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YOUR FRIENDLY PARTNER IN SYSTEM FLUSHING, OIL FILTRATION AND TESTING WITH LASER PARTICLE COUNTER & OFF LINE FILTRATION SYSTEM.

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Cleaning and Flushing Basics for Hydraulic Systems and Similar Machines

Over the past several years, extensive resources have been used to improve flushing techniques for hydraulic and lubrication systems. This has led to a large body of knowledge on flushing evidenced by the many articles, international standards and procedures on the subject. Despite the efforts, there is probably no area relating to hydraulic and lube oil systems with a wider deviation between theory and practice.

Because there are a number of well-written papers addressing flushing technology, methodical practices and specific practical procedures are discussed here. The experiences of Mator AS, a Norwegian offshore company, are extensive in this area and are based on work with oil and gas drilling and production platforms in the North Sea, larger land-based production facilities as well as small hydraulic and lube oil systems.

Figure 1. These samples were taken from a hydraulic system operating in the North Sea. The system had a history of component failures. The top sample was from the reservoir after 15 years of service, before proper cleaning. The bottom sample was after cleaning. The cleaning was performed with the system pressurized and in full service. After the flushing, the system experienced no failures in two years.

When to Flush a System : A newly fabricated system or one that is in-service requires different approaches for when and how to perform flushing. This is because of different procedural methods deployed, but more so because of practical limitations and overall requirements of individual machines. It is important to consider that flushing can become time-consuming, and it may be difficult to predict the time needed to do so. Often, due to system design constraints, as little as one-third of the total time is spent on the flushing activity itself. Two-thirds of the time is used to mobilize flushing equipment and workers, disassemble sensitive components, assemble by-pass lines, connect flushing hoses, preclean the flushing fluid, fill up the system and heat the flushing fluid and piping. Well-planned and well-performed flushing practices give considerable return on investment.

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The Fabrication Stage : Because flushing is designed as a part of the lifelong maintenance program, preparations for such should be included in the design phase. This seldom occurs, for it is not common to design special flushing connection ports, top and bottom air-bleed ports, premounted by-pass loops, etc. in the system. In addition, sufficient requirements for subcontractors regarding procedures and documentation for flushing subsystems are needed. This is why the final flushing of complex systems often becomes a challenge for management because of increasing costs and delayed completion and recommissioning. Shortcuts often become an easy and sometimes preferred choice. Although such shortcuts can postpone problems, they don't always solve them.

To transition past flushing practices to best practice, follow these steps:

1. Prepare a thorough flushing procedure. Include it in all suppliers' bids and contracts. Reexamine if flushing guidelines from API, ASTM, ISO, etc. can support your own requirements (these standards are guidelines only). It is important to specify any templates required for documentation in order to support the results from fluid analysis. Traceability is as important as liability insurance. Request the equipment supplier to perform the flushing as specified and to obtain permission to deviate from the specifications.
2. Make flushing documents for equipment an important part of acceptance checks in your quality assurance program. Report compliance to the overall program plan.
3. Develop a plan for how to systematically control hook-up of subsystems into the main system. The important issue is to prevent spreading infections between systems. Document results as part of the total flushing procedure.
4. Describe standards for flushing connectors (dimensions, placement, etc.) as a part of the design handbook for the engineering contractor.
5. Specify sampling points to be used for condition monitoring - during flushing and in-service.
6. Authorize a technical specialist to manage and approve the performance and documentation of flushing procedures. The specialist should also handle cases of procedure deviation from suppliers. The authorization should be independent of discipline with respect to technical and commercial departments (piping, instrumentation, purchasing, etc).

It is important to include verification routines each time a subsystem is connected to the main system. Providing for these specific recommendations in the overall plan builds confidence and eliminates costly rework at the end of the project.

Flushing Strategies for Systems In-service :

1. Cleaning after breakdown, repair or time-based maintenance (inspections, etc.).

a. In a properly designed system, contaminants from pumps or motor failures are restricted to a certain part of the system by in-line filters. In these cases, flush the reservoir, piping and components within the contaminated area.

b. In most cases, contaminants from breakdowns are spread throughout the system. Although some contaminants may be removed by an in-line return filter (with by-pass) and some settle in the reservoir, the whole system must be flushed.

c. Considering time-based maintenance, it is important to plan the work to minimize the amount of external contamination that enters the system. Use proper coverings as soon as possible until the system is assembled and sealed. For replacing complete components (such as bearings or pumps), it is possible that the system can operate without extensive flushing. It is important that the work be performed by trained technicians. It is also important that the system run without a full load (unpressurized) until the contamination level is confirmed to be within acceptable limits.

2. Flushing after modifications and/or updates. Handle this the same way as for newly fabricated systems.
3. Proactive flushing.
Older system designs collect contaminants in the reservoir. Low fluid velocity allows contaminants to settle in piping as well. Lack of sufficient filtration intensifies the accumulation effect. These layers of contaminants will occasionally rip off and could result in breakdown and/or failure.
In some cases, it is more cost-efficient to perform periodic cleaning (such as a proactive flushing) instead of a costly upgrade or a complete modification of the system. Note that it is often possible to perform a flush while system is in operation.

General Cleaning and Flushing Requirements.

To Achieve and Retain Satisfactory Initial Cleanliness Level

1. Chemically clean and treat internal system surfaces (components, tubes and hoses).
2. Perform hot oil flushing to reach target cleanliness level.
3. Inspect and verify that the cleanliness level was achieved.
4. Follow the proper steps when disassembling the flushing loops to prevent contaminants from penetrating the cleaned system. Seal off all components with plugs, blind flanges, etc.
5. Perform routine maintenance to stabilize contaminant levels to within control targets.

Strategy for Maintaining Cleanliness After Flushing :

1. Prevent new contaminants from entering.
2. Select suitable system filters. New oil should be filled through a system filter or another suitable filter.
3. All new components and/or modules to be connected to the system must meet the preceding requirements. Perform new cleaning and hot oil flushing after component changes, assembly, disassembly or similar procedures have occurred.

Flushing Strategy Tips

1. Connect circuits in series.
2. Components that can be damaged by high fluid velocity or by fluids containing moisture, particles or flushing chemicals should be isolated from the flushing circuit and cleaned individually.
3. Components that restrict the flow rate, and thereby increase the pressure drop, should be isolated from the flushing circuit and cleaned individually.
4. Manifolds, blocks, pump stations, motors, reservoirs, assemblies and components should be delivered clean according to a specific procedure. If not clean, they must be flushed separately. This also applies where space does not allow flushing of installed piping system.

Component Cleanliness Level : Some components and assemblies are often connected to the main system after flushing. Their level of cleanliness must be at least as good as the desired cleanliness of the main system. The supplier should provide a cleanliness certificate with the components. The system assembler must clean these components according to specified procedures if cleanliness certificates are not available from the supplier. Cleanliness certificates should not be considered valid if the cleaning has not been performed to these requirements.
NOTE: If components contain anticorrosion agents not compatible with the system fluid, flush the components using system oil with 5 to 10 percent degreasing agents added to the flushing fluid. The degreasing agent should be selected to ensure no harm to component seals.

System Cleaning Preparation

Mechanical Tube Cleaning : Precision steel tubes - cut, graded and free from scale and corrosion - should be subjected only to chemical cleaning and hot oil flushing. Welded tubes should be mechanically cleaned inside by a plastic pig. A pig, also referred to as a go-devil or rabbit, is a plug with brushes, scrapers and rollers on its periphery. It moves under the oil pressure through a pipeline and cleans it. This ensures the tubes and tube flanges are smooth and free from slag, welding beads (spatter) and foreign particles.

All tubes and hoses should be inspected and blown with highly filtered industrial compressed air. This removes most of the larger particles made by the cutting of tubes and hoses as well as the mounting of fittings.

Components Dismantled Prior to Flushing : To ensure proper cleaning is achieved in all parts of the system and to avoid damage to sensitive components, certain parts should be by-passed or dismantled during cleaning. Each component or subsystem should be cleaned to the required cleanliness level as a part of a flushing circuit or in separate circuits. Partitioning of the overall system is typically needed to achieve this.

To clean the pipe system, disconnect all components and subsystems that restrict the flow and those components that can be damaged during cleaning and flushing.

Chemical Cleaning and Hot Oil Flushing : Each circuit should be connected to achieve the specified fluid velocity and Reynolds number, as well as the fluid pressure in all components, lines and fittings. Avoid flushing configurations that can lead to settling of particles in quiescent zones, dead legs, etc. The pressure and flow capacity of the cleaning/flushing rig must also be considered.

Chemical Cleaning : Chemical cleaning, according to the DEWA DPI System, consists of a specially developed group of chemicals that can be used in series in the same pickling reservoir. DEWA is Greek for “green and vigorous.” DPI stands for degreasing, pickling and inhibiting. Developed by the Norwegian company DPI Chemical Industries AS, this patented system is used in the United Kingdom and other countries. All the chemicals are water-soluble, environmentally friendly and inorganic.

The cleaning sequence is divided into five phases:

Phase I - Alkaline Degreasing and Pickling : Fill the reservoir with pure water. Heat it to 122°F (50°C), up to a maximum of 176°F (80°C). Add Chemical A until it reaches pH 14. By circulating maximum flow rate for 30 minutes, any grease and oil film should have been removed. Control pH and temperature during processing.
Phase II – Pickling : Reduce the fluid pH to 5.5 by adding chemical B. Then add Chemical C until 10 percent (volume) is reached. Circulate maximum flow rate for 60 minutes. Control pH and temperature during processing.
Phase III – Neutralizing : Continue to circulate the fluid as you add Chemical D until reaching pH 7.5. Keep the temperature as in Phase I. Circulate maximum flow rate for 30 minutes. Control pH and temperature.
Phase IV - Preservation (corrosive steel) : A corrosion inhibitor is not required if the time between chemical cleaning and hot oil flushing is less than 24 hours. If this condition is not fulfilled, add 2 to 4 percent (volume) of Chemical E. Continue circulation for 30 minutes without heating. The fluid is thinned out with 4 to 5 percent water before it drains into the standard sewers. Control pH before draining.
Phase V – Drying : Dry the tubes with warm, dry air within 30 minutes after neutralization. Use high quality filtered and oil/water separated compressed air or cleaned nitrogen. The easiest way to control achieved dryness is to check moisture content during the following hot oil flushing.
Minimum Process Equipment Required
The pickling unit requires a reservoir, pump, filter and heating facility. It is preferred to have a fluid velocity of 3 m/sec. (106 ft./sec.). The filter should be selected according to the same requirements as for the hot oil flushing rig.

A supply of dry, clean and warm air or nitrogen is needed. It is important that the air is absolutely free of any oil content.

Special flanges, manifolds and connectors may be needed to assemble the components to be cleaned in series.

Process Control : To verify proper chemical cleaning, the following measurements must be documented during the process:

1. pH analyses
2. Temperature
3. Volume of chemicals in each phase
4. Flow rate
5. Hot Oil Flushing

Generally speaking, the required cleanliness level to target during flushing is half the level during normal operation. For example, if the normal operation level is ISO 15/13/11, flush to an ISO14/12/10. Requirements for cleanliness levels of both solid particles and moisture should be achieved.

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Flushing Fluids : The flushing fluid should be compatible with the fluid used during normal system operation as specified by the client. The viscosity of the fluid at different temperature levels should be specified. As a guideline, standard flushing units normally provide sufficient turbulent flow if the viscosity is in the 10 to 15 cSt range at 104°F (40°C). Ideally, the flushing fluid should obtain that viscosity at no higher than 158°F (70°C).

Turbulent Flow, Fluid Velocity, Temperature and Pressure : With a Reynolds number equal to or greater than 4,000, the fluid is certain to have turbulent flow. This is required to remove particles from the surface inside tubes. To also prevent remaining contaminants from becoming suspended during operation, it is required that: Re-flushing number is equal or greater than 1.2 x Re-in service, but always a minimum of 4,000.

Example: a hydraulic system has a flow rate and tube diameter to achieve Re=3,400 in normal service. Flushing requires a minimum of Re=4,080.

The fluid velocity (V) should not be less than 2 to 3 m/sec. (106 ft./sec.) in any part of the flushing loop. This prevents settling of particles inside tubes and hoses.

The coldest part in the flushing loop should have a minimum temperature of 122°F (50°C). This can be achieved by using a minimum flushing fluid supply of 140°F (60°C). In certain cases, this can be achieved only by insulating certain parts of the loop.

The pressure should be held to a minimum 3 to 5 bar (22 to 73 psi), measured downstream from the flushing circuit, before the return line filter and sampling port. Cleaning of ball, plug, butterfly and needle valves is an important part of the hot flush process. To ensure cleanliness has been reached in all zones, the hydraulic valves should be actuated to full-stroke movement during each step of the cleaning process.
Flushing Reservoirs, Filter Housings, Cylinders, Accumulators, Pumps and Motors
Each of these components should be cleaned in separate loops.

1. **Reservoirs -** This is one of the most difficult components of a system to flush. The system reservoir should be cleaned manually then filled with flushing fluid. Use a flushing pump with an in-line filter to circulate and flush the reservoir.
2. **Filter housings -** These units can be connected to the flushing loop or cleaned separately as in the case of the reservoir.

Cylinders, accumulators, motors and pumps - Clean these separately. The components that have bidirectional movement must be actuated to full movement (stroke) to achieve volume flow of at least 10 times their internal volume.

Minimum Flushing Time : Once samples from the system indicate the specified cleanliness level has been reached, continue flushing for at least 30 more minutes at turbulent flow. This increases the probability of removing adherent particles from tube walls.

Verify Flushing Results : Each flushing loop should be unique and traceable. Create individual drawings or use suitable piping and instrumentation diagrams (P&IDs). Mark position of sampling points for temperature, flow and oil samples.

Document all parameters such as startup time, temperature, flow, particle contamination level and moisture and finish time. It is recommended that a uniform and consistent method of documentation be used.

Third-party verification may be needed to confirm the cleanliness level of the final flushing loop and the complete system.

Flushing Skid : A flushing procedure should be adapted to the conditions of the flushing rig. To obtain sufficient results, the following criteria must be met:

1. The filter system should have sufficient capacity and performance to remove both solid particles and moisture to the required level, within a reasonable time.
2. The original filters in the system to be flushed should not be used as flushing filters. The flushing filter is important for two essential reasons: 1) it determines the final cleanliness level, and 2) it determines the rate at which this level can be reached.
3. A common practice seen lately is to over-specify the filters. A filter with B3>200 with a pressure differential indicator is suitable as long as the dirt-holding capacity is sufficient. Also, it is important for the indicator to provide a warning long before actual fluid by-pass.
4. There are several options for moisture removal. These include water-absorbing filter elements, coalescing filters, oil purifiers (such as vacuum distillation), and simply replacing the oil.
5. In normal conditions, a water-absorbing filter should be sufficient, assuming the moisture levels are low. Certain synthetic fluids must be dehydrated with oil purifiers.
   NOTE: Flushing filters to remove solid particles should not be replaced by the water-removing filters. The pump unit should deliver flushing fluid with flow, velocity, viscosity and pressure ratings sufficient to clean the internal surfaces in the system. It should also transport the contaminants out of the system and into the downstream flushing filter.
6. The fluid temperature should be monitored and controlled to verify that the oil viscosity provides sufficient turbulent flow in all parts of the flushing loop and at values within the specification for the actual flushing pumps.

Although system flushing can be a time-consuming and expensive process, it is often required, especially at the completion of construction and after a catastrophic component failure during service. Additionally, flushing should be performed as part of a periodic proactive maintenance activity for systems in service. Both the duration and cost of the flushing can be reduced if the system is designed for flushing by the equipment builder. Seek to optimize the flushing procedure for all subsystems and components. But first, systemize and manage the flushing as a complete process for all lines and components throughout the entire system. This will provide reliable service that performs according to design specifications.

Compiled by Mr. V.S.Dave
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