

State-of-the-Knowledge Document on the Use of REOB/VTAE in Asphalt

Asphalt Binder ETG Meeting

Fall River, MA

September 13, 2016

- **Task Force**
 - 18 month effort
 - 19 individuals from member companies, AI staff & a FHWA liaison
- **Document: “State-of-the-Knowledge: The Use of REOB/VTAE in Asphalt”**
 - approved by AI’s Technical Advisory Committee and HS&E Committee, April 12-13
 - 6 sections, ~60 pages of discussion (plus 42-page appendix that provides summary of each of the 26 published papers)
 - Designed to provide an objective and thorough review of all available information
 - Included extensive review process
 - Becomes AI’s official document on REOB/VTAE

1) General Overview & Intent of Educational Document

- Carefully defines REOB/VTAE as the non-distillable residuum from a vacuum tower in a used oil re-refinery

2) REOB / VTAE Production Overview

- Description of re-refining process from collection of used oils to REOB/VTAE production

3) Literature Review of REOB / VTAE Use and Performance in Asphalt Industry

- Review of 26 published papers pertaining to REOB/VTAE (published prior to Jan 1, 2016)

4) HSE Aspects

- Data provided demonstrating the re-refining process removes carcinogens present in the unrefined used oils
- Leaching studies show no differences between REOB/VTAE modified asphalts & unmodified asphalts
- Data shows similar fume composition for unmodified asphalt and REOB/VTAE modified asphalts

5) Discussion of Alternate Tests & Aging Protocols

- Recommend ΔT_c after 40 hours of PAV be explored as an improved method for characterizing long-term binder embrittlement
- Assist with formulation & forensic analysis, but not to be used as a purchase specification

6) FAQs by Agencies and the Answers

- Provides answers to 21 frequently asked questions

- Announced the release of IS-235, *State-of-the-Knowledge: The Use of REOB/VTAE in Asphalt* at AASHTO SOM Annual Meeting in Greenville, SC in August
- Available as free PDF download at:
asphaltinstitute.org/re-refined-engine-oil-bottom/
- Available as a free eBook at:
bookstore.asphaltinstitute.org/reobvtae

- <http://www.asphaltinstitute.org/re-refined-engine-oil-bottom/>
- 26 published papers
 - Linked to published journal
 - Current through December 2015
- 30+ presentations at recent FHWA Expert Task Group (ETG) meetings and other industry meetings
 - Download directly



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Re-refined Engine Oil Bottom

The Asphalt Institute's Technical Advisory Committee has formed a task force on re-refined engine oil bottoms (REOB), also known as Vacuum Tower Asphalt Extender (VTAE). The objectives of this REOB task force are to:

- Learn more about REOB/VTAE materials, processing, effects/benefits when blended in asphalt and best practices.
- Recommend a course of action for Asphalt Institute that could include sponsoring a symposium, conducting research and/or developing information and guidance on REOB modification that may be similar to IS-220 for PPA modification.

Toward those objectives, the task force has developed this repository of REOB/VTAE information and wanted to share it with industry.

Members:

As an Asphalt Institute member you may submit Technical Question to AI Engineering Staff
You may also view all of the Asphalt Institute Regional Engineer Quarterly Reports

Re-refined Engine Oil Bottom Residue Information:

Published Papers

TITLE	AUTHOR(S)	PUBLICATION DATE
Use of Re-refined Oil Distillation Bottoms As Extenders For Roading Bitumens	P.R. Herrington	Journal of Materials Science – Vol. 27 No. 24 – December 1992
Waste Oil Distillation Bottoms As Bitumen Extenders	P.R. Herrington, V.K. Dravitzki, C.W.B. Wood, and J.E. Patrick	Road & Transport Research – Vol. 2 No. 4 – December 1993
Asphalt modification with used lubricating oil	Aaron Villanueva, Susanna Ho, and Ludo Zanzotto	Can. J. Civ. Eng. Vol. 35, 2008
Five Year Performance Review of a Northern Ontario Pavement Trial: Validation of Ontario's Double-Edge-Notched Tension Test (DENT) and Extended Bending Beam Rheometer (BBR) Test Methods	S.A.M Hesp, S.N. Genin, D. Scafe, H.F. Shurvell and S. Subramani	CTAA – 2009
Asphalt Cement Loss Tangent as Surrogate Performance Indicator for Control of Thermal Cracking	Abdolrasoul Soleimani, Shanan Walsh, and Simon A. M. Hesp	Transportation Research Record: Journal of the Transportation Research Board, No. 2126; 2009
Characteristics of Rejuvenated Bitumen With Used Lubricating Oil As Rejuvenating Agent	Kemas A. Zamhari, Madi Hermadi, Choy Wai Fun	International Conference On Sustainable Infrastructure and Built Environment in Developing Countries – November 2009 –

Thanks!

Asphalt Institute Background

Asphalt Institute (AI) supports the responsible modification of asphalt materials for improved performance and better life cycle costs, but does not endorse any specific or proprietary form of modification. Furthermore, AI encourages the continued development of performance related specs.

- REOB/VTAE Task Force formed in 2014 to develop a State-of-the-Knowledge document to become AI's official document on REOB/VTAE use
 - About 19 AI staff and members. Includes FHWA liaison.
 - Many F-T-F and WebEx mtgs.
- Synthesized literature and other info.
 - Available to public

Section 1: Introduction

Purpose

- Need for objective and thorough review of available information
- Help agencies and others make informed decisions
- Focus on paving asphalts, not roofing

Section 1: Introduction

Scope

- “REOB/VTAE” herein refers to the residual distillation product from a vacuum tower in a re-refinery of used lubricating oil.
 - Not cleaned up WEO, or residual from only atmospheric tower or simpler used oil re-refinery
 - Not residual from a vacuum tower of a crude oil refinery (that’s asphalt!)

Terminology

- “REOB” is prevailing term by States and FHWA, while “VTAE” is preferred term by manufacturers
 - This document uses “REOB/VTAE”
 - Both “Re-refined” and “Vacuum tower” are important descriptors for this specific product (as defined above)

Many Names in the Literature

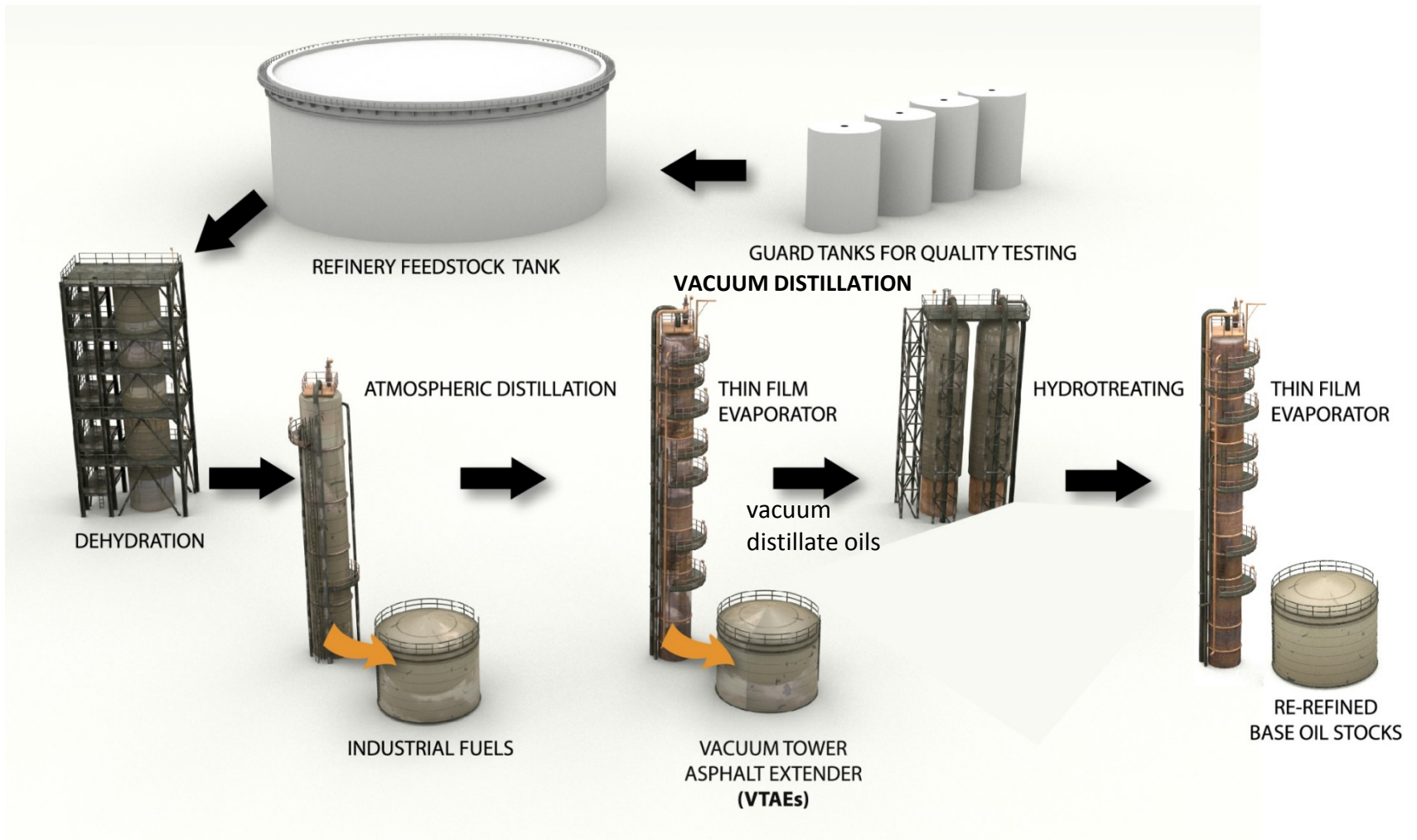
TABLE 1. Various Names Associated with REOB / VTAE

Acronym	Name
	Asphalt Flux
	Asphalt Blowdown
EOR	Engine Oil Residue
RHVDB	Re-refined Heavy Vacuum Distillation Bottoms
RHVDO	Re-refined Heavy Vacuum Distillation Oil
REOB	Re-Refined Engine Oil Bottoms
RVTB	Re-refined Vacuum Tower Bottoms
VTB	Vacuum Tower Bottom
VTAB	Vacuum Tower Asphalt Binder
VTAE	Vacuum Tower Asphalt Extender
WEOR	Waste Engine Oil Residue
WODB	Waste Oil Distillation Bottoms

Background and Use

- REOB/VTAE used to soften binders since 1980s
 - Lowers both high and low continuous PG grade
- Heightened use of blending agents to soften binders
 - Increased rates of RAP and RAS require softer grades to meet combined blend
 - Limit of crudes & refineries to produce softer grades without back blending
- FHWA testing revealed 20% of samples had REOB/VTAE
- Some states expressed concerns, even banned
- Manufacturers report typical dosages 4-8%
 - Also report 160K tons produced annually in N.A.
 - Represents roughly 0.5% of asphalt produced in N.A.
 - May not represent all re-processed engine oils in market

Section 2: Production of REOB/VTAEs



Section 3: Literature Review

- 26 published papers
 - 1992 through 2015
- Unbiased review
 - Some favorable (use is beneficial or not detrimental)
 - Some not so favorable (use is harmful or detrimental)
- Listed chronologically in a table
- Summary of papers (13 pages)
- Detailed summaries in Appendix (41 pages)

- Credit goes to Greg Harder

Detrimental (harmful)

- REOB/VTAE - (11)
 - 8 papers by Hesp et al.
 - 2 papers (same) by Zaumanis
 - 1 paper by Uzarowski

- Waste engine oil (WEO) – (3)
 - 2 papers (same) by Zaumanis
 - 1 paper by DeDene

Not Detrimental (Beneficial)

- REOB/VTAE – (11)
 - 3 papers by Herrington et al.
 - 1 paper by Villanueva
 - 2 papers by D'Angelo
 - 2 papers by Golalipour
 - 3 papers by Wielinski

- Waste Engine Oil (WEO) – (2)
 - 1 paper by Zamhari
 - 1 paper by Oliveira

- Current Superpave testing/specification doesn't properly predict field performance
- Need for additional aging/testing protocols
- Poor field performance of binders containing zinc
 - 15%+ REOB/VTAE estimated in binder
- Proposed extended aging/new test methods (DENT, ExBBR) would have predicted poor performance

Not detrimental

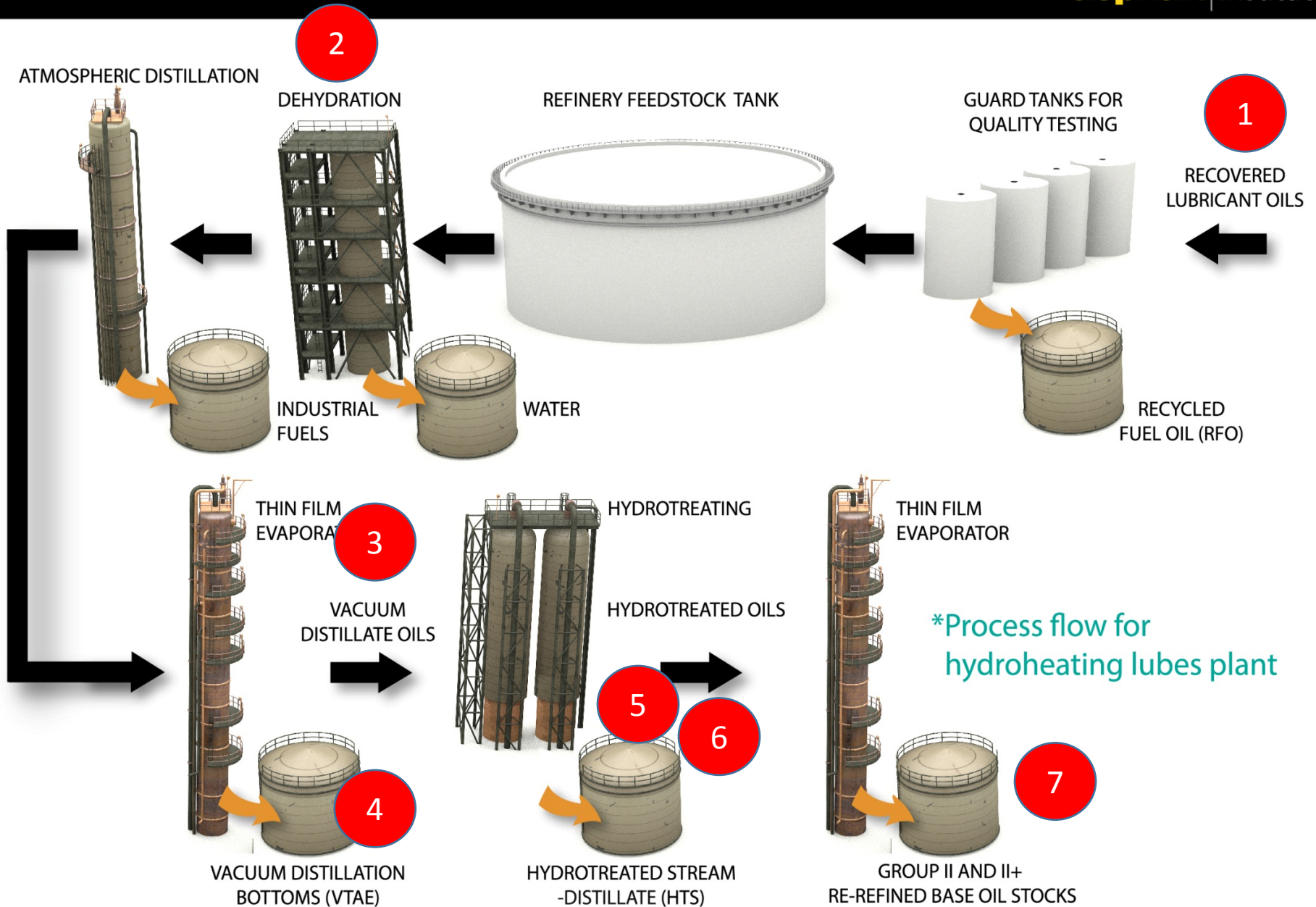
- Binder testing showed improved properties with most blends containing up to 10% REOB/VTAE (some binder testing done at 20%)
- Additional aging was included
- Mixture testing indicated equal or improved laboratory properties up to 10% REOB/VTAE
- Limited field data – one trial showed equal performance for REOB/VTAE after 57 months

Section 4: HSE Considerations

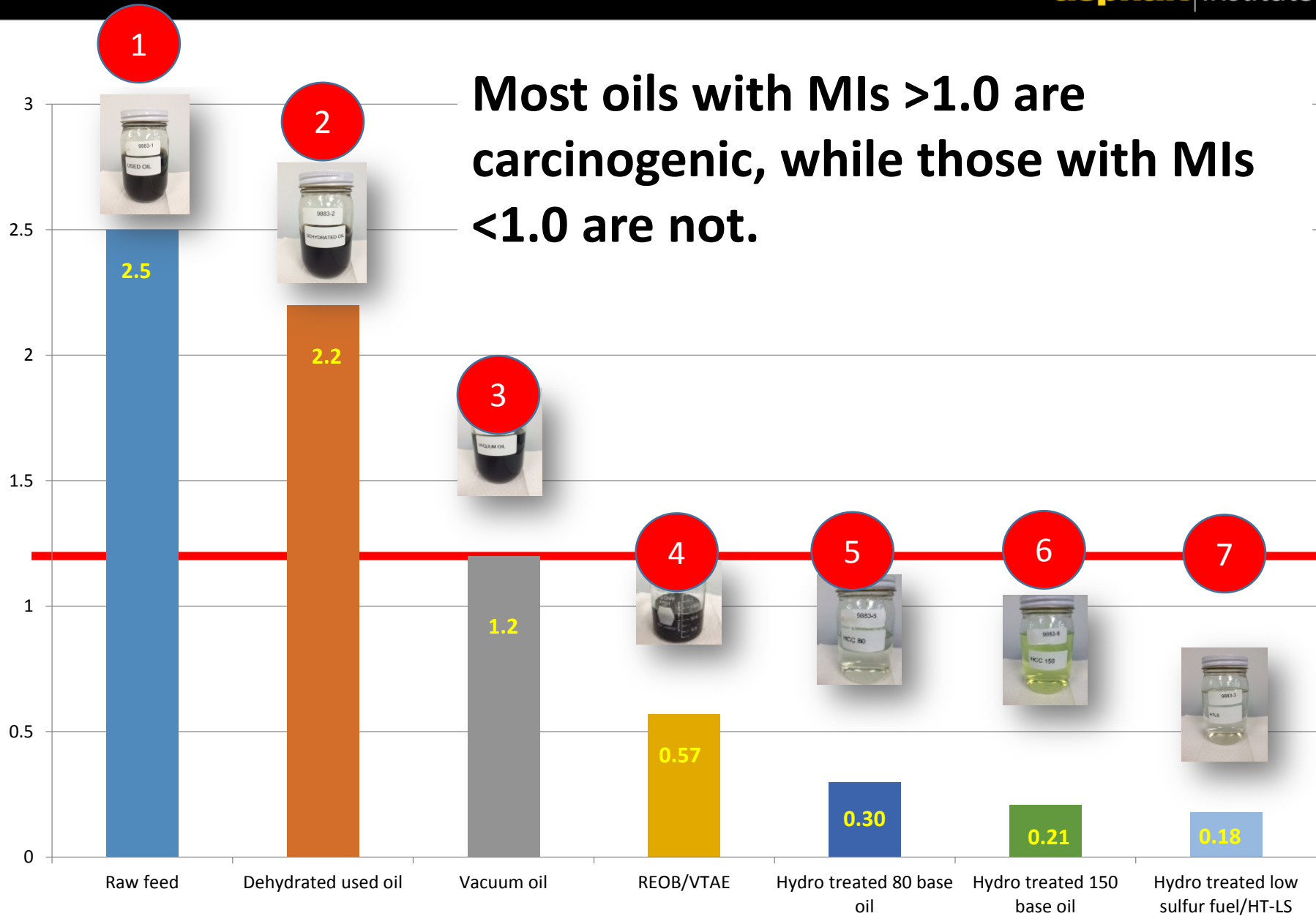
- Tested samples throughout the re-refining process for Mutagenicity Index (MI) and Polycyclic Aromatic Compounds (PACs)

1. Raw feed/unprocessed used oil
2. Dehydrated used oil
3. Vacuum oil
4. REOB/VTAE
5. Hydro treated 80 base oil
6. Hydro treated 150 base oil
7. Hydro treated low sulfur fuel/HT-LS

REOB / VTAE Processing



Mutagenicity Index



Section 5: Discussion of Alternative Tests, Parameters and Aging Protocols and Relation to Binder Durability/Performance

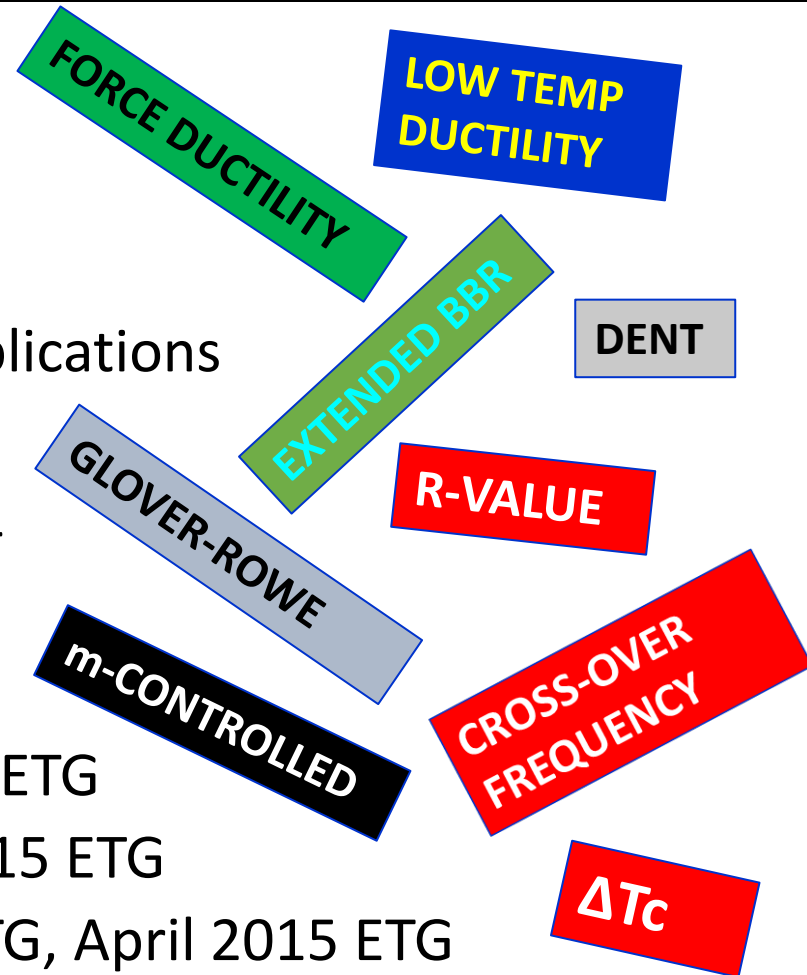
- Outline

1. Background Information

- a) Kandhal
- b) Hesp, et al, Numerous Publications
- c) Charles Glover
- d) Anderson, et al AAPT 2011
- e) Rowe, AAPT 2011

2. Recent Research

- a) Gibson, FHWA, April 2015 ETG
- b) Bennert, Rutgers, April 2015 ETG
- c) Reinke, MTE, Sept 2014 ETG, April 2015 ETG



All that research leads to...

- As binders age, they lose their ability to relax stresses, mechanical or thermal
 - Ductility decreases
 - ΔT_c becomes less (more negative)
 - R-Value increases & Cross-Over Frequency decreases
 - Glover-Rowe value increases
- Binder embrittlement in field can translate to early cracking (low temp and fatigue), raveling, aggregate loss
- Important to have a means of predicting when this is expected to become an issue

These are not only REOB/VTAE issues, these are general concerns for all binders

- Derived from standard BBR test

$$\Delta T_c = (T_{\text{critical, Stiffness}}) - (T_{\text{critical, m-value}})$$

- Negative value means m-controlled.
- ΔT_c becomes more negative as binder ages, loses ability to relax
 - Paraffinic additives, including REOB/VTAE, increase rate of decrease
 - Rate affected by type and amount of additives, crude source, and additive/binder interaction
- ΔT_c becomes more negative with RAP and especially RAS binder
- Correlates to other binder durability parameters
- $\Delta T_c < -5^\circ\text{C}$ for 40 hr PAV has been suggested to relate to onset of binder durability distress after about 5 years in field
 - Not suggesting spec change at this time. More work needed

Section 6: FAQs and Answers

- Twenty-one (21) FAQs Currently
 - Submitted by user agencies
 - Concise answers based on contents of document
- Serves as a Document Summary
- Key Themes:
 - 1) Definition/variability of REOB/VTAE used in asphalt modification
 - 2) Detection of REOB/VTAE in asphalt binders / mixes
 - 3) Appropriate use, limits of REOB/VTAE

Thanks!

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