# Frequently Asked Questions About The LaserNet Fines

1. What is LaserNet Fines?

LaserNet Fines (LNF) is a bench-top automated oil debris analysis instrument. It is a particle counter and shape classifier that identifies, sizes and trends wear debris in all types of lubricants and hydraulic fluids.

2. How does the LaserNet Fines work?

The operation of the LNF is based on technology that combines laser imaging and artificial intelligence to characterize wear debris. A representative oil sample is drawn from a lubricating system and taken to the instrument for analysis. The LNF draws the sample fluid through a viewing cell that is illuminated by a pulsed laser diode that freezes the particle motion for between 1 and 350 µsec. The light transmitted through the fluid is then imaged onto

a video camera with macro focusing optics. Thirty such images are collected per second. The images are analyzed by the software to determine the type of particles present and their size distribution.
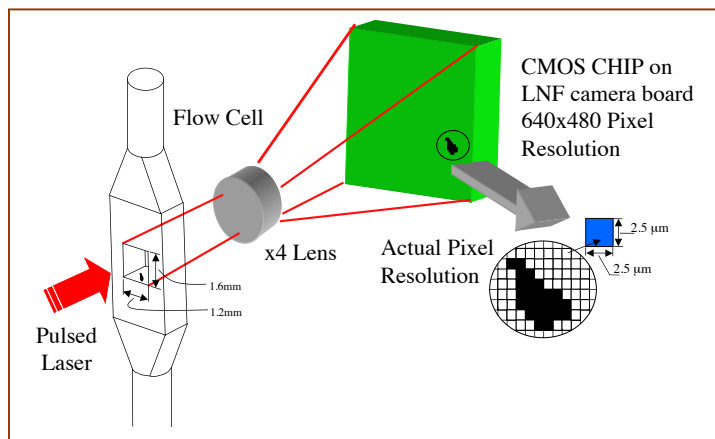
3. What are the key features of the LNF?

• *Algorithms perform shape analysis and wear particle identification.*
• *Measures particles from 4 µm to greater than 100 µm.*
• *Classifies particles greater than 20 µm in size.*
• *Categorizes sample per cleanliness ratings ISO 4406, NAS 1638 and NAVAIR 01-1A-17.*
• *Detects air bubbles greater than 20 µm and excludes them from particle counts.*
• *Automatically compensates for fluid darkness and soot levels.*
• *Requires no calibration, sizing set by known linear dimensions in flow cell.*
• *Compatible with synthetic oils, mineral-based lubricants and hydraulic fluids.*
• *Windows 2000-based operating system.*
• *Built-in database for trending.*
• *LAN interface for data export.*

4.   What are the main components of the LNF?

• *Collimated Laser Diode – Operates at 830 nm with a peak power of 100 mW.*
• *Flow Cell – A 100 µm thick cell*
• *Imaging Optics – Images an approximate 1.6 mm x 1.2 mm area of the flow cell onto the camera at 4X magnification.*
• *CCD Video Camera – A 640 x 480 pixel camera captures images of the sample in the flow cell and digitally transfers them via USB port to the computer.*
• *Computer – Manages the operational parameters, data management and interpretation tasks.*
• *Operating and Data Analysis Software – Controls operational parameters of the instrument and processes particle information such as size, shape and particle type. Trends for each uniquely defined machine or sample point are also stored.*

5.   Who developed the LNF?

Lockheed Martin developed the LNF in cooperation with the Naval Research Laboratory for the Office of Naval Research. It was initially developed to meet the needs of automated shipboard machinery diagnostic capability. Lockheed Martin has since partnered with Spectro Incorporated for commercial distribution and field support of the LNF.

Lockheed Martin: a highly diversified global enterprise principally engaged in the research, design, development, manufacture and integration of advanced technology systems, products and services. Lockheed Martin employs approximately 140,000 people. Lockheed Martin is the manufacturer of the F-16 Fighting Falcon and the new US Air Force F-22 Raptor.

6.   What type of sample can the instrument handle?

It can handle synthetic and mineral base lubricants, hydraulic fluids, samples with high soot levels and samples with high particle concentrations. It is not intended for samples with high water content or fluids that are water-based.

7.   What about the viscosity and contamination level of the sample?

Samples with viscosities of up to 150 cSt at 40 degrees C (ISO 150 Grade oil) can be analyzed at room temperature without solvent dilution. Samples of higher viscosities can be analyzed by first thinning them with an appropriate solvent. For example an ISO 220 Grade oil requires 1 part solvent to 6 parts oil sample. The software has a data field to input the dilution factor so that particle counts are corrected for undiluted sample.

The LNF can handle particle concentrations ranging from 0 to over 5,000,000 particles/ml. Conventional light attenuation particle counters cannot handle samples with such high particle concentrations.   The LNF can do it because it examines a large area of the flow cell each time an image is captured. Many particles can be present at once without overlapping. In
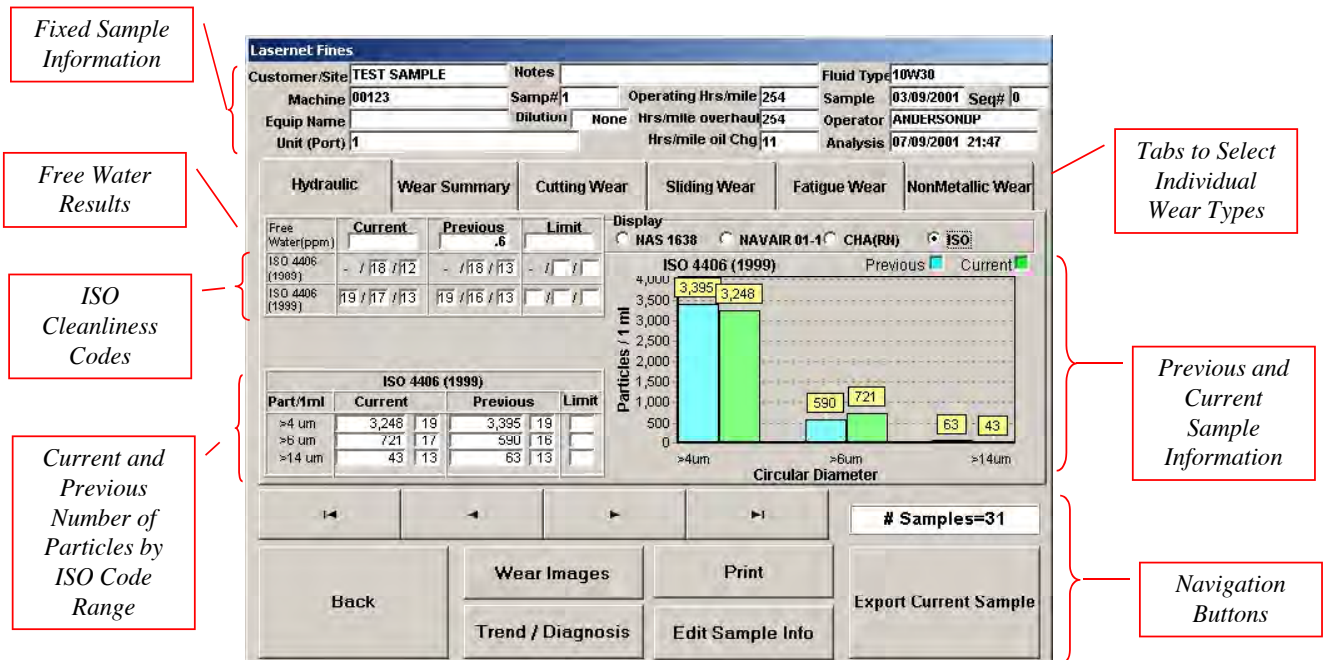
aconventional particle counter, two or more particles present in the sensing cell are measured as a single larger particle, and this causes counting errors for samples with high particle concentrations.

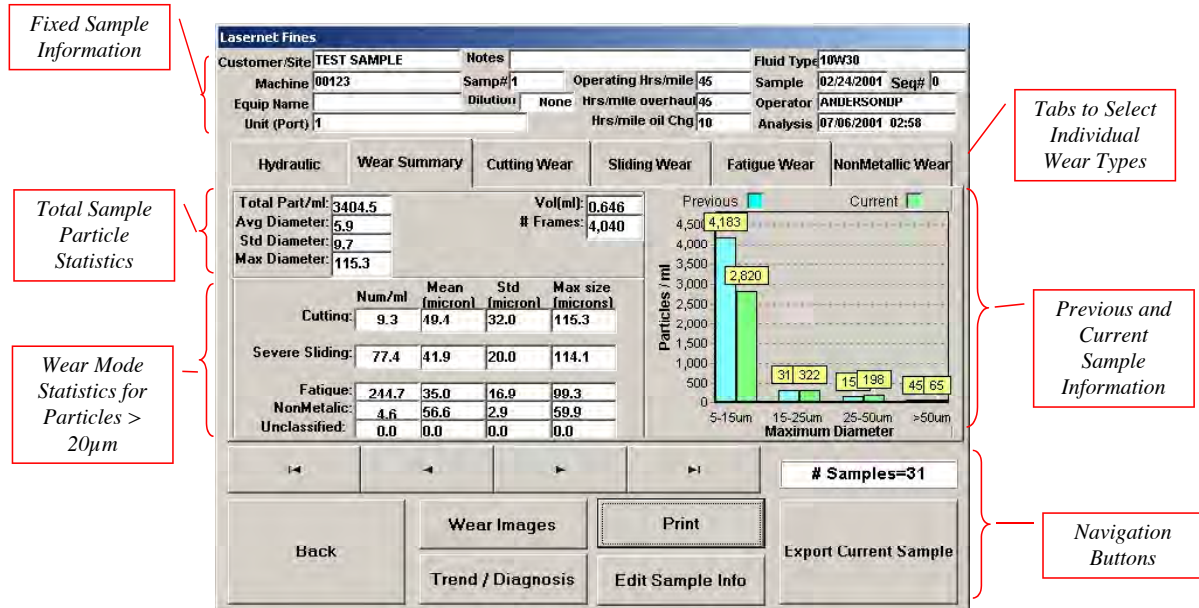## 8. What kind of data and information can be obtained from the instrument software?

The LNF software offers the following features:
* *Data presentation in tabular and graphical form.*
* *Trending graphs are provided for each of the wear debris categories – total particles and large particle fractions.*
* *Sample particle distribution.*
* *Statistical calculation such as mean, particle size and standard deviation are determined for each category.*
* *Largest particle size for each category.*
* *Information for each of the wear classes (cutting, severe, fatigue, nonmetallic, fibers and water droplets).*
* *Total particles/ml, diameter standard deviation, average diameter, volume analyzed, amount of frames of digital information analyzed.*
* *Histograms showing particle counts for given size ranges compared to previous results.*
* *Wear images.*
* *Identifies and distinguishes between air bubbles and water droplets when they are greater than 20 μm. Air bubbles are eliminated from the count.*

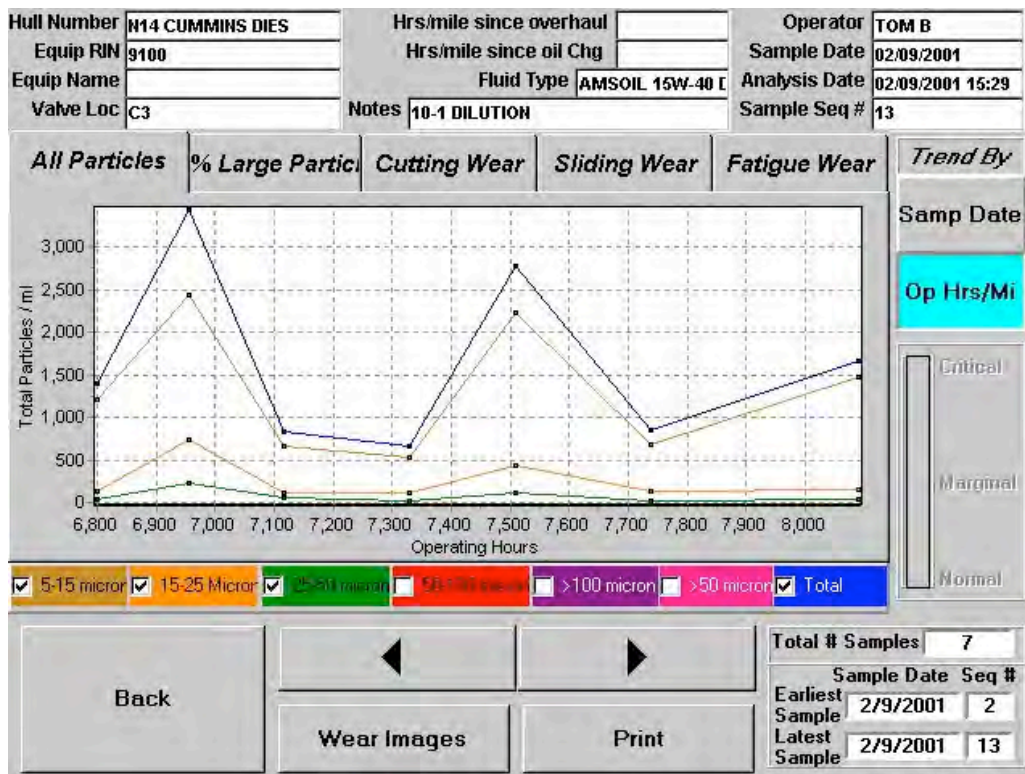## Sample ISO Particle Screen

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Wear Summary Screen

Fixed Sample Information

Total Sample Particle Statistics

Wear Mode Statistics for Particles > 20µm

Tabs to Select Individual Wear Types

Previous and Current Sample Information

Navigation Buttons

Lasernet Fines

Customer/Site TEST SAMPLE Notes Fluid Type 10W30
Machine 00123 Samp# 1 Operating Hrs/mile 45 Sample 02/24/2001 Seq# 0
Equip Name Dilution None Hrs/mile overhaul 45 Operator ANDERSONUP
Unit (Port) 1 Hrs/mile oil Chg 10 Analysis 07/06/2001 02:58

Tabs: Hydraulic | Wear Summary | Cutting Wear | Sliding Wear | Fatigue Wear | NonMetallic Wear

Total Part/ml: 3404.5 Vol(ml): 0.646
Avg Diameter: 5.9 # Frames: 4,040
Std Diameter: 9.7
Max Diameter: 115.3

	Num/ml	Mean (micron)	Std (micron)	Max size (microns)
Cutting:	9.3	49.4	32.0	115.3
Severe Sliding:	77.4	41.9	20.0	114.1
Fatigue:	244.7	35.0	16.9	99.3
NonMetalic:	4.6	56.6	2.9	59.9
Unclassified:	0.0	0.0	0.0	0.0

Chart: Previous / Current — Particles / ml vs Maximum Diameter
5-15um: 4,183 / 2,820
15-25um: 31 / 322
25-50um: 15 / 198
>50um: 45 / 65

Buttons: Back | Wear Images | Print | # Samples=31 | Trend / Diagnosis | Edit Sample Info | Export Current Sample

Trend/Diagnosis Screen

Hull Number N14 CUMMINS DIES Hrs/mile since overhaul Operator TOM B
Equip RIN 9100 Hrs/mile since oil Chg Sample Date 02/09/2001
Equip Name Fluid Type AMSOIL 15W-40 D Analysis Date 02/09/2001 15:29
Valve Loc C3 Notes 10-1 DILUTION Sample Seq # 13

Tabs: All Particles | % Large Partici | Cutting Wear | Sliding Wear | Fatigue Wear | Trend By

Samp Date | Op Hrs/Mi | Critical | Marginal | Normal

Total Particles / ml vs Operating Hours (6,800 – 8,000)

Legend: 5-15 micron | 15-25 Micron | 25-50 micron | 50-100 micron | >100 micron | >50 micron | Total

Buttons: Back | Wear Images | Print
Total # Samples 7
Sample Date   Seq #
Earliest Sample 2/9/2001   2
Latest Sample 2/9/2001   13

9. What are the main advantages of the LNF over ferrography?

• *The total time to obtain a complete analytical result with the LNF is approximately 5 minutes (preparation and analysis included), versus 20 to 30 minutes for a ferrogram.*
• *No trained analyst is required, computer algorithms interpret size and identify particles.*
• *Quantitative results: LNF counts and classifies all particles in its viewing cell to provide quantitative analysis. Metallic and nonmetallic particles are identified and counted.*
• *No sample preparation is required unless the sample is very viscous or heavily sooted.*
• *No consumables are used, other than rinse solvent. Hardware store grade kerosene is adequate for routine applications.*
• *Identifies and quantifies water droplets greater than 20 μm in diameter.*
• *Provides objective and consistent analysis; does not depend upon the skill and experience of the technician doing the analysis.*
• *Ability to distinguish between air bubbles and water droplets when they are greater than 20 μm.*

### 10. What are the main advantages of the LNF over conventional particle counters?

• *The LNF particle count is "intrinsically correct", that is, the count is based on the actual images of the particles, whereas an optical particle counter measures the decrease in light as a particle passes through the sensing cell. An optical particle counter must be calibrated with a sample of known particle size distribution, whereas the LNF optics are set at the factory and calibration thereafter is not required.*
• *The LNF can accurately count much higher concentrations of particles than an optical particle counter.*
• *The LNF does a shape analysis.*
• *The LNF can "see through" sooted (black) engine oils.*
• *The LNF can report maximum dimension as well as a calculated equivalent diameter.*

11. Can you export data from the LNF?

The LNF can be part of a computer network. An Ethernet interface is included in the computer. Sample analyses are transmitted as text files and there is an option to download image files.

12. Is there more than one version of the LNF?

There are two models. They are the LNF-M and LNF-C. The LNF-M is designed for military use. It has a rugged case with vibration and shock protection and it uses a touch screen for instrument operational control. The LNF-C is a reconfigured version that uses an external computer and a mouse for instrument operational control. Both instruments have the same analytical capabilities. Lockheed Martin is also working on an in-line variant of the LNF.

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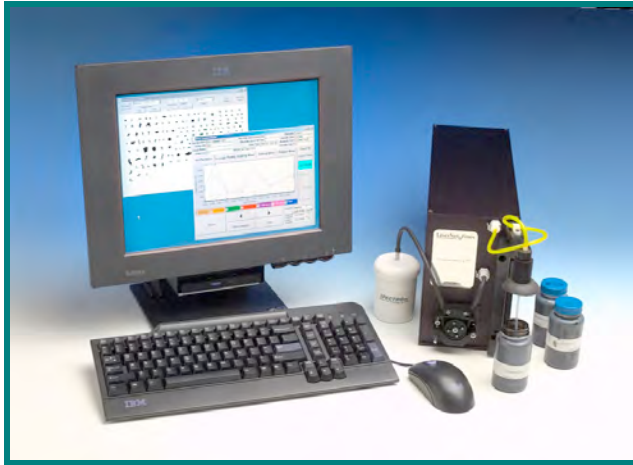
LaserNet Fines-C   LaserNet Fines-M

13. How does the instrument perform the analysis of black oils?

This capability relates to the design of the LNF's laser and flow cell. The oil sample passes through a cell that has an approximate thickness of 100 μm. A powerful laser illuminates the cell. A picture of the center of the cell, an area of 1.6 by 1.2 mm, is taken of the flowing samples. When dark oils are flowing, the laser is pulsed with more power and for a longer duration. Soot particles are very fine, on the order of 0.01 μm. They cannot be identified as individual particles because they are far smaller than the 2.4 μm per pixel resolution of the LNF.   The soot particles block light but a strong light source is able to see through the flow cell.

14. How does the instrument photograph the particles?

The sizing is set by the geometry of the cell and the magnification of the optic. The images taken by the camera are transferred to a computer and are analyzed at a rate of 30 frames per second. The images undergo a pixel-by-pixel subtraction of any background images and a threshold is set. Objects are detected in each frame as the frame is received. Statistics on the objects are saved and bitmap images of objects greater than 20 μm in length (actually 8 pixels in chord length is the minimum size – this is more precisely 8 x 2.4 μm = 19.2 μm) are saved and can be viewed with the particle viewer. The direct imaging of particles by the LNF eliminates any need for calibration. Each image is processed with a raster scan analysis to identify objects. The laser is pulsed to freeze the objects in motion. The image is taken from an approximate 1.6 mm x 1.2 mm area of the flow cell onto the camera at 4X magnification.

The LNF analyzes the silhouette image of objects. Therefore, additional information that may come from color and/or surface texture is not available. However, the analysis is repeatable, reproducible and objective. Objects are analyzed to determine about a dozen features including maximum diameter, equivalent circular diameter and aspect ratio (area/maximum diameter^2). Perimeter and circularity are determined for particles larger than 20 μm in length.

Shape features were chosen to give optimal distinction between the assigned classes of fatigue, cutting, severe sliding, nonmetallic, fibers, water bubbles and air bubbles. The artificial neural-

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net was trained on an extensive library of particles from known wear modes that were generated by tribologists at Swansea University in Wales under contract to the U.S. Naval Research Laboratory.

Nonmetallic particles are characterized by transparent interior pixels; that is, the particle is allowing transmission of light. Metallic particles, even if extremely thin, block light.

15. What particle sizes can be measured with the LNF?

The LNF measures objects from 4 µm to over 100 µm in size. It also identifies particles by wear type in the size range of 20 µm to more than 100 µm using a neural net. A neural-net classifier uses object shapes and size features to sort them into various categories such as cutting, fatigue wear, sliding wear and nonmetallic. Particles are sorted into several size categories, including NAS categories of 5-15 µm, 15–25µm, 25-50 µm, 50-100 µm and greater than 100 µm. The LNF also reports ISO Code 4406 (1999) for particles greater than 4 µm, greater than 6 µm and greater than 14 µm.

16. Does the LNF require calibration?

NO, the LNF is calibrated at the factory and does not require calibration thereafter. During manufacture, a special flow cell with objects of known dimension photo-deposited on the inner cell walls is used to set the focus and magnification of the LNF.   As a final QC procedure, ISO Medium Test Dust in Hydraulic Fluid, traceable to NIST SRM 2806, is run through each LNF to confirm proper operation. Users are encouraged to periodically run this test fluid to make sure the LNF is operating properly. The LNF software has a special routine for running test fluid. The record of the factory check is included in the software with delivery of each instrument.

17. What is AGC?

AGC stands for Automatic Gain Control. It is an automatic adjustment that the laser uses to verify fluid darkness, enabling solid particles to be distinguished from oil and soot. The gain of the laser automatically increases for dark and heavily sooted samples. Occasionally, the AGC may not be able to compensate for highly sooted diesel oil samples. Diluting the sample with a clean, clear oil in the ratio of 1:1 usually reduces the soot level sufficiently to allow the sample to be run.
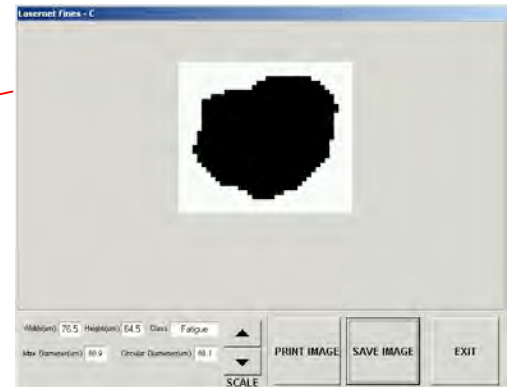
18. What is the wear particle viewer?

An additional software capability of the LNF is that the pixel images of all particles greater than 20 µm in length (8 pixels) are presented as a composite image map, as shown below. Each individual particle may be selected and expanded for a more detailed view by double-clicking on the particle.

Example of Wear Particle Viewer
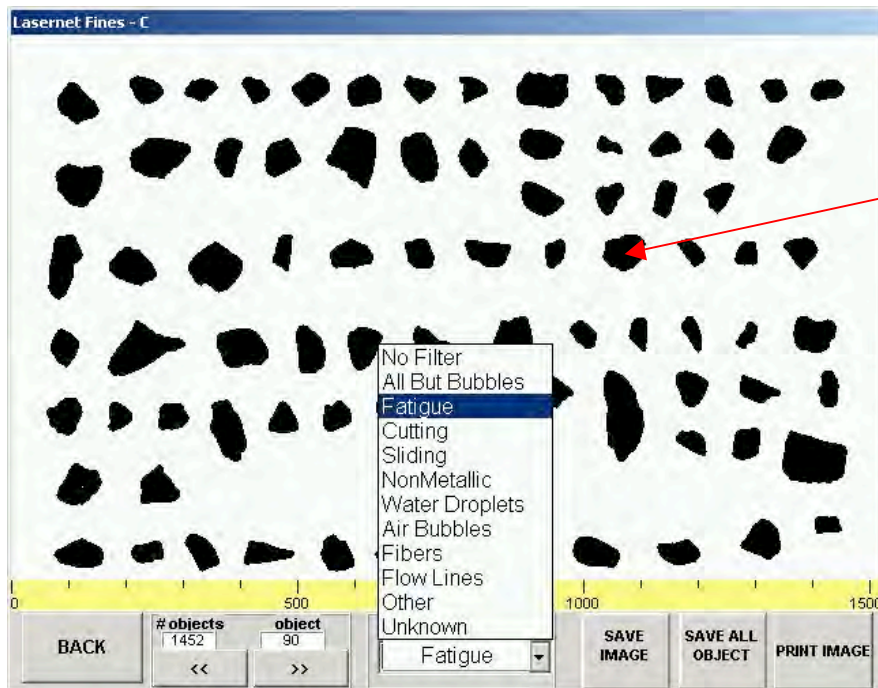
"Double-click on Particle for Zoomed View"

20. How does the LNF calculate ppm water?

The water result is a recent addition to LNF. It enables free water droplets greater than 20 μm in diameter to be quantified in terms of their volume. The water index is thus an analysis of the parts per million (ppm) of large free water droplets in the sample. The LNF is able to detect water droplets and differentiates them from air bubbles by their difference in refractive index. The LNF water result may be considered an indication of gross water contamination if the readings are high. The LNF does not measure water droplets less than 20 μm, nor does it measure dissolved water, so the result is not quantitatively accurate or very repeatable since the number of large droplets will depend to a large extent on how the sample was handled before the sample was run on the LNF.

21. How much sample is required for an analysis?

Sample volume is dependent upon viscosity. Hydraulic fluids being less viscous require more fluid; 15 ml is the approximate volume of hydraulic fluid drawn into the LNF during analysis. Less than 10 ml is consumed for more viscous engine or gear oils. Please note that unlike conventional particle counters, flow rate through the cell need not be regulated. This is because the laser pulse and CCD video camera "freeze" the image of the particles as they flow through the cell.

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