STLE 2018
Turbine Oil Developments

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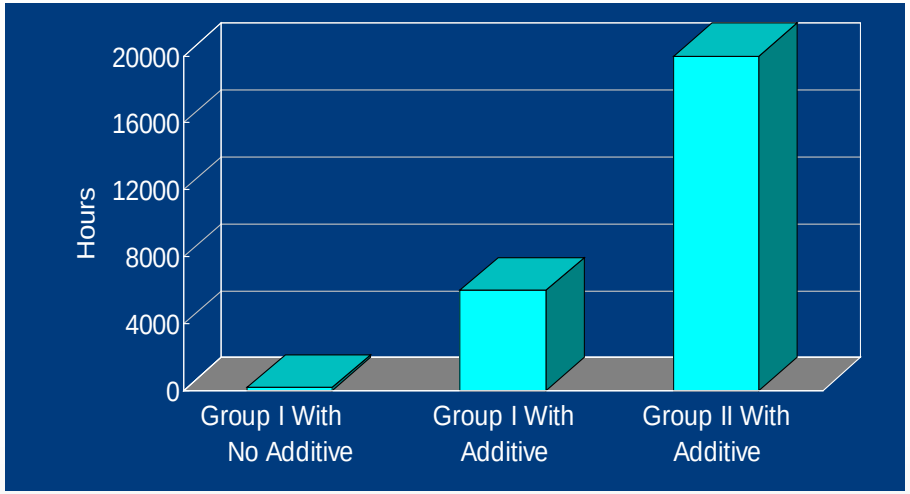
BSME, CLS, OMA 1

Topics

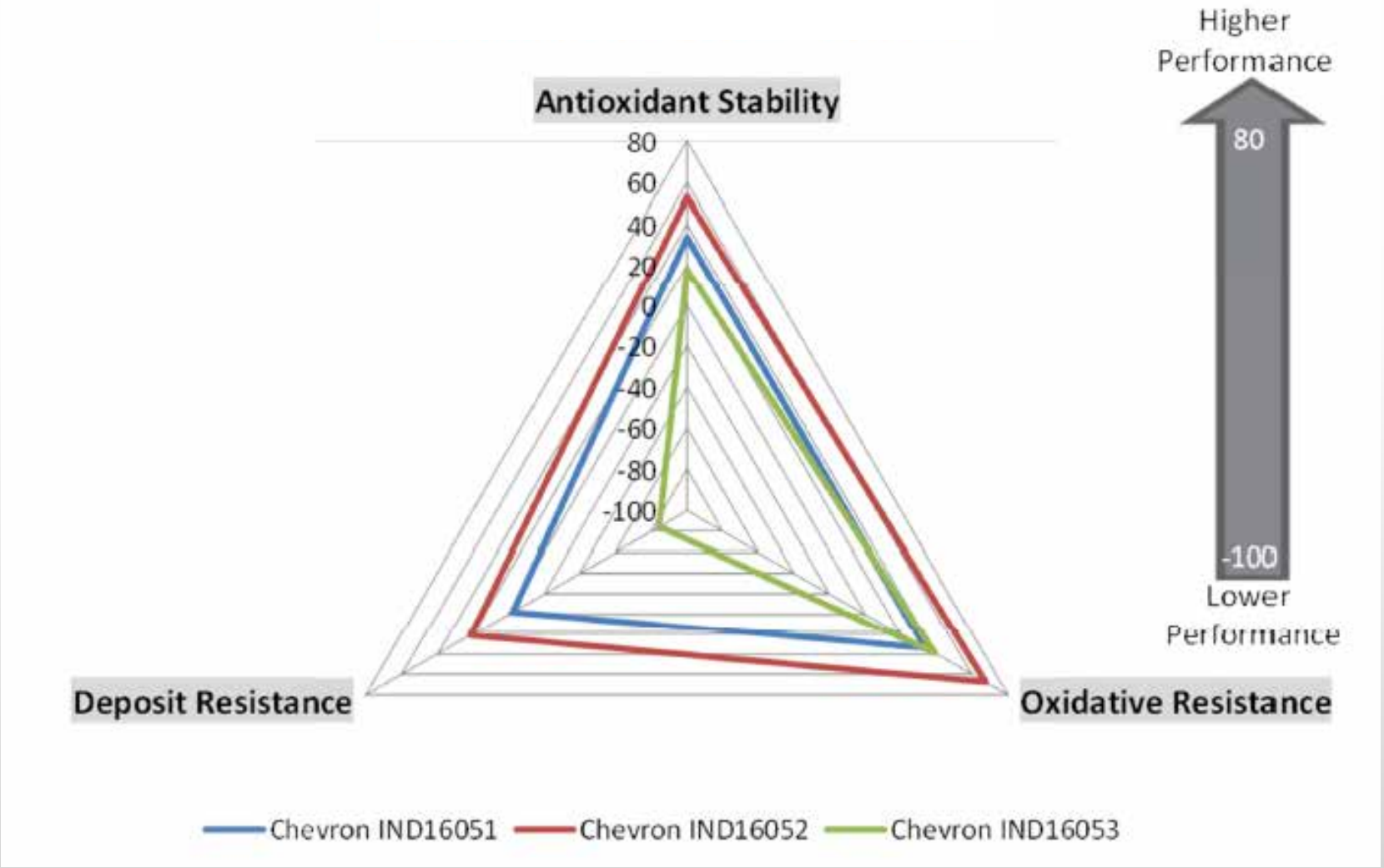
- Formulation advancements
  - Degradation prevention and
  - Deposit prevention
- Examples of special applications
  - Combustion turbine – no rust inhibitor, no water sep
  - Steam turbine bowser vs. coalescing filter vs. vacuum dehy / Ultidri
- Filtration impact
- Tailored oils for specific applications
- Chevron product line

Current formulation changes have a Varnish focus

- 1983 – 2003 Move from Group I to II
  - Huge leap in oxidation stability (less degradation)
  - Resulting increase in varnish reports
    - Formulation challenges
    - Lower stability for varnish precursors
- Varnish reduction approaches
  - Prevent degradation – front end - antioxidants
  - Prevent deposits – back end – detergent / dispersants, solvency enhancers

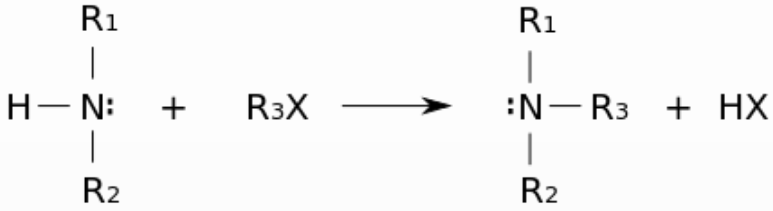


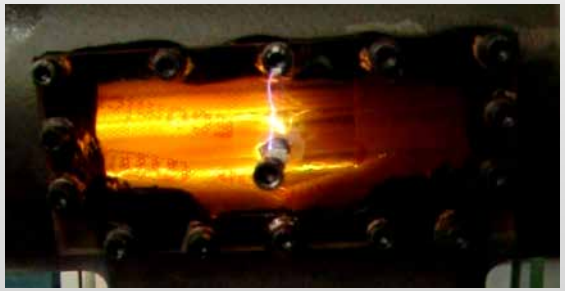
Formulating Turbine Oil for High Performance



Preventing degradation

- Antioxidant improvements
  - Phenol only
  - Phenol + Amine
  - Amine – trending toward alylkated amines
- Additive reactions
  - Rust inhibitors and antioxidants
- Conductivity enhancers
  - Often aromatic
  - Testing indicates their effective life is limited





Antioxidant improvements

DRY TOST D7873 AT 1000 HOURS

Cincinnati Machine (CM) Thermal Stability Test A
(Fives Cincinnati)

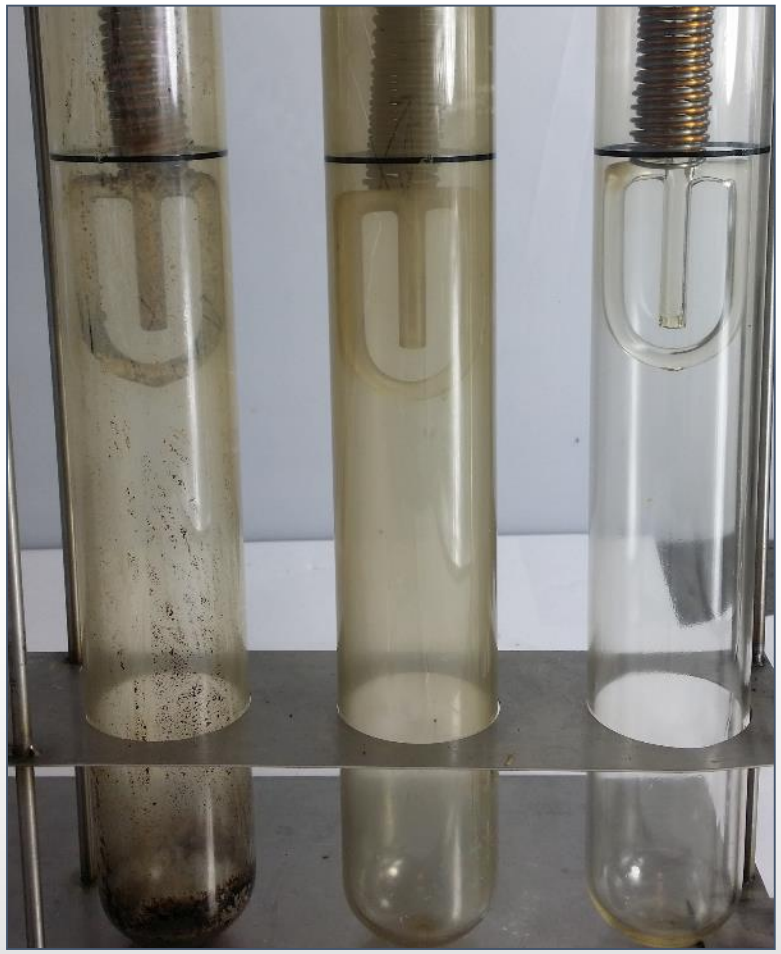
Preventing deposits

- Detergent / dispersant
  - Traditionally affect water separability
- High varnish solvency
  - PAG turbine oil
  - Oil soluble PAG as top treat
- Synthetic Solvency Enhancers – alkylated naphthalene
  - Good seal compatibility / good stability
  - Minor water separability impact

Leading toward special oil for specific applications?

Detergent dispersant

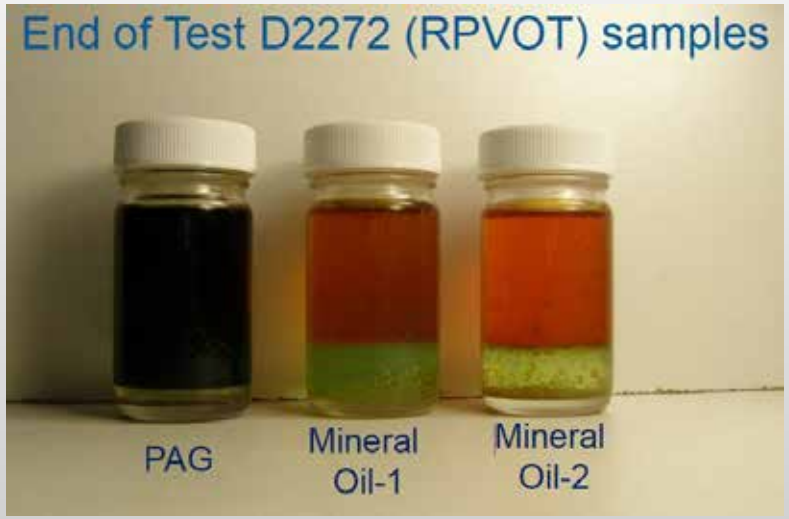
- Significantly reduces deposits
- Compatibility with acidic rust inhibitors?
- Impacts on water separability?
- How long will it last?



Poor oil | Good oil | Good oil with Det/disp

High varnish solvency – PAG lubricant

- Keeps degradation byproducts dissolved well
- Mineral oil compatibility test – surprisingly good
- Low RPVOT oxidation life test
- Poor paint compatibility
- No water separability 2000 – 7000 ppm “normal”
- Poor hydrolytic stability
- Mid use varnish potential good
- End of life varnish similar to mineral oil



	Fresh PAG	9 year PAG	9 year Group II	Fresh Group II
D7843 (dE) no IPA		9	29.3	
D7843 (dE) with 25 IPA		4.4	7.3	

ASTM D7843 – 16 Standard Test Method for Measurement of Lubricant Generated Insoluble Color Bodies in In-Service Turbine Oils using Membrane Patch Colorimetry

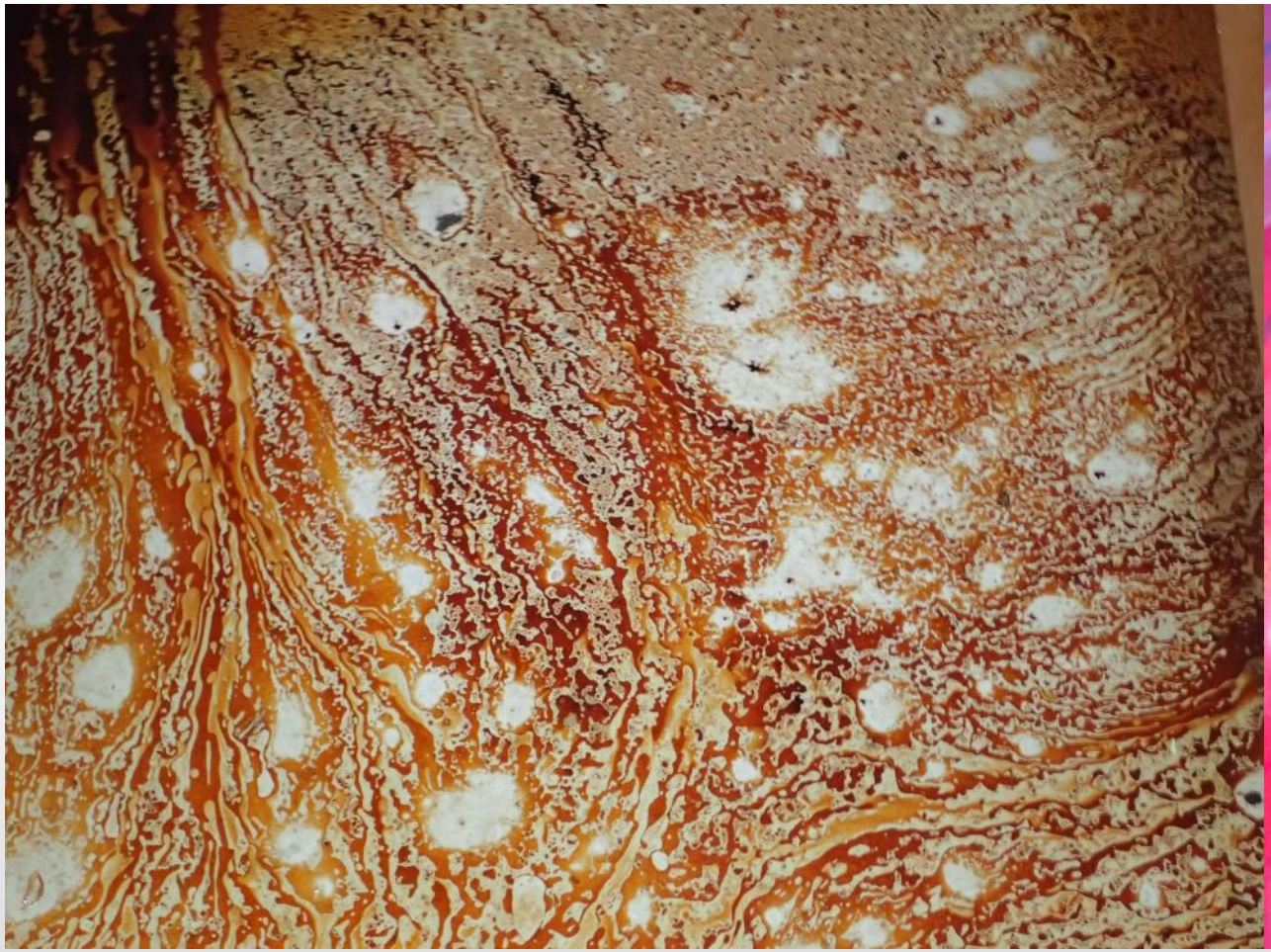
PAG / mineral comparison

	PAG	Group II	
Beginning RPVOT	500	1000	Degrade how fast?
AN @ 25% RPVOT	25	3	Acid number skyrockets
VPR @ 25% RPVOT	68	74	both poor
Beyond end of test MPC	80+	80+	both fail
9 year samples			
MPC ASTM 7843 no IPA	9	29	some difference but not bad
MPC ASTM 7843 25% IPA (modified as per ACT)	4.4	7	similar
Demulsibility	0	37/40/3	
Water ppm	4000	100	

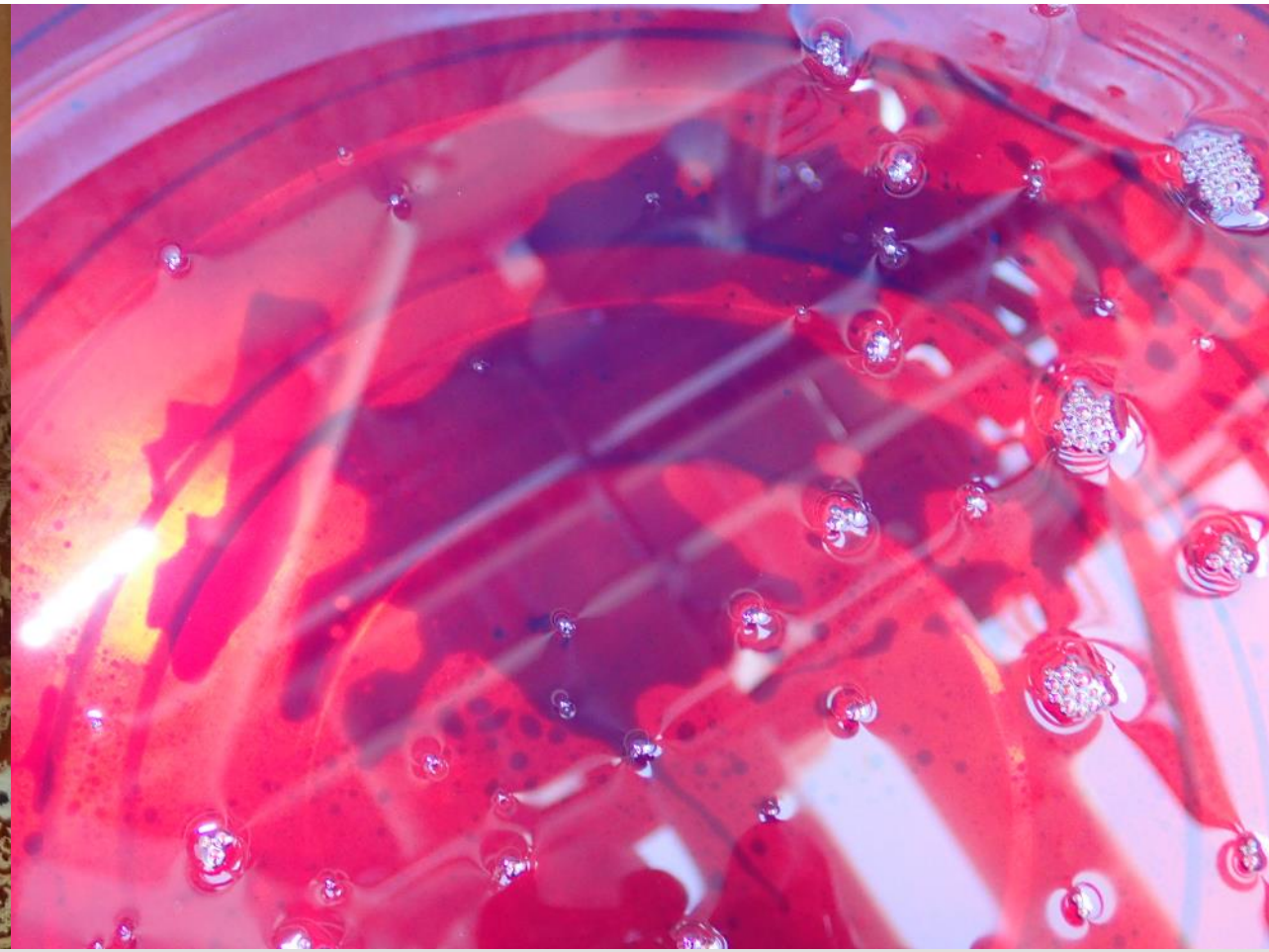
High varnish solvency – Oil Soluble PAG

- Used as top treat
- Works for cleaning varnish
- Cannot be used with most resin varnish removal
- Longer term problematic
  - Separates into 2- phase system
  - Polarity pulls antioxidants from the mineral oil
  - Causes screen and filter plugging

7FA reservoir with OSP in mineral oil



Oil drained from pipe with OSP in mineral oil



Solubility in mineral oil is not apparent. Polar component (OSP) appears to pull antioxidants from mineral oil accelerating mineral oil degradation.

Synthetic Solvency Enhancers

- Used in OEM formulations for additive solubility (PAO)
- Retains degradation byproducts in solution
- Stable (not volatile like solvents)
- Can be top treated – conservative
- Slight water separability change
- Works with some resin varnish removal

Filtration impacts

- Resin will remove most rust inhibitors
- Depth media may remove foam inhibitors
- Vacuum dehydration may remove aromatic conductivity enhancers

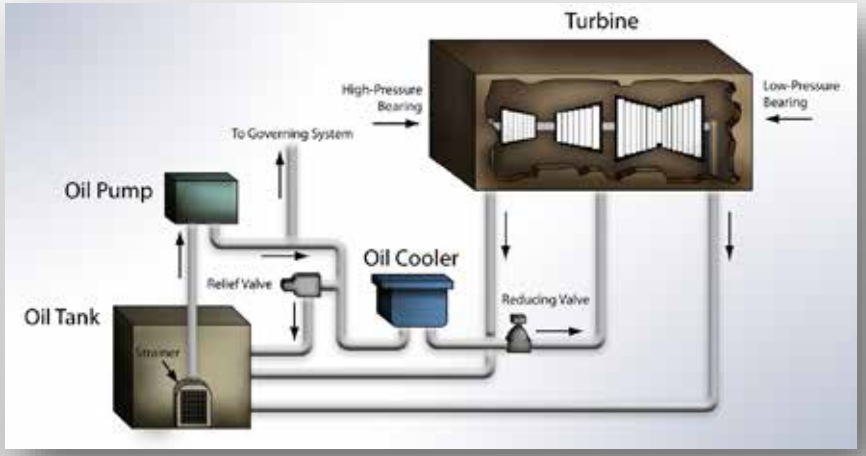
- Upgrading water removal – less water separability importance
  - Bowsers
  - Coalescing filters
  - Centrifuge
  - Vacuum dehydration
  - Membrane technology

The Future

- Boutique oils for specific R&O applications
  - Is water a concern?
    - Balance deposit performance and water sep performance
    - Choose good varnish oil and upgrade water removal technology
  - Is rust a concern? – no R in R&O
    - Construction materials
      - Stainless steel / carbon steel / aluminum
      - Plastics and composites
  - Is foam a concern?
    - Leave out the inhibitor
    - Balance foam vs air entrainment performance
    - Larger, slower reservoirs for settling

Successful Turbine Oil Selection

1) Understand what performance is needed *for your application*
2) Ensure the Lubricant meets the OEM requirements
3) Understand how the oil is delivered and chain of custody to ensure no contamination takes place
4) Work with a lubricant supplier who offers comprehensive support



Example: Path of lubricant in a steam turbine.

Sampling optimization – ASTM D4378-13

	Cost	Steam	Gas	Term	Notes
Appearance	$0	daily	100 hr	Short	Seldom done
Color	$0	weekly	200 hr	Short	Seldom done
Acid NO.	$10	3 months	1000 hr	Long	Annual
Water Content	$15	3 months	-	Short	
Particle Count	$20	3 months	1000 hr	Short	
Viscosity	$5	6 months	500 hr	Long	
Rust Test	$60	12 months	-	Long	
RPVOT / RULER / FTIR	$300	12 months	2000 hr	Long	
ICP metals	$10	-	-		
MPC	$200	-	-	Long	Selective
Water Separability	$40	-	-	Short	Selective
Foam test					

Quarterly	
Annual	

Tailoring analysis focus

- Steam turbines
  - Watch water content closely – online monitoring?
  - Stretch degradation longer (RPVOT, RULER, FTIR)
- Gas turbines
  - Degradation annually to trend
  - Varnish potential has increased importance
    - May change with solubility enhancers / detergent dispersants
  - Water separability not very important
- Rust test (ASTM D665)
  - Additive will naturally deplete over 2 years
  - Resin will remove polar rust inhibitors
- ICP / metals mostly for wear and contamination

Summary

- Turbine oil is a simple formula
- Formulation is not simple
- Determine your primary performance focus then evaluate oils
- Real world performance results lag testing by 10-20 years