Reducing Commissioning and Downtime Through Advanced Flushing and Lubrication System Cleaning

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Contribution to Reliability/Availability. Turbines

For any power generation facility, the turbine is considered the lifeblood of the operation. Any problem requiring an unexpected shutdown of the main turbine is likely to cause a significant unplanned outage, potentially resulting in millions of dollars of downtime costs. According to a 1991 study by General Electric (GE), turbines contribute on average 20 percent of all forced outages in a conventional power plant. Among this 20 percent, GE noted that 19 percent of turbine/generator problems were associated with the lube oil system. For this reason, monitoring turbine oils has become commonplace in the power generation industry.

Table D.2 — Typical dynamic film thickness for equipment

Component		Thickness µm
Roller bearings		0,4 to 1
Ball bearings		0,1 to 0,7
Journal bearings		0,5 to 25
Gears		0,1 to 1
Seals		0,05 to 0,5
Servo valves:	— orifice	130 to 450
	— flapper to wall	18 to 63
	— spool to sleeve	1 to 4
Hydraulic actuators		25 to 250

2µ - Bacteria 40µ - Human lower limit of visibility

159µ - 100 Mesh screen opening

Contribution to Reliability/Availability. Turbines

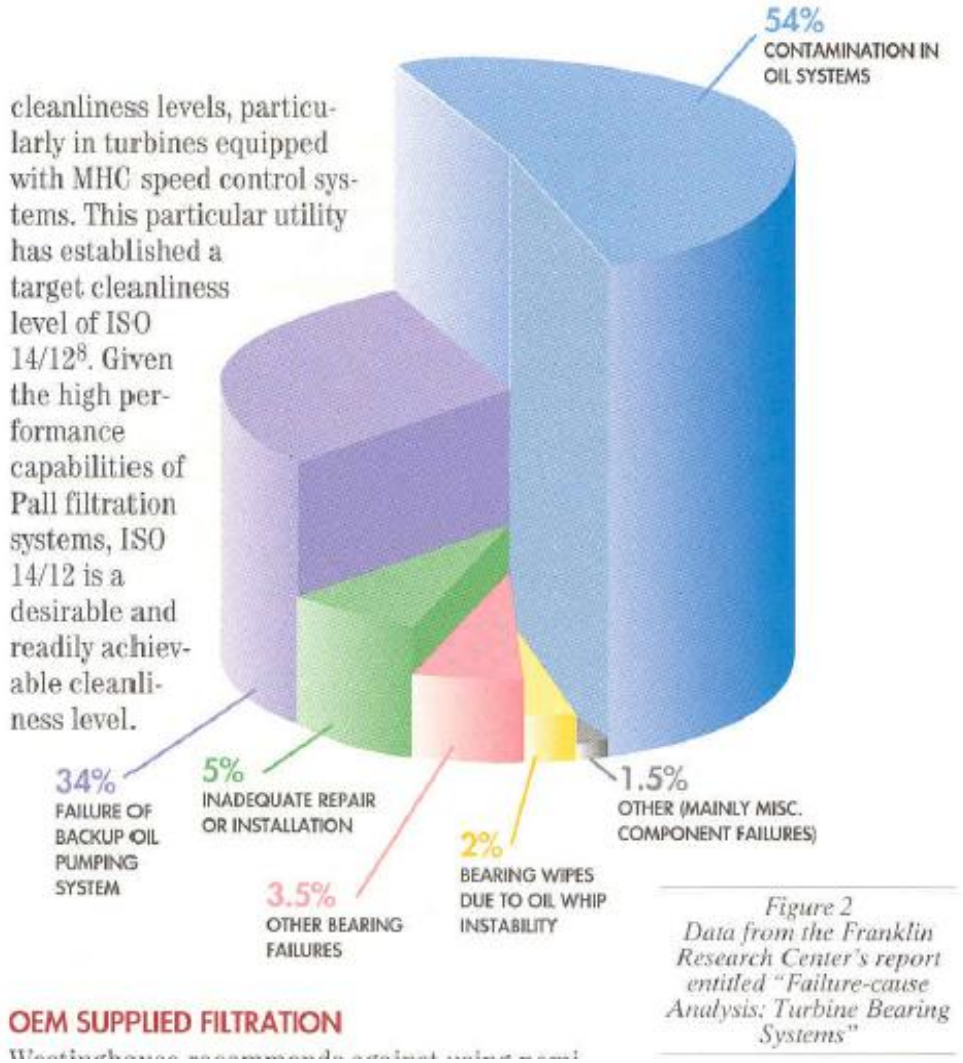


Figure 2
Data from the Franklin Research Center's report entitled "Failure-cause Analysis: Turbine Bearing Systems"

Bearing failures cost 200 MUSD/year in USA.

54% of bearing failures are related to contamination in lube oil systems.

High Velocity Oil Flushing

ASTM D-4378

5.1.2 *Condition of System on Start-up:*

5.1.2.1 The individual components of a lubrication system are usually delivered on-site before the system is installed. The length of on-site storage and means taken to preserve the integrity of the intended oil wetted surfaces will determine the total amount of contamination introduced during this period, the magnitude of the task of cleaning and flushing prior to use, and the detrimental effects of the contaminants. Guidance on cleaning, flushing, and purification of steam, gas, and hydro-electric turbine lubrication systems is provided in Guide D6439 or may be sought from the equipment/lubricant supplier or other industry experts.

Designation: D6439 – 23

Standard Guide for Cleaning, Flushing, and Purification of Steam, Gas, and Hydroelectric Turbine Lubrication Systems[1]

This standard is issued under the fixed designation D6439; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

- Procedure carried out to clean Lubrication and Control Systems prior to the startup of a Steam Turbine, either during Commissioning or during a Scheduled Shutdown/Turnaround.

- It has two main objectives: to achieve an effective cleaning process in order to provide greater Equipment Reliability, and to perform the intervention in the shortest possible time, since Commissioning and Scheduled Shutdown/Turnaround durations can be optimized, with Flushing becoming a Critical Path activity.

- To achieve both objectives, ASTM D-6439 standard must be followed.

ASTM D-6439-23. Flushing

Wherever possible, turbulent flow should be achieved in system pipes. Jumpers are installed around critical components such as bearings and control valves to elevate bearing supply

7.7.1 Elevated oil temperature, oil temperature cycling and vibration contribute to the success of an oil flush. Hammering or vibration at pertinent points will promote loosening of solids in the system. Once solids are loosened, a high-velocity flush should carry the solids to the filters. Otherwise, they will settle by gravity in the main oil tank, eventually be caught by temporary screens, or removed by filtration.

7.7.2 *Monitoring of Contaminant During Flushing:*

7.7.2.1 Monitoring of contaminant, especially particulate, is commonly performed during the flush and is strongly recommended. These analyses ensure that clean oil is being used for the flush and provide the best measure of the flush's progress.

7.7.2.2 The analyses for particulate may be performed on site using a particle count method or field analysis of contaminant from a sample drawn through an analysis membrane as discussed in X2.5.2 or performed in a laboratory as discussed in X2.6. If the analysis is performed on site, the person performing the analysis should be completely familiar with the operation and limitations of the apparatus. If the analyses are to

External High Flow Pumps. Reach Reynold number higher than 10,000

High Efficiency Filter Elements (Beta higher than 1,000 for 3 microns).

On Site Oil Analysis.

Increase Temperature. Apply vibrations.





Confidential

Importance of Velocity

Laminar – Re # < 4000

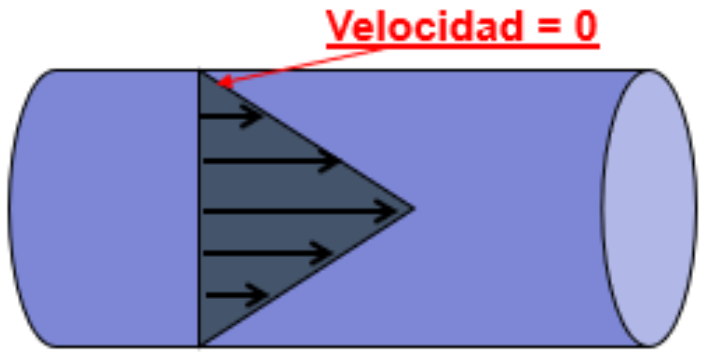


Turbulent/Restricted - Re # >= 4000

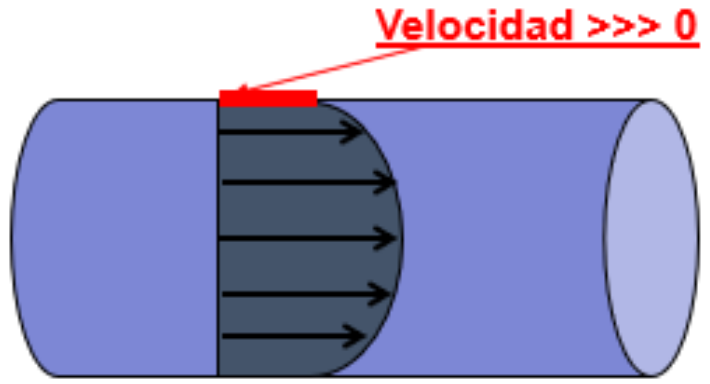


High Velocity Flow – Re # > 10,000





Régimen Laminar

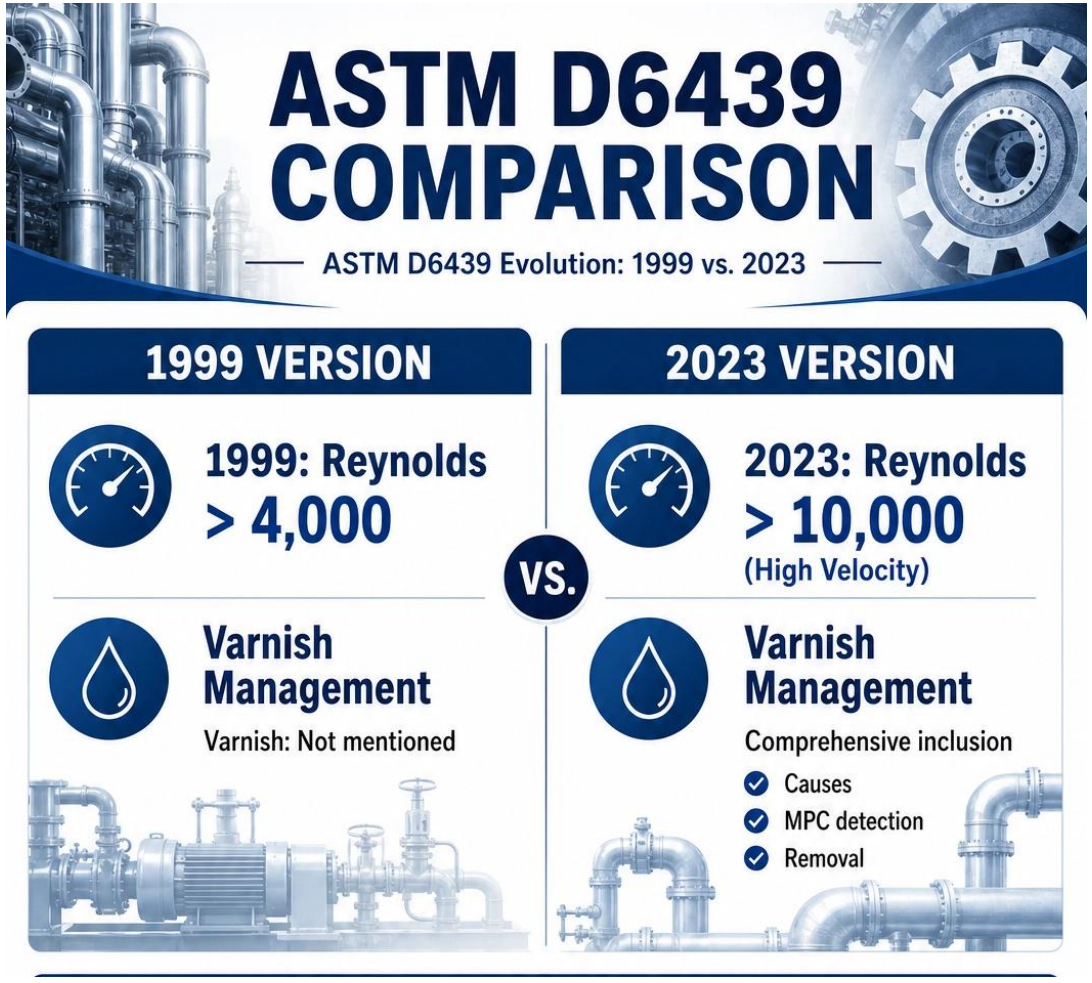


Régimen Turbulento

$$Re = 21{,}200 \times Q / (\gamma \times d)$$

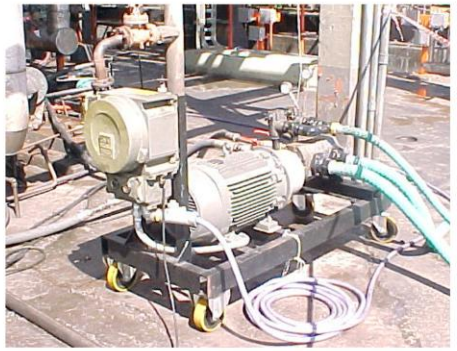
Q – Flow (l/min)
γ – Kinematic Viscosity (cSt, mm^2/s)
d – Inner Diameter (mm)

ASTM D-6439. Evolution



Año 2000. Norma ASTM D-6439-1999

150 GPM





2 x 39" filter elements

Año 2025. Norma ASTM D-6439-2023



500 GPM
4 x 36" filter elements

Air Compressor driven by Steam Turbine in FCCU Refinery.
Flushing performed in Nov 2000, versus Oct 2025

Benefits

- ✓ Increase Reliability in Startup up to 50% (less probability of infant mortality)
- ✓ Reduce time performing flushing, impacting directly to Commissioning Schedule. Reduction time down to 50%.
- ✓ Increase Reliability for Normal Operation Cycle.
- ✓ Technical support.

Most important Benefit: Perform a high level cleaning in the shortest time!

Case Study

HVOF Centrifugal Compressor

Case Study: Centrifugal Compressor in Italy

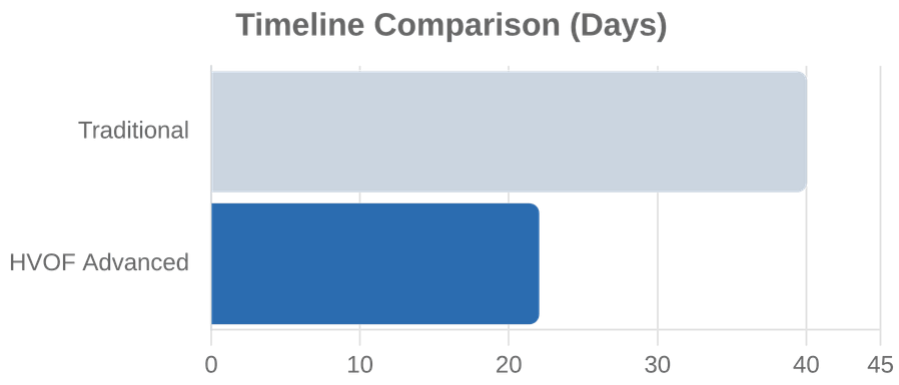
TRADITIONAL APPROACH

- System pumps and filters utilized for initial flushing
- ISO Cleanliness level extremely difficult to achieve
- Project delays and high associated execution costs
- **Total Timeline: ~40 Days**

HVOF ADVANCED APPROACH

- External high-flow flushing and filter skids
- Strict ISO Cleanliness achieved in record time
- Compliance with Mining HSE standards
- **Total Timeline: 22 Days**

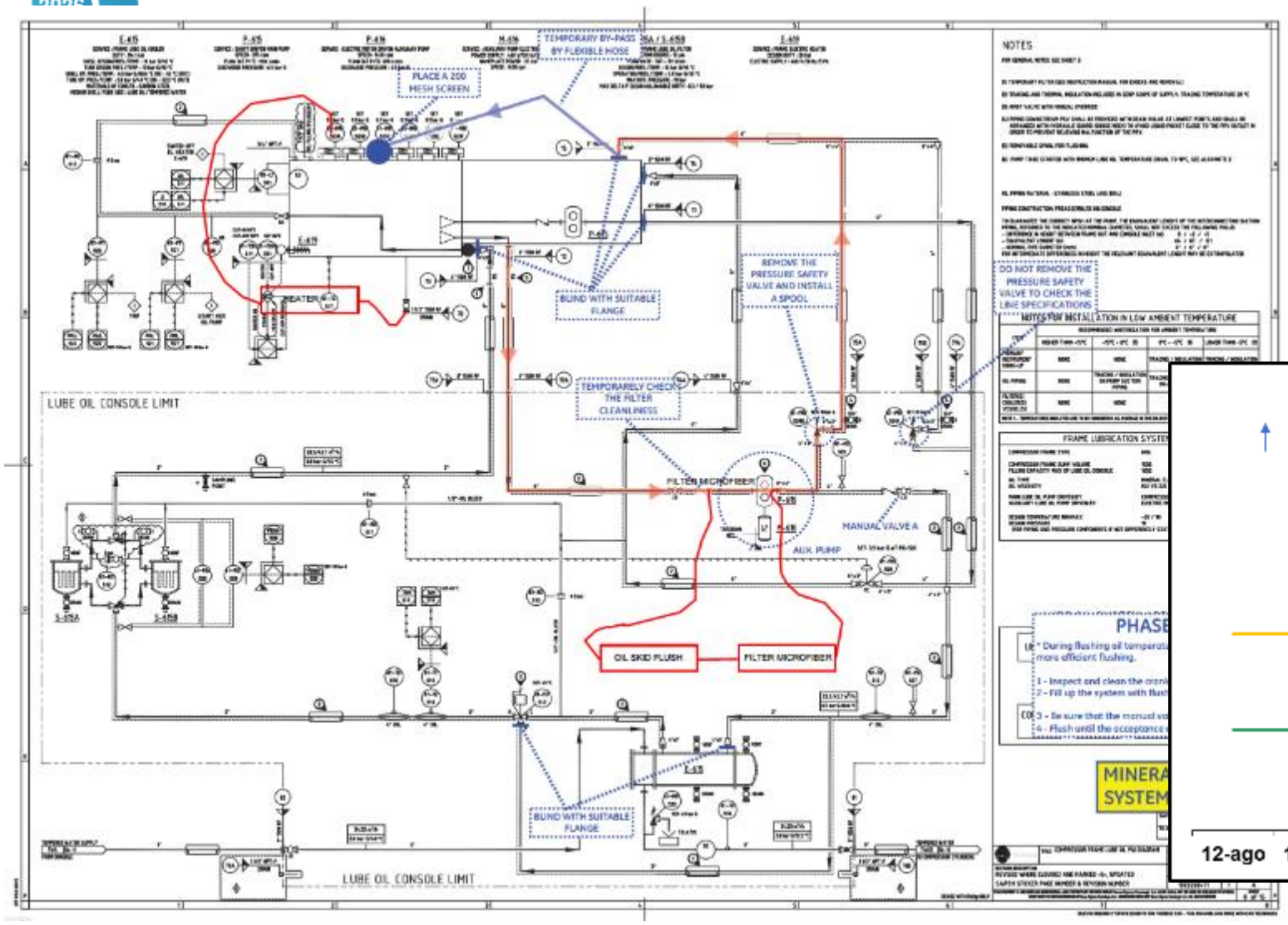
50% TIME REDUCTION

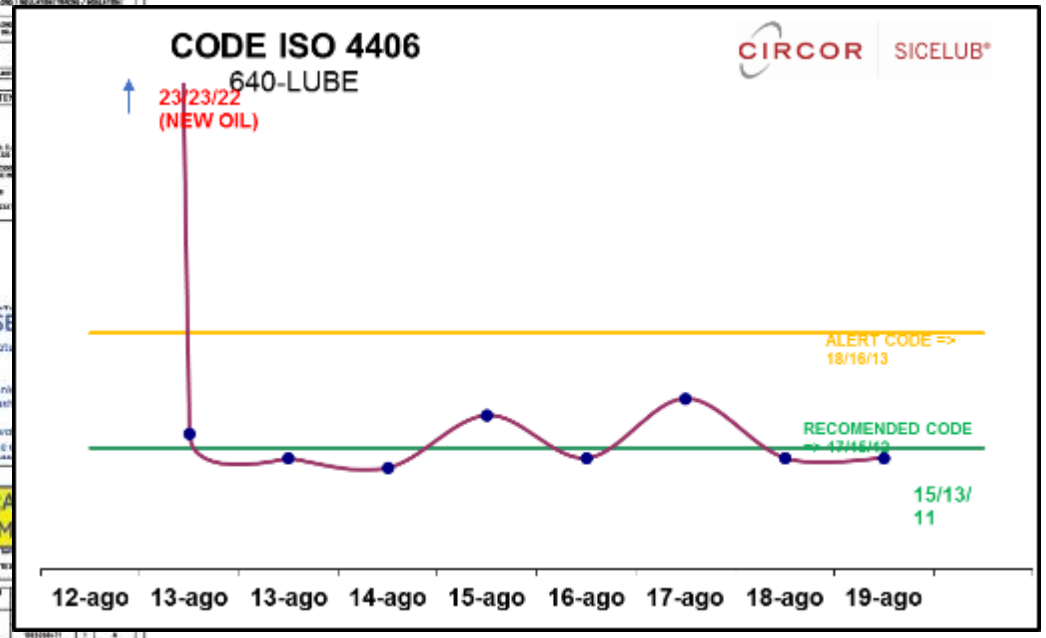




Case Study. Centrifugal Compressor in Italy

P&ID and evolution of ISO Cleanliness

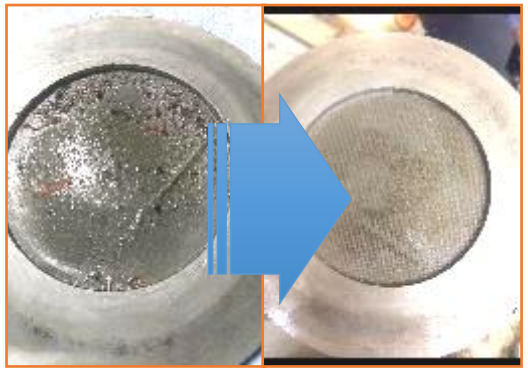




Case Study. Centrifugal Compressor in Italy







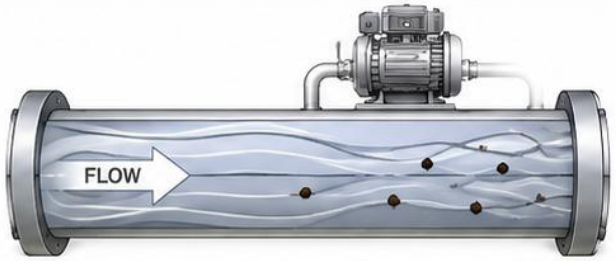
Case Study. Total Operational Benefit

EVOLUTION OF FLUSHING BEST PRACTICES – ASTM D6439

Higher Reynolds, Higher Turbulence, Superior Cleaning

1 CONVENTIONAL CIRCULATION PRACTICE

System Lubrication Pump



Laminar Flow

Low energy – Minimal contaminant removal

Reynolds Number (Re)	< 1,000
Typical Flow Rate	~200 L/min (53 gpm)
Pump Source	System Lubrication Pump
Flow Regime	Laminar
Cleaning Effectiveness	★☆☆☆☆ Poor

2 ASTM D6439 (1999)

Turbulent Flow Requirement



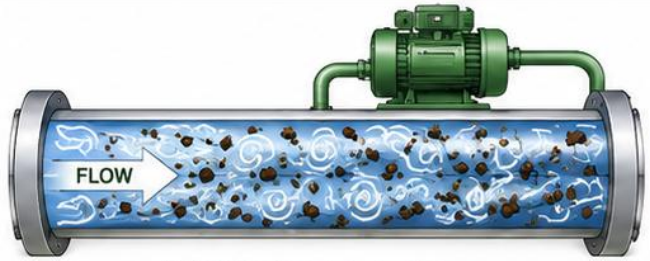
Turbulent Flow

Moderate energy – Improved contaminant removal

Reynolds Number (Re)	> 4,000
Minimum Flow Rate	~920 L/min (243 gpm)
Pump Source	High-Flow Flushing Pump
Flow Regime	Turbulent
Cleaning Effectiveness	★★★☆☆ Improved

3 ASTM D6439-23 (BEST PRACTICE)

High-Velocity Flushing – Varnish Control



High-Velocity Turbulent Flow

High energy – Maximum contaminant and varnish removal

Reynolds Number (Re)	> 10,000
Minimum Flow Rate	~2,300 L/min (608 gpm)
Pump Source	High-Flow Flushing Pump (High HP)
Flow Regime	High-Velocity Turbulent
Cleaning Effectiveness	★★★★★ Maximum

INCREASING TURBULENCE AND CLEANING EFFECTIVENESS

Higher Reynolds = Higher Turbulence = Better Contaminant & Varnish Removal = Greater System Reliability

Flow rates are illustrative for a typical 300 MW steam turbine lube oil system (ISO VG 68 oil, 40 °C). Actual values may vary by system.

Varnish Prevention and Removal

ASTM D-6439-23. Varnish Removal

D6439 – 11 (2017)

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components are generally established by their manufacturers' specifications. These and recommendations of the fluid manufacturer must be considered when employing contamination control systems. In addition, there are insoluble contaminants (oxidation precursors) that are below machine tolerances, but as their volume amasses they create a potential for sludge and varnish creation as a normal consequence of oxidation reactions.

7.2.3.1 Some turbine and associated hydraulic systems may require a surface active flush to clean inaccessible internal surfaces of varnish. The term varnish is being used to include all internal deposits, including sludge. Flushing with a surface active cleaner is typically reserved for gas turbines with combined hydraulic and turbine oil reservoirs. Minor levels of oil soluble cleaners or solvent cleaners may impact operating

7.5.4 *Surface Active Cleaner Selection*—Varnish removal is greatly accelerated with the use of cleaners but there can be negative impact from cleaner residue on the system operating oil and equipment components. Cleaners are segmented as follows:

The 1999 version of ASTM D-6439 did not mention varnish extensively. However, in more recent versions, the subject is addressed in much greater detail, and several methods are suggested for performing flushing procedures aimed at varnish removal

Conclusion

- **Perform Flushing Procedure according to Best Practices of ASTM D-6439-23**. Focus on Turbomachinery, Rolling Mills, Hydraulic Systems.

- **Develop technical procedures to include in tender process.** Don't just include "Flushing" in scope.

- **Review with OEM's and update Procedures.** Most of existent equipment were installed several years ago when Normative scope was different.

- **Varnish Removal & Prevention**. Analyze case by case, in order to recommend action to prevent/remove varnish. Several options in the Market for this approach.



Questions

