PALL Aerospace

Green Run Filtration For The CFM56-7 Engine

Scientific and Laboratory Services (SLS) of Pall Aerospace

Nicholas Brown
SLS Staff Scientist

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Introduction

Proper lubrication system filtration is crucial in aircraft gas turbine engines to minimize fluid system component wear and potential failure that could result from the circulation of damaging particulate debris. Over the years, filtration technology has been specifically developed to address contamination control in lubrication systems in aircraft gas turbine engines and can even alert operators in advance of pending lube system problems, reducing costly in-flight engine shutdowns. Improved fluid cleanliness will similarly provide the benefits of longer MTBF of systems and components. Several of the important aspects of filtration technology for engine lubrication systems are discussed in this document, intended as a guide to 'best lubricant filtration practices' for OEMs, operators and other engine maintenance and test personnel.

Contamination and Related Component Damage

The various processes involved in the assembly, maintenance and overhaul of engine components, including associated teardown and reassembly of subsystems and systems during maintenance and overhaul, can result in the generation of contaminant debris. This includes built-in debris in new components, machining chips, residual grinding debris, fine polishing compounds, and debris generated from making or breaking fittings. It also includes environmental contaminant such as silica sand and other mineral compounds, and contaminant introduced from the fluids utilized, such as cleaning solvents and improperly filtered service fluids. The type, amount, and size distribution of debris is related to the levels of cleanliness control employed in the various processes during assembly, overhaul and maintenance.

The detrimental impact of built-in debris includes catastrophic component failure, and the initiation of component damage such as denting of bearing surfaces. Very often, new oil from a barrel can be heavily contaminated and more damaging than the oil it replaced.

Figure 1 shows examples of contamination found in new oil from a barrel, built in contaminant in new systems oil and contamination found in poorly filtered oil. The fluid cleanliness Class per SAE AS4059 [1]

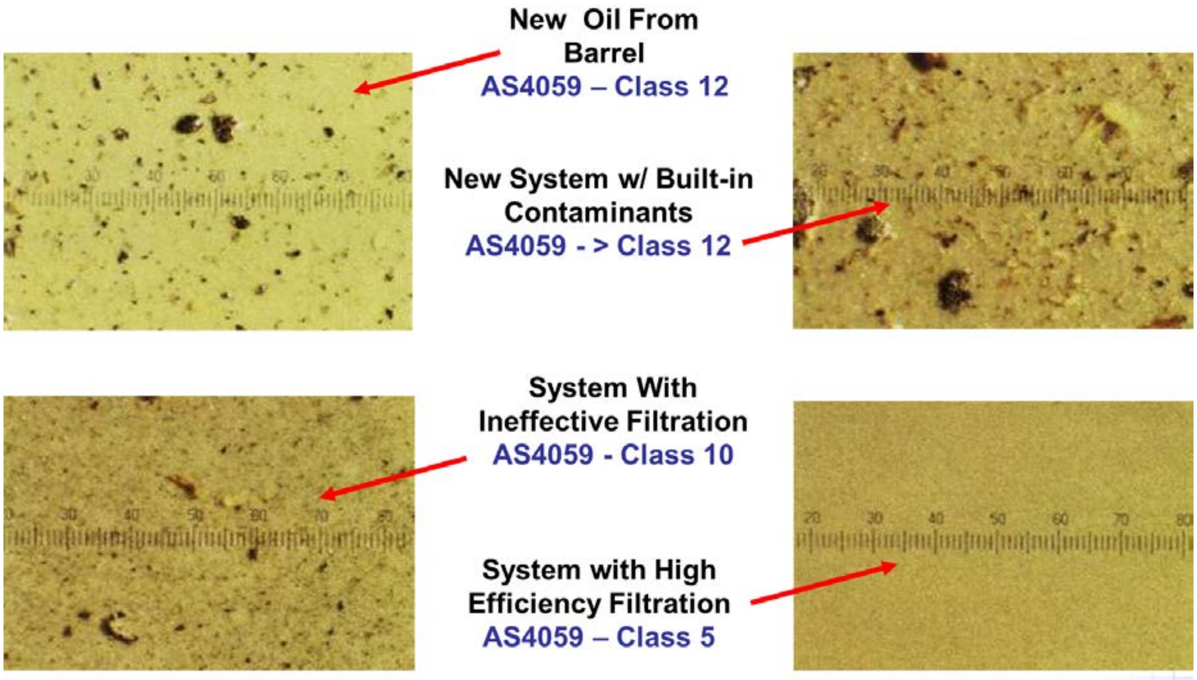

Figure 1. Contamination level for various filtration states of engine oil

When contamination is poorly controlled fluid system components such as: journal bearing, roller bearings, gears and seals prematurely wear resulting in costly overhauls, downtime and disruption. Figure 2 shows examples of damaged bearings due to poor contamination control.

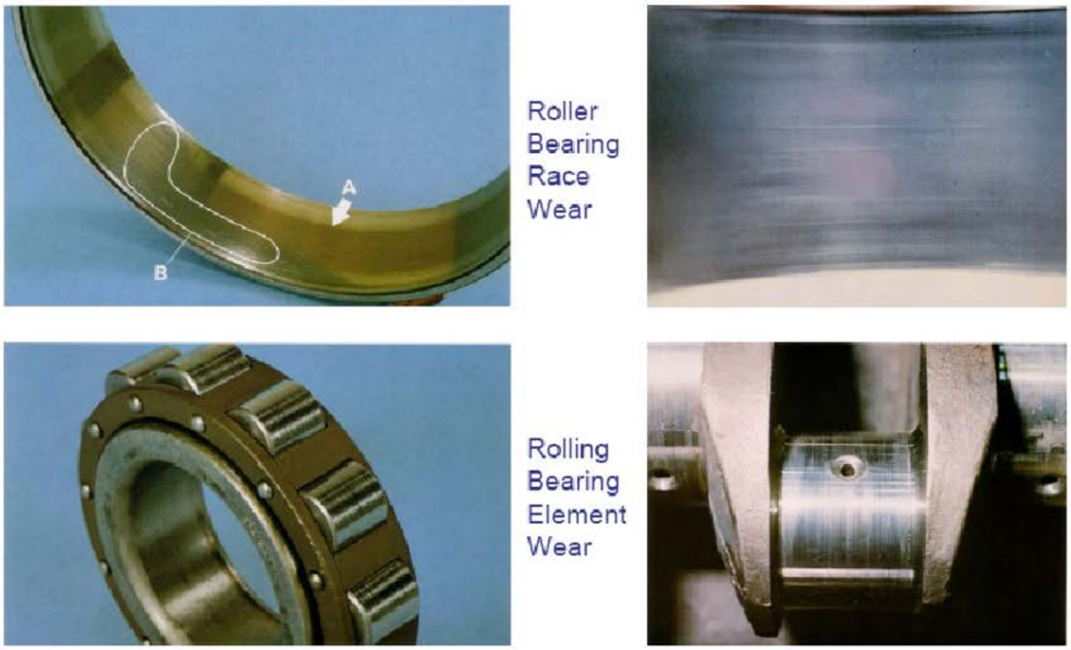

Figure 2. Bearing wear due to poor contamination control

Since turbofan engine main shaft bearings typically operate in the elasto-hydrodynamic or partial elasto-hydrodynamic lubrication regime, lubricant film thickness of ~ 0.1 µm or less, the presence of particulate contamination in the lubricant could lead to the initiation of bearing damage. Based on an examination of approximately 200 incidents in current aircraft gas turbine mainshaft bearings, involving engines in the field, Averbach, B. L., and Bamberger, E. N. [2] concluded that, in most cases, damage in bearings was initiated at the surface. Among the important factors contributing to surface damage were surface defects, scores, and dents, caused by hard, abrasive particulate contamination. The detrimental effects of lubricant fluid contamination on rolling element bearings, in terms of contributing to surface damage was evaluated in a bearing life and reliability study, presented at the 33rd MFPG Meeting by Bachu, Sayles and MacPherson. [3] The study concluded that finer filtration (3 µm or 5µm(c)) could increase the bearing life due to fatigue failure by four times when compared to traditional 25µ system filtration, as seen in Figure 3.

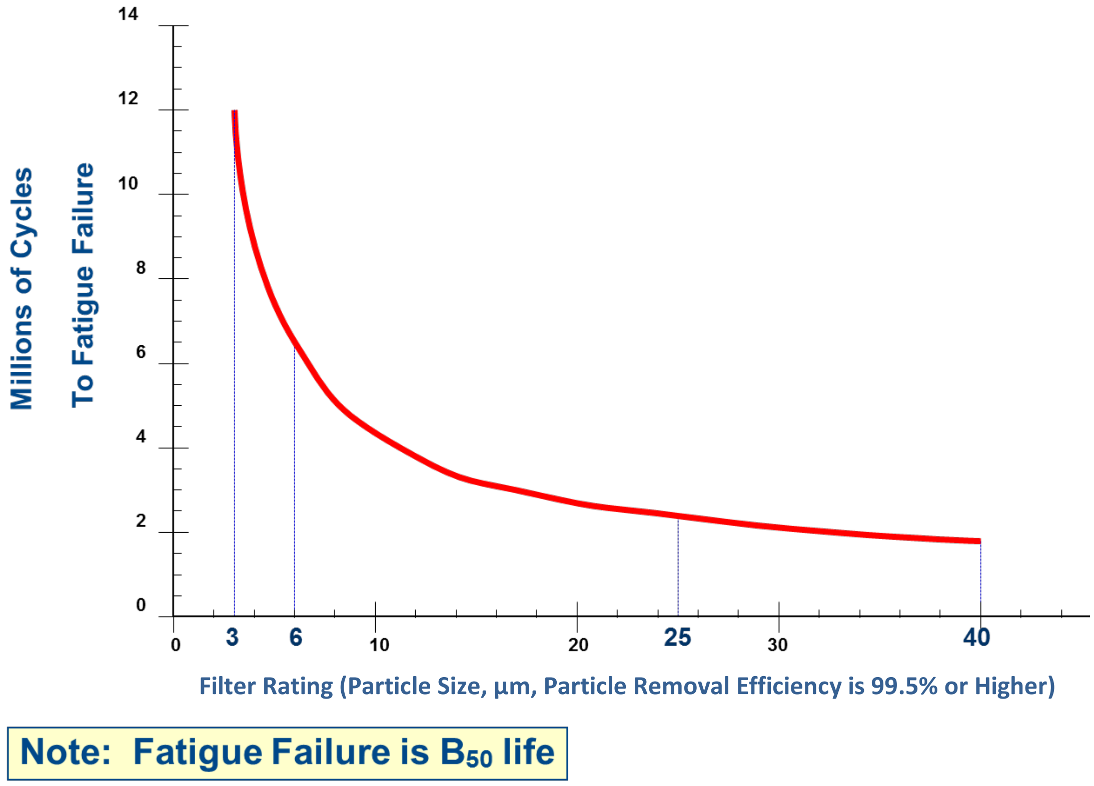

Figure 2. Macpherson Curve for bearing Fatigue

Protection for 'Green Run' of engines

High efficiency, fine filter elements, are available for 'Green Run' applications that remove debris effectively on a 'single pass' basis and prevent recirculation of damaging debris through the fluid system. They are characterized by high particle removal efficiencies: 99.5% - 99.9% for particles in the 1–3 µm, and larger, size ranges. They also exhibit significant particle removal efficiencies in the smaller size ranges, including sub-micron size ranges, for removal of hard, abrasive contamination (polishing compounds). Figure 3 depicts our CFM56-7 engine 'Green Run' filter element which was configured to replace the service filter element during 'Green Run' testing.

Figure 3. CFM56-7 Engine Oil 'Green Run' Filter Element

When running a green engine with a 'Green Run' filter element, particle counts downstream of the oil tank decrease exponentially over time. Ideally the more time an engine can run with a fine filter element, the lower the contamination levels which will lead to longer component life along with improved reliability.

Figure 4 contains Particle Counts for particle greater than 2µm in size versus Test Time during an Engine 'Green Run'. [4]

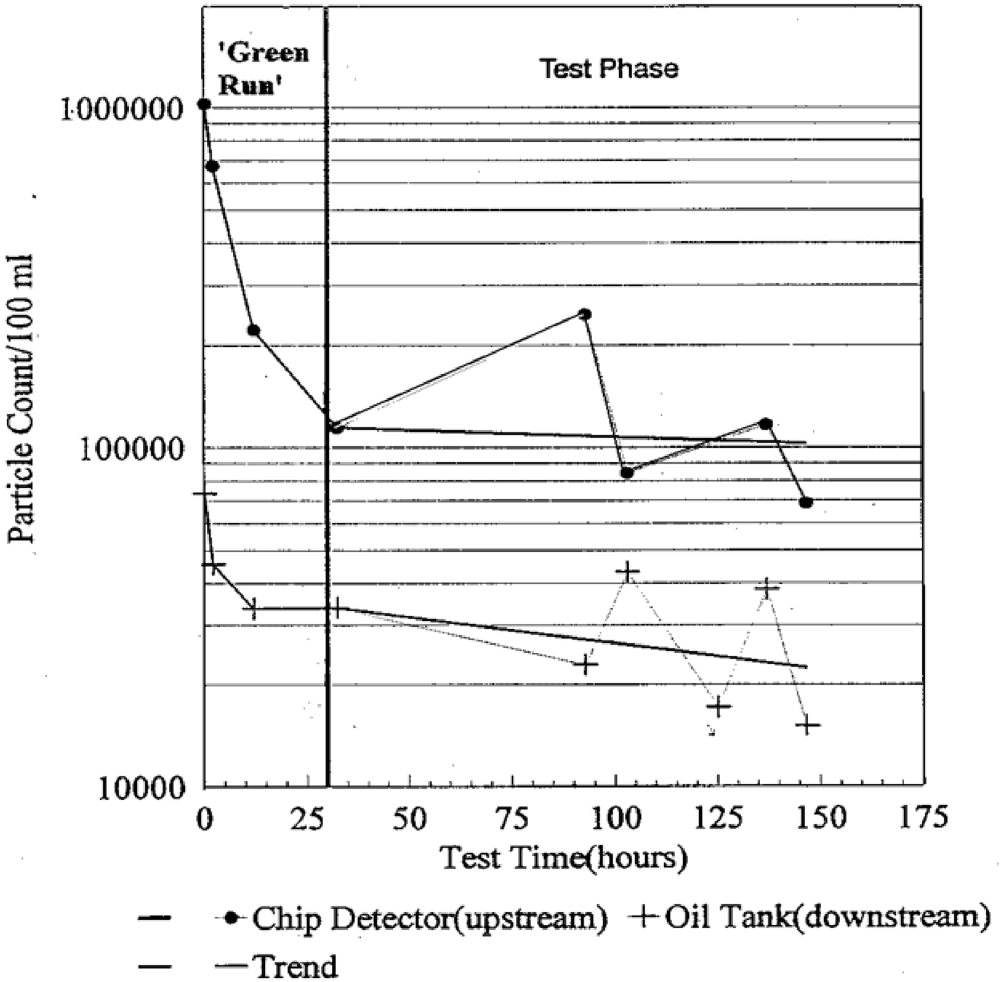

Figure 4. Particle Counts versus Test Time during an Engine 'Green Run' Testing (Particle Size > 2 µm)

Note: the break in phase for this test was 27 hours which is typically longer than most 'Green Runs' of only 2-4 hours.

On-site diagnostics available during 'Green Run' testing of engines

Monitoring of debris present in the fluid provides valuable information about the condition of fluid wetted components. It allows for the characterization of 'normal' or 'atypical' component wear and hence, provides the possibility of preventive maintenance prior to component malfunction and/or failure in flight. The 'full-flow' characteristics of filter elements are ideal for efficiently capturing metallic wear debris as well as nonmetallic debris of interest, such as material from seals and lubricant degradation products such as coke.

The Dirt Alert diagnostic filter element has a removable diagnostic layer which is pleated upstream of the filter support mesh and filter medium. It can be easily removed for visual inspection of the collected contaminant or for more sophisticated laboratory analyses, such as the determination of the chemical elemental composition of the contaminant via X-Ray Fluorescence Spectroscopy (XRF) [5][6]

Figure 5. Dirt Alert Filter Elements.

Examination of the debris on the diagnostic layer during 'Green Run' testing can provide information about the debris built in, or introduced into the engine, during overhaul and maintenance processes. Once a baseline has been established by the operator, the debris collected on the diagnostic layer offers a way to pinpoint 'abnormal' engines, allowing for the necessary corrective action prior to engine installation in the aircraft. The wear debris collected on the diagnostic layer can also provide valuable information about component wear during regular flight operation and augment on-board magnetic/metallic debris detectors, particularly in the ability to distinguish between 'nuisance warnings' and more significant wear debris.

The Dirt Alert version is available for the CF6, CFM56-7, F100, F135, GP7200, PW1133G and PW6000.

Customer Trials

Two new 'Green Run' CFM56-7 filter elements with the Dirt Alert layer were provided to a large operator for trials. Engine 'Green Run' testing was completed in cold ambient conditions to confirm the filter element acceptability due to higher fluid viscosity (i.e. possibility of filter element differential pressure build-up and filter bypass). The Green Run tests were completed satisfactorily (without high differential pressure indication or bypass) and the elements were returned to the Scientific and Laboratory Services (SLS) department at Pall Aerospace in New Port Richey, Florida, for evaluation.

Both serviced filter elements were evaluated for residual dirt capacity to determine the estimated percentage of remaining service life. The dirt capacity of filter element S/N1 was 19.9 grams to 30 psid terminal differential pressure compared to the new filter element baseline of 21.8 grams. The dirt capacity of filter element S/N2 was 18.8 grams to 30 psid terminal differential pressure compared to the new filter element baseline of 21.8 grams. The plots of the filter element differential pressures build-up with contaminant are summarized graphically in Figure 6, and depicts that the first returned filter element labeled "S/N1" had 91% of its service life remaining and the second returned filter element labeled "S/N2" had 86% of its service life remaining.

Overall the results show that the filter elements have significant remaining service life after 'Green Run' testing so that filter element differential pressure indication or by-pass would not be a risk.

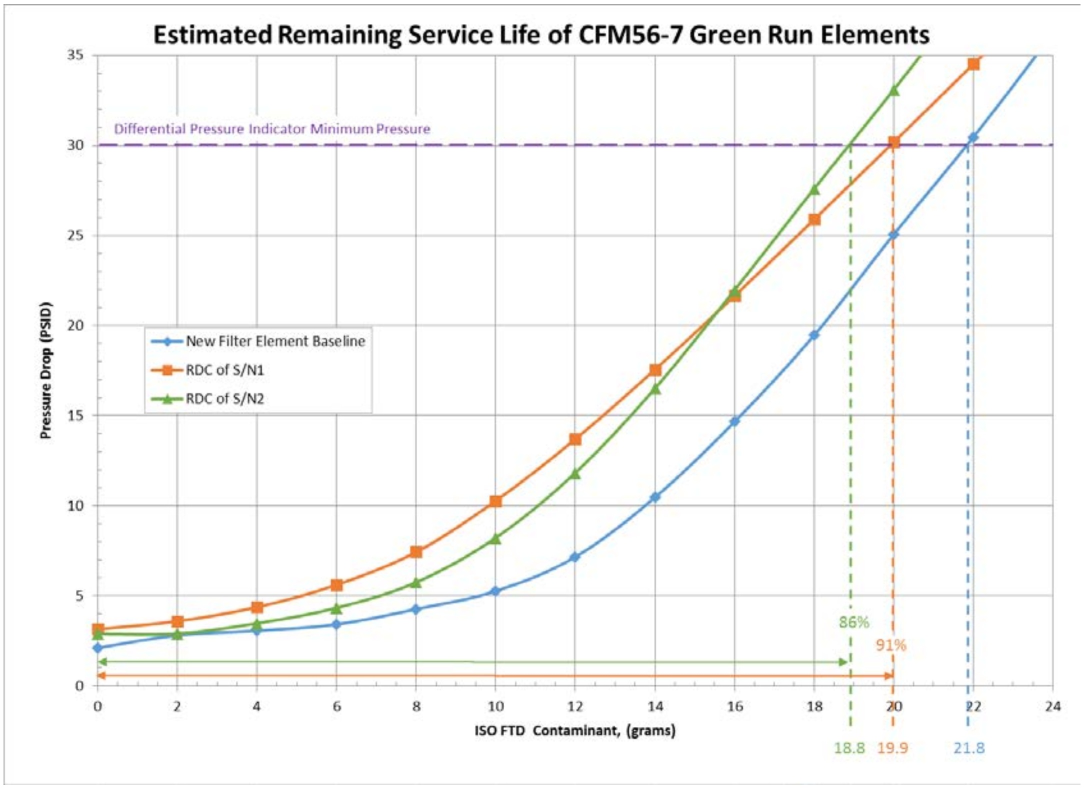

Figure 6. Residual Dirt Capacity for 'Green Run' Filter Elements

A contamination analysis was performed to determine the type and amount of contamination present in the the serviced filter elements.

Microscopic examination of the contaminant extracted from the serviced filter elements showed the contamination to be comprised of fine to coarse particulate contamination, primarily black with a metallic sheen and some clear, tan, amber and red particles. A few clear, twisted and gnarled fibers of natural origin were present.

Figure 7 and depict representative areas of the contamination extracted from filter element S/N2 at magnifications of 50X.

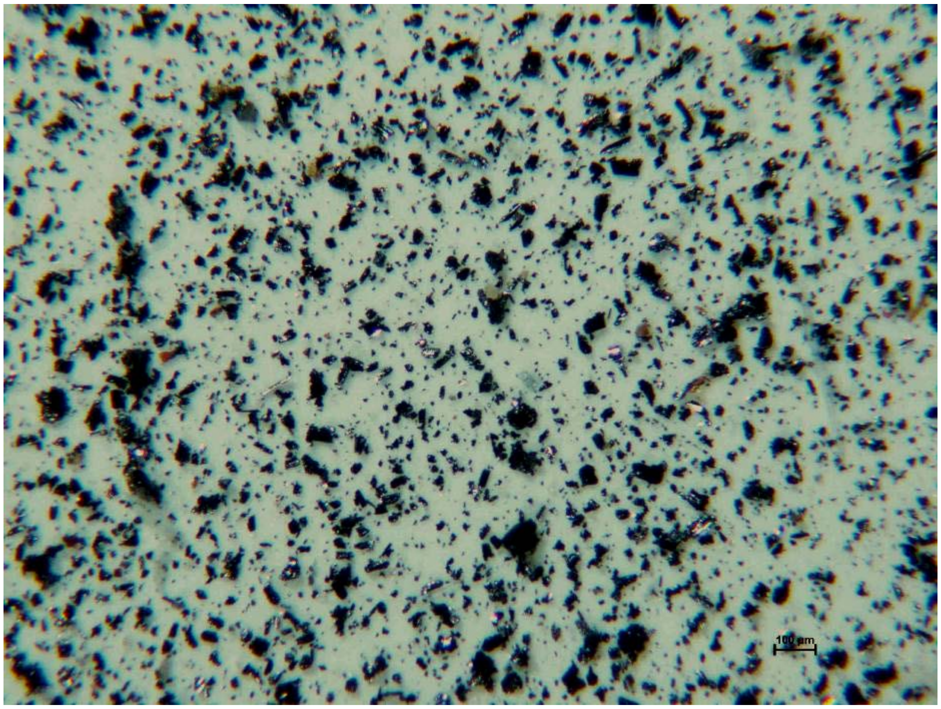

Figure 7: Optical Photomicrographs, at 50X magnification, of the contaminant rinsed off representative areas of the serviced filter element

The analysis of the chemical elemental composition of the contamination extracted from the serviced filter elements showed a preponderance of carbonaceous contaminant along with trace amounts of Silicon and Aluminum containing particulates. The carbonaceous material may originate from the thermal degradation of the lubricant. The silicon may be environmental contaminant. The presence Aluminum is likely from normal component wear of internal components.

Conclusion and Recommendations

- The various processes involved in the assembly, maintenance and overhaul of engine components, including associated teardown and reassembly of subsystems and systems during maintenance and overhaul, can result in the generation of contaminant debris.

- The detrimental impact of built-in debris includes catastrophic component failure, and the initiation of component damage such as denting of bearing surfaces.

- High efficiency, fine filter elements, are available for 'Green Run' applications that remove debris effectively on a 'single pass' basis and prevent recirculation of damaging debris through the fluid system.

- The debris collected on the pull out Dirt Alert diagnostic layer can pinpoint 'abnormal' engines, allowing for the necessary corrective action prior to engine installation in the aircraft.

- List of 'Green Run' engine filter elements:

Platform (Engine)	Pall Part Number
CF6	AC9380F4003DA
CFM56-7	QA06422DA
F100	AC9348F1603DA
F135	ACC541F2003DA
F136	ACC669F123GR
GE90	ACC189FGE90GR
GP7000	ACC413F2003Y2DA
JT8D	AC8832F3GR
PW1000	ACC630F2403GR
PW1133G	ACC731F2403Y1DA
PW2000	AC9806F3Y2GR
PW4000	ADB863F3Y1GR
PW530	ACB475F103Y2GR
PW6000	ACC413F2003DA
T56	AC9215F2022DAKT

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[1] “Aerospace - Cleanliness Classification for Hydraulic Fluids,” SAE AS 4059, 2013.

[2] Averbach, B. L., and Bamberger, E. N., 'Analysis of Bearing Incidents in Aircraft Gas Turbine, Mainshaft Bearings', Tribology Transactions, Vol. 34, pp. 241-247, (1991).

[3] Bachu, R., Sayles, R., Macpherson, P. B., 'The Influence of Filtration on Rolling Element Bearing Life', Proceedings of 33rd MFPG meeting, Gaithersburg, MD, April 21-23, pp. 326-347, (1981).

[4] Johnson, N., Madhavan, P., 'Fine Filtration for Turbofan Engine Lube Systems', Proceedings of SAE E34 Aviation Propulsion Lubricants Committee, Munich, Germany, September 28 and 29, (1994).

[5] Humphrey, G. R., Little, D., Godin, R., Whitlock, R., 'Energy Dispersive X-Ray Fluorescence Evaluation of Debris from F-18 Engine Oil Filters', Proceedings of JOAP International Condition Monitoring Conference, 1998 JOAP Technology Showcase, Mobile, AL, April 20-24, 1998.

[6] Humphrey, G. R.,, 'Joint Strike Fighter – Analysis of Filter Debris by Energy Dispersive X-Ray Fluorescence', JOAP International Condition Monitoring Conference, Technology Showcase 2000, Mobile, AL, April 3-6, 2000.

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AEROSPACE@PALL.COM