Creating Value Through Oil Analysis
Part I

The webinar will begin in less than 10 minutes.

Mystik LUBRICANTS
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Creating Value Through Oil Analysis
Part I

The webinar will begin in less than 5 minutes.

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Webinar starting soon; until then…

TEST YOUR KNOWLEDGE

Oil is the life blood of an engine.

True

False

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Webinar starting soon; until then…

TEST YOUR KNOWLEDGE

Water by Crackle is a way to evaporate water from oil.

True

False

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Webinar starting soon; until then…

TEST YOUR KNOWLEDGE

FTIR is the acronym for:

- First Time Inspection Results
- Fourier Transform Infrared Spectroscopy
- Front Turbine Inverted Rotation
- Frequent Test Interpretation Results

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Creating Value Through Oil Analysis

Part I

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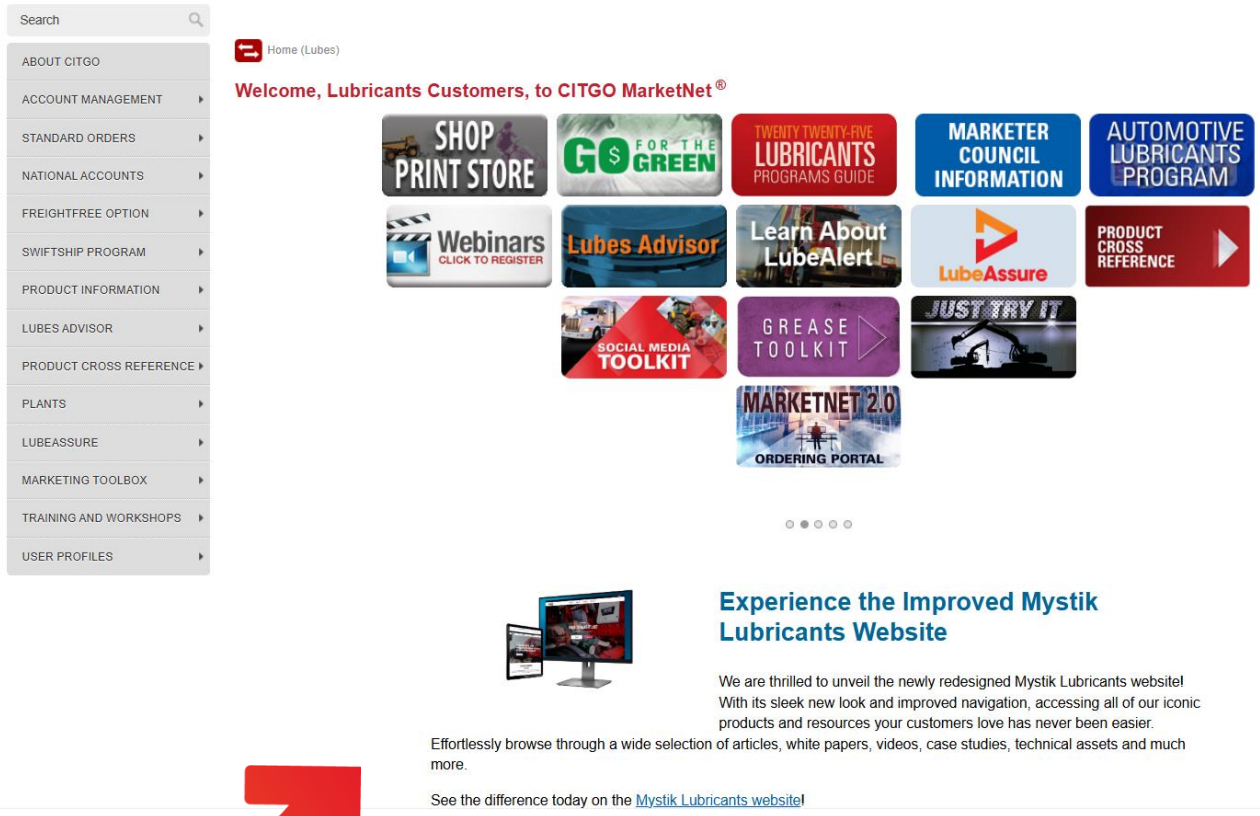
Amber Fessler - NLGI CLGS; STLE CLS & OMA-I

- CITGO Senior Sector Manager
- Materials Engineer
- 14 Years of Experience in Lubricants
- STLE Certified
  - Certified Lubrication Specialist
  - Oil Monitoring Analyst I
- NLGI Certified
  - Certified Lubricating Grease Specialist

Want Resources?

- Program Guides
- Support Literature
- Social Media Resources
- Webinars



Future Webinars

October 27: Creating Value Through Oil Analysis, Part II

November 17: Solving Problems with Industrial Synthetics

December 15: Guiding Customers and Solving Problems with PI Sheets

Frank Hayes – STLE CLS & OMA-I, MLA-I, MLT-I, CRC & NLGI CLGS

- CITGO Senior Product Specialist
- B.S. Mechanical Engineering
- 27 Years of Experience in Lubricants:
  - Petro-Canada Lubricants, Sr. Technical Services Advisor
  - Conoco, Lubrication Engineer

David Turner – NLGI CLGS, STLE CLS & OMA-I

- CITGO Senior Technical Services Representative
- Chemical Engineer
- 40+ Years of Experience in Lubricants
- Active in STLE, NLGI, and ASTM

Agenda


The Value of Oil Analysis
Equipment Health Monitoring & Assessment
Lubricant Health Monitoring
Routine Tests

The Value of Oil Analysis

Setting Oil Drain Intervals – HD Diesel Engines

Extended drain intervals beyond OEM-recommended drain must be supported by routine oil analysis

Run Viscosity, Base Number, Oxidation and Nitration

1. Sample at OEM recommended drain interval
2. Sample at increments of 100 hours or 10K miles
3. Continue part 2 until two of the above properties are at condemning
4. Drain crankcase at condemning and make note of hours or miles of drained oil
5. Continue steps 1 through 4, five times
6. Decide to establish the drain at the lowest interval or the average of five intervals.

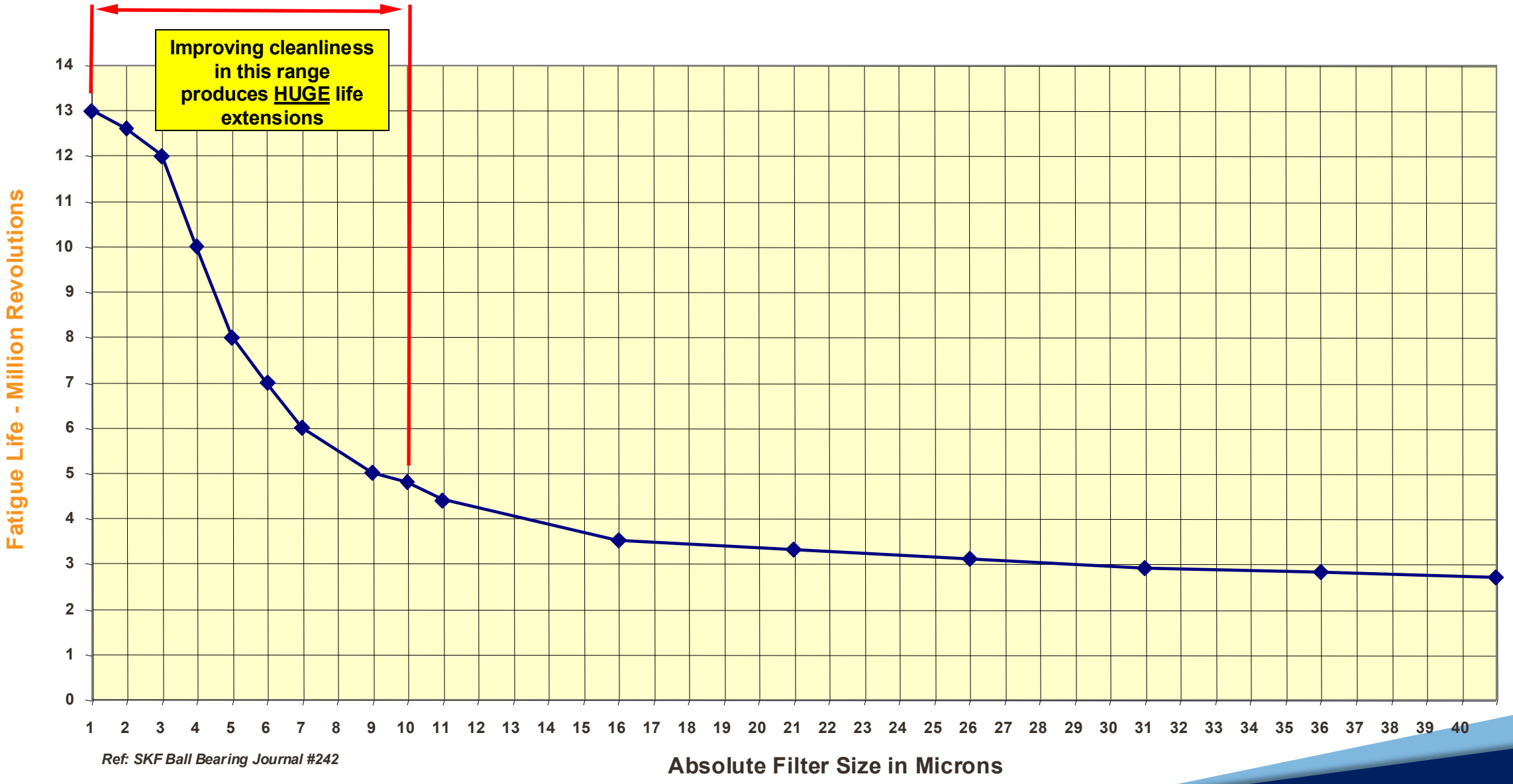
Setting Oil Drain Intervals – Natural Gas Engines

Extended drain intervals beyond OEM recommended drain must be supported by routine oil analysis

Run Viscosity, AN, BN, Oxidation, and Nitration

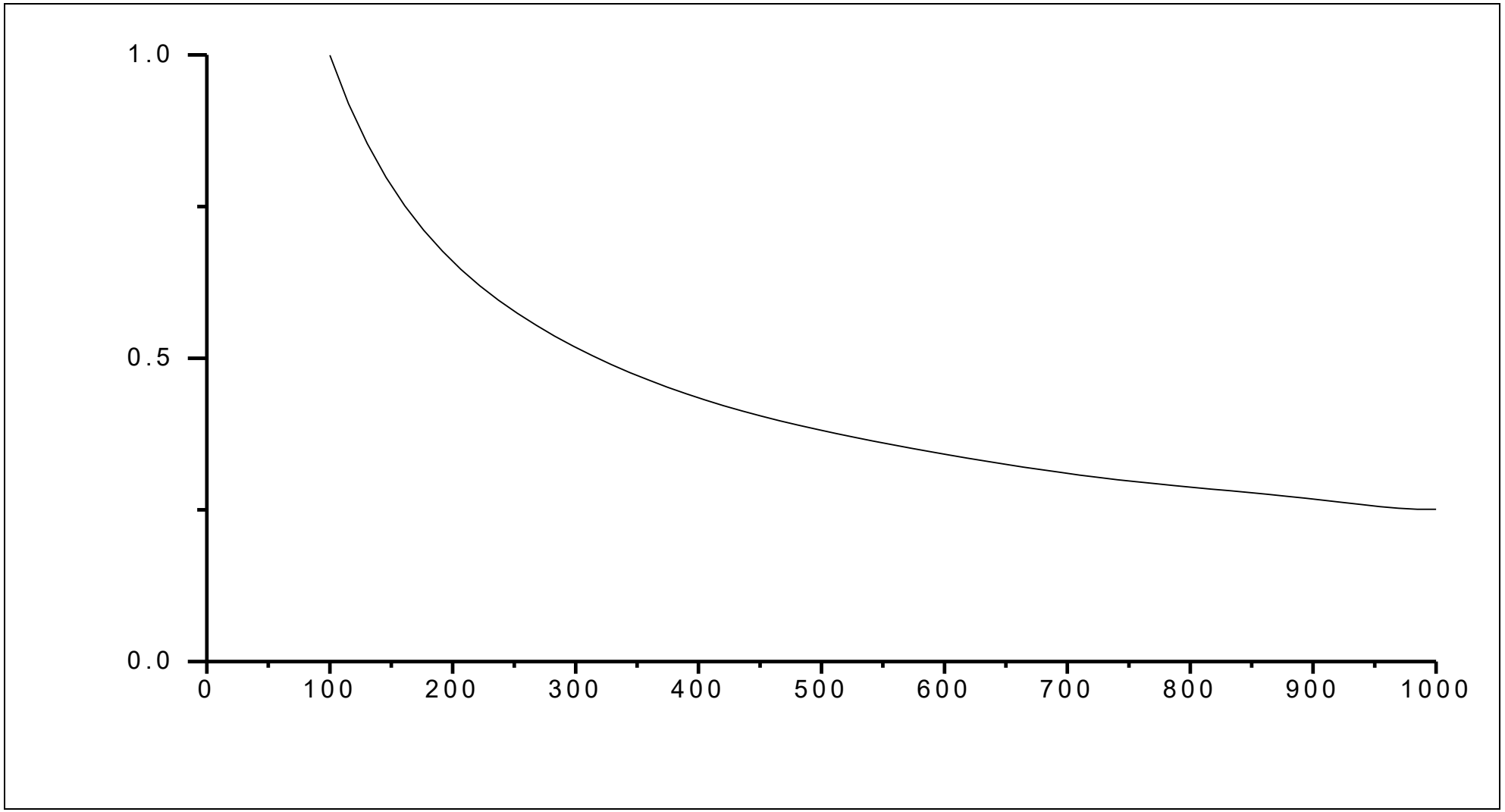
1. Sample at OEM recommended drain interval
2. Sample at increments of 500 hours or 2 weeks
3. Continue part 2 until two of the above properties are at condemning
4. Drain crankcase at condemning and make note of hours of drained oil
5. Continue steps 1 through 4, five times
6. Decide to establish drain at lowest interval or the average of five intervals.

Extend Equipment Life - Particles



Ref: SKF Ball Bearing Journal #242

Extend Equipment Life - Water



*Cantley, R., “The Effect of Water in Lubricating Oil on Bearing Fatigue Life”

Cost of Equipment Replacement

- HD Diesel Engine = $200K
- HD Automated Manual Transmission = $8K
- High Speed Natural Gas Engine = $500K
- Rotary Screw Gas Compressor = $100K
- Rotary Screw Air Compressor = $70K
- Hydraulic Power Unit = $50K
- Flender Gearbox = $70K

Cost of Equipment Repairs

- Diesel Engine Head Gasket = $10K
- Diesel Engine Rod Bearing = $3K
- Natural Gas Engine Cylinder Head = $8K
- Hydraulic Servo Valve = $5K
- Hydraulic Pump = $4K
- Gearbox Bearing = $1.5K

Equipment Health & Monitoring Assessment

Wear Metals

Contaminant Metals

Particles

Oxidation

Nitration

Lubricant Health Monitoring

Additive Metals

Particles

Contaminant Metals

Oxidation

Nitration

Acid Number

Base Number

Viscosity

LubeAlert Fluid Condition Monitoring Service

LubeAlert Basic Packages

LubeAlert BASIC	Elemental Metals by ICP	Fuel Soot %	Fuel Dilution %	Water by Crackle	Viscosity @ 40	Viscosity @ 100	Acid Number	Base Number by FTIR	Ox/Nit/Sul by FTIR	Particle Count	Particle Quantification Index	Test Package Tier Level
	ASTM D5185	ASTM D7844	Viscosity Shift ASTM D7593	Crackle or ASTM D6304	ASTM D445	ASTM D445	ASTM D664	ASTM E2412	ASTM E2412	ASTM D7647	ASTM D8184	
Diesel Engine	X	X	X	X		X		X	X			Tier 1
Gasoline Engine	X			X		X		X	X			
Transmission	X			X		X			X			
Differential	X			X		X			X			
Stationary Gas Engine	X			X		X	X		X			Tier 2
All Gearboxes	X			X	X		X		X			
Natural Gas Compressor	X			X	X		X		X			
Air Compressor	X			X	X		X		X			
Refrigeration Compressor	X			X	X		X		X			
Industrial Hydraulics	X			X	X		X		X			
Bearings	X			X	X		X		X			
Gas Turbine	X			X	X		X		X			

LubeAlert Advanced Packages

LubeAlert ADVANCED	Elemental Metals by ICP	Fuel Soot %	Fuel Dilution %	Water by Crackle	Viscosity @ 40	Viscosity @ 100	Acid Number	Base Number by FTIR	Ox/Nit/Sul by FTIR	Particle Count	Particle Quantification Index	Test Package Tier Level
	ASTM D5185	ASTM D7844	Viscosity Shift ASTM D7593	Crackle or ASTM D6304	ASTM D445	ASTM D445	ASTM D664	ASTM E2412	ASTM E2412	ASTM D7647	ASTM D8184	
Diesel Engine	X	X	X	X		X		X	X		X	Tier 3
Gasoline Engine	X			X		X	X	X	X		X	
Stationary Gas Engine	X			X		X	X	X	X		X	
Transmission	X			X		X	X		X		X	
Differential	X			X		X	X		X		X	
All Gearboxes	X			X	X		X		X		X	
Natural Gas Compressor	X			X	X		X		X	X		Tier 4
Air Compressor	X			X	X		X		X	X		
Refrigeration Compressor	X			X	X		X		X	X		
Industrial Hydraulics	X			X	X		X		X	X		
Bearings	X			X	X		X		X	X		
Gas Turbine	X			X	X		X		X	X		

LubeAlert ADVANCED	Elemental Metals by ICP	Glycol Contamination	iPh	Water by Crackle	Viscosity @ 40	Viscosity @ 100	Acid Number	Base Number by FTIR	Ox/Nit/Sul by FTIR	Particle Count	Particle Quantification Index	Test Package Tier Level
	ASTM D5185	ASTM D2982	ASTM D7946	Crackle or ASTM D6304	ASTM D445	ASTM D445	ASTM D664	ASTM E2412	ASTM E2412	ASTM D7647	ASTM D8184	
Landfill/Biogas Gas Engine	X	X	X	X		X	X	X	X		X	Tier 5

Routine Tests

Description, Procedure,
Results and Significance

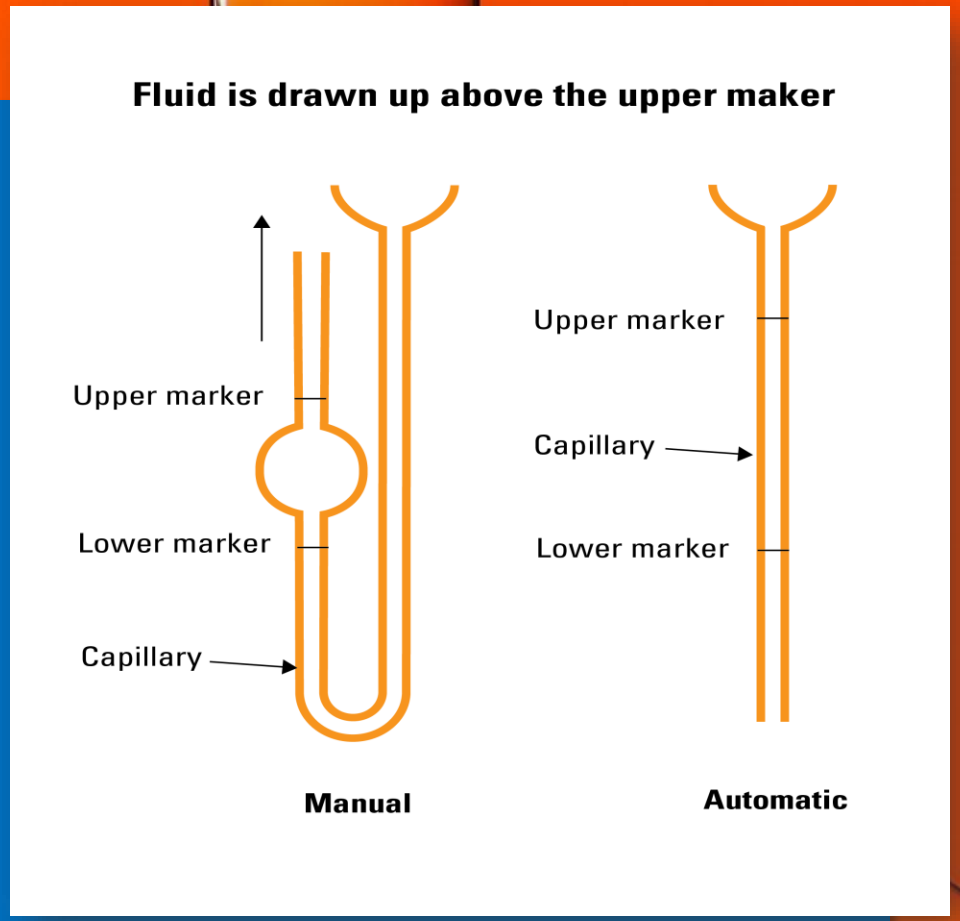
Viscosity ASTM D445

The most fundamental property of a lubricant

Measure of a fluid's resistance to flow at a given temperature:

- **Kinematic viscosity**: Calculated time for a volume of liquid to flow under gravity through a calibrated glass capillary viscometer.
- **Saybolt viscosity**: Direct measurement of kinematic viscosity by recording flow time through a straight tube.

Viscosity ASTM D445



Manual Procedure:

1. Capillary tube in hot bath of oil medium (40°C or 100°C)
2. Test fluid is drawn to above top marker
3. Time measured for oil to flow between two markers
4. Capillary tube constant applied for cSt

Automated Procedure Difference:

- Test fluid dispensed from above

Viscosity ASTM D445

Results:

- There are two types of viscosity, the dynamic (absolute) viscosity, η, and kinematic viscosity, υ
- The kinematic viscosity is easier to measure and is typically measured using a capillary viscometer
- The units of kinematic viscosity are mm2/s
- 1 mm2/s = 1 centistokes (cSt), a more commonly used unit
- Saybolt Viscosity (SSU) ~ cSt X 5
- The dynamic viscosity, μ, can be obtained by multiplying the kinematic viscosity, ν, by the density, ρ, of the liquid.

Elemental Analysis (Spectroscopy)
ASTM D5185

Measure of Elemental Metals in the Fluid

- Additive Elements
- Wear Metals
- Contaminants

Fluids

- Used Lubricants
- Unused Lubricants
- Base Oils
- Water/Glycol Fluids

Atomic Emission Spectroscopy (AES)

- Inductively coupled plasma (ICP), argon plasma, most common
- Rotating disc electrode (RDE), high voltage discharge

Procedure

A weighed portion of a thoroughly homogenized used or unused lubricating oil or base oil is diluted tenfold by weight and introduced into the ICP instrument by free aspiration or pumping. Emission intensities are compared to standards to determine elemental concentrations.

Elemental Analysis

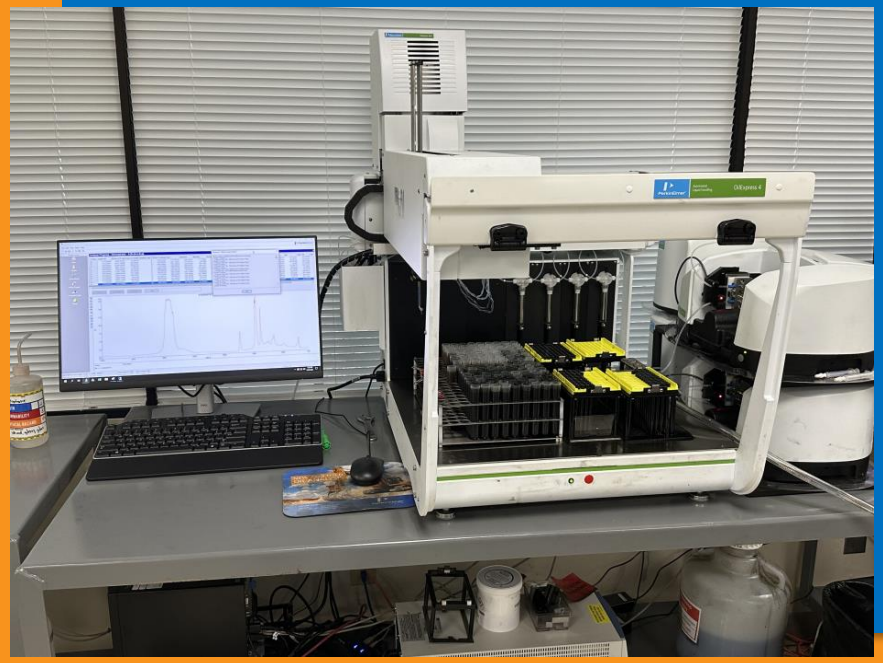
Results: Parts Per Million (PPM)

Significance of Results:

- Additive element reduction may indicate additive depletion
- Foreign additive elements may indicate contamination
- Concentrations of wear metals may indicate abnormal wear
- Sodium, potassium, and silicon can indicate an engine coolant leak

Fourier Transform Infrared (FTIR) Analysis

ASTM E2412



Use of infrared light to identify and quantify a substance's chemical composition.

Infrared spectrum features indicate molecular level components

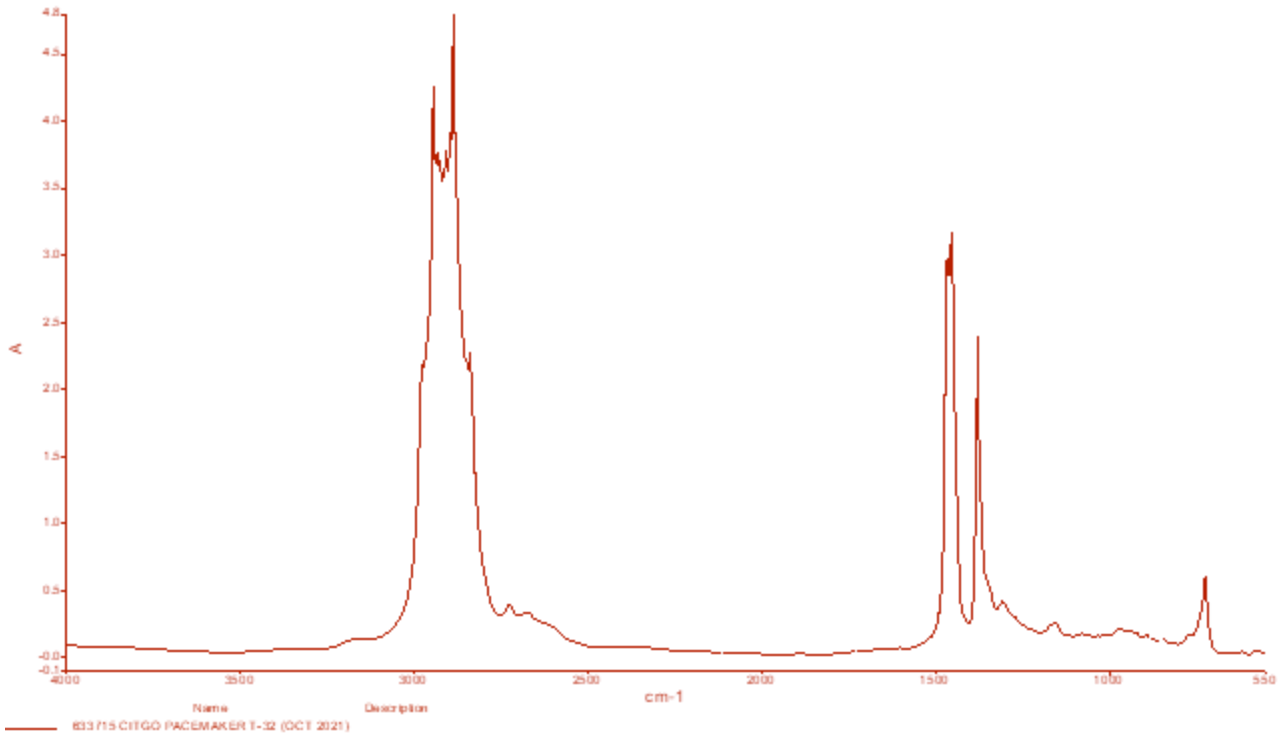
- Water
- Fuel
- Antifreeze
- Additive
- Degradation

Procedure

Absorbs infrared radiation to generate a spectrum

- Very small sample
- Performed in approximately one minute
- Provides multiple pieces of data
- Most bang for your buck

Fourier Transform Infrared (FTIR)



Significance of Results:

- Indicates fluid contaminants and conditions
- Spectrum comparison to indicate changes to in-service products

Results:

- In-service Lubricants
- Additive Depletion
- Contamination Buildup
- Base Stock Degradation

Contaminants:

- Water
- Soot
- Ethylene Glycol
- Fuels
- Incorrect Oil
- Lubricant Condition (Abs/Cm):
  - Oxidation, Nitration, and Sulfonation

Water by Crackle

Observation test to detect
the presence of water in oil

Procedure:

1. Heat hot plate to 160°C (320°F)
2. Dispense two drops oil on hot plate
3. Note visual characteristics of oil on plate

Significance of Results:

Will vary per lubricant

If positive, run Water by Karl Fisher

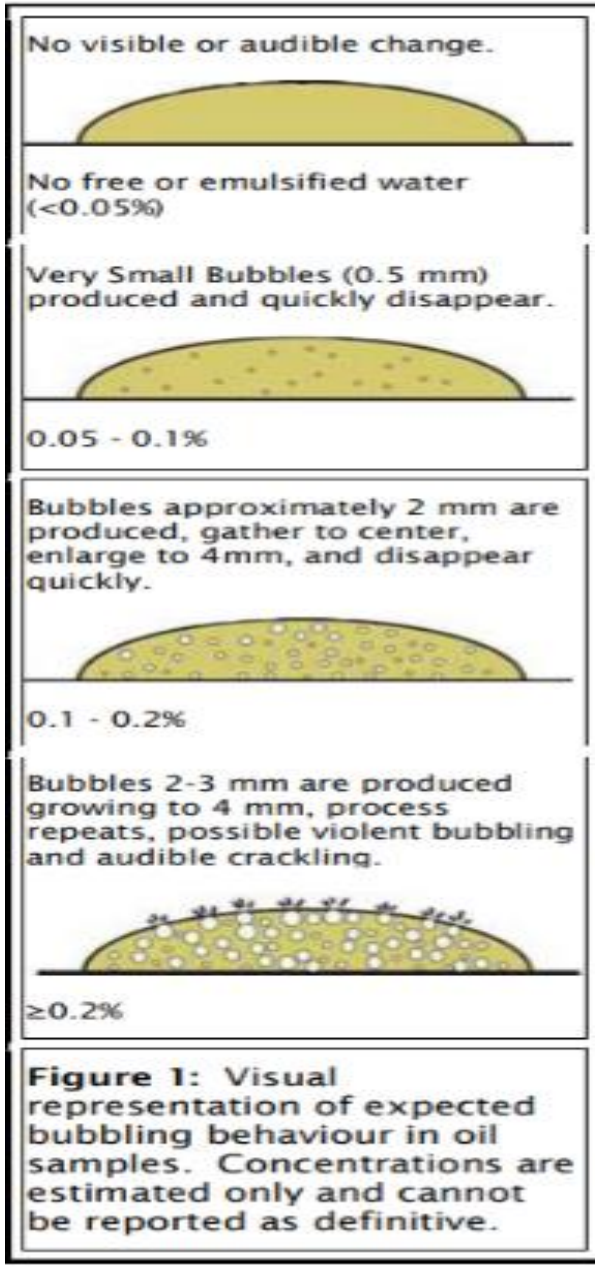


Figure 1: Visual representation of expected bubbling behaviour in oil samples. Concentrations are estimated only and cannot be reported as definitive.

Water by Karl Fischer Titration

ASTM D6304

The direct measurement of water in an in-service oil sample.

When the water by crackle test is positive, the Karl Fischer titration test is a follow-up test

Procedure:

- Oil sample injected directly into titration cell
- The instrument performs the titration
- Numerical result produced

Water by Karl Fischer

Results:

- Total water content
- Range of 20 parts per million (ppm) to 25,000 ppm (2.5%)

Significance of Results:

- Stay in service
- Dehydrate
- Replace fluid

Acid Number ASTM D664

Used to measure how much acid or base material it takes to neutralize an alkaline or acid fluid, respectively.

Procedure:

The sample is dissolved in a titration solvent and titrated potentiometrically with alcoholic potassium hydroxide.

Acid Number ASTM D664

Significance of Results:

- New and used lubricants may contain acidic constituents such as additives or degradation products formed during service
- Acid Number is an indication of the condition of in-service lubricants
- Acid number increases with oxidation of the oil
- The relative amount of acidic constituents can be determined by titrating with a base
- Acid number limits (value or change from baseline) are included in several standards for in-service oil monitoring

Base Number ASTM D4739

Used to measure how much acid or base material it takes to neutralize an alkaline or acid fluid, respectively.

Procedure:
The sample is dissolved into a combination of solvents and titrated potentiometrically with alcoholic hydrochloric acid solution.

Base Number ASTM D4739

Results:

Base Number is a measure of the alkalinity of a lubricant. In particular, engine oils are formulated with alkalinity to neutralize acidic products of combustion.

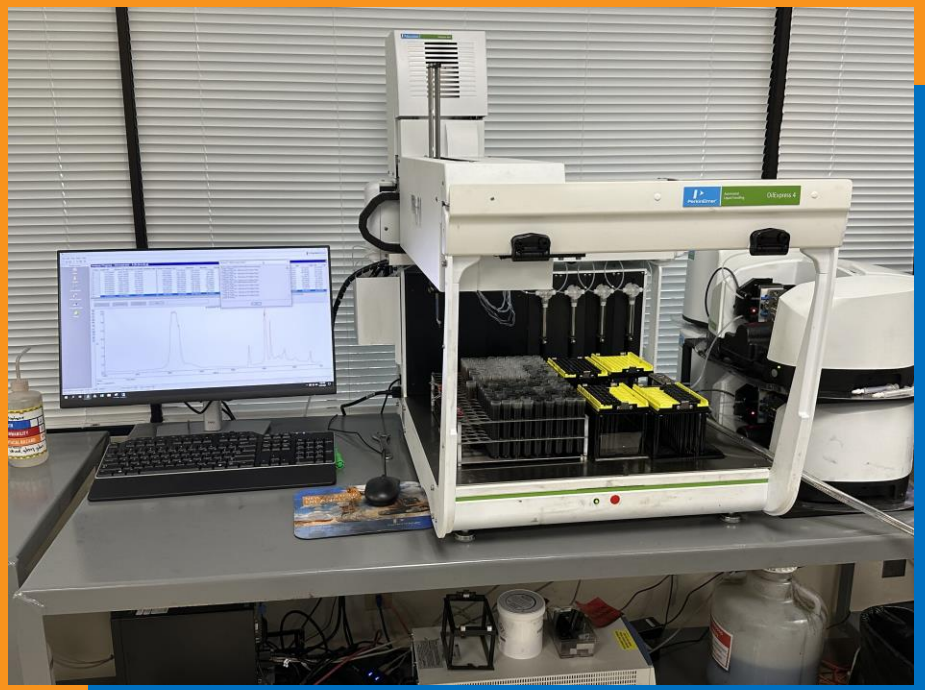
Significance of Results:

A decrease in base number generally indicates consumption of the basic additive components (typically detergents) in the oil formulation.

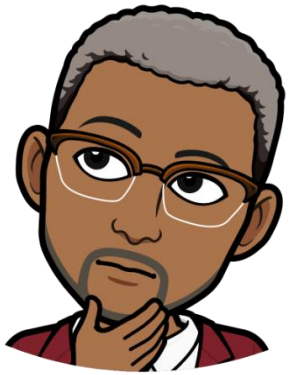
Standards for in-service engine oil monitoring often contain a lower limit for base number (value or change from baseline).

Base Number
By FTIR

A practical method to determine Base Number by FTIR has been developed to produce ASTM D4739-similar BN results.



Procedure: Numeric algorithms are used to calculate Base Number based on curves from common alkaline compounds detected by FTIR (ASTM E2412).



Base Number by FTIR

Results:

Expressed as mg KOH/ml - same as in ASTM D4739

Significance of Results:

- Repeatability is high.
- Service laboratories can achieve significant savings in time and labor.
- Reduces environmental and maintenance impact associated with titration.
- Game changer.

ASTM D7593 Gas Chromatography is the first indication of fuel dilution is often a lower oil viscosity

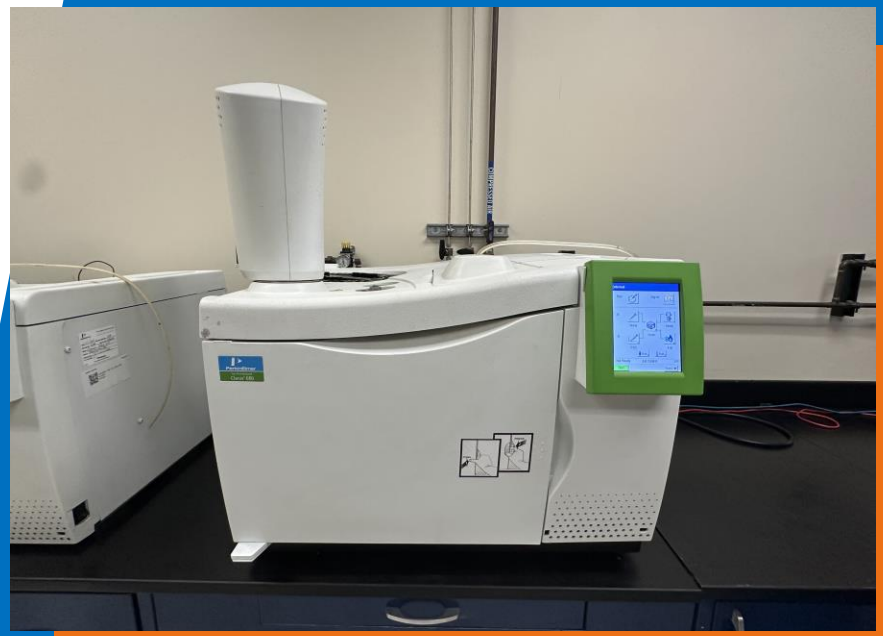
Procedure:

Methods for detecting fuel dilution:

- Viscosity
- Flash Point
- Fourier Transform Infrared (FTIR) Analysis

Tests that indicate or confirm fuel dilution:

- Surface Acoustic Wave Vapor Sensor
- Gas Chromatography



Fuel Dilution

Results: Vol%

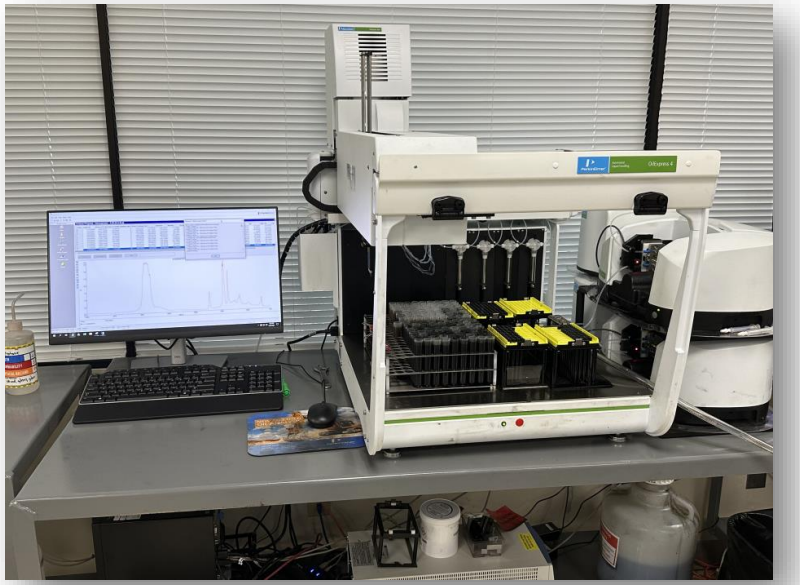
Significance of Results

Multiple conditions can contribute to fuel dilution

- Stop-and-go driving
- Cold weather start-up
- Fuel injector issues
- Poor combustion
- Worn-out engine parts
- Excessive acceleration
- Fuel/air mixture too rich
- Faulty fuel injectors

Soot by FTIR – ASTM D7844

Determines the concentration of soot in in-service engine oils and other products where soot can occur.



Procedure:

Soot in engine oil is determined by the absorption intensity at a prescribed wavenumber. The value for the in-service oil is compared to the value of new reference oil using either direct trend analysis or differential trend analysis.

Soot by FTIR

ASTM D7844

Results:

The soot content in a sample is determined by comparison with the FTIR spectrum for the unused oil. The soot content can be trended over multiple oil samples. Due to formulation effects, the soot values for oils of different formulations should not be compared.

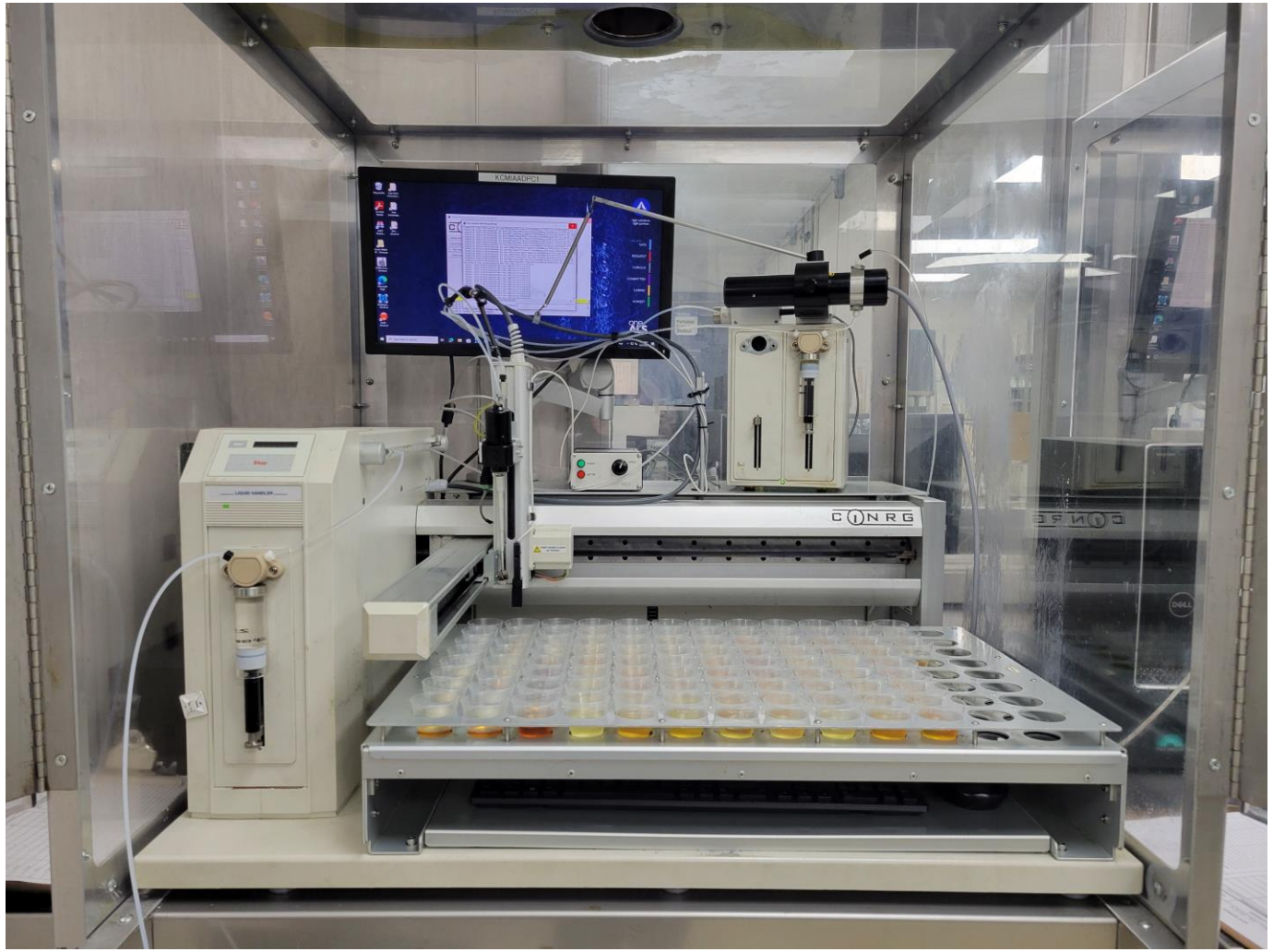
Significance of Results:

Soot is generated during combustion in engines, primarily in diesel engines. The accumulation of soot in engine oil tends to cause the oil to become more viscous (thicken).

Particle Count – D7647, ISO 4406

- The test method is specific to automatic particle counters that use the light extinction principle.

- A sample is agitated to make sure it is homogeneous. It is diluted with an appropriate solvent to mask the presence of water, agitated again, degassed, and then passed through the particle counter.



Particle Count – D7647, ISO 4406

- Technique for quantifying the number of microscopic particles in a lubricant and the size distribution of the particles.
- ISO 4406 is a system whereby the raw numbers of particles are converted to codes that cover a range of numbers of particles.
- Hard particles can have a negative effect on the equipment
- Particle count results can help the user assess the operation of the equipment and the effectiveness of filtration systems

Particle Quantification (PQ) Index

Relative measurement of the total ferrous metal content of an oil sample, regardless of the size or shape of the particles, by means of detection by a magnetic field.

Procedure:

1. Sample bottle is shaken to release sediment from sample bottle bottom.
2. Sample bottle inverted and magnet worked across cap to drag ferrous particulates to cap.
3. Bottle is placed on test carousel upside down with cap on tight.
4. Ferrous metals detected through cap as carrousel turns.

Particle Quantification (PQ) Index

Results: Measures total ferrous material in sample

Significance of Results: A higher PQ Index value indicates a higher concentration of ferrous material in the sample

Questions?

Please post your questions using the Q&A function.

For technical inquiries or issues:
Lubes Answer Line 800-248-4684
lubeshelp@citgo.com

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Thank You!

See you next time