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TECHNICAL NOTE

PLUGGED SCREENS/STICKING SERVO-VALVES

BACKGROUND: As a last chance measure to prevent mechanical binding of servo-valve spools the valve manufacturers usually provide metal mesh screens on the fluid supply. These are small but are quite robust to be able to take high differential pressures. They can also be expensive for their size but this reflects the construction. The screens are typically fairly coarse having a rating of only 90 microns and are generally intended to only stop relatively large particles. In comparison, the rating of filter elements on the pump discharge might be 2 microns.

CONSEQUENCES: In many cases the servo-valve screens should last between 12-18 months before they have to be replaced. This is done by changing the screen which in most cases can be done without removing the servo-valve or by exchanging the complete servo-valve. The valve can be new or rebuilt. Each turbine manufacturer should be consulted for their specific recommendations. Also note that if a screen is plugging, it is doing its job. The action should be taken to determine if the life is too short and if so, what action should be taken. The intention being to ensure that the function of the servo-valve is not compromised and that the steam valves will work as required.

Rapid blocking can arise for a variety of reasons including the following; material generated or ingested downstream of the pump discharge filters, build-up of particulates, overloading of the pump discharge filter elements, failure of pump discharge filter element, reusing filter elements or screens and/or fluid degradation byproducts.

1. MATERIAL GENERATED OR INGESTED DOWNSTREAM OF THE PUMP DISCHARGE FILTERS.

This could be the result of contamination through any piping or components that had been opened, weld repairs or hot spots on piping. The later can be a result of heat shields or lagging being removed and not replaced or the result of lagging hydraulic supply lines in with a steam line. The lines should be walked to determine if there are any hot spots and action taken to make corrections.

Material in the lines can also be deposited over a long period of time or left from previous work but was loosened by a trip or other repairs. This might reduce in time because it should be trapped by filters or screens and/or be deposited in the reservoir. However, if considerable amounts are present corrective action would likely require a real system flush. The servo-valves should be replaced with flushing blocks. It only takes a few seconds to contaminate a system for months so it is generally much better to take extra effort to keep particles out than to try to remove them later.

2. BUILD-UP OF PARTICULATES.

Most filter elements do not have an absolute rating but instead the performance is characterised by a parameter called the beta ratio. This is the ratio at a set size of the number of particles counted in the fluid before a filter to the number after the filter. Even so this ration can vary with the size of the particles, with the type of fluid, with the pressure drop and with pressure pulsations.

For a particular size rating a beta ratio of 75 is usually adequate. While good this does mean that many particles are still getting downstream which can be caught by the servo-valve screen or trapped in the very tight clearances between the spool and the valve body.

For example, the recommended maximum fluid cleanliness for some turbines in the 5-10 micron size range is 24,000 particles per 100 ml. Consequently, even with a beta ratio of 200 this means that 120 particles per 100 ml is in the fluid going to the valves. Assuming a servo-valve leakage flow of just 1 gpm this is 500,000,000,000 particles per year! While this might be the worst case and this size particle may not be the most damaging, it does indicate what can accumulate. It also assumes that the filter element is working correctly so the situation can be much worse.

3. OVERLOADING OF THE PUMP DISCHARGE FILTER ELEMENTS.

Situations can also arise because of system or reservoir maintenance, fluid additions or even just changing of the purification media that can mean a large number of particles are added to the system. While the pump discharge filter will try to handle as many as it can, because of the beta ratio, some will end up going to the servo-valves. This can be controlled by ensuring that the fluid is clean after any maintenance and before the main pumps are started, that only 2 micron filtered fluid is added as make-up and that the trap filters (back-up filter) after the purification media, such as the fuller's earth, are good enough.

The trap filter can be of particular concern if the filter element media is the type in which the beta ratio (efficiency) gets better with time. The reason being that the maximum number of fines can be expected when new fuller's earth is first valved in and that is when you need the best beta ratio. Not the worse. Options might be to leave the old filter element in for a week or so after the purification media is changed, to run the fuller's earth system in a recirculation mode to 'cake' the trap filter, or to use a better trap filter.

4. FAILURE OF PUMP DISCHARGE FILTER ELEMENT.

Filter elements are manufactured constructions of various materials. While generally very good, there can be variations. It is for this reason that 100% bubble point testing is recommended.

In addition, many filter element suppliers have been making changes to the media and to the design so that these have to be considered. For some turbines the performance can be monitored by observing the differential pressure across the filte to ensure that it is not too low, too high or rising too fast.

Too low a pressure drop is of concern because it can mean that the fluid is not being filtered. The reason can be because of the filter element itself, missing housing internals or improper replacement of the filter element. The result can be very rapid plugging of servo-valve screens. Unfortunately, many systems do not have differential pressure gauges but these can usually be fitted to the housings or to supply lines. Fluid samples for particle counts can also often be taken upstream and downstream of the filter elements to determine if the filter is working. In addition, when the servo-valve screens are changed they should be examined for material such as fibres. These can be from the filter elements and/or from rags and wipes.

5. REUSING FILTER ELEMENTS AND/OR SCREENS

While quality filter elements are expensive, in most cases it is considered a false economy to leave them in too long or to try to reuse them. First, with some media the beta ratio is the best when they are new. This is then when they are most efficient. Consequently, leaving them in too long can mean that more fines are getting to the servo-valves and it also can increase the chance of mechanical failures from fatigue or dumping a load of particle downstream when the pump is cavitating or had been started with cold fluid. In addition, the depth type media used in most of the better filter elements can not be cleaned effectively and in any cases the solvents used can compromise the materials.

This can also true for the metal screens on the servo-valves but for different reasons. This is because cleaning even in a range of solvents and using ultrasonics is reportedly not 100% effective. As a result, the life will be degrading each time. Also there is danger of mechanical damage to the screens or exceeding the fatigue life when they are reused repeatedly.

Using substitute screens in the servo-valves can also be a danger and risk of a valve failure or even one early plugging is thought to far exceed any perceived savings. In addition, because Parker Aerospace state that they do not authorize any independent repair shops for Abex servo-valves nor do they sell shops screens, what is really being done and used should be closely examined.

6. FLUID DEGRADATION BYPRODUCTS.

As well as solid material that can plug the open areas in screens, there are also situations where fluid byproducts such as gels or soaps can be a problem.

For example, in normal use the fluid will be stressed and this is controlled by purification. However, if the temperature has been excessive, the water content too high for too long or the acid number too high at any time, it can mean that the fluid has degraded. This can lead to the formation of higher molecular weight fluid byproducts or to the reaction of fluid byproducts with metals from the purification media. These can then form gums, gels, soaps, black scum and the like.

The solubility of these in the fluid can be temperature dependent so that they can get through the pump discharge filter to form on downstream surfaces or screens. This material may also come out when a unit is shutdown or when the acid number drops.

Further, there can possible be reactions of the fluid degradation byproducts with material previously trapped on the servo-valve screens.

ANALYSIS

If the life of the screens is too short, one of the first steps should be to identify the material on the screens. Parallel work can be undertaken to test the fluid and to check all the filter elements. Care is required that the appropriate tests are performed so that erroneous conclusions are not reached. A variety of testing is often required.

Generally there is too little material for extensive testing but the following are suggested;

> Optical examination of servo-valve screen before cleaning. Typically 40x is sufficient and photos can be very useful.
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> Testing both the fluid and deposits by FTIR (Fourier transform infrared) analysis and in particular look for oxidation and nitration. FTIR on the deposit might require a special microprobe version.
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> Consider also trying to remove the deposit material in a controlled manner and examining after each step. First use hot water to get lower molecular weight materials as might be caused by hydrolysis. It can also remove some water soluble sodium compounds. Then alcohol to remove phenols, heptane to remove hydrocarbons and lastly, toluene or acetone to get any remaining phosphate ester material. Confirm with optical examination that the majority of the material debris has been removed.
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> Filter the fluid and/or the material removed with the above solvents using a patch of 0.8_ or better and both phosphate ester and solvent compatible. Optically examine the debris. Analyse each solvent by ICP for metals. Consider analysing the material on the patches by acid digestion and ashing followed by ICP or X-ray fluorescence. EDAX in an SEM can be useful to determine the elemental composition of particles but any volatile organic phase might be lost. If sufficient material is present, molecular weight determination by LC/MS (liquid chromatography/mass spectroscopy) can be very valuable to determine the source of any metal soaps or gels.

In addition, to get a handle on the past fluid maintenance consider;

> Full fluid analysis and trace metals by ICP.
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> Examination of historical fluid test data.
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> Determination of pump discharge filter changes, differential pressures and actual beta ratios by upstream and downstream sampling.
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> Confirmation of the filter elements being used.

It is important to keep in mind that the reason the analysis is being done is to identify the reason for the blockage so that there are no further unplanned shutdowns or deratings. This normally requires being able to achieve the turbine manufacturers recommended change out intervals. For example, with servo-valves on some General Electric systems the screens were to be inspected annually. Achieving longer lives will require exceeding the fluid specification requirements.