

SPINNER II®

Oil Cleaning Centrifuge

CHEMISTRY SURVEY OF CENTRIFUGED SOLIDS
FROM INGERSOLL RAND KVS 412 ENGINE

Oiltech

1-888-785-0027

1995 02 18

Introduction

With the advance of engine design and increasingly more complex lube oil and filter waste management, powerplant maintenance managers are facing an increasing array of sophisticated auxiliary components. Some are necessary to secure and maintain satisfactory engine performance, while others are designed to provide operating cost savings and thus, a competitive position in the market.

The Spinner II® Oil Cleaning Centrifuge has proven to be an effective means of providing just such a cost savings, first by displacing conventional disposable bypass filters with a cleanable component, and secondly by controlling abrasive contaminants known to limit engine life. Extension of engine wear life results in longer time between overhauls on both basic engine components such as bearings, rings and cams, but also on other engine-lubricated accessories like turbochargers.

This report contains the results of a complete chemical analysis of contaminants collected by two Spinner II Oil Cleaning Centrifuges applied on a single integral, gas-fired compressor engine. This engine is used to pump pipeline grade natural gas.

Centrifuge Contaminant Analysis Natural Gas Integral Compressor Engine Field Test

Spinner II Products has completed analysis of a field test samples from two Spinner II Oil Cleaning Centrifuges installed on an integral compressor engine. The 9.5 pounds of contaminant collected in the Model 600 centrifuge bowls was retrieved for solids analysis. This dirt volume was relatively large due to the fact that this 800 hour service interval occurred during the initial use of the centrifuge, and the engine, pan and lube oil were experiencing a clean-up of accumulated debris.

An assessment of contaminant centrifuged from this engine is attached (Appendix A). This is a copy directly from a local analytical supplier without much interpretation, so there is also a complete technical summary of the findings.

Major conclusions are on one sheet, which precedes the technical summary.

At the lab, we requested a series of separate analysis methods, each designed to reveal different traits of the centrifuge material and the condition of the engine. These methods are listed in the summary and interpretive comments are written in *italics*. (Please refer to Figure 1 for an outline of the process).

There is a significant amount of technical detail here, but it all confirms the most important conclusion: *the Spinner II Oil Cleaning Centrifuge is capable of removing the very lube oil contaminants which shorten engine life and hamper oil performance*. This performance results in lower operating costs with enhanced engine up-time.

Major Conclusions - **Integral Compressor Engine Field Test Spinner II® Model 600 Centrifuges**

- The Spinner II® Oil Cleaning Centrifuge effectively controls the very sizes of lube oil abrasives causing the most wear in heavy-duty low and medium speed engines.
- Application of a centrifuge in the engine lube circuit provides a high performance complement to the full-flow engine lube oil filters, removing abrasives these filters miss, and resulting in longer component wear life and extending full-flow filter life.
- Ferrographic analysis of the centrifuge solids can allow direct inspection of engine health, so catastrophic failures can be anticipated (see slides of the photomicrographs and photo index)
- In excess of 32 % of the total solids removed by the centrifuges over the engine service interval were metal oxides of wear debris and externally ingressed contaminants

Qualitative analysis demonstrates that the Spinner II® Oil Cleaning Centrifuge removes contaminants shown to have significant adverse impact on engine life and lube oil performance. Virtually 100% of the solid deposit in the centrifuge has been shown to either increase engine wear or shorten oil life.

Integral Compressor Engine Field Test Spinner II® Model 600 Centrifuge

(Data from Appendix A follows):

Baseline Data: Weight.

weigh entire sample as delivered (Refer to Table 1, "Used Bowl Contaminant Summary")

Comments: Bowl contaminant weight after 800 hours was 4535 grams (9.5 lbs.), with solids of a specific gravity of approximately 1.36.

Sequence 1A: Qualitative, by Thermo-Gravimetric Procedure

Select representative section of sample & weigh
Qualitatively analyse to answer: fraction of sample which is volatile (combustable), amount that can be fully oxidized, and fraction remaining

Comments : Through a series of steps involving drying at different temperatures, the centrifuge deposit was found to be composed of the following constituent fractions:

<u>Constituent</u>	<u>Percentage of Total</u>	<u>Weigh</u>
Total Sample (removed through heating:)	100.0 %	4535.0 grams
Retained Water / Light HC's	0.5 %	20.4 grams
Volatile Organics	40.9 %	1777.3 grams
Oxidizable Fraction	26.4 %	1147.2 grams
Residual Ash	32.3 %	1403.6 grams

Those components removed from the sample by heating are representative of combustion products which generally have adverse impact on oil life, and have been associated with increased rates of oil degradation.

Integral Compressor Engine Field Test Spinner II® Model 600 Centrifuge

Sequence 111: Qualitative, by Solvent Wash & Ashing Procedure

Select representative section of sample & weigh
Qualitatively analyse to answer: fraction of sample which is
soot (carbon), fraction that is wear-causing abrasives, and
character of remainder

Comment : Through a series of steps involving solvent washes, a centrifuge deposit can typically be broken into constituent fractions.

<u>Constituent</u>	<u>Percentage of Total</u>	<u>Weight</u>
Total Sample	100.0 %	4535.0 grams
Carbon (soot)	31.5 %	1368.8 grams
Toluene Soluble	36.2 %	1573.1 grams
Metal oxides	32.3 %	1403.6 grams

The carbon fraction, interacting with the combustion products, has the ability to deposit on operating surfaces (reducing engine performance) and has been shown to diminish the capability of engine lube oil anti-wear additives.

The metal oxides are the most obnoxious components in the group, since they contain the hard abrasives of internally-generated wear debris as well as ingressed contaminants like airborne debris. This group is responsible for the bulk of the wear that occurs in an engine's cams, bearings and rings.

Integral Compressor Engine Field Test Spinner II® Model 600 Centrifuge

Sequence 2: ICM Spectrographic Survey Preceded By Acid Dissolution

Select representative section of sample & weigh
Suspend in appropriate solution
Spectrographic survey, especially focused on key metallic elements like Cu, Fe, Sn, Ni, Cr, Pb, Si

Comments: The sample (acid digested & ashed solids) was composed of 21.55 % abrasive wear oxides, or 2431.5 grams. Key wear metals being controlled by the centrifuge were deposited at the following levels (by mass fraction of total abrasive material in sample):

<u>Wear Oxide</u>	<u>Mass</u>
Iron	36212 mg
Lead	1825 mg
Copper	3509 mg
Chromium	4070 mg
Aluminum	1263 mg
Tin	0 mg
Nickel	0 mg
Silicon	3088 mg

Identify other constituents in oxide ash by sequential analysis using appropriate solution

Comment: Other non-metallic constituents can not be analyzed through conventional spectrographic techniques, but can be segregated through sequential exposure to water and acid solutions:

<u>Constituent</u>	<u>Percentage of Total</u>	<u>Mass</u>
Gravimetric Sulphates	3.00 %	42108 mg
Water Soluable Sulphates	2.58 %	36212 mg
Gravimetric Silicon Dioxide	1.00 %	14036 mg

There are two conclusions from this assessment:

1-The centrifuge is removing quantities of sulfur-bearing components, which, if left in the oil, tend to decrease its life by hastening acid buildup.

2-The silicon levels detected by this sequential solution technique are additional to that indicated by spectrography, another indication that spectrographic analysis, even when augmented by acid dissolution, is unable to detect all of the abrasive wear metals present in the sample.

Integral Compressor Engine Field Test Spinner II® Model 600 Centrifuge

Sequence 3: Ferrographic Debris Analysis

Select representative section of sample
Solvent wash sample (toluene)
Analysis via Direct Reading (quantitative) approach
Analysis via Indirect (qualitative) approach

Comment : The Ferrograph® is a device which segregates wear materials from a lube oil by use of the forces of magnetism and gravity. Contaminated oil traverses a glass slide which is suspended at an angle over a magnetic field. Wear materials deposit along the slide's length, and can be observed under a microscope for their appearance; with the use of special optics, their composition can be determined.

The contaminant collected from this IR engine was processed through the Ferrographic Direct and Indirect Read Systems. The quantitative assessment (Direct Read) was not possible due to the high contaminant concentration in the sample

The Indirect Read System (qualitative) results are summarized as follows, with copies of the slide format photomicrographs available upon request and tabulated in the report at Appendix B:

- Significant volumes of ferrous particles in the two-to-five micron size range were present*
- other wear debris, like lead babbitt material (30 µm) from bearings was present*
- There was a large amount of sand & silicious debris throughout this sample*

Integral Compressor Engine Field Test Spinner II® Model 600 Centrifuge

(Data from Appendix C follows):

Sequence 4: Determine Particle Size Distribution of Sample

Select representative section of sample & weigh
Solvent wash sample

Particle count via: Laser (Suspend & sonicate sample in counting solution)

Comments: (Qualitative traits: see Method 4) This laser counting approach was not possible within the technical limits of the lab operation. The report and conversations with the lab staff verified the nature of the contaminant to be so soot-filled so as to obscure the accuracy of the laser-based counting method.

Another lab, owned and run by Coulter Electronics of Hialeah, FL, has prepared a special resistive method analysis of a Spinner II® centrifuge sample from this gas fueled integral compressor engine. A copy of this lab report is attached (Appendix C), and shows the median particle size of these solids is 1.07 µm; further, the report shows this size distribution in the debris collected by the centrifuge:

Percentage		Micron Size
90.0 %	Greater Than	0.8 µm
50.0 %	Greater Than	2.4 µm
25.0 %	Greater Than	3.5 µm
10.0 %	Greater Than	4.9 µm
2.0 %	Greater Than	8.8 µm
0.9 %	Greater Than	10.0 µm

This analysis reveals that a significant fraction of the abrasive contaminant removed by the Spinner II® model 600 Oil Cleaning Centrifuge is of a size range (0 to 10.0 µm) that no other bypass or full-flow filtration product on the market can control, and that this approach provides an effective performance complement to any full-flow filter.

(If the reader is interested, a technical paper reviewing both the physical chemistries and lube oil particle counts on other gas engines was published by the Pipeline and Compression Research Council; request paper number 92-0-2.)

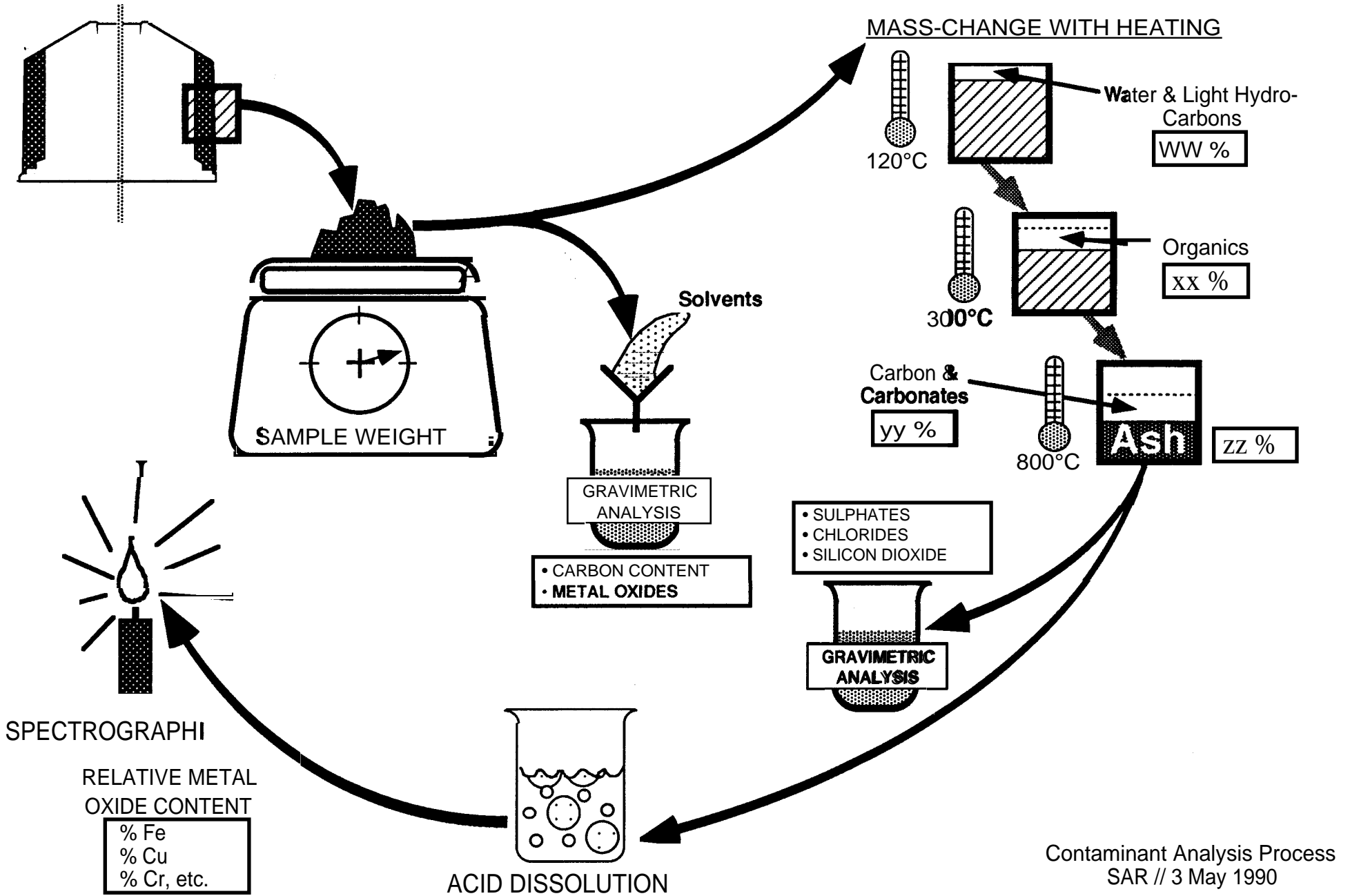
Table 1

**Spinner II® Model 600 HD Oil Cleaning Centrifuge
Used Bowl Data
(Installation Applied Two Centrifuges)**

Engine Function:	Gas Compression
Unit Number:	#4, Taylor Station #1, Westcoast Energy, BC
Engine Make & Model:	Ingersoll Rand KVS 412
Engine Rated Power:	2000 HP
Engine Serial Number:	197
Type of Fuel Used?:	Pipeline grade natural gas
Sump Capacity:	550 gallons
Hours Since Overhaul:	approx 10000 (239940 hrs on engine)
Date Spinner 11 Installed:	2 Model 600HD- 12's, Sept-94
Date of This Bowl Sample:	30 Nov 94 with 973 hours
Sediment Accumulation at Return:	9.56 pounds total
Hours on This Sample:	Approximately 800 hours
Brand / Type Lube Oil Applied:	Shell Mysella LA 30 (SAE 30)
Lube Oil Add Rate:	50 gallons per week
Full-flow Element Applied:	Peco FT336-0-5, qty 56 "10 micron nominal" (BETA unknown)
Scheduled Service Interval:	Change filters when A Pressure >20 PSID Service Spinner II monthly

Figure 1

CENTRIFUGE CONTAMINANT ANALYSIS PROCESS



SOUTHWEST SPECTRO-CHEM LABS
1009 LOUISIANA AVE SOUTH HOUSTON. TX 77587

713/944-3694

LABORATORY DIVISION OF P/PM SERVICES, INC.

713/944-3694

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DEPOSIT ANALYSIS REPORT

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CUSTOMER: T.F HUDGINS
SOURCE: SPINNER II CENTRIFUGED ENGINE DEBRIS

LAB SAMPLE NO: A0717 DATE: 01/26/95 ANALYST: CV

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PHYSICAL PROPERTIES

DESCRIPTION: BLACK SOLIDS

MAGNETISM: SLIGHT ACID EFFERESCENCE: NONE
ACID SULFIDE ODOR: MODERATE H2O BY KARL FISHER: NOT DONE

PERCENT WEIGHT LOSS: AMBIENT	120C (1 HR):	0.47	%	PREDOMINANTLY WATER & LIGHT END HYDROCARBONS
PERCENT WEIGHT LOSS:	120C 300C (1 HR):	40.87	%	PREDOMINANTLY ORGANICS
PERCENT WEIGHT LOSS:	300C 800C (1 HR):	26.38	%	PREDOMINANTLY CARBON, CARBONATES. & BICARBONATES
PERCENT TOTAL ASH:	800C (1 HR):	32.28	%	PREDOMINANTLY METAL OXIDES

RELATIVE METAL OXIDE CONTENT OF DIGESTED ASH

SILICON DIOXIDE (SiO ₂):	0.22 %	LEAD OXIDE (PbO):	0.13 %	POTASSIUM MONOXIDE (K ₂ O):	0.00 %
IRON OXIDE (Fe ₂ O ₃):	2.58 %	TIN OXIDE (SnO ₂):	0.00 %	MOLYBDENUM TRIOXIDE (MO ₃):	0.45 %
COPPER OXIDE (CuO):	0.25 %	BORON TRIOXIDE (B ₂ O ₃):	0.00 %	TITANIUM DIOXIDE (TiO ₂):	0.00 %
CALCIUM OXIDE (CaO):	68.10 %	NICKEL OXIDE (NiO):	0.00 %	ANTIMONY TRIOXIDE (Sb ₂ O ₃):	0.00 %
MAGNESIUM OXIDE (MgO):	0.00 %	BARIUM OXIDE (BaO):	0.04 %	SILVER OXIDE (Ag ₂ O):	0.00 %
ALUMINUM OXIDE (Al ₂ O ₃):	0.09 %	SODIUM MONOXIDE (Na ₂ O):	0.27 %	VANADIUM PENTOXIDE (V ₂ O ₅):	0.00 %
CHROMIUM OXIDE (Cr ₂ O ₃):	0.29 %	PHOSPHORUS PENTOXIDE (P ₂ O ₅):	12.70 %	INDIUM OXIDE (In ₂ O ₃):	0.00 %
ZINC OXIDE (ZnO):	10.13 %	MANGANESE OXIDE (Mn ₃ O ₄):	0.03 %	CADMIUM OXIDE (CdO):	0.00 %

GRAVIMETRIC/WET CHEMISTRY ANALYSIS OF DIGESTED ASH

GRAVIMETRIC SILICON DIOXIDES: 1.00 % GRAVIMETRIC SULFATES: 3.00 %

WATER SOLUBLES ANALYSIS

WATER SOLUBLE SULFATES:	2.58 %	WATER SOLUBLE CHLORIDES:	0.02 %
WATER SOLUBLE PHOSPHATES:	0.01 %	WATER SOLUBLE NITRATES:	<0.01 %

COMMENTS: % SOOT = 31.5: INITIAL SAMPLE WEIGHT = 4347 GRAMS :

SCIENTIFIC INSTRUMENTS

COULTER CORPORATION
 Mail Code 195-10
 P. O. Box 169015
 Miami, Florida 33116-9015 USA

(305) 885-0131 ext. 3910

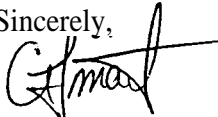
Product Information:
 (800) 523-3713

February 10, 1995

Scott A. Rodibaugh
 T.F. Hudgins, Inc.
 PO Box 920946
 Houston, TX 77292-0946

Enclosed find the Particle Size analyses results on the sample you submitted (PO# 950494). The sample was analyzed on the COULTER® MULTISIZER ii Particle Size analyzer. A summary of the results is enclosed along with the data generated by the instrument.

Sincerely,



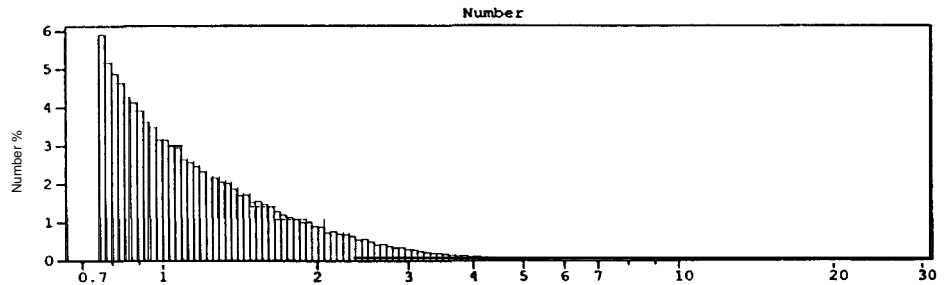
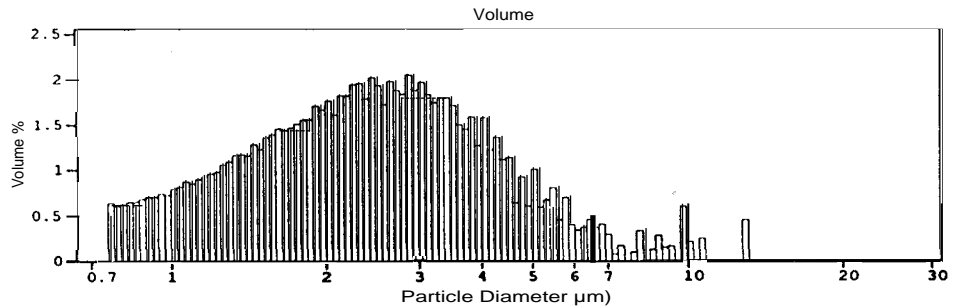
Guillermo Smart
 Research Associate
 Coulter Scientific Instruments

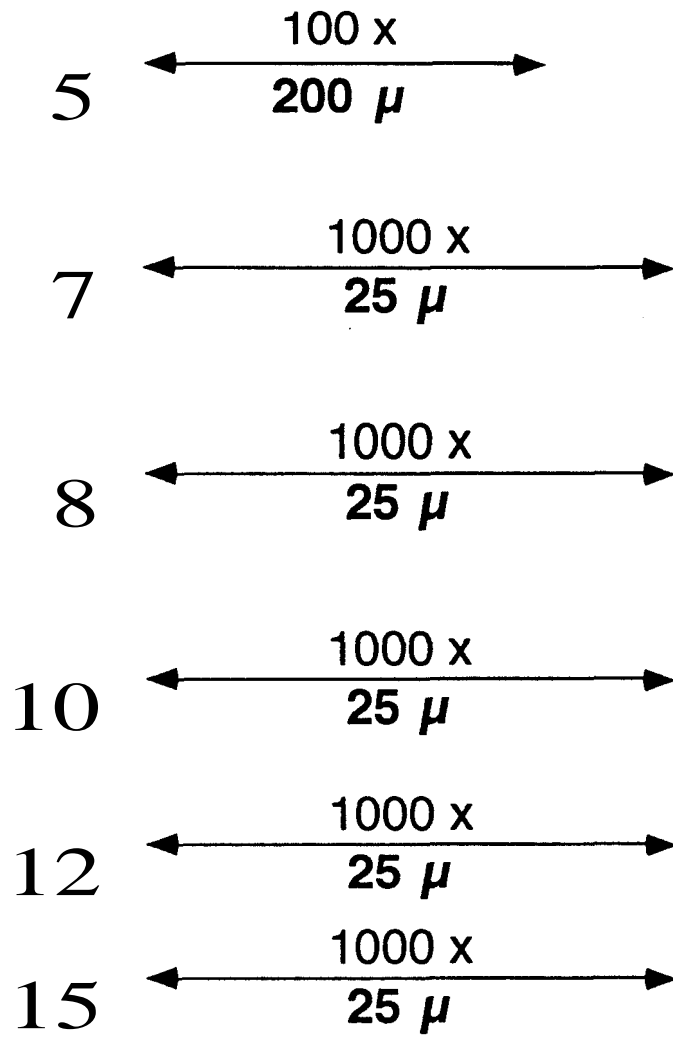


COULTER

Multisizer AccuComp® 1.18.21

Filename:	HUDGES. #04	Sample Number:	999
Group ID:	HUDGINS		
Sample ID:	CENTRIFUGED DEBRIS		
operator:	GS		
Electrolyte:	5% LiCl - METHANOL		
Dispersant:	TOLUENE - 30sec SONICATION		
Aperture Size:	30 µm	Aperture Current:	800 µA
Channels:	128	Kd:	348.39
Full Data, Log Diameter		Gain:	4
Control Method:	Manual		
Elapsed Time:	60.5 Seconds		
Raw Count:	112974		
Coinc. Corr. Count:			
Acquired:	12:19 9 Feb 1995		
Serial Number:	devlab 3		
Analytic Volume:	50 µl		





FERROGRAPHIC CONTAMINANT ANALYSIS

Field Test of Ingersoll-Rand 412 KVS Integral Compressor Engine
Deposit Analysis from Spinner II® Model 600 Oil Cleaning Centrifuges

<u>Photo #</u>	Magnification	<u>Lab Description</u>
5	100 x	Raw Carbon Deposit
7	1000 x	Ferrous/Ferrous Oxides
8	1000 x	30 µm Lead Babbitt Particle
10	1000 x	7 µm White (Non-ferrous) Particle
12	1000 x	10 µm Copper Particle
15	1000 x	Sand / Dirt / Ferrous Oxides

FERROGRAPHIC CONTAMINANT ANALYSIS

The photomicrographs attached (and others) were taken from Ferrogram® slides especially prepared by deposition of the centrifuge bowl solids collected in a field test of two Model 600HD Spinner II Oil Cleaning Centrifuges installed on a gas-fired integral compressor engine used for gas pumping. Ferrographic analysis can reveal wear particle concentration, their size distribution and morphology (shape). These traits are indicative of the type and severity of wear in lubricated equipment.

Because Ferrography relies largely on magnetic forces to separate metal particles, when traditional oil samples are analyzed, iron particles are the most often detected (separated) wear materials deposited on the slide. The Spinner II Centrifuge is itself a wear debris concentrator, so as a result, the distribution of material on these slides is heavily weighted toward wear metals.

Color of the contaminants in these photomicrographs is affected by the use of both color and polarizing lenses on the microscope, and by the use of different lighting techniques. Elemental analysis of the constituents is done on the basis of appearance and by using comparison against a photographic lexicon of known contaminants, although EDAX is possible.

These photomicrographs are simply a look at the centrifuge sediment by use of a microscope. Before the bowl sediment is placed on the microscope stage, it is concentrated and arranged by a special contaminant preparation process called Ferrography. The solids, suspended in clear oil and then placed on a glass slide, are placed above a large magnet; the slide is at an angle so that as the 'liquified' sediment sample flows down the slide, different ferro-magnetic components, and anything else that is drug along with them, get separated. The Ferrographic process tends to 'bunch up' the big stuff at the leading end of the slide, and make finer and progressively less concentrated deposits toward the end of the slide.

