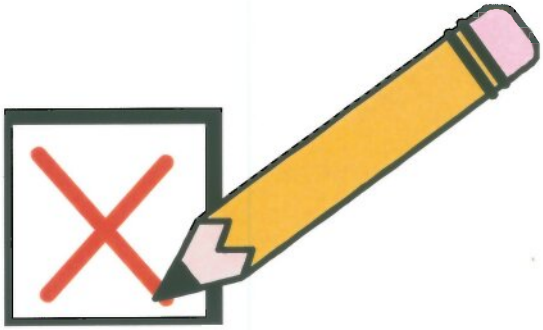
Rating System for Wear Debris



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Quantitative Results

WPC : Wear Particle Concentration	This is a numeric reading from the Direct Reading Ferrograph. It is used to trend the amount of ferrous debris present from sample to sample so any changes are apparent. This reading is trended over time to produce a set of statistics for each individual piece of equipment. The assumption is that the generation and removal of wear debris particles will reach an equilibrium in a normally operating system. This provides a stable concentration of wear debris, but this level will be specific to that system. Some correlation between similar units can be made (as will be shown) but analysis must be made on an individual basis.
PLP : Percentage of Large Particles	The Direct Reading Ferrograph Measures the amount of ferrous debris present in a sample at two points. This allows us to quantify the amount of wear debris over 5 microns in size against the amount of wear debris under 5 microns in size. This measurement usually remains stable in equipment with a WPC over 25 and can be trended as well.
Particle Rating and Size	Two numbers are given to describe the severity of the wear condition that the discovery of a certain type of wear debris represents. The rating given each type of wear debris observed in a sample is a combination of the size of the wear debris and the concentration of particles of the same type. The maximum size of particles points to the severity of an abnormal wear condition at any individual wear contact in the system. The concentration of wear debris points to the prevalence of the abnormal wear condition throughout the system.

Rubbing Wear

In most systems, the amount of ferrous rubbing wear can be tied together with the Wear Particle Concentration. This does not completely correlate to the iron or other wear metals concentration of an emission spectrometer as those pieces of equipment are insensitive to particles over 8 microns across without special testing procedures.

These readings will also not correlate to a particle count as that equipment is more sensitive than the DR Ferrograph to nonferrous material such as sand and dirt contamination. The density of nonferrous materials allows them to be collected to an analytical slide by gravity, but does not allow them to be easily read by the Direct Reading Ferrograph. Abnormal wear modes involving onferrous metal components and contaminants are usually accompanied by an increase in the amount of ferrous wear that is generated. Note that none of the quantitative methods mentioned above give a complete picture of equipment health.

Rating of 1-3 There is less ferrous rubbing wear debris than expected (as indicated by the Wear Particle Concentration) or the system is particularly clean running, such as in a turbine. Nonferrous rubbing wear is usually not expected and may be cause for concern at even these low levels.

3-6 There is an expected amount of ferrous rubbing wear debris for the system. These levels of nonferrous rubbing wear usually do not indicate an abnormal wear condition.

7-10 There is a higher than expected concentration of ferrous or nonferrous rubbing wear particles. While this points to an abnormal wear condition, other clues will be necessary to determine the problem at this point.

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Severe Sliding Wear

Usually observed in plain bearing/shaft wear or gear wear. This debris is the result of the loading between surfaces being too high for the lubricant film to bear.

Rating 1-2 Trace amount in most systems, not indicating a problem. May also be used when a single particle over 80-100 microns is observed, and may indicate a problem in that case.

3-4 May indicate a problem based on the size of the particles. Particles under 50 microns are acceptable. In exceptionally clean running systems, where the WPC is 10 or less, this indicates an abnormal wear condition regardless of size.

5-6 Particles indicate a problem regardless of size. Particles over 70 microns at this stage indicates a critical wear condition.

7-10 High concentrations of this type of particle will draw a critical rating, indicating lubricant starvation or excessive loading between surfaces in contact.

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Cutting Wear

There are two primary types of this kind of wear. Abrasive contaminants will generate one type of cutting wear, while misalignment will generate another type. Size is more of a concern in the misalignment form of cutting wear while concentration is more of a concern in the abrasive form of cutting wear. Once identified, the type of wear is mentioned in the body of the report.

Rating of 1-2/ size of up to 30 microns	These readings are not likely cause for concern.
3-6 / up to 50 microns	In an abrasive wear situation, the analyst feels the damage being done is great enough to warrant removing the abrasive media from the lubricating system. In a misalignment condition, this debris is indicating a significant loosening of tolerances, but the damage is likely to be limited to a single contact. The need for maintenance is not clear.
7-10 / over 50 microns	In an abrasive wear condition, the damage caused by the abrasive media is severe enough to require an inspection to determine whether the equipment can continue to operate. In a misalignment condition, there is likely to be secondary damage from this condition.

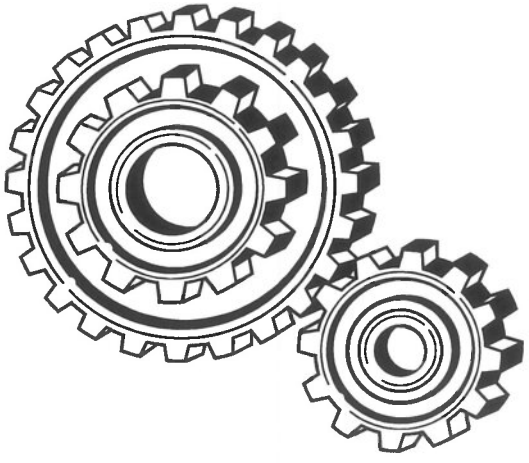
Gear Wear

This type of wear can usually be split into two sources, fatigue pitting from the pitch line and scoring or scuffing near the tip or root. The former type is most commonly found. Wear debris due to scuffing or scoring will be mentioned as such in the text body of the report.

Rating of 1-4 This is an expected amount of this type of wear debris, especially if the particles are under 60 microns in size.

5-6 These rating and particles under 100 microns will not usually be cause to perform a physical inspection. However, oil changes and other measures designed to reduce the rate of wear will be recommended.

7-10 These high ratings, whether mainly due to particle size or concentration, indicate a severe wear condition for gear teeth. Some types of gears may tolerate this volume loss for as long as a year, but most will fail in the space of a few months.



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Bearing Wear

This type of wear debris corresponds to fatigue spalling at a rolling contact or babbitting metal from a plain bearing.

Rating of 1-2 This is only a trace amount of wear debris and not likely to indicate a problem.

3-4 These ratings are size dependent. Particles over 40 microns are likely to indicate an abnormal wear condition, while particles under 40 microns do not. Babbitting metal has a high settling rate and a lesser tendency to generate particles than steel, so debris observed at this level is an indication of a severe wear condition

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5-6 This concentration does indicate an abnormal fatigue spalling condition regardless of the sizes observed. Particles over 80 microns in size represent a severe wear condition, and maintenance is likely to be recommended at that point.

7-10 This amount of wear debris is severe regardless of size, and requires an inspection and repair action.

Iron Oxides

Ferrous Spheres The generation of these particles is a rare occurrence, but indicates a problem in almost any concentration when they are present. They are formed in fatigue cracks before spalling occurs. Electrical discharge in the equipment can also cause the generation of this type of particle.

Black Oxides These particles are generated due to lubricant starvation. When observed by themselves, they indicate a severe wear condition when given a rating over 5. They can be observed along with the presence of increased amounts of rubbing wear, red oxides, corrosive wear, and contaminants. In this case, they all point to an abnormal lubricant condition and he need for an oil change.

Red Oxides These particles are a form of corrosion where individual debris particles are visible under the microscope. These particles are abrasive in themselves and should be removed for a rating over 5. In lower concentrations, they may be an early indicator of water or other corrosive contaminants.

Corrosive Wear These particles are similar to rubbing wear debris, in that increases from previous samples are more important than the current concentration of particles. They can also be trended by observing the Wear Particle Concentration and wear metal results of spectrographic analysis.

Contaminants

Lube Degradation This applies to any kind of amorphous residue in addition to friction polymers that are generated by chemical action on the lubricant. The concentration of debris is considered here. Ratings over 5 are considered an abnormal amount.

Sand/Dirt This applies to many kinds of abrasive and other contamination. The concentration of debris is of primary importance, but abrasive appearance and size are also given consideration. Ratings over 5 are considered abnormal.

Fibers Units are assumed to have filter elements unless proven otherwise. This type of debris may be general contamination, but is more likely to indicate filter element damage. Ratings over 3 are considered abnormal.

Contaminant Spheres Spheres over 40 microns across can get into wear contacts and cause abrasion. Ratings over 3 are considered abnormal.

Other This category is often used for break-in wear when it can be positively identified. It will be given ratings similar to the other types of wear debris, but is likely to be discounted when determining the overall recommendations.

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Characteristics of Equipment

Main Turbine Lubricant Oil

Normal WPC Range	Median PLP	High WPC	Low WPC
1-10	22%	14.9	1.1

This equipment is a clean system in which almost no wear or contamination is expected. The major components being examined are the babbitted plain or thrust bearings. Ferrous wear debris may be observed from auxiliary gearboxes on the unit or pumps on the lubricating system.

Boiler Feed Pumps

Normal WPC Range	Median PLP	High WPC	Low WPC
1-10	15%	17.4	0.4

This equipment is a clean system in which almost no wear or contamination is expected. The major components being examined are babbitted plain and thrust bearings. Babbitting metal and ferrous wear debris is usually accompanied by either water and red oxide contamination or sand contamination. Ferrous debris is usually the result of wear from auxiliary portions of the lubricating system (oil pump, coolers) and not the major components.

Electric Motor Bearings

Normal WPC Range	Median PLP	High WPC	Low WPC
1-15	49%	2330	0.4

This equipment usually runs clean. Its wearing components are babbitted bearings, an oil slinger ring, and the shaft near the slinger ring. This ring will generate copper alloy rubbing and severe sliding wear particles, but their presence alone does not necessarily indicate an abnormal wear condition. Ferrous cutting wear can be an indication of misalignment in the shaft.

Characteristics of Equipment

Fan Bearings

Normal WPC Range	Median PLP	High WPC	Low WPC
1-10	38%	55.3	0.5

The comments on the electric motor bearing apply to these bearings as well.

Reciprocal Compressors

Normal WPC Range	Median PLP	High WPC	Low WPC
1-50	35%	205	0.4

The crankcase is the usual sampling location for this type of equipment. The main wear mode is scoring of the crankshaft bearings. This usually involves observing babbitting metal. However, there is a much greater possibility in this equipment that babbitting metal will settle out of the system before reaching the sampling point. This makes trending of the wear particle concentration especially important for these systems. Ferrous wear from the oil pump, drive system, and the crankshaft are sometimes observed in the form of severe sliding or gear wear.

Internal Combustion Engines

Normal WPC Range	Median PLP	High WPC	Low WPC
5-75	35%	503	0.4

The several different types of engines differ in their wear signatures by the fuel they are designed to use. In general, natural gas engines will run between 5 and 40, gasoline engines between 10 and 50, and diesel engines between 20 and 75. The characteristics of their abnormal wear are similar. The normal sample is taken from the crankshaft, and shows wear similar to that found in the reciprocating compressors from the crankshaft, oil pump, and auxiliary drive systems. Pistons and cylinders are in the lubricating system, which can generate severe sliding wear particles, cutting wear particles, fatigue spall particles, black oxides, and corrosive wear particles. Finally, wear debris from the camshaft or valve train are occasionally identified.

Characteristics of Equipment

Thickener Gearboxes

Normal WPC Range	Median PLP	High WPC	Low WPC
800-8000	55%	379,000	102

The rate of wear particle generation is greater then the rate of particle removal in this equipment. This makes for high and unstable wear particle concentration readings. Almost all of the wear observed is in the form of gear fatigue, which is routinely in the range of 50-70 microns in size. These gears are not likely to fail, but a steady erosion of gear tooth volume occurs.

Bowl Mill Gearboxes (Not Worm Gear Based)

Normal WPC Range	Median PLP	High WPC	Low WPC
20-200	48%	78,500	2.4

The major wear mechanism in this equipment is the ingestion of flyash, a form of process contaminant in this equipment. The identifying symptoms here are the presence of contaminant spheres and the generation of cutting wear particles formed by abrasives. The presence of white, nonferrous metal wear debris along with this contamination indicates damage to a seal. Otherwise, the filtration system must be suspect. Bearing and gear fatigue spalling can be initiated by loading or by overrolling flyash or other contaminant debris. Copper alloy cutting, severe sliding and (less frequently) bearing wear particles indicate bearing cage damage and should be investigated where noted.

Characteristics of Equipment

Ball Mill Gearboxes

Normal WPC Range	Median PLP	High WPC	Low WPC
100-600	36%	24,700	35

The major wear condition is gear fatigue spalling. This equipment generates this wear debris in a steady size range based on the equipment loading. Other types of abnormal wear are observed only occasionally.

Scrubber Gearboxes

Normal WPC Range	Median PLP	High WPC	Low WPC
100-300	39%	13,940	160

These units have not been sampled enough to form a picture of their wear conditions. As of this writing, four different units have each been sampled twice. Wear particle concentrations vary substantially from unit to unit. The main wear mechanism appears to be gear fatigue spall, but no patterns based on loading or contamination have been established.

Air Preheater Gearboxes

Normal WPC Range	Median PLP	High WPC	Low WPC
10-500	42%	5230	3.2

These units operate under a wide variety of wear conditions. Some run smoothly with wear particle concentrations never above 50 while other routinely run at several hundred WPC. The primary mode of wear is gear fatigue spall, and bearing fatigue spall is not uncommon.