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Inaccurate, unreliable partical counting can hamper your ability to make smart oil suitability decisions. That can cost your company considerably in tearms of time and money.

It's no mystery to Maintenance professionals that clean oil promotes enhanced equipment performance and reliability. There is, however, something that many of them do not know. Today's most commonly used particle counting tests for determining oil cleanliness—Filter & Count Method; Light Blockage Method—too often yield inaccurate and inconsistent results.

As detailed in this article, the inconsistency and lack of precision with these current practices can lead companies to waste considerable amounts of money and time developing maintenance plans based on inaccurate and unreliable information. But, by incorporating innovative methods to address sources of errors—*including air entrainment, water content, and additive effects* —particle counting precision and accuracy can be greatly improved. Maintenance professionals can then make better oil suitability decisions, garner a stronger return on their lubricant investment and enhance their equipment performance.

What is cleanliness?
Oil cleanliness can be defined as a measure of the level of dirt, other insoluble or hard particles in fresh or in-service oil. There are a number of factors that can impact a lubricant's cleanliness, most notably contamination and harsh operating conditions, such as extremely high temperatures, pressures and operating speeds. To this end, maintenance professionals are implementing oil analysis programs with the desire to gain accurate readings on the cleanliness of their oil to support oil suitability decisions.

Oil cleanliness is typically determined by particle counting. The Filter & Count (ISO 4407) and Light Blockage or Extinction (ISO 11500) tests are the most widely used methods of particle counting. Thus, the results of these tests were used as the foundation for the discoveries detailed in this article.

Filter & Count Method–ISO 4407…
Particle counting using the Filter & Count Method is conducted exactly how it sounds. Oil samples pass through a fine-patch filter that captures particles that are greater than four

microns (> 4µ) in size. After the sample has passed through the filter, the particles on the filter patch are counted and measured under a microscope. The Filter & Count Method is considered to be the most accurate method of particle counting because the test is not normally affected by fluid color, air or water.

There is, however, no precision statement for the test, so the accuracy of the measurements is unknown. In addition, agglomerated particles, particle coincidence (excessively high particle counts that prevent accurate detection by the instrument), sometimes emulsified water and even air bubbles can contribute to false readings. It also is important to note that this test is extremely laborintensive and expensive. Furthermore, human error and variability can contribute to inaccurate readings and low test precision.

Fig. 1. ISO Cleanliness Code –ISO 4406 chart

Range Code	Number of Particles per ml	
	More Than	*Up to & Including*
24	80,000	160,000
23	40,000	80,000
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
9	2.5	5
8	1.3	2.5
7	0.64	1.3
6	0.32	0.64
5	0.16	0.32
4	0.08	0.16
3	0.04	0.08
2	0.02	0.04
1	0.01	0.02
0	0.005	0.01
00	0.0025	0.005

Fig. 2. Under ISO 4006, to determine an ISO code, particles are measured and grouped into three categories based on their size in microns. In this example, an ISO cleanliness code of 21/17/12 is indicated.

Size Groups	Particle Quantities	ISO Code
>4 microns	11250	21
>6 microns	1050	17
>14 microns	28	12

[illegible]

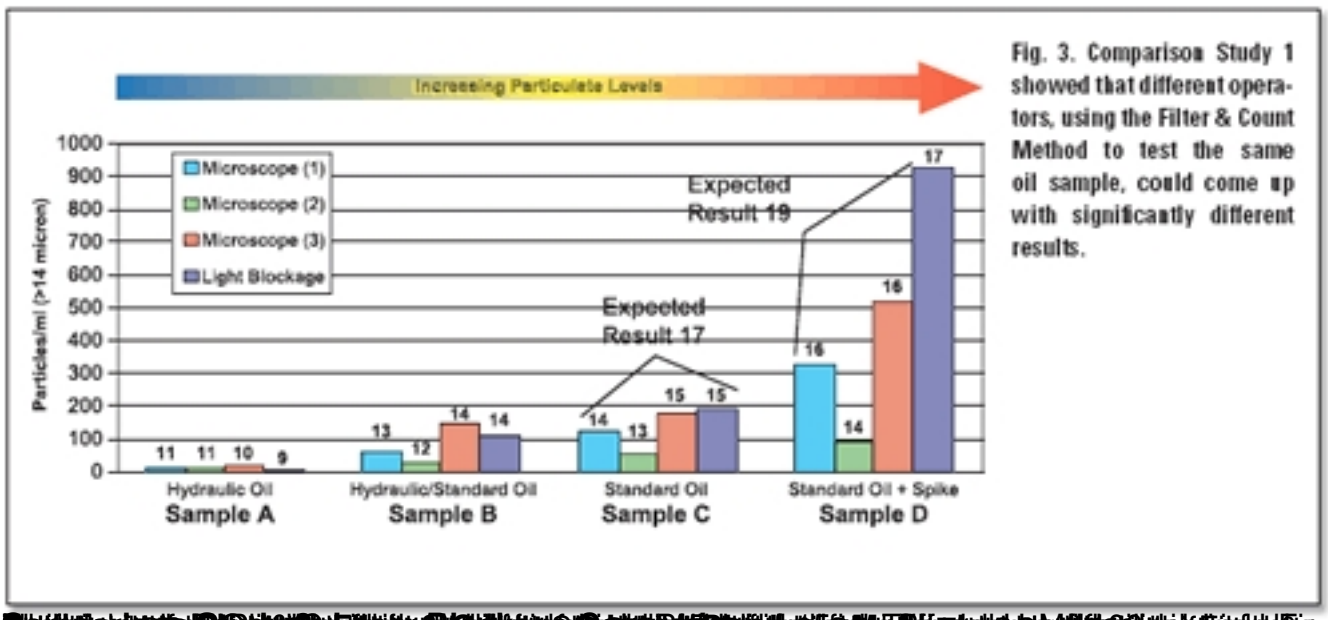

Fig. 3. Comparison Study 1 showed that different operators, using the Filter & Count Method to test the same oil sample, could come up with significantly different results.

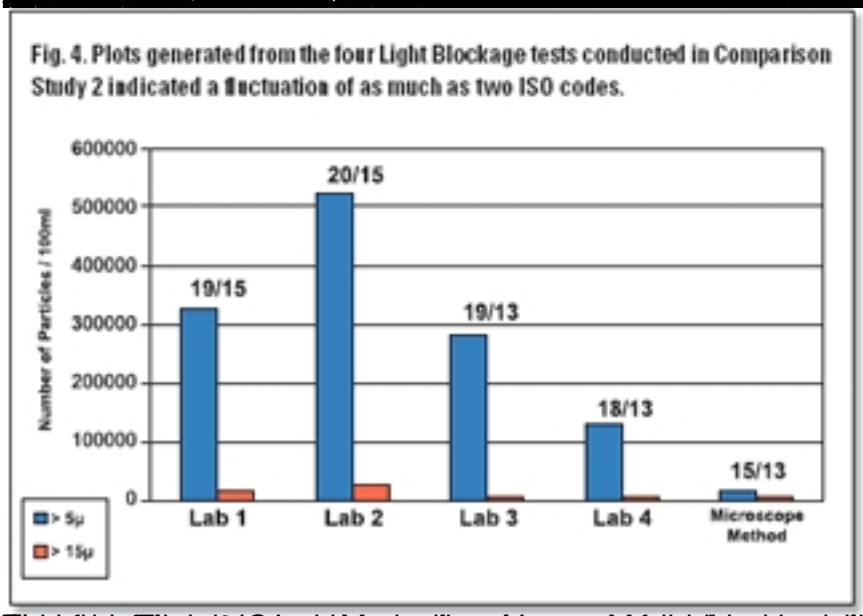

Fig. 4. Plots generated from the four Light Blockage tests conducted in Comparison Study 2 indicated a fluctuation of as much as two ISO codes.

Fig. 5. Ultrasonic pre-treatment of an oil sample can minimize inaccuracies in particle count as a result of air bubbles.

ISO 32 Hydraulic Fluid				
Particle Size (Microns)	No Sonic Treat	3 Minute Sonic Treat	5 Minute Sonic Treat	5 Minute Sonic Treat Under Vacuum
>4	685,365	623,590	626,625	646,514
>6	155,210	94,175	90,750	106,715
>14	55,540	6,005	5,540	7,995
ISO 4406 Code	20/18/16	20/17/13	20/17/13	20/17/13

Fig. 6. An antifoamant substantially increases the cleanliness rating of an oil. This interference can be avoided through use of a diluent, which is a miscible liquid or solvent that dilutes and lowers the viscosity of the sample.

Particle Size (Microns)	Basestock	Basestock + 0.02% Antifoam	Basestock + Antifoam+ Diluent A	Basestock + Antifoam+ Diluent B
>4	379,565	3,592,005	83,150	55,200
>6	25,305	1,722,785	23,230	14,540
>14	1,125	203,690	10,610	2,620
ISO 4406 Code	19/15/11	22/21/18	17/15/14	16/14/12

[redacted]

Fig. 7. The oil cleanliness rating (indicating "dirtier oil") increases when water is added to a lubricant. When a diluent is added, the oil cleanliness rating is reduced and a more accurate particle count is generated.

150 SN Basestock with Variable Water Content			
Sample ID	Sample A	Sample B	Sample C
Water, ppm	29	122	182
Particle size (Microns)	Particle Count / 100 ml		
>4	242,580	6,205,510	7,223,415
>6	19,220	3,212,260	5,186,110
>14	1,620	124,545	380,380
ISO 4406 Code	18/15/11	23/22/17	23/23/19

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