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Phosphate Ester Fluid Testing, Maintenance Challenges, and Solutions in EHC Systems

Common Issues that Significantly Impair Asset Reliability, and Increase Fluid Maintenance

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Common Issues that Significantly Impair Asset Reliability, and Increase Fluid Maintenance

Despite the excellent lubricating and safety properties of Phosphate ester lubricants, many turbine and Electro-Hydraulic-Control (EHC) users struggle with their maintenance. While proper EHC fluid maintenance is not difficult, users often lack the tools and the updated technical training for effective maintenance. Outdated or incorrect EHC fluid maintenance is a common problem in the power generation industry that is costing 100's of millions of dollars each year in unnecessary failures and lost production. With the cost per MW/hour averaging $50/MWh, a single failure can cost $20,000-$50,000/per hour. At one nuclear power station, a severe EHC system failure attributed to fluid quality resulted in a 30 day shut-down of the 1100MW Steam turbine. At these average market rates, this failure resulted in a production loss totaling 40 million dollars.

When results matter

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> "This contamination is not normally measured and when present, frequently impairs servo valve response time."

Common Issues That Significantly Impair Asset Reliability, and Increase Fluid Maintenance

Lab Analysis is Missing Key Information Necessary to Manage These Fluids.

- ISO4406 only measures particles greater than 4 microns, however up to 90% of the total solids by weight can be below this range. For proper servo valve operation, particles <4 microns should be tested and monitored. Membrane patch testing at 0.45microns (see Figure 1), quantifies these particles by mass so a more comprehensive assessment can be made.
- Metals in EHC fluids are not routinely tested which is problematic for several reasons. Metals provide the fluid breakdown pathways that increase the rate of acid production by up to 5X (or the inverse, reduce fluid life by 5x). Metals are also involved in the formation of gels and other solid deposits. When you investigate the source of metals in EHC systems, you will find that the acid removal filters are a primary source (see Figures 2, 4 & 5).
- Dissolved contaminants, including fluid break down products, accumulate over time and eventually come out of solution to form deposits on servo valve components (see Figures 6 & 7). This contamination is not normally measured, and when present, frequently impairs servo valve response time, and presents an elevated risk of servo valve malfunction and or failure (see Figure 3).

EHC Fluid Maintenance is not Removing Harmful Types of Contamination

EHC fluid maintenance is not removing harmful contamination including metals, fine particulate, and high pressure filter fibers (see Figure 5). This contamination is responsible for varnish and deposit formation, low resistivity, and high rates of fluid breakdown. Not only does existing fluid maintenance not remove this contamination, it has been proven to be a major source of contamination.

***Fig.1**—Membrane patch test at 0.45 microns*

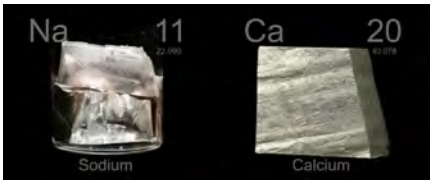

***Fig.2**—Metals frequently added to EHC fluids from acid filters*

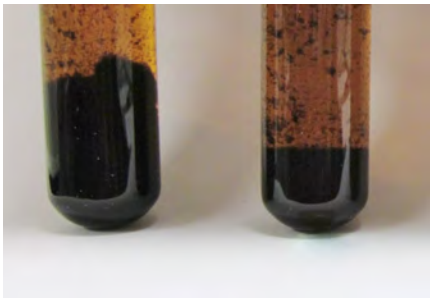

***Fig.3**—Deposition Tendency test, no solids should form*

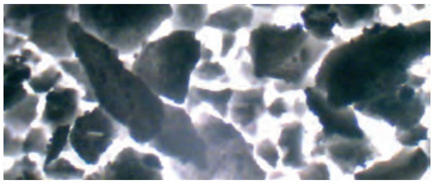

***Fig.4**—Acid filter material is abrasive, contributes fine particulate and metals.*

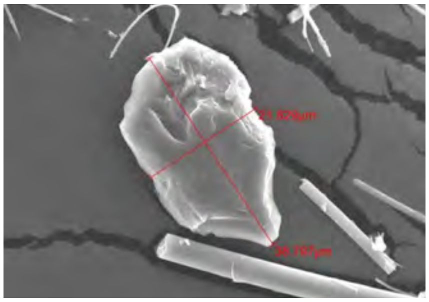

***Fig.5**—SEM Photo of Calcium particle from Acid filters found on HP Filter.*

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EHC Fluid Maintenance Does not Manage the Factors that Cause Fluid Breakdown.

Heat, Water, Oxygen, and Metals determine the rate of oxidation and therefore the rate at which EHC fluid breakdown occurs. These factors are not usually managed in most EHC systems which results in higher than desired rates of EHC fluid breakdown.

EHC System Operating Practices

EHC system operating practices often accelerate fluid problems. Flow rates, operating temperatures, fluid operating levels (see Figure 9), and mechanical system component operation all need to be reviewed so they are not unnecessary contributing to EHC fluid break-down.

> *"Deposits on servo valves are created from dissolved contamination that can be tested for using the deposition tendency test."*

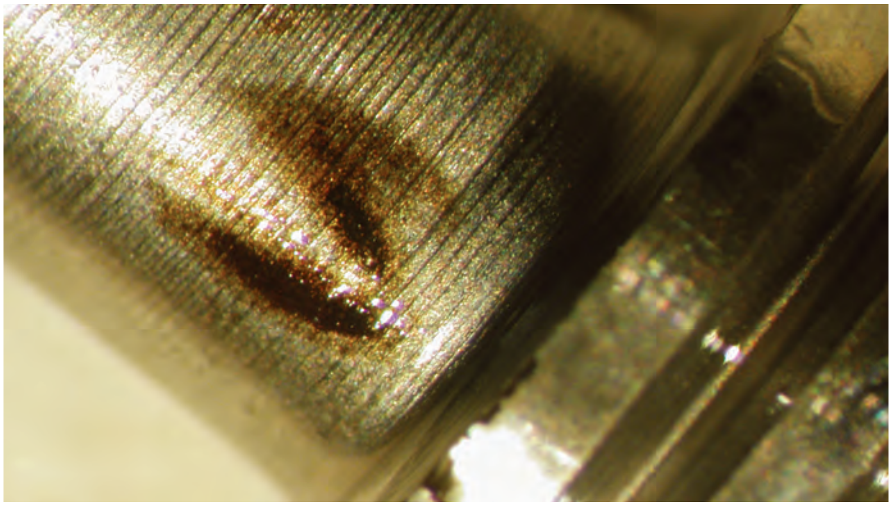

***Fig.6**—Deposit on servo.*

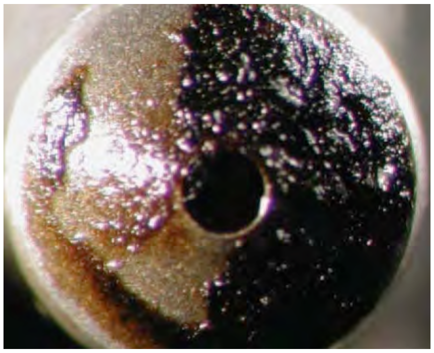

***Fig.7**—Deposit on nozzle.*

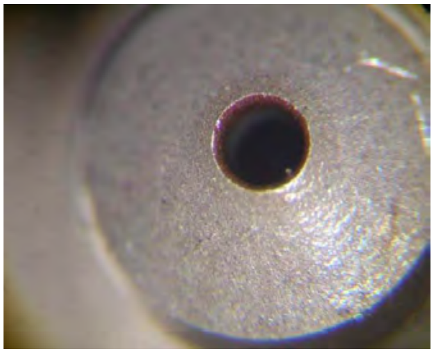

***Fig.8**—Evidence of electrokinetic wear from low resistivity.*

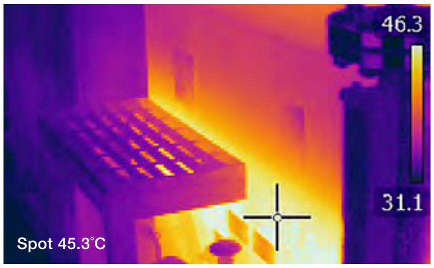

***Fig. 9**—Low operating fluid level in reservoir.*

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Phosphate Ester Fluid Maintenance Solution for EHC Systems

A Smarter Approach to Drastically Reduce Production Losses and to Provide Stable, Trouble-Free EHC Fluid

EHC Fluid quality related failures and their resulting production losses can be virtually eliminated through EPT's industry leading fluid maintenance and testing program which is the result of 20 years of specialization in the EHC fluid application. EPT's 4 step approach is comprehensive in scope, targets common weaknesses, and removes the contamination responsible for servo valve deposits. Our program offers turbine owners and operators a clear path forward to protect their equipment from failure and save money.

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***Fig. 10**—In Step 1 of the Deposition Tendency Test referred to in the EPRI EHC Fluid Maintenance Guide 2002, Page 4-39, EHC fluid is mixed with Hexane which forces out dissolved contamination into solid form. In the first three test tubes, EHC fluid using conventional treatment form visible solids. Servo-valve performance and reliability would be significantly impaired using EHC fluid in this condition. In the last 2 test tubes where the EHC fluid was cleaned with ICB™, no deposition or solids of any form are observed. Servo-valve response time and reliability would be maximized operating EHC fluid in this condition.*

> *"EPT's 4 step approach is comprehensive in scope, targets common weaknesses, and removes the contamination responsible for servo valve deposits."*

Step 1–Improved Fluid Testing

EPT's Phosphate ester maintenance and testing program measures the hidden contamination that accumulates in most phosphate ester systems. While water, acid, and particulate testing is routinely performed, most analysis fails to measure the dissolved break-down products that are responsible for varnishing, servo-valve sticking, low resistivity, and high rates of fluid-breakdown.

Our EHC fluid maintenance and testing program precisely measures contamination levels to identify problem areas and to track cleaning progress. To have our expert team provide you with a complimentary fluid assessment, complete our sample submission form at www.cleanoil.com/oil-analysis-consulting.

Step 2–Removing Fluid Contamination Responsible for Mechanical Issues

Acids and Dissolved Contamination

While Fuller's Earth and Selexsorb® filters have been widely used as acid removal filters in phosphate ester based EHC fluid applications, an entirely new level of EHC fluid purification is available through the use of ICB™. ICB™ is a specialized Ion exchange product developed by EPT™ that not only removes acids, but more importantly removes the dissolved contamination responsible for servo-valve sticking (Figure 6). This contamination is normally hidden in the EHC fluid as it is not tested as part of routine fluid analysis. In Figure 10, results of a Depositing Tendency Test are shown. In this test, EHC fluid is mixed with Hexane which forces dissolved contamination out of solution so that it can be viewed. In the first 3 test tubes, EHC fluids using conventional treatment form visible solids when mixed with hexane, while samples 4 and 5 that have been cleaned with ICB, show that this contamination has been eliminated.

ICB™ filter for removing acids, metals, dissolved contaminants, and restoring fluid resistivity

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ECR™ 8000, Electrostatic Cleaning System For Removing fine particulate and restoring fluid color

This additional benefit of being able to remove this contamination using ICB™ is a game changer for phosphate ester based EHC fluid maintenance. For the past 40 years, steam turbine EHC operators have worked to manage acid numbers and fluid resistivity values, without the ability to remove the contamination responsible for servo-valve sticking. ICB™ removes this limitation, allowing for significantly improved servo valve operation.

Solid Contamination

There are 2 basic categories of solid contamination, particulate >4 micron which is measured by ISO4406, and particulate <4 micron which is not measured. When looking at particulate levels > 4 microns we frequency observe particulate levels 50-100x greater than the maximum allowed level permitted in servo valve applications. The "trouble-free" operating window of a servo-valve operating above this specification is 0 hours. The reason many EHC systems are at such high levels is because the efficiency of the filters used is often far below what is reported in the filter spec sheets. Standard filter efficiency (i.e. 99.5%) is measured under ideal laboratory conditions. While a filter may perform well in the lab under static conditions, in real-life dynamic conditions, filter efficiencies are typically much lower. For this reason, specialized particulate filters are recommended that are rated at 99.5% under dynamic conditions.

TMR™ N2 Water Removal System

For particulate <4 micron, conventional particulate filters can only go down to 1-2 microns. Our investigation has shown that up to 90% of the total particulate contamination in a system can be below this size. Because ISO 4406 does not measure below 4 microns, we use a patch weight test at 0.45 microns to determine the mass of this particulate contamination. This contamination is responsible for fluid darkening and is generally produced from micro-dieseling, which is a type of high temperature fluid breakdown that is caused by air-release issues. When patch weight values are high we recommend the use of our ECR™, Electrostatic product which is highly effective in removing this contamination.

Step 3–Removing Water and Preventing Atmospheric Contamination

Water, Metals, and Oxygen are the primary factors that cause EHC fluid breakdown. Existing maintenance does not manage these variables, so at best maintenance can be considered reactionary in scope with fluid breakdown rates out of control. EPT's Phosphate ester and EHC fluid treatment program manages each of these variables actually transforming maintenance from reactionary to proactive. By managing these variables, EPT's program brings consistent, stable fluid quality that reduces the amount of acid created and therefore the amount of EHC fluid maintenance required. EPT's TMR-N2™ products are used to remove existing water and more importantly to prevent additional water and other atmospheric contamination from entering the system.

Step 4–EHC System Review and Fluid Monitoring

EHC systems are mechanical in nature and frequently have failing components. In addition, fluid maintenance and operating practices frequently increase EHC fluid stress and the rates of fluid breakdown. EPT and our trained partners will review these common issues and operating practices to promote optimal EHC fluid health. EPT's Fluid Testing Program is available at no-charge to all customers until results have been documented. Ongoing fluid testing packages are recommended to verify steady state EHC fluid condition is maintained.

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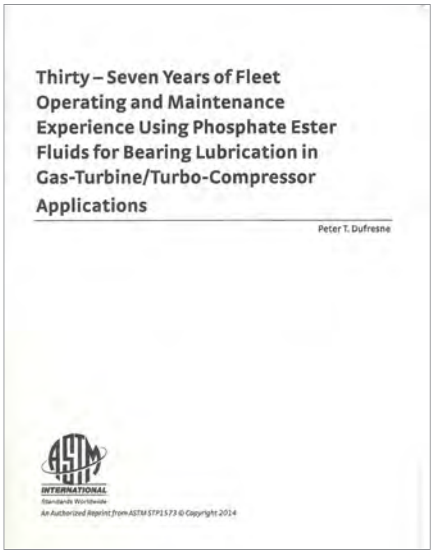

Thirty – Seven Years of Fleet Operating and Maintenance Experience Using Phosphate Ester Fluids for Bearing Lubrication in Gas-Turbine/Turbo-Compressor Applications

Peter T. Dufresne

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ASTM Article outlining cost saving in excess of US$90 million

South Eastern USA, more than $10 million in savings

Singapore, more than $6 million in savings

Return on Investment (ROI)

Because of the extremely high value of production in these applications, a single failure in a 10 year period would likely cost more than proper EHC fluid maintenance and testing over the same 10 year period. Our 20 years of experience suggests that failures are much more common than 1 every 10 years. In the 3 case studies below, cost savings greater than 1 million dollars per turbine have been achieved using EPT's program.

1. In an ASTM publication from April 2014, an economic analysis is provided for a fleet of 100 turbines operating over a 37 year period. It was reported that traditional lubricant and fluid maintenance was costing 5 million per year and mechanical failure costs from poor lubricant condition another 13 million per year. Optimized fluid maintenance, as provided by EPT, reduced maintenance costs by over 80% and reduced lubricant related mechanical failures to nil. Total fluid and maintenance cost savings totaled 97 million for the fleet or on average 1 million dollars per turbine. Total mechanical and failure cost reductions totaled 243 million or on average 2.4 million dollars per turbine. Ongoing ROI is >600% per year vs previous lubricant maintenance spending.

2. In 2004, one of the largest power stations in the South Eastern United States had to de-rate their 1300MW ST to 1000MW because of serious EHC mechanical issues associated with EHC fluid quality. Using EPT's program, which was installed on an on-line basis without replacing any mechanical components, EHC problems were eliminated and the output was increased to 1300MW within 30 days. With the cost per MW/hour averaging $50/MWh at an average capacity factor of 75%, the lost production and resulting cost savings were an estimated 11 million dollars per month.

3. In 2002, a large power station in Singapore prepared a comprehensive white paper on their EHC fluid maintenance costs using traditional lubricant and fluid maintenance, and the resulting cost savings using optimized maintenance provided by EPT. Total savings were estimated at 6.3 million dollars or 1 million per turbine.

Additional Resources and Information

EHC Fluid Resistivity White Paper

ICB™ Filter Element Upgrades

TMR™-N2 Total Moisture Removal

ECR™ For EHC Application

EHC Case Studies using ICB™, ECR™, TMR™-N2

Contact Information

For Assistance please contact sales@cleanoil.com

1.403.450.1760

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