Predictive Maintenance
Indaba 9/92, S. Africa

Technical Application Article

Diagnetics, Inc.

Article # 1

Proactive Maintenance Can Yield More Than a 10-Fold Savings Over Conventional Predictive/Preventive Maintenance Programs --

Contaminant monitoring targets root causes and is the key to implementation

By: James C. Fitch, P.E.
President

Introduction

Plainly stated, the burgeoning cost of maintenance is a serious business problem. According to DuPont, "maintenance is the largest single controllable expenditure in a plant: in many companies it often exceeds annual net profit." One major U.S. automotive manufacturer has a maintenance staff of between 15,000 and 18,000, all plants combined. They say "85% to 90% is crisis work" (breakdown).

While preventive maintenance, when well implemented, has been shown to produce savings in excess of 25 percent, beyond that its benefit quickly approaches a point of diminishing return. According to a Forbes Magazine study, one out of every three dollars spent on preventive maintenance is wasted. A major overhaul facility reports that "60 percent of hydraulic pumps sent in for rebuild had nothing wrong with them." These inefficiencies are the result of maintenance performed in accordance with a schedule (guess work) as opposed to the machine's true condition and need.

Most recently, predictive maintenance (also known as condition monitoring) has been leading the way to additional savings over preventive maintenance. The use of real time or portable instruments such as vibration monitors, thermography, ferrography, etc. has been effective at recognizing the symptoms of impending machine failure. The major benefit is the availability of an earlier warning, from a few hours to a few days, which reduces the number of breakdown "catastrophic" failures. Predictive maintenance is usually implemented concurrently with preventive maintenance and targets both the warning signs of impending failure and the recognition of small failures that begin the chain reaction that leads to big failures (i.e., damage control).

Proactive "Life Extension" Maintenance

Proactive maintenance has now received worldwide attention as the single most important means of achieving savings unsurpassed by conventional maintenance techniques. The approach supplants the maintenance philosophy of "failure reactive" with "failure proactive" by avoiding the underlying conditions that lead to machine faults and degradation. Unlike predictive/preventive maintenance, proactive maintenance commissions corrective actions aimed

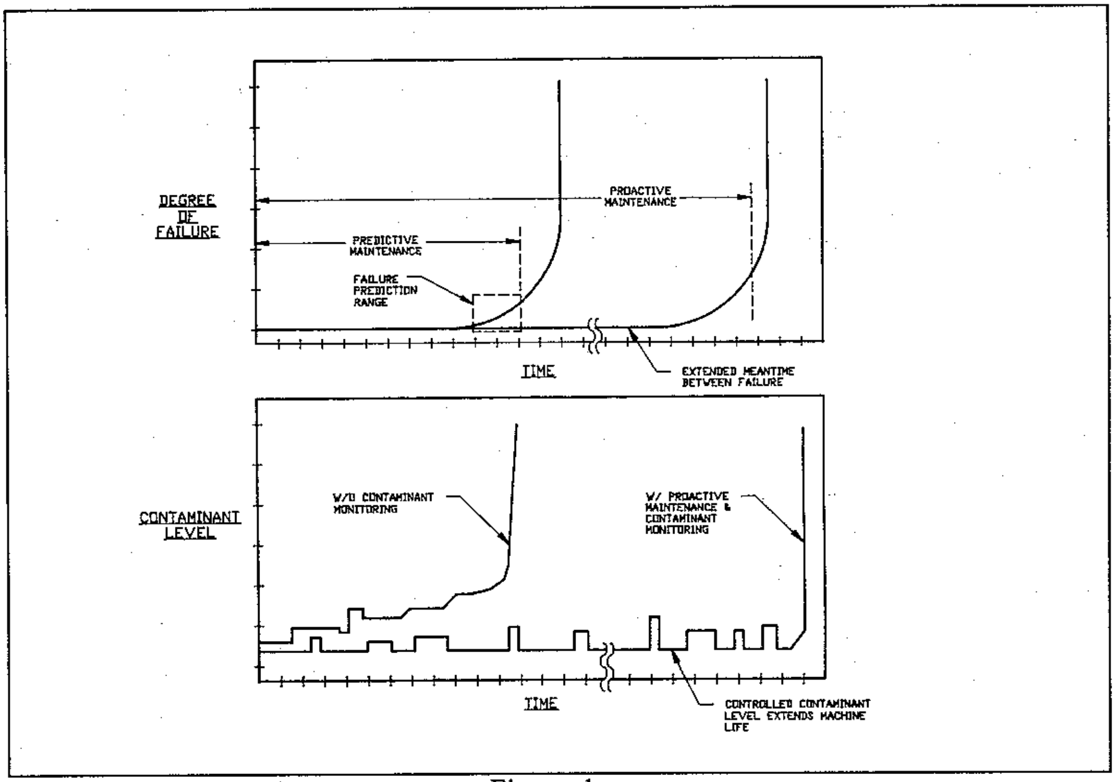

Figure 1

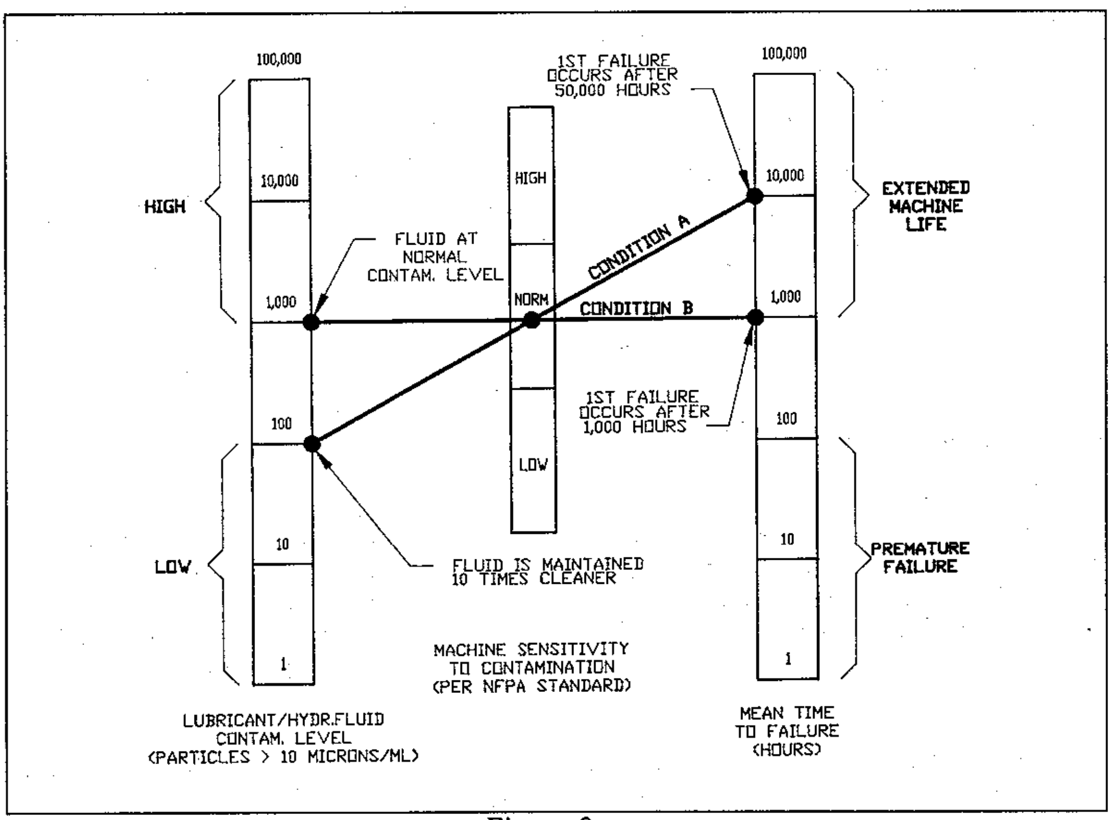

Figure 2

ingression rates of 10 million to 100 million particles greater than 10 microns (per minute) characterize field systems" (Figure 4).

Hence, the filter, if existent, is challenged with the formidable task of removing particles from the fluid at the same rate at which they are entering (ingression). Tests by machinery manufacturers show that filters have great difficulty achieving this task in the field, where they are subjected to conditions of frequent and large changes in temperature, fluid viscosity, pressure, and flow (surges), plus the effects of shock, vibration, and fatigue. Other common problems are filter bypass valves that get stuck open, damaged or missing filter gaskets, and filters that are installed backwards or crooked. Accordingly, the spoils and vagaries of field-oriented situations are many. As a result, fluid contaminant levels must be frequently monitored to verify filter performance and to provide the essential "feedback" that gives integrity to a contamination control program.

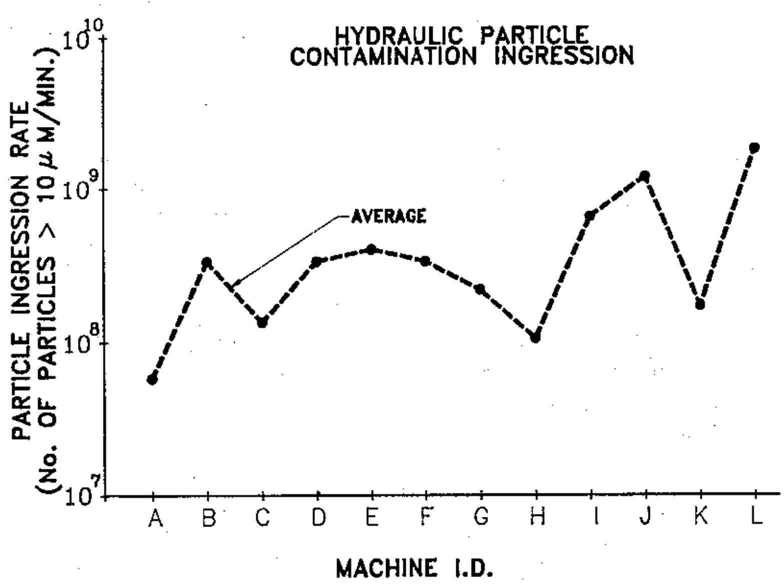

Figure 4

Hydraulic Maintenance Savings

When it comes to proactive contamination control maintenance, the Japanese may be the global leaders. They have clearly taken a "do-it, don't-just-talk-about-it" approach. Evidence of this comes from reports by two of the world's largest steel mills, Nippon Steel and Kawasaki Steel, both in Japan:

A. After Nippon Steel implemented a hydraulic system contamination control program plant-wide, involving both improved filtration and rigorous fluid cleanliness monitoring, pump replacement frequencies were reduced to one fifth

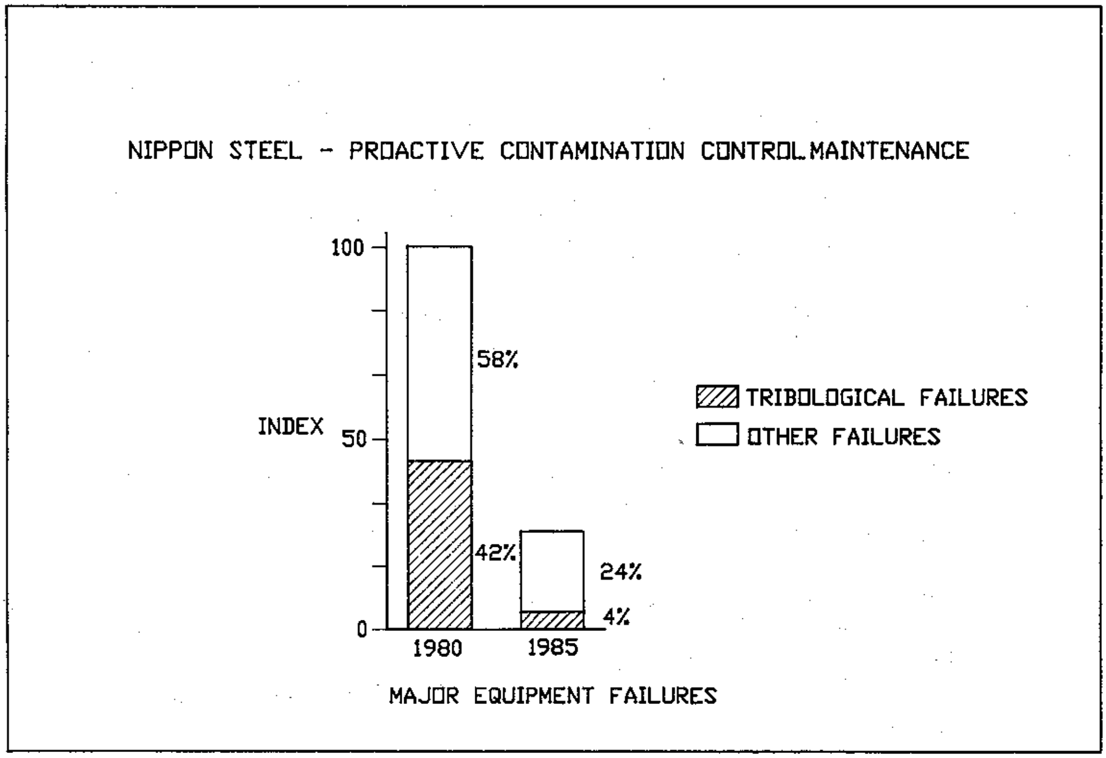

Figure 6

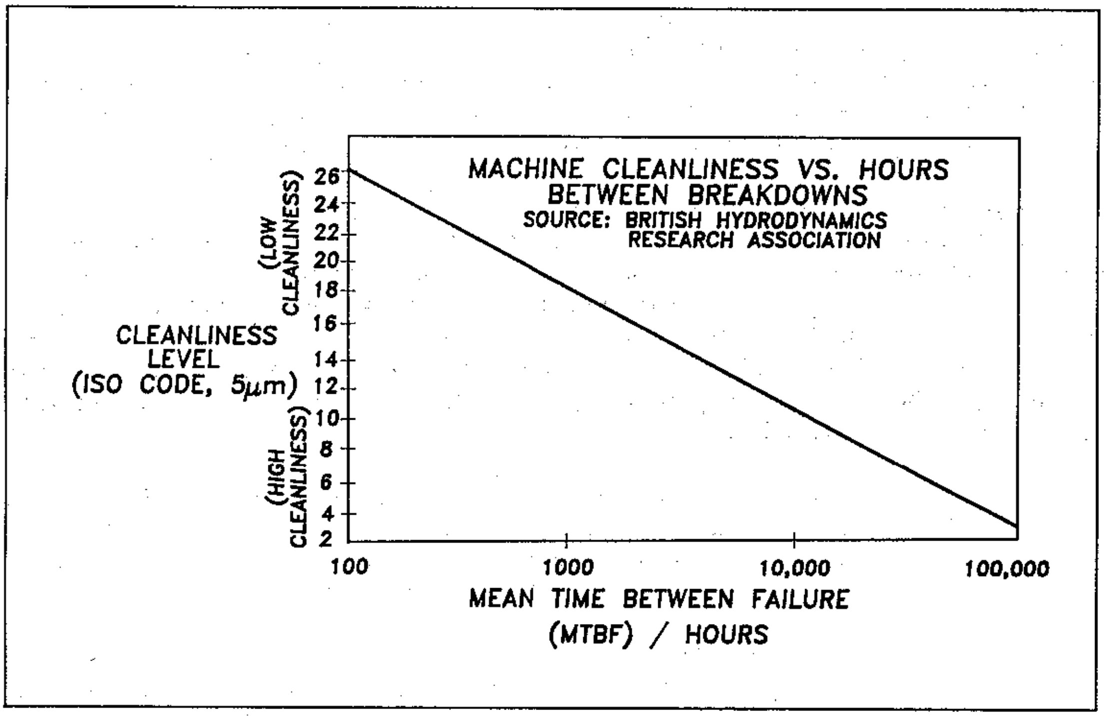

Figure 7

engine wear was reduced by 50% with 30 micron filtration. Likewise, wear was reduced by 70% with 15 micron filtration."

3. A study conducted by the supermarket chain Albertson's Inc. on a series of over-the-road Cummins tractor engines found markedly reduced wear rates with greater lube oil cleanliness. After analyzing six engines having 600,000 operating miles, Albertson's reports, "engine crankshaft journals showed only 0.0005 inches of wear. The rod and main bearings hadn't even worn through to the copper layer. Compression-ring and oil-ring wear were negligible."

4. An independent European university study, as published in Lubrication Engineering Magazine, reports a reduction in diesel engine wear by a factor of 14 when better lube oil cleanliness is maintained. The study also equates the resulting friction reduction with a 5 percent increase in fuel economy.

In reference to gas turbine engines, the U.S. Department of Defense states that "approximately 30 percent of all engine failures are caused by metal particulate contamination in lubricating oil systems." More precise studies, if conducted, would likely prove the true percentage to be much higher. After all, the wear processes and failures of gas turbines, by design, should be very similar to diesel engine and bearings failures, as previously reported and well documented.

It is interesting to note that currently an estimated 25 to 50 million lube oil samples are analyzed by commercial and in-house fluid analysis labs in the United States each year. Yet, despite the fact that contamination is the largest contributor to engine failure, fewer than 5 percent of these labs do particle counting on lube oil samples. Wear metal analysis and elemental analysis are too often confused as being indicative of actual particle sizes and concentrations in lube oils. Only accurate particle counting devices can determine this.

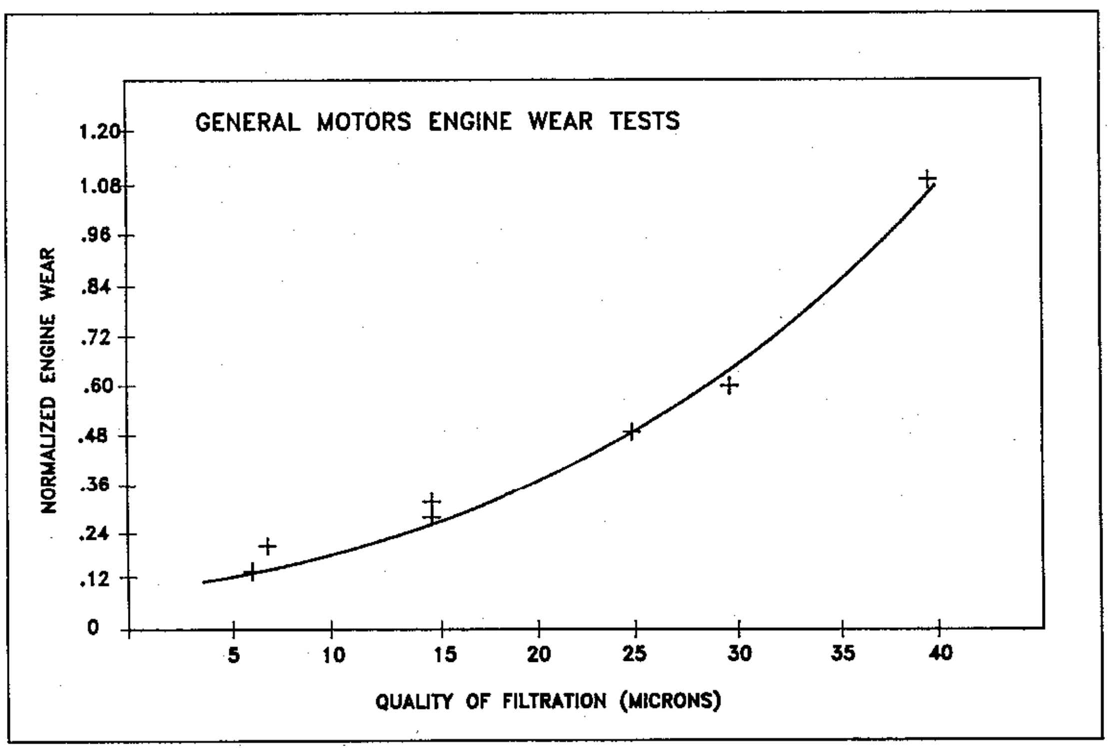

Figure 8

Fluid contaminant monitoring can be accomplished in the field or plant by extracting samples of fluid into bottles for lab analysis or by portable instruments used right at the machine. Recently there has been a trend away from bottle sampling and lab analysis for routine contaminant monitoring due to the associated higher cost, reduced accuracy, and time delay. In its place has been the use of portable monitors that receive fluids directly out of machines for on-the-spot analysis.

One instrument, sold by Diagnetics, called Digital Contam-Alert (DCA), is battery operated and extremely lightweight (Figure 9). It consists of a sensor attached by cable to a hand-held computer. During a test, the sensor is placed momentarily on a special diagnostic port permanently installed on the machine. A small sample of fluid under pressure passes into the sensor and after a minute or two the particle count is displayed on the computer screen.

The unit can be used with a variety of different fluids, such as lube oils, hydraulic fluids, transmission fluids, gear oils, and coolants. After each test the handle on the sensor is depressed, which expels the sample, making it immediately ready for reuse. Particle count data can be easily stored in the computer, tagged to machine I.D., the date, and user comments. Later, the data can be printed out with a portable printer or it can be down-loaded to a desk-top personal computer.

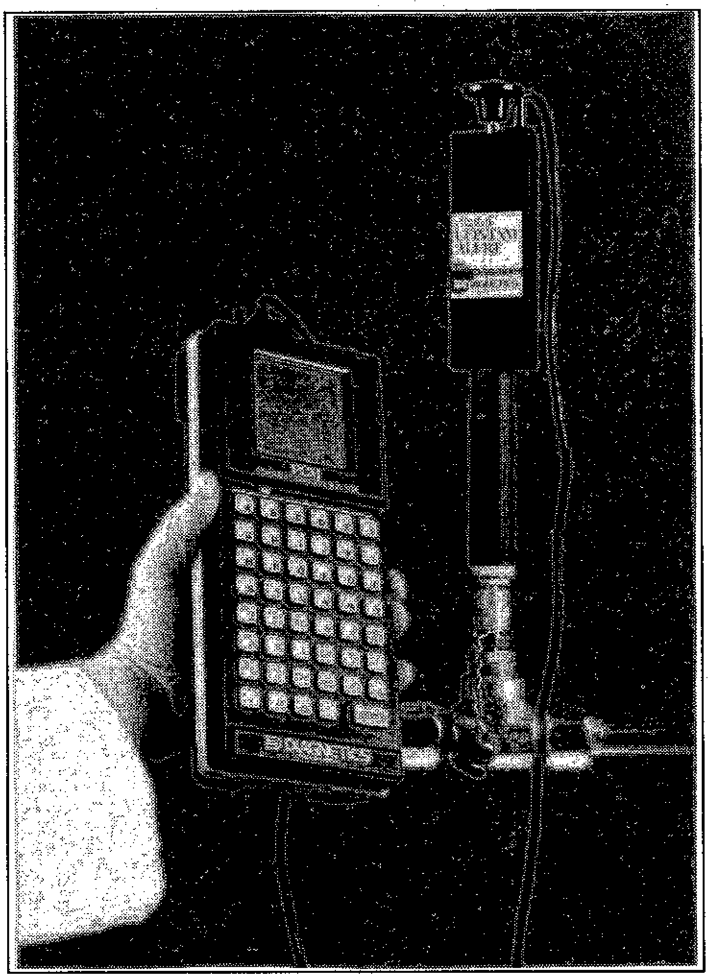

Figure 9

1. "High contamination levels in these systems contribute to higher levels of wear, accelerate the process of wear, and results in premature failure."

2. "By the time wear metals analysis alone [as opposed to contaminant monitoring] indicates an increase in wear, the abrasive process may be irreversible and the system may in fact be at the point of catastrophic failure."

3. "It is interesting to note that spectroscopic wear metal analysis results DID NOT CHANGE significantly [despite greatly improved filtration], however an overall reduction in total wear was achieved after several months of monitoring the system."

Still, another study showed that "spectrographic analysis did not predict the failure of oil-wetted components on aircraft." Amazingly, after analyzing an oil sample taken from an electric generator in another report, the spectrographic results indicated "no major problems." In fact, the sample had been taken from the engine AFTER catastrophic failure, a point at which exorbitant wear metal levels should have been detected.

System Monitoring Hierarchy

It has been stated that the fundamental purpose for contamination control and contaminant monitoring is to achieve greatly extended mean time between failures (MTBF), not damage control. However, when anomalous conditions are present, as first measured contamimetrically, further analysis using ferrography or vibration can identify the source of the problem. Figure 10 shows such a system monitoring hierarchy with an example.

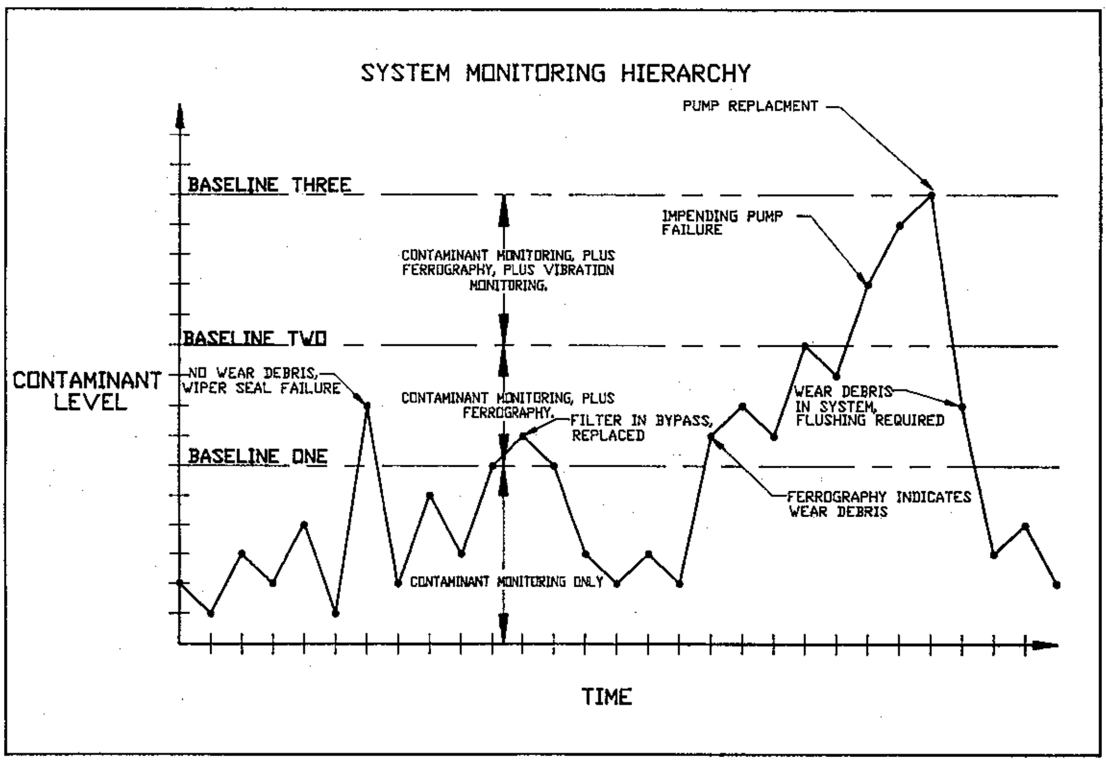

Figure 10

References

Beercheck, Richard C. "How Dirt and Water can Slash Bearing Life." Machine Design. July 6, 1978.

Bertele, Otto V. "Why Condition Monitor?" 3rd International Conference on Condition Monitoring. October 15-16, 1990.

Blok, Peter, Jim C. Fitch, and Kim A. Hodgson. "Measuring Contaminant Levels in the Field (Bestimmung des Olreinheitsgrades on Ort und Stelle)." Olhydraulik und Pneumatik, 34. No. 5. 1990.

Chaplin, James. "Improving Vehicle Productivity Through Better Contamination Control." SAE Paper No. 861300. September, 1986.

Cooper, Richard. "Prevention of Ball Bearing Failures." Plant Services. December, 1985.

Cunningham, Ernest R. "Contaminant Removal Methods and Equipment for Cleaning Hydraulic Fluids." Plant Engineering. June 11, 1987.

Dodd, Ray V. "Condition Monitoring of Major Turbomachinery Cuts Costs Over 4-year Period." Oil and Gas Journal. March 12, 1984.

Editor. "Early Warning Helps Avoid Costly Repairs." Heavy Equipment Maintenance. April, 1989.

Editor. "Troubleshooting Hydraulics." Equipment Management. January, 1991.

Farris, John A. "Controlling Contamination in Hydraulic Systems." Contractors and Engineers Magazine. May, 1974.

Fitch, E. C. "A Perspective of Contamination Control Economics." The BFPR Journal. 1978, 11, 1: 49-53.

Fitch, E. C. "An In-line Contaminant Monitor for Fluid Power and Lubrication Systems." The Fluid Power Research Center, OSU. 1982.

Fitch, E. C. Fluid Contamination Control. Sillwater: FES, Inc., 1988.

Fitch, J. C. "Hydraulic Fluid Analysis - Avoiding the Potential Pitfalls." Hydraulics and Pneumatics Magazine. Part 1, December, 1987. Part 2, January, 1988.

Fitch, J. C. "Quantifying the Contaminant Tolerance of Hydraulic Systems Using the Contaminant Life Index." National Conference on Fluid Power. 1986.

Hankins, Carrol F. "Increasing Bearing Life in Paper Machines by Contamination Control." PALL Symposium on Contamination and Wear. 1984.

Hitchcox, A. L. "Portable Equipment Evaluates Hydraulic Performance." Hydraulics and Pneumatics Magazine. July, 1987.

Jones, H. J. "Coming to Terms with Contamination in Naval Hydraulic Systems." IMECHE, C243/84. 1984