ENVIRONMENTALLY ACCEPTABLE LUBRICANTS (EALS) FOR USE IN WATER BOUNDARY PROPULSION SYSTEMS

Presented by:

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2013 Final Vessel General Permit (VGP)

Regulations Forcing Change in the Marine Industry

Briefing - US EPA Regulations

- **2008 VGP**
  - **Suggested the use of environmentally friendly lubricants**
  - **Referenced the Clean Water Act**
    - **Including "No-Sheen" language**
- **Intention for 2013 VGP was to provide a definition of "Environmentally Acceptable Lubricants" – EAL's**
  - **Independent concern hired to evaluate lubricant base stock options**

US EPA – White Paper

- Findings were drafted into a *white paper* for the EPA
  - Four (4) types of base stocks were identified that satisfied the requirements for an EAL
    - Water
    - Vegetable Oil
    - Synthetic Ester
    - Polyalkylene Glycol (PAG)
- EAL's were then specifically referenced for use in the 2013 Vessel General Permit (VGP)

VGP – Equipment Impacted

– 2.2.9 Controllable Pitch Propeller and Thruster Hydraulic Fluid and Other ***Oil-to-Sea Interfaces*** Including Lubrication Discharges from Paddle Wheel Propulsion, Stern Tubes, Thruster Bearings, Stabilizers, Rudder Bearings, Azimuth Thrusters, Propulsion Pod Lubrication, and Wire Rope and Mechanical Equipment Subject to Immersion

VGP - Time Frames / Language

- “Effective on December 19, 2013, all vessels must use an EAL in all oil-to-sea interfaces, unless technically infeasible.”
  - “Technically Infeasible”
    - No EAL products are approved that meet OEM specifications
    - Products which come pre-lubricated (e.g., wire ropes) have no available alternatives manufactured with EAL’s
    - Products meeting OEM specifications are not available within any port in which the vessel calls
    - Change over and use must wait until the vessel’s next dry-docking
  - If a vessel is unable to use an EAL, you must document in your recordkeeping documentation consistent with Part 4.2 why you are unable to do so, and must report the use of a non-environmentally acceptable lubricant to EPA in your Annual Report.

VGP – Addresses "Sheen"
Consideration of EAL Densities
What Owners/Operators Must Consider

Spill/Discharge – “Sheen”

- VGP / sVGP
  - “Lastly, any discharge of oil, including oily materials, from any of these oil-to-sea interfaces may not result in a discharge that may be harmful as defined by 40 CFR Part 110 or *result in the production of a visible sheen*.”
- US Coast Guard SFLC / US Army Corps MDC
  - Technical Standard / Bulletin (respectively)
    - Lubricant Must Satisfy US EPA EAL Criteria
    - Lubricant Must Pass 40CFR435 Static Sheen Test

“Sheen” - Black Light Comparison

Water *Soluble*

Polyalkylene Glycol
(PAG)

Water *Insoluble* Fluids

Mineral Oil

Synthetic Ester

Polyalphaolefin
(PAO)

Vegetable Oil

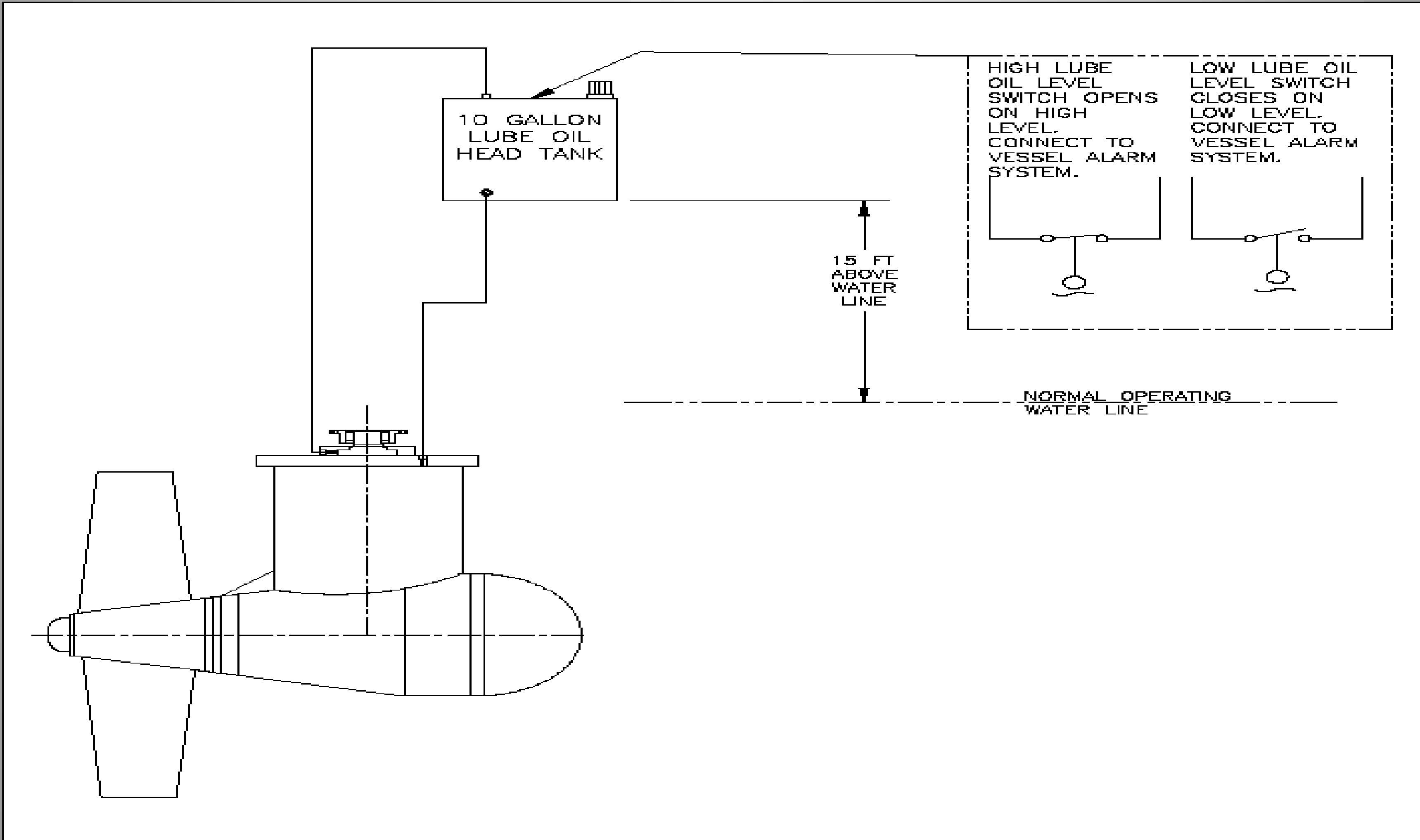
40CFR435 Static Sheen Results

	Water-Soluble Polyalkylene Glycol (PAG) fluid	Vegetable oil based fluid	Synthetic ester based fluid	White-oil based fluid	Petroleum based fluid
Silvery or metallic sheen	**NO**	**NO**	**NO**	**NO**	**NO**
Increased reflectivity	**NO**	**NO**	**YES**	**YES**	**NO**
Visual Color	**NO**	**NO**	**NO**	**NO**	**NO**
Iridescence	**NO**	**NO**	**NO**	**NO**	**NO**
Oil Slick exceeding 10% of surface area	**NO**	**YES**	**YES**	**YES**	**YES**
Appendix 1 to Subpart A of 40CFR435 result	**PASS**	**FAIL**	**FAIL**	**FAIL**	**FAIL**

Performance Characteristics of EAL's in Marine Applications

What Owners/Operators Must Consider

In a Perfect System……….



Comments from Around the Industry

- In your opinion, what is the leading cause of failure?
  - Holcim Cement
    - "Our boat has hydraulic motors that drive it and the biggest problem is the outer seal. We have seal guards but we still get trash caught around the prop and it *wears out the seals.*"
  - North Carolina Dept of Transportation
    - "Seals are the main issue with *leakage on thruster units.*"
  - US Coast Guard
    - "I can say that oil leakage for systems having a seawater boundary (CPP, Z-drives, Azipod, thrusters) is a significant concern because it results in the need to do an *emergency dry-docking*. Seal failures can be due to *abrasive wear* or *installation related damage*, frequently there is no obvious damage to the seal element that would be significant enough to explain the leakage."

Water Removal Equipment

- Stern Tube / CPP / larger Azipod Systems
  - Equipped with Purifiers (high speed centrifuges)
    - Remove water / low micron particulate filtration
- Smaller Azipods / Thrusters / Stabilizers, etc.
  - *<u>Not</u>* typically equipped with any means of water removal

Hydrolytic Stability – ASTM D-2619

EAL PRODUCT	Change in Acid Number - mg KOH/g	Total Acidity of the Water Layer - mg KOH
Polyalkylene Glycol - PAG	**-0.01**	**Water Solubilized**
Polyalphaolefin - PAO	**-0.08**	**6.90**
Synthetic Ester	**+0.83**	**19.37**

Fluids which are unstable to water under conditions of the test form corrosive acidic and insoluble contaminants. **75g of fluid, 25g of water**, and a polished **copper strip** are sealed in a bottle then placed in a **200°F (93°C) oven** and rotated end-to-end at 5 rpm for 48 hrs. Reported values are Acid Number Change, Total Acidity of Water, Weight Change and Appearance of Copper Strip, and can also include Total Sediment Weight.

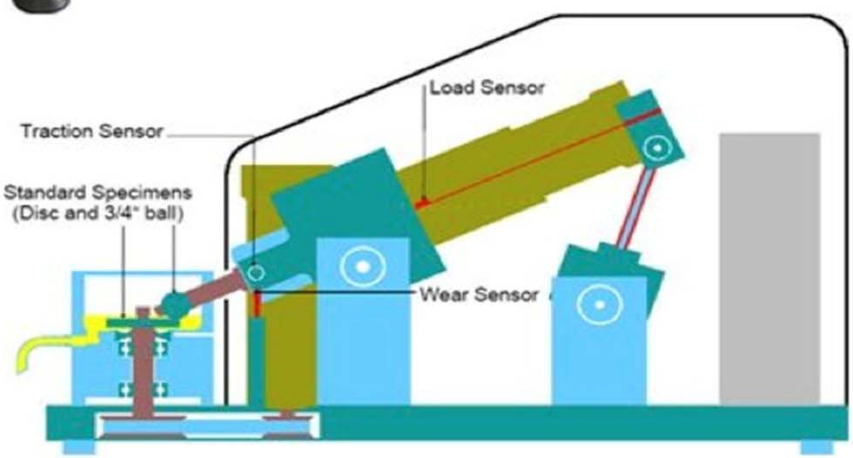
Comparative EAL Water Limits

- End-Users should conduct ASTM D 6304 (Karl Fisher) or other tests to confirm water %
  - Mineral Oil / Vegetable Oil / Synthetic Esters
    - 200 to a Maximum of 500 ppm
    - Excess water - removed by High Speed Centrifuge
      - Critical that water be removed promptly
  - Polyalkylene Glycol
    - Inert to Water/Condensation
    - Up to 7,500 ppm
      - No change in lubricity or corrosion inhibition
    - Excess water – removed by Vacuum Dehydration

Mini-Traction Machine (MTM) – Sliding & Rolling

Performance results – *Friction Control*

Mini-Traction Machine (MTM)



$$U_S = |u_1 - u_2|$$

$$U_R = 0.5*(u_1 + u_2)$$

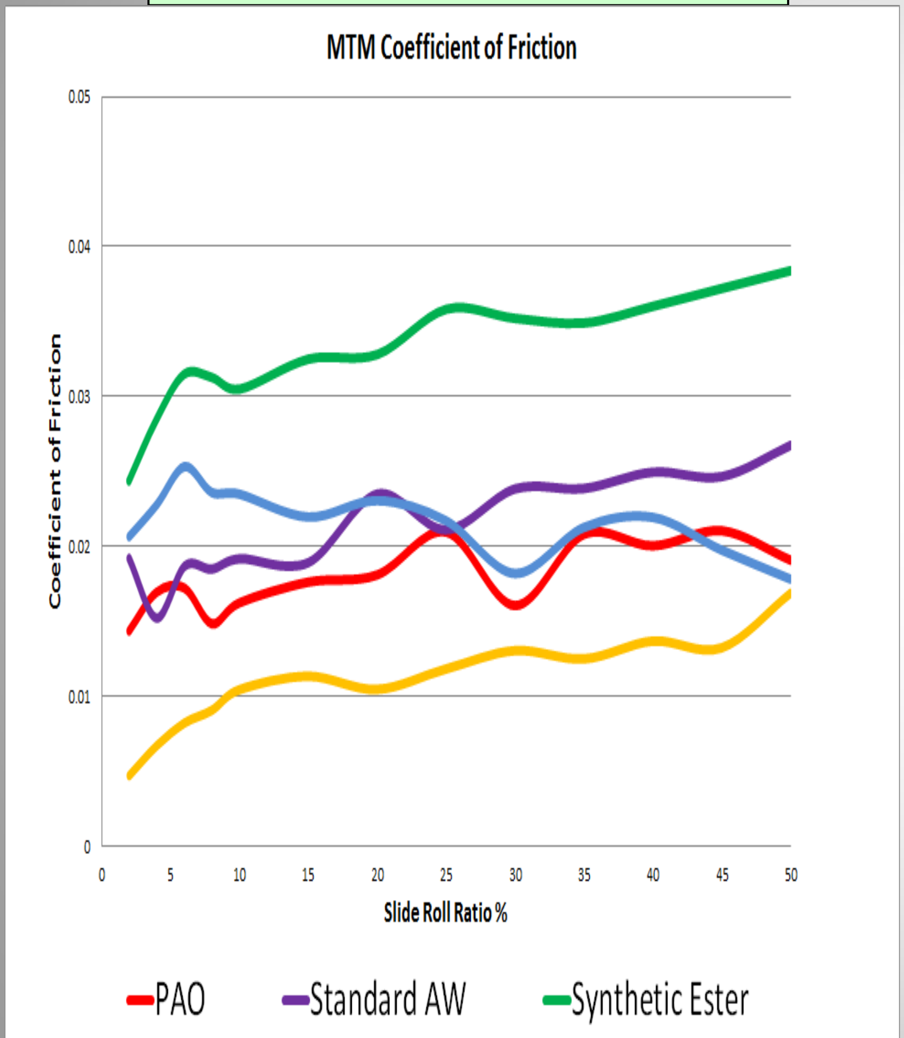
$$SRR = \left(|u_1 - u_2| \big/ 0.5*(u_1 + u_2) \right)$$

u_1=disc speed

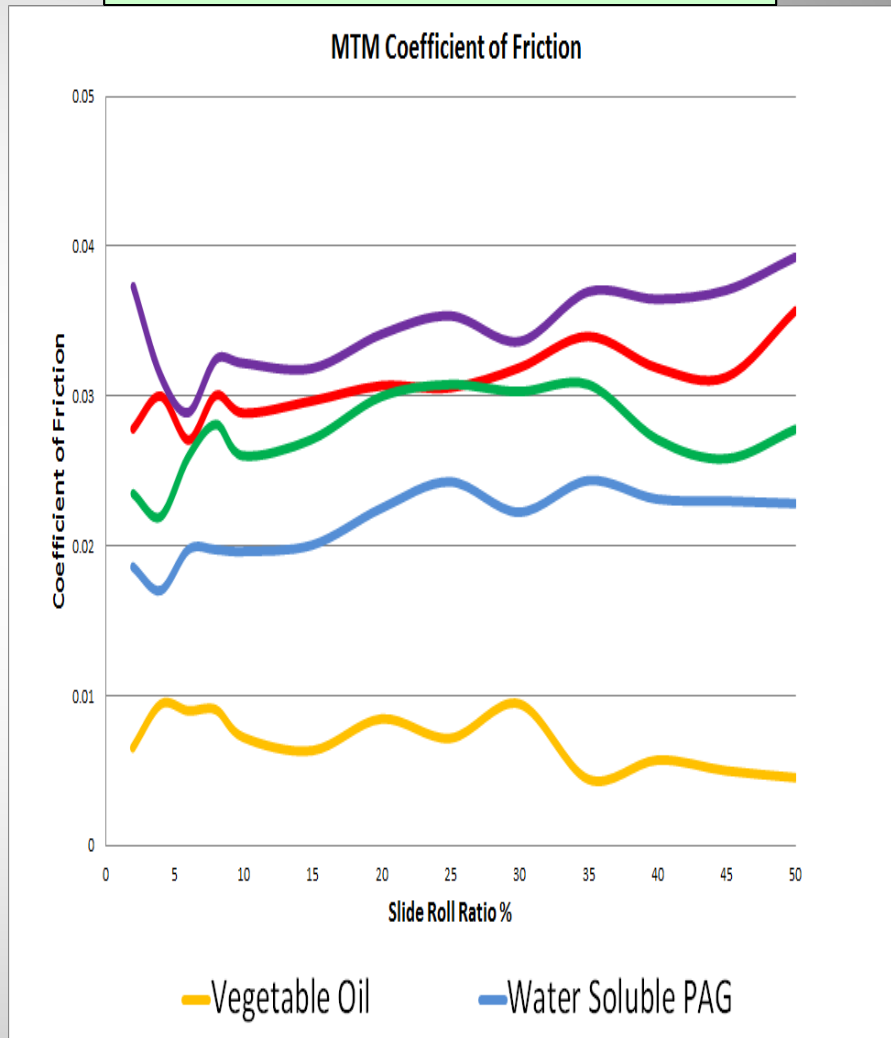
u_2=ball speed

Comparative Coefficient of Friction

EAL's



EAL's with 10% Saltwater



The Coefficient of Friction is the measure of the slipperiness of two mated surfaces.

Long-Term Saltwater Exposure

- C of F test alone doesn't tell whole story
- Can't simulate long-term saltwater interaction
  - PAO/AW
    - Saltwater *displaces* lube from metal surfaces / leaches additives
  - Vegetable and Synthetic Esters
    - *Reduces adherence* to metal surfaces
    - Long-term exposure will deteriorate the ester proportional to the hydrolytic instability
  - PAG
    - Interact with saltwater to create a true solution
    - *Reduces adherence* to metal surfaces
    - Long-term exposure yields good corrosion resistance
      - Holds water away from surface

Elastomer Compatibility Chart – EAL's

Elastomer	Water Soluble Polyalkylene Glycol	Water Insoluble Polyalkylene Glycol	Polyalphaolefin	Vegetable Oil	Synthetic Ester
Nitrile NBR	C	C	C	C	C > 30% nitrile NR < 30% nitrile
Hydrogenated Nitrile HNBR	C	C	C	C	NR
Styrene Butadiene SBR	C	C	NC	NC	NC
Ethylene Propylene EPDM	C	C	NC	NR	NR
Fluorocarbon FKM	C	C	C	C	C
Polyacrylate ACM	NC	NC	C	C	C
Butadiene BR	C	C	NC	NC	NC
Polyurethane AU,EU	NC	NC	C	C	C
Silicone MQ, VMQ	C	C	NC	C	C
Fluorosilicone FVMQ	C	C	C	C	C
Natural Rubber	C	C	NC	NC	NC

USACE "Wheeler" Dredge – Main Seal

Industry standard is *change in volume and change in hardness at 1000 hours of less than +/- 12%* when exposed to fluids that are ≤ ISO viscosity grade 46 and +/- 10% when exposed to fluids that are ISO viscosity grade > 46.

DUROMETER ASTM D 2240-05(10):

Shore A Durometer Point	86.0
Confidence (+/-)	1.0

FLUID IMMERSION PROPERTIES, ASTM D 471-10

Elastomers immersed @ 65°C in UCON Trident AW-68

1000 hrs.			
Durometer, points change		-0.0	
Volume Change		+3.0 %	
Weight Change		+6.0 %	

Conversion Procedures

What Owners/Operators Must Consider

Conversion Objectives

- Convert to a fluid that performs as reliably and predictably as the petroleum-based lubricants
- Use a fluid that drives Value relative to Cost
  - Extends Drain Intervals to offset high price tag
- Procedure adequately removes toxic mineral oil
  - Minimize residual (toxic) petroleum oil

Example: USACE Hopper Dredge - CPP Conversion

- Propulsion Systems, Inc.
  - Built CPP
- Atlantic Industrial
  - Built HPU System

- Confirmed seal/system compatibility with OEM's
- Addressed all lubricants used in the CPP assembly process
  - established non-sheening water soluble PAG-based alternatives

Conversion: USCG Icebreaker

- Bow Thruster
  - Thrustmaster Tunnel Thruster
    - Model # 47TT500L

- Confirmed seal compatibility
- Conducted fluid compatibility with petroleum-based lubricant
- Thruster difficult to access pod / reservoir to drain old oil
- Goal to minimize toxic oil in the end

Oil Compatibility / Conversions

80% water-insoluble PAG 20% white oil lubricant	50% water-insoluble PAG 50% white oil lubricant	20% water-insoluble PAG 80% white oil lubricant

Commit to a Sample Analysis Program

US Army Corps of Engineers - Pine Bluff
4001 Port Road

Pine Bluff, AR 71601

8932
Tim
Terrell
918-
519-
1568

Port ←**Select a system name for trending report**

Fluid:		**Trident AW-32**	**Trident AW-32**	**Trident AW-32**	**Trident AW-32**	**Trident AW-32**	**Trident AW-32**
Pulled:		**10/21/10**	**1/12/11**	**3/2/11**	**3/22/12**	**1/0/00**	**3/5/13**
Received:		**10/25/10**	**1/19/11**	**3/17/11**	**3/28/12**	**1/0/00**	**3/15/13**
Completed:		**10/25/10**	**1/19/11**	**3/17/11**	**4/2/12**	**1/0/00**	**3/21/13**
Visual:		Clear-Lt.Brown	Clear-Orange	Clear-Dk.Orange	Clear-Orange	0	Clear-Orange
	Range	**Results**	**Results**	**Results**	**Results**	**Results**	**Results**
Viscosity (cSt)†	**38.2 - 44.8**	**38.71**	**30.65**	**37.91**	**38.67**		**36.00**
Total Acid Number	**0.1 - 5.0**	**0.65**	**0.63**	**0.65**	**0.75**	**~**	**0.56**
Water (ppm)	**<7,500**	**1651**	**1598**	**2601**	**2358**	**~**	**2794**
Tramp Oil % (T)	**≤2%**	**No**	**No**	**No**	**No**	**No**	**No**
ISO Particle Count Typical Maximum:	**17 / 15 / 12**	**17 / 16 / 14**	**V P C**	**16 / 15 / 11**	**15 / 14 / 11**		**[illegible]/ 14 / 12**
Specific Gravity	**> 1.0**	**1.021**	**1.017**	**1.028**	**1.0169**		**1.018**
Sheen Test**		**Trace**	**Trace**	**Trace**	**Trace**		**Pass**
Other							
Oil Change*			**CHECK FILTRATION**				
Reason for Sample		Routine	Routine	Routine	Routine		Routine

Conclusion

- Petroleum lubricants – Reliable/Predictable
- All EAL's can perform in the right environment
  - Each has benefits & drawbacks - *must* be considered
- US EPA VGP is forcing change in Water Boundary Propulsion System to EAL's
  - These applications challenge an EAL!
    - Catalysts - Water + Heat = Wear & Oxidation
- Regardless of EAL selected – commit to a Sample Analysis Program
  - Confirm condition of the Lifeblood - Routinely

Thank You!