FUEL

and

LUBE OIL

By Charlotte Røjgaard
MAN Diesel

Technical course
Fuel og lubricating oil

Fuel

- Quality
- Composition
- Low sulphur fuel
- Treatment
- Case stories

System oil

- System oil contamination on larger engines
- Design modifications on stuffing box
- Piston undercrown deposits
- General evaluation of system oil analyses

Cylinder oil

- MBD requirements
- How do we check / follow up on cylinder oil performance?

Fuel

MBD two-stroke engines can operate on:

- MGO
- MDO
- Low S HFO
- High S HFO

The fuel should be in accordance with:

- ISO8217
- CIMAC recommendation 21

Relationship between the CIMAC HFO group and ISO 8217

CIMAC HFO Group	ISO 8217
(Marine and stationary plants)	(Marine plants)
Ⓐ Recommendation	Ⓐ Standard
Ⓑ Short lead time	Ⓑ Long lead time
Ⓒ High flexibility	Ⓒ Limited flexibility

* Participant overlap between the groups
* Support to the other groups
* Rational use of resources in the groups by avoiding duplication of work

CIMAC Recommendation no 21

- CIMAC recommendation (No 21) specifies limit for Zn, P and Ca as indicator of lube oil contamination
- Also a recommendation for TAN (Total Acid No) is given

CIMAC recommendation no 21 for residual fuel

<table>
<tr><th>Characteristics[1)]</th><th>Unit</th><th>Limit</th><th>CIMAC A 30</th><th>CIMAC B 30</th><th>CIMAC D 80</th><th>CIMAC E 180</th><th>CIMAC F 180</th><th>CIMAC G 380</th><th>CIMAC H 380</th><th>CIMAC K 380</th><th>CIMAC H 700</th><th>CIMAC K 700</th><th>Test method reference</th></tr>
<tr><td>Density at 15 °C,</td><td>kg/m³</td><td>max.</td><td>960,0</td><td>975,0</td><td>980,0</td><td colspan="2">991,0</td><td colspan="2">991,0</td><td>1010,0</td><td>991,0</td><td>1010,0</td><td>ISO 3675 or ISO 12185 (see also 6.1)</td></tr>
<tr><td rowspan="2">Kinematic viscosity at 50 °C</td><td rowspan="2">mm²/s [2)]</td><td>max.</td><td colspan="2">30,0</td><td>80,0</td><td colspan="2">180,0</td><td colspan="3">380,0</td><td colspan="2">700,0</td><td>ISO 3104</td></tr>
<tr><td>min. [3)]</td><td>22,0</td><td></td><td>-</td><td colspan="2">-</td><td colspan="3">-</td><td colspan="2">-</td><td>ISO 3104</td></tr>
<tr><td>Flash point,</td><td>°C</td><td>min.</td><td colspan="2">60</td><td>60</td><td colspan="2">60</td><td colspan="3">60</td><td colspan="2">60</td><td>ISO 2719 (see also 6.2)</td></tr>
<tr><td>Pour point (upper)
- winter quality
- summer quality</td><td>°C</td><td>
max.
max.</td><td>
0
6</td><td>
24
24</td><td>
30
30</td><td colspan="2">
30
30</td><td colspan="3">
30
30</td><td colspan="2">
30
30</td><td>
ISO 3016
ISO 3016</td></tr>
<tr><td>Carbon residue</td><td>% (m/m)</td><td>max.</td><td colspan="2">10</td><td>14</td><td>15</td><td>20</td><td>18</td><td colspan="2">22</td><td colspan="2">22</td><td>ISO 10370</td></tr>
<tr><td>Ash</td><td>% (m/m)</td><td>max.</td><td colspan="2">0,10</td><td>0,10</td><td>0,10</td><td>0,15</td><td colspan="3">0,15</td><td colspan="2">0,15</td><td>ISO 6245</td></tr>
<tr><td>Water</td><td>% (V/V)</td><td>max.</td><td colspan="2">0,5</td><td>0,5</td><td colspan="2">0,5</td><td colspan="3">0,5</td><td colspan="2">0,5</td><td>ISO 3733</td></tr>
<tr><td>Sulfur [4)]</td><td>% (m/m)</td><td>max.</td><td colspan="2">3,50</td><td>4,00</td><td colspan="2">4,50</td><td colspan="3">4,50</td><td colspan="2">4,50</td><td>ISO 14596 or ISO 8754 (see also 6.3)</td></tr>
<tr><td>Vanadium</td><td>mg/kg</td><td>max.</td><td colspan="2">150</td><td>350</td><td>200</td><td>500</td><td>300</td><td colspan="2">600</td><td colspan="2">600</td><td>ISO 14597 or IP 501 (see also 6.8)</td></tr>
<tr><td>Total sediment potential</td><td>% (m/m)</td><td>max.</td><td colspan="2">0,10</td><td>0,10</td><td colspan="2">0,10</td><td colspan="3">0,10</td><td colspan="2">0,10</td><td>ISO 10307-2 (see also 6.6)</td></tr>
<tr><td>Aluminium plus silicon [5)]</td><td>mg/kg</td><td>max.</td><td colspan="2">80</td><td>80</td><td colspan="2">80</td><td colspan="3">80</td><td colspan="2">80</td><td>ISO 10478</td></tr>
<tr><td>Used lubricating oil (ULO)</td><td></td><td></td><td colspan="10">The fuel shall be free of ULO. A fuel shall be considered to be free of ULO if one or more of the elements Zinc, Phosphorus and Calcium are below or at the specified limits. <u>All</u> three elements must exceed the same limits before a fuel shall be deemed to contain ULO.</td><td></td></tr>
<tr><td>Zinc
Phosphorus
Calcium</td><td>mg/kg
mg/kg
mg/kg</td><td>-
-
-</td><td colspan="10">15
15
30</td><td>IP 501 or IP 470
IP 501 or IP 500
IP 501 or IP 470
(see also 6.7)</td></tr>
</table>

1) See General Recommendations paragraph 3 for additional characteristics not included in this table
2) 1 mm²/s = 1 cSt
3) Fuels with density close to the *maximum*, but with very low viscosity, may exhibit poor ignition quality. See Annex 6.
4) A sulphur limit of 1.5% m/m will apply in SOx Emission Control Areas designated by the IMO, when its relevant Protocol comes into force. There may be local variations.
5) See Annex 3.

<u>Note</u>: ISO 8217 limit is for bunker not at engine inlet

Significance of fuel parameters

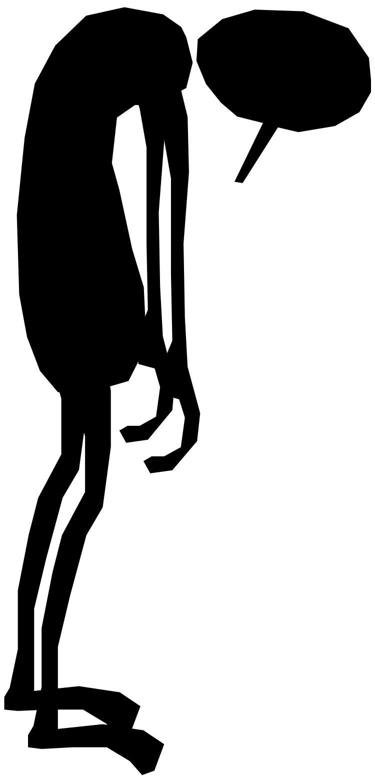
- Density: Proper centrifuging
- Viscosity: Heating and injection
- Water: Corrosion, deposits and emulsification
- MCR: Deposits
- Sediments: Centrifuge and filter
- Ash: Contamination, wear
- Flash point: Storage and handling

Significance of fuel parameters

▪ Vanadium:	High temperature corrosion
▪ Sodium:	Deposits, high temperature corrosion
▪ Pour point:	Filter clogging
▪ Contaminants:	Various
▪ CCAI:	None
▪ FIA/FCA:	Ignition quality for four-stroke at low loads
▪ Al + Si:	Abrasive wear
▪ Sulphur:	SOx emission, corrosion and TBN

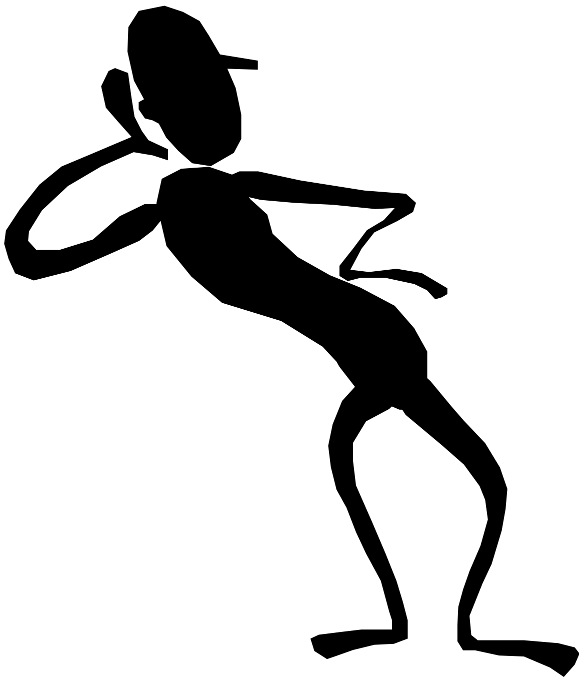
Components
Not Affected by Separation

- Density
- Viscosity
- CCAI
- Flash Point
- Pour Point
- MCR
- Sulphur
- Vanadium
- Asphaltenes
- Nickel



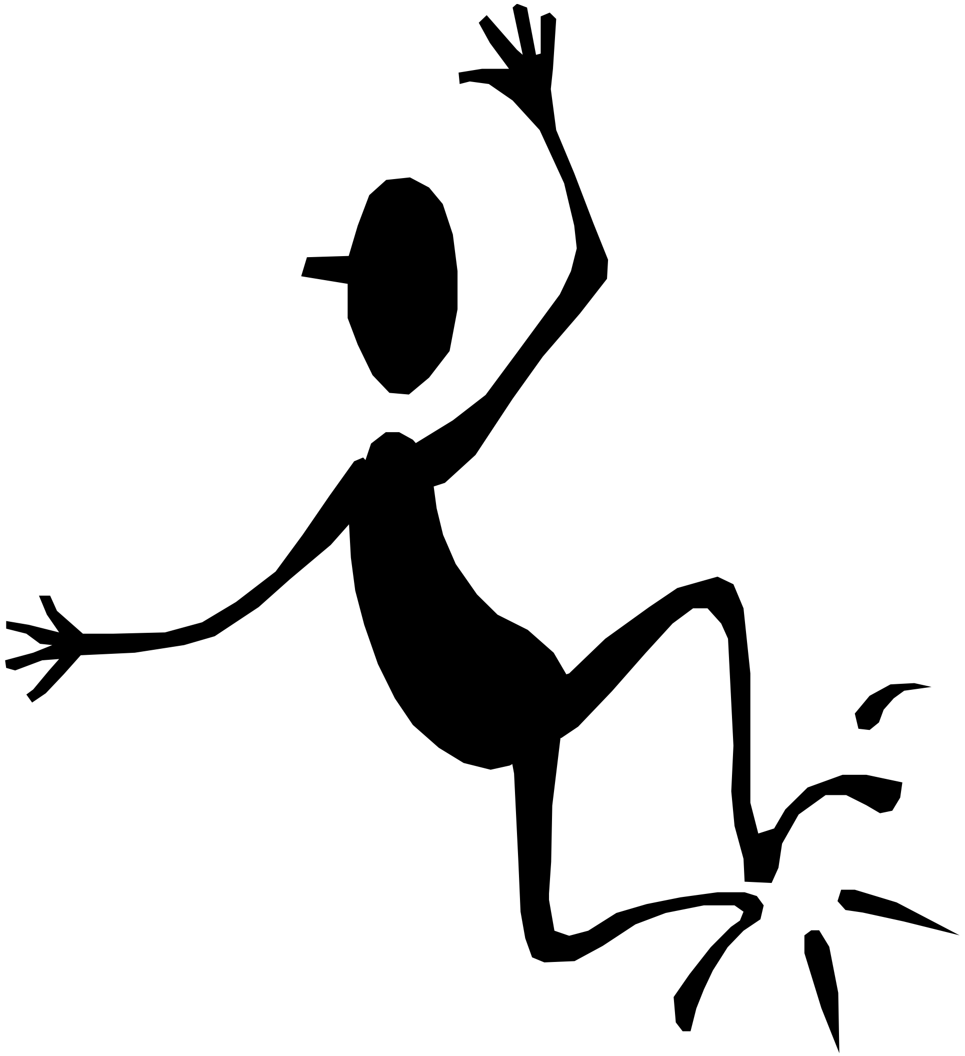
Components
Slightly Affected by Separation

- Total Sediment
- Ash
- Calcium



Components
Strongly Reduced by Separation

- Water
- Sodium
- Aluminium
- Silicon
- Iron
- Magnesium



Water content (H2O)

- Loss 1: Water reduces specific energy:
  (1% H_2O = > 1% energy loss)
- Loss 2: Buyer pays for water instead of fuel
- Salt or fresh water?????
- Salt:
  - 1% water approx = 100 ppm Na; 12 ppm Mg
  - corrosion damages to fuel pumps and injectors
  - deposits on exhaust valves and turbochargers
  - risks related to the vanadium content

Sulphur

- Sulphur has a low energy content.
  The higher the S, the lower the energy content
- Combustion of sulphur forms sulphur oxides and corrosive sulphuric acid
- Acidic components condensate on ‘cold’ surfaces in the engine
- Correct choice of cylinder oil BN is of vital importance to neutralise acids
- Negative environmental effects (emissions)

Ash

- The ash content of a fuel indicates the presence of incombustible inorganic material
- Some ash components are hard and abrasive
- Abrasive ash can seriously damage a vessels machinery.

Flash point (FP)

- The temperature at which a test flame under specified conditions will ignite the vapours given off by a fuel oil.
- Safety factor: Indicates presence of volatile components
- Indicates risk of fire or explosion in fuel tanks
- The SOLAS Convention requires that the fuel should have a flash point above 60 C.

Micro Carbon Residue (MCR)

- MCR is a measure of the residue left from burning the fuel under certain conditions
- Carbon content indicate the fuels carbon depositing tendency and combustion capabilities
- When burning a high carbon residue fuel, it's important to avoid engine conditions which tend to increase deposits formation.
  - Avoid, if possible, continuous low load operation
  - Maintain scavenging and cooling water temps
- Some engines more prone to problems when burning a high carbon residue fuel.

Pour point (PP)

- The pour point is the lowest temperature at which an oil will flow
- Temperatures below the pour point may cause filter problems and the fuel might solidify completely

Net Specific Energy

- Energy content: Calculated value using density, sulphur, ash and water.

- High density fuels are less valuable than low density fuels in terms of energy.

- Sulphur has a low energy value, hence high sulphur fuels are less valuable than low sulphur fuels.

$ - Buying fuel is buying energy.

Contaminants

Contaminants seen recently:

- Chlorinated solvents – fuel pump / valve damages
- Carboxylic acids – corrosion on fuel pumps / valves (seen after 8 hrs of operation)
- Polymer contamination – filter clogging
- Sodium – Exhaust gasways and T/C fouling

Fuel pump plunger attacked By carboxylic acids

Polystyrene deliveries in Antwerp

13 vessels bunkered from 7 Sept. to 31 Oct 2003

- 1 additional delivery in December 2003
- 1 additional high viscosity, March 2004

13 vessel reporting operational problems – filters

3 vessels known to have debunkered

Low temperature filter problems:

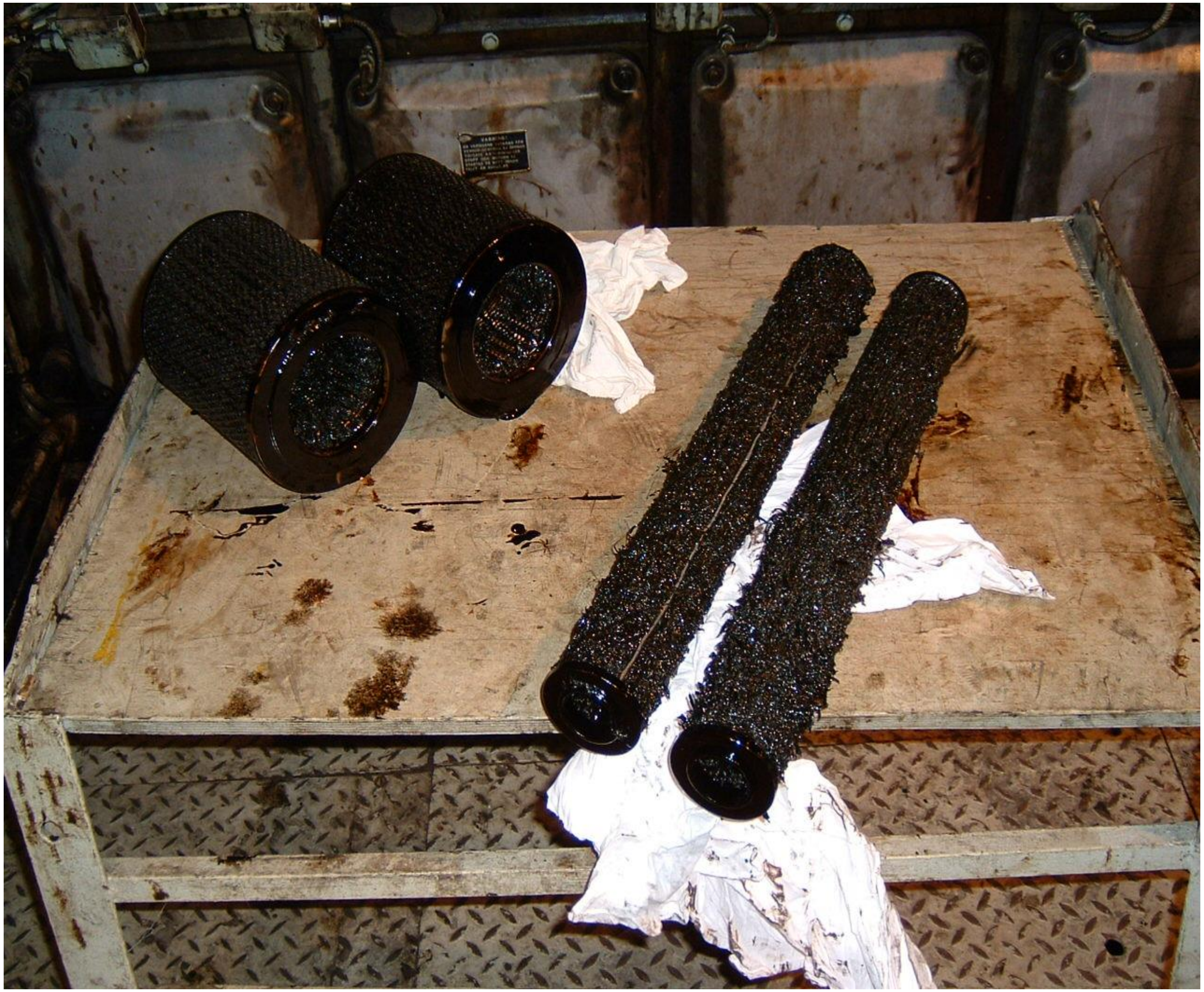
- coarse filters
- transfer pump filters
- before separator filters

POLYSTYRENE

Sludge Problems

Polystyrene…..

Polystyrene……



Polystyrene….

Tested results HSFO LSFO; MV K***

Tested Results	Units			RMG380
Density @ 15C	kg/m3	982.0	970.0	991.0
Viscosity @ 50C	mm2/s	361.0	177.2	380.0
Water	%V/V	LT 0.1	0.3	0.5
Micro Carbon Residue	%m/m	11	8	18
Sulfur	%m/m	2.36	1.41	4.50
Total Sediment Potential	%m/m	LT 0.01	0.03	0.10
Ash	%m/m	0.04	0.05	0.15
Vanadium	mg/kg	121	68	300
Sodium	mg/kg	24	53	
Aluminium	mg/kg	5	11	
Silicon	mg/kg	8	27	
Iron	mg/kg	14	22	
Nickel	mg/kg	38	25	
Calcium	mg/kg	2	15	
Magnesium	mg/kg	1	4	
Lead	mg/kg	LT 1	LT 1	
Zinc	mg/kg	LT 1	LT 1	
Phosphorus	mg/kg	LT 1	LT 1	
Potassium	mg/kg	1	6	

GCMS analysis MV A***

GC-MS analysis performed on the vacuum distillate <250°C of the sample detected monophenols and diphenols which are not normally found in residual fuels.

The types of phenols detected are listed below:

- Monophenols (Phenol, methyl phenols, dimethyl phenols and methyl-ethyl phenols)
- Diphenols (5-methylresorcinol (also known as Orcinol), dimethylresorcinol, other alkyl-substituted resorcinols)

The concentration of monophenols and diphenols in the sample was estimated to be at 0.4% and 0.2% respectively.

Apart from phenols, GC-MS analysis also detected a significant level of alkenes (estimated 0.9%) in the sample.

GCMS analysis MV A*** Notes

Monophenols, diphenols and alkenes are found in significant percentages in shale oil.

The detection of phenols in combination with alkenes in this sample, implied that shale oil could have been used as a blend stock for this lot of fuel oil.

Monophenols

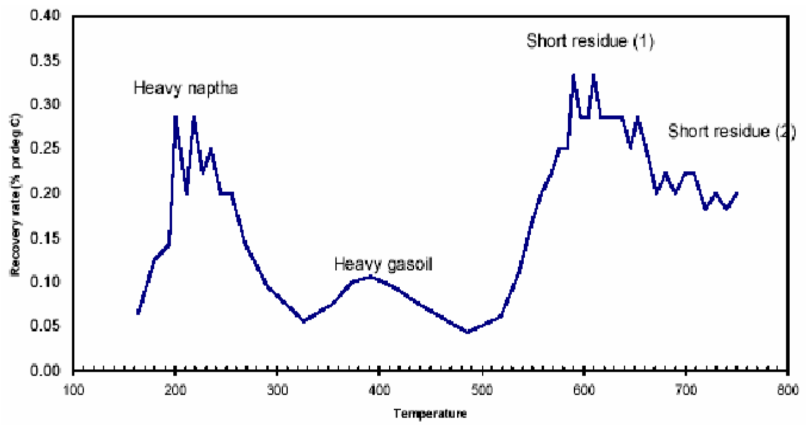
- Soluble in water
- Generally volatile
- Odor objectionable

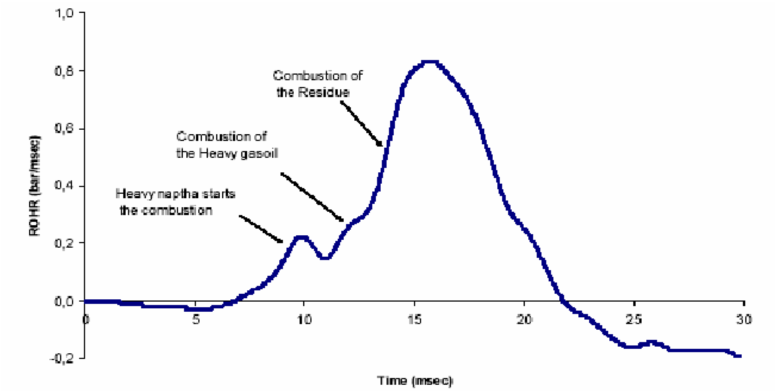
Diphenols

- Generally non-volatile.
- Relatively high melting temperature.
- E.g., melting point of 5-methylresorcinol is 108 -111°C.
    - 2,5-dimethylresorcinol is 160-164°C.
    - 5-methylresorcinol and 2,5- dimethylresorcinol exist as white crystals at ambient temperature.

Low sulphur fuel

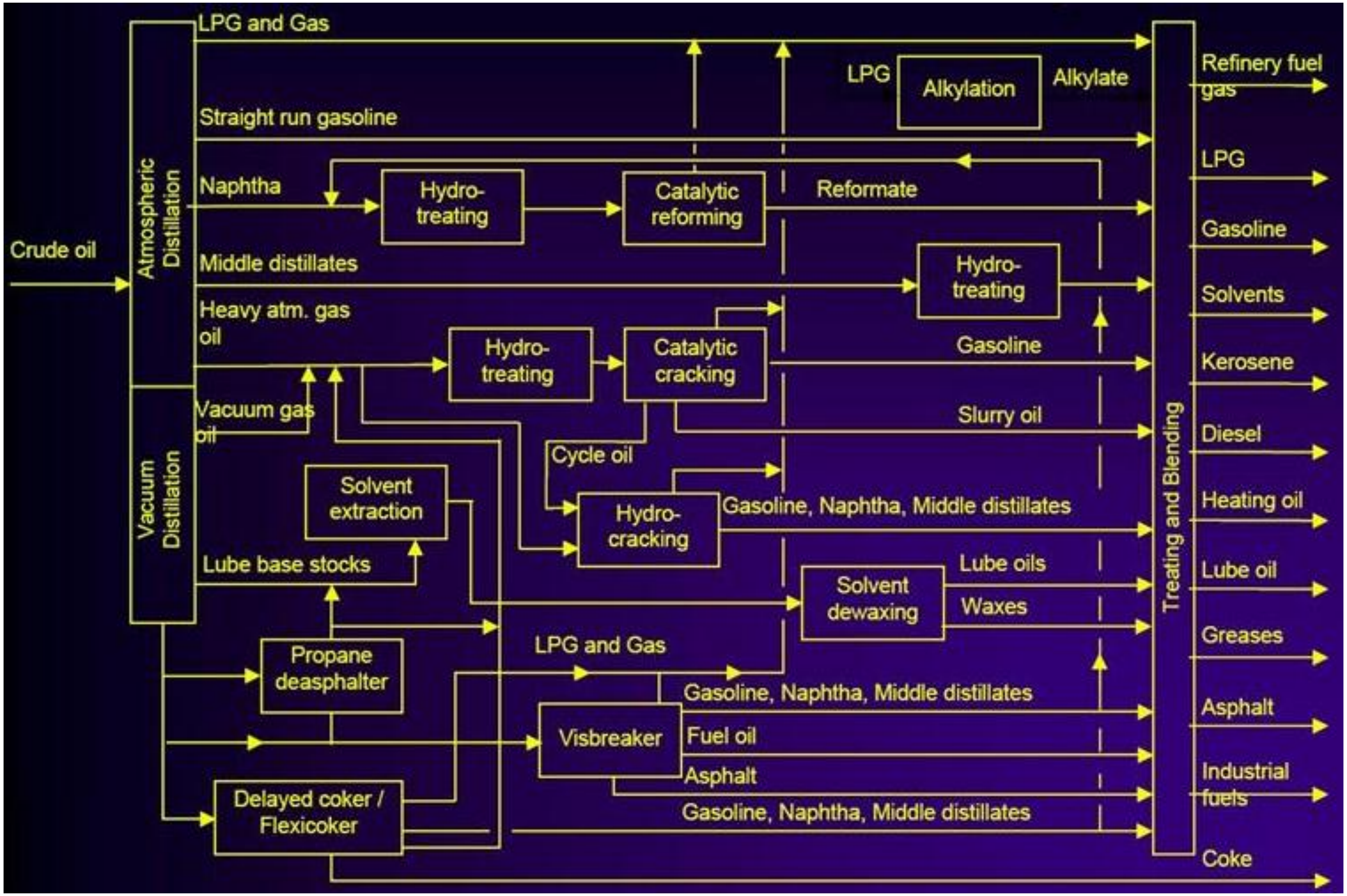
- Sweet Crude oil
- Refining - desulphurisation
- Blending – high sulphur residual fuels with low sulphur distillates



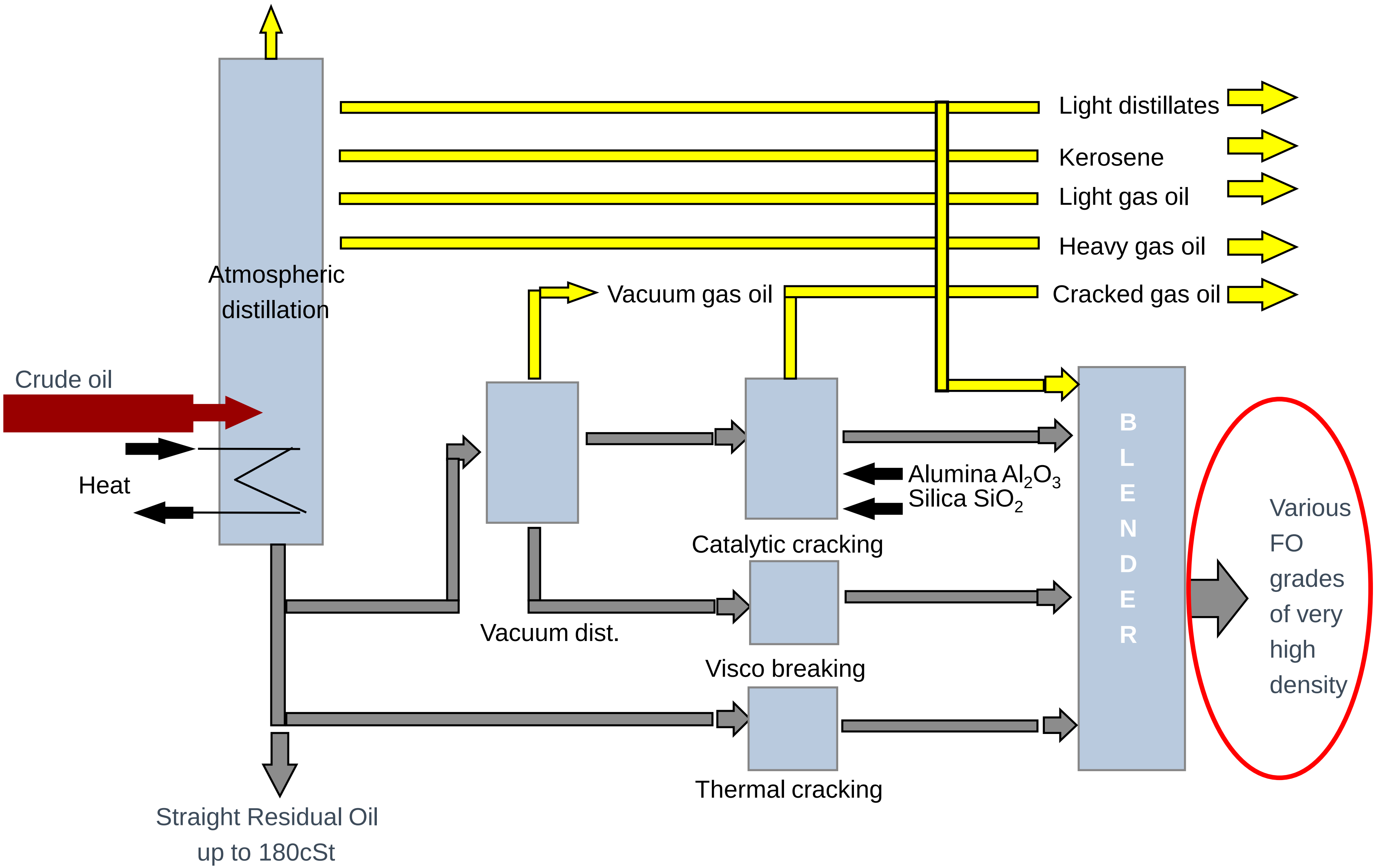


Oil Refinery Now

Compliments from DNVPS

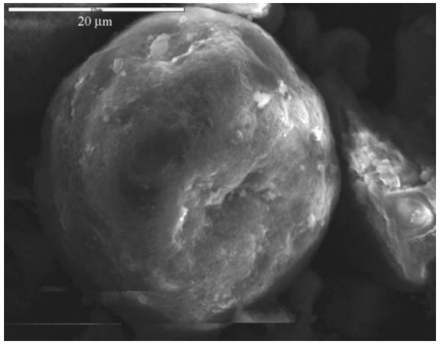


Cat fines added at the production process.



Low sulphur fuel oil
Quality problems

- Petroleum products of different origin may lead to instability in blended fuel and during mixing onboard.
- Different blends of different types of fuel can lead to additional quality problems e.g. ignition and combustion problems
- Waste streams (polypropylene/polystyrene)
- Increased cat fine levels



Lube Oil Properties related to Low Sulphur Fuels

- History Two-stroke:
  - Low sulphur fuel with high alkaline lubricants was not an issue (BN 70 CLO)
  - Excessive lubrication apparently gave no operational problems.

- Current Two-stroke:
  - Recent problems with $CaCO_3$ deposits and scuffing due to continuous low sulphur fuel operation with BN 70 CLO and high feedrate.

Lube Oil Properties related to Low Sulphur Fuels

Liner scuffing:

- Excess lube oil ($CaCO_3$ additive) not used due to lack of S (less acid to neutralise) forms hard deposits on piston crowns
- Lack of controlled corrosion – sulphuric acid adds to "holding pockets" for lube oil film (preventing bore polish)

Gas oil – impact on fuel pump lubrication

- Potential pump damages on low viscosity gas oil with low sulphur (less than 0.05% S and 2 cSt). Lubricity additives indicated as remedy by certain manufacturers
- Thermal shock in case of fast change-over
- Gassing of hot marine gas oil
- Pump leakages
- Increased ignition delay (aux engines)

Compatibility of fuels

Expected that most ships will switch from high sulphur fuel in open sea to low sulphur fuel in restricted areas

- When switching from HFO to a distillate fuel with low aromatic hydrocarbon there is a risk of incompatibility.
- The asphaltenes of the HFO are likely to precipitate as heavy sludge with clogging filters as result.
- Use of test compatibility kit on board or guarantee from fuel supplier that fuels used can be blended

Low Sulphur Fuel Benefits

- Reduced SOx emission
- Reduced vanadium content in LSFO may reduce high temperature corrosion (exh. valves) ?
- Energy content increase ?
- Reduced lube oil consumption ?

Fuel parameters
Ignition delay and combustion qualities

Methods for determination of fuel qualities:

- **CCAI / CII**
  Calculation of fuel ignition quality by use of viscosity and density

- **FIA (Fuel Ignition Analyser)**
  Ignition delay
  Combustion quality (Rate of Heat Release ROHR)

Calculated Carbon Aromaticity Index (CCAI)

- CCAI is a calculation (old formula) which used to be used as an indication of the ignition properties of a residual fuel.
- Derived by density and viscosity
- Rule of thumb:

  CCAI < 860 – Acceptable quality

Fuel parameters - CCAI / CII

- CCAI Developed by Shell

$$CCAI = \rho - 81 - 141 \cdot \log([\log(v+0{,}85)]) + 483 \cdot \log((T+273)/323)$$

- CII Developed by BP

$$CII = (270{,}95+0{,}1038 \cdot T) + 0{,}254565 \cdot \rho + 23{,}708 \cdot \log[\log(v+0{,}7)]$$

Where
T = Temperature (0C) at which the viscosity is determined
v = Kinematic viscosity (mm^2/s)
ρ = Density at 15^0C (kg/m^3)

Engine Makers used CCAI as Guideline

CCAI – Nomogram – Major engine maker

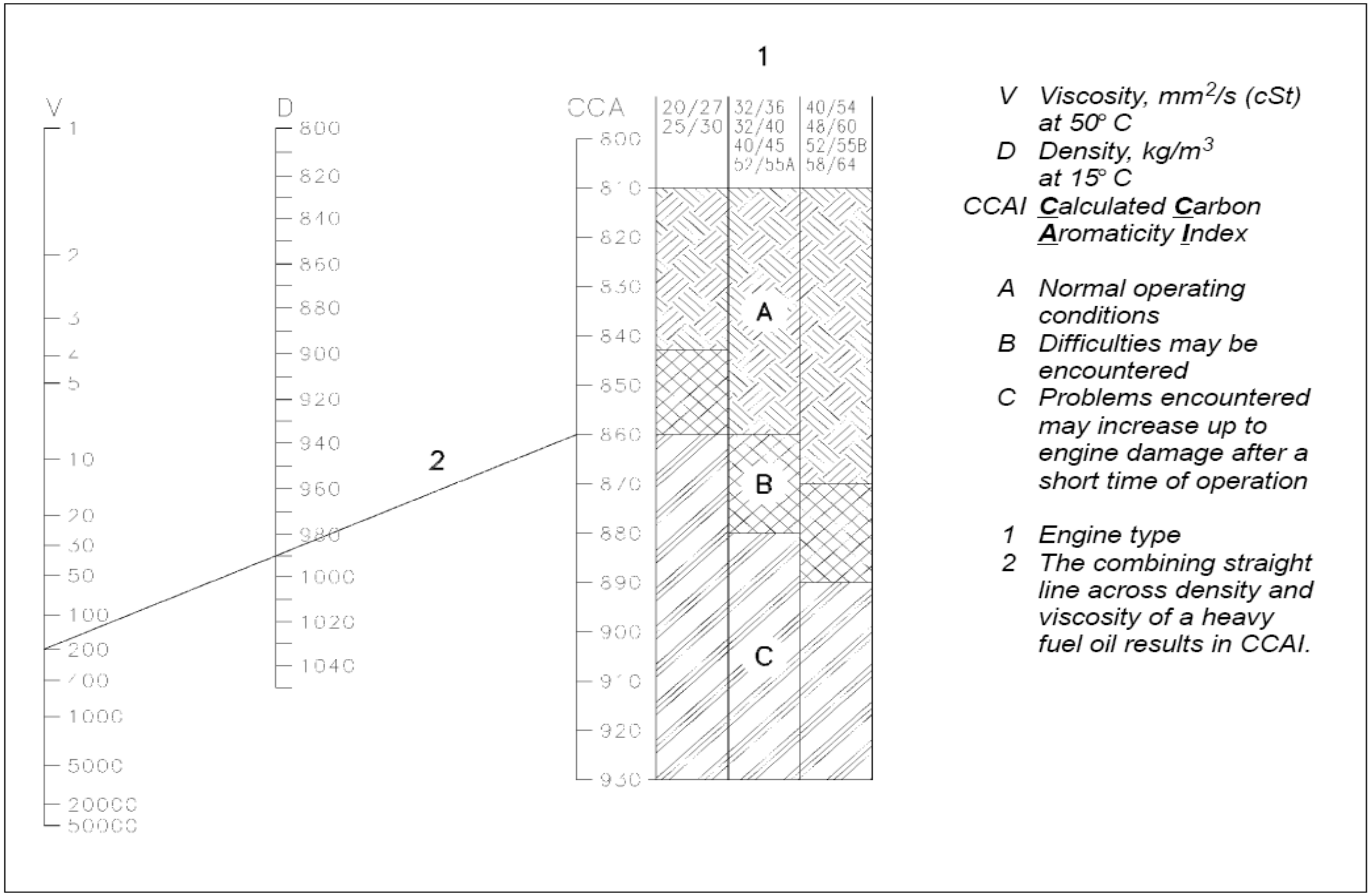


Figure 2. Nomogram for the determination of CCAI (suitable for heavy fuel oil viscosities ≥ 180 mm2/s at 50° C) – Assignment of CCAI ranges to engine types

Compliments from DNVPS

Fuel parameters - CCAI

Fuel No	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Units
Viscosity	3.8	84	85	141	198	255	470	520	560	690	710	800	1200	50,000	-	cSt/50°C
Density	968	995	970	993	938	977	985	983	1,010	1,008	1,030	935	998	1,040	1.01	kg/m³ at 15°C
Flash point	98	84	80	103	100	106	90	95	90	79	84	>40	80	>60	>70	°C
Conradson Carbon	0.3	17.2	12.1	13.3	9.4	14.5	16.8	14.8	17.3	22.1	24.7	9.4	14,1	24.2	11.7	% weight
Asphalt	0.78	15.1	8.9	9.2	3.7	10.0	11.3	12.8	14.6	19.3	29.0	1.02	12	-	-	% weight
Sulphur	0.10	2.72	1.16	0.91	0.83	0.87	0.90	1.18	2.22	3.52	3.30	0.37	4	4.8	2.8	% weight
Water	0.01	0.01	0.01	0.00	0.01	0.02	0.02	0.01	0.00	0.00	0.00	-	0,65	0.05	-	% weight
Ash	0.00	0.065	0.025	0.03	0.03	0.025	0.03	0.035	0.04	0.07	0.09	0.043	-	0.035	0.18	% weight
Aluminium	-	-	-	-	-	-	-	-	-	-	-	-	12	2.0	1	mg/kg
Vanadium	0	220	20	23	12	17	24	45	122	300	370	415	312	149	-	mg/kg
Sodium	0	27	23	24	25	40	35	22	22	24	50	9	-	-	-	mg/kg
CCAI	912	874	849	866	807	843	844	841	868	864	885	-	-	-	-	-

FIA-100/3 & FIA-100 FCA

Standard test method IP 541/06 Developed by Energy Institute

Compliments from DNVPS

FIA-100/3 & FIA-100 FCA - Differences

FIA 100/3
(Fuel Ignition Analyzer)

- FIA: Originally developed to measure Ignition
- Quality of Residual fuel
- Calibration down to CN=18.7

FIA-100 FCA
(Fuel Combustion Analyzer)

- Based on gathered experience. Improved
- Determination and interpretation of ignition quality
- In addition: **Combustion Properties!**
- Calibration down to **ECN=5**
- FIA-100 FCA utilizes the approved **IP 541/06** test method

FIA-100 FCA - Working Principle

Fuel is injected (x25) into warm and compressed air

- 45 bar
- 500 C

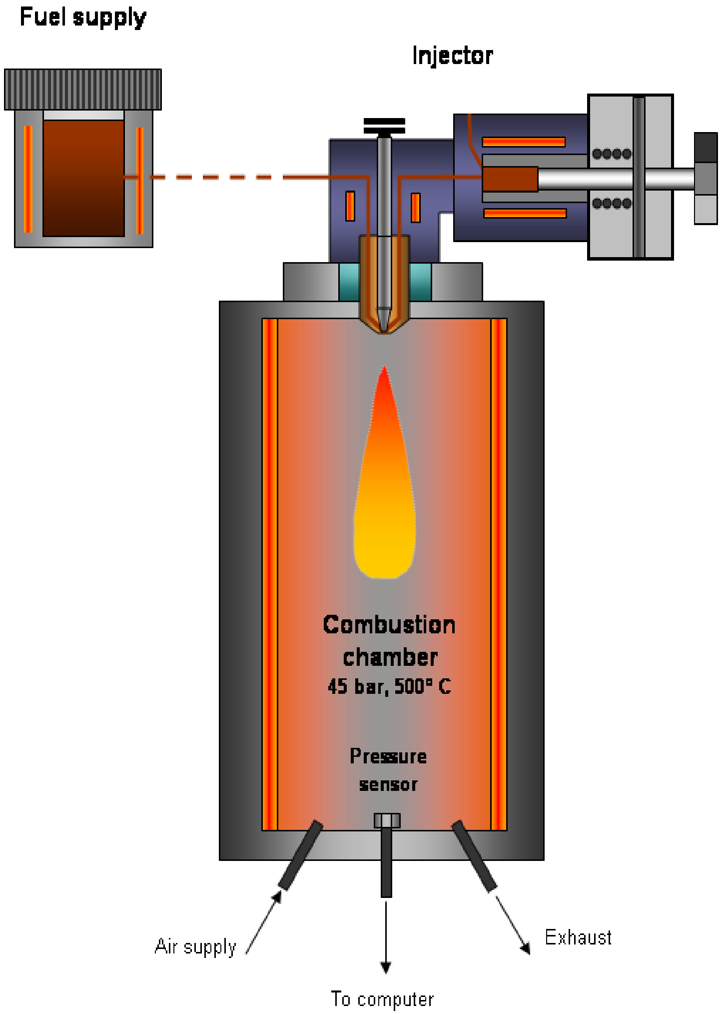
Self-ignition of the fuel

Pressure increase in the combustion chamber

The pressure change are measured and stored

Following parameters are measured/ calculated

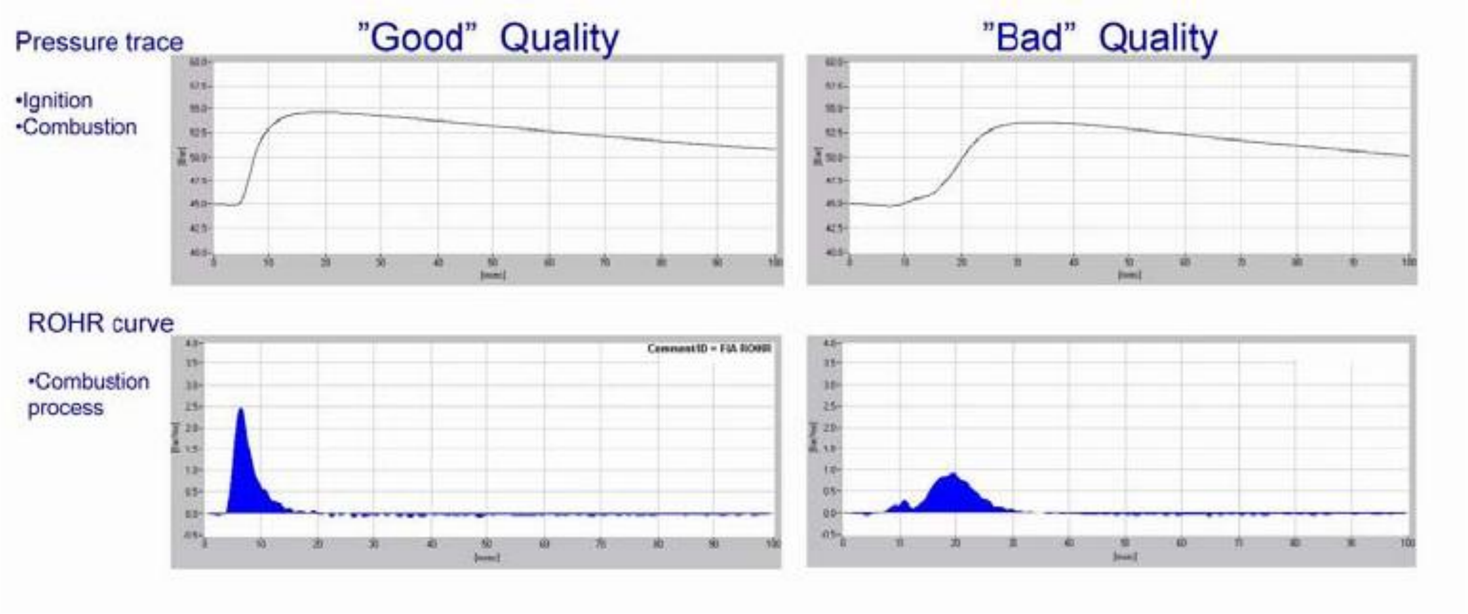
- Start of Main Combustion →
  Estimated Cetane Number ECN
- Combustion Period
- Rate of Heat Release etc..



Standard test method IP 541/06

Compliments from DNVPS

FIA test result (example)



Compliments from DNVPS

Ignition delay in engine

- Injected into a combustion chamber of 30-170 bar and 575-725^{0}C
- Injection continues after ignition
- Physical ignition delay
  - Oil moving through the fuel valve
  - Injection
- Chemical ignition delay
  - Self ignition
  - Combustion starts
- Physical ignition delay is 10 x chemical ignition delay
- The total ignition delay is typically 0.5 – 3 msec

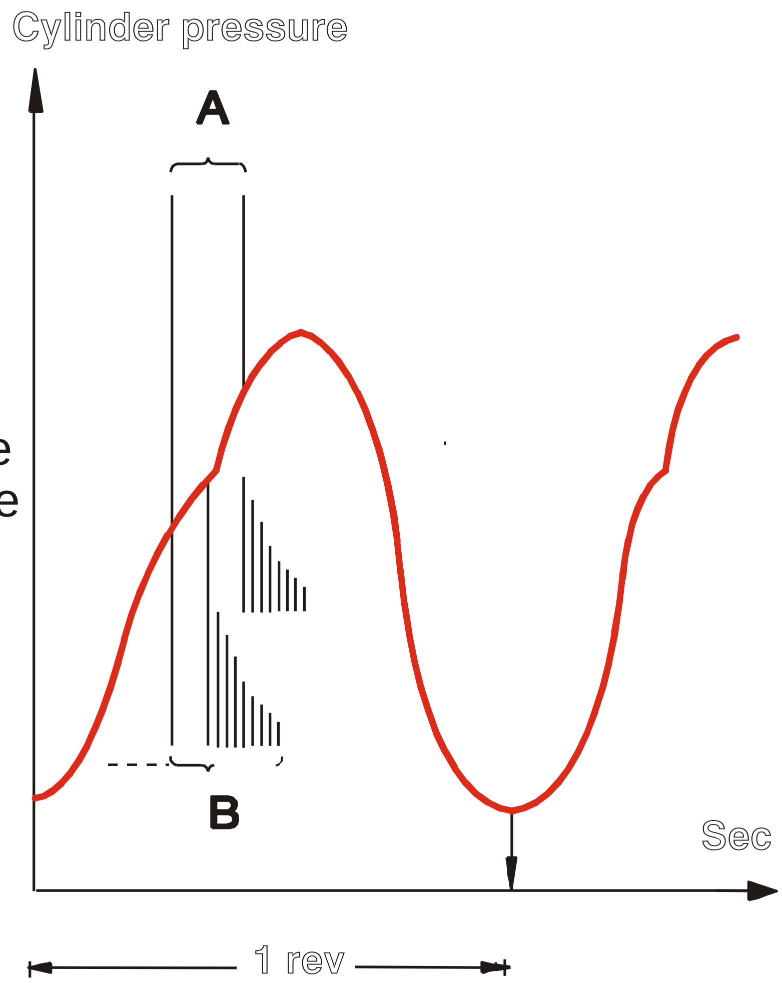
Fuel Acceptance

Low speed (two-stroke)
60/103.4 = 0.58 sec/rev

Medium speed (four-stroke)
60/600 = 0.10 sec/rev

A: Fuel injection period
(~22 deg. crankshaft) ~35 msec for two-stroke
~ 9 msec for four-stroke

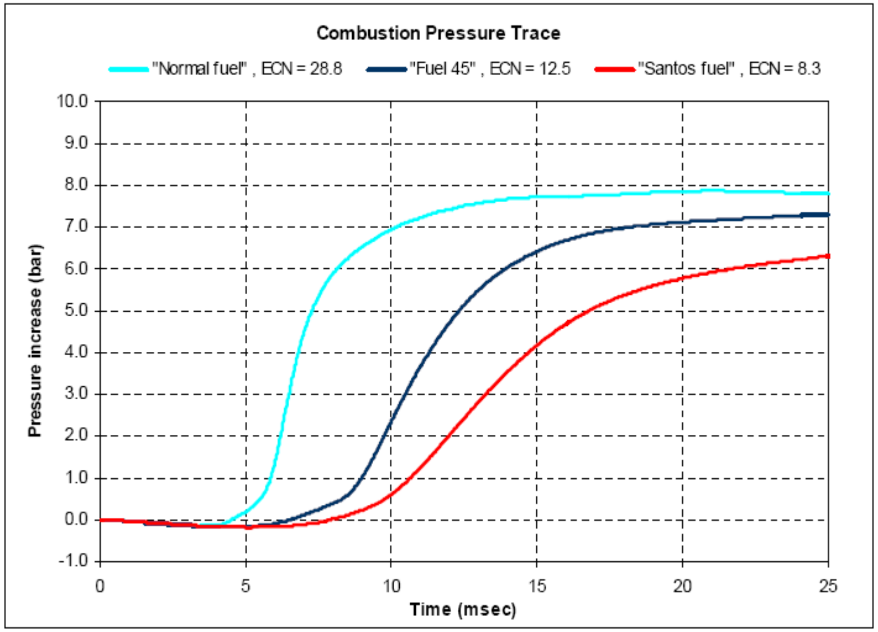
B: Possible max ignition delay
~20 msec for two-stroke and four-stroke
In medium speed engines all fuel can be injected before ignition i.e. detonation may occur if delay due to fuel quality is large.



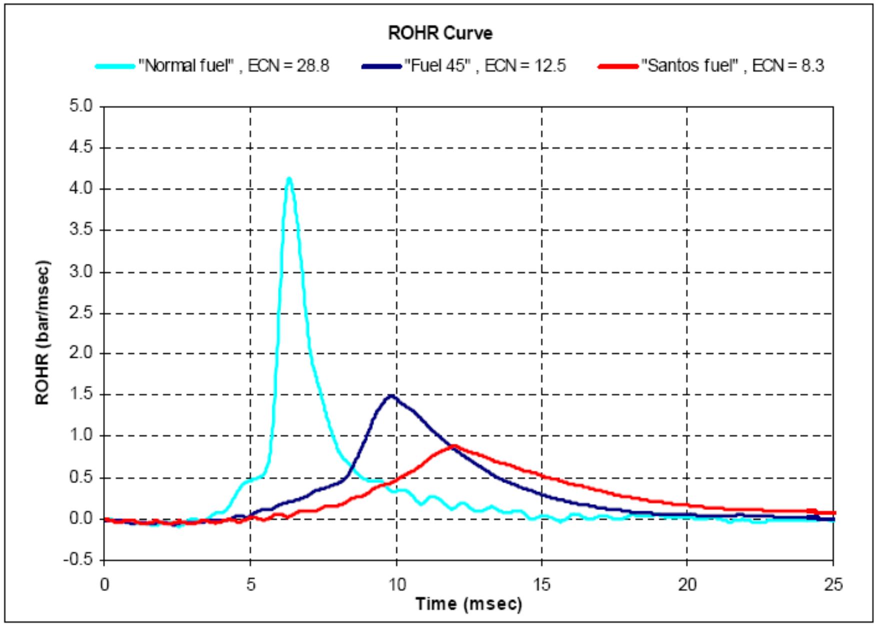
Constant volume spray combustion chamber:

- **Tinit = 800K,**
- **Pinit = 45bar**

Pressure trace



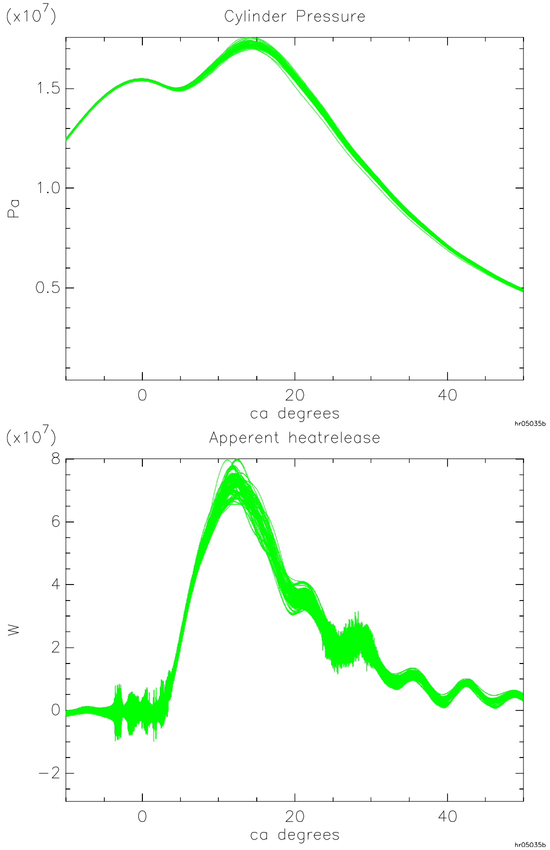
Heat release rate



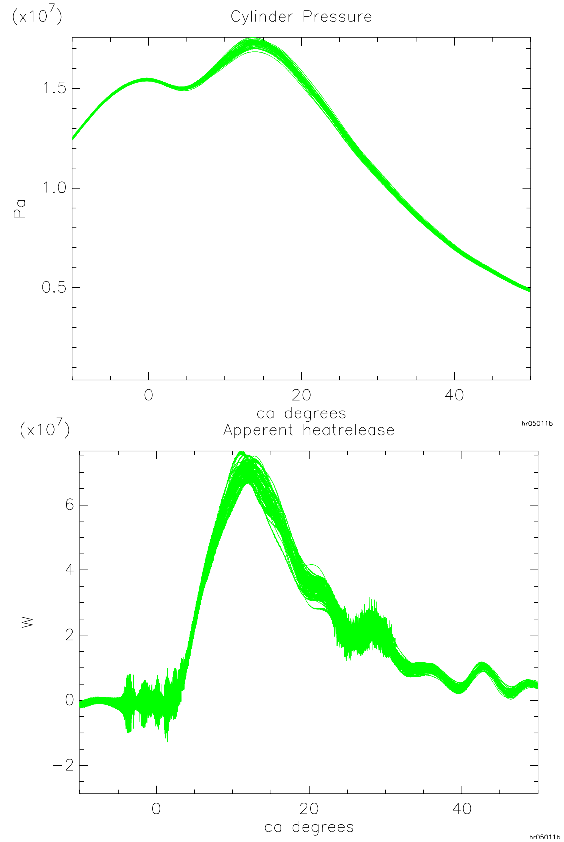
Measurement of ignition delay on the 4T50MX test engine

Direct comparison of fuels, 100 % engine load

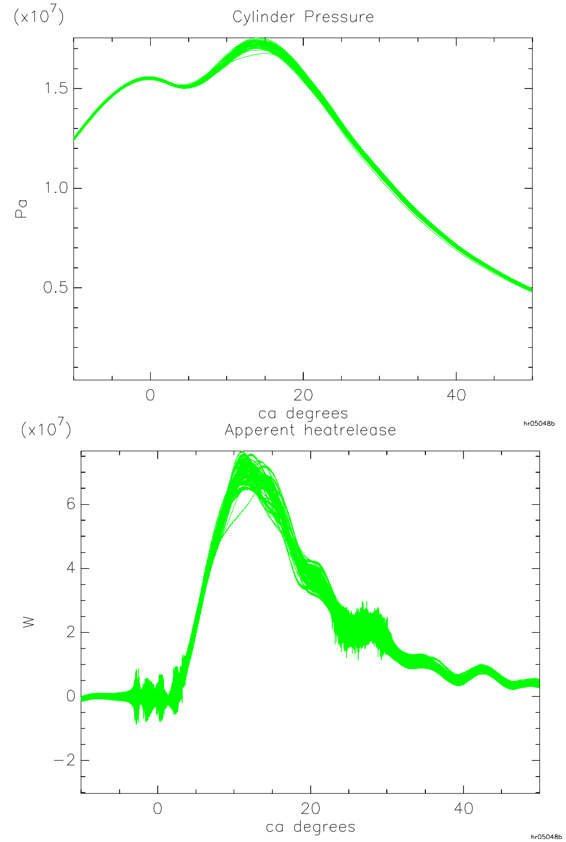
- Diesel



- HFO



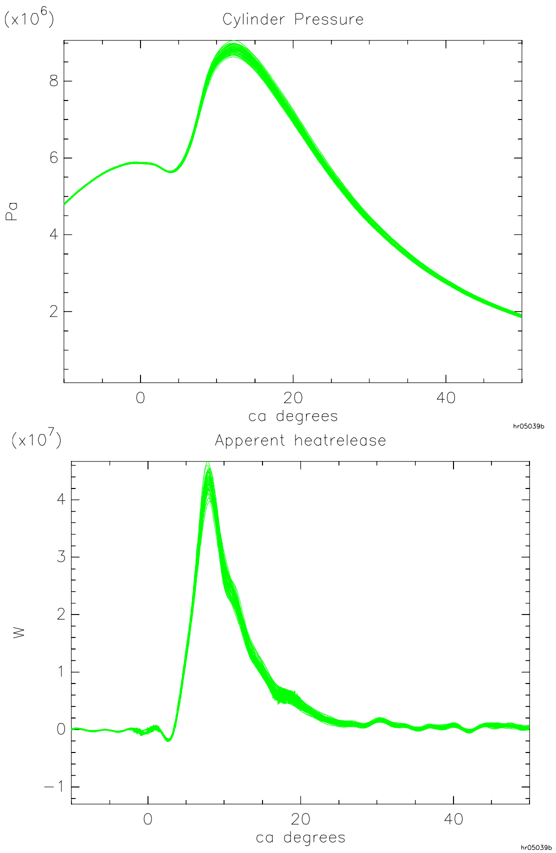
- Santos



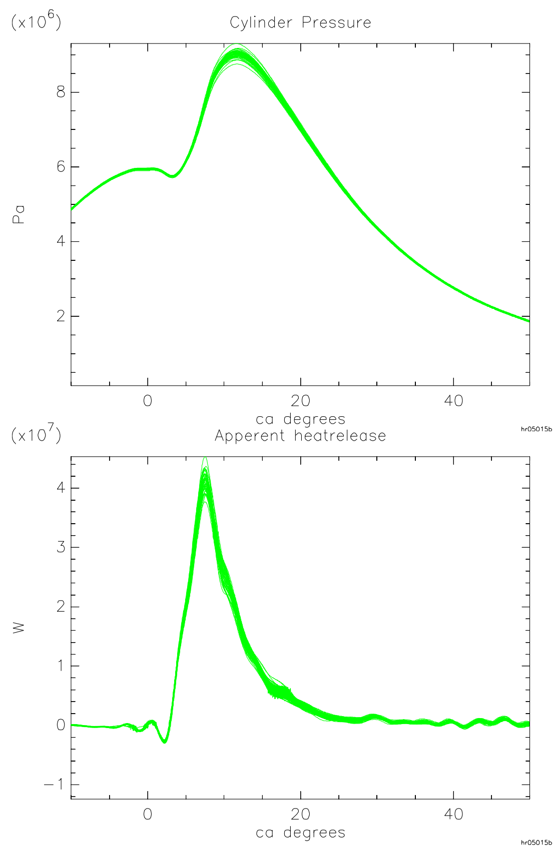
Measurement of ignition delay on the 4T50MX test engine

Direct comparison of fuels, 25 % engine load

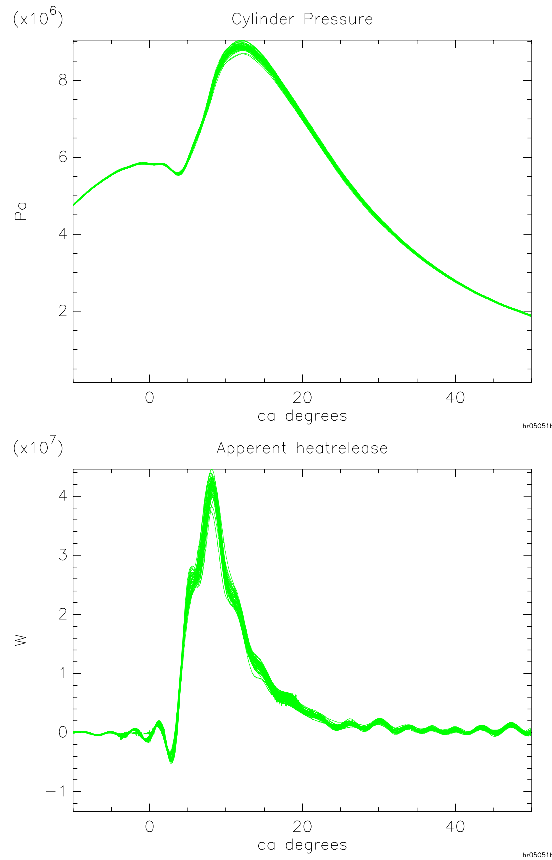
- Diesel



- HFO

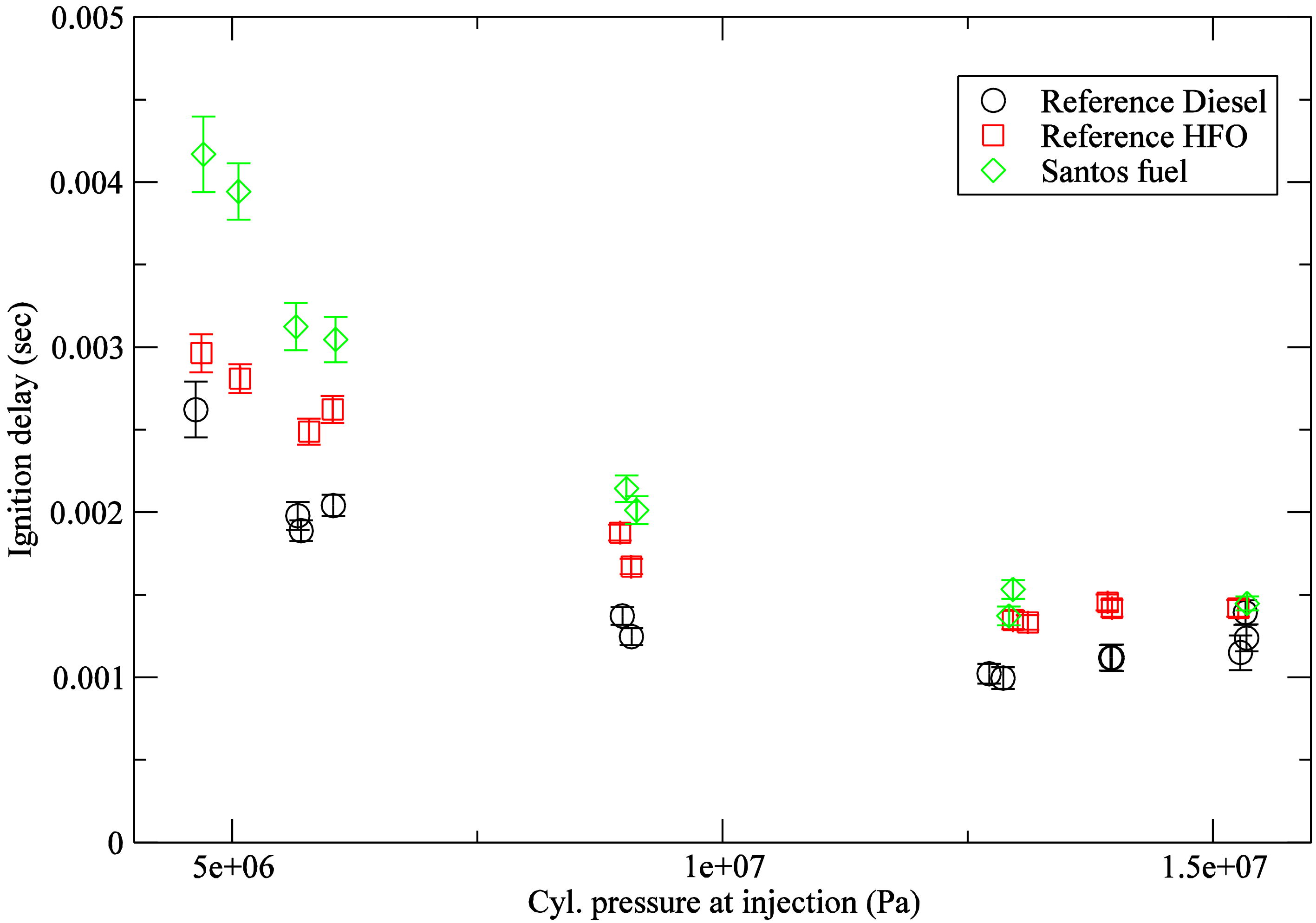


- Santos



Measurement of ignition delay on the 4T50MX test engine

Ignition delay vs. cylinder pressure



Conclusion:

None of the existing methods to evaluate fuel combustion quality can be used for MBD two-stroke engines!

The FIA can be used for evaluating combustion quality on four-stroke engines – especially at low load.

Case Story - FIA

- A vessel trading across the pacific suffered from high wear / scuffing after 9000hrs.
- Occasionally bunkered low sulphur fuel from South America with FIA CN < 18.7
- Engine manufacturer recommended to increase cylinder oil feed rate as they claimed the poor combustion qualities as well as ’faulty running-in of component”

  MBD recommended to lower cylinder oil feed rate to handle the low sulphur fuel.
- Owner followed engine builders recommendation and the scuffing incidents continued

Case Story - FIA

- As the problem continued the engine manufacturer stopped answering inquiries from the owner who instead turned to MBD again.
- Once more we recommended to lower cylinder oil feed rate, however, the owner was afraid to do so due to FIA CN < 18.7.
- We convinced the owner to lower cylinder oil feed rate to match the low sulphur fuel.
- This was July 2003. We have not heard from the owner (about this ship) since.

Fuel parameters - Cat fines

Origin

- By-product from the catalytic cracking process in the refinery
- Catalyst consists of complex crystalline particles containing aluminium silicate
- Catalyst fines result from catalyst particles breaking into smaller particles
- Catalyst is expensive, i.e. refiners minimise loss but not 100%

Fuel parameters - Cat fines

Specification

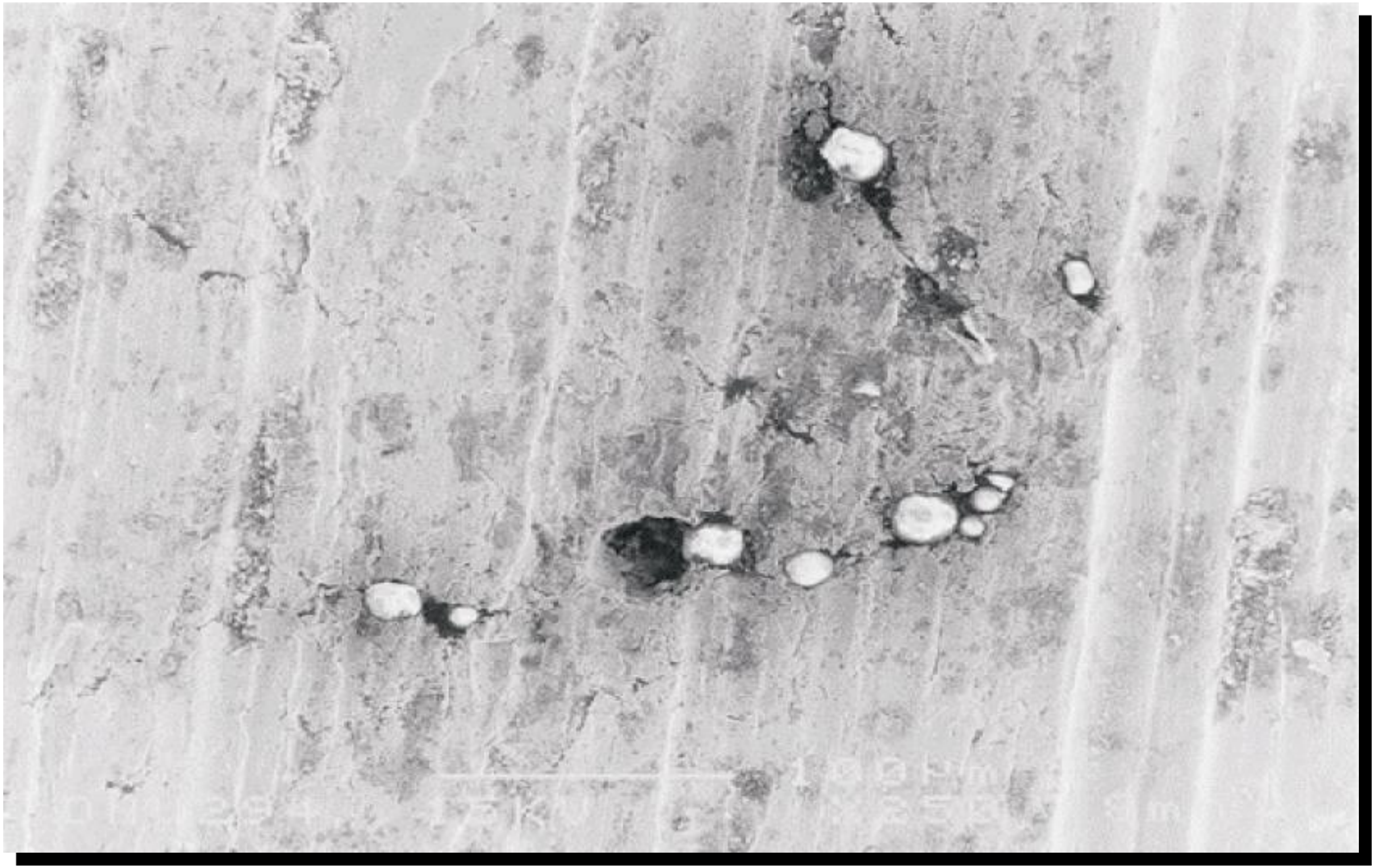
- Variable in size ranging from sub microic to about 30 microns – even seen larger
- Frequently considered spherical but this is not necessarily the case
- Hard particles
- Hardness not directly related to relative hardness of Al or Si
- Can cause abrasive wear

- ISO 8217 specifies the catalyst fines by Al and Si
- ISO 8217 limit is 80 mg/kg Al+Si for marine residual fuels

Note: ISO 8217 limit is for bunker not at engine inlet

Cat fines in 50µ automatic filter

Cat fines pressed into piston ring surface



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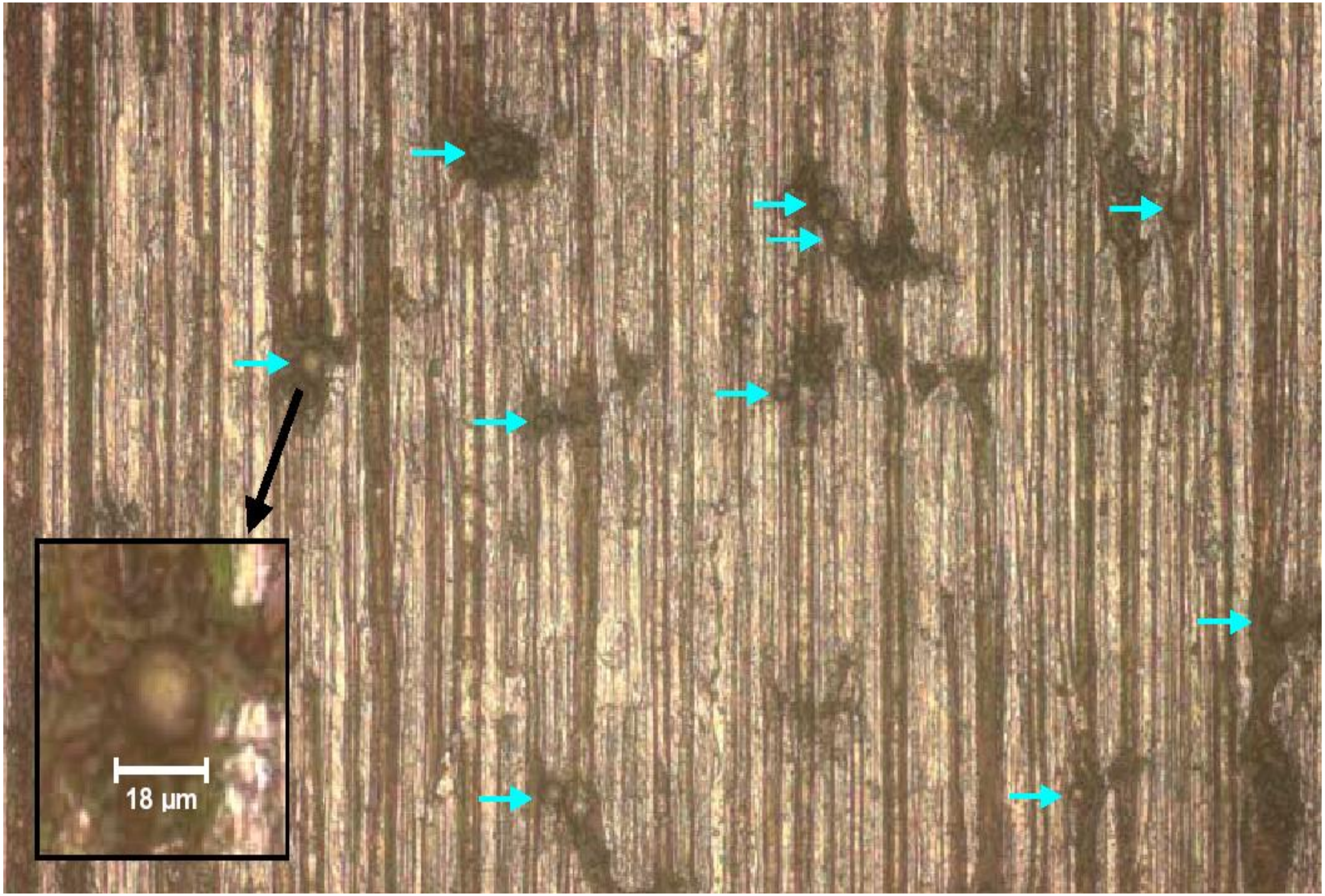
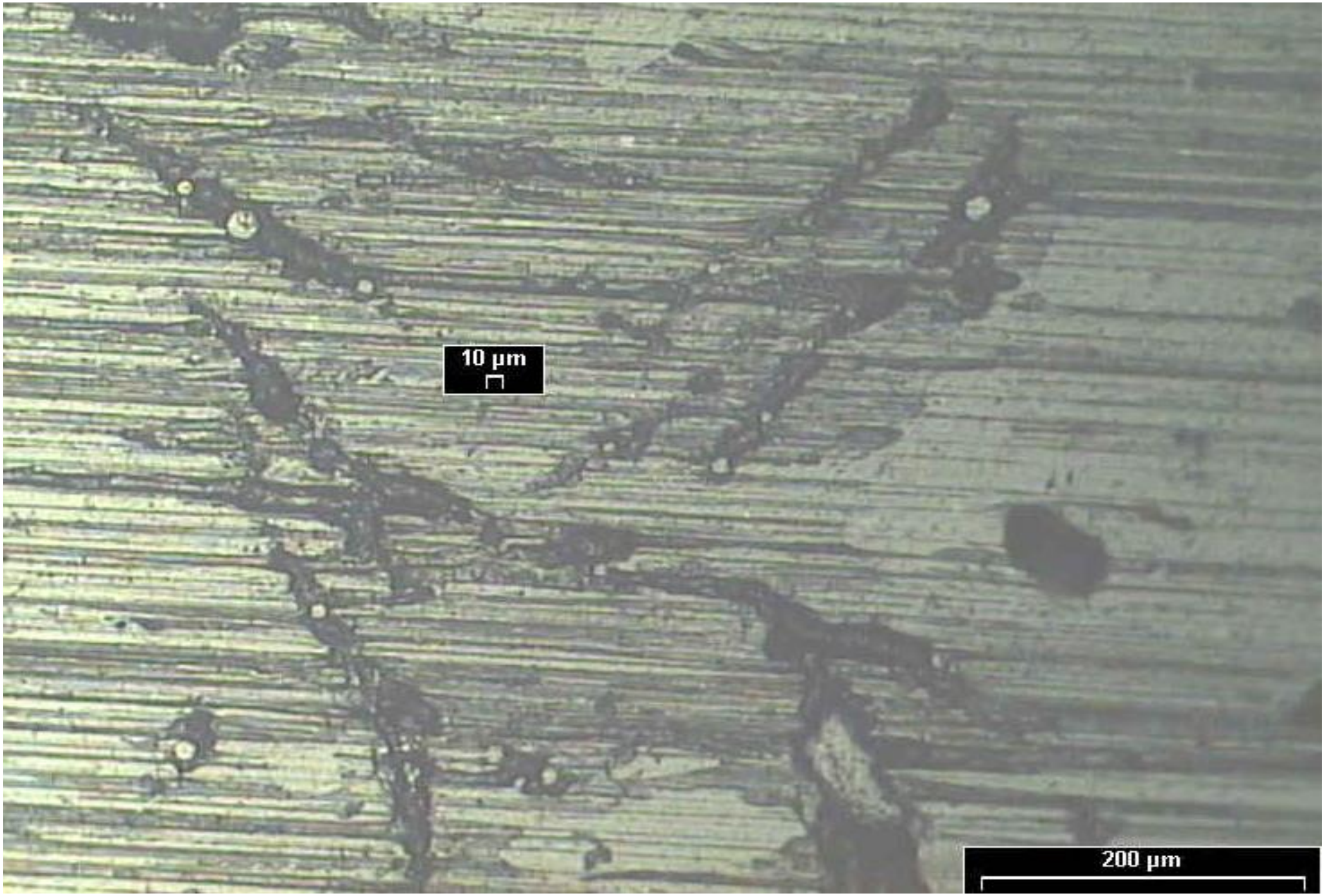
Cat fines in piston ring running surface



Cylinder liner surface



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Fuel parameters - Cat fines

Reduction

- Gravitational settling
- Centrifuge

Note: Homogenisers will not reduce the amount of catalyst fines but might instead break them into even smaller particles

Cat fines – centrifuge operation

- Overhaul and maintenance intervals must be kept according to manufacturers recommendation

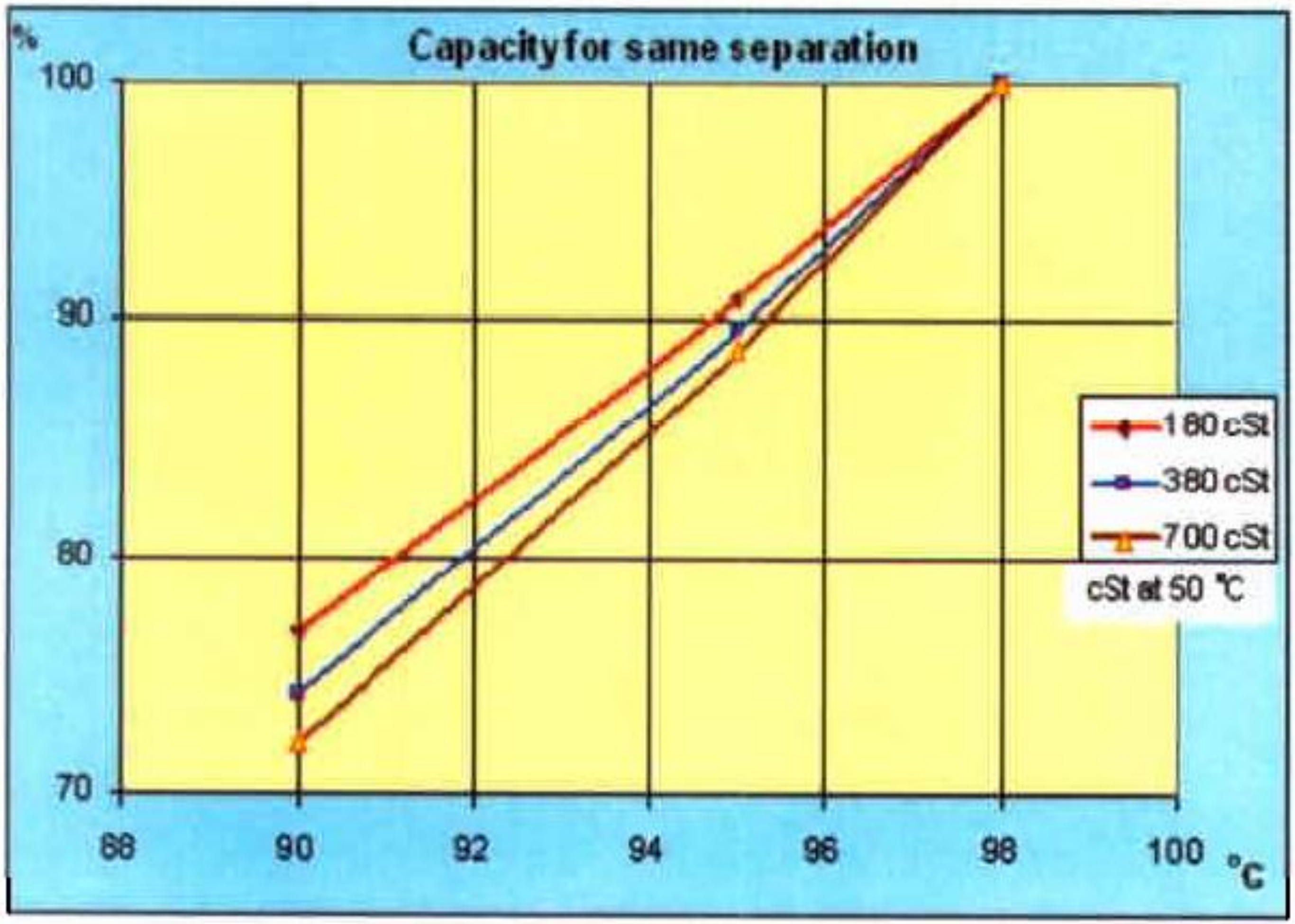
- Temperature control very important

The higher the temperature the better the separation efficiency. Both density and viscosity of the oil decrease when the temperature rises, thereby increasing the settling velocity (Stoke's law)

If the separation temperature is lowered from 98ºC to 90ºC the separator throughput has to be reduced by 25-30% to maintain the same separation efficiency!!

Centrifuge efficiency

Relationship between throughput and temperature:



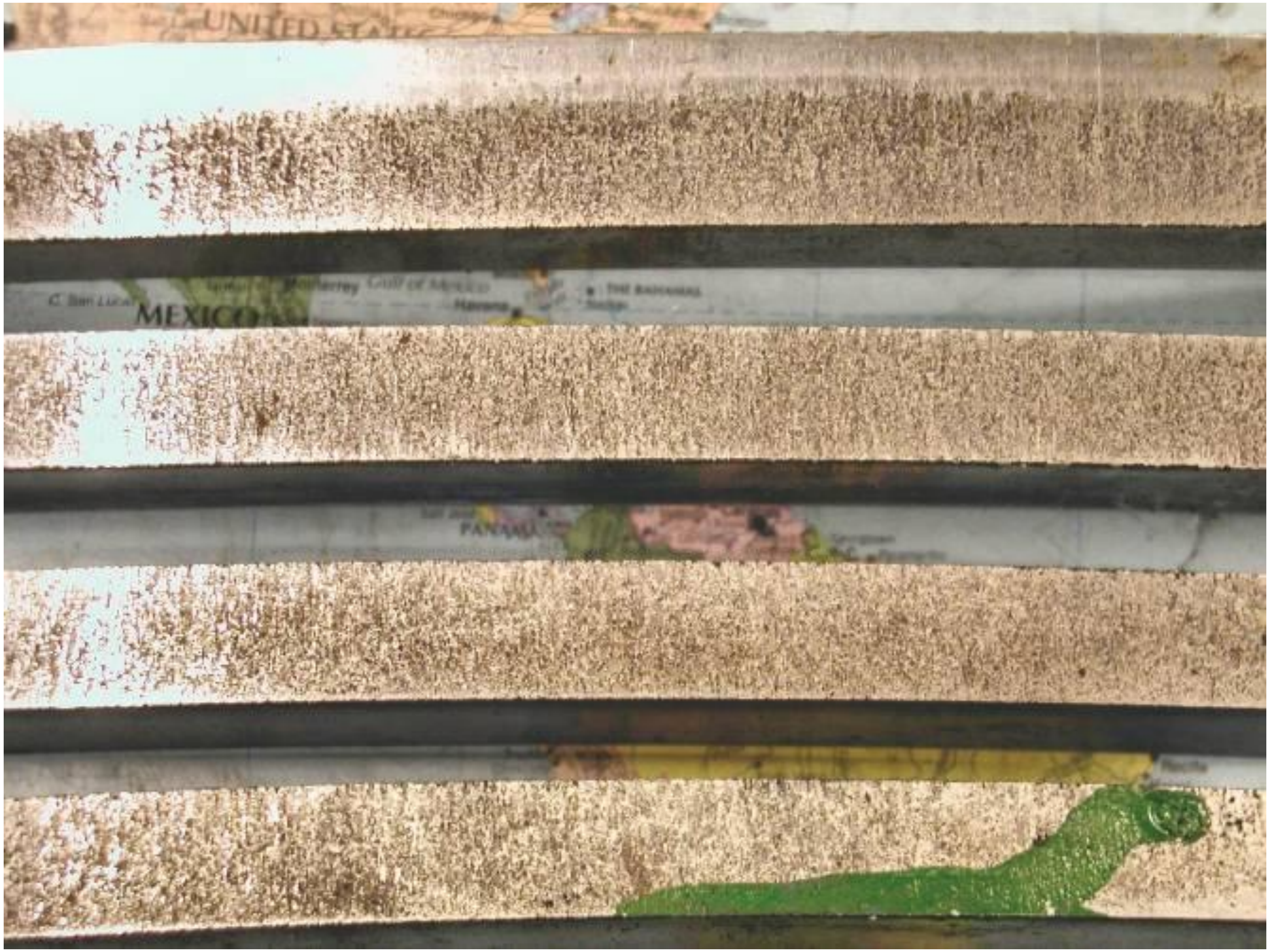
Cat fines

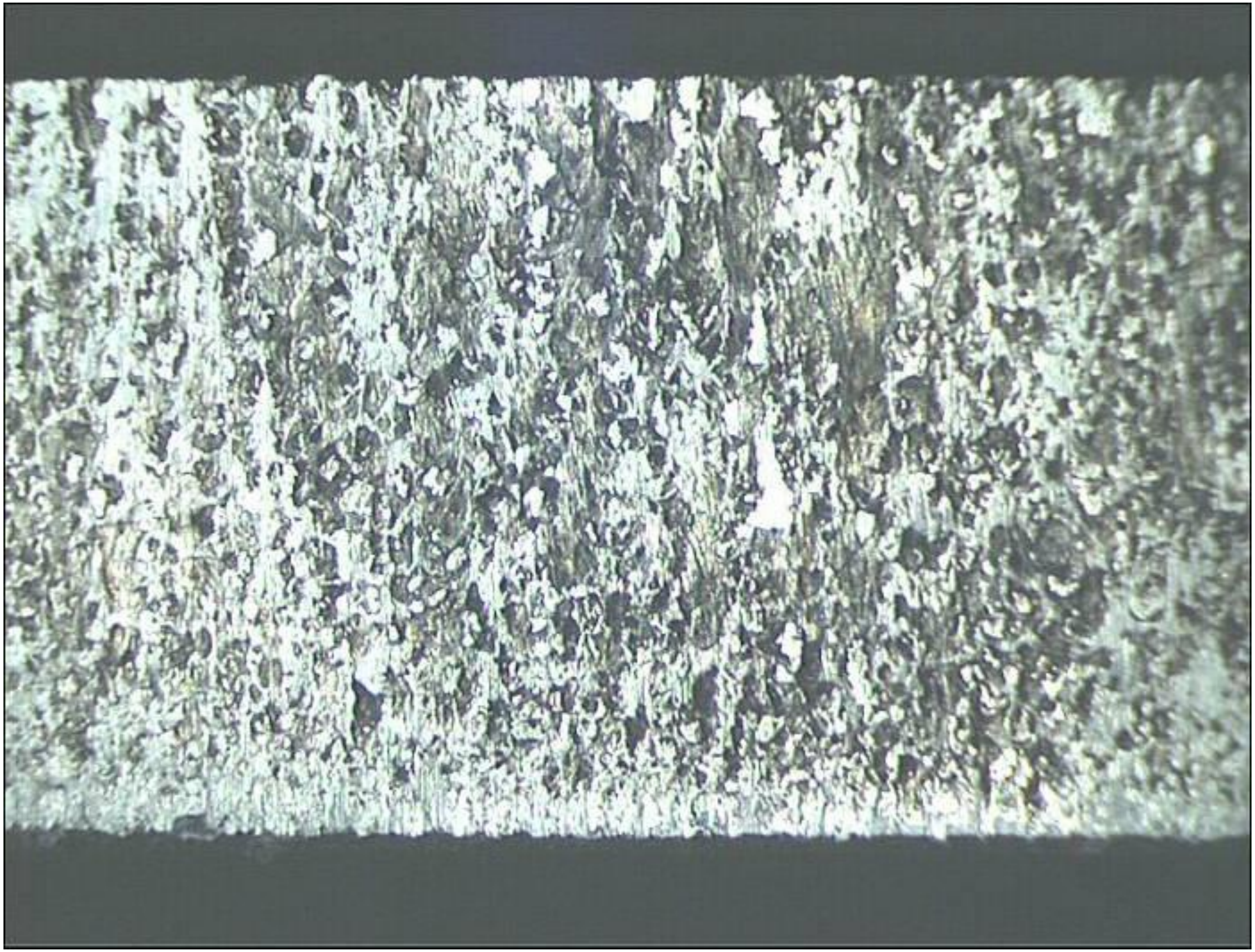
High Cat. Fines – No Proper Household

To evaluate the situation:

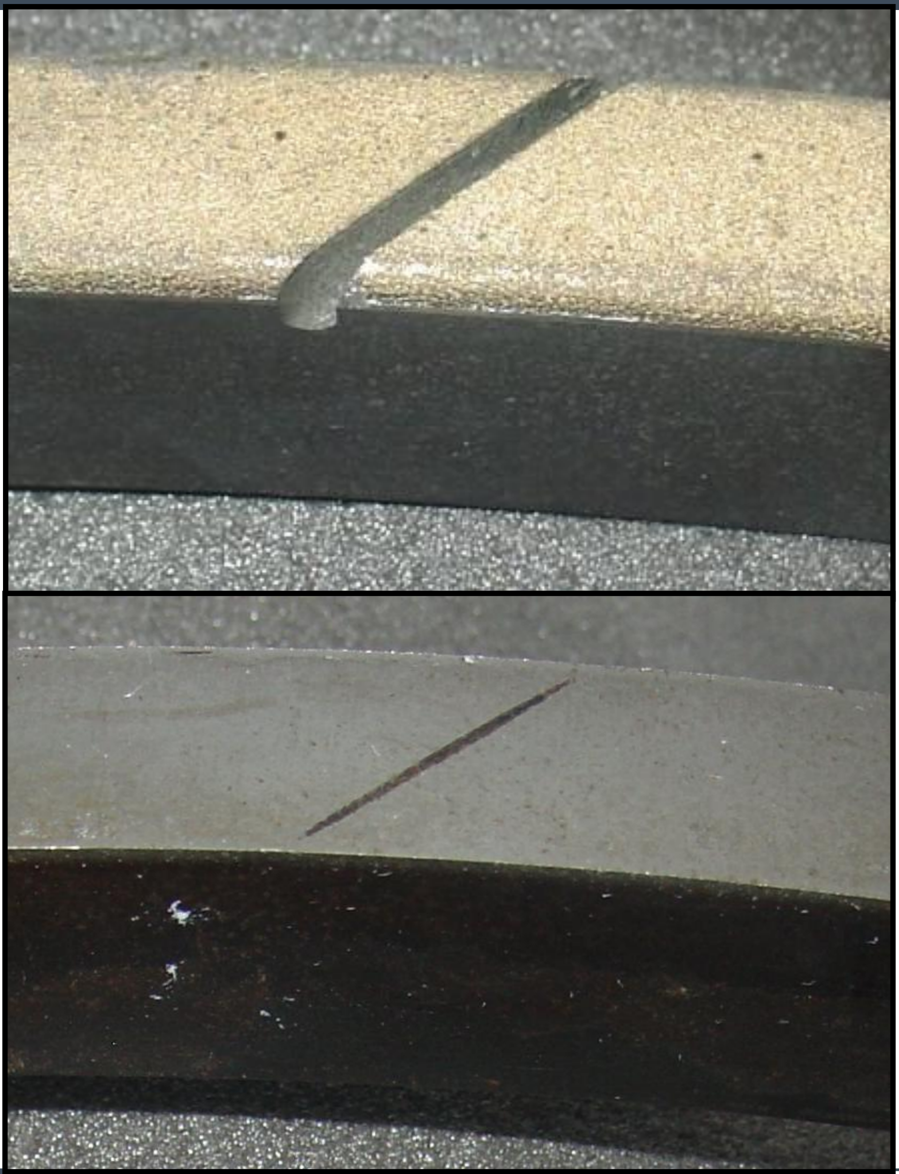
- **Damage to engine:**

  Scuffing ring pack


MEXICO
Havana
PANAMA



ABRASIVE WEAR



Problem

Cat fines in fuel:

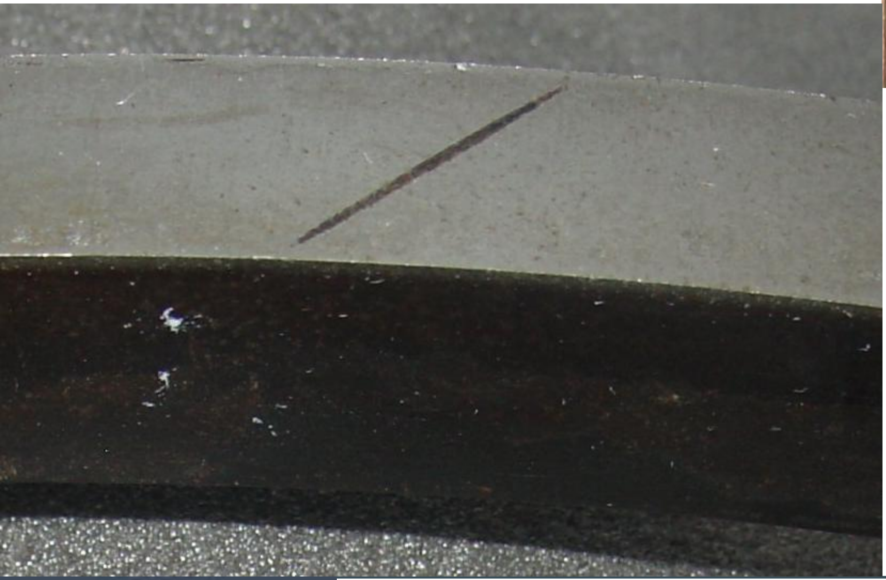
Severe wear of liners

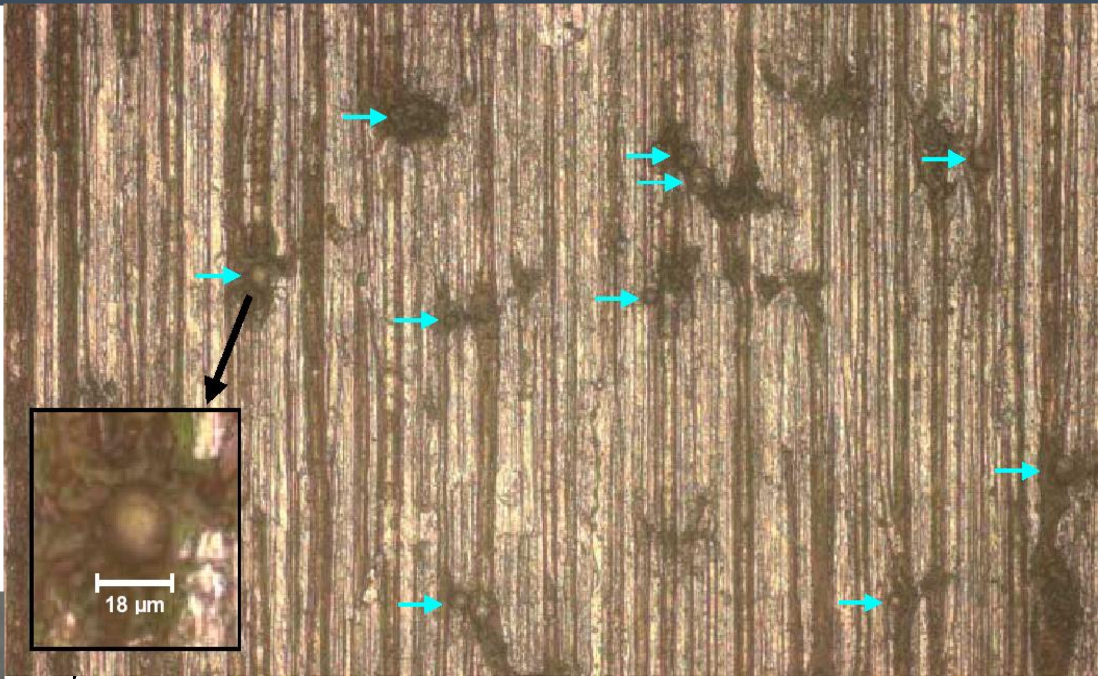
Severe wear of rings

Wear out of CL-grooves

Scuffing

ABRASIVE WEAR





Cat-fines embedded in piston ring running surface

Cat fines

High Cat. Fines – No Proper Household

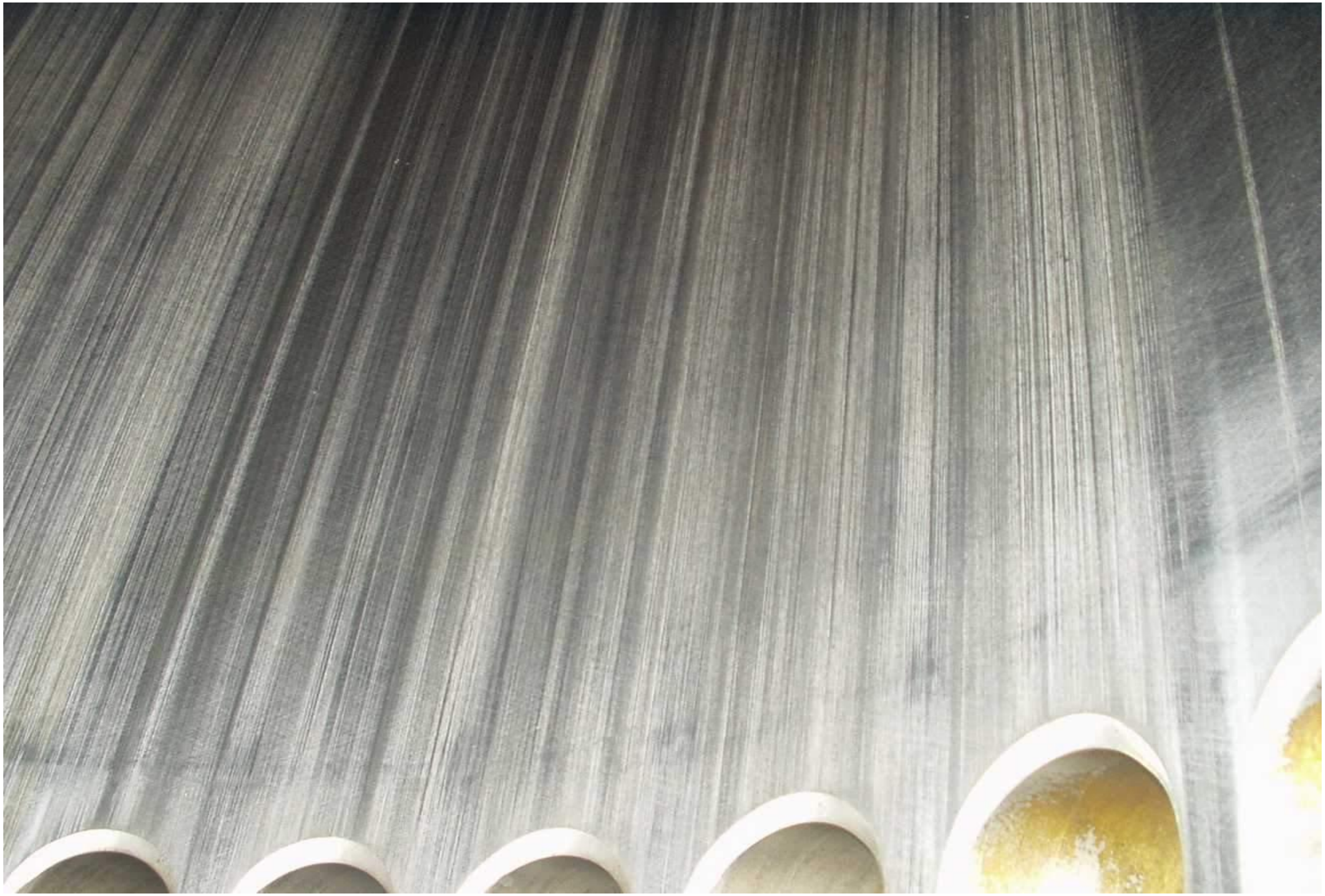
To evaluate the situation:

- **Damage to engine:**

  Scuffing ring pack

  Scuffing liner

Scuffed cyl liner.



Scuffed piston rings due to Cat fines

Cat fines

High Cat. Fines – No Proper Household

To evaluate the situation:

- **Damage to engine:**

  Scuffing ring pack

  Scuffing liner

  Injection equipment

ABRASIVE WEAR

Fuel Valve Complete (Plate 90910-0141)

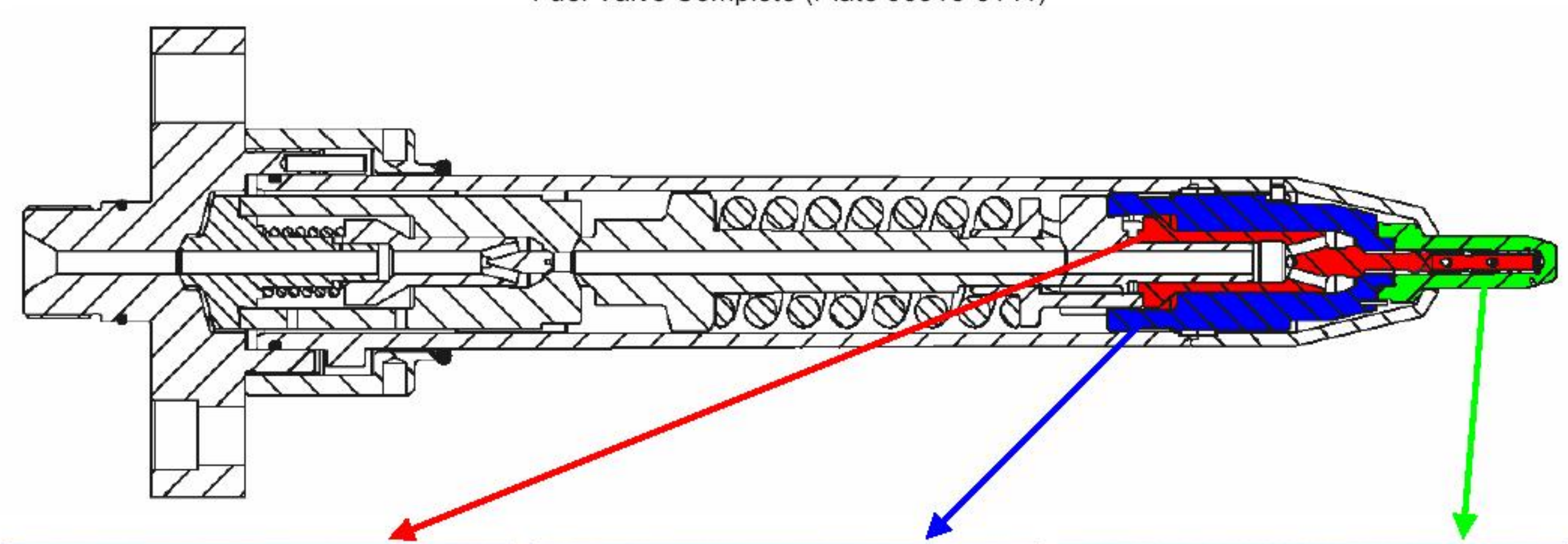
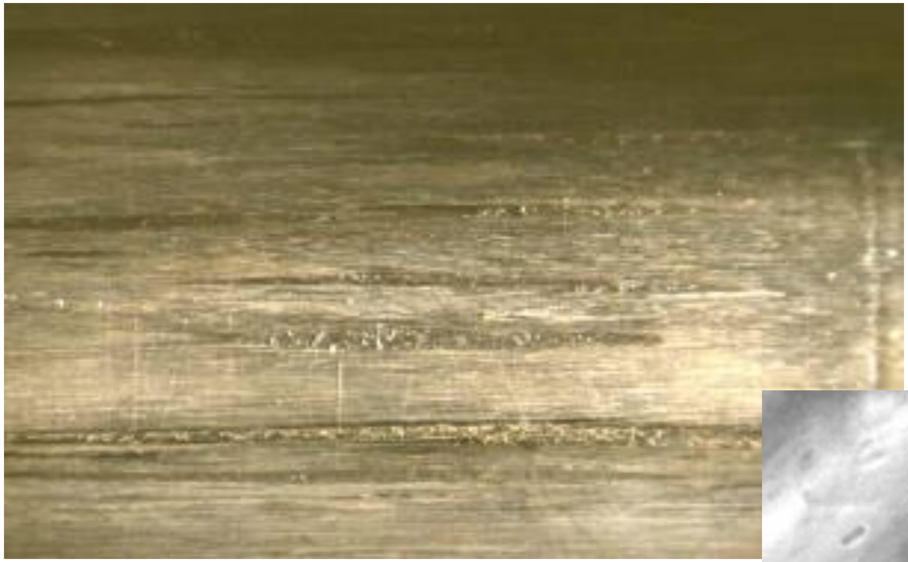


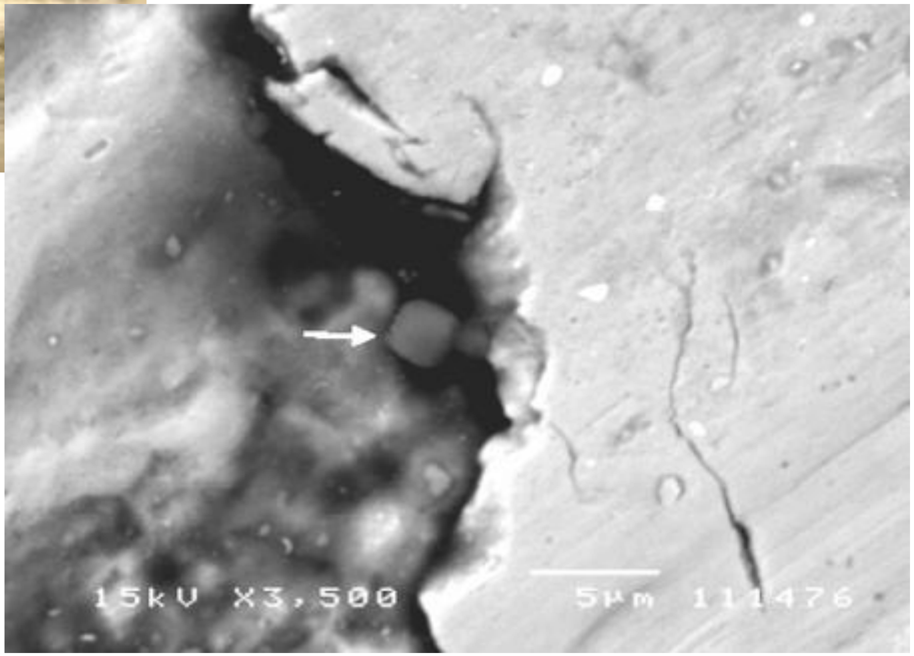
Fig.1 Cut-off shaft

Fig.2 Spindle guide (cut open)

Fig.3 Fuel nozzles

Fuel pump spindle guide scuffing





Cat fines

High Cat. Fines – No Proper Household

To evaluate the situation:

- **Damage to engine:**

  Scuffing ring pack

  Scuffing liner

  Injection equipment

- **Investigation made:**

  Cyl. feed rate

  HFO cleaning

  Lube oil

  Component materials

  Operational profiles

Conclusion:

Investigations to find the reason are time-consuming and expensive

Cat fines - Case Story

Dec 1998:	Sea Trial on 6S42MC
Feb-Mar 1999:	Sticking fuel pumps. Plunger/barrel replaced
May-June 2000:	All piston rings and two piston crowns replaced
Aug-Oct 2000:	Piston rings and crowns replaced on 4 cylinders, 1 liner replaced
June 2001:	All liners and piston rings replaced
	PC rings fitted on all cylinders
June 2002:	# 2 liner wear: 4.45mm, i.e. 0.63/1000hr (liner hrs: 7060)
July 2002:	# 6 liner wear: 0.67mm, i.e. 0.11/1000hr (liner hrs: 6133)
	# 5 liner replaced – test parts installed
Nov 2002:	# 3 liner wear: 1.73mm, i.e. 0.22/1000hr (liner hrs: 7722)
	# 4 liner wear: 1.05mm, i.e. 0.13/1000hr (liner hrs: 7757)
	# 1 liner wear: 1.14mm, i.e. 0.14/1000hr (liner hrs: 7783)

Cat fines – Case story

Feb 2003:	# 5 liner wear: 1.18mm, i.e. 0.49/1000hr (liner hrs: 2400)
	# 3 liner wear: 1.81mm, i.e. 0.20/1000hr (liner hrs: 9105)
Apr 2003:	# 6 liner wear: 2.97mm, i.e. 0.30/1000hr (liner hrs: 9894)
May 2003:	# 4 liner wear: 2.98mm, i.e. 0.28/1000hr (liner hrs: 2627)
Sep 2003:	All liners, piston rings and crowns replaced Centrifuges overhauled – **temperature controller found broken.**
Sep 2004:	Follow-up inspection on cylinder condition. As of June 2004 no reports of poor cylinder condition

Cat fines – case story

Feb 2003: Fuel monitoring starts

Each set consists of 3 samples

In total: 15 sets of fuel and drain oil samples ship #1

7 sets of fuel samples ship #2

Cat fines – case story

Ship #1

Date	Sampling point	Al	Si	Water
2003-02-19	Before purifier	<5	<5	<0.05
	After purifier	<5	<5	<0.05
	Before engine	<5	<5	<0.05
2003-05-15	Before purifier	<5	<5	<0.05
	After purifier	<5	<5	<0.05
	Before engine	<5	<5	<0.05
2003-05-28	Before purifier	19	18	0.09
	After purifier	19	19	0.08
	Before engine	19	15	0.11
2003-06-16	Before purifier	6	<5	0.19
	After purifier	5	<5	<0.05
	Before engine	<5	<5	<0.05
2003-08-01	Before purifier	5	<5	0.07
	After purifier	<5	<5	0.06
	Before engine	<5	<5	0.06
2003-08-15	Before purifier	5	5	0.18
	After purifier	<5	<5	0.13
	Before engine	5	<5	0.11
2003-10-06	Before purifier	4	18	0.1
	After purifier	1	1	<0.05
	Before engine	1	2	<0.05
2003-11-03	Before purifier	6	<5	<0.05
	After purifier	6	<5	<0.05
	Before engine	<5	<5	<0.05
2003-12-03	Before purifier	6	<5	<0.05
	After purifier	<5	<5	<0.05
	Before engine	<5	<5	0.07
2003-12-28	Before purifier	<5	<5	0.19
	After purifier	<5	<5	0.16
	Before engine	<5	<5	0.16

Cat fines – case story

Conclusions

- Cat fines and insolubles not reduced before centrifuges overhaul
- Cat fines and insolubles reduced after centrifuge overhaul

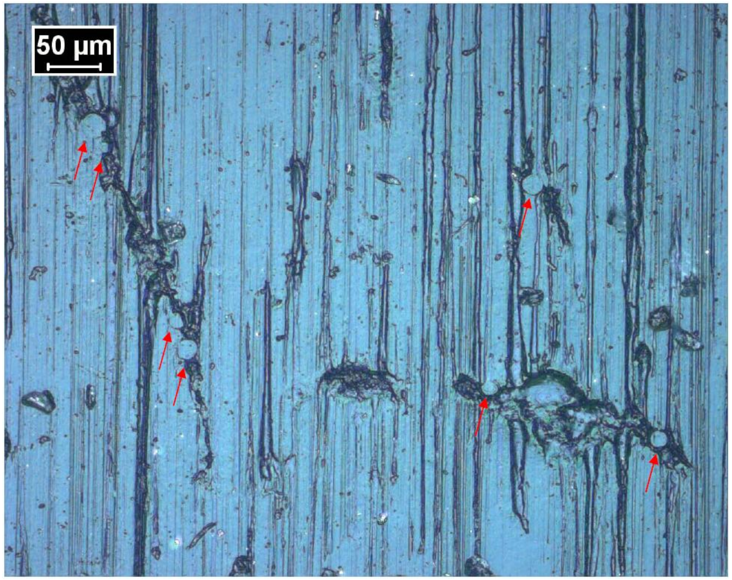
- Poor cylinder condition due to malfunctioning centrifuges
  and a few cat fines!

Cat fines – Case story 2

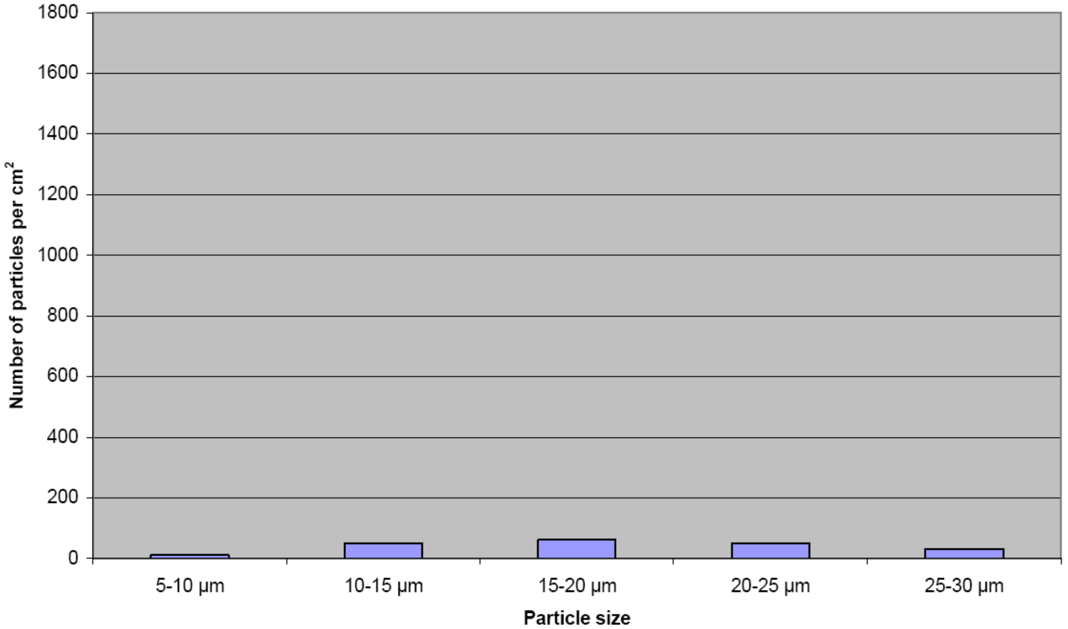
- An engine was completely worn out after the maidenvoyage from Europe to America (1000 engine hours)
- After having replaced the piston rings in LA (no liners available), the engine went back to Europe. Upon arrival in Europe, the piston rings were worn out.
- Replicas from the liner showed cat fines embedded in the liner surface

- No cat fines was found in the fuel samples
- Only one fuel was not represented in the samples, namely, the fuel filled in the engine for the sea trial
- The purifier temperature, flow etc were according to specification

Cat fines – Case story 2

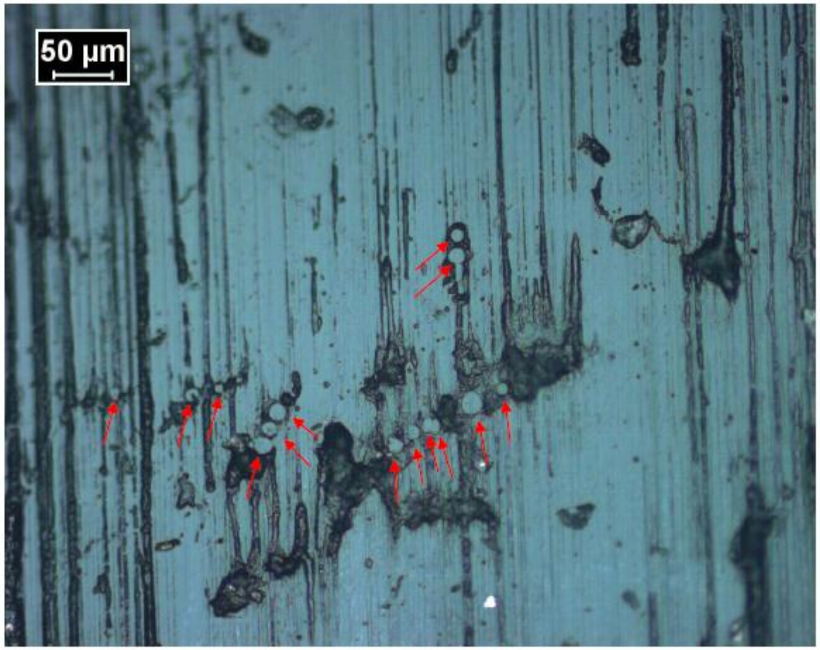


Cat fines in running surface, liner #1

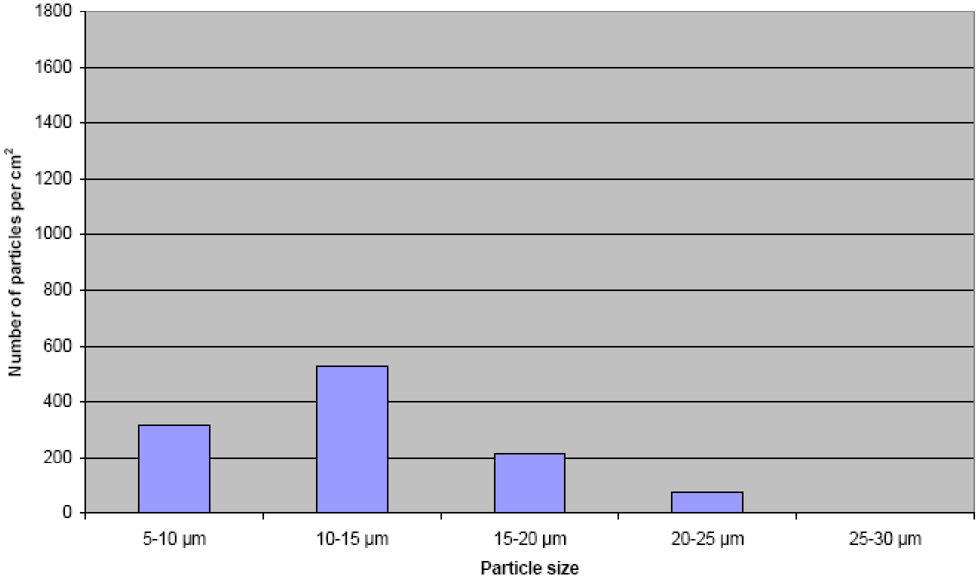


Cat fines countings on the running surface of cylinder liner from unit #1

Cat fines – Case story 2



Cat fines in the running surface of cylinder liner from unit #4



Cat fines countings on the running surface of cylinder liner from unit #4

Cat fines – Case Story 2

Conclusion:

- The fuel filled in the tanks from the yard was contaminated by cat fines. Possibly due to low level (settled cat fines) in the yard's tank
- Cat fines entered the engine – perhaps the purifier was not operating according to specification during sea trial
- These cat fines extended the engine wear significantly
- As the liners were not replaced in LA, the cat fines stayed in the liner surface the wore the newly installed piston rings out

- Cat fines related wear may last for a long time when first in the engine has been contaminated

Homogenisers

Homogeniser manufacturers claim:

Homogenisers can reduce purifier sludge amount by installing a homogeniser before the centrifuge. Also, it is claimed that the homogeniser improves combustion.

Homogeniser said to make particles smaller and keep asphaltenes dissolved in fuel.

MBD comment:

BUT – then particles, water etc. enter the engine.

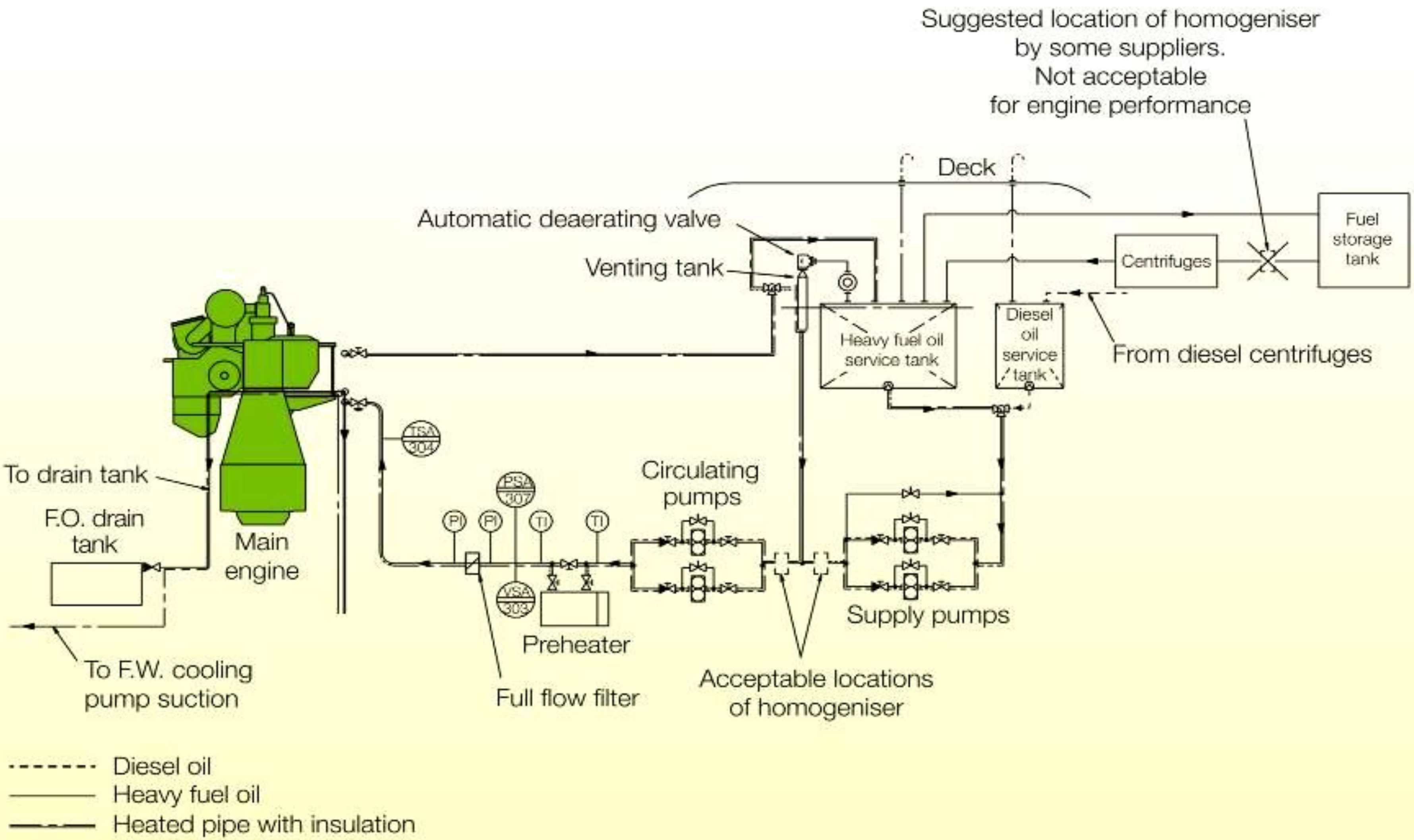
Homogeniser test

Tests on 4T50ME-X show that water is an important factor when using a homogeniser:

<1% water: The separator efficiency is maintained

>1% water: Separator performance is compromised

Fuel Injection System.



How to evaluate a fuel?

- Many factors, however, usually related to cat fines or sulphur.
- If cat fines level above 15 ppm: Check centrifuge and density.
  - Do centrifuge capacity and density match?
  - Is centrifuge operated at >98degC?
- If sulphur level below 1.5%: Check cylinder oil BN and feed rate
- Concern among owners/operators regarding FIA and CCAI.

Unless with regards to four-stroke: No Worries!