

## BEST PRACTICES

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*Fourth of a five part series on oil analysis*

# Strategic oil analysis: Time-dependent alarms for extended lubricant lifecycles

*Following these strategies allows you to calculate rate of wear generation, a more insightful metric than total wear.*

### KEY CONCEPTS

- Time-dependent alarms reveal the actual rate of wear per unit of time.
- The unit of time could be replaced with other incremental units, including production values, miles or operating cycles.
- As time intervals per oil change increase, the rate of top-up volume should be factored to reflect dilution effects.

**O**il analysis is a powerful tool in the machine condition monitoring toolbox—if used properly. Much like other technologies, it performs best within a well-developed plan. When accomplished, a well-devised plan can provide an effective long-term view into the health of any machine with lubricated components.

TLT has provided STLE members with information about test methods, alarm methods and about the best alarm fit for the noted test methods to construct an effective oil analysis approach. The November 2009 TLT provides an overview that would be a worthwhile preview to this article. This article can be found on the STLE Web site ([www.stle.org](http://www.stle.org)).

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## There are three common alarm types for grading the underlying problems for sumps and lubricated components: statistical, absolute and percentage.

These are statistical (alarms used to identify machine wear problems), absolute (aka aging alarms, used to identify lubricant health and degradation) and percentage-based alarms (used for lubricant health and contamination monitoring).

The focus of Part IV of this five-part series addresses rate-of-change (ROC) and volume-compensation alarms. These are common process alarms and could be effectively used to track machine conditions operating under a variety of considerations. When coupled with top-up volume normalization, ROC alarms may help the engineer make decisions about the lubricant's long-term surface protection characteristics something difficult to track with routine lubricant-analysis processes. Accordingly, this approach helps with evaluations between high-performance and commodity grade products.

Aside from wear debris analysis, this technique also could be used to measure contamination control effectiveness for hydraulic and circulation systems, and improve sump life-cycle management.

### TIME-DEPENDENT ALARMS

There are a variety of circumstances under which a ROC or time-dependent alarm is useful. For instance, if the site had a machine that was sputtering through final cycles/hours/units of production and it was necessary to stop the machine before it failed in service, one might use ROC alarms to track the increase in the selected indicator of failure over short blocks of time.

For example, suppose a machine has already produced wear debris indicating an aggressive wear pattern from the routine oil analysis cycle. Perhaps a degraded bearing or gear surface condition is also evident in vibration data. The oil is changed and an inspection conducted to obtain corroborating evidence of a failure symptom. Following conclusion that a repair is pending, the owner wants to squeeze as much time from the machine as possible but wishes to do so safely to avoid collateral damage. An ROC alarm could provide the owner with a wear debris value per unit of time that tells more about the ongoing rate of wear development than an interval reading.

A ROC alarm could be used to measure the rate of oxidative degradation of a large sump volume as well. For instance, as oil ages its rate of degradation often increases. If the oil is hot, wet and/or contaminated with iron or copper wear debris, the rate of decay could accelerate.

Coupled with oil top-up volumes, this method could be used to gauge engine wear for large industrial engines driving ships, trucks and earth-moving vehicles. Particularly, as it pertains to wear debris for engines, the small wear particle

size in engine oil analysis is below typical OEM filter element capture size, meaning wear data should be well represented.

### WEAR RATES USING ROC ALARM LIMITS

A ROC alarm is applied to a system where the amount of change must be considered relative to the amount of time through which the change occurs.

Consider the data set in Figure 1. This represents the amount of wear that has occurred in a compressor sump during a 24-month period, beginning with an oil change (Month 1) and accounting for routine top-ups that have occurred during the analysis period.

Period	Fe Wear Rate	Top-up Vol., Gallons
Mo. 1	19	1
Mo. 2	20	1
Mo. 3	27	2
Mo. 4	15	1
Mo. 5	16	1
Mo. 6	23	1
Mo. 7	45	1
Mo. 8	49	1
Mo. 9	39	10
Mo. 10	41	1
Mo. 11	45	1
Mo. 12	54	1
Mo. 13	56	1
Mo. 14	50	2
Mo. 15	59	1
Mo. 16	54	1
Mo. 17	49	5
Mo. 18	57	1
Mo. 19	67	2
Mo. 20	71	1
Mo. 21	65	10
Mo. 22	68	1
Mo. 23	74	2
Mo. 24	80	0

Figure 2 shows the iron values plotted out over the period of samples. The plot would seemingly suggest that the wear problem is becoming significant. The black trend line adds credence to the concern. However, the timeline for wear generation should be considered.

Figure 1 | Compressor sump 24-month iron wear and top-up volume record.

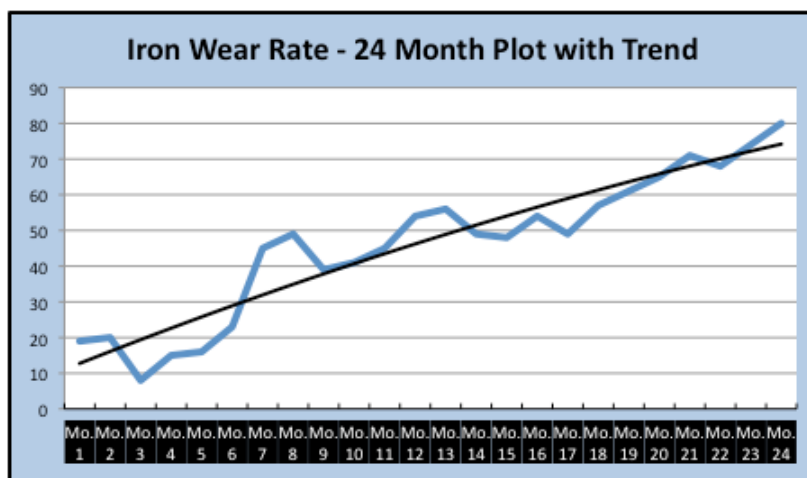


Figure 2 | A 24-month wear debris plot and trend.

## *The chief concern is the ongoing rate of wear generation. Total wear is important but can be misleading.*

The chief concern is the ongoing rate of wear generation. Total wear is important but can be misleading. The iron value shown in Month 24 reflects two years of accumulation, less leakage, and does not reflect the extent to which the rate of wear is increasing or not. Figure 3 reflects the same data set adjusted to reflect wear produced per month.

After accounting for growth over time, it appears that the rate of wear generation fluctuates between 5 and 30 ppm per month but is steady. The plateau toward the end of the sequence may be explained by a variety of conditions, including weather, operational inconsistencies or operating loads.

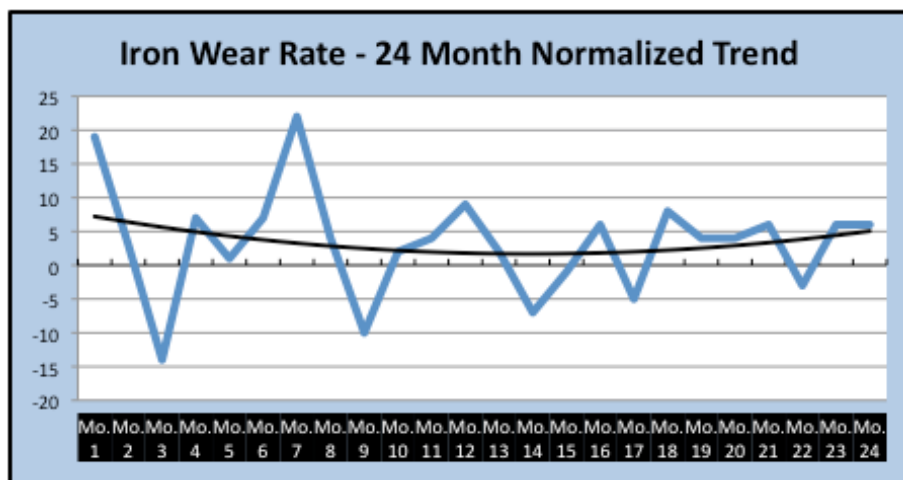


Figure 3 | The 24-month wear trend factored to reflect debris generated each month.

The formula for normalization for any type of data set, both process and maintenance measurements, is:

$$Pf = \frac{(P_0 - P_{-1})}{(T_0 - T_{-1})}$$

where:

- $P_f$  = Factored data point, in this instance iron
- $P_0$  = Current data point
- $P_{-1}$  = Previous data point
- $T_0$  = Current time period
- $T_{-1}$  = Previous time period

The values for,  $P$ , time period, also could be units of production, tons, miles, years or any other parameter. The actual units must be the same, but the nature of the units can be any parameter defined by the user.

Also keep in mind that the values for  $V_{-1}$  should reflect an actual condition. In this instance, the iron reading for  $V_0$ , which is Month 1, follows an oil change. The wear debris from the previous period is not provided, so the value for  $V_{-1}$

is zero. If the parameter measured (AN/BN, RPVOT hours, viscosity, etc.) has a definable starting point, use that value. Wear rate for period zero is not measurable.

### WEAR RATES & EXTENDED DRAIN INTERVALS

Extension of drain intervals is an expected outcome of improvements in lubrication practices. Mineral oil lifecycles should be extendable by a factor of three to five if the lubricant is maintained in a cool, clean (no atmospheric contaminants and/or wear debris) and dry state. Heat, contaminants and moisture all contribute markedly to oxidation and shortened lifecycles.

Following the example, assume this compressor has a 55-gallon sump and experiences nominal leakage across separator and seals. Rather than change oil at the traditional one-year intervals, the owner is operating on a condition-based change plan. As time passes, total wear in the sump increases, as reflected in the concentration of wear per unit of oil (ppm). When oil is added to the sump, the existing concentration of wear is diluted, being distributed into a larger unit of oil volume. If a significant amount of oil is added, it can appear that the rate of wear is less severe than it truly is. To avoid misinterpretation, the top-up volumes should be

factored into the wear rate.

A simple formula to account for added volumes is:

$$Vn_p = \frac{(V_0 + V_1 + V_2 + V_n \dots)}{(V_0)}$$

where:

- $Vn_p$  = Normalized volume per period
- $V_0$  = Initial volume
- $V_1$  = Period 1
- $V_2$  = Period 2
- $V_n$  = Period N

In this example, wear debris is factored by the period (month) to determine the rate of wear. This value can be further factored by the cumulative top-up for that period to provide a monthly wear rate accounting for the total amount of oil added to date.

Treating each monthly data point with the two factors ( $P_0 * P_f * Vn_p$ ) enables the reliability engineer to see the ongoing change in light of both time and top-up volume. When

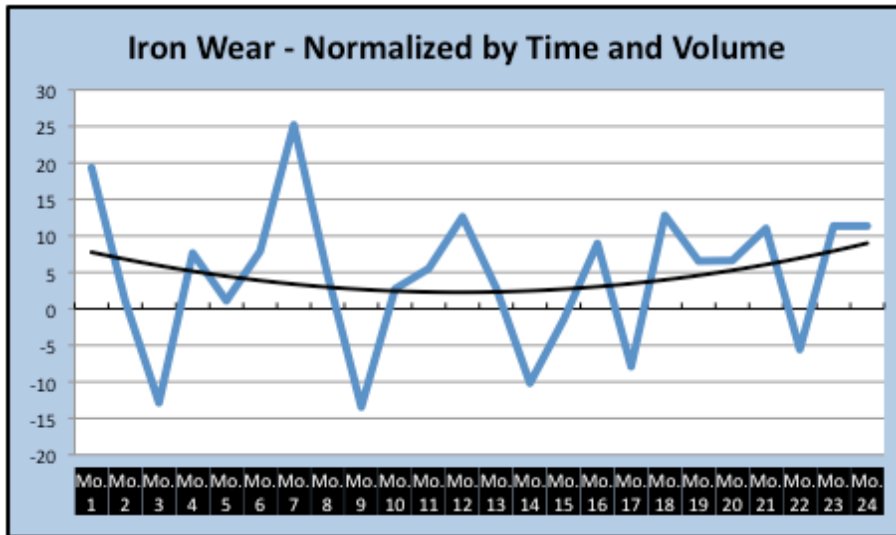


Figure 4 | Data set normalized by time and top-up volume.

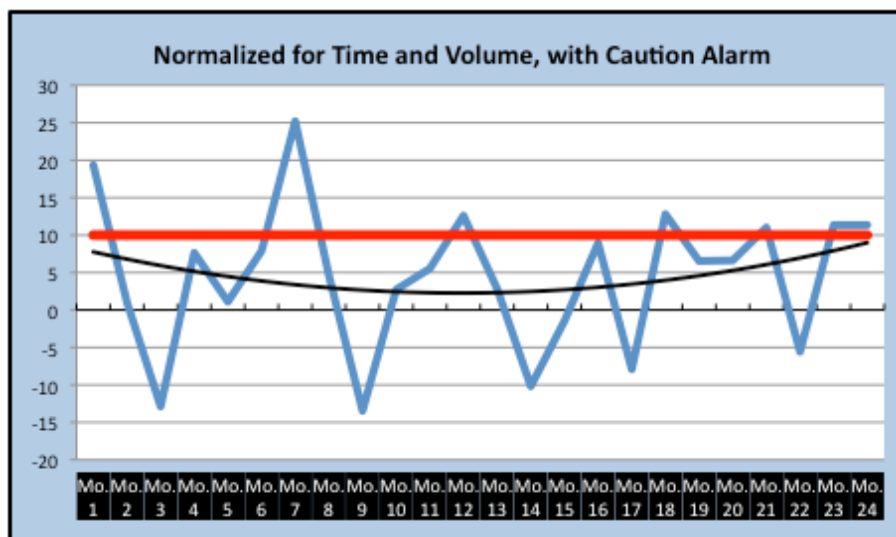


Figure 5 | Initial alarm overlaid to contrast actual against allowable wear results.

applied to the data set from Figure 1, the current plot and trend line, as shown in Figure 4, provides a clearer picture of the machine's health. Comparing Figures 2, 3 and 4, it is apparent that the wear rate is still tolerable for the machine, but after factoring for top-ups, the rate is twice that perceived from the ROC values. In both instances, the impression of dramatic growth in wear over the 24-month period is lessened.

#### PRACTICAL APPLICATION FOR NORMALIZED DATA

Whether a compressor sump, gearbox, engine or other machine type that produces wear debris, factoring data and then applying rate alarms allows the owner to make more informed decisions. Showing the allowable wear rate of <10 ppm per month for the first alarm level overlaid on the graph (see Figure 5), the reliability engineer can see that the rate of wear is higher than desired and warrants action but is not a cause for dire concern. Options to consider for addition in-

spections and analysis could include:

- First, verify that the samples are representative of current conditions.
- Evaluate with wear debris analysis (ferrography) to identify the wear mode. For cutting wear, improved system cleanliness; for scuffing wear, improved lubricant quality or increased viscosity.
- Inspect system feed lines to assure lubricant delivery.
- Verify that the sump temperature is within the suggested operating range.
- Verify that machine performance is within the expected profile (no misalignment, looseness or load balance issues).

#### SUMMARY

Machine owners can expect lubricant lifecycles to become extended as they pursue precision lubrication activities. Total wear metals values may give the appearance of a problem where none exists. Total wear debris measurement is most common but does not reflect the state of ongoing machine change and machine health,

To avoid mischaracterizing data, reliability engineers may wish to factor key data points (lubricant health, machine wear debris, contaminant load)

to allow for changes over time. Time normalization allows the user to grade the data points for change per unit of time. Sump volume normalization allows the user to grade the data points for change, both for time and for any changes in total sump volume during the whole time increment.

Statistical alarms are particularly helpful if data sets from identical makes and models of a machine type can be grouped to create an expected typical profile for that make and model. Once done, alarm sets can be constructed at 1, 2, 3 and 6 sigma values to provide truly meaningful reporting health interpretation. **TLT**



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