality of the port of supply, especially if there are any relevant warnings issued by testing laboratories, P&I Clubs and marine press.
- Ensure the vessel has sufficient fuel on board to enable the testing of new bunkers prior to usage. It should avoid using newly purchased fuel without obtaining and acting on the results of fuel analysis.

Contractual Agreements:

In the Charterparty and Bunkering contracts, the agreed value of ppm of Aluminium (Al) and Silicon (Si) should be kept to less than 50ppm (irrespective of the ISO 8217:2012 limit of 60ppm), to ensure that the centrifuges can effectively bring this value down to less than 15ppm at the entry to the engines.

NB: If bunkered oil contains more than 50ppm of catalytic fines, injected oil is still likely to have higher than the recommended levels of cat fines due to the limitations of on board fuel treatment equipment.

2 - During and immediately after Bunker Fuel Delivery

The Vessel should:

Ensure that representative bunker samples are drawn in line with industry guidelines and tested by a suitable independent laboratory against the ISO 8217:2012 specification requirements:

- Drip fuel samples should be taken during bunkering, from each bunker source/barge/tanker.
- Expedient dispatch to follow, from bunker port to analysis laboratories with the provision that the Fuel Analysis Report returns to the vessel as soon as possible and in any case prior to using the bunkered oil.

In the unlikely case of emergency where the use of bunker fuel has to be used without receipt of analysis results, contact the technical superintendent for permission.

3 - During use of Bunker Fuel

Regular Testing post Bunker Fuel Purchase:

- There should be a system of analyzing oil at the entrance to the engine through a system of fuel system audits to ascertain and improve the efficiency of the purification and filtering system.
- Samples of heavy fuel oil should also be taken before and after each separator at intervals of 4 to a maximum 6 months. The samples should be sent to accredited laboratories such as DNVPS, FOBAS or Intertek for analysis using the ISO 8217 standard specification for comparison.
- In the event of an amber warning on levels of silicon and aluminium levels in the fuel, then fuel samples should be taken before and after purifiers. Max allowable total Si + Al 50ppm before purifier, and 15ppm after purifier.

Purifiers:

- Where possible, run two purifiers in parallel with minimum flow and keep the HFO inlet temperature at the optimal of 98º C to ensure efficient purification.
- Purifier capacity should be sufficient to cope with daily fuel consumption plus 10% in order to enable some recirculation of fuel in the settling tank to occur.
- Purifier efficiency tests should be carried out annually by fuel specialist bodies, such as DNVPS or FOBAS.
- Regular checks of the purifiers should be made by the manufacturer's service engineers to enhance system efficiency.
- Fuel system filters should be regularly inspected and cleaned – not only when high differential alarms are activated.

Fuel Storage, Settling & Service Tanks:

- New bunkers should be put into empty tanks, and blending of different fuels should be avoided.
- Frequent (daily) draining of water and settled bottom sediments from fuel storage, settling and service tanks should take place. During calm weather, the heavy components in the HFO (Heavy Fuel Oil), such as cat fines, will settle in the tank bottom, and in heavy weather these abrasive particulates can be stirred up and fed into the purifiers in concentrations exceeding the maximum acceptable levels of 50ppm. If unchecked, this can impede the efficiency of the treatment system, leading to large quantities of cat fines at the engine inlet.
- Drained oil from automatic fuel oil backwash filters should not be reintroduced into the fuel treatment system.
- Clean settling and service tanks during dry docking in order to deal with any long term build-up of cat fines and sediment in the bottom of the fuel oil storage tanks.

Equipment Maintenance:

- Fuel treatment heaters should be opened and cleaned regularly to ensure that the optimal temperature of 98 º C for purification is reached.
- Purifiers should be opened for cleaning at the scheduled intervals recommended by the manufacturers, or more often if poor fuel quality is suspected. Vessels should maintain the necessary spare parts on board.

Training:

- There should be company Bunker Procurement, Handling and Management plans provided to vessels.
- The Operator should ensure that the responsible personnel are sufficiently trained to fully and independently operate and maintain all above mentioned equipment as appropriate, both through existing qualifications prior to employment as well as on-going training courses and market practice updates, if and where necessary.
- The responsible personnel should be familiar with the issues raised in these guidance notes (JH2013/006).

Record Keeping:

Crew and operator to maintain records of bunker fuel management procedures, including maintenance records and reports of mechanical or procedural failures.

4 - If a Problem is Found

If engine damage is thought to be due to cat fines, experts should be instructed to confirm the presence of cat fines. Such confirmation can only be achieved by replica testing of the affected cylinder liners and piston rings carried out by the engine maker technicians.

If cat fines are confirmed, all necessary work to eradicate them from the fuel should be carried out immediately. This should include the:

- Removal of contaminated fuel oil from the vessel,
- Cleaning of storage, settling and storage tanks, and fuel system components,
- Replacement or machining of all affected engine components.

This will help to avoid the escalation of further engine damage caused by cat fines, and minimise further delays in commercial operations and the unnecessary additional costs and insurance claims.

5 - Options for Improvement

Operators may wish to focus their attention on the subjects noted in these guidance notes and carry out an internal review of their bunker handling and treatment procedures. They may also wish to enhance their planned maintenance by increasing inspections of engine cylinder assembly parts in order to provide early identification of fuel related problems.

The fitting of proprietary cat fine analysis equipment that enables the vessel engineers to see levels of cat fines in the system in real time should be actively considered.

JH 2013/007A
26 September 2013

Engine Room, Machinery and Bunker Fuel Risk Assessment

In each case as a condition precedent to the liability of the Underwriters under the insurance

1. the vessel shall be subject to an Engine Room Risk Assessment with specific reference to:

    a. the engine room management
    b. a machinery risk analysis
    c. bunker fuel management

    by Marine Engineer Surveyor ……………… within thirty days of …………….. ; and

2. all recommendations shall be complied with by the date or dates required by the surveyor; and

3. all recommendations described by the said surveyor as *"ongoing"* shall be complied with throughout the period of this insurance and any extension thereof.

It is further agreed that:

a) the cost of the survey will be borne by the assured;

b) the surveyor's recommendations may include that additional surveys be carried out;

c) Underwriters shall receive a copy of any recommendations and/or reports directly from the surveyor within …….. days of completion of any survey;

d) Underwriters shall be entitled, but not obliged, to request the surveyor to report to them concerning compliance with any recommendations made by the surveyor.