What’s Next for Locomotives

Railroad Engine Oil Additive Technology
Addressing Emerging Fuel & Emission Standards
Agenda

• Brief Oronite Introduction
• Brazil RR Market Overview
  • General Market Overview
  • Key Rail Freight Operators
• Locomotive Lubrication & Railroad OEMs
  • Diesel Engine Oil
    • Evolution, Development & Approval Processes
  • What’s Special About RREO
• What’s Next for Locomotives
Oronite – A Heritage of Innovation

1917 Global fuel and lubricant additives company was established

1917 First diesel fuel additive

1935 Revolutionary gasoline additive to keep carburetors deposit free; first thermally stable phenate additives for marine engine lubricants

1935 First compound oil for diesel locomotives

1941 First detergent oil for passenger cars

1941 Fuel additive specifically for unleaded gasoline cars

1941 First compound oil for diesel locomotives

1954 Dispersant for natural gas engine oil

1954 First engine oil formulation for Group II base oils

1980 Additive for multi-grade diesel locomotive engine oil

1989 Polybutene-based dispersant for CJ-4

1998 First fully qualified ILSAC GF4 product

1998 Patented additive technology for new generation of low emission diesel engine oils

1998 Revolutionary gasoline additive to keep carburetors deposit free; first thermally stable phenate additives for marine engine lubricants

1998 Oronite acquired the PARATONE® viscosity index improver business

1999 Built Asia’s first world-scale lubricant additive plant in Singapore

1999 First railroad oil additive formulated for low sulfur fuels

2000 Oronite became wholly owned subsidiary of Chevron Corporation

2004 Additive for multi-grade diesel locomotive engine oil

2004 Patented Marine Trunk Piston Engine Oil Carboxylate Technology

2004 First railroad oil additive formulated for low sulfur fuels

2004 Introduction of Polyether carrier fluids

2004 First engine oil formulation for Group II base oils

2004 First fully qualified ILSAC GF4 product

2005 Patented additive technology for new generation of low emission diesel engine oils

2005 First railroad oil additive formulated for low sulfur fuels

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2008 Additive for multi-grade diesel locomotive engine oil

2008 Patented Marine Trunk Piston Engine Oil Carboxylate Technology

2008 First railroad oil additive formulated for low sulfur fuels

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INTRODUCTION OF ZEROLENE F, AN ANTI-CHATTER ADDITIVE USED TO LUBRICATE FABRIC TRANSMISSION BANDS IN THE HISTORIC MODEL T FORD

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Four Major Components of Railroad Lubricant Team

- **Oil Companies**
  - Respond to OEM Needs, Manufacture and Market The Required Products

- **Locomotive Builders**
  - Make Engines, Identify and Approve Lubricant and Additive Performance Requirements

- **Railroads**
  - End Users

- **Oronite**
  - Respond to OEM, Oil Company and RR needs, Produce Products which give oil the desired performance, Manage OEM approvals for the Oil Companies

End Users
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  - Diesel Engine Oil
    - Evolution, Development & Approval Processes
- Additive Technology Performance
- What’s Next for Locomotives
## Logistic Infrastructure

### Brazil Vs. World

<table>
<thead>
<tr>
<th>BRIC</th>
<th>BR</th>
<th>CN</th>
<th>IN</th>
<th>RU</th>
<th>US</th>
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<tr>
<td><strong>Brasil</strong></td>
<td>8,5</td>
<td>9,6</td>
<td>3,0</td>
<td>17,0</td>
<td>9,1</td>
<td>9,0</td>
</tr>
<tr>
<td><strong>China</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>India</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rússia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Rodovias Pavimentadas** | 219 | 1,576 | 1,569 | 776 | 4,375 | 416 |
| **Ferroviárias** | 29 | 86 | 64 | 87 | 225 | 47 |
| **Dutoviárias** | 19 | 87 | 35 | 260 | 2,225 | 100 |
| **Hidroviárias** | 14 | 110 | 15 | 102 | 41 | 0,6 |

**Fonte:** iilos

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# Modals – Cost & Utilization
## Brazil Vs. EUA

<table>
<thead>
<tr>
<th>Mode</th>
<th>Brazil 2012</th>
<th>EUA 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rodoviário</td>
<td>67%</td>
<td>US$ 133</td>
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<tr>
<td>Ferroviário</td>
<td>18%</td>
<td>US$ 22</td>
</tr>
<tr>
<td>Aquaviário</td>
<td>11%</td>
<td>US$ 30</td>
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<tr>
<td>Dutoviário</td>
<td>3%</td>
<td>US$ 25</td>
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<tr>
<td>Aéreo</td>
<td>0.04%</td>
<td>US$ 1.060</td>
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</table>

<table>
<thead>
<tr>
<th>Mode</th>
<th>Brazil 2012</th>
<th>EUA 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rodoviário</td>
<td>31%</td>
<td>US$ 310</td>
</tr>
<tr>
<td>Ferroviário</td>
<td>37%</td>
<td>US$ 29</td>
</tr>
<tr>
<td>Aquaviário</td>
<td>10%</td>
<td>US$ 10</td>
</tr>
<tr>
<td>Dutoviário</td>
<td>21%</td>
<td>US$ 9</td>
</tr>
<tr>
<td>Aéreo</td>
<td>0.3%</td>
<td>US$ 1.107</td>
</tr>
</tbody>
</table>

*Fonte: ilos*

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The new company, created in 2015, is the result of the merger of ALL (Latin America Logistics S.A.) and Rumo, a logistics company controlled by the Cosan Group.

From its head office in Curitiba (Paraná), the company operates four concessions:
- ALL Southern (ALL Malha Sul S.A.)
- ALL Western (ALL Malha Oeste S.A.)
- ALL Paulista (ALL Malha Paulista S.A.)
- ALL Northern (ALL Malha Norte S.A.)

These total approximately 13 thousand km of railways, or 45% of the rail network in Brazil. The structure operates in six states of Brazil – Paraná, Rio Grande do Sul, Santa Catarina, Sao Paulo, Mato Grosso and Mato Grosso do Sul.

• VLI - Valor Logística Integrada - was controlled by Vale until 2014, but now is organized as a holding with headquarters in the state of Sao Paulo. VLI’s shareholding structure includes the following companies: Vale, Mitsui, FI-FGTS, and Brookfield.

• The company operates 2 Railroads:
  - FCA
  - FNS

• VLI covers around 8 thousand kilometers of railway networks in Brazil. The structure runs through nine Brazilian states (Minas Gerais, Maranhão, Tocantins, Espírito Santo, Rio de Janeiro, Sergipe, Goiás, Bahia, São Paulo e Distrito Federal).

http://www.vli-logistica.com/en
Vale S.A. (Vale) is a Brazilian multinational diversified metals and mining corporation. Vale is headquartered in Rio de Janeiro and through VLI - Valor Logística Integrada – Vale also provides logistics services to third parties. In addition, the company operates long-distance passenger trains on two important stretches in the country, the Vitória – Minas and Carajás Railroads.

The company operates 2 Railroads:
1. EFVM
2. EFC

[Links to Vale's website: http://www.vale.com/brasil/EN/Pages/default.aspx]
• MRS Logística S.A. is a Brazilian concessionary that controls, operates and monitors the Southeastern Federal Railroad Network. The company operates in cargo railway transportation since 1996. It interconnects the states of Rio de Janeiro, Minas Gerais and São Paulo.

• From Rio de Janeiro, the MRS's headquarters, the company manages 1643 kilometers of railway, which is equivalent to approximately 6% of the national structure.

https://www.mrs.com.br/
## Market Overview

### Evolution - transported cargo (thousands of useful ton) tu

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<thead>
<tr>
<th></th>
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<td>VALE</td>
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<td>236965</td>
<td>236881</td>
<td>200584</td>
<td>236704</td>
<td>248005</td>
<td>250913</td>
<td>240302</td>
<td>244639</td>
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<td>RUMO ALL</td>
<td>42069</td>
<td>39627</td>
<td>43459</td>
<td>43840</td>
<td>47622</td>
<td>50589</td>
<td>47778</td>
<td>47317</td>
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<tr>
<td>MRS</td>
<td>101998</td>
<td>114064</td>
<td>119799</td>
<td>110954</td>
<td>123030</td>
<td>130009</td>
<td>131404</td>
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<tr>
<td>VLI</td>
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<td>18957</td>
<td>20704</td>
<td>19094</td>
<td>23254</td>
<td>21499</td>
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<td>FERROESTE</td>
<td>1511</td>
<td>862</td>
<td>996</td>
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<td>471</td>
<td>400</td>
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<td>433718</td>
<td>452950</td>
<td>458557</td>
<td>449555</td>
<td>463993</td>
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</table>

### Evolution - Locomotives in operation

<table>
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<td>673</td>
<td>603</td>
<td>533</td>
<td>537</td>
<td>546</td>
<td>623</td>
<td>1269</td>
<td>1324</td>
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<tr>
<td>RUMO ALL</td>
<td>657</td>
<td>672</td>
<td>875</td>
<td>948</td>
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<td>718</td>
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<td>789</td>
<td>782</td>
<td>762</td>
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<tr>
<td>VALE</td>
<td>463</td>
<td>495</td>
<td>518</td>
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<td>539</td>
<td>555</td>
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<td>13</td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
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<td>2203</td>
<td>2685</td>
<td>2782</td>
<td>2882</td>
<td>2974</td>
<td>3108</td>
<td>3035</td>
<td>3620</td>
<td>3634</td>
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</tbody>
</table>

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• Brief Oronite Introduction

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  • Key Rail Freight Operators

• Locomotive Lubrication & Railroad OEMs
  • Diesel Engine Oil
    • Evolution, Development & Approval Processes
  • What’s Special about RREO

• What’s Next for Locomotives
Locomotive Lubrication

- Compressor Oil
- Diesel Engine Oil
- Hydraulic Oil
- Traction Motor Support Bearing Oil
- Several Types of Greases
Railroad OEM's

- General Electric (GE)
  - 4 Stroke Engine
    - 7FDL models - 4,000 to 4,400 horsepower (HP)
    - EVO models - 4,400 – 6,000 HP (circa 2005 – present)
  - Increasing market share globally
  - Developing new low emissions engine (Tier 4)

- Electro-Motive Diesel (EMD)
  - 2 Stroke Engine
    - 710 model 4,000 to 4,300 HP (circa 1984 – present day)
    - Older models – 645 & 567 in service worldwide
  - 4 Stroke Engine
    - “H” model – 6,000 HP (in service in China)
  - Purchased by Caterpillar in 2010 (directly under Progress Rail)
  - Developing new low emissions engine (Tier 4)
Railroad Fleet Trends
Impact on Railroad Diesel Engine Oil

- New Engine Designs
- Fleet Modernization
- Lower Oil Consumption
- Higher Locomotive Utilization
- High HP Locomotives
- Emissions Reqs + Fuel Quality
- Longer Maintenance Intervals
- Used Oil Analysis Quality

Higher Demands on the Engine Oil
## Locomotive Muscle Vs. Trucks

### On-Highway Truck Engine
- **Displacement, liters**: 11 to 15
- **Typical RPM**: 2,000
- **Horsepower**: 450 to 500
- **Torque, ft-lbs**: 1,100 to 1,300

### Railroad Engine
- **Displacement, liters**: 120 to 220
- **Typical RPM**: 400 to 1,000
- **Horsepower**: 3,000 to 6,000
- **Torque, ft-lbs**: 22,000 to 25,500

*Source: Lubes & Greases*
What Makes Up a Locomotive Engine Oil

EMD requires mono-grade oils for “Break-In” purposes. AESS equipped locomotives benefit from the functionality of multi-grade RREOs.

**SAE 40**
- Base Oil: 11.9 cSt
- Lubricant Additives: 15.0 cSt
- Higher levels Heavy Neutral Base Oil needed

**SAE 20W-40**
- Base Oil: 10.3 cSt
- Lubricant Additives: 13.4 cSt
- VI Improver: 15.3 cSt
- Selection of Base Oil choices

**Typical fresh Oil Viscosity**
- 10.3 cSt
- 13.4 cSt
- 15.3 cSt

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**Typical fresh Oil Viscosity**
- 10.3 cSt
- 13.4 cSt
- 15.3 cSt
Mono-grade and Multi-grade Oils

Benefits of Multi-grade:

• Fuel and Lubricant consumption savings have been proven

• Benefits depend on duty cycle
  o Largest affect at idle (fuel used to rotate the engine)
  o Minimal affect at full load (fuel used for brake power)

• Fuel savings are more difficult to measure
  o Need to resolve fuel consumption to about 0.2%
  o Need to measure operating conditions and control them closely including load, RPM, water and oil temperatures
  o Need to correct for ambient conditions including pressure and temperature
RREO Requirements

• Good Detergency
  o Control piston & engine deposits
  o Oxidation inhibition
  o Acid neutralization & prevent corrosive wear
  o Wear inhibition (Unique in RREO No Zinc – ZDDPs)

• Good Dispersancy
  o Keep soot dispersed & control sludge
  o Piston deposit control
  o Solubilize acids

• Non-chlorinated
What’s So Special About RREOs?

• EMD and GE have formal approval systems
  o Bench tests, engine tests and extensive field tests
  o Railroads require OEM approvals for RREOs utilized in their locomotive fleets
  o LMOA Generation 6 & LMOA Generation 5 (GE GEN 4LL) are the current specifications used extensively worldwide

□ Emission and fuel regulations are coming
  o Engine oil performance is expected to be challenged due to engine modifications, new emission & fuel mandates being implemented around the globe
# LMOA Generations

<table>
<thead>
<tr>
<th>LMOA Generation</th>
<th>Introduction Year</th>
<th>TBN Requirements</th>
<th>Performance Milestones</th>
<th>Formulation Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1940</td>
<td>&lt;7</td>
<td>Straight mineral oils</td>
<td>Lost alkalinity, Pb corrosion, bearing failures</td>
</tr>
<tr>
<td>2</td>
<td>1964</td>
<td>7</td>
<td>Ashless dispersants, improved alkalinity with Ca detergents</td>
<td>Reduced sludge and better oil filtration</td>
</tr>
<tr>
<td>3</td>
<td>1968</td>
<td>10</td>
<td>Improved alkalinity retention, higher dispersant levels, Ca detergents</td>
<td>Reduced piston ring wear</td>
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<tr>
<td>4</td>
<td>1976</td>
<td>13</td>
<td>Improved alkalinity retention with improved detergents and dispersants</td>
<td>Increased protection for adverse engine operating conditions</td>
</tr>
<tr>
<td>5/GE 4 LL</td>
<td>1989</td>
<td>13/17/18</td>
<td>Improved drain intervals in low oil consumption engines</td>
<td>Longer life oils that meet LMOA definitions and requirements</td>
</tr>
<tr>
<td>6</td>
<td>Target 2010</td>
<td>9</td>
<td>Optimized dispersant and detergent system for LSD and ULSD fuel for low consumption engines</td>
<td>Proper balance of alkalinity to fuel sulfur with no compromise to oil drain life; significant reduction in oil sulfated ash</td>
</tr>
<tr>
<td>7</td>
<td>2016, *Potential effective day</td>
<td>11</td>
<td>TBD – based on Tier 4 requirements</td>
<td>TBD – based on Tier 4 requirements</td>
</tr>
</tbody>
</table>
Gen 6 Additive System Highlights

- Reduced ash content (reduced from 2.0% to 1.0%)
  - Lower fresh oil BN *(TBN = 9)*
  - Reduce non-VOF (i.e., ash content, particulate matter)
  - Reduce PM filter maintenance
- Advanced dispersant technology
  - Successfully address 180-day maintenance interval (Rail service)
  - Manage higher soot loading
  - Maintain oil filter life
- Enhanced oxidation and thermal stability
  - Address increased oil residence time due to lower consumption rates
  - Optimized detergency and base retention
- Maintain excellent wear protection
  - Proprietary additive technology
Scenario on Petrobras’ Diesel Production / 2009 - 2020

Production of this Diesel TFM product restricted to the Paulinia Refinery (Sao Paulo state)
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What’s Next for Railroad Engine Oils?
March 2008, EPA finalized Tier 3 and Tier 4 emission standards for compression ignition engines utilized in Inland Marine and Locomotive applications

Enabling Technology to Meet Tier 3 and 4
- Engine design changes for Tier 2
  - Combustion efficiency improvements
  - Reduced oil consumption

Increased use of low and ultra-low sulfur diesel fuel for off-highway applications

EPA 2012 mandate for large refineries

Tier 4 requirements will be more stringent and may require the use of:
- Diesel Particulate Filters (DPFs)
- Diesel Oxidation Catalysts (DOCs)
- Selective Catalytic Reduction (SCR)
General OEM Trends (Drivers)

EPA Requirements

Line Haul PM, g/bhp-hr

- Tier 0 '01
- Tier 1 '02
- Tier 2 '05
- Tier 3 '12
- Tier 4 '15

Line Haul NOx, g/bhp-hr

- '02 Trucks
- '98 Trucks
- '91 Trucks
- '94 Trucks
- '07 Trucks

Brazil does not set emission requirements for railroad
Majority of locomotives currently in service are Tier 0 & 1-compliant

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Potential Chemistry limits & Targets

- Zero phosphorus content
- Zero zinc content
- Limiting SASH content
  - Low/Zero ash component

- Better oxidation control
- Seals compatibility
- Improved wear protection
- Improved Base retention
General OEM Trends (Drivers)

- Thousands of new locomotives (EMD & GE) have been added to Class 1 RR fleets since 2005 -- effectively address emissions & more fuel efficient
  - Both OEMs offer Contract Maintenance

- Emission Regulations have impacted engine design
  - GE developed the “EVO” engine to meet Tier 2 and beyond
  - EMD re-designed their 710 series 2 cycle engine to meet Tier 2
  - Both EMD and GE are developing Tier 4 compliant locomotives
  - Fuel sulfur levels are decreasing around the world

- Alternate Fuels
  - GE and EMD are investigating LNG technology in their locos
  - GE and EMD are investigating Bio Diesel in their locomotives

- Both GE and EMD are looking outside of NA for growing locomotive/engine sales

- Base Oil availability & quality is receiving more attention
Muito Obrigado!

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Cel. 55 21 98196-9844