VTAE Oils in Asphalt

Rocky Mountain User/Producer Group
The Coeur d’ Alene
Coeur d’ Alene, Idaho
15 October 2014

by
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and
Safety-Kleen, Clean Harbors Inc.
Al Palmer & Steve Lewis

The Industry

• Two (2) Sectors
  – Re-refiners
    • Multi-Step Selective Processes
    • Provide on purpose products for reuse
      – Distillate fuels
      – VGO’s
      – Lube bases
      – VTB’s for use in asphalts
  – Recycled Fuel Oil (RFO’s) Processors
    • Simplified processes (dehydration) when used
    • Provide
      – Low grade, off-spec fuels
      – Extender blend stock without treatment
        » Off shore use
Re-refiners

Definition:
Auto & industrial oils recycled through a selective process of collection, stringent qualification and re-refining of non-hazardous oils.
Historically product used in asphalt is commonly referred to as ‘Heavy’ Vacuum Tower Bottoms (VTB’s).

• New definition
  – Vacuum Tower Asphalt Extender (VTAE)
• To replace:
  – RREO, Re-refined Engine Oils
  – Asphalt Flux, Flux
  – Heavy Vacuum Tower Bottoms, VTB’s
Recycled Fuel Oil (RFO’s) Processors

- Description:
  Collected oils reused with only minimal processing, typically dehydration via simple gravity, chemical and/or heat methods of dewatering.
  Used as low grade, ‘off spec’ burner fuels or extenders for standard fuels.

North American Used Oil Market

- Lube oils sold in North America: ≈ 8.3 million tons / yr.
- How Used / Distribution:
  - Consumed in Use: 4.3 million tons / year (≈ 52%)
  - Disposed of: 1 million tons / year (≈ 12%)
  - Burned: 2 million tons / year (≈ 24%)
  - Re-Refined: 1 million tons / year (≈ 12%)
  - Other Uses: 0.3 million tons / year to (≈ 4%)
Trends in Used Oil Disposition

- **Increased collection rates**
  - Environmental awareness
  - Economic value of used oil

- **Increases in regulations on used oil burning**
  - EPA's Definition of Solid Waste rule could greatly restrict burning of off-spec used oil fuel
  - Restrictions on burning in space heaters

- **“Consumed in Use” category will slowly decline**
  - Vehicle emissions standards
  - Less waste in industrial processes
Used Oil Availability

- The amount of used oil collected will remain relatively flat
  - Longer drain intervals will be offset by more cars on the road and improved collection rates
- Low natural gas prices and efforts to restrict burning will help to make used oil more available to re-refiners
- Seasonal trends will continue
  - More used oil generated in the summer
  - Hot mix asphalt plants are a major outlet for used oil fuel; their peak season is in the summer

Existing Re-refineries

North American Re-refining Capacity

- Capacity (thousands of tonnes/year)
- Year

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Growth in the Re-refining Market

- Growth in the market is being supported by:
  - Availability of capital
    - Ability to buy “proven” technology
  - Low natural gas prices
    - Used oil fuel burners are converting to natural gas
  - Acceptance of re-refined oil in the market
    - Supported by Valvoline’s entry into the market
  - Sustainability initiatives
## Existing Re-refineries

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Capacity, k tons/yr</th>
<th>Lube Quality</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evergreen / [S-K / Clean Harbors]</td>
<td>Newark, CA</td>
<td>67</td>
<td>Group II</td>
<td>1986 / 2013</td>
</tr>
<tr>
<td>Newalta</td>
<td>North Vancouver, BC</td>
<td>67</td>
<td>Group II</td>
<td>1986</td>
</tr>
<tr>
<td>Safety-Kleen / Clean Harbors</td>
<td>Breslau, Ontario</td>
<td>167</td>
<td>Group II</td>
<td>1988</td>
</tr>
<tr>
<td>Safety-Kleen / Clean Harbors</td>
<td>East Chicago, IN</td>
<td>366</td>
<td>Group II</td>
<td>1991</td>
</tr>
<tr>
<td>Bango</td>
<td>Reno, NV</td>
<td>40</td>
<td>Group II</td>
<td>2008</td>
</tr>
<tr>
<td>Universal Lubricants</td>
<td>Wichita, KS</td>
<td>40</td>
<td>Group II</td>
<td>2009</td>
</tr>
<tr>
<td>Heartland</td>
<td>Columbus, OH</td>
<td>40</td>
<td>Group II</td>
<td>2009</td>
</tr>
<tr>
<td>Heritage – Crystal Clean</td>
<td>Indianapolis, IN</td>
<td>167</td>
<td>Group II</td>
<td>2012</td>
</tr>
<tr>
<td>Southeastern Petroleum</td>
<td>Chester, SC</td>
<td>15</td>
<td>Group I</td>
<td>2012</td>
</tr>
<tr>
<td>Greenview Technologies</td>
<td>Rollinford, NH</td>
<td>10</td>
<td>Group I</td>
<td>2012</td>
</tr>
<tr>
<td>Avista / Universal Environ.</td>
<td>Peachtree, GA</td>
<td>100</td>
<td>Group I</td>
<td>2013</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td></td>
<td><strong>1,116</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Announced Re-refineries

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Capacity, k tons/yr</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama Green Lubricants</td>
<td>Childersburg, AL</td>
<td>90-117</td>
<td>2014 / 2015</td>
</tr>
<tr>
<td>VeroLube</td>
<td>Bowden, Alberta, Canada</td>
<td>35</td>
<td>??</td>
</tr>
<tr>
<td>VeroLube</td>
<td>Houston, TX</td>
<td>200</td>
<td>??</td>
</tr>
<tr>
<td>Heritage – Crystal Clear</td>
<td>Indianapolis, IN</td>
<td>92 increase</td>
<td>2014</td>
</tr>
<tr>
<td>Lubricycle</td>
<td>Bucks County, PA</td>
<td>??</td>
<td>??</td>
</tr>
<tr>
<td>FCC Environmental</td>
<td>Baltimore, MD</td>
<td>133</td>
<td>2015</td>
</tr>
<tr>
<td>NexLube</td>
<td>Tampa, FL</td>
<td>80</td>
<td>??</td>
</tr>
<tr>
<td><strong>Additional Capacity</strong></td>
<td></td>
<td><strong>≥ 630</strong></td>
<td></td>
</tr>
</tbody>
</table>
Major Vacuum Distillation Oil (VDO’s) Producers

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Capacity, k tons/yr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omega</td>
<td>Marrero, LA</td>
<td>167</td>
</tr>
<tr>
<td>DK</td>
<td>Compton, CA</td>
<td>167</td>
</tr>
<tr>
<td>Noble Oil</td>
<td>Stanford, NC</td>
<td>100</td>
</tr>
<tr>
<td>Vertex</td>
<td>Baytown, TX</td>
<td>77</td>
</tr>
<tr>
<td>Veolia</td>
<td>Montreal, PQ</td>
<td>53</td>
</tr>
<tr>
<td>ORRCO</td>
<td>Portland, OR</td>
<td>30</td>
</tr>
</tbody>
</table>

North American Used Oil Facilities
Re-refining Technology

- Distillation followed by hydro-treatment is still the predominant process
  - Short path evaporators have largely replaced thin film evaporators
- Some small distillation / clay contact processors still exist
  - Greenview Technologies recently started up with this technology in New Hampshire
- Avista / Universal Environmental started up their distillation / solvent extraction plant in Georgia in 2013

The Product
**Perceptions - Misconceptions**

- “It is an asphalt”
- Referred to as “flux”
  - a roofing asphalt terminology
- “It contains wax”
  - waxes in asphalt may mean poor performance
- “It is ‘bad’ for asphalt”
  - use reduces an asphalt’s performance
- All recycled oils are the same
  - lack of industry understanding

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**Reality**

- Provides numerous benefits to asphalt used in:
  - Paving
  - Roofing
  - Industrial
- Does not contain wax
- Not an asphalt
- Easy & safe to use
- Provides ‘Green’ / Sustainable benefits
# General Composition

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Results, Approximate 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash, %</td>
<td>AASHTO T 111</td>
<td>5.7 - 8.8</td>
</tr>
<tr>
<td>Water, %</td>
<td>ASTM D 95</td>
<td>0.0 - 0.0</td>
</tr>
<tr>
<td>Asphaltenes</td>
<td>2.6 - 6.6</td>
<td></td>
</tr>
<tr>
<td>Polar Aromatics</td>
<td>ASTM D 4124, SARA Fractions by Iatroscan</td>
<td>44.7 - 51.9</td>
</tr>
<tr>
<td>Naphthene Aromatics</td>
<td>0 - 0</td>
<td></td>
</tr>
<tr>
<td>Saturates</td>
<td>52.7 - 41.5</td>
<td></td>
</tr>
<tr>
<td>Wax, %</td>
<td>EN 12606-1</td>
<td>0.28 - 0.1</td>
</tr>
<tr>
<td>Solubility, %</td>
<td>ASTM D 2042</td>
<td>99.3 - 98.7</td>
</tr>
</tbody>
</table>

1. Based on 5 sources using various re-refining processes

# General Physical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Results, Approximate 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>15.6°C</td>
<td>0.920 - 0.975</td>
</tr>
<tr>
<td>RTFOT Mass Change, %</td>
<td>ASTM D 2872</td>
<td>-0.16 - 0.45</td>
</tr>
<tr>
<td>TFOT Mass Change, %</td>
<td>ASTM D 1754</td>
<td>-0.13 - 0.40</td>
</tr>
<tr>
<td>Flash Points, °F</td>
<td>ASTM D 92</td>
<td>≥ 550 2</td>
</tr>
<tr>
<td>Rotational Viscosity, cps</td>
<td>70°C</td>
<td>1,000 - 4,000</td>
</tr>
<tr>
<td></td>
<td>135°C</td>
<td>≤ 300</td>
</tr>
<tr>
<td>Absolute Viscosity, P</td>
<td>60°C</td>
<td>1,500 - 5,000</td>
</tr>
</tbody>
</table>

1. Based on 5 sources using various re-refining processes
2. Meets roofing requirements
Uses

- History
  - Initial Technology from Europe
  - Established in North America in the 1980’s
  - ‘VTB’s’ used in asphalt ≥ 1.7 MM tons since 1990
- Paving
- Roofing
- Industrial

Paving Uses:

- Hot Mix Asphalt Binders
  - PG, PMA’s, Penetration & Viscosity Graded
- Cold Mix
- Crack and Joint Sealants
- Pavement Maintenance & Rehabilitation
Paving – PG & Other Binders

• Benefits (Dosage Dependent)
  – Improve Cold Temperature Properties
    • PG (PAV Properties), Fraass, Low Temperature Pens
  – Reduce Viscosity
  – Improves Resistance to Aging
  – Extends Conventional Asphalt
  – Reduces Carbon Footprint
  – Compatible with Nearly All Asphalts
  – Long History of Use

Paving – Pavements /Asphalt Cements

• Pavements with VTAE Modified Binders
  – Suitable for Base & Wearing Courses, provides:
    • Improved Fatigue Crack Resistance
      – Fracture Energy, TX Overlay, Beam Fatigue
    • Improved Thermal Crack Resistance
    • Improved Resistance to Oxidative Aging (Wearing Courses)
    • Improved Rheological Profile (easier to compact)
    • No Change in:
      – Resistance to Water (Hamburg, T-283. Modified Lottman)
      – Aggregate Adhesion
      – Rut Resistance (APA)
Roofing Uses:

• Steep Slope Roofing / Shingles
• Low Slope Roofing:
  – BUR (Mopping) Asphalts
  – Underlayments
    • Saturated Felts
    • Peel-n-Stick Membranes
  – BUR Roofing Membranes
  – Modified Bitumen Membranes
• Repair & Maintenance Products
  – Cutback Based Coatings, Cements & Mastics

Roofing - Shingles

• Air Blown Shingle Coatings & BUR’s:
  – Dosage Dependent
    • Extender
    • Improved SP – Pen relationships
    • Improved Resistance to Weathering / Aging
    • Improved Cold Temperature Flexibility
    • Improved Process Viscosities
    • Compatible in Nearly All Fluxes
    • History of Use
Roofing – Underlayments

• Saturated Felts
  – Extender
  – Improved Saturation Process
  – Compatible in Nearly All Saturates

• Peel-n-Stick Membranes
  – Improved Viscosity Profile
  – Improved Surface Tension
  – Compatible in Most P-n-S Compounds

Roofing – BUR & MB Membranes

• BUR Membranes
  – Air Blown Coatings
  – Saturates
  – Extender
    - Reduced Carbon Footprint
  – Cold Applied Systems

• MB Membranes
  – Compatibilizer for Polymers
  – Viscosity Modifier
Roofing – Repair & Maintenance

• Cutback Based Coatings & Cements
  — Extender / Replacement
  — Lubricity Additive

Industrial

• Below Grade Water & Damp proofing

• Extender

• Metal Coatings

• Building Mastics (Wraps, Caulks & Sealants)
Limitations

• Dosage Dependent
• Quality Variance by Re-refiner
  – Dependent Upon Process Used
• Not an Asphalt
• Misunderstood
  – Perceptions

Current Status

• ASTM Specification Developed
  – Initial presentation for ballot
• NORA, North America Re-refiners Association
  – Industry specification to be issued
• Technical Studies Starting or In-Progress
  – University of Illinois, Illinois DOT
  – University of MA at Dartmouth, 8 NE States, MA DOT
  – Ontario, Canada
S-K Studies & Publications

• CTAA, November, 2012: Binders w/ VTAE’s
  — Full PG Grading + Select Properties
    • 2 base asphalts x 2 VTAE’s @ 5 Dosages
• CTAA, November, 2013: SP 12.5 mm Mixes
  — Complete Mix and Performance Properties
    • Dolomite Aggregate (Poor) x 2 base binders w/ 5 dosages
    • Three Levels of Accelerated Aging, Initial, 8-10 & 15-18 years
    • Performance Properties
      — Dynamic Modulus & Flow No., FE, Hamburg, Beam Fatigue, IDT

S-K Studies to be Published

• SP 12.5 Mix w/ RAP
• SP 12.5 Mix w/RAS
Special Thanks

PRI offers special thanks to Safety-Kleen’s (Mark Bouldin, PhD, William (Al) Palmer, Rodney Walker & Steve Lewis) a Division of Clean Harbors, Inc. for providing the invaluable history, information and data on the re-refining industry of industrial and automobile oils.