OilDoc Conference & Exhibition

May 13-15, 2025
Bavaria · Germany

Lubricants
Maintenance
Condition Monitoring

Ghost Particles – Particle Counting Methods & Impact on ISO Codes

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Particle Counting Methods & Impact on ISO Codes

The **Authors**

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CINRG manufactures particle counting, and robotic instrumentation for the oil analysis industry.

HF Sinclair / Petro-Canada Lubricants

A manufacturer of world-class lubricants, specialty fluids and greases for over 30 years.

Canada Inc.

An oil analysis laboratory and service provider for 57 years. The leader in oil analysis.

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About Us


Don’t just automate, innovate
CS-APC-3
Automated
Auto-Diluting
Particle Counter

Fluid Cleanliness and Ghost Particles

WHAT

Soft (or Ghost) particles are non-abrasive “particles” present in lubricating oils

WHY

These particles cause laser light-scattering in optical particle counting instruments causing high ISO Cleanliness Codes

WHY

OPA cannot distinguish between these soft (ghost) particles and true abrasive contaminants

HOW

Using dilution for particle counting with the proper solvent produces accurate ISO Cleanliness Codes

Oil Filtration - Life Extension Tables

Clean & Dry Oil

↓

Increases MTBF

ISO Cleanliness

↓

Particle Counting

NEW CLEANLINESS LEVEL (ISO CODE)

Current Cleanliness Level (ISO CODE)

	20/17	19/16	18/15	17/14	16/13	15/12	14/11	13/10	12/9	11/8	10/7
26/23	5 3	7 3.5	9 4	>10 5	>10 6	>10 7.5	>10 9	>10 >10	>10 >10	>10 >10	>10 >10
	4 2.5	4.5 3	6 3.5	6.5 4	7.5 5	8.5 6.5	10 7	>10 9	>10 >10	>10 >10	>10 >10
25/22	4 +2.5	5 3	7 3.5	9 4	>10 5	>10 6	>10 7	>10 9	>10 >10	>10 >10	>10 >10
	3 2	5.3 2.5	4.5 3	5 3.5	6.5 4	8 5	9 6	10 7.5	>10 >10	>10 >10	>10 >10
24/21	3 2	4 2.5	6 3	7 4	9 5	>10 6	>10 7	>10 8	>10 >10	>10 >10	>10 >10
	2.5 1.5	3 2	4 2.5	5 3	6.5 4	7.5 5	8.5 6	9.5 7	>10 8	>10 9	>10 >10
23/20	2 1.5	3 2	4 2.5	5 3	7 3.5	9 4	>10 5	>10 6	>10 >10	>10 >10	>10 >10
	1.7 1.3	2.3 1.5	3 2	3.7 2.5	5 3	6 3.5	7 4	8 5	>10 6.5	>10 8.5	>10 10
22/19	1.6 1.3	2 1.6	3 2	4 2.5	5 3	7 3.5	8 4	>10 5	>10 6	>10 7	>10 >10
	1.4 1.1	1.8 1.3	2.3 1.7	3 2	3.5 2.5	4.5 3	5.5 3.5	7 4	8 5	10 5.5	>10 8.5
21/18	1.3 1.2	1.5 1.5	2 1.7	3 2	4 2.5	5 3	7 3.5	9 4	>10 5	>10 7	>10 10
	1.2 1.1	1.5 1.3	1.8 1.4	2.2 1.6	3 2	3.5 2.5	4.5 3	5 3.5	7 4	9 5.5	10 8
20/17		1.3 1.2	1.6 1.5	2 1.7	3 2	4 2.5	5 3	7 4	9 5	>10 7	>10 9
		1.2 1.05	1.5 1.3	1.8 1.4	2.3 1.7	3 2	3.5 2.5	5 3	6 4	8 5.5	10 7
19/16			1.3 1.2	1.6 1.5	2 1.7	3 2	4 2.5	5 3	7 4	9 6	>10 8
			1.2 1.1	1.5 1.3	1.8 1.5	2.2 1.7	3 2	3.5 2.5	5 3.5	7 4.5	9 6
18/15				1.3 1.2	1.6 1.5	2 1.7	3 2	4 2.5	5 3	7 4.5	>10 6
				1.2 1.1	1.5 1.3	1.8 1.5	2.3 1.7	3 2	3.5 2.5	5.5 3.7	8 5
17/14					1.3 1.2	1.6 1.5	2 1.7	3 2	4 2.5	6 3	8 5
					1.2 1.1	1.5 1.3	1.8 1.5	2.3 1.7	3 2	4 2.5	6 3.5
16/13						1.3 1.2	1.6 1.5	2 1.7	3 2	4 3.5	6 4
						1.2 1.1	1.5 1.3	1.8 1.5	2.3 1.8	3.7 3	4.5 3.5
15/12							1.2 1.2	1.6 1.5	2 1.7	3 2	4 2.5
							1.2 1.1	1.5 1.4	1.8 1.5	2.3 1.8	3 2.2
14/11								1.3 1.3	1.6 1.6	2 1.8	3 2
								1.3 1.2	1.6 1.4	1.9 1.5	2.3 1.8
13/10									1.4 1.2	1.8 1.5	2.5 1.8
									1.2 1.1	1.6 1.3	2 1.6

% Increase in Extension

35% Increase in Life Extension

able Legend

aulics l Engines	Rolling Element Bearings
Bearings Turbo inery	Gear Boxes and Other

MOISTURE	NEW MOISTURE LEVEL PPM (%)				
	1000 (0.1%)	500 (0.05%)	250 (0.025%)	100 (0.01%)	50 (0.005%)
5000	2.3x	3.3x	4.8x	7.8x	11.2x
2500	1.6x	2.3x	3.3x	5.4x	7.8x
1000		1.4x	2.0x	3.3x	4.8x
500			1.4x	2.3x	3.3x
250				1.5x	2.3x
100					1.4x

Ref: SKF / OSU

Ref: Lubrigard

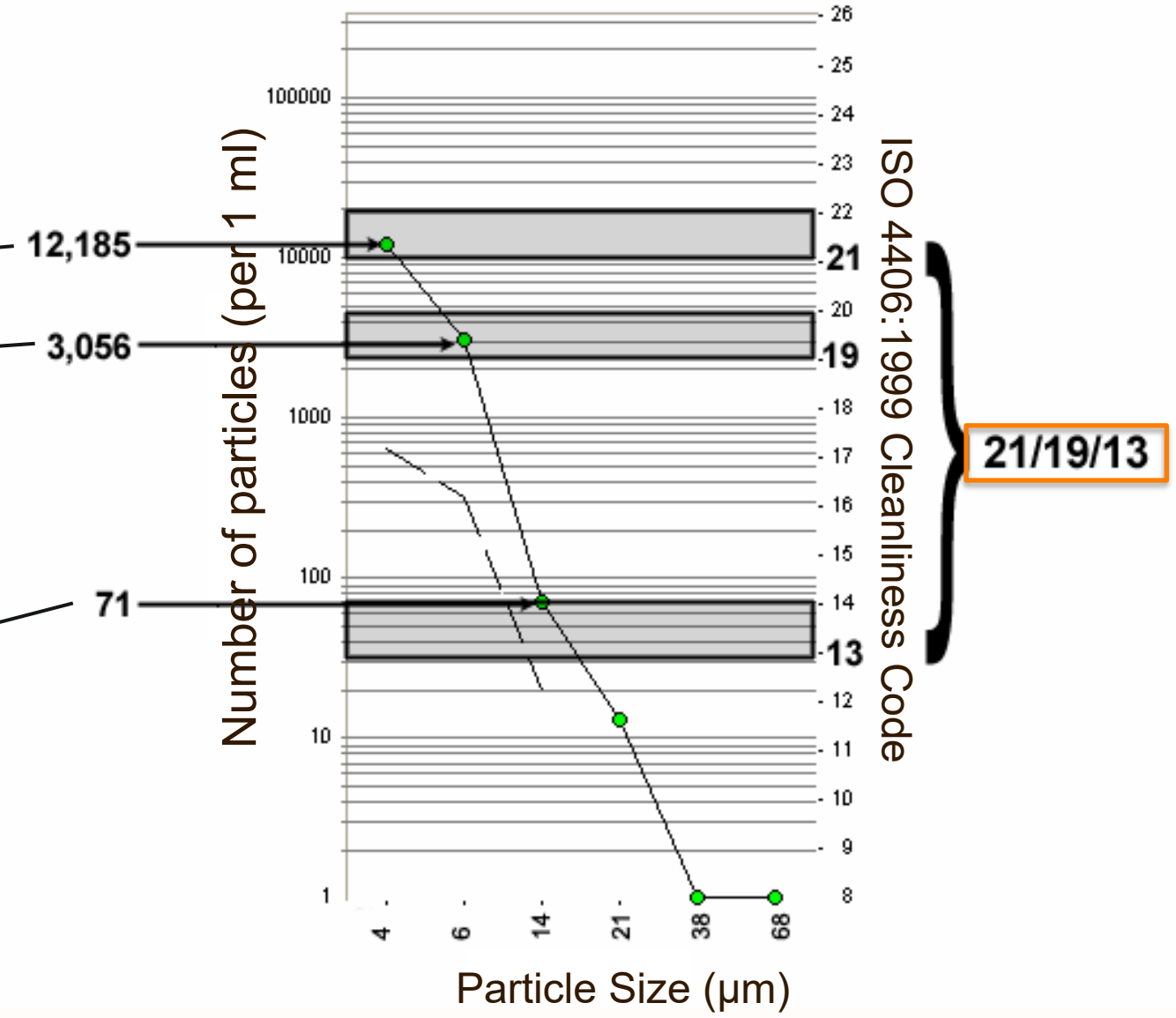
Ref: Reliable Plant

How is Oil Cleanliness Measured?

ISO 4406:1999 Classification

ISO code number	Number of particles per ml	
	More than	Up to and including
22	20,000	40,000
21	10,000	20,000
20	5,000	10,000
19	2,500	5,000
18	1,300	2,500
17	640	1,300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
09	2.5	5
08	1.3	2.5
07	0.64	1.3

ISO 4406 Cleanliness Code



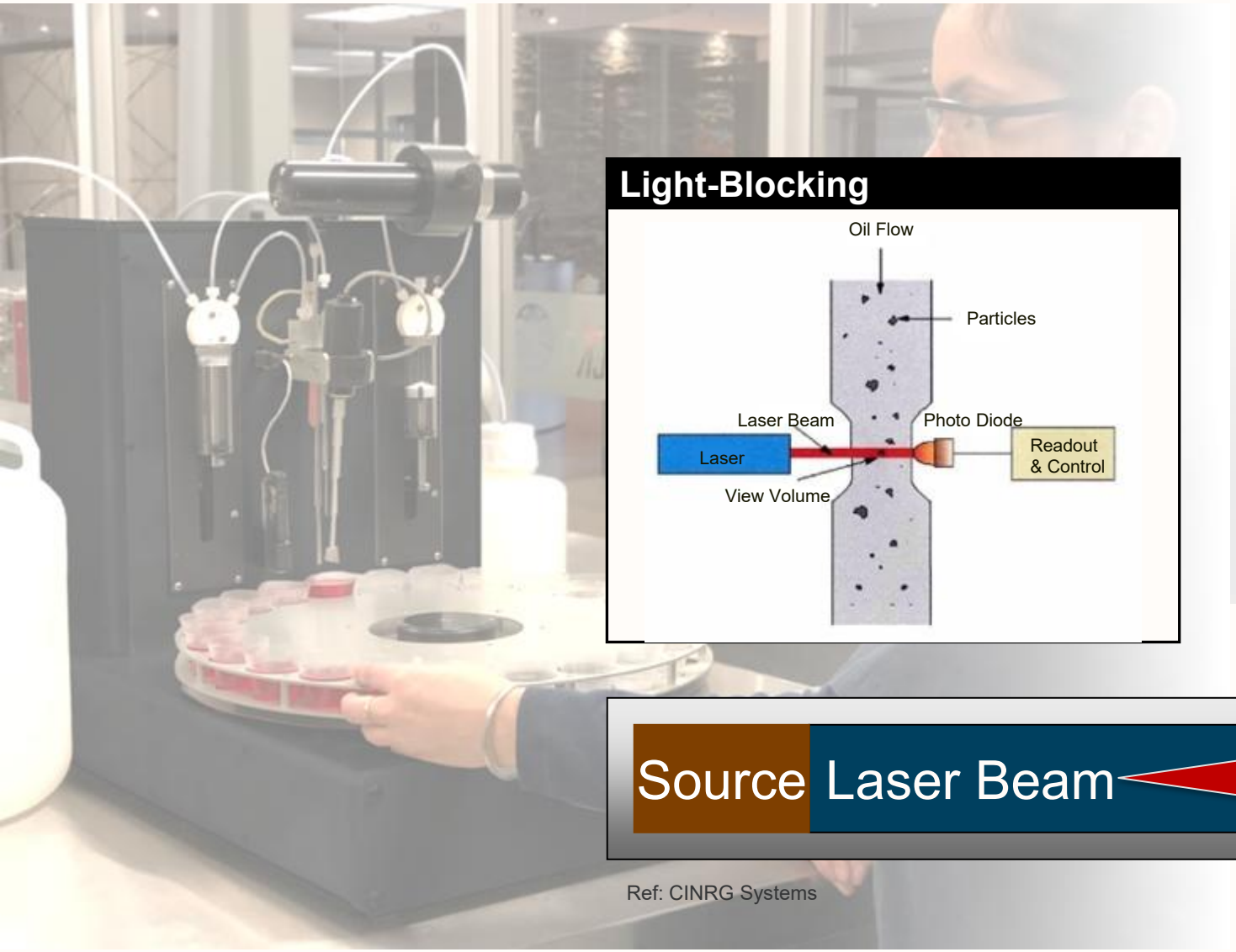
Ref: WearCheck

Particle Counting Instrumentation

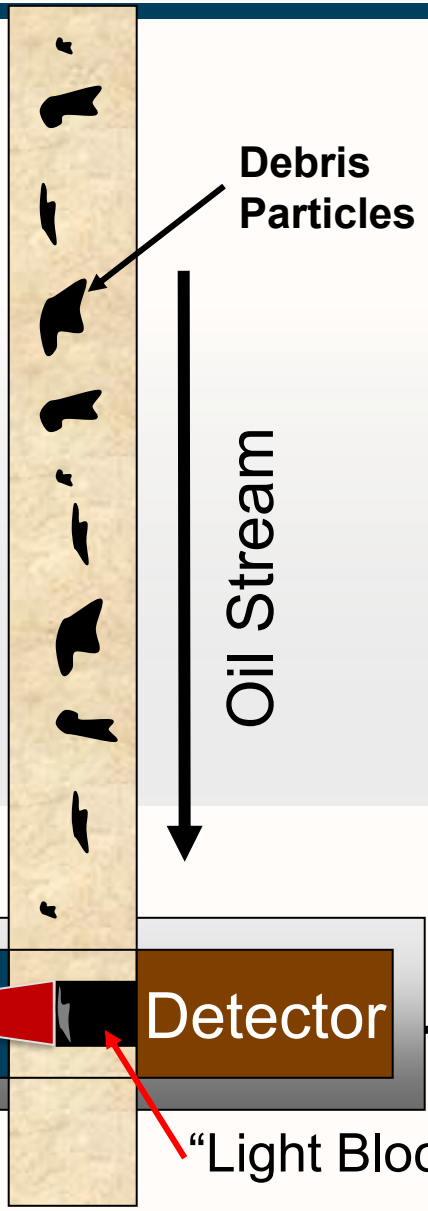
On-site / In-Line / Laboratory

Entek Contam-Alert	MP Filtri ICM	MP Filtri LPA2	Hiac Royco SDS	CINRG CS-APC-2
				
On-Site Flow Decay	In-line Optical	On-site Optical	Laboratory Optical	Laboratory Automated Optical

How an Optical Particle Counter Works



Light-Blocking



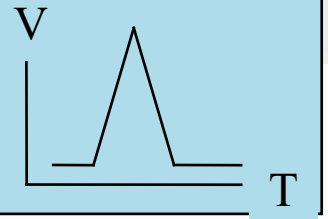
Debris Particles

Oil Stream

Particle Size Data

>4µm : 4,324
>6µm : 1,245
>14µm : 345

Voltage Pulse Counter

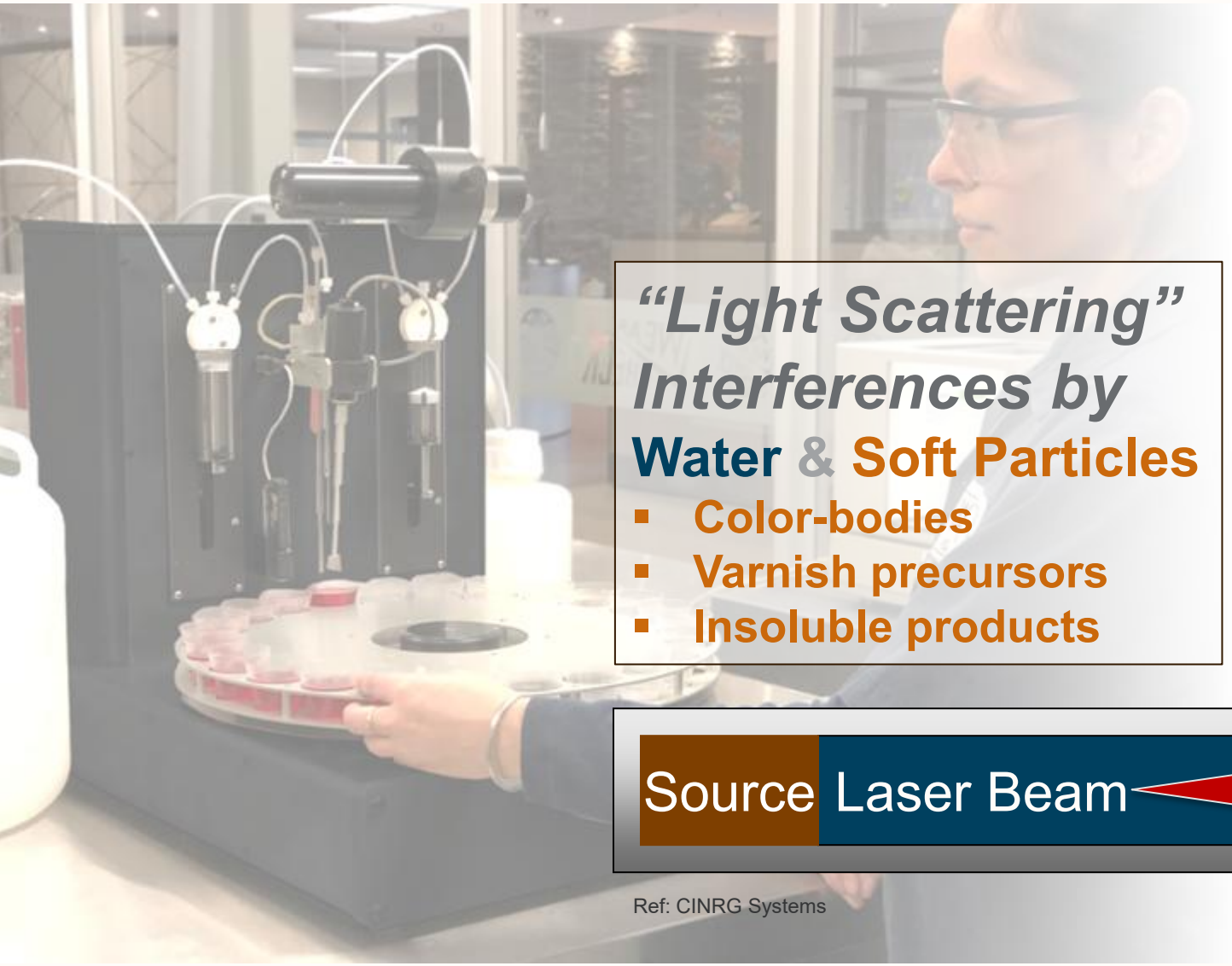


(Detector Response)

"Light Blockage"

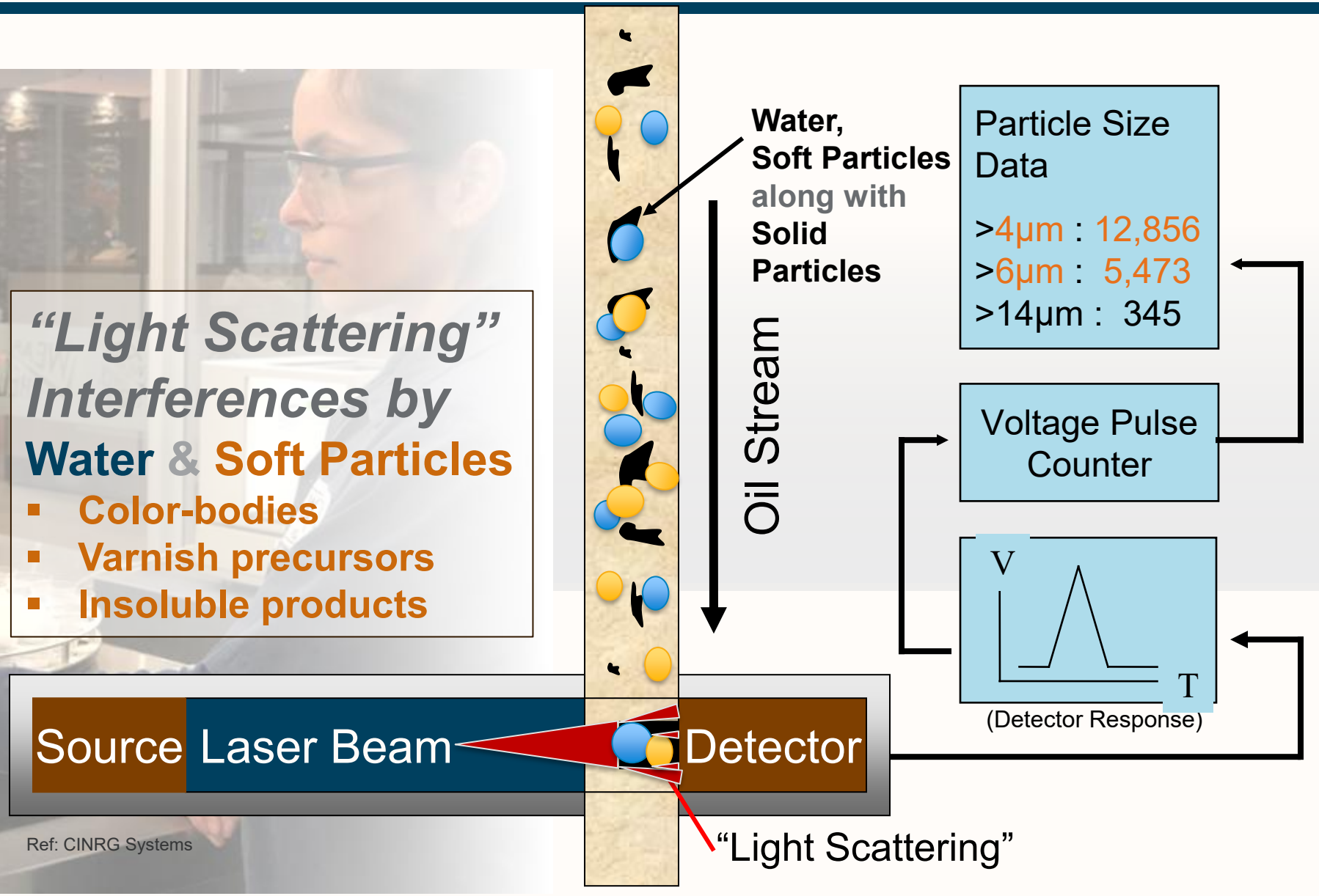
Ref: CINRG Systems

How an Optical Particle Counter Works



"Light Scattering" Interferences by
Water & Soft Particles

- **Color-bodies**
- **Varnish precursors**
- **Insoluble products**



Ref: CINRG Systems

ASTM D7647-10

ASTM INTERNATIONAL

Why ASTM D7647?

Eliminates “soft particles”

- Water
- Additives
- Varnish Precursors

This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: D7647 – 10 (Reapproved 2018)

Standard Test Method for Automatic Particle Counting of Lubricating and Hydraulic Fluids Using Dilution Techniques to Eliminate the Contribution of Water and Interfering Soft Particles by Light Extinction[1]

This standard is issued under the fixed designation D7647; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scop

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concen
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1.2 I
200 µm
automa

NOTE
by the
particles

NOTE
calibrate
applies t

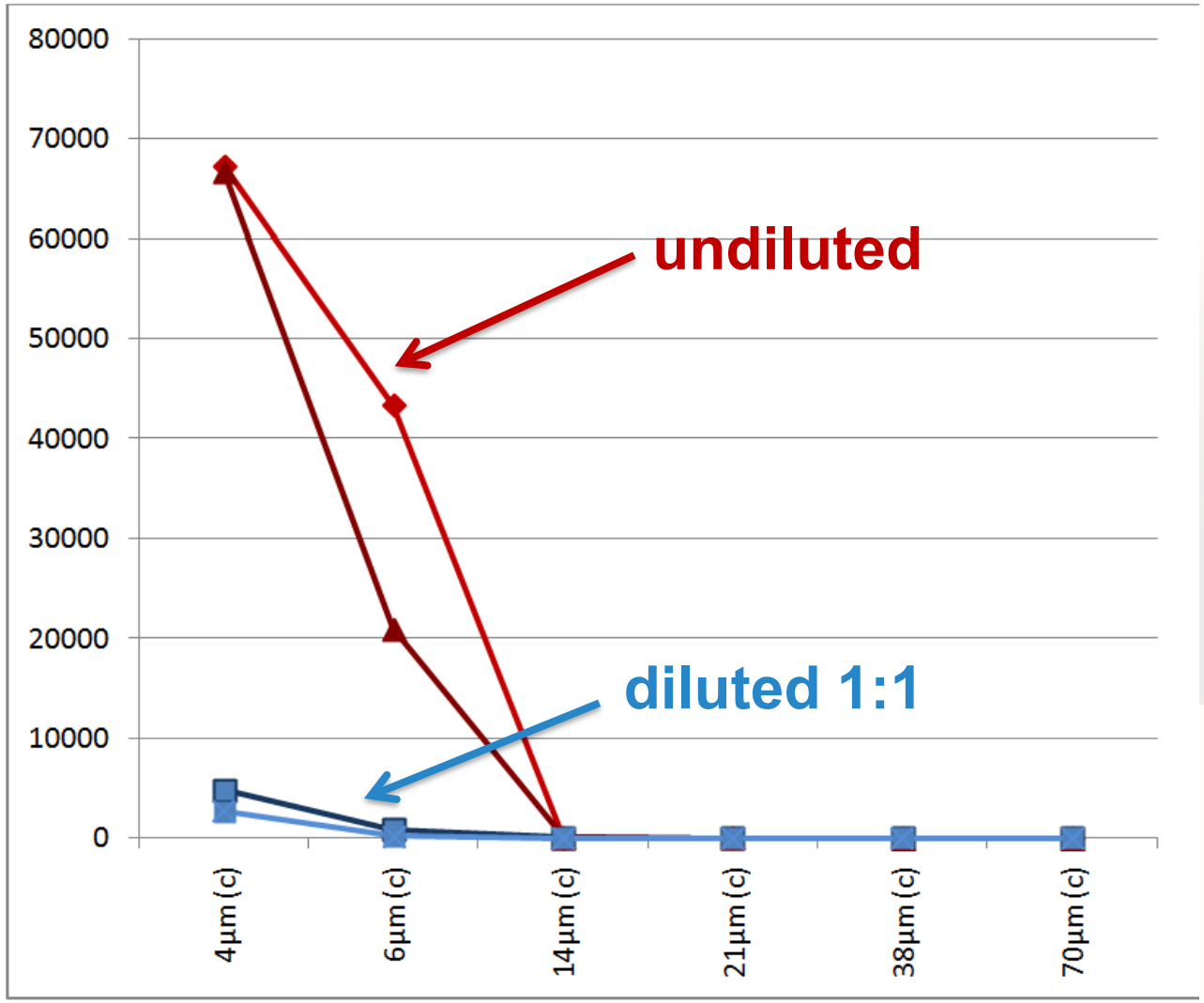
Diluent	Is this a water-masking diluent?
Stoddard solvent, also called Type 1 mineral spirits or white spirits	no
kerosene	no
lamp oil*	no
25 % 2-isopropanol / 75 % toluene	yes
dipropylene glycol n-propyl ether*	yes

Investigate Solvents used in ASTM D7647

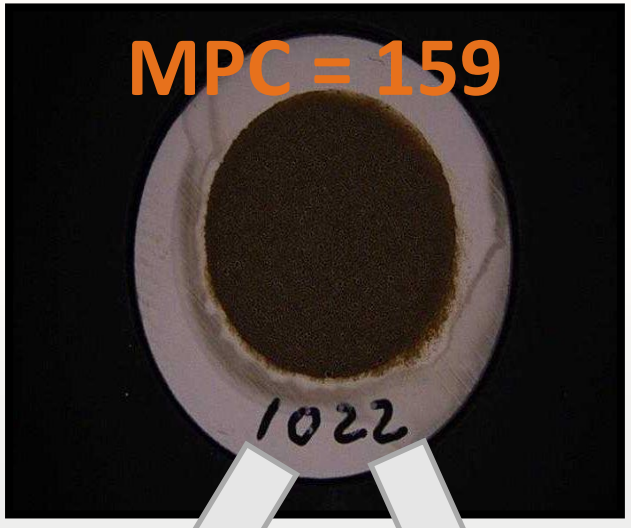
Solvents Investigated

- Toluene/IPA 75/25%
- Ethylene Glycol Butyl Ether (EGBE)
- Dowanol (DPnP)
- Kerosene
- Varsol (Stoddard Solvent).
- Kerosene / DPnP 67/33%

Insolubles & Particle Counts



Ref: CINRG Systems



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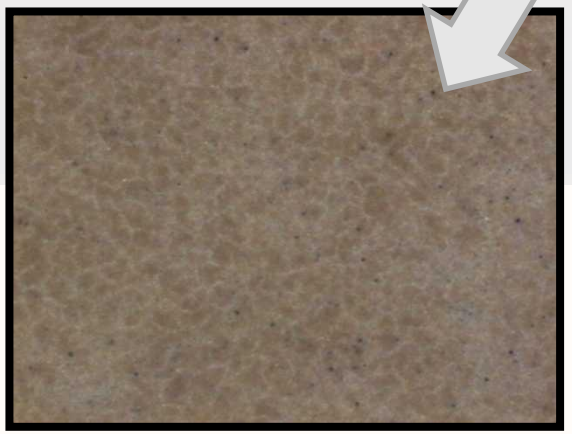
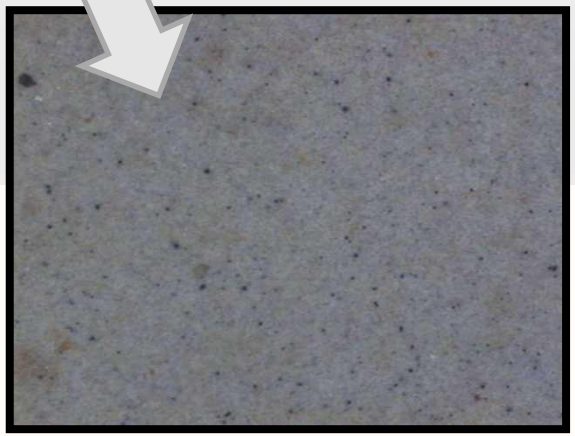


PDF Kerosene
ISO 23/23/21



PDF Toluene
ISO 17/15/11

Soft Particle Effects (Varnish Precursors)

(Used) Mobil DTE 846

Insolubles -> 23/23/19 -> 13/12/10

MPC (ΔE) = 60

Ref: WearCheck (02530825)

Solvent	ISO Code Avg
Undiluted	23/23/19
Butyl Glycol	14/12/9
75 Toluene 25 IPA	14/13/10
Dowanol(DPnB)	14/13/11
Kerosene	24/24/18
Varsol	24/24/19
90 Toluene 10 IPA	15/13/10
67 Kerosene 33 DPnB	17/16/13

Ref: CINRG Systems

Results Disparity even with low levels of Insoluble

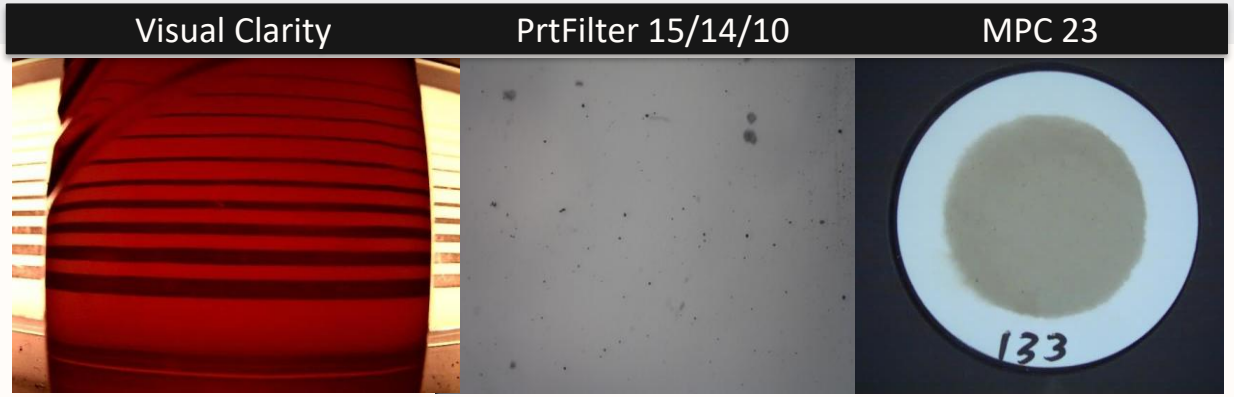
Petro Canada TurboFlo R&O 46

Dilution Solvent	ISO CODE
Undiluted	18/15/11
Diluted 1:1 Toluene/IPA	18/15/11
Diluted 1:1 Varsol	18/15/11
Diluted 1:1 EGBE	18/15/12
Diluted 1:1 Kerosene	18/15/11

02515720

Castrol Perfecto XPG 32

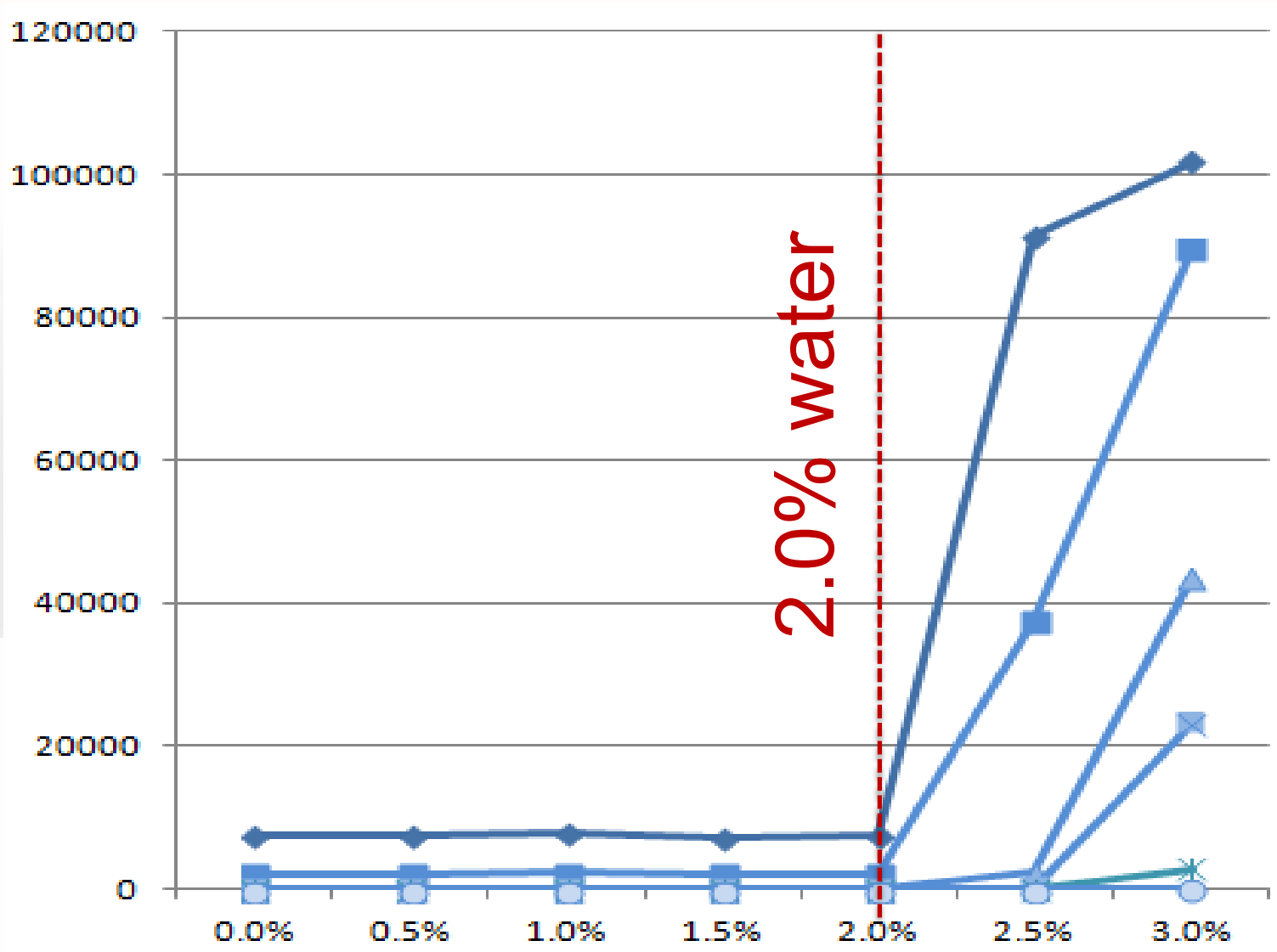
Dilution Solvent	ISO CODE
Undiluted	20/18/14
Diluted 1:1 Toluene/IPA	15/14/10
Diluted 1:1 Varsol	20/18/14
Diluted 1:1 EGBE	16/14/10
Diluted 1:1 Kerosene.	20/18/14



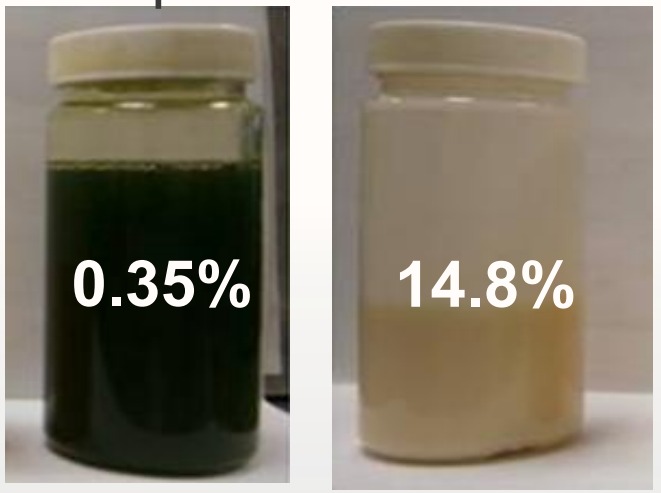
02521133

Ref: CINRG Systems

Water Contamination & Particle Counts



Samples as Received



Mixed with masking solvent

Ref: CINRG Systems

Soft Particle Effects (Water)

(Spiked) Medium Test Dust (MTD)

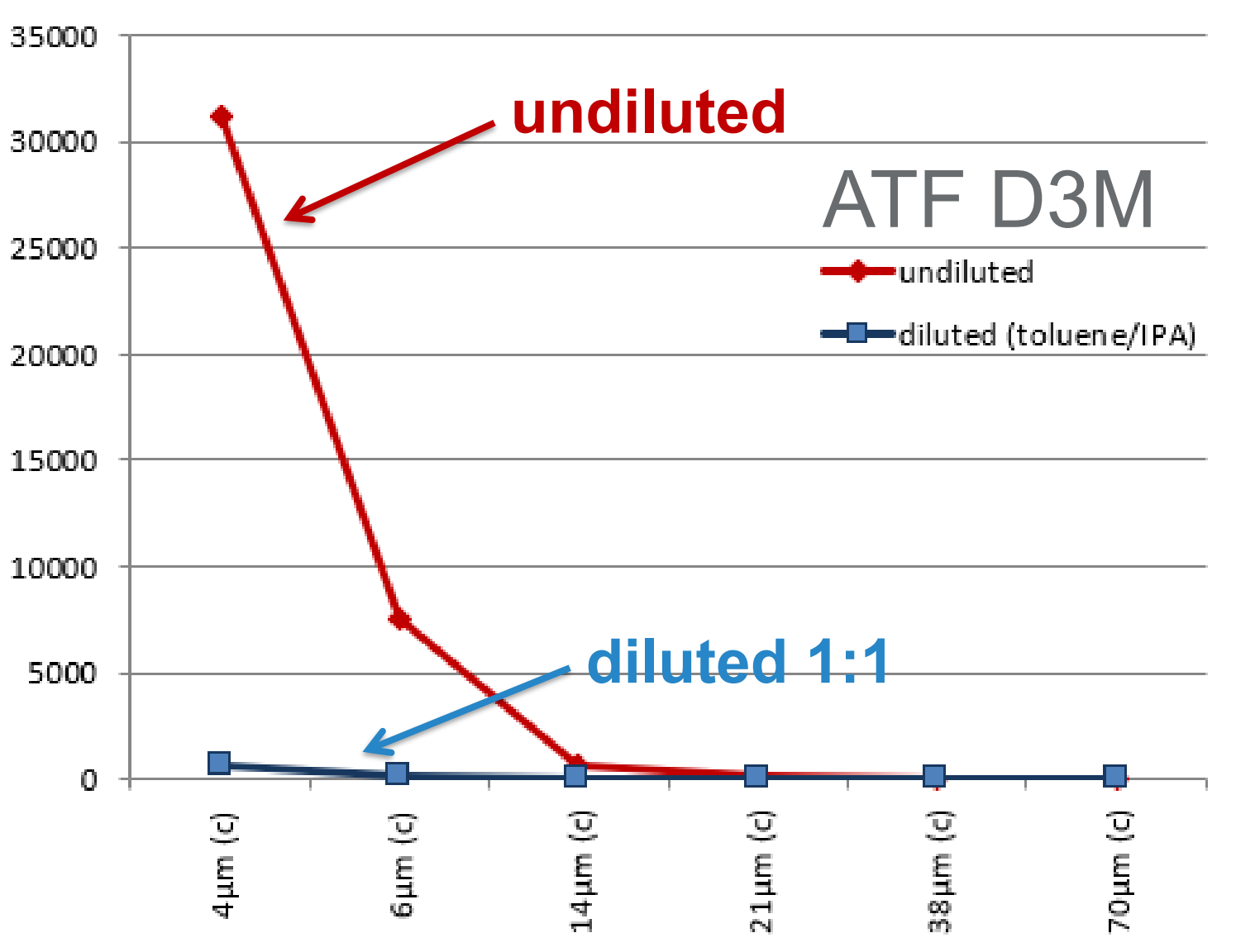
Water -> 25/25/25 -> 20/19/16

H_2O = 1%

Solvent	ISO Code Avg
Undiluted	22/22/22
Butyl Glycol	21/20/16
75 Toluene 25 IPA	21/19/16
Dowanol(DPnB)	21/19/16
Kerosene	25/25/25
Varsol	25/24/24
90 Toluene 10 IPA	20/19/16
67 Kerosene 33 DPnB	22/21/21

Ref: CINRG Systems

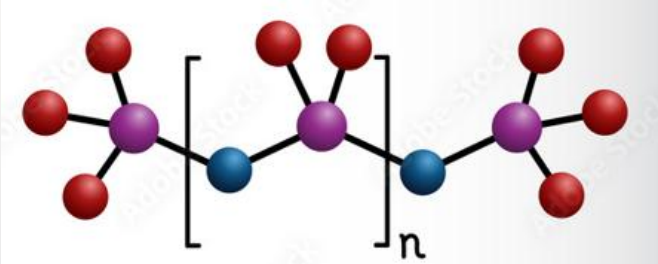
Oil Additives & Particle Counts



Polydimethylsiloxane

PDMS

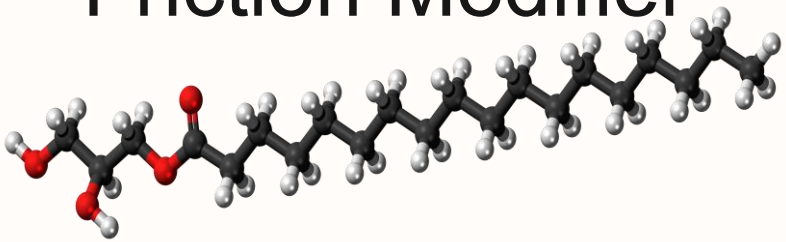
Anti-foaming Agent



Glycerol monooleate

GMO

Friction Modifier



Ref: CINRG Systems

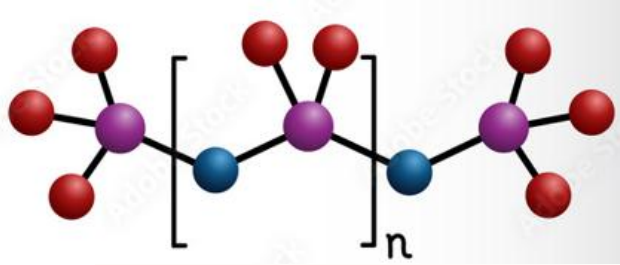
Soft Particle Effects (Anti-Foam Additive)

(New) Petro-Canada ATF D3M

Additives -> 22/20/16 -> 16/14/11

Polydimethylsiloxane

PDMS



Solvent	ISO Code Avg
Undiluted	22/20/16
Butyl Glycol	20/17/14
75 Toluene 25 IPA	16/14/10
Dowanol(DPnB)	19/17/14
Kerosene	17/15/11
Varsol	17/15/12
90 Toluene 10 IPA	16/14/11
67 Kerosene 33 DPnB	17/15/12

Base Oil & Additives Effect on ISO Cleanliness Code

Components	ISO Cleanliness Code
Commercial ATF	23/20/17
Base Oils	19/15/10
Friction Modifiers	20/17/12
Friction Modifiers + **Antifoam**	**22/20/15**
Dispersants + **Antifoam**	**21/19/14**
Dispersants + Viscosity Index Improver (VI) + **Antifoam**	**21/19/14**
Detergents	20/17/11
Dispersant + Friction Modifier + VI	20/17/11
Detergent + Friction Modifier + Dispersant + VI	20/17/12
Detergent + Friction Modifier + Dispersant + VI + **Antifoam**	**21/19/14**

1- Paul W. Michael, Thomas S. Wanke, and Michael A. McCambridge; Additive and Base Oil Effects in Automatic Particle Counters - Journal of ASTM International, Vol. 4, No. 4 Paper ID JAI100941

Ref: HF Sinclair / Petro-Canada Lubricants

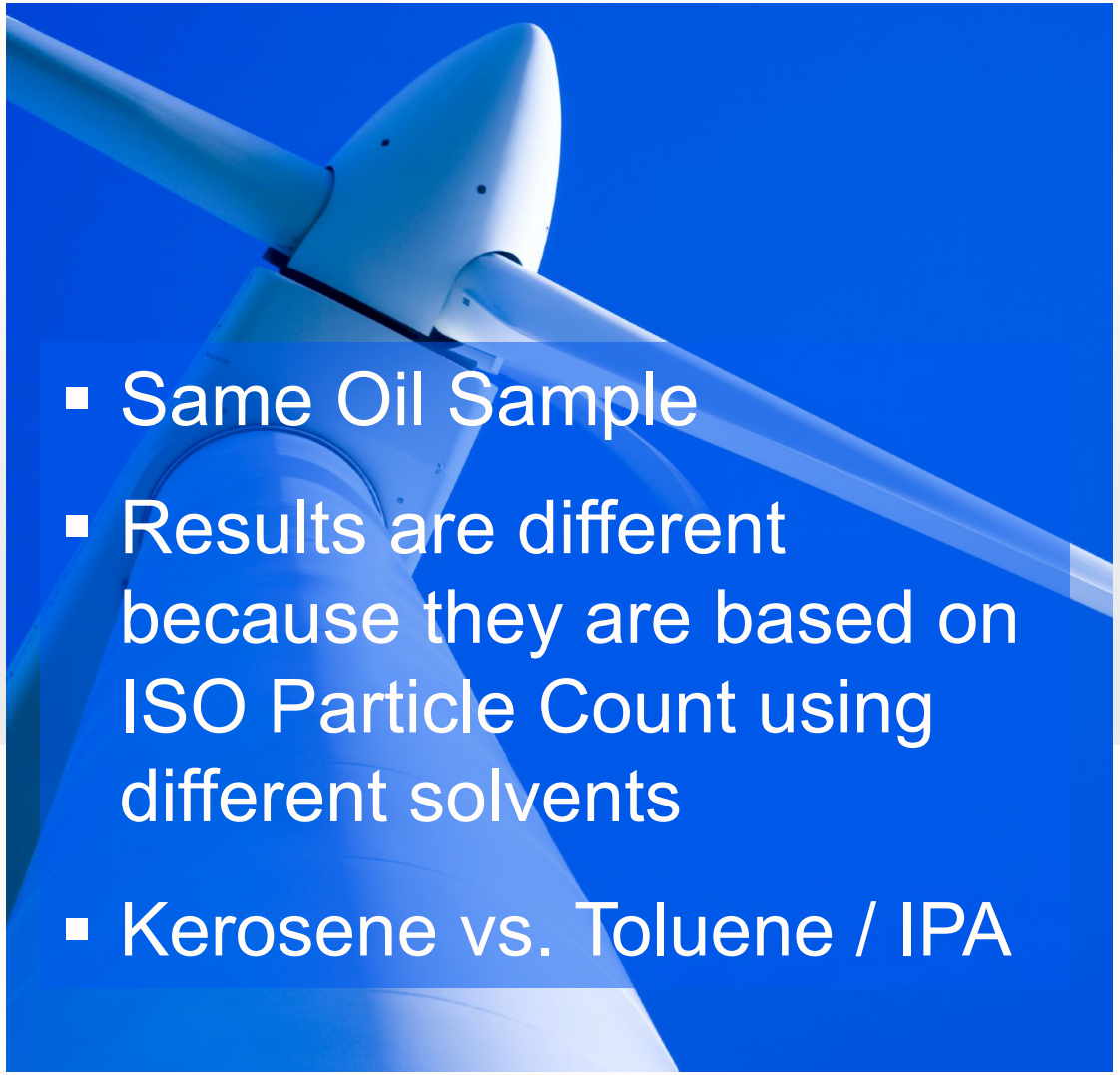
Filtration Effects on Oil Additives

Sample Description	ATF A production batch	ATF A production batch after 3µm filtration*	ATF A production batch after 1µm filtration*
ISO Cleanliness Code	22/21/17	19/17/10	18/17/12
Silicon, ppm	6.7	4.4	2.0
Boron, ppm	86	82	81
Calcium, ppm	64	56	57
Phosphorus, ppm	203	194	193
Sulfur, ppm	1282	1246	1240

* Membrane filters were use in this evaluation – single pass
NOTE: Filtration was performed using a laboratory filtration system

Ref: HF Sinclair / Petro-Canada Lubricants

What is the Issue with High Particle Counts?

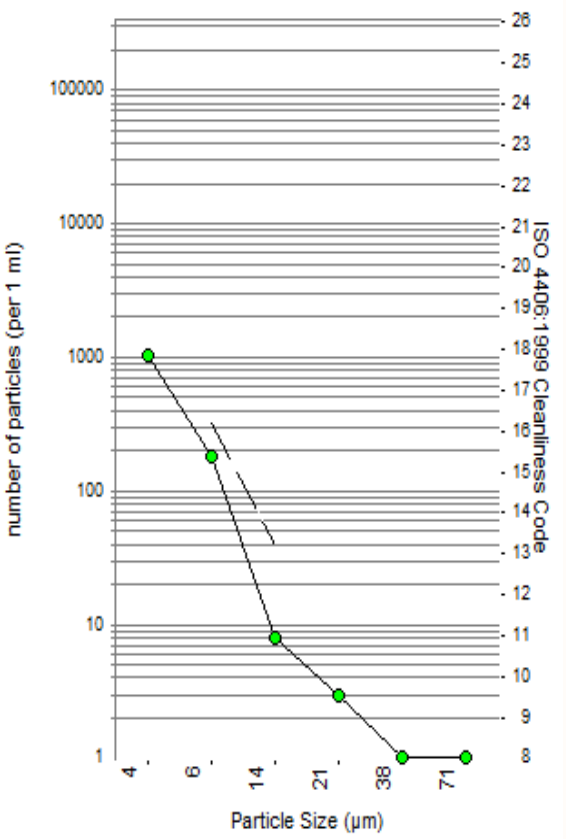


- Same Oil Sample
- Results are different because they are based on ISO Particle Count using different solvents
- Kerosene vs. Toluene / IPA

1- Alistair Geach, William A. Quesnel; Particle Counting of Heavily Contaminated Oil Samples – OilDoc Conference, Rosenheim Germany, January 2015

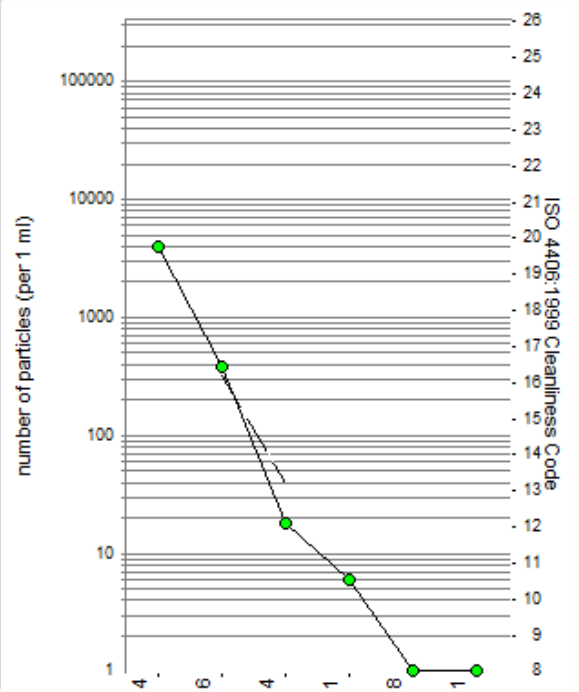
Ref: CINRG Systems

17/15/10
Toluene/IPA



=$0.00

19/16/11
Kerosene



2 x tech x 3 hrs + Oil Filter

$700.00 x 133

=$93,100.00

Ref: G. Tapp – GE Wind

Conclusions & Recommendations

Questions?

- Water & “Soft” Particles increase the apparent ISO Cleanliness Code (soft particles include insoluble oxidation by-products and some oil additives)
- The dilution method for particle counting (ASTM D7647) mitigates or eliminates the effect of water and “soft” particles
- Not all solvents used for dilution have the same masking effect. 75% Toluene / 25% Isopropanol (IPA) is the most effective solvent mix for water and “soft” particles
- Ultra-fine filtration can lead to the removal of some oil additives (notably anti-foaming agents and detergency additives)
- Before taking action based on your oil samples ISO Cleanliness results, ensure that your laboratory is using the appropriate particle counting method