Understanding the CFA Oil Analysis Tests and Report

Critical Success Factors To realize the full condition monitoring and equipment management benefits of the Cashman Fluids Analysis Program the user should follow these ***Critical Success Factors:***

1. Pull clean samples and provide adequate volume - about 4 oz (120 ml). Avoid external contamination such as dirt and water.
2. Fill out the sample information label completely. Provide accurate information about the equipment, the oil brand and type and the operating time on the oil
3. Send samples promptly to the laboratory. Avoid delay.
4. Build reliable operating trends by pulling samples on a regular basis – preferably every 250 operating hours.
5. Build a working relationship with the Analyst. Promptly communicate any concerns, additional information or repair activity.

Fine Metal Wear Rate Analysis uses inductively coupled plasma spectrometry (ICP) to measure the type and amount of *fine* elemental concentration and is reported in parts per million (ppm). These particles are typically less than 10 microns in size and can easily pass through system filtration. Elevated test results generally indicate abrasive wear, inter-compartment oil transfer, a different brand/type of oil being used and/or external physical contamination such as coolant or dirt entry. ICP can also help determine the type of smaller particles 10 microns and less being counted by Laser Net Fines It is essential for the user to provide the operating time on the oil so the CFA Analyst can determine if the rate at which the wear metal element and additive element concentrations are being generated is acceptable.

Element	Report Symbol	Typical Sources
Aluminum	Al	Pistons, sleeve bearing/bushings, crankshaft bearings, camshaft bearings, torque converter, pump housings; aluminum is also present in soil
Cadmium	Cd	Coatings on metals, bearing and low-melting alloys, brazing compounds, machinery enamel
Chromium	Cr	Piston rings, roller/ball bearings, hydraulic cylinder rods, plating for liners and crankshafts (rare)
Copper	Cu	Typically alloyed with other elements (lead, tin, aluminum, zinc); found in brass/bronze components such as thrust washers, sleeve bearings/bushings and metallic brake/clutch discs. High copper alone may be due to chemical leaching and is not 100% indicative of component wear or failure.
Iron	Fe	Cylinders/liners, valve train components, gears, housings, carriers, pumps, hydraulic cylinders, clutch/brake reaction plates; iron is also present in soil
Manganese	Mn	Alloying element in steel components
Nickel	Ni	Crankshaft bearing alloy, alloying agent in other brass, bronze and steel components, spray weld compound
Lead	Pb	Crankshaft/camshaft bearings, alloying element, transmission clutches, aftermarket oil additives
Silver	Ag	Plating on some wrist pin bushings, solder, aftermarket cooling system sealers, clutch material, needle bearing cage, sprag clutch
Tin	Sn	Alloying element in brass/bronze components, engine piston coating
Titanium	Ti	Alloying element in turbine compressor blades and other steel components; anti-wear additive in some oil blends
Vanadium	V	Alloying element used in various steels to increase strength; also present in heavy fuel oils at varying levels
Antimony	Sb	Alloying element used with lead in Babbitt bearings; anti-wear, EP and anti-oxidant additive in oil and grease
Bismuth	Bi	Alloying element used in various metals such as iron and copper and is fast becoming a non-toxic replacement for lead
Indium	In	Alloying element used in journal bearing products (crankshaft and camshaft) similar to tin and antimony

Contamination		
Potassium	K	Coolant entry indicator, oil additive; potassium is present in soil in very small amounts
Silicon	Si	Dirt entry indicator when present with aluminum; cellulose fibers, silicone based gaskets, sealers, greases, antifoam additive
Sodium	Na	Coolant entry indicator, sea water, additive
Additives		
Barium	Ba	Oil additive (corrosion and rust inhibitor, detergent)
Boron	B	Oil additive (detergent, dispersant, anti-oxidant), coolant additive
Calcium	Ca	Oil additive (detergent, dispersant, alkalinity increaser), airborne contaminate
Magnesium	Mg	Oil additive (detergent, dispersant, alkalinity increaser), sea water, soil
Lithium	Li	Used as a thickener in grease
Molybdenum	Mo	Oil/grease additive (lubricant, EP additive), coolant additive, may also result from wear of moly-coated components (rare)
Phosphorus	P	Antiwear additive (ZDDP), extreme pressure (EP) additive
Zinc	Zn	Antiwear and antioxidant oil additive (ZDDP), alloy in brass/bronze components, galvanizing agent

Coarse Metal Wear Rate Analysis (OA3) uses rotrode filter spectroscopy (RFS) to measure the type and amount of *coarse* metal concentration. Test results are expressed as a unitless index and are not comparable to fine metal test results. These particles are typically between 20 and 70 microns. Elevated test results generally indicate more aggressive wear modes such as cutting, sliding or fatigue wear. RFS can also help determine the type of larger particles being counted by Laser Net Fines. One way severity level is determined is by carefully evaluating the ratio between fine metal and coarse metal test results.

Element	**Report Symbol**	**Typical Sources**
Aluminum	Al RFS	Pistons, sleeve bearing/bushings, crankshaft bearings, camshaft bearings, torque converter, pump housings; aluminum is also present in soil
Chromium	Cr RFS	Piston rings, roller/ball bearings, hydraulic cylinder rods, plating for liners and crankshafts (rare)
Copper	Cu RFS	Typically alloyed with other elements (lead, tin, aluminum, zinc); found in brass/bronze components such as thrust washers, sleeve bearings/bushings and metallic brake/clutch discs. High copper by RFS is typically *not* associated with chemical leaching and is more indicative of component wear.
Iron	Fe RFS	Cylinders/liners, valve train components, gears, housings, carriers, pumps, hydraulic cylinders, clutch/brake reaction plates; iron is also present in soil
Nickel	Ni RFS	Crankshaft bearing alloy, alloying agent in other brass, bronze and steel components, spray weld compound
Lead	Pb RFS	Crankshaft/camshaft bearings, alloying element, transmission clutches, aftermarket oil additives
Silver	Ag RFS	Plating on some wrist pin bushings, solder, aftermarket cooling system sealers, clutch material, needle bearing cage, sprag clutch
Tin	Sn RFS	Alloying element in brass/bronze components, engine piston coating
Titanium	Ti RFS	Alloying element in turbine compressor blades and other steel components; anti-wear additive in some blends
Vanadium	V RFS	Alloying element in various steels

Classic Wear Metal Combinations

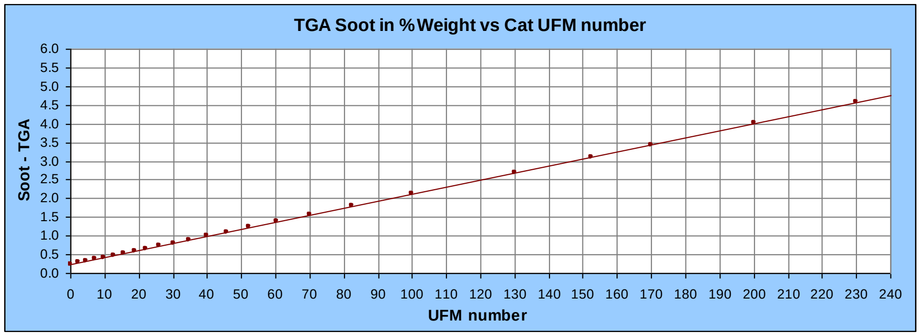
Element(s)	Component	Potential Wear Source	Possible Cause
Silicon, aluminum, iron, chrome	Engine	Liner/cylinder walls, piston rings	Dirt entry through intake system
	Final Drive/Differential	Roller bearing wear	Dirt entry
	Hydraulic system	Cylinder rod wear	Dirt entry at wiper seal
Silicon, aluminum, iron	Final drive	Duo-cone seal face wear	Dirt entry
Silicon, lead, tin, aluminum	Engine	Crankshaft bearings	Lower end dirt entry
Copper, lead, tin	Engine	Thrust bearing, wrist pin bushing	Poor lubrication, wear out
	Transmission	Clutches, brakes, thrust washers, bushings	Abuse, severe application, wear out
	Final drive, differential	Thrust washers, bushings	
Lead, tin/nickel, aluminum, iron	Engine	Crankshaft bearings	Low oil pressure, fuel entry, high soot, dirt entry, oxidation
Potassium, sodium, copper, chrome	Engine	Coolant entry w/ ring wear	Cylinder head or gasket failure
Iron, silicon	Differentials	Brake wear	Abuse, severe application, wear-out

Ferrography uses a number of different instruments and methods to analyze the iron content in a fluid sample. The size of the iron particulate ranges from microscopic to well beyond the lower visual capability of the human eye which is approximately 40 microns.

Test Type	**Report Symbol**	**Typical Sources**
Total Ferrous Debris	pqL	Total Ferrous Debris (pqL) is a standard test on all fluid samples. It is a measure of the total iron content in the sample regardless of the size of the particulate and is reported in a unitless index. Engines, powershift transmissions, hydraulic systems and turbine oils typically return a 0 pqL index.

Oil Condition Analysis uses an infrared spectrometer (aka “FT-IR”) to measure engine soot and oil degradation byproducts. These organic (non-metallic) compounds are generated by heat, oxygen exposure and other contaminates. They are found in all lube oil systems with engine oil being particularly susceptible due to the normal combustion process of the engine. Oil Condition Analysis test results are based on absorbance units and are determined using a method called Unsubtracted FT-IR Method, or UFM. The UFM method *does not* require a sample of the new oil as a reference. Soot values can range from 0 – 300+ with typical readings less than 60. Oxidation, sulfation and nitration can range from 0 – 50+ with typical values less than 30 (oxidation in transmissions and hydraulic systems should be maintained at less than 17). Other Oil Condition Analysis also includes viscosity testing, Total Base Number and Total Acid Number.

Compound	**Report Symbol**	**Typical Sources**
Soot	Soot	A combustion byproduct caused by restricted air filters, lugging, poor airflow, low boost pressure, poor fuel injector performance or other conditions affecting air-to-fuel ratio. Suspended soot particles are typically less than 0.5 microns. As soot dispersants deplete and smaller particles agglomerate into larger particles oil thickening, filter plugging, carbon deposits and wear can result.



Sulfation	Sulf	A combustion byproduct originating from the normal sulfur in diesel fuel. When combined with water from normal condensation it can result in acidic metal corrosion from high sulfuric acid. It typically results from high load-factor, extreme duty applications where fuel consumption is high. However it can also indicate combustion inefficiency and excessive crankcase pressure due to normal wear out.
Oxidation	OXI	Oil reacts with oxygen resulting in oxidation during normal use. Heat, water and/or coolant will act as a catalyst and increase the rate of oxidation which doubles for every 10-degree increase in oil temperature. The oxidation will result in increased viscosity, generation of sludge and varnish deposits, depletion of anti-wear and anti-oxidant additives and, ultimately, increased component wear.
Nitration	NIT	Generally only a concern in natural gas engines that contain high nitrites. A combustion byproduct originating from the normal nitrites in gaseous fuels (methane, natural gas, digester gas). When combined with water from normal condensation it can result in acidic metal corrosion from nitric acid. It typically results from high load-factor, extreme duty applications. However it can also indicate combustion inefficiency and normal wearout. Nitration can also indicate thermal degradation (localized heat) in non-engine components.
Anti-wear	AW	The anti-wear additive ZDDP (zinc dialkyldithiophospate) is a common oil additive in lubrication oils with the highest levels seen in diesel engine oils. Decreasing AW can signal oil degradation.
Viscosity	V40 V100	Viscosity (kinematic) is a measure of oil's resistance to flow and is the most important physical property of the oil. It is a basic indicator of oil condition and oil film strength. Viscosity is reported in centistokes (cSt) at a standard temperature of 40 degrees Celsius (V40) or 100 degrees Celsius (V100). Viscosity will decrease with diesel fuel entry and cross contamination of less viscous fluids from other compartments. Viscosity can increase due to elevated soot, increased oxidation bi-products, general oil degradation and cross contamination. Industrial hydraulic oils and gear oils are typically classified using the ISO viscosity grade scale at 40C.
Viscosity Index	VI	Viscosity index is a calculation derived from V40 and V100 values which is used to characterize the performance of the oil's viscosity over a change in temperature. A higher VI indicates the oil is better able to maintain its viscosity as the temperature increases. Group III base stocks (synthetic and hydro-cracked) have a VI greater than or equal to 120.

Viscosity Range Table

SAE Viscosity Grades for Engine Oils (SAE Specification J300)			SAE Viscosity Grades for Gear Oils (SAE Specification J306)		
SAE Viscosity Grade	Kinematic viscosity @100C		SAE Viscosity Grade	Kinematic viscosity @100C	
	Min (cSt)	Max (cSt)		Min (cSt)	Max (cSt)
0W	3.8	--	70W	4.1	--
10W	4.1	--	75W	4.1	--
15W	5.6		80W	7.0	--
20	5.6	<9.3	85W	11.0	--
30	9.3	<12.5	80	7.0	11.0
40	12.5	<16.3	85	11.0	<13.5
50	16.3	<21.9	90	13.5	<24.0
60	21.9	<26.1	140	24.0	<41.0

ISO Viscosity Grades for Industrial Oils

ISO Viscosity Grade	Kinematic viscosity @40C		ISO Viscosity Grade	Kinematic viscosity @40C	
	Min (cSt)	Max (cSt)		Min (cSt)	Max (cSt)
22	19.8	24.2	150	135	165
32	29.8	35.2	220	198	242
46	41.4	50.6	320	288	352
68	61.2	74.8	460	414	506
100	90	110	680	612	748

Test Type	Report Symbol	Description
Total Base Number	TBN	Also known as Base Number, TBN (OA2) is a measure of the reserve alkalinity in oil. During the normal combustion process, diesel engine oil will become acidic and the reserve alkalinity will neutralize the acid. Decreasing TBN can indicate oil additive depletion and degradation. The first indications of oil degradation are typically detected with FTIR, Therefore the TBN test is used more for a secondary confirmation rather than an initial indicator.
Total Acid Number	TAN	Also known as Acid Number, TAN (OA2) is a measure of the total acidity of the oil. Transmission, hydraulic and turbine oils benefit from this analysis. As oil oxidizes and ages acids are generated which will increase the TAN. A TAN test is advantageous when oil change intervals are being customized and, perhaps, extended beyond the manufacturer recommendations.

Oil Contamination Analysis consists of tests for water, diesel fuel, gasoline, and glycol contamination using a combination of various methods including elemental, physical and chemical analyses.

Contaminate	Report Symbol	Contaminate Description
Debris	Debris	Each sample is examined for visible debris. If visible debris is detected a photo of the settled debris in the oil sample jar cap (after being inverted for a period of time) will be photographed and graded (see Cap Inspect). Samples with visible debris are not eligible for particle count testing.
	Cap Inspect	Visible debris which has settled into the oil sample jar cap is graded based on the appearance (fine, granular, flake, chunk) and estimated quantity (trace-light, light-moderate, moderate-severe) of the particulate (see also Cap Inspection section).
Water screening	FT-IR Water	The FT-IR is used to screen all samples for water contamination. Oil samples with values 25 absorbance units or larger will receive a Crackle Test on the hot plate. Test values are not quantitative and do not represent a certain percentage or content of water.
Water	Water	The Crackle Test is performed when the FT-IR indicates water contamination may be possible. Water acts as an oxidation catalyst and will result in sludge formation, oil film breakdown and excessive wear. Water contamination can be from coolant entry, an external source (rain, pressure washing, sample contamination) or condensation. Water can be particularly damaging to cellulose (paper) clutch and brake discs. The Crackle Test results are reported as "Pos" or "Neg".
Water	K-F Water	The Karl Fisher water test can more accurately determine the amount of water but is considerably more time consuming and costly to perform. The test results are reported in parts per million. ASTM specifies a valid reporting limit of 10 to 25000 ppm (0.001% to 2.5%).

Contaminate	Report Symbol	Contaminate Description
Diesel fuel	GC Fuel	All engine samples with a viscosity of 13.0 or less will receive analysis for fuel dilution. Diesel fuel contamination is determined by gas chromatography (GC) and is reported in percent of volume. It is far superior to flashpoint or head space (flash point, seta flash or "sniffer") analysis. Diesel fuel in the engine oil reduces viscosity and oil film strength, which can eventually result in bearing surface polishing, abnormal wear and possibly surface fatigue failure.
Gasoline	GC Fuel	Gasoline contamination is determined by gas chromatography (GC) and is reported in percent of volume. Gasoline in the engine oil reduces viscosity and oil film strength, which can eventually result in bearing surface polishing, abnormal wear and possibly surface fatigue failure.
Glycol	GC Glycol	The amount and severity of coolant contamination is determined with a combination of elemental coolant indicators (sodium, potassium, molybdenum, boron), water content and the GC Glycol test. Any amount of coolant is undesirable and excessive amounts will cause rapid oxidation of the oil. Small leaks can be very difficult to isolate making condition monitoring and oil change interval management with Cashman Fluids Analysis a viable option.

Particulate Count uses a direct imaging particle count technology called **Laser Net Fines** to quantify metallic and non-metallic particles in non-engine oil samples. The test results are referred to as "particulate contamination". The number of particles in 1 milliliter of sample are counted, sorted by size and reported in 6 different micron (µm) channel sizes. It is a cumulative count where the results of the larger size channel are included in the next smaller size channel. Smaller particles are typically associated with abrasive wear. Larger particles suggest a progression to adhesive, fatigue and/or cutting wear. A shift in this particle distribution (increasingly more, larger sized particles) of microscopic particulate can indicate more severe wear conditions. The oil cleanliness in filtered systems is typically described using the ISO 4406 Fluid Cleanliness Code, a convenient method for indicating the amount of smaller particulate in the oil sample.

The **Wear Debris Summary** is generated by the Laser Net Fines using a technology called direct imaging to classify wear particles greater than 20 microns into 5 different categories: Cutting, sliding, fatigue, non-metallic and fibers. The instrument analyzes an optical image of the particle and compares it to a library of over 30,000 pre-classified shapes in order to determine the type of wear particle. The various types of particles are then counted and reported under its specific category in the Wear Debris Summary section.

Channel Size	Report Symbol	Particle Count Description
≥4 microns	4µ	The number of particles 4 microns and greater in 1 milliliter of oil. The 4 micron particles are generally considered as a silting particle. Corresponds to the first digit in the 3-place ISO Fluid Cleanliness Code.
≥6 microns	6µ	The number of particles 6 microns and greater in 1 milliliter of oil. Code. The 6 micron particles are generally considered as abrasive wear particles. Corresponds to the second digit in the 3-place ISO Fluid Cleanliness Code.
≥14 microns	14µ	The number of particles 14 microns and greater in 1 milliliter of oil. The 14 micron particles are generally considered as the first stages of fatigue, cutting and sliding wear particles. This channel corresponds to the third digit in the 3-place ISO Fluid Cleanliness Code.
≥21 microns	21µ	The number of particles 21 microns and greater in 1 milliliter of oil. The 21 micron particles are generally considered as the continuing stages of fatigue, cutting and sliding wear particles.
≥38 microns	38µ	The number of particles 38 microns and greater in 1 milliliter of oil. This size of particle is at the lower limit of human visibility. The 38 micron particles are generally considered as a more aggressive stage of more aggressive fatigue, cutting and abrasive wear particles.
≥70 microns	70µ	The number of particles 70 microns and greater in 1 milliliter of oil. The 70 micron particles indicate more severe stages of aggressive fatigue, cutting and abrasive wear particles.

Particle Type	Report Symbol	Wear Debris Summary Description
Cutting	Cutting	The number of particles 20 microns and greater in 1 milliliter of oil that are classified as cutting wear debris.
Sliding	Sliding	The number of particles 20 microns and greater in 1 milliliter of oil that are classified as sliding wear debris.
Fatigue	Fatigue	The number of particles 20 microns and greater in 1 milliliter of oil that are classified as fatigue wear debris.

Particle Type	Report Symbol	Wear Debris Summary Description (cont'd)
Non-metallic	Non-metallic	The number of particles 20 microns and greater in 1 milliliter of oil that are classified as non-metallic wear debris such as clutch material or dirt.
Fibers	Fibers	The number of particles 20 microns and greater in 1 milliliter of oil that are classified as fibrous debris such as cellulous clutch or filter media.

The ISO 4406 Fluid Cleanliness Code is a 3-place code describing the level of contamination in the oil. Each scale number represents a range of total particles within a certain particle size channel. The first number in the 3-place code represents the count in the 4 micron channel The second number represents the count in the 6 micron channel and the third number corresponds to the count in the 14 micron channel An ISO code of **18**/**15**/**11** would have 1300-2500 particles 4 microns and greater, 160-320 particles 6 microns and greater and 10-20 particles 14 microns and greater. The ISO code does not represent particle size channels larger than 14 microns.

ISO 4406 Cleanliness Code		
ISO Scale	**More than**	**Less than**
10	5	10
11	**10**	**20**
12	20	40
13	40	80
14	80	160
15	**160**	**320**
16	320	640
17	640	1300
18	**1300**	**2500**
19	2500	5000
20	5000	10000
21	10000	20000
22	20000	40000
23	40000	80000
24	80000	160000

General Recommended Cleanliness Limits for Mobile Equipment

	ISO Code	4µm	6µm	14µm
New fill oil	-/16/13	-	640	80
Diesel fuel	18/16/13		640	80
Hydraulic system	-/18/15	-	2500	320
Transmission (a)	-/18/15	-	2500	320
Transmission (b)	-/21/17	-	20000	1300
Differentials (c)	-/18/15	-	2500	320

(a) Mechanical (b) Electronic (c) 777 and larger Haul Trucks

General Recommended Cleanliness Limits for Industrial Equipment

	ISO Code	4µm	6µm	14µm
Turbines	17/15/12	1300	320	40
Hydraulic, Vane or Gear Pumps (d)	18/16/13	2500	640	80
Hydraulic, Piston Pumps (d)	17/15/12	1300	320	40
Hydrostatic Drives (d)	17/15/12	1300	320	40
Test Stands	15/13/10	320	80	10
Journal Bearings	20/18/15	10000	2500	320
Ball Bearings	20/18/15	10000	2500	320
Roller Bearings	20/18/15	10000	2500	320
Gearboxes	20/18/15	10000	2500	320

(d) High Pressure >3000 psi, Hydac Overview Publication

How big is a micron? One micron is one one-millionth of a meter, .000039 inches, about 1/25,000 of an inch or 0.063 inches in a mile. Talcum powder: about 10 microns; Dust particle: about 40 microns; Human hair: about 80 microns;
Limit of human visibility: about 40 microns

Cap Inspection is a manual process where all samples are inspected for visible debris prior to laboratory testing. Visible metal debris can indicate serious issues that are not capable of being detected by laboratory instruments. Visible non-metallic debris can possibly indicate sample contamination from an outside source. Samples with visible contamination will not be analyzed with Particulate Contamination testing. Sample bottles are inverted to allow the particulate to settle into the cap. After a predetermined amount of time the caps are removed, the particulate visually analyzed and graded by appearance and amount. The particulate and the cap are photographed and the image is captured and stored with the other lab tests for viewing. The grading results are reported with a two-place alpha numeric code:

A: Fine **B**: Granular **C**: Flake **D**: Chunk

***0**: None **1**: Trace-Light **2**: Light-Moderate **3**: Moderate-Heavy

* When a sample is too dark for particle count a cap inspection is performed and photo is captured of the cap. If no debris is present the a grade of A0 is assigned.

Additional Analysis

Microscope Analysis is a supplemental, value-added method used to visually determine the type of microscopic particles in the oil. It is especially useful when the particle count indicates a high level of particulate contamination. It's also useful to look for larger non-ferrous debris such as babbitt bearing material or copper alloy wear debris. Active component wear is typically indicated with varying degrees of microscopic metal, depending on the compartment. On the other hand, outside-sourced sample contamination is indicated by microscopic dirt and debris with no metal present.

Filter Debris Analysis is a supplemental, value-added analysis used to determine the composition of particles captured by the fluid filter. Twenty square inches of filter media are immersed in 100 ml of lab-grade kerosene and agitated vigorously in a mechanical shaker for at least one minute. The fluid is then analyzed for Fine Metals by ICP, Coarse Metals by RFS, Total Ferrous Debris by pqL and a microscope analysis. Test results are considered as qualifying data only because they are not completely representative of the system or component due to the high concentration of particulate in the filter.

Interpretation Process is a vital component of the superior value of Cashman Fluids Analysis and consists of four distinct steps. Each step is a conscience thought process followed by the Analyst as the laboratory data is interpreted into meaningful and useful recommendations.

1. **Interpreting the data**
   The analyst will first "interpret" the lab test results, describing in straight-forward words what the test data is communicating.
2. **Evaluating the data**
   Next, the analyst evaluates the severity level of the results using one, or a combination of, 3 different approaches:
   - Evaluate the absolute value of each test result
   - Evaluate against statistical limits for each test result
   - Evaluate the rate of change from previous sample for each test result
3. **Generating recommendations**
   The analyst will offer a meaningful and useful recommendation or course of action.
4. **Assigning an Overall Evaluation**
   Finally, the analyst will assign an Overall Evaluation. The Overall Evaluation is based on the level of urgency of action required, not the overall severity level of the analysis. The Overall Evaluation will fall into one of four categories:
   A-Green – No Action Required indicates all test results fall within acceptable parameters and *no action* is necessary.
   B-Yellow - Monitor indicates the analyst has noted some cause for concern in one or more of the test results. Based on information supplied with the sample there may be *no need for additional action*. Continue to operate the component in a normal manner but caution the operator to elevate the awareness level and be sensitive to any abnormal conditions that develop. A B-Yellow recommendation may or may not include a short interval resample recommendation.
   C-Orange – Action Required indicates the analyst feels there is a need for *additional investigation* and/or intervention. Typically the action can be performed at the next available downtime such as a shift change or the end of the day.
   X-Red – Immediate Action Required is used for the most critical situations where *immediate action* is required. The analyst feels further operation of the equipment may subject the component to the potential of severe damage or catastrophic failure.

Recommended Sampling Intervals are as close as possible to the OEM standard recommended maintenance intervals. In order to realize the full benefits of Cashman Fluids Analysis a consistent trend of data must be established. Reliable and accurate data trends developed by sampling fluids every 250 operating hours from all compartments and systems provides the foundation for optimum component life cycle management. The approximate operating cost for one fluid sample every 250 hours from one compartment is about 7 cents per operating hour.