Flushing lube oil systems

A CORRECT PROCEDURE AND CAPABLE VENDOR CAN PREVENT TURBINE FAILURE

Greg Livingstone
Kevin Sapp

Recently, the lube oil of four GE Frame 7 FA gas turbines with severe system contamination was changed after flushing. Just before fluid change out and while using the equipment's on-board system pumps, the contractor who performed the flushing added a popular detergent-based system cleaner to the existing system fluid, and then circulated it through the main lube oil system and partially through the associated sub-systems, such as hydraulics and lift oil.

Apparently, there was not enough time to thoroughly rinse and drain the cleaner from the system. It was assumed that the cleaner was compatible with the lube oil.

Approximately two weeks after the plant's re-start, oil analysis showed calcium levels of up to 175 ppm, while turbine oil should have not have any calcium. Additional testing revealed that approximately 60% of the remaining useful life of the newly supplied lubricant had been depleted in just one month.

The antioxidant additive package of the new fluid had been compromised in all four systems as the result of incompatibility. Water separability properties of the lube oil were also devastated.

The total damage exceeded $500,000. Exasperating the plant was the fact that the flush was going to have to be immediately repeated by another contractor during an unplanned outage, which would significantly impact the plant's availability and ultimately its bottom line. This article examines effective strategies (Figure 3) for dealing with contaminated fluid systems and how to avoid the pitfalls such as the example cited above.

Flushing procedure

During the service-life of a piece of equipment, there are a whole host of contaminants that can build up (Figures 1,2) and require a flush to clean internal surfaces and restore system performance. Solids, moisture, sludge, varnish, foreign liquids and gases are all contaminants that impact system reliability and are addressed during decontamination. These contaminants are either introduced externally or produced within.

Figures 1, 2: A contaminated lube oil reservoir (left) and system pipeline (right)

Correct procedures dictate that a thorough visual inspection, collection of removed debris and detailed fluid analysis be conducted immediately before, during and after the decontamination process. API 614 and ISO 4406 documentation should be conducted on-site and in real-time to determine the ending point of a flush. It is this collection of data that can be extrapolated into a real, demonstrated value.

A successful system decontamination depends on the ability to remove contamination quickly and effectively, while at the same time preventing recontamination from outside sources. Because plant uptime is so important, a successful project is defined as restoring a contaminated system to a contamination-free level in a minimal amount of time.

An effective way to mitigate sludge, varnish and other insoluble system deposits is through chemical cleaning. The chemical cleaning process involves the application of specifically designed chemistries for the dissolution of accumulated build-up and other insoluble contaminant deposits. The chemicals applied during the process are specifically chosen or formulated with the type of contamination to be removed in mind. Once these chemicals are circulated throughout the system and come into contact with the contamination residue, the build-up is dissolved and flushed out of the system.

Because sludge and varnish can act like fly paper by grabbing hold of and retaining solid particles that may have been circulated through the system over time, large amounts of trapped debris could be released during the chemical cleaning process. For this reason, chemical cleaning should always be followed with a high-velocity flush.

Figure 3: During decontamination of a lube oil system, multiple jumpers and flushing loops are required to isolate every part of the system

True chemical cleaning processes involve the complete drain down and removal of the existing system fluid prior to installing the chemistry and beginning circulation. Frequently, the system fluid in question can be purified and refortified which avoids unnecessary disposal and replacement. The use of water-based chemical formulas is preferable due to their ability to be completely drained and washed from the system upon completion of the chemical cleaning process. Because water is inexpensive and easy to obtain, there is no real chance that a complete rinse of the system cannot be achieved. Additionally, any residual moisture contamination will be in the form of pure water and is easily removed through vacuum distillation, which will be conducted simultaneously with the ensuing high-velocity flush. The end result will always be a clean, dry fluid system.

With the susceptibility of and sensitivity to cross contamination in today's turbine lubricants, aftermarket additives

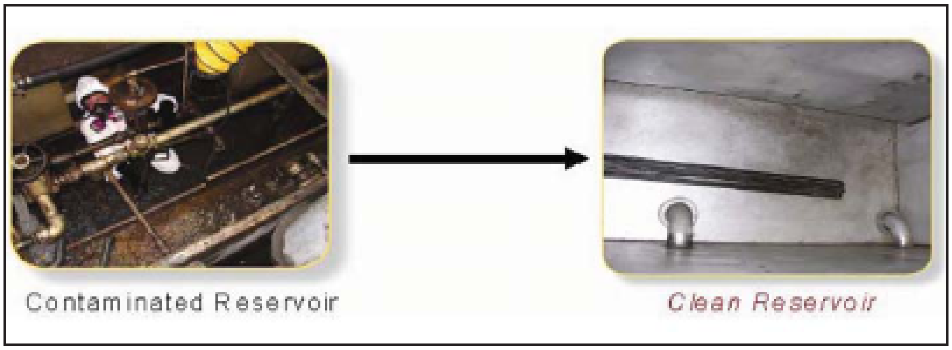

Figure 4: Results of a reservoir decontamination

and cleaning products that can be applied as system cleaners to existing fluids should never be used. All too frequently these additives are used while the equipment is operational and result in large amounts of previously adhered contamination being released in a short timeframe, causing significant damage to critical components. This release of contamination will cause abrasive wear in lubricated components, rapid plugging of filters and fluid passages as well as the obvious damage to the fluid itself as the result of incompatibility.

Most fluid and lubricant manufacturers strongly object to the addition of "additive-based" system cleaners because of their probable interference with the original fluid. In lubricants, such additives will frequently deplete a lubricant's antioxidant capabilities as well as interfere with its demulsibility properties. Even when such a process calls for a post-flush of the cleaning solution from the system by using sacrificial flush oil, the results are typically not effective. This is because displacement-type flushes produce poor results due to the intermingling of the different products during contact and circulation.

The most effective way to remove cleaning chemicals and incompatible fluids is through a series of drains, fills and rinses. This process may take up to 10 cycles before the system is free of contamination and cleaning chemistries, but then it will be safe for the installation of the system's new or purified operating fluid without worry of fluid destruction.

Frequently, system components that are not protected by some form of inert purge or rust preventative will begin to experience corrosion. This corrosion effect will produce system contamination as the oxidation particles flake off in operation and then cause damaging wear to equipment internals. Prior to a high-velocity flush, a chemical chelation process will dissolve all corrosion and leave the metal surfaces clean and passivated, thereby protecting the surface from future corrosion. A similar chemical cleaning process can also be effective in eradicating other tightly adhered solid contamination such as mill and water scale.

If the equipment in question is to be placed into long-term storage or will experience a significant amount of downtime between the commissioning flush and actual operation, corrosion of unwetted surfaces can be minimized by the use of vapor-space-inhibiting oils. Care must always be taken to consult the lubricant manufacturer in choosing a compatible product for this purpose to avoid cross contamination.

Reservoir decontamination (Figure 4) before and after any chemical cleaning or flushing process is key in maximizing the effectiveness of the decontamination and protecting against possible cross contamination of fluids. This is because the reservoir is the "dumpster" of the system. This is an area where, because of low flow velocities, solids and loosened insolubles will flow downstream and settle out. It is difficult, if not impossible, to flush this amount of material out of a large, stagnate area, so an entry into the reservoir, complete with a manual cleaning and wipe down, is the most effective way to remove the contamination.

Effective cleaning

An important component of a comprehensive system decontamination is the high-velocity flush. Typically the velocity is at least two to three times normal system flows. Because flow rates are important and published pump curves in this application are unreliable (rarely found to lie on the curve because of extreme system conditions), the most accurate way to measure flow rates is through the use of an inline flow meter.

Once flow can be accurately determined, fluid turbulence is best measured using Reynolds numbers. The Reynolds number (Re) is the measure of turbulence based on surface roughness of the pipe, internal pipe diameter, flow rates and fluid viscosity, which can be highly dependent on temperature. A Re value of less-than-or-equal-to 4,000 represents laminar flow, whereas a Re value of greater-than-or-equal-to 4000 represents turbulent flow — the minimum flow condition required for effective flushing. While a Re of 4,000 is a good minimum establishment, Re values of 25,000+ are far more effective at totally removing contamination and shortening the duration of the flush by a factor of several fold.

To achieve an effective level of contamination removal, turbulent flow should be achieved in all system fluid conduits. Contamination frequently builds up more prevalently in low velocity areas, so special attention needs to be focused on return lines, heat exchangers, filter housings, expansion and run down tanks, and so forth. All of these are areas that will hold significant amounts of contamination but are often ignored during the typical flush. The use of outside pumps is always recommended to achieve desired flow rates.

Elevating fluid temperatures through the use of inline heaters, using pipe vibrators, and relying on full-flow filtration all contribute to the success of a flush. Hammering and vibrating system

WHAT A FLUSHING SERVICE PROVIDER SHOULD OFFER

- Turnkey service - minimal support required
- Fast, on-time completion
- Exceed OEM - industry requirements
- Real-time analysis and reporting
- 24/7 management by trained and certified technicians
- Extensive personnel and equipment resources
- Auxiliary "Jumper" hoses and piping provided
- Pipe fitting included - turnkey
- High-velocity flow - Reynolds Numbers >25,000
- Full-flow sub-micron filtration
- Minimal project footprint
- Procedure-based operations
- Chemical cleaning capabilities
- Real-time, laser particle counting
- Purpose-built, stainless steel process units
- Supplemental vacuum dehydration as required
- Confined-space reservoir decontamination
- Self-powered as necessary - no electrical support required
- Emergency response - 24/7

piping will hasten the loosening of solids in the system and also speed up the timeframe of the flush. Using a special flushing fluid with a low viscosity and low aniline point — a measure of the amount and type of aromatic hydrocarbons — and applying outside heating will further speed up the flushing process by increasing turbulence and solvency capabilities.

Since most plant maintenance teams do not have the time, budget or inclination to become system cleaning experts, the most important factor in executing a successful system decontamination and flush is to select the correct service provider. Care should be taken to select a provider who can deliver in the following areas (Box in p. 41).

Choosing the provider

The service provider should have a satisfactory safety record and possess a reasonable amount of insurance coverage. The use of purpose-built equipment rather than obsolete or rented equipment is always preferable. Process equipment should be equipped with safety factors and fail safes in order to guard against the unforeseen. Spill containment and stainless steel, flanged hoses and other highly safe equipment should be the norm.

The service provider should also be able to provide the equipment owner with a list of references from other similar companies who have recently commissioned the contractor company to provide similar services. The contractor should have the necessary equipment assets and employee manpower to execute the project in a turn-key fashion so the equipment owner is free to address other plant issues during the outage. When possible, the service provider should develop a working relationship with the fluid supplier to further guard against off-specification fluid installation upon delivery.

The contactor company should provide trained, experienced and certified personnel to execute the project. Both the company and its employees should have an intimate understanding of what is expected and what results are desired during the service. There should also be an open line of communication between the equipment owner and the contractor's personnel.

The service provider should provide the equipment owner with a thorough proposal that outlines the entire scope of the project, provides Material Safety Data Sheets and describes the processes to be performed. The proposal for services should also clearly state the charges for the service and address project warranty guidelines. The equipment owner should be able to jointly monitor the progress of the project, along with the service provider, by directly contacting field service personnel and reviewing real-time data. After the project is completed, the service provider should provide the equipment owner with a detailed summary of services provided, fluid analysis, and a complete technical summary report (see online edition for a typical high velocity flushing report).

Authors

Greg Livingstone is the director of fluid technology at EPT, Inc (www.cleanoil.com). He is currently chair of ASTM's Committee for Turbine Oil Analysis and Problem Solving and has published over 20 papers.

Kevin Sapp has been involved in the lubrication and reliability engineering field for the last nine years. He currently heads IAS, a company focused on delivering improved equipment reliability and uptime through turn-key, engineered services.