XVII Convegno di Tribologia

**"Attrito, Usura e Lubrificazione in Campo Marino
Applicazioni e Sfide Tecnologiche"**

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Conditions' Monitoring in Ambito Navale Mediante le Analisi del Lubrificante in Esercizio

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AMME ASMECCANICA

CT Centro Tribologia
AMME - ASMECCANICA

ATENA
ASSOCIAZIONE ITALIANA DI TECNICA NAVALE

5 Maggio 2016 - Napoli

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50 Anni di Tribologia

Circa 50 anni fa nasceva la "**Tribologia**" una scienza in cui sono confluite diverse tecniche derivate dallo studio di tutti i fenomeni legati all'usura.
Tra i sistemi preposti al controllo dell'usura, le procedure di lubrificazione svolgono un ruolo primario. Di seguito la notizia ricavata dal comunicato della **Società di Tribologia**:
The 9 March 2016 sees the 50th anniversary of the publication of the ground breaking report "Lubrication (Tribology) Education and Research".

This report, commonly referred to as the "Jost Report", described the findings of a committee, chaired by Prof H Peter Jost and organized on behalf of the UK government. It also coined the word "tribology" for the first time and outlined dramatic financial savings that could be gained through the correct application of tribological principles, leading to global development and integration of inter-disciplinary studies in friction, wear and lubrication to form the subject of tribology as it is known and understood in 2016.

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COMPANY'S GROWTH AND DEVELOPMENT

Mecoil has been giving full support to predictive maintenance strategies since 1990.

Oil analysis for machines' health assessment became vital part of any Predictive/Proactive Maintenance Program

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DIAGNOSTIC POWER OF OIL ANALYSIS

An industrial plant is like an organism, so take care for its good health!

IN SERVICE OIL ANALISYS

LUBE OIL QUALITY

PLANTS' LIFE OPTIMIZATION

EFFICIENT MANAGEMENT OF MAINTENANCE

IMPROVING THE ENTIRE COMPANY PRODUCTION PROCESS

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MECOIL SERVICE: la risposta per ogni applicazione!

Mecoil assists customers with tailored chemical & physical oil test packages recommending the most appropriate analysis

Engine

for diesel and gasoline engine

Standard

for industial and vehicle gear box

Standard e

for eolic gear box

Clean

for hydraulic system

Gas

for gas engine

Simple

for aviation

Plus

for compressor system

Deep

for compressor system, centrifugal compressor

Fuel

for gasoline sample

Diatermico

for diathermic oil

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UCVD: OUR PATENTED SYSTEM FOR OIL SAMPLING

UCVD = Ultra Clean Vacuum Device

Il campionamento di olio non mai stato così semplice, pulito e veloce!

QUICK	• draws any practical viscosity in seconds
EASY	• hands-free sampling, no other device is required
CLEAN	• pre-charged vacuum allows a high cleanliness level
SURE	• no possible cross-contamination
SAFE	• no oil spills, keeps oil away from the user and the environment

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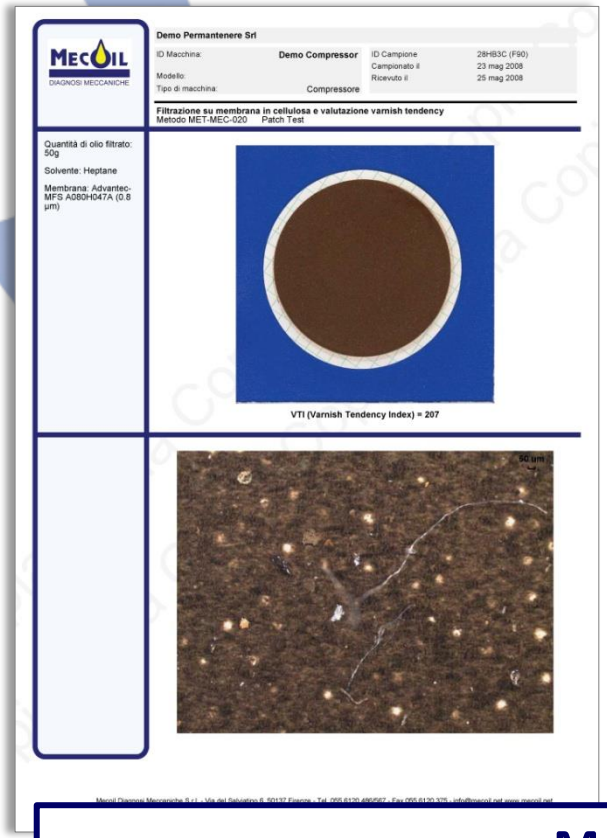
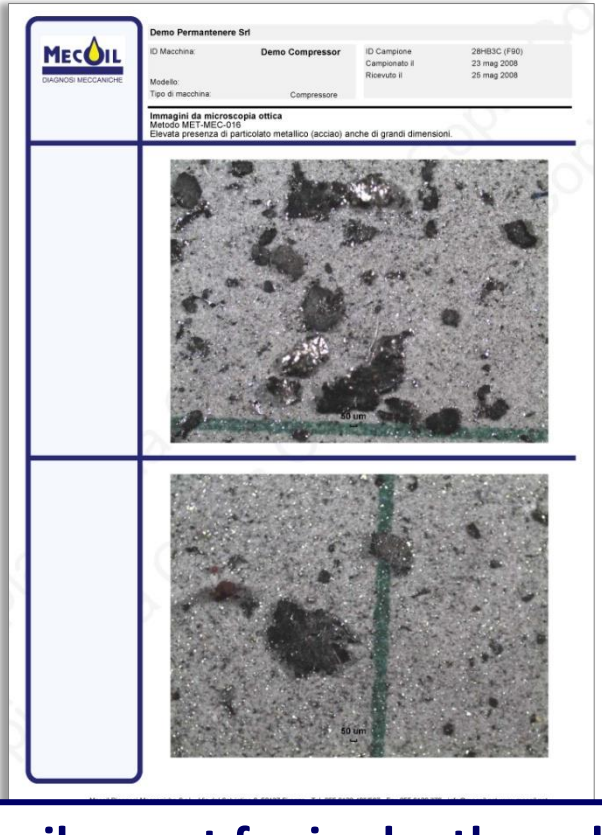
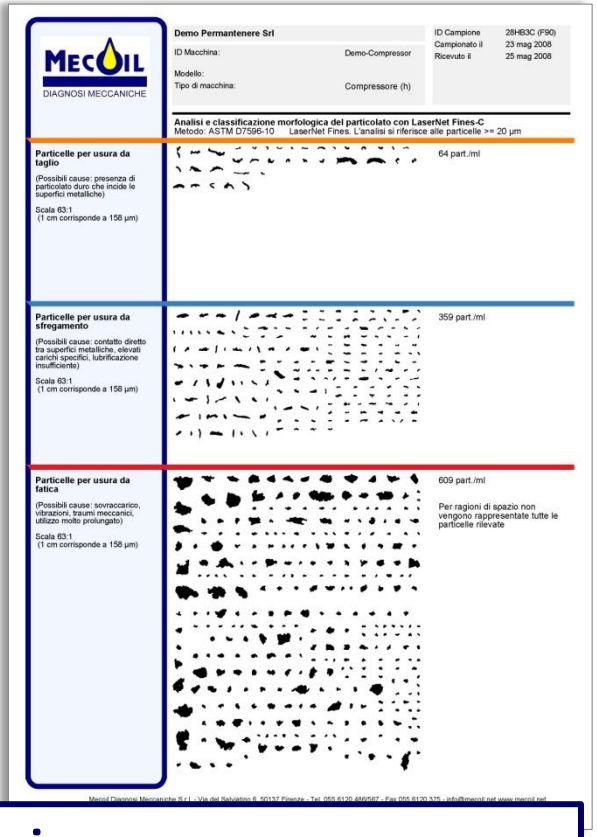
MECOIL REPORT and TREND ANALYSIS







Mecoil report for in-depth analysis

- Evaluation of hidden problems such as varnish tendecy
- Representative imagines of most important contaminations
- Automatic recognition of main wear and contamination modes

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STRENGHT OF OIL ANALYSIS

Operative advantages

- Elimination of machine unplanned downtime
- Better machinery utilization
- Oil life extension
- Better control of contamination cause
- Increase of plant useful life

Economic advantages

- Reduction of the plant costs:
  - spare parts
  - repairs
  - labor
- provides more than 25% cost advantage compared to direct reactive maintenance costs
- Most cost-effective policy for asset conservation

Supportiamo il cliente nelle scelte strategiche per una maggior efficienza gestionale

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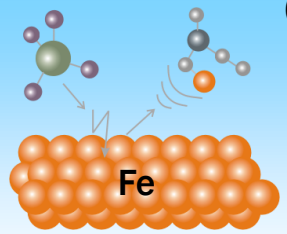
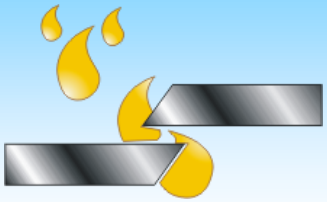
Come invecchia l'olio lubrificante?

Causes of Oil Aging

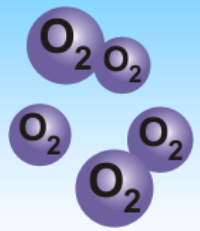
Temperature
Stress



Catalysts
(Metal Particles)



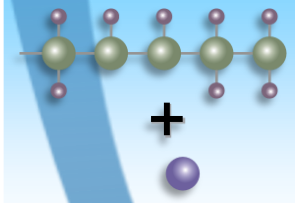
Shear Stress



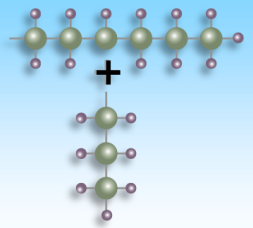
Aeration

Water

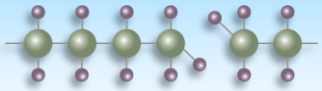
Aging Mechanisms



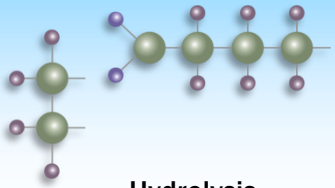
Oxidation



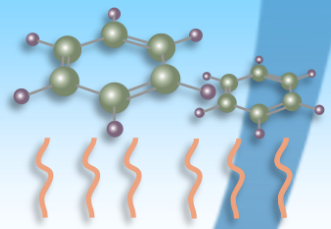
Polymerization



Cracking



Hydrolysis



Evaporation

Which Alter Fluid Properties

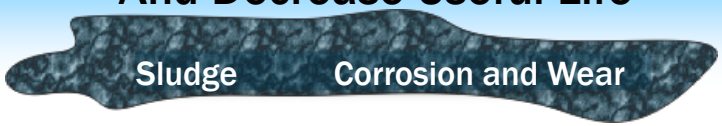
Physical

Density
Viscosity

Chemical

Acid Content
Sludge

And Decrease Useful Life



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Cause prime dell'ossidazione

These root causes when occurring together will have a marked effect on the lubricant aging process. Two of these root causes are detectable by routine oil analysis.

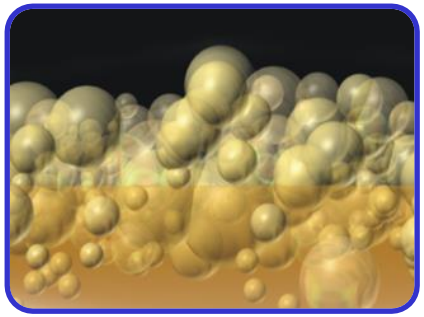
Heat

Temperature		Relative No. of Oil Changes
°C	°F	
80	180	16
70	160	8
60	140	4
50	125	2
40	105	1

Water

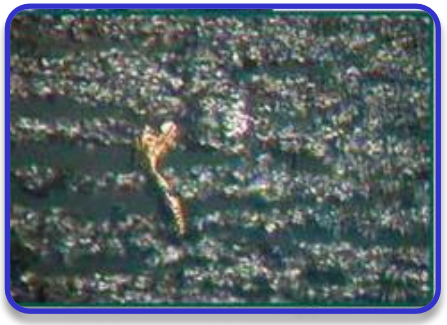
Water in oil can increase oil degradation rate by more than 10 times

Air



%AIR	Acid Number
0	0.1
3	0.15
6	0.25
9	0.5
12	0.6

Metal Particles



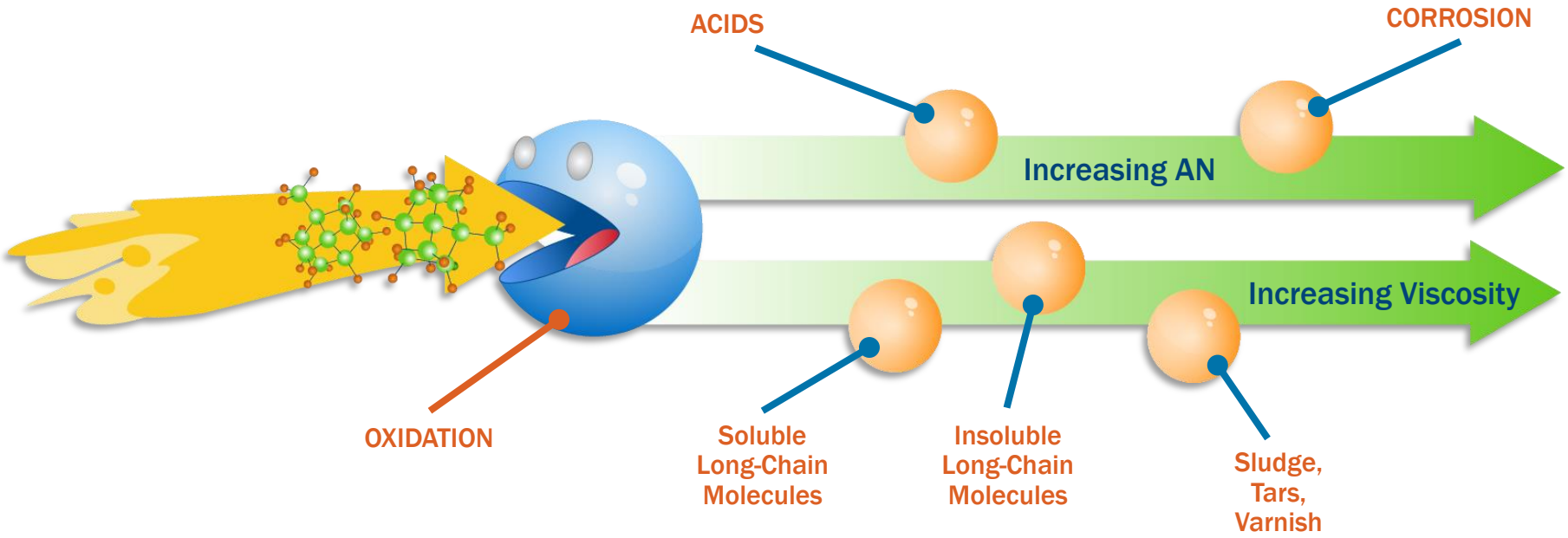
Metal Catalyst	Acid Level (AN)
None	0.17
Iron	0.65
Copper	0.89
Copper and Water	11.2

Dual Course of Oxidation

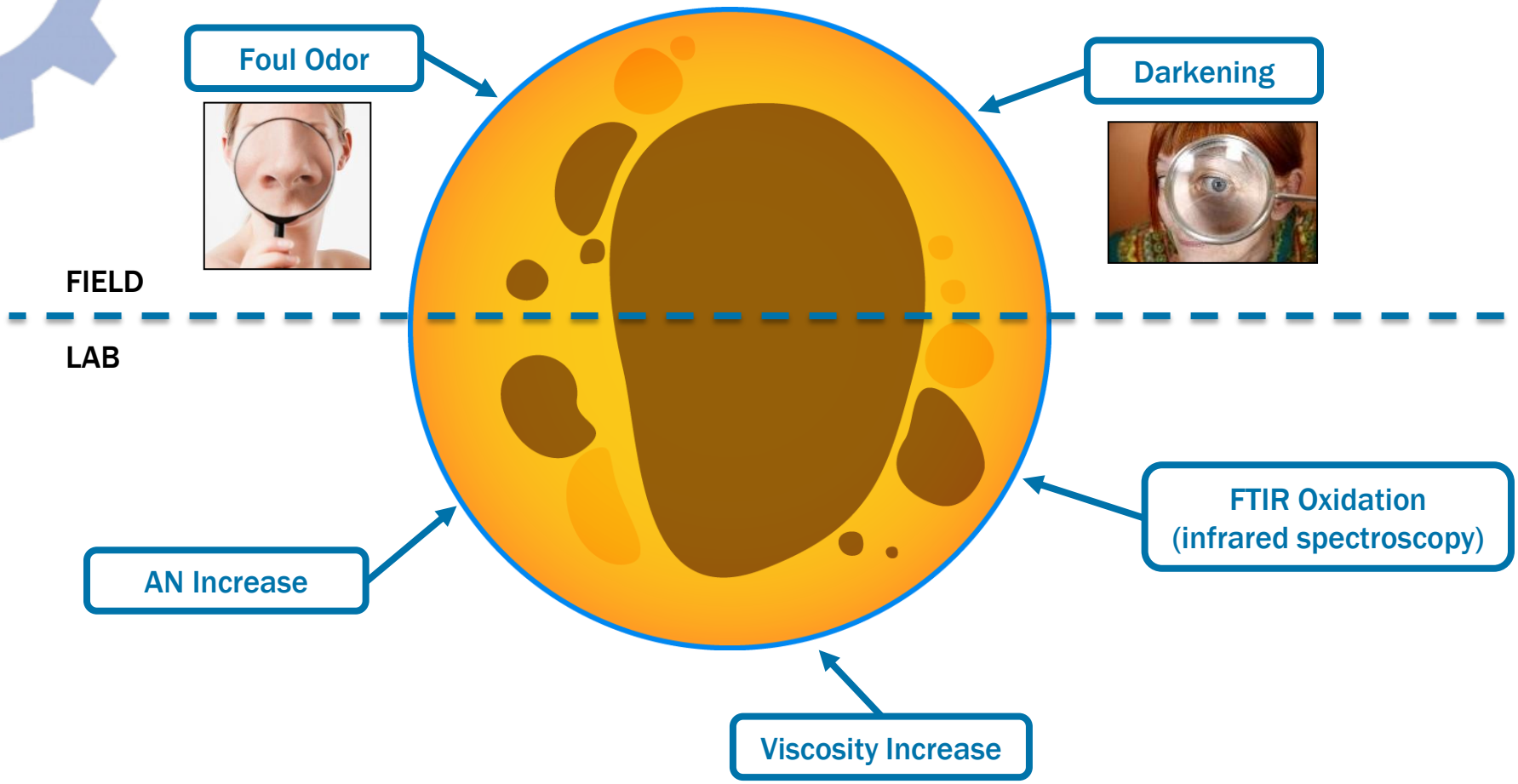
La degrazione ossidativa è un fenomeno irreversibile, autocatalitico, in cui sono coinvolti prodotti lubrificanti in ambiente ricco di ossigeno.

As Oxidation Progresses...

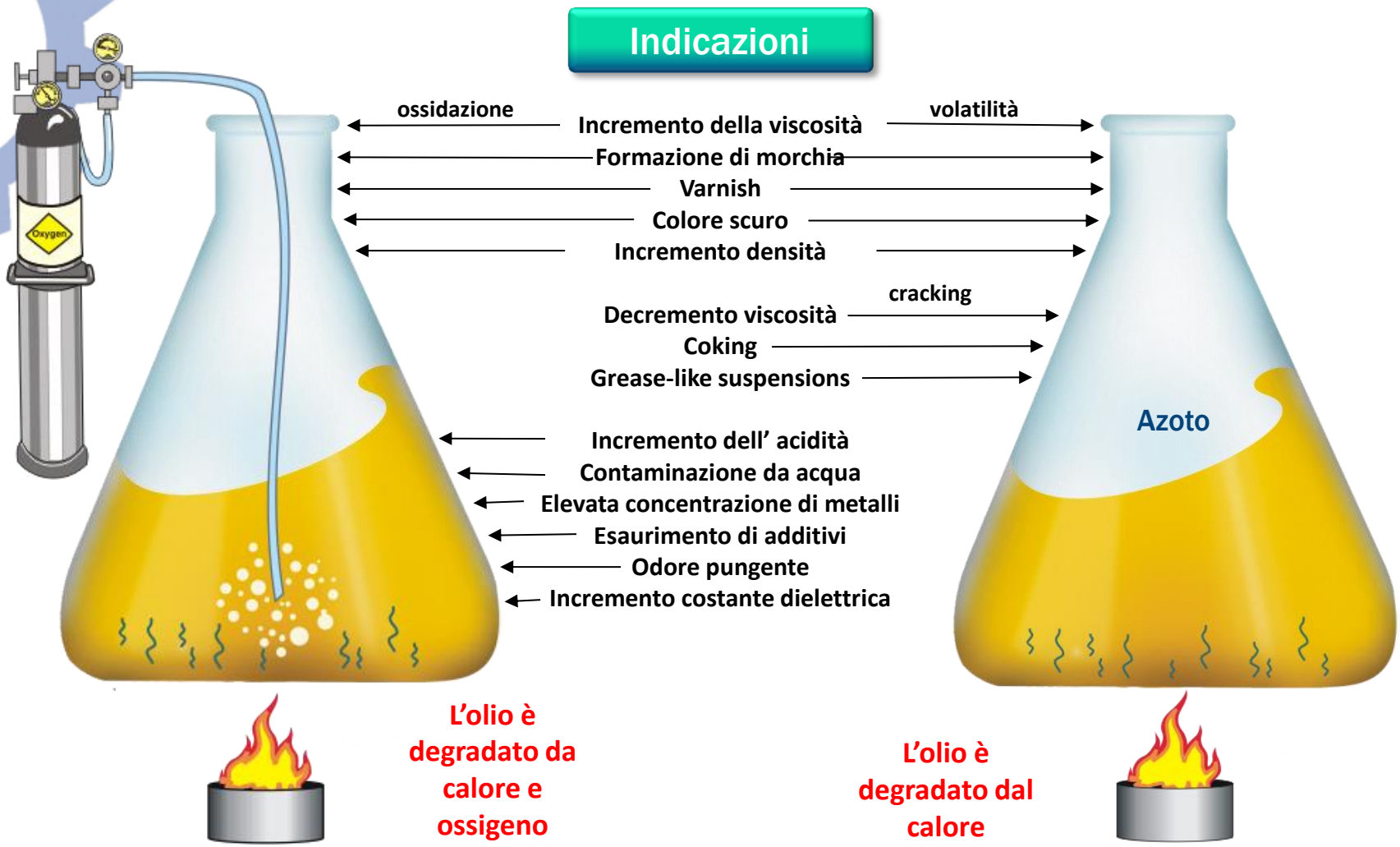
- Long-chain molecules are produced, which leads to sludge, tars and varnish.
- Acids are produced, which leads to corrosion.



La percezione dello stato di ossidazione dell'olio

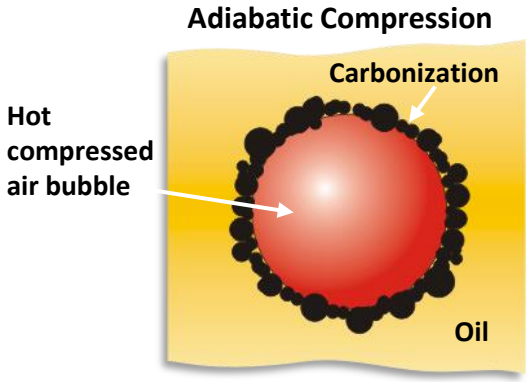


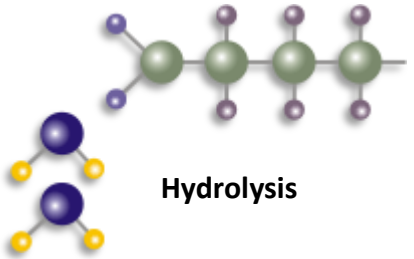
Differenze tra degradazione termica ed ossidativa

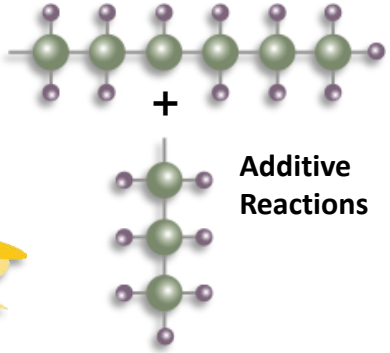


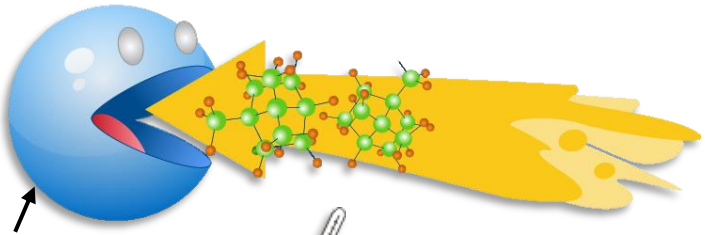
Cause e caratteristiche di degradazione del lubrificante

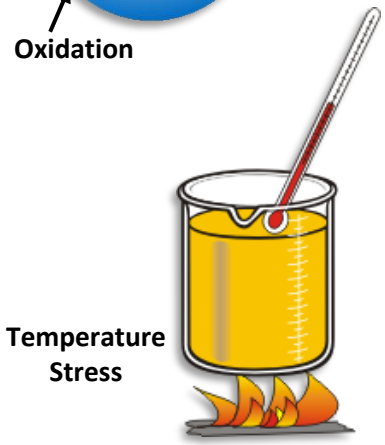
- Aerazione del lubrificante
- Scariche elettrostatiche
- Degradazione termica della base
- Contaminazione da antigelo
- Coagulazione del soot
- Degradazione ossidativa della base
- Idrolisi (esteri)
- Stoccaggio prolungato a basse T
- Nitrazione
- Contatto con superfici clade (coking)
- Perdite di efficienza della combustione e blowby
- Combustibili altamente aromatici
- Solfatazione (fuel, H_2S, etc.)
- Incompatibilità tra additivi
- Incompatibilità tra basi olio

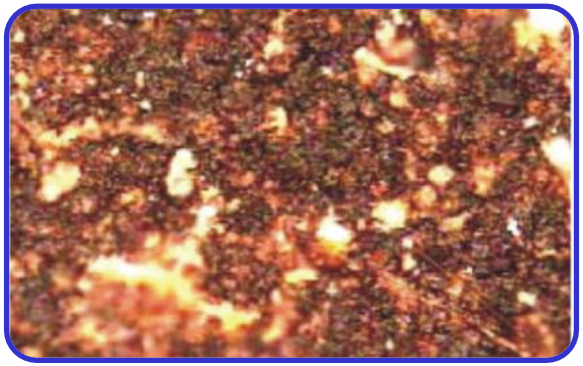












An Upset Lubricant Up Close

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Il fenomeno delle Varnish come conseguenza dell'invecchiamento dell'olio

Una nuova sfida diagnostica!

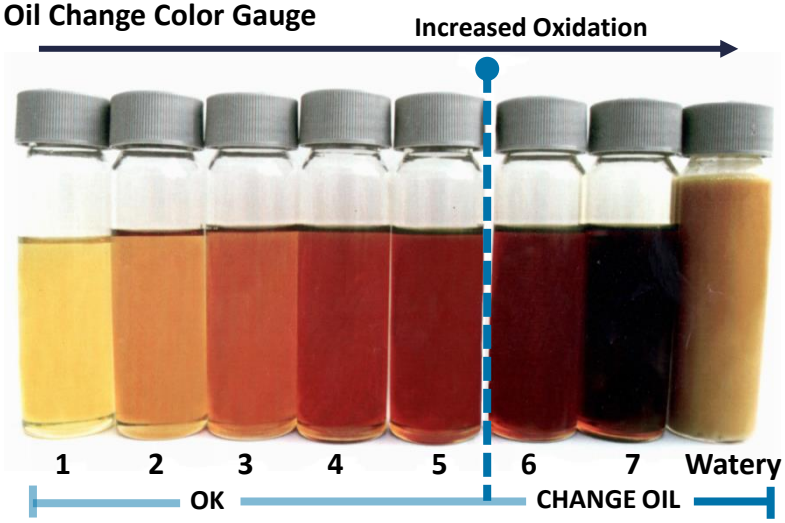
- Hydrocarbon (oil)
- Primary Oxidation Products
- High-Molecular-Weight Products
- Varnish and Sludge from Oxide Insolubles

Progressive removal of oxide insolubles

Oxidized Oil

New Oil

Oil Change Color Gauge



Use glass or PET plastic bottles

Aged but serviceable - spot and ring darker but uniform throughout

Mildly oxidized oil - dark in center with lighter color oil outward

Severely oxidized oil - dark center (sludge) with distinct outer ring

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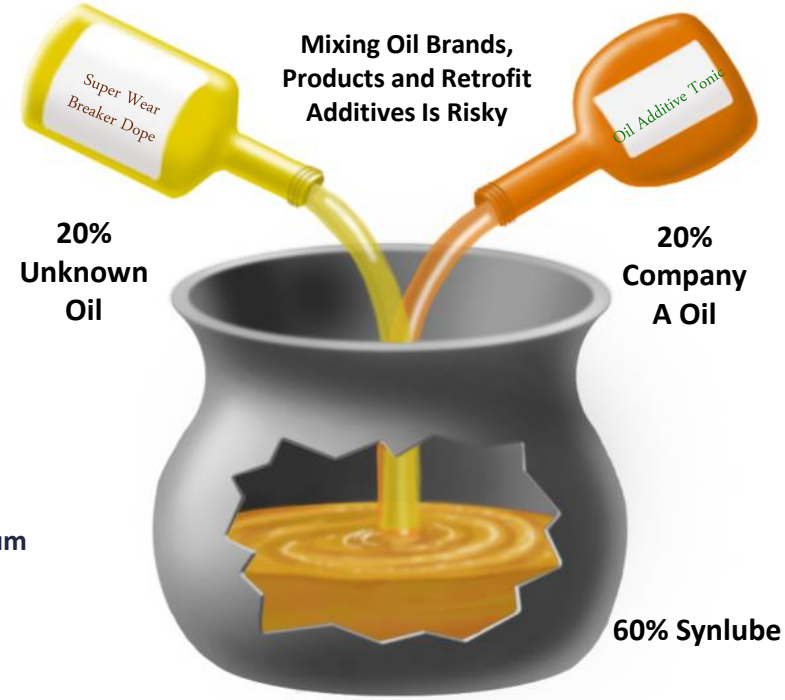
Lacche e Morchie in conseguenza della precipitazione degli additivi

Chemical Contamination				
	New Oil (ppm)	Used Oil (ppm)	Filter Residue (ppm)	Centrifuge Residue (ppm)
Calcium	1,490	991	105,500	>18,000
Phosphorus	714	817	3100	310
Zinc	882	691	45,100	6,422
Sodium	22	47	2,330	592

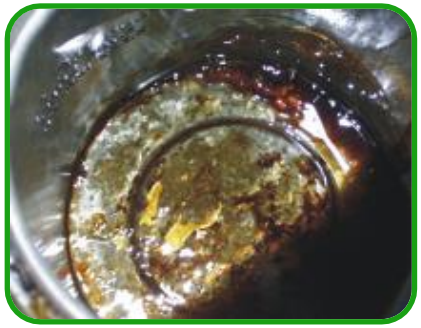
Additive Precipitant

Caustic contaminant (sodium hydroxide)reacts with oil to form sodium carboxylate soaps



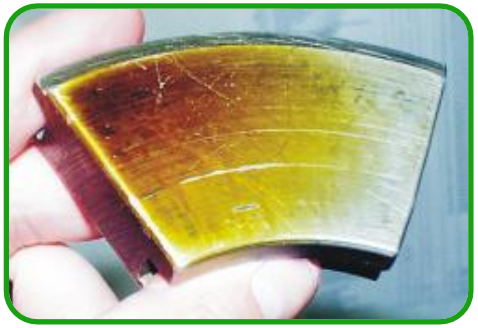
Where Dead Additives Ended Up ...

On Filters



Centrifuge Sediment

Bottom Sediment



On Bearing Surfaces

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Esaurimento degli additivi per Decomposizione

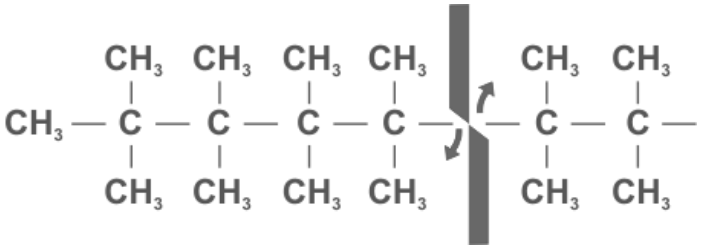
Neutralizzazione

Acido + Base = Sale + Acqua

Detergente

Modificazione irreversibile degli additivi

Rottura



Ossidazione

ZDDP Fenolo + Idroperossidi e radicali liberi = Polimeri

Idrolisi

ZDDP + Acqua + Calore

=

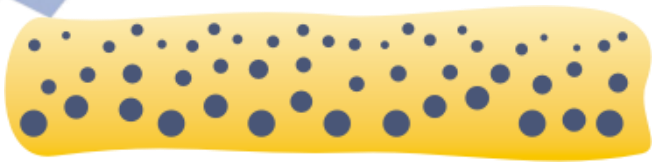
Acido solforico + Solfuro di idrogeno

Degradazione termica

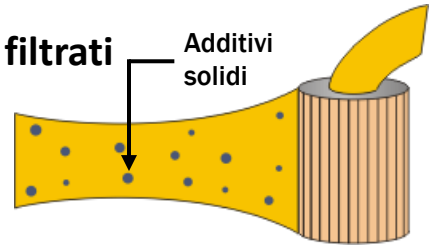
ZDDP S-P EP additivi + Calore = Fosfati Fosfuri Solfati solfuri

Esaurimento degli additivi per “separazione” massiva

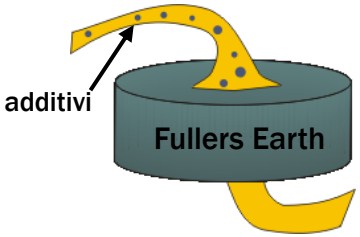
Condensazione e decantazione –
Gli additivi diventano insolubili e decantano



Filtrazione –
Gli additivi solidi o condensati vengono filtrati

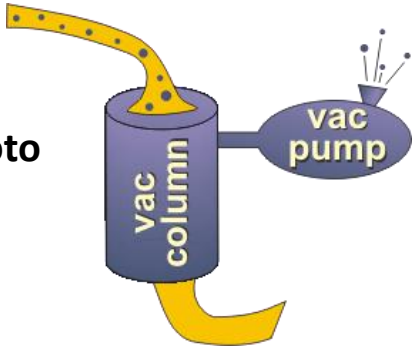


Adsorbimento di aggregati–
La separazione per adsorbimento rimuove le molecole polari

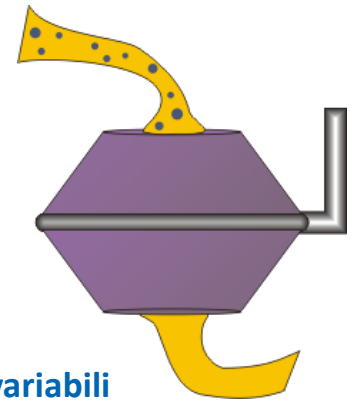


Gli additivi possono separarsi o venire separati dall’olio, come fenomeno massivo.

Evaporazione –
Deidratatori sottovuoto possono rimuovere additivi volatili*



Centrifugazione –
Gli additivi più pesanti possono separarsi per centrifugazione*



*In funzione di condizioni variabili come tipo di olio e temperatura.

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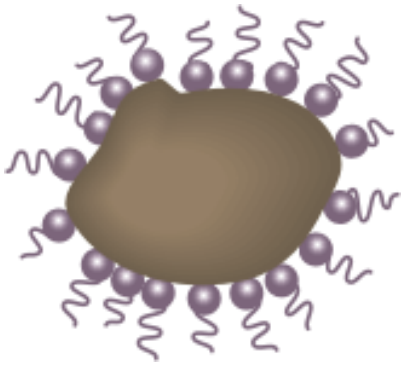
Esaurimento degli additivi per Adsorbimento

Intrappolamento

Le particelle intrappolano gli additivi e li portano ai filtri o li trascinano sul fondo

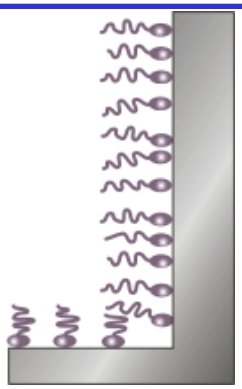


Contatto per Sfregamento

Gli addittivi EP e AW polari formano un film d'olio sulla superficie metallica e di conseguenza sono soggetti ad un progressivo esaurimento

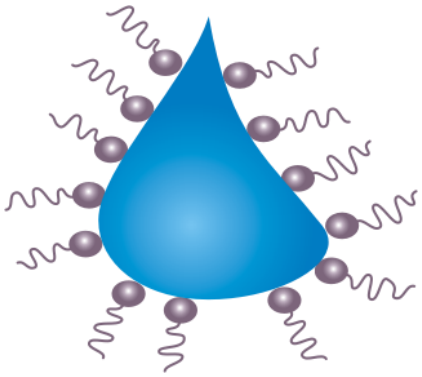
Adsorbimento superficiale

Gli additivi polari aderiscono alle superfici della macchina



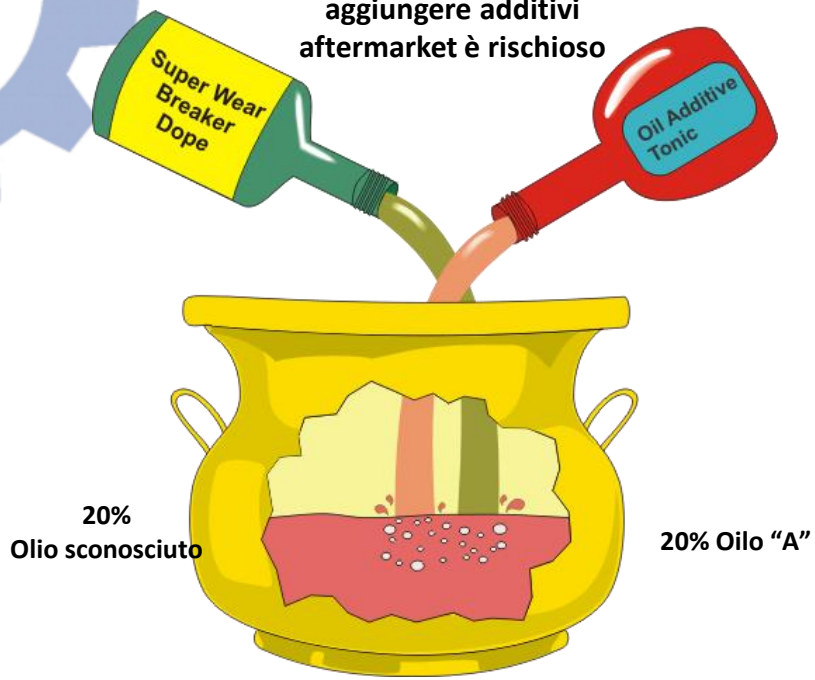
Dilavamento

L'acqua, essendo polare, trascina gli additivi sul fondo del serbatoio



Lubrificanti fatti in casa?

Mescolare diverse marche o tipi di olio e aggiungere additivi aftermarket è rischioso



Alcune associazioni di additivi sono:

Sinergiche
- Ammine e fenoli antiossidanti
- Alcune combinazioni AW/EP

Neutre

Antagoniste
- Disperdenti e additivi EP/AW
- Inibitori della corrosione e EP/AW
- Modificatori d'attrito ed EP

- **Potenziali rischi del lubrificante "fatto in casa"**
- Precipitazione degli additivi
- Perdita di proprietà antiusura
- Perdita della proprietà demulsiva
- Riduzione della stabilità all' ossidazione
- Instabilità allo stoccaggio

Come analizzare il lubrificante "fatto in casa"
- Normalizzare le baselines dopo il blending
- Ripetere il test ad alta frequenza per tre campioni consecutivi

Test di compatibilità:
- Olio: 50/50, 90/10, 10/90, filtrabilità, sedimentazione, colore, RPVOT, stoccaggio, forza-film, demulsività.
  Vedi ASTM D7155
- Grasso: 75:25, 25:75, consistenza, punto di goccia, resistenza allo stress, ASTM D6185

1 Litro di olio motore ha abbastanza disperdenti per annullare la demulsività di 6000 Litri di olio turbina

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Incompatibility of Lubricant Mixing

Class A Oils Containing Acidic Additives	Class B Oils Containing Alkaline Additives	Class C Oils Not Containing Either
Aviation Hydraulic Fluids	Automatic Transmission Fluid	Aero Engine Oils
Clarity Paper Machine Oils	Delo 400 Cyloils	Aviation Engine Oils Uncompounded
Cylinder Oils W	Delo Cyloils	Cylinder Oils
Gear Compounds EP	Delo 400 Multigrade	Delo Gear Lubricants
Lubricating Oils FM	Delo 100 Motor Oils	Quenching Oil 70
Machine Oils R&O Symbol	Diesel Engine Oils Delo 6170	Refrigeration Oils WF
Machine Oils R&O	Drive Train Fluids HD	Ultra Gear Lubricants
Marine Oils E	Hydraulic Oils AW	Utility Oils LVI
Paper Machine Oil N	Industrial Oils EP	Utility Oils HVI
RPM Universal Gear Lubricants	Journal Bearing Oil	
Synthetic Compressor Oils Tegra	Machine Oils AW	
Synthetic Gear Lubricants Tegra	Paper Machine Oils D	
Turbine Oil Symbol 2190 TEP	RPM Gear Oils	
Turbine Oils GST	Supreme Motor Oils	

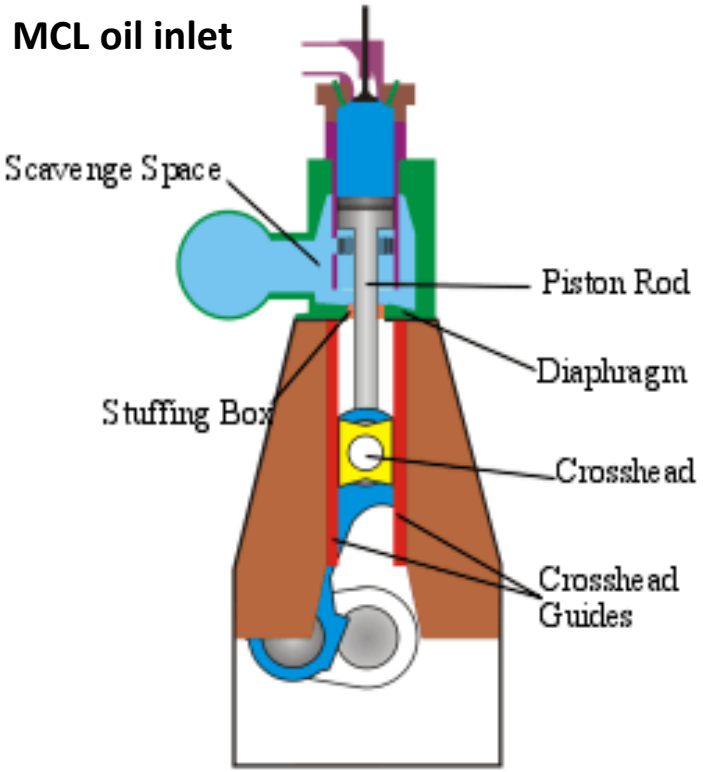
All Oils Chevron Brand

- Mixing within class: May be chemically compatible although there is risk of diluted performance
- Mixing between classes:
  1. Don't mix A with B
  2. Oils from C can be mixed with A or B but with risk of diluted performance
- Flushing
  1. Flush when switching between A and B
  2. No flushing required when switching from A or B to C
- When in doubt perform compatibility testing such as ASTM D7155 or D6185

How lubricant Properties Change (Irreparably)

	Mixed Lubricants	Contamination	Mechanical Shear	Storage (Static Conditions)	In-service Environment
Base Oil	Incompatibility: • Sludge • Varnish • Viscosity change • Oxidation stability	• Oxidation • Physical properties • Hydrolysis • Thermal degradation • Radiation • Process gases	Oxidation (continuous agitation of pro-oxidants; water, metal particles and air)	Minimal risk under normal storage conditions	• Oxidation • Thermal degradation • Chemically reactive machine surfaces
Additives	Incompatibility: • Neutralization • Impaired performance • Sludge and varnish	• Oxidation • Stripping and washing • Accelerated normal depletion • Miscellaneous chemical reaction	VI Improver and pour point depressant shear down	Gravitational separation of organometallic and insoluble additives	• Filtration (separation) • Surface activity • Evaporation • Separation
Thickener (Grease)	Incompatibility: • Change in consistency • Separation	• Change in consistency • Separation • Wash out	Change in consistency	• Separation • Thixotropy	• Centrifugal separation • Thermal separation

Application: TWO-STROKE MARINE DIESEL ENGINES



Two-stroke marine diesel engines cylinder lubrication

- Marine Cylinder Lubricating (MCL) oil is injected between cylinder lining and piston.
  - Flows through the cylinders once, then discharged as waste oil
- System Oil
  - Recirculated to lubricate all other moving parts.

Over 95% of these vessels are powered by two-stroke engines made by:

- **Wärtsilä**
- **MAN Diesel**

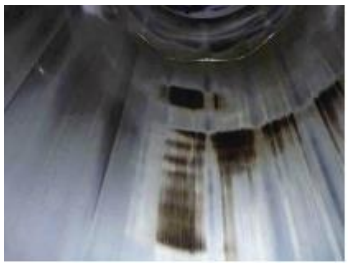
Problems on marine vessel

- **“Slow steaming”**

  This results in “cold corrosion” if engine cylinder lubrication is not managed well

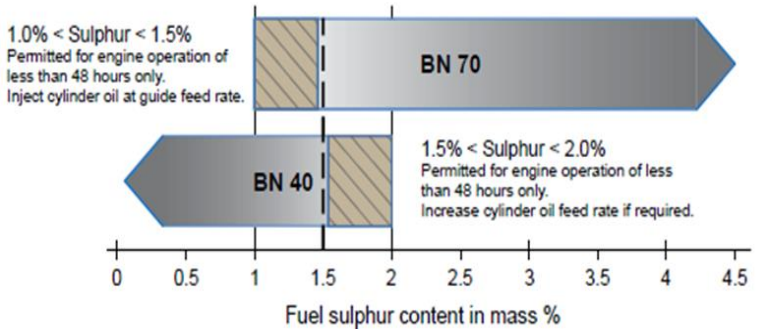
  Premature failure of cylinder liners and piston rings due to cylinder scuffing (under lubrication) and cylinder scaling (over lubrication)

“Cold Corrosion” is a very aggressive corrosive attack on the engine cylinder linings running high sulfur fuels at low load



- **New sulfur emissions requirements drive vessels to carry two fuel types**

  Each fuel needs a different lubricant with different Base Number (BN) to compensate for the different Sulfur levels in the fuel



LUBRIFICANT MAINTENANCE ON BOARD

Shore-based Offices

Fleet Manager/Marine Superintendent

- Concern with vessel operating costs
- Compliance with Insurance requirements
- Must adhere to OEM recommendations

Shipboard

Chief Engineer

- Follows OEM recommendations
- Knowledgeable about oil analysis
- Will ask about iron corrosion

Mechanic/Ship's mate

- Ease of use for crew
- Fast measurement, data logging
- < 30 crew members maintain all shipboard systems

LIMITATION OF EXISTING MONITORING APPROACHES

Shore based Labs

- Transit delay
- Results come after the damage is done

On-board Shaker kits

- Products are time consuming to use, 10 minutes per test
- Wet chemistry require HAZMAT reagents
- Results obtained are operator sensitive
- High consumables cost

Existing approaches do not provide accurate, economical or fast BN measurement

CONDITION MONITORING ON-SITE&ON-LINE

On-site, off-line
(manual detection of temperature, pressure, vibration)

On-site, intranet
(signal digitization and automation of its transfer)

Dedicated tool - expensive

Off-site, off-line
(traditional oil analysis)

Off-site analysis, on-line reports

No real time service
(delay in delivery)

On-site On-line Real-Time

- Engine real-time monitoring
- Simultaneously control of several systems
- Trend of the health machine
- Rapid and punctual maintenance service

MECOIL
DIAGNOSI MECCANICHE

FLUIDSCAN® Q1200 SERIES

a partnership of Spectro Scientific and Wärtsilä Services

New approach	• innovative approach to a critical test that must be performed onboard
Specific	• Daily test for BN (Base Number) in Marine Cylinder Lubricant
Database	• The software can store up to 5000 measurement results export these results by .csv file

Measuring corrosive iron is UNNECESSARY if you properly control residual cylinder oil BN and never let it fall below 15 (Wärtsilä recommended limit).

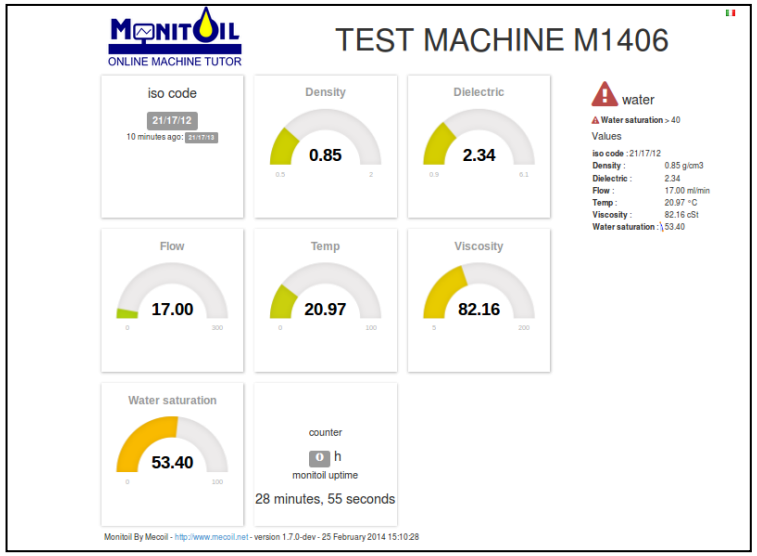
FLUIDSCAN® Q1200 SERIES

Easy to use!

- Uses just one drop of oil to test
- Results in less than 1 minute
- After test, just wipe clean, no solvents required
- Provides immediate, actionable data
- Pre-defined labels simplifies record keeping
- Minimal training required

Application	Q1210: Marine Cylinder Oil (MCL) BN (Base Number) Q1220: MCL Oil BN and Engine (System) oil parameters Q1230: MCL BN, Engine (System) and Machinery oil parameters			
Output	**UNITS**	**Q1210**	**Q1220**	**Q1230**
Cylinder Lube Oil BN	mg KOH/g	Yes	Yes	Yes
Base Number (System and Engine oil)			Yes	Yes
Oxidation	Abs/0.1 mm		Yes	Yes
Nitration	Abs/cm		Yes	Yes
Sulfation	Abs/0.1 mm		Yes	Yes
Soot	Abs/cm		Yes	Yes
Glycol	% wt		Yes	Yes
Water, ppm (dissolved and Free + Dissolved with Comprehensive water option)	ppm		Yes	Yes

Sailing toward on-line monitoring



- **Power Requirements** Power consumption: 12 Watts
- **System I / O** 8 connectors (CanBus, ModBus, RS485, RS232, analogic or output), 1 connector 5-pin version: to extend
- **Communication ports** 1 USB port, 1 Ethernet port

Miscellaneous

CPU: ARM11 @ 800Mhz
Memory: 8 GB SD
Software web upgradeable
Set-up via web page
Case: Pelican 1150
Protection Grade: IP65
Weight: 1.620 kg (3.6 lbs)
Dimensions: 232 x 192 x 111 mm
(9.1 x 7.6 x 4.4 in)

Data is collected from each sensor every 2 minutes

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UNA SFIDA CULTURALE!

CORSI DI FORMAZIONE MECOIL

Mecoil Diagnosi Meccaniche, grazie alla collaborazione con ICML, ed in qualità di Licensed partner Noria Corp., organizza Corsi MLT "Machine Lubrication Technician", allo scopo di fornire ai tecnici di manutenzione elementi utili per gestire al meglio impianti oleodinamici e sistemi di lubrificazione complessi. La qualifica di Specialista di Lubrificazione è riconosciuta a livello internazionale secondo quanto riportato in www.lubecouncil.org

Diventa Specialista di Lubrificazione

Qualifica MLT riconosciuta in tutto il mondo

Professionisti della Manutenzione Predittiva

Argomenti trattati:

- teoria della manutenzione
- principi di lubrificazione
- funzione del lubrificante
- controllo contaminazione
- stoccaggio lubrificanti
- analisi olio

Calendario Corsi 2016

- 1ª Sessione: dal 16 al 18 Marzo
- 2ª Sessione: dal 8 al 10 Giugno
- 3ª Sessione: dal 12 al 14 Ottobre

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