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PHOSPHATE ESTER TECHNICAL NOTE
LOW RESISTIVITY

1. BACKGROUND

Resistivity is important because some early systems using phosphate ester fire resistant fluids (FRF) experienced problems with electrokinetic wear of the servo-valves. This wear was associated with both a high chlorine content and a low resistivity.

There are also other bench tests such as those for streaming or wall currents and there are tests on actual servo-valve spools. The latter are thought to be more applicable, however, such tests are not widely available.

It should be noted that not all investigators found a definite link with resistivity and it is not commonly measured on industrial hydraulics systems using phosphate ester fluid. However, resistivity can be measured relatively easily and in view of the consequences of a loss of the control function on steam turbines, a test parameter is required.

Related to fluid resistivity is chlorine because very small quantities, particularly as chloride ions, in phosphate esters can contribute to servo-valve erosion. Contamination can result from the use of chlorinated solvents for cleaning the system, from cleaning parts, or from chloride in the air where power stations are close to the sea. The use of such chlorinated solvents for the control system parts should be avoided at the station, at any external repair shops and by component suppliers. Some lubricants can also contain chlorine as additives. For example, chlorinated paraffins. Check with your suppliers before any products are used on the control system. If no data is available quick and inexpensive testing (<$45) for chorine should be readily available using such techniques as X-ray fluoroescence, micro coulometric techniques and neutron activation.

In addition, the resistivity of the fluid will tend to decrease with the following; high water levels, high acid numbers and high particle counts. Plus, it will decrease with rising temperatures. This is why the temperature of the fluid during testing must be known and taken in account.

As well as testing for the resistivity and chlorine content it is also prudent to do the other tests recommended by the turbine manufacturers. For example, in GE turbines to measure the motor amps to determine if it working too hard. One reason can be excessive servo-valve wear. It is also very important that when servo-valves are being replaced or over-hauled that the internals be inspected for deposits, particulate wear, and electrokinetic wear. This is necessary in case the replacement interval requires correcting.

2. TYPICAL VALUES

The following table gives the turbine manufacturers' recommended limits for resistivity and chlorine with in-service fluids. Those for new fluids can be different.

IN-SERVICE LIMITS		
	Resistivity (ohm cm)	**Chlorine (ppm)**
General Electric	$>5 \times 10^9$	100
Westinghouse	$>5 \times 10^9$	100
NEIP	$>5 \times 10^9$	<100/150

It has also been observed that the resistivity levels with 'synthetic' fluids or blends, can be lower than the turbine manufacturers' limits. This can be without causing problems but each situation should be reviewed specifically.

In addition, the fluids currently in use today usually have chlorine levels that are an order of magnitude lower than those that gave problems. For example, the chlorine content is now often between 15-25 ppm.

3. TEST METHODS

The test for resistivity requires a test cell, a voltage supply and a meter. It should also be possible to measure the temperature of the fluid so that the appropriate corrections can be made. The resistivity is usually reported at 20°C (68°F). Test methods can include IEC 247 or a modified ASTM D 1169. The test results can vary from lab to lab and if different people are doing the test, so it is important to try to compare like testing.

4. APPLICABILITY

Electrokinetic wear is of concern for control systems with servo-valves, especially those operating at higher pressures. While there are apparently no guidelines for the actual pressure, those in steam turbine control systems range from 1,000 psi (6.9 MPa) to 1,600 psi (11 MPa). In such systems routine monitoring is necessary and this is typically monthly or bimonthly testing for resistivity.

5. CORRECTIVE ACTION

This is not simple because the correct action depends on other parameters. These include the condition of the fluid and whether there are any indications of electrokinetic wear on the servo-valve spools.

Fluid resistivity is normally controlled by the off line or bypass purification system provided by the turbine supplier. These typically treat 5% of the fluid flow and contain fuller's earth in cartridges or as bulk material. Other purification media are reported to control acidity but apparently are not as good at keeping the resistivity high. Low resistivity is often the result of insufficient purification.

5.1 LOW RESISTIVITY, HIGH CHLORINE

This is of great concern and a full or part fluid change out might be required. The fluid supplier should be contacted for additional testing and the servo-valve maintenance history should be reviewed.

Parameters that indicate the servo-valve leakage flow or the null bias setting changes should be reviewed. It is also strongly suggested that a servo-valve be pulled and examined for excessive leakage and for electrokinetic wear. It may also be prudent to review the recent history of servo-valves changes or problems.

Prompt action is required because all the servo-valves spools can be damaged beyond repair in a few weeks. Internal leakage past the spools can also get to the point where it is not possible to maintain system pressure, even with all pumps operating.

In addition, the fluid should be tested to determine the nature and source of the chlorine. This is recommended for the following reasons; in case the chlorine can be removed, to determine the potential for electrokinetic wear and to change procedures so that the fluid is not as likely to be contaminated again. The following are possible sources; chlorinated solvents used to clean parts, storage fluids, pump run-in lubricants, greases, flush fluids, improper make-up, salt (NaCl or sodium chloride) or color indicating desiccants with cobalt chloride ($CoCl_2$).

5.2 LOW RESISTIVITY, LOW CHLORINE AND LOW ACID NUMBER

This can be less of concern but the servo-valve history should still be reviewed and the internal leakage of the servo-valves checked. If in doubt pull a servo-valve for examination.

Treatment with fuller's earth should restore the resistivity to specification. If the resistivity is not showing an upwards trend in a few days, check the operation of the purification system. For additional information, see the Technical Note on High Acid Number.

The fluid should also be tested to find the source of the chlorine. This is recommended to determine the potential for electrokinetic wear and to change procedures so that it

cannot happen again.

5.3 LOW RESISTIVITY, LOW CHLORINE AND HIGH ACID NUMBER

In this case the fuller's earth will not be as effective and the high acid number might have resulted in elevated levels of such metals as magnesium and calcium. These may cause other problems with foaming, high air release times or deposits.

Action could be a partial or complete drain. If the metal content is high, a flush with new fluid or used fluid in good condition may be required. In many cases the acid number can be brought down by treatment with ion exchange resin followed by other treatments to bring the resistivity back up.

As in all cases, the fluid should be tested to find the source of the chlorine. This is recommended to determine the potential for electrokinetic wear and to change procedures so that it cannot happen again.

5.4 LOW RESISTIVITY AND 'OTHER'

Again the correct action will depend on what is found. It can include the following;

High Particle Count: Determine reason for high counts. If a chronic problem do not assume that the filter housings or the filter elements are working as expected. Consider upgrading the filter elements. Off line purification and a flush may be required in severe cases.

High Water Content: Change purification media because it will be wet and therefore will not be effective. Remove excess water with suitable methods. This can include the purification media itself, fluid part drains, desiccant cartridges, mass transfer dehydrators or vacuum dehydrators.

Contamination: Hydraulic fluids and motor oils have many additives can affect the resistivity. These can be the result of make-up with the wrong fluids.

Unfortunately mineral oil is very difficult to remove and would normally require a part or full fluid change.

6. POSSIBLE ACTIONS

Assuming that the right fluid and purification media is being used, corrective action can include some or all of the following;

1. Change the purification media. If this is not effective do the following;

1.1 Dry a new change of the purification media per the suppliers' recommendations and look for a weight change. If 'significant' install the dry cartridges. If no weight loss or still no increase in resistivity do the following;

1.2 Check the purification housing(s) is not air bound by opening the air vent. If it have been in-service there should be very little is any air. If no air and no increase in resistivity do the following;

1.3 Check the flowrate through the purification media. Too high or too low can be problematic.

2. If no improvement and damage is suspected to be occurring do a part drain of enough fluid to get the resistivity back within specification. This can often be done on-line by draining a small quantity of fluid and adding new fluid.

3. To determine if servo-valve replacement should be scheduled, measure the pump motor amps and/or otherwise determine the servo-valve leakage rate. Checking the null bias can also sometime be helpful.

4. Also, examine a servo-valve recently taken out of service to determine if there has been electro-kinetic wear. The suppliers can normally provide this service as part of rebuilding. If not available pull a servo-valve.

5. Lastly, if the root cause of the problem was identified take action so that it not likely to be repeated.

6. SUMMARY

A sudden drop in fluid resistivity can be cause for concern and can lead to electrokinetic wear of the servo-valve spools. This can happen quite quickly. The cause of the drop should be identified as soon as possible and the correct action taken.

Additional testing and a review of site data are likely required. It is also usually appropriate to involve the fluid supplier. Using the 100% natural fluids with higher resistivities can also be beneficial.