ZSCHIMMER & SCHWARZ

EVALUATING THE DEPOSIT FORMING TENDENCIES OF INDUSTRIAL LUBRICANTS

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Gear Technical Track 1E
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EsterTec
synthetic esters

Deposit Formation Tendency of Esters

- Various synthetic esters have been used for decades to improve lubricant formulation polarity, enhancing the solubility of oxidation by-products in aging lubricants
- **How does the new ester class with VSP molecular structure perform in terms of reducing deposits and sludge compared to esters with the same viscosity?**
- A variety of laboratory techniques are used to simulate the accelerated oxidation of lubricants and determine how sludge and deposits can be prevented or minimized
- All tests were done on the base stock without additives

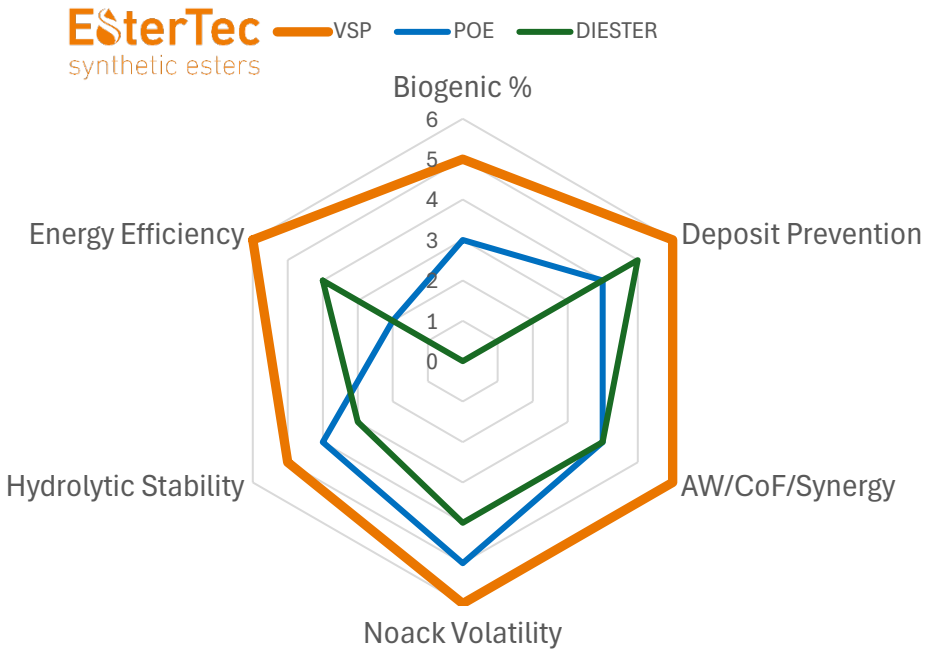
- All fluids were ISO 68
- Tested 20 hours at 260°C

VSP Molecular Structure

Laboratory Simulations of Lubricant Deposit Formation Tendency

Test	Method	Temperature	Environment	Water?	Catalyst	Screening Purpose
Oxidation						
OOT Oxidation Onset Temperature	ASTM E2009	Ramp	Air	No	None (aluminum pan)	All
RPVOT Rotating Pressurized Vessel Oxidation Test	ASTM D2272	150 °C	Oxygen	YES	Copper coil	Industrial
Deposits						
Panel Coker	FTM 791a	315 °C	Air	No	Steel panel (or other metal choice)	Engine Oils
3PP Three Phase Pan Test	Z&S	200 °C	Air	No	None (aluminum pan)	Industrial Gear/Chain
RCR Ramsbottom Carbon Residue	ASTM D524	550 °C	Air	No	None (glass)	All

EsterTec Delivers All the Performance Advantages Expected from a Standard Diester or Polyol Ester, Plus…



Standard POE Features

- Low Pour Point
- High Flash Point
- Low Foam Tendency
- Good Demulsibility
- Not Corrosive to Copper
- Good Oxidative Stability
- Strong Dielectric Properties
- Good Thermal Conductivity
- Clear with Low Odor & Color

EsterTec
synthetic esters

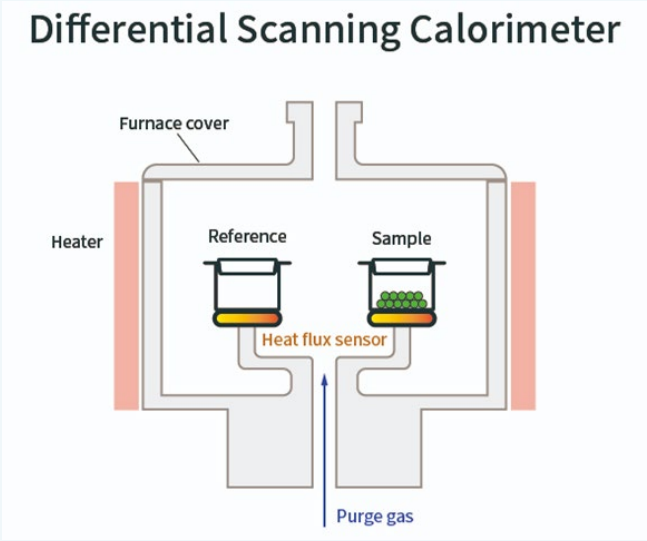
The VSP Molecular Technology Platform. Exceptional Performance in a Wide Viscosity Range.

Product Name	ESTERTEC 2N-1416	ESTERTEC 2LN-1418	ESTERTEC 2L-1425	ESTERTEC 2G-1432	ESTERTEC 7GX-1446	ESTERTEC 7GX-1468	ESTERTEC 8LX-14100	ESTERTEC 8LX-14150
KV100, cSt	3.6	4.1	5	7	9	11	14	18
KV40, cSt	16	18	25	32	46	68	100	150
Viscosity Index	115	125	140	180	165	155	140	130
Pour Point, °C	-60	-40	-25	-42	-40	-40	-35	-30
Density	0.895	0.893	0.890	0.890	0. 900	0.915	0.925	0.935
NOACK volatility, %	9	7	3	1	1	1	1	1
Biogenic Content, %	64	65	70	74	60	50	40	30
Oxidative Stability	☑	☑	☑	☑	☑	☑	☑	☑
Hydrolytic Stability	☑	☑	☑	☑	☑	☑	☑	☑
Friction/Wear Reduction	☑	☑	☑	☑	☑	☑	☑	☑
Energy Efficiency Advantage	☑	☑	☑	☑	☑	☑	☑	☑
Cost/Performance Advantage	☑	☑	☑	☑	☑	☑	☑	☑

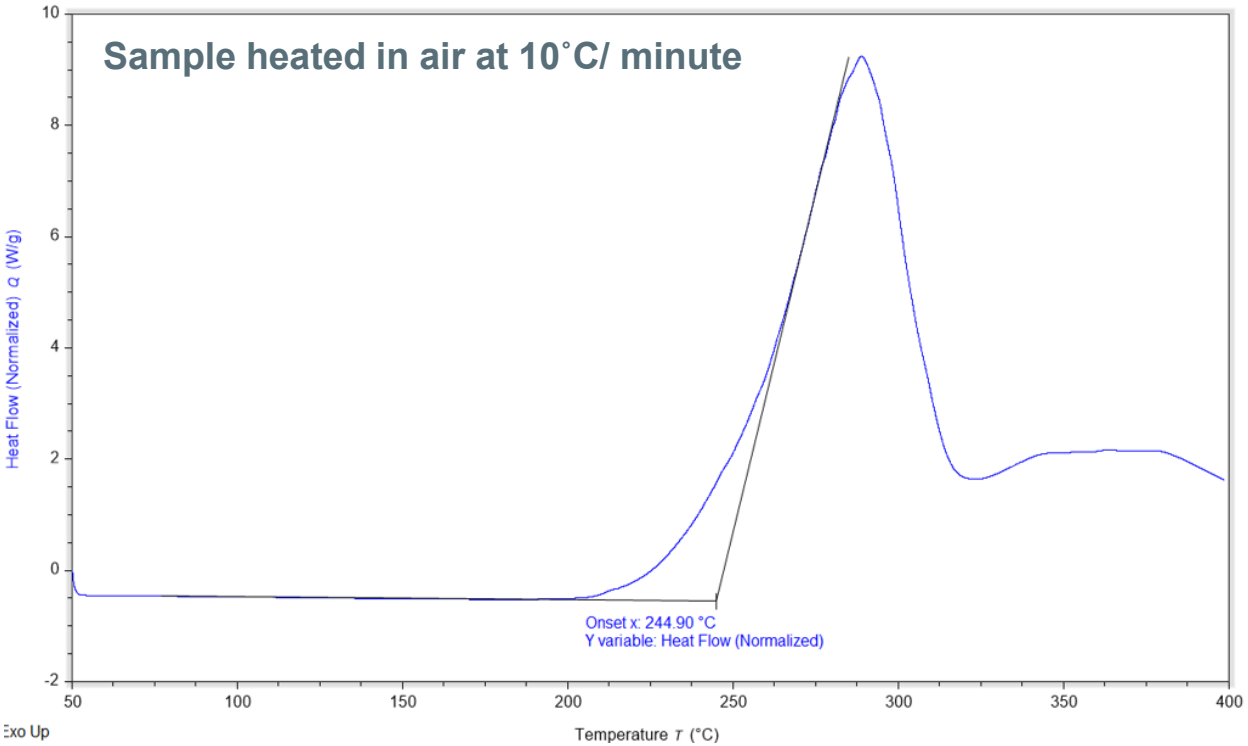
☑ = Equal or Better than standard synthetic esters

Oxidation Onset Temperature

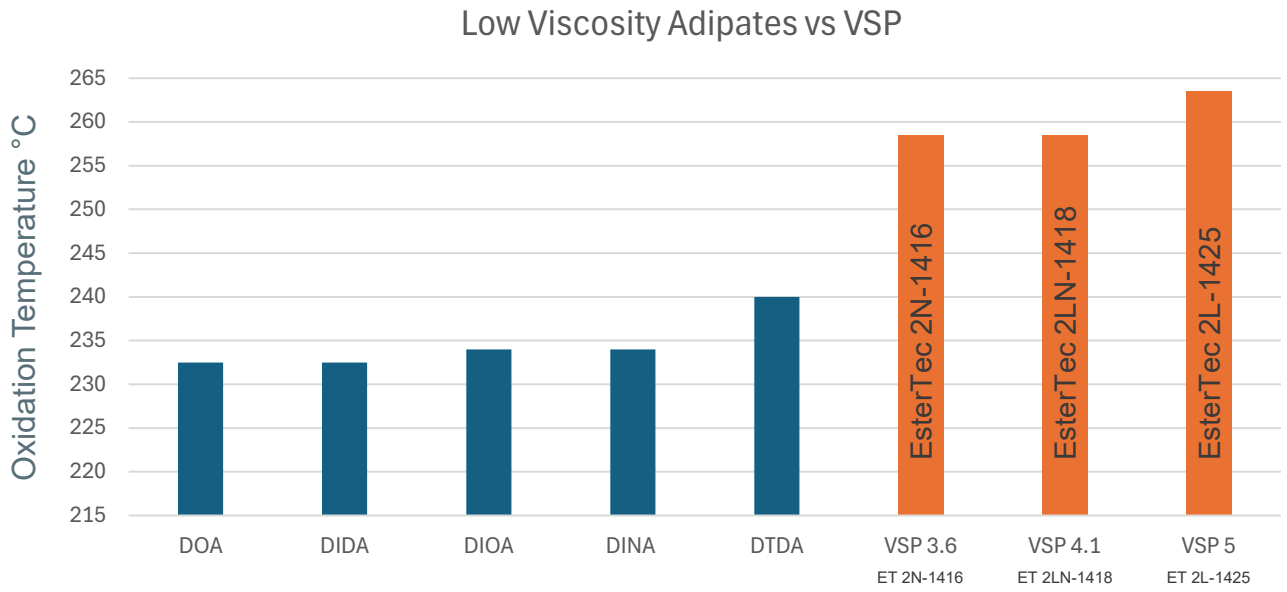
- Oxygen Onset Temperature by DSC
  - ASTM E2009 Method C
  - 1 Atm in air
  - ΔH 10˚C/ minute from RT to exotherm
  - Aluminum pan interface
- Industry standard technique for evaluating the initial oxidation temperature in air of lubricant components used in:
  - Engine oils
  - Industrial oils
  - Dielectric fluids
- Can be influenced by the initial TAN of the sample



DSC Scan Example

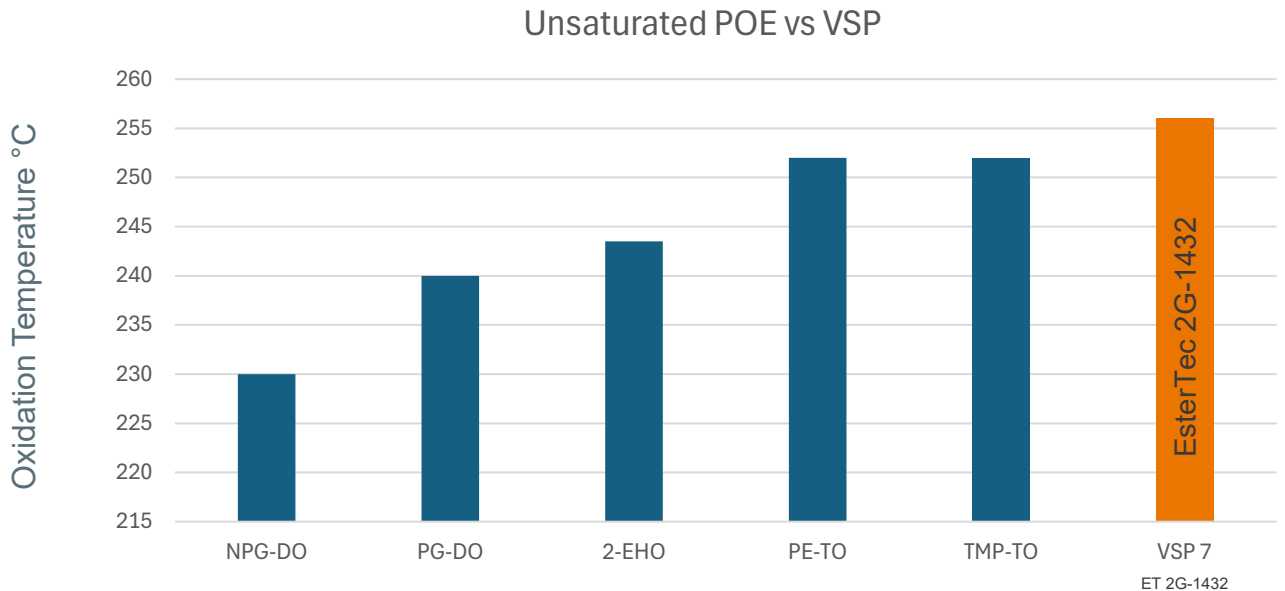


ESTERTEC VSP compared to Adipate Diesters



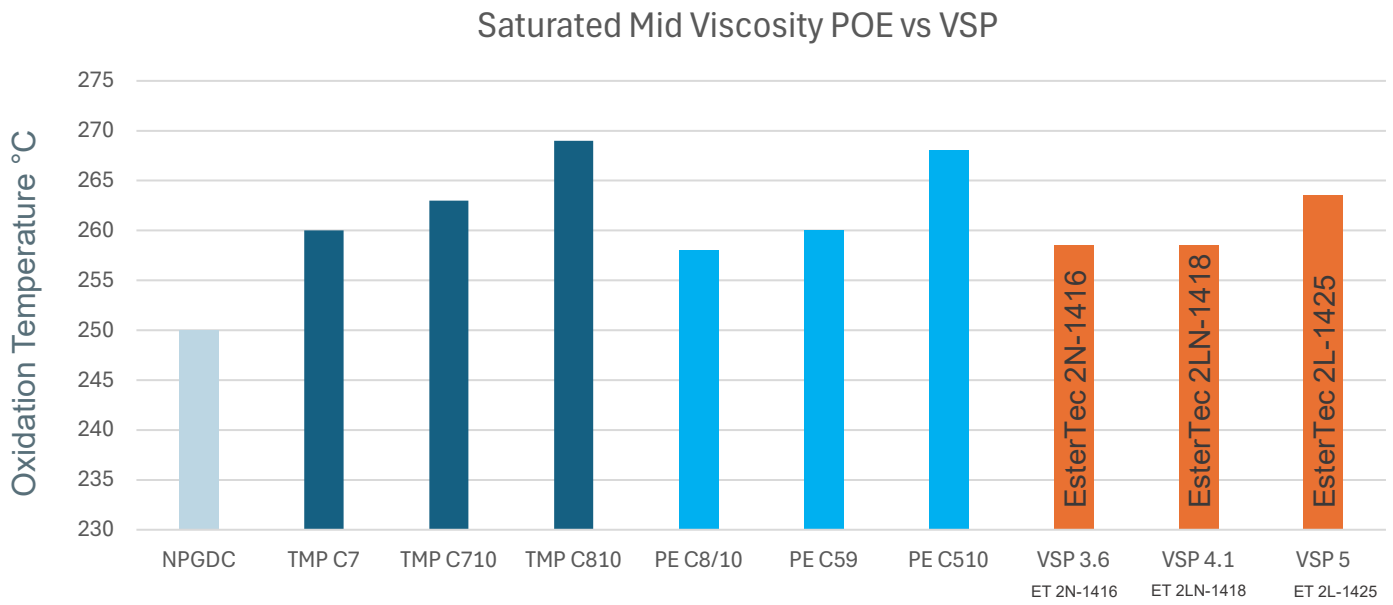
Saturated Adipate Diesters with KV100: 2.3 – 5.3 cSt
Relevant for Engine and Driveline oils

ESTERTEC VSP compared to Unsaturated Esters



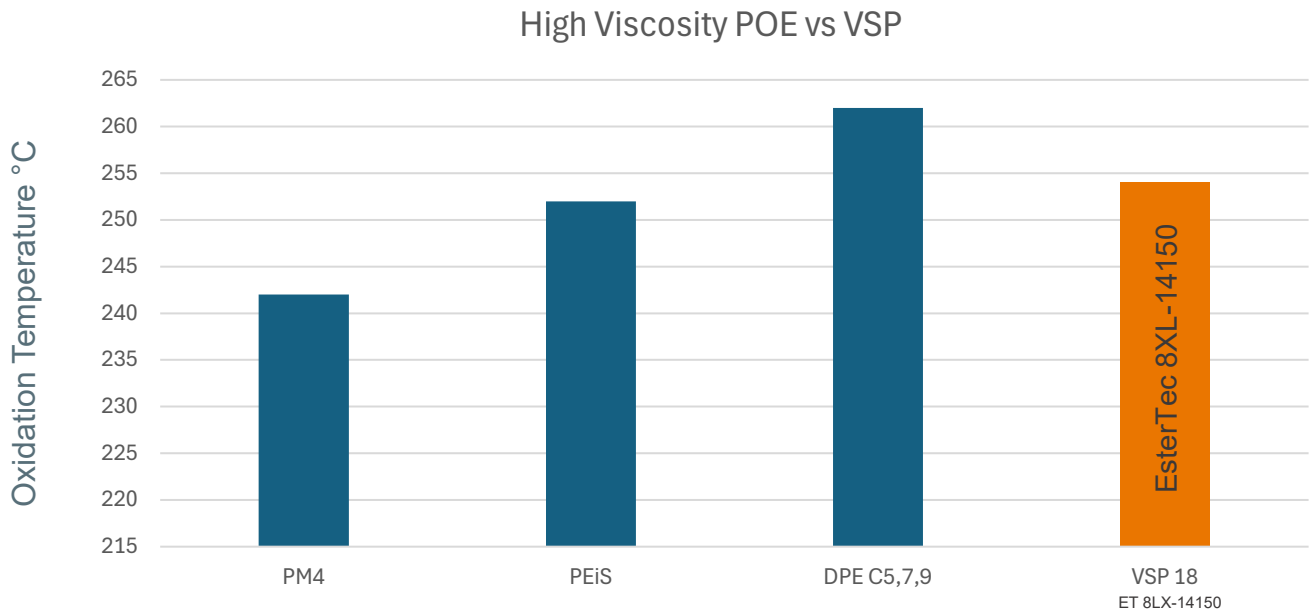
Unsaturated polyol esters with KV100: 5 – 12 cSt
Relevant for standard MW and Industrial Oils

ESTERTEC VSP compared to Saturated Polyol Esters



Saturated Polyol Esters with KV100: 3.5 – 6.5 cSt
Relevant for High Performance Industrial Oils

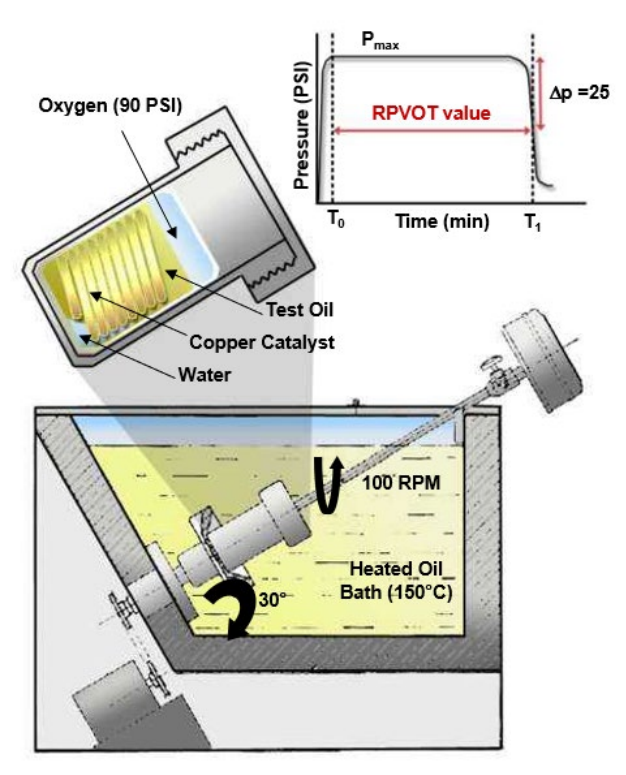
ESTERTEC VSP compared to High Viscosity Polyol Esters



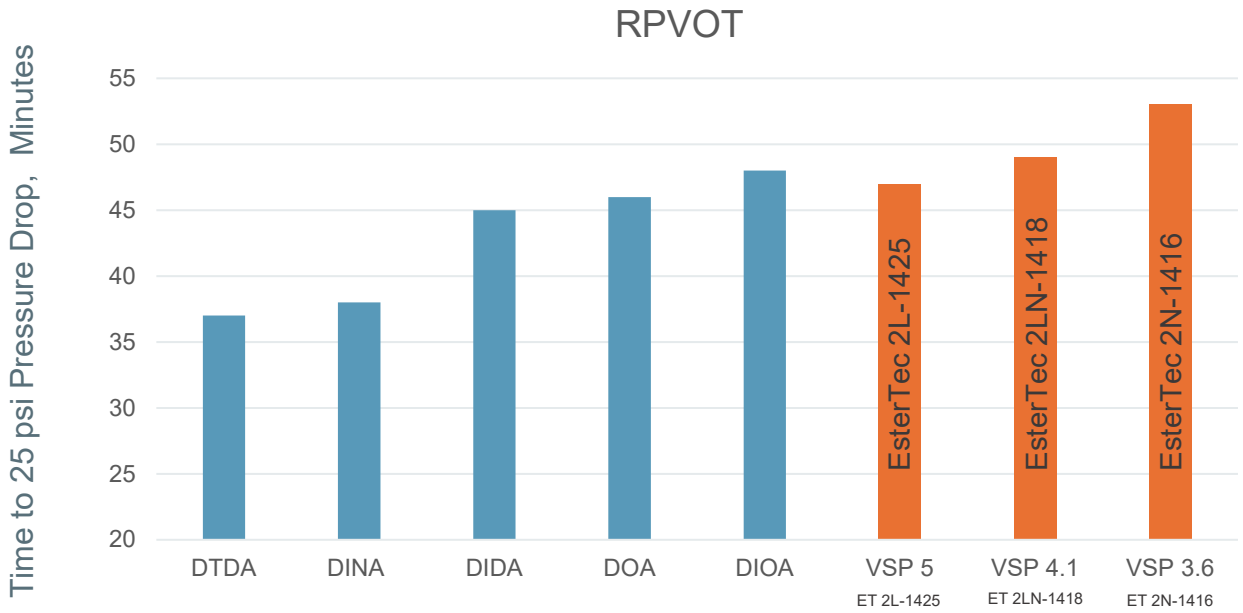
Saturated Polyol Esters with KV100: 15 – 20 cSt
Relevant for High Temperature Gear, Compressor and Oven Chain Oils

Rotating Pressurized Vessel Oxidation Test

- Rotating Pressure Vessel Oxidation Test
  - ASTM D2272
  - 50g Oil / 5 g water + Cu Coil
  - 90psi/150˚C/100 rpm
  - Time to pressure drop of 25.4 psi
  - Copper interface
- Relevant for Industrial lubricants:
  - Turbine bearing oils
  - Hydraulic fluids
- RPVOT is typically used to evaluate fully formulated lubricants. We are measuring base stocks with no antioxidants or stabilizer additives.

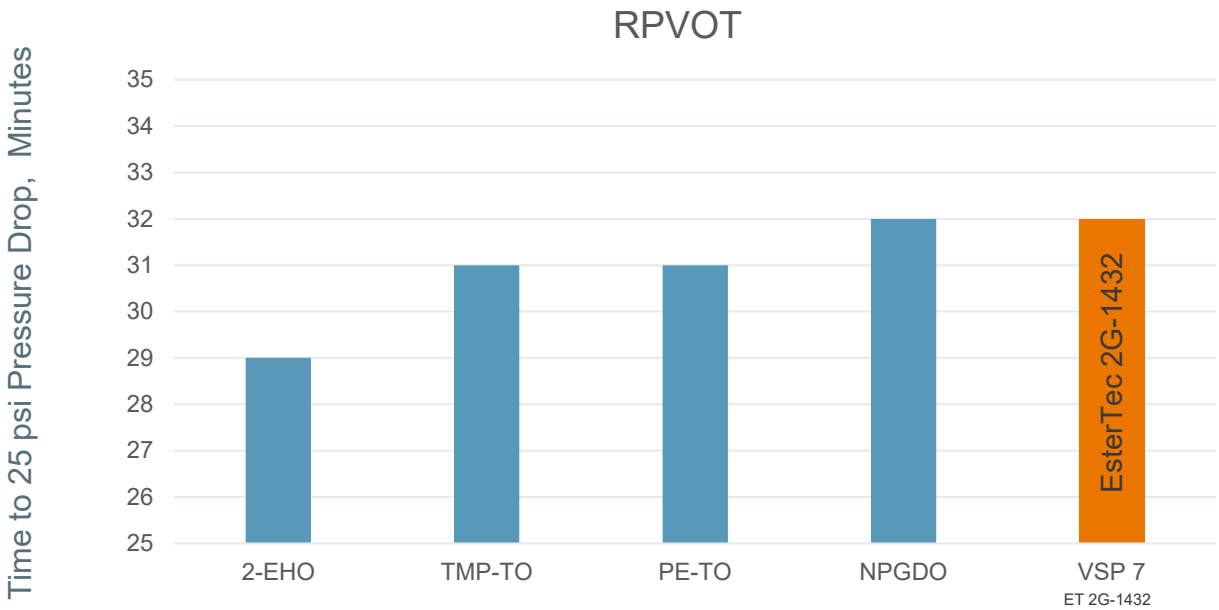


ESTERTEC VSP compared to Adipates Esters



Saturated Adipate Diesters with KV100: 2.3 – 5.3 cSt
Relevant for Engine and Driveline oils

ESTERTEC VSP compared to Unsaturated Polyol Esters



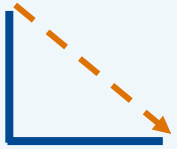
Unsaturated polyol esters with KV100: 5 – 12 cSt
Relevant for standard MW and Industrial Oils

OBSERVATIONS

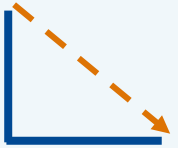
- VSP synthetic esters offer similar or higher Oxidation Onset Temperatures or RPVOT performance compared to:
  - Adipate diesters
  - Unsaturated polyol esters
  - Saturated mid-viscosity polyol esters
  - Many high viscosity polyol esters for high temperature applications

- VSP synthetic ester composition follows the common structure property relationships about chain length, linearity, branching and unsaturation

Oxidation Onset & Oxidation Life Trends



Unsaturation

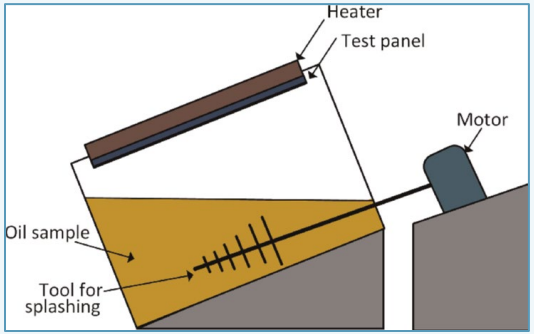


Chain length

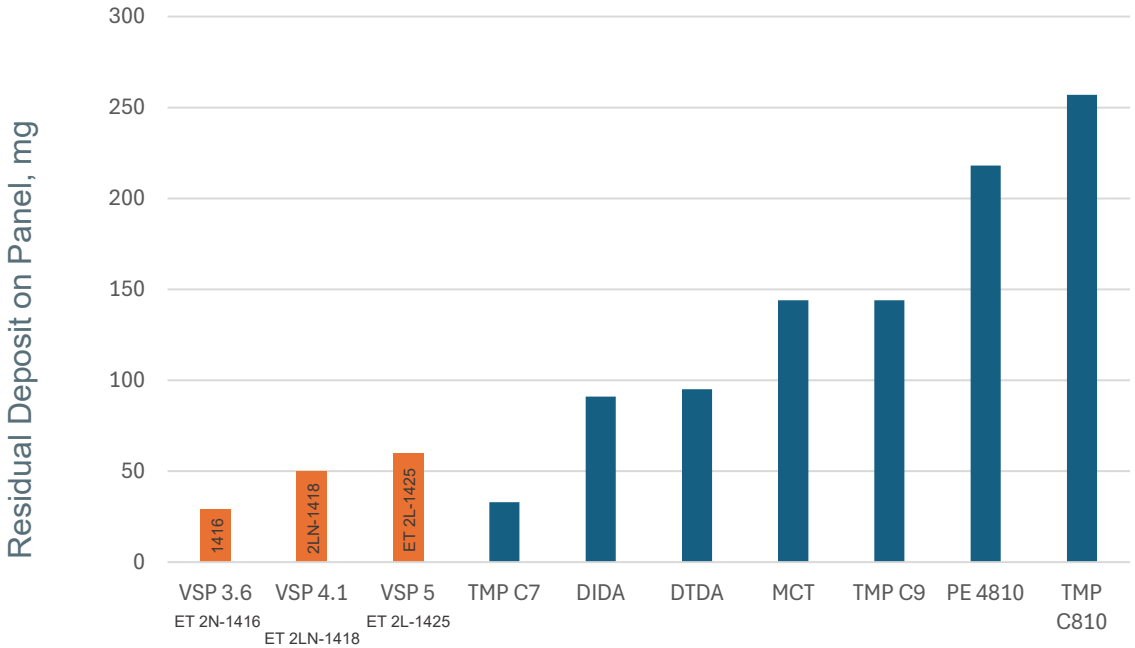
Branching

Panel Coker Test

- FTM 791a - 3462
  - Commonly Run @ 315°C for 8 hours
  - Steel interface (or any metal selected)
  - Oil is splashed on an inverted metal panel
  - Residual sludge deposits are measured by weight at the end of the test
- Relevant for:
  - Compressors
  - Bearings
  - Engine oils
  - High temperature industrial applications

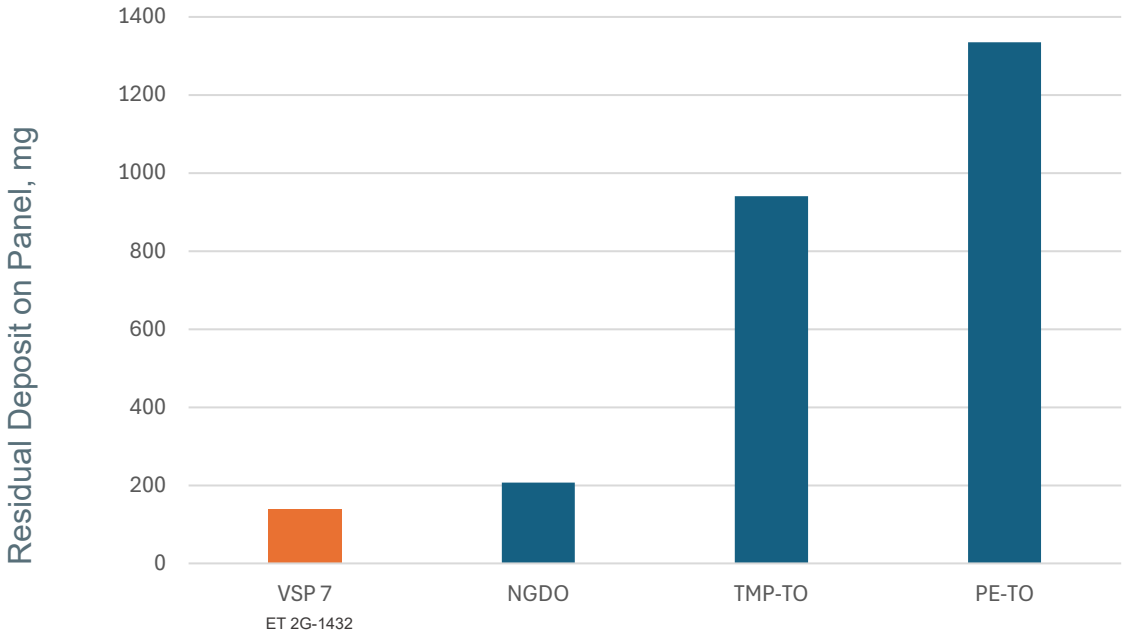


ESTERTEC VSP compared to Saturated Esters



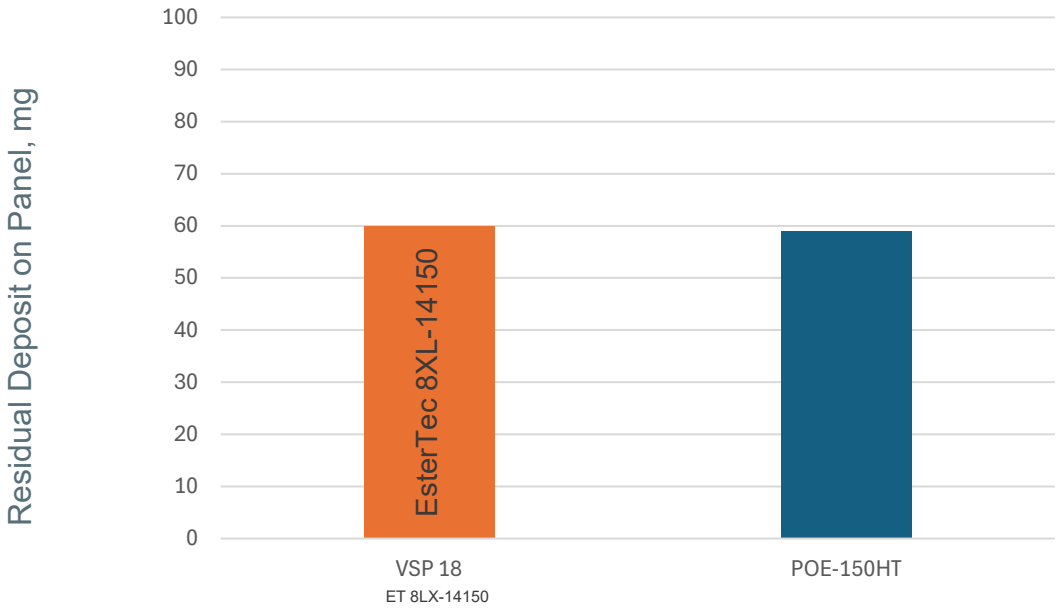
Saturated Polyol Esters with KV100: 3.5 – 6.5 cSt

ESTERTEC VSP compared to Unsaturated Esters



Unsaturated polyol esters with KV100: 5 – 12 cSt

ESTERTEC VSP compared to High Viscosity Saturated Esters



Saturated polyol esters with KV100: 15-20 cSt

Three Phase Pan Test

- Z&S modification of standard oven pan testing
  - Conventional gravimetric procedure:
    - Tared pans, samples weighed before and after
    - 200°C / 20 hours
  - After cooling pans are drained for 10 min
    - 90° tilt
    - Pans reweighed after draining
  - Allows for differentiation of non volatiles
  - Aluminum pan interface
- Relevant for:
  - Oven Chain Lubricants
  - Gears
  - Oil MWF

3PP Images

Pictures 24 hours after oven tests

Example: Good

Residual “solids” after tilting

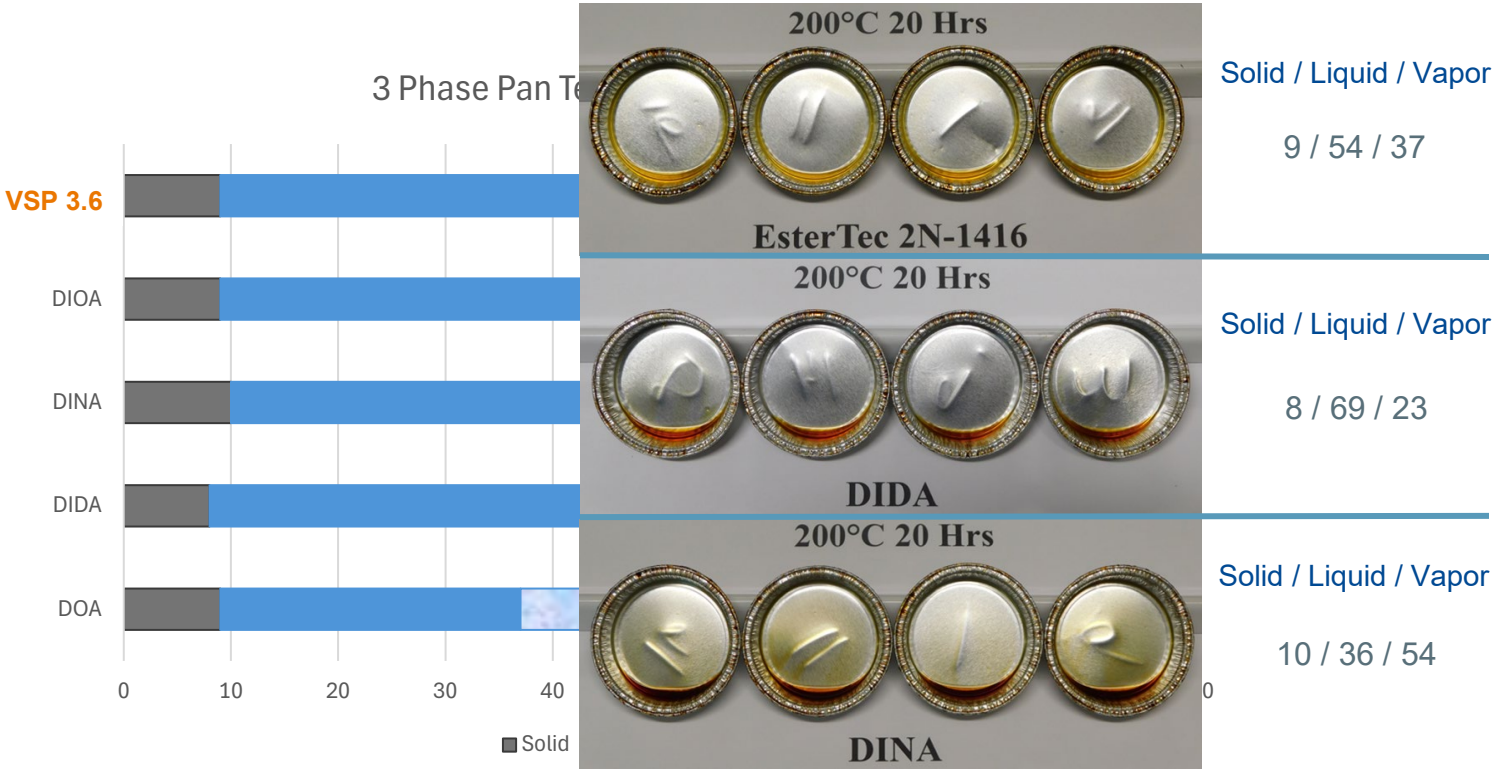
Example: OK

Solid / Liquid / Vapor

<25 / >50 / <40

Example: Poor

ESTERTEC VSP compared to Low Viscosity Adipate Diester



Solid / Liquid / Vapor

9 / 54 / 37

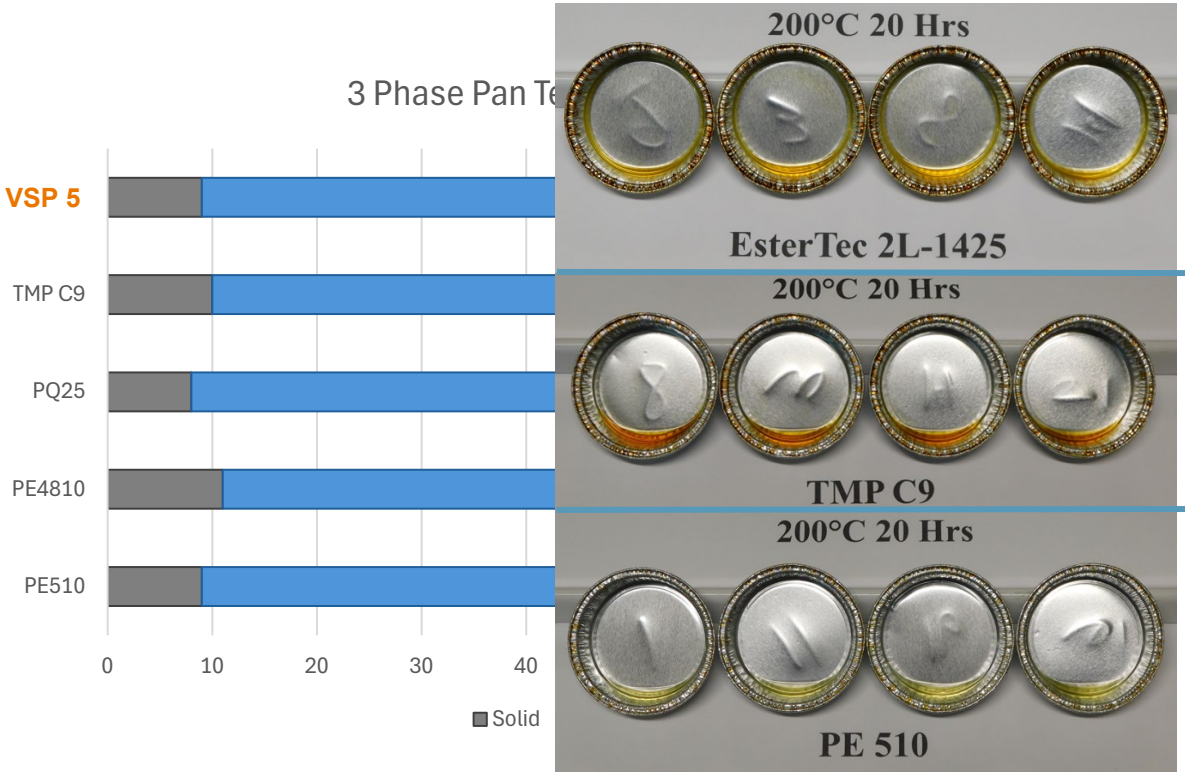
Solid / Liquid / Vapor

8 / 69 / 23

Solid / Liquid / Vapor

10 / 36 / 54

ESTERTEC VSP compared to Medium Viscosity Saturated Polyol Esters



Solid / Liquid / Vapor

9 / 66 / 25

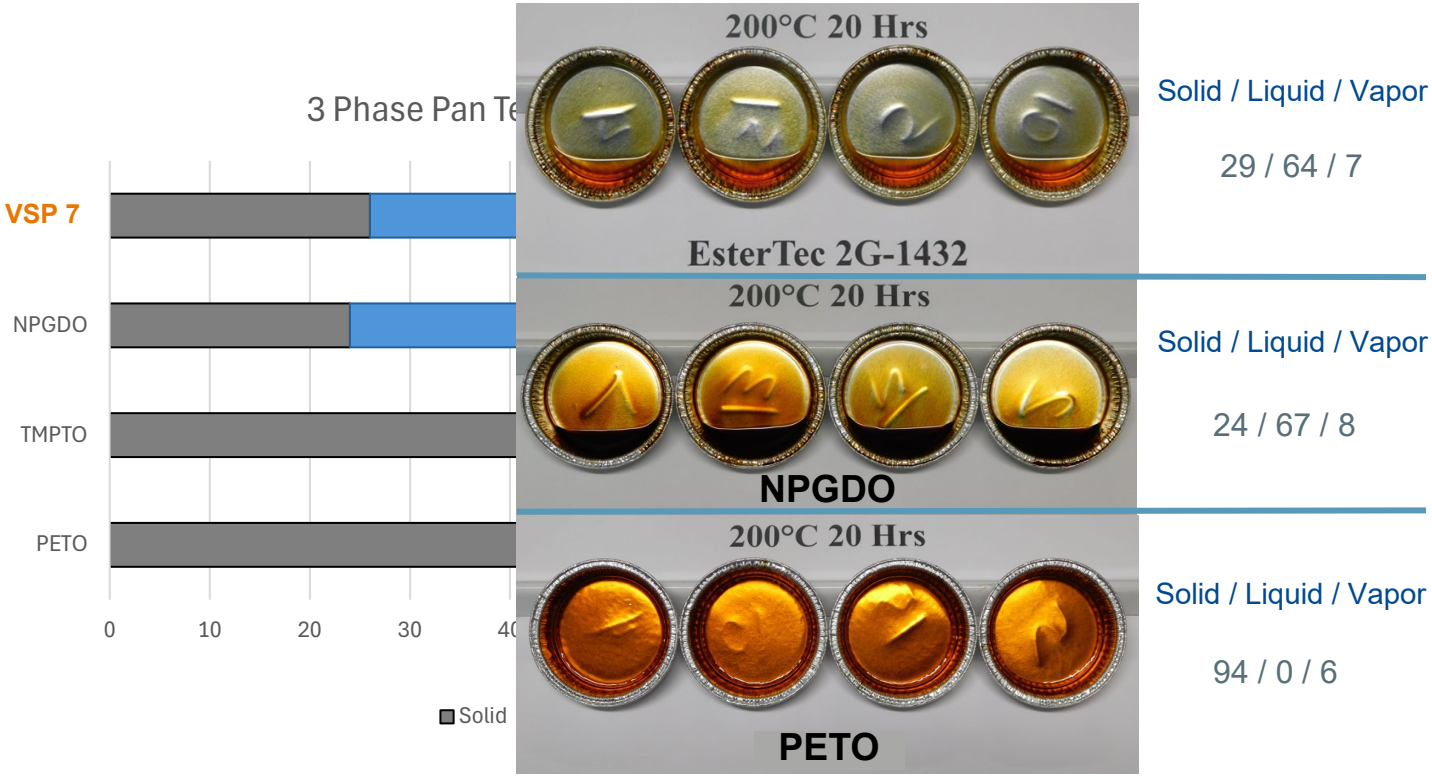
Solid / Liquid / Vapor

10 / 74 / 16

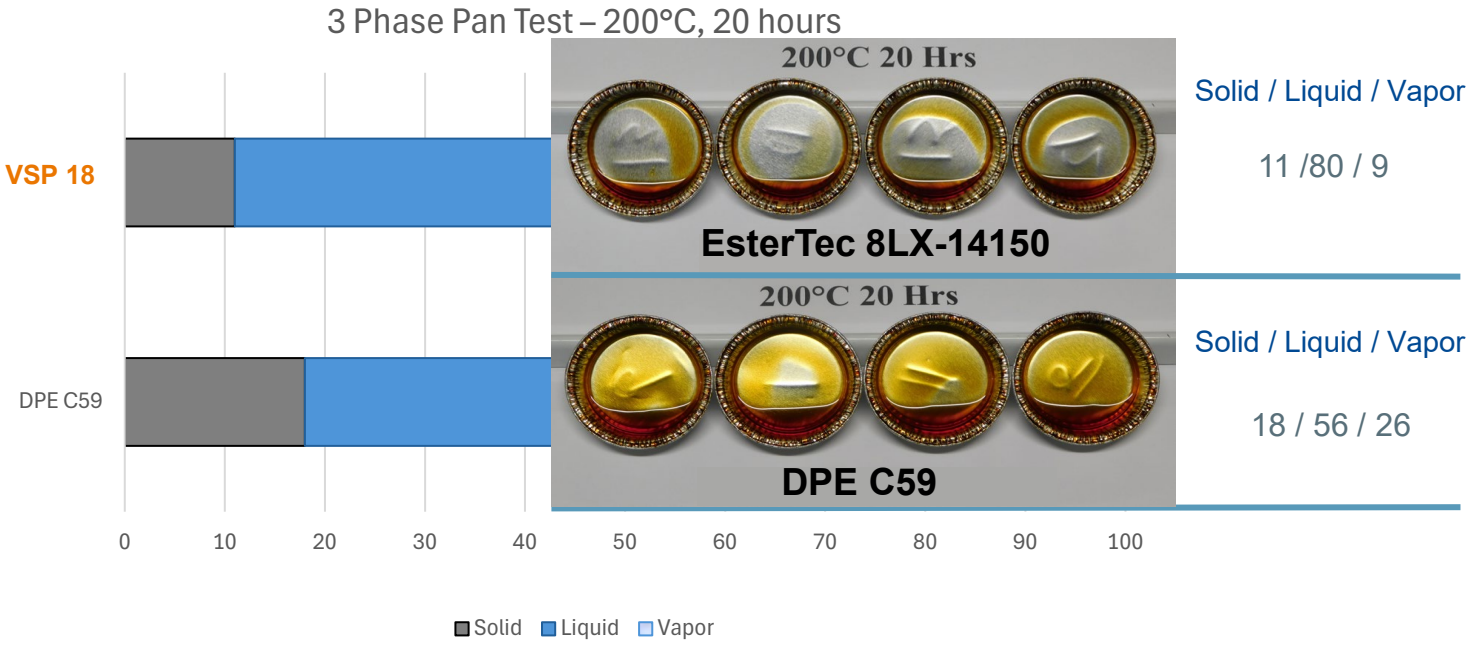
Solid / Liquid / Vapor

9 / 66 / 25

ESTERTEC VSP compared to Unsaturated Polyol Esters



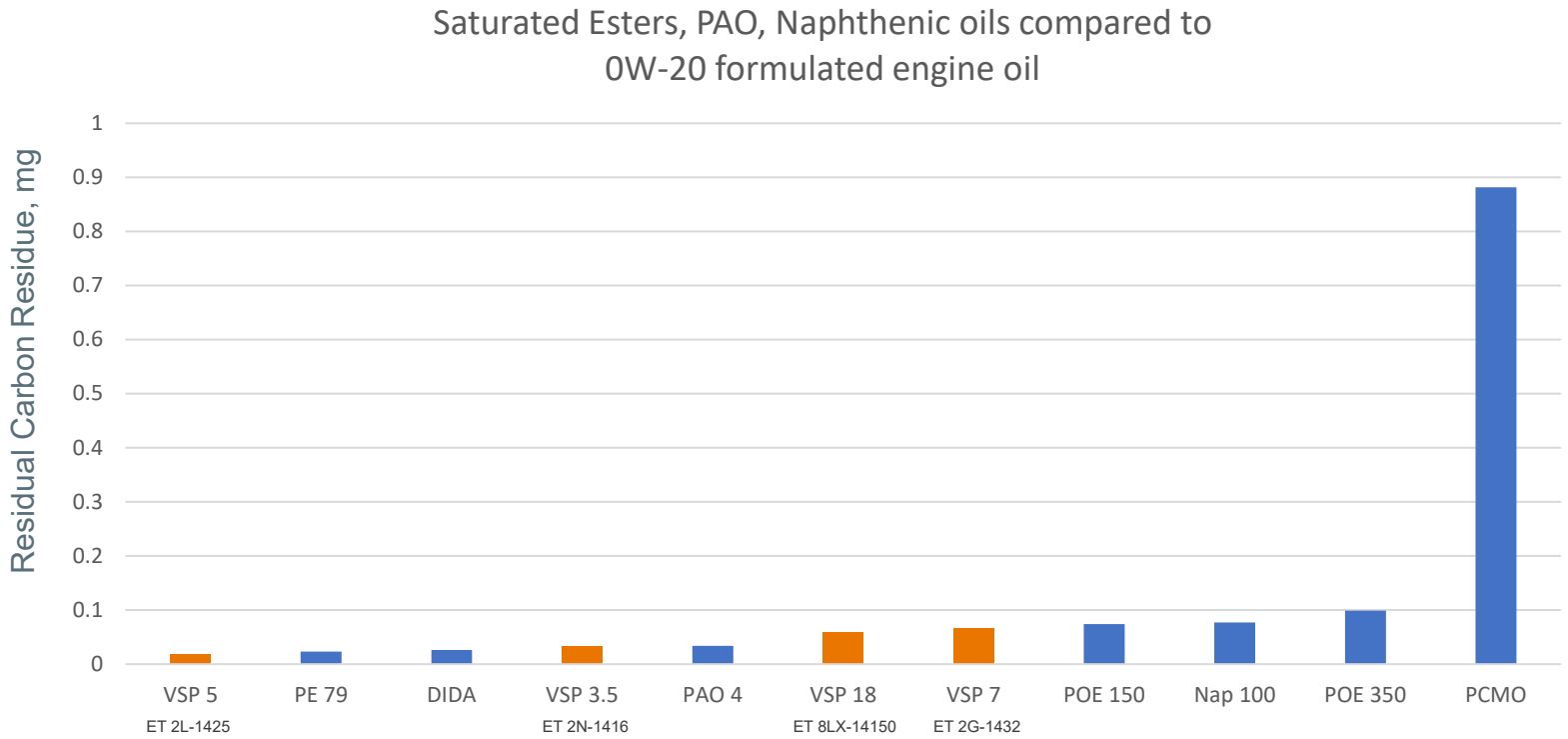
ESTERTEC VSP compared to DPE Polyol Esters



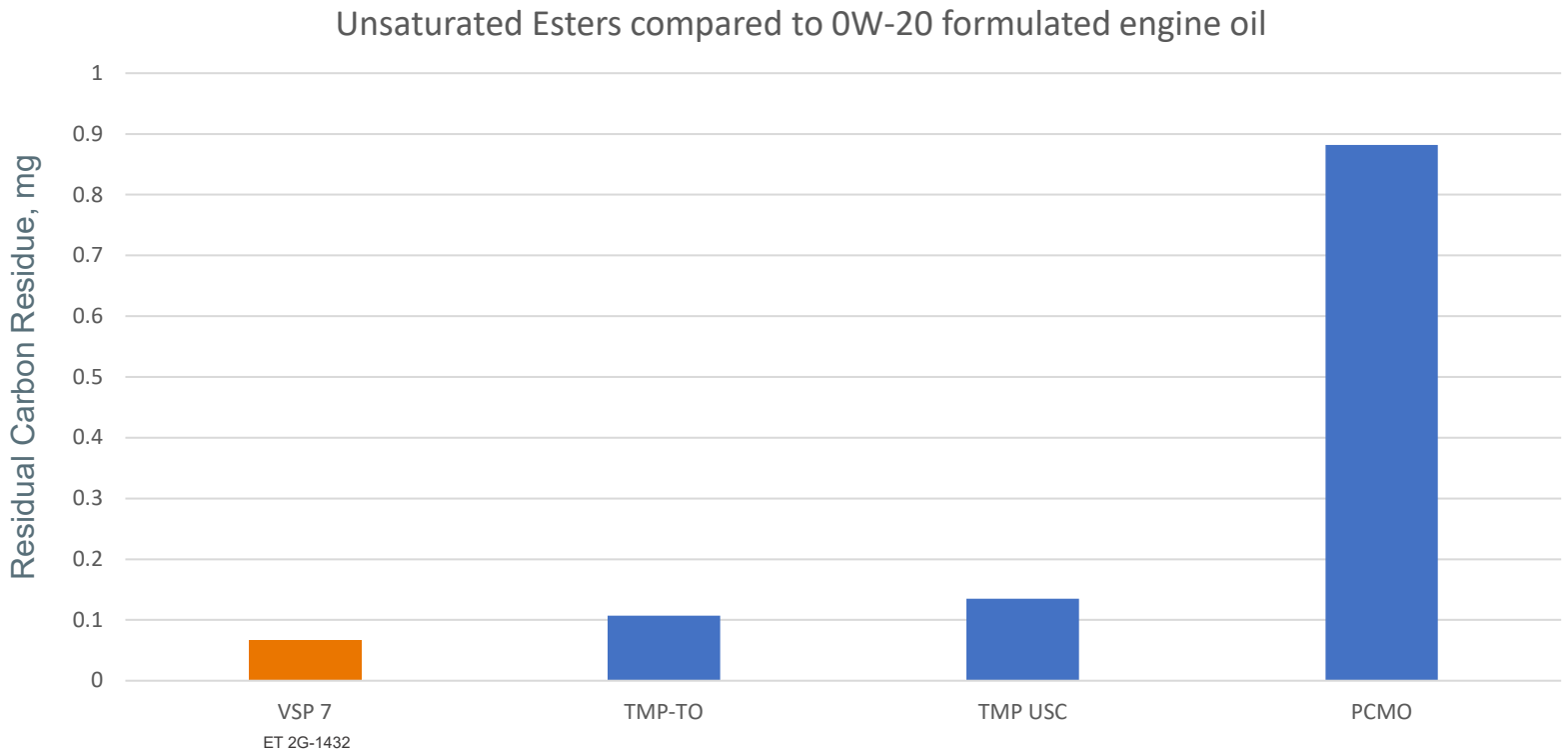
Ramsbottom Carbon Residue

- According to ASTM D524
  - 4g of sample is added to the glass bulb
  - Weigh the loaded bulb
  - Place the bulb into a preheated metal furnace (coking bath) maintained at 550°C for 20 min
  - Remove the bulb from the furnace, cool briefly in the air, and then place it in a desiccator to reach room temperature
  - Weigh the cooled bulb to determine the mass of the residual carbon
- Relevant for:
  - Detecting residues

ESTERTEC VSP compared to Saturated Esters



ESTERTEC VSP compared to Unsaturated Esters



OBSERVATIONS

- VSP synthetic esters offer similar or lower deposit levels compared to:
  - Adipate diesters
  - Unsaturated polyol esters
  - Saturated mid-viscosity polyol esters
  - Many high viscosity polyol esters for high temperature applications

- VSP synthetic ester composition follows the common structure property relationships about chain length, linearity, branching and unsaturation

Deposition Tendency Trends

Unsaturation

Chain length

Branching

CONCLUSIONS

- Low viscosity adipate esters demonstrate moderate deposit forming tendency, leading to their use in low and high performance engine oils
- Medium viscosity polyol esters demonstrate low deposit forming tendency, leading to their use in high performance industrial oils
- Low cost unsaturated polyol esters demonstrate significant deposit forming tendency, leading to their use in standard industrial oils
- High viscosity polyol esters demonstrate low deposit forming tendency, leading to their use in high performance industrial lubricants for high temperature applications

VSP synthetic esters are a new class of base oils and additives demonstrating oxidative stability and deposit forming tendency that is equal or better than standard adipate or polyol esters

EsterTec
synthetic esters

Acknowledgements

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- Andy Johnson
  - Applications Technology Manager
- Michael Creamer
  - Technical Specialist

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QUESTIONS?

VISIT Z&S AT EXHIBIT BOOTH #501

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