

# Lubricant-Based Techniques for Condition Monitoring of Non-Circulating Gear and Bearing Systems

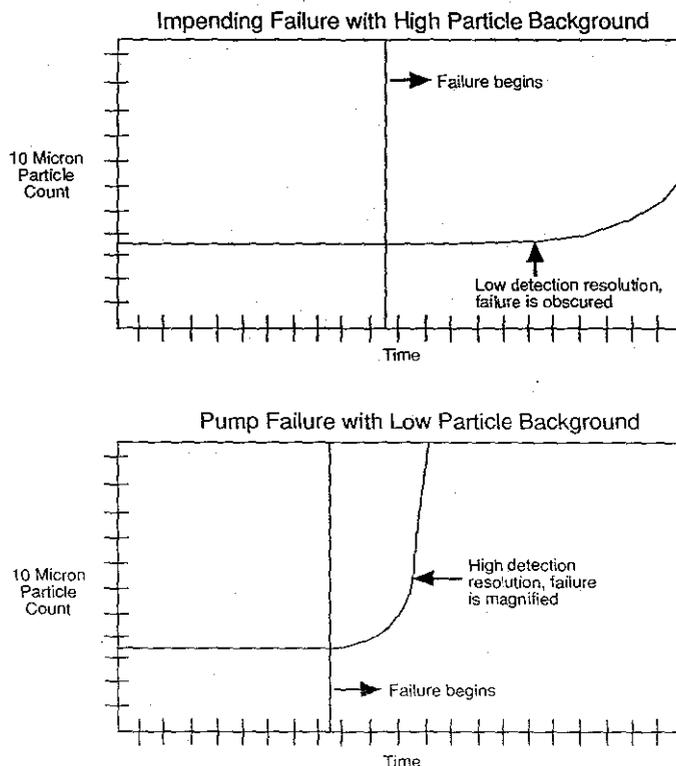
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*The real-time maintenance needs of a machine vary according to changes in specific operation conditions. These conditions fall into two categories: root causes of failure and symptomatic conditions.*

**Figure 1 - Failure Types Detectable Using Contaminant Monitoring**

| <u>Failure Root Cause</u> | <u>Revealed by Particle Generation From</u> |
|---------------------------|---|
| Moisture in Oil           | Corrosion Debris                            |
| Additive Depletion        | Wear Debris                                 |
| Chemical Contamination    | Debris From Corrosion and Wear              |
| Viscosity Change          | Wear Debris                                 |
| Misalignment & Imbalance  | Wear Debris                                 |
| High Pump Inlet Vacuum    | Cavitation Debris                           |

**Figure 2 - Influence of Background Levels**



The first set of conditions are operating and environmental conditions that precede failure, i.e., root causes of failure. They are not failure symptoms, which occur after the fact. Root cause conditions include misalignment, lubricant contamination, and overheating. Detecting and correcting root cause conditions can be referred to as proactive maintenance. Its singular purpose is to extend a machine's operating life.

The second set of conditions that reveal the early stages of machine failure are defined as "symptomatic conditions." Examples of such conditions are the presence of wear debris, abnormal vibration, and corrosion products. Monitoring symptomatic conditions is often referred to as predictive maintenance.

The majority of wear related failures occur as the direct result of particulate contamination. A recent article published in Lubrication Engineering magazine concludes that more than 82% of wear related losses are contaminant induced. And, the largest portion of this is abrasive wear; the direct result of particles wedged between rolling and sliding surfaces.

According to work done by SKF, bearings can have "infinite life" when the influence of particle contamination is eliminated. In some cases more than a 75-times life extension can be achieved by maintaining exceedingly clean lubricating fluids. It is also worth noting that the penalty associated with a contaminated lubricant is identical to that of using a lubricant with just 25% of the recommended viscosity.

There are few forms of internal machine failure that don't release particles into the lubricant; detecting increases in particle contamination can be extremely important. Figure 1 lists some of the failure types detectable using contaminant monitoring.

As a predictive maintenance technique, abnormal particle trends are the early symptoms of several non-particle induced conditions. Once the abnormal trends are recognized, a more precise assessment of lubricant condition or machine malfunction can be pursued.

For contaminant and wear particle analysis to be successful, care must be taken throughout the sampling and analysis steps.

First, all primary fluid sampling points must be upstream of filters. Filters, by design will remove particles which are important sign of failure or abnormal particle ingestion. As result, dynamic changes in contaminant trend can be obscured when samples are taken downstream of filters.

Monitoring frequency is also important. The frequency is influenced by several factors including the target cleanliness level at

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contaminant environment severity.

When a program is well designed and implemented, failures that are not directly caused by particles can be detected (using contaminant trend analysis). In some cases these indicators will appear long before abnormal vibration signals are detected.

Proactive maintenance identifies the role of contamination on machine life and reliability, and consists of three steps:

1. Set cleanliness targets for each fluid system, sufficient to achieve machine life extension.
2. Upgrade or add filtration to achieve and stabilize cleanliness within the target.
3. Monitor contaminant levels at frequent time intervals, based on target cleanliness and environment, to insure cleanliness is achieved.

(A technique called the Life Extension Method (LEM) can be used to set the target cleanliness level. The LEM upgrades the operating lubricant cleanliness (usually dramatically) to extend the Mean-Time-Between-Failures (MTBF) by 5 to 10 times. Contact the authors regarding information on LEM.)

One benefit of improved lubricant cleanliness is that the background particle levels that normally result in "noise" in a contaminant trending program are eliminated. The higher the particle concentration, the less sensitive and less "real-time" contaminant monitoring techniques can be (Figure 2). When background levels are reduced or effectively eliminated, even minute changes in wear rates or particle ingestion are detectable.

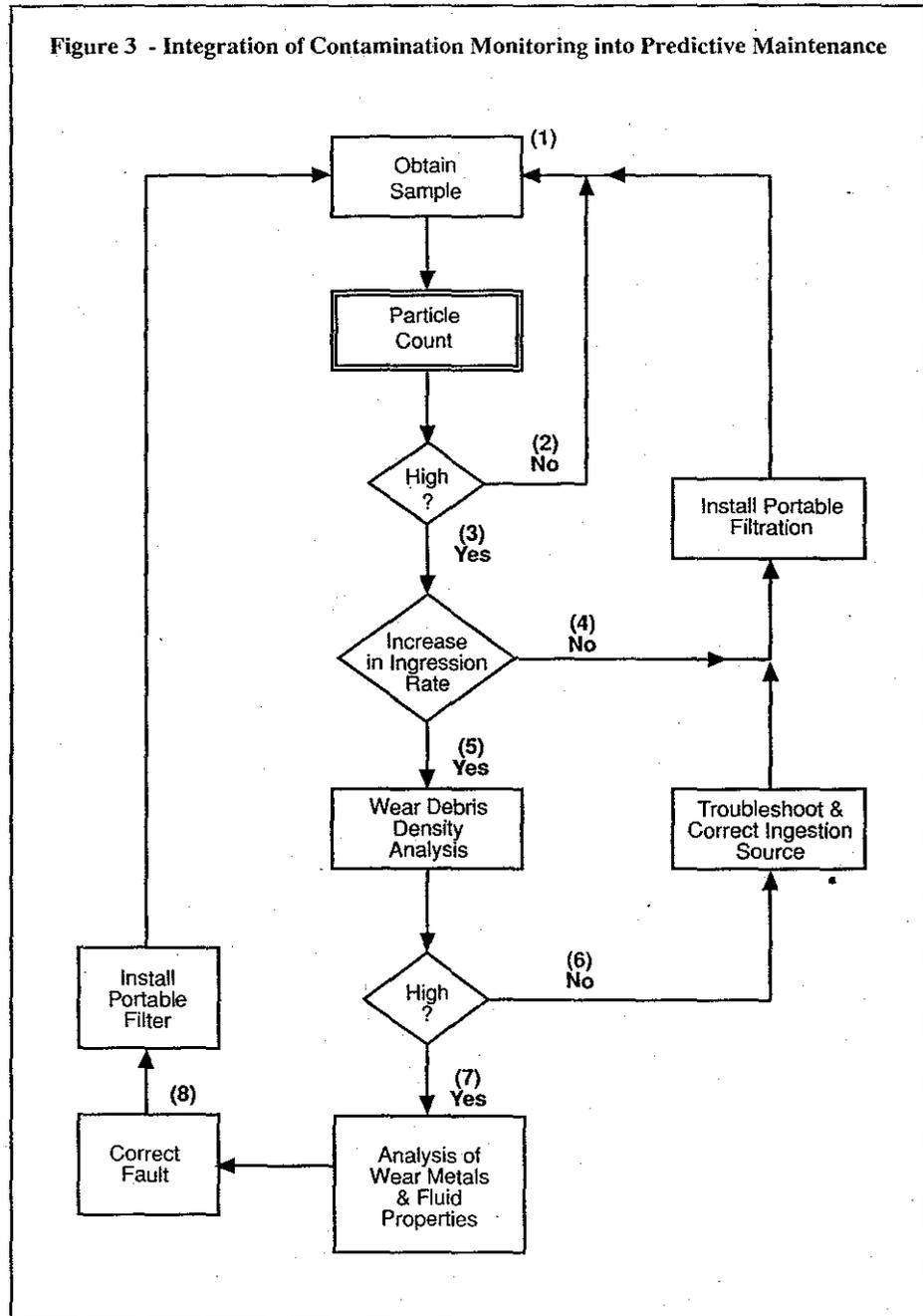
**Contaminant Analysis for a Gearbox**

With a splash-lubricated non-circulating gearbox, particles accumulate in the fluid until external filtration is applied or until the fluid is changed. A rate increase in particle level accumulation suggests a rate increase in wear/ingestion. The addition of wear debris analysis at specific points in the process can help identify the specific cause of the problem.

The flow chart in Figure 3 illustrates an approach for integrating contaminant monitoring into a combined proactive/predictive maintenance strategy. Starting at the top, (1) samples are taken and analyzed on a frequent basis using an inhouse particle counter (portable or benchtop). If the contaminant level is within the target (2), no action is taken and the next sample is scheduled. Note, if a significant increase is noticed, even though the current sample is below target, then this condition accelerates the time to the next sample.

If the current sample is above the target, step 3 is triggered. Step 3 analyzes the particle ingestion rate. This is calculated by subtracting the particle count of the previous

Figure 3 - Integration of Contamination Monitoring into Predictive Maintenance



sample  $C(t_1)$  from the current sample  $C(t_2)$ . This value is divided by the hours between the samples  $(t_2 - t_1)$  to obtain the ingestion rate in particles per hour of operation.

If the ingestion rate is not significantly increased from previous rates, then portable filtration is installed and the cleanliness is restored (4).

If the ingestion rates are measurably higher (5), the cause of the increase must be investigated.

A wear debris density test can be conducted to determine the Apparent Wear Metal Fraction (AWMF). This is the approximate fraction of

the total particles that is wear debris (metallic). Several laboratory techniques can be used to estimate this value. If a low fraction of the particles is metallic (6) then the rate increase in contamination is probably caused by a particle ingestion source, e.g., failed breather or seal. The source of the ingestion should then be located and corrected. The fluid is then filtered to restore cleanliness (Figure 4).

A high fraction of wear metals (with respect to total particle concentration) suggests that wear is being induced by either the lubricant (e.g., loss of antiwear additive) or operating conditions (e.g., misalignment).

## Contamination Analysis

Figure 4 -

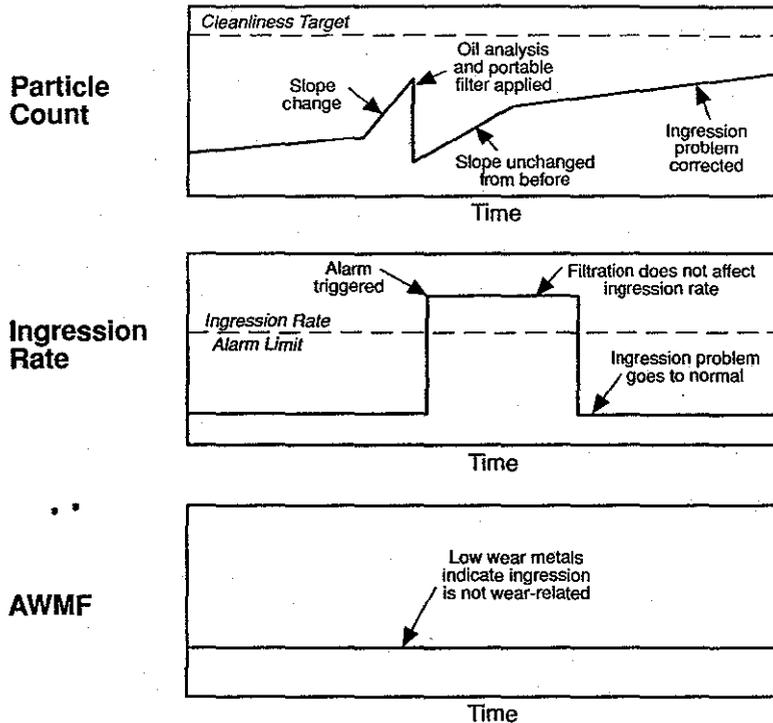
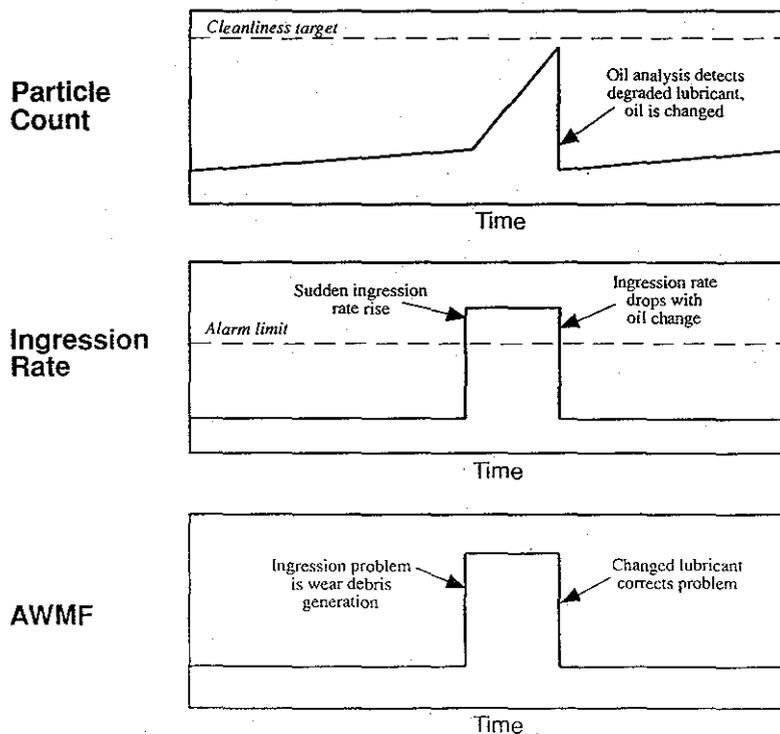


Figure 5 -



To find the source of the problem (7) the lubricant is analyzed completely (unless done at step 5). If the quality of the lubricant is not satisfactory, then the oil should be changed or restored (Figure 5). If the oil quality is good, then other possible problems must be investigated.

Vibration and shaft alignment instruments may also be used to troubleshoot the problem. After correcting the fault, the fluid cleanliness is restored (8). Future particle counts will confirm the remedy (Figure 6).

### Hardware For Gearbox Monitoring

Without the proper connection hardware, an effective proactive/predictive maintenance program for a gear box will be difficult. The following components can be retrofitted on standard industrial gear boxes with minimal cost and effort:

1. Male quick-disconnects with dust covers for the fill and drain ports.
2. T-Fittings with plugs between the casing and the quick-disconnects for optional fill and drain access.
3. Positive retention breather filter on casing top.
4. Port identification tags.

Once the hardware is installed, a portable filter cart can be easily installed to:

- a) flush and restore cleanliness,
- b) transfer lubricant (or top off) to the gear box from a storage container, and
- c) to drain quickly by pumping instead of gravity drain (Figure 7).

In addition, the hardware makes oil analysis much simpler and more reliable. Figure 8 shows an off-line sampler (OLS) which attaches to the quick-disconnects. The OLS has an internal pump and motor to circulate the fluid out of the drain port and back to the fill port. This circulation is necessary to achieve a uniform contaminant concentration in the fluid before sampling. After several minutes of circulation, oil can be sampled into a bottle from a port on top of the OLS. Alternatively, using a portable particle counter, the fluid can be analyzed at the machine site.

This is greatly preferred, since questionable results can be double checked without delay.

### Conclusion

The cost of uncontrolled lubricant contamination can be enormous. While the processes of wear appear slow and almost unnoticeable, destruction and costly deterioration occurs. In addition, even the most sophisticated vibration monitoring techniques may not detect abrasive contaminant-induced wear. In fact, some experts have noted that vibration signals are actually attenuated when contaminants are added to lubricants (surface irregularities are smoothed out or lapped).

## Contamination Analysis

The symptomatic information provided from contaminant trend analysis can also be extremely valuable. Contaminant trends can identify the source of problems which are often unrelated to the fluid. This combined proactive/predictive maintenance approach can yield significant financial benefits.

For more information on condition-based monitoring of gearboxes contact Diagnostics, Inc., 5410 S. 94E. Avenue, Tulsa, OK 74145; (800) 788-9774.

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Figure 6 -

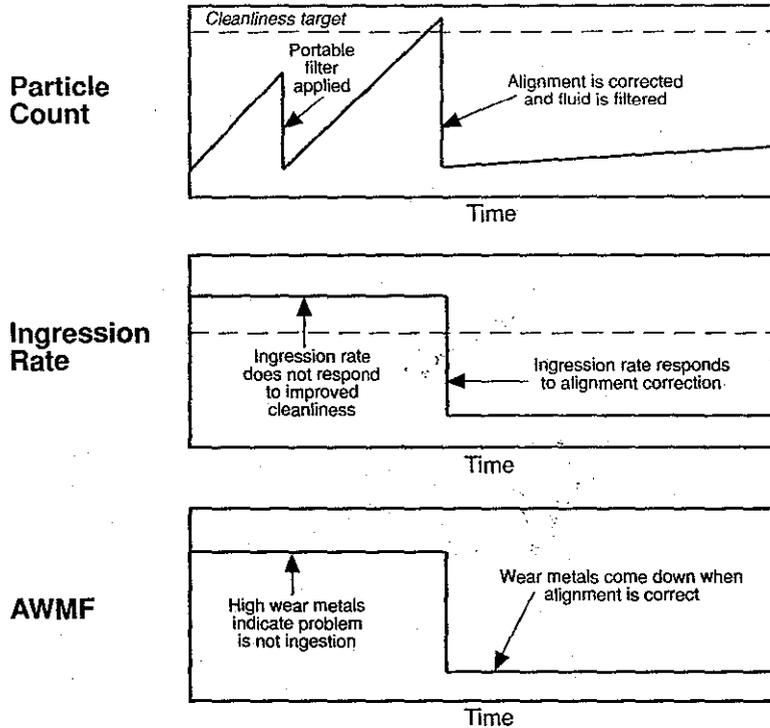


Figure 7 -

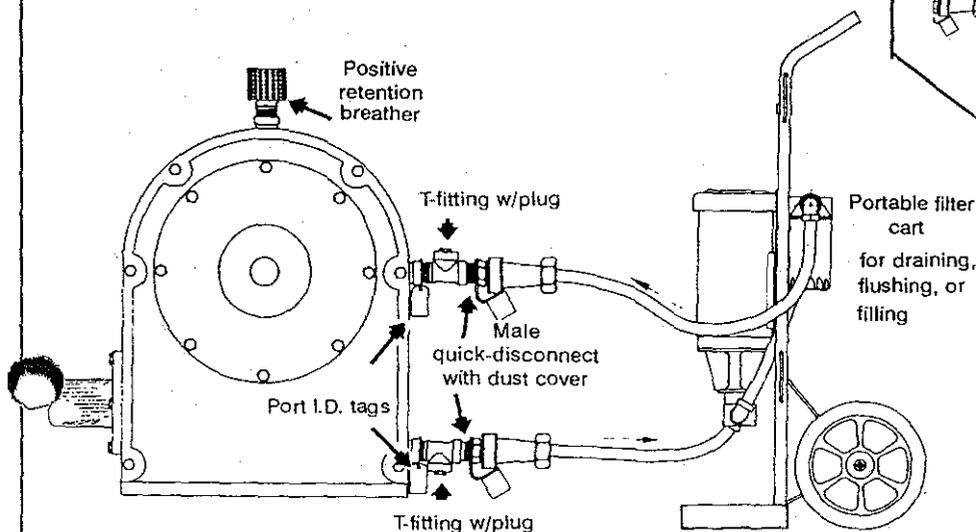


Figure 8 -

