Investigation of Super Absorbent Polymer (SAP) Migration in Commercial Aviation Turbine Fuels

Edition 1

IATA

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On behalf of IATA Technical Fuel Group (TFG)

IATA Filter Monitor Task Force

George P. Zombanakis
Continental Airlines
IATA Task Force Chairman

Tracy Boval
Chevron
IATA Task Force Vice Chairman

Michel Baljet
IATA
Assistant Director, Fuel Services

IATA Filter Monitor Task Force
Technical Fuel Group

Montreal - Geneva

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The contributors to this report and the companies they represent are listed below:

Zombanakis, P. George - Chairman Task Force	Continental Airlines
Akoum, Alain	Sofrance, S.A
Anderson, Steve	Air BP Ltd
Appadoo, Ravin	Ravin Aviation
Aurand, Paul	Honeywell, Inc
Baljet, Michel	IATA
Bessee, Gary	Southwest Research Institute
Biddle, Tedd	Pratt & Whitney
Biscardi, Gerard	Allied Aviation, Inc
Bocchi, Alberto	Alitalia
Bolognesi, Bruno	Alitalia
Boval, Tracy - Vice-Chair Task Force	Chevron
Buffin, John	U.S Navy
Crosley, Carl	American Airlines
Detrift, Didier	CFM
Estrella, Earl	Swissport
Farmery, Mike	Shell
Gerlich, Nathan	Southwest Airlines
Grenough, Paul	BP Plc
Himmanen, Paavo	Finnair
Hoskins, Dennis	ExxonMobil
Hunnybun, Martin	Energy Institute
Jones, Christopher	ExxonMobil
Jones, Michael D	Boeing
Kastelitz, Joe	Swissport Fuelling
Keith, Brad	ASIG
Locke, Bob	British Airways
Lodrigueza, Enrico	ConocoPhillips
Mackiewicz, Stan	National Air Transportation Association
Madhavan, Puliyur	Pall Corporation
Mashimoto, Yukio	Japan Airlines
Mason, Nic	Air BP Ltd
Minter, Steven	Allied Aviation
Nguyen, Hung	U.S Airways
Owen, Steve	My Travel Airways Ltd
Rezé, Alexandre	Airbus
Schmalz, Russ	Continental Airlines
Shaeffer, Steven	U.S Air Force
Seto, Stan	G.E Aircraft Engines

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GLOSSARY OF TERMS

AGGLOMERATE:
A group of two or more particles combined, joined, or clustered, by any means.

AGGREGATE:
A relatively stable assembly of dry particles formed under the influence of physical forces

CAKE:
Solids deposited on the filter media

CENTRIFUGATION:
Process of separating two substances of differing densities by high speed spinning to create centrifugal force. Typically used to separate suspended particles from liquid.

CHROMATOGRAPHY:
The separation of substances in a mixture based on their affinity for certain solvents and solid surfaces.

CLARIFICATION:
To clear a liquid by filtration, by the addition of agents to precipitate solids, or by other means

CONTAMINANT:
Any material or substance, which is unwanted in a system

CONGLOMERATE:
A group of two or more particles or particulates of heterogeneous materials joined or clustered by any means.

CLAY:
A firm, fine-grained earth composed chiefly of hydrous aluminium silicate minerals.

CLEAN ELEMENT:
A new or re-conditioned filter element which is essentially free of contamination introduced during manufacture, assembly, storage, or use.

CLOGGED ELEMENT:
A filter element which has collected a quantity of contaminant, such that it cannot maintain rated flow without excessive differential pressure

DiEGME:

Diethylene glycol monomethyl ether (DiEGME) is an anti-icing inhibitor added to JP-8 jet fuel to prevent free water in a plane's fuel system from freezing at high altitudes

DIFFERENTIAL PRESSURE:
The difference in pressure between the upstream and downstream sides of the filter. Also called delta P, psid or pressure drop. May be modified with applied, available, clean, dirty, initial, or maximum.

FSII:
Fuel System Icing Inhibitor (FSII) is an additive to aviation fuels prevents the formation of ice in fuel lines. FSII is sometimes referred to by the generic trademark Prist®.

FILTER:
A device having a porous medium for collecting particulate matter. The major filter components are the housing and the element.

FILTER ELEMENT:
A sub-assembly of a filter which contains the filter medium or media.

FILTER HOUSING:
A ported enclosure which contains the filter element and directs fluid through it.

FILTER MEDIUM:
The porous material which performs the process of particulate separation and retention**.**

FILTER MESH:
A sieve-like arrangement of interlocking metal links or wires.

FILTER PAPER:
A porous paper matted or felted sheet of fibers**.**

FILTER MEDIA MIGRATION:
Problem caused by a filter medium which is constructed of a non-continuous or fibrous polymeric matrix such that portions of the filter change structure causing undefined pore size/distribution, as a function of fluid flow.

FLOW RATE:
It is the speed at which a liquid flows and is measured in gallons or liters per minute. Flow rate of a liquid can be affected by the liquids' viscosity, differential pressure, temperature and type of filter used.

GAUGE PRESSURE:
The pressure measured by a pressure gauge. Pressure above ambient pressure. Symbolized as psig when the pressure is expressed in psi units.

GRAVIMETRY:
Term used in chemistry to define a class of analytical procedures relying upon weighing a sample of material.

GRANULOMETRY:
Technique for determination of the different grain size in a granular material

MEDIA:
In filtration, the material through which fluid passes in the process of filtration and which retains particles. Also, the nutrients containing solutions in which cells or micro-organisms are grown.

MEDIA MIGRATION:
Migration of the materials making up the filter medium. May cause contamination of the filtrate.

MEMBRANE FILTER:
A continuous matrix with pores of defined size.

MICROFILTRATION:
Separation of particles ranging from 0.1µm to 10µm from a fluid by passing the fluid through a membrane. Used for clarification, sterilization or to detect or analyze bacteria and other organisms and particulate matter.

MICROMETER (m):
Also referred to as "micron." It is a 1/1,000,000 of a meter (1µm = 10^{-6}µm = .000039 in);
25.4µm = 0.001 inch;
60µm = approximately the diameter of a human hair.

PARTICLE:
Any discrete unit of material structure; a discernible mass having an observable length, width, thickness, size and shape.

PARTICULATE:
Relating to or occurring in the form of fine particles

PARTICLE SIZE:
The maximum dimension of the particle.

PLEATS:
A series of folds in the filter medium used to increase effective filter area within a given space.

PORE SIZE:
Diameter of pore in membrane.

PORE SIZE-ABSOLUTE RATING:
The rated pore size of a filter at which particles equal or larger than the rated pore size are retained with 100% efficiency.

PRIST®:
See FSII

ROOT:
The inner fold of a pleat.

SAND PARTICLE:
A particle of the soil within the size range of 75 microns to 4.76 mm

SILT:
Fine particulate matter with particles smaller than sand and larger than clay.

SURFACTANT:
A soluble compound that reduces the surface tension of a liquid, or reduces interfacial tension between two liquids (causing formation or micelles) or between a liquid and a solid, thereby functioning as a wetting agent.

SURFACE MEDIUM:
A filter medium that primarily separates and retains contaminant on the influent surface face.

THROUGHPUT:
The amount of solution which will pass through a filter prior to clogging.

TOTAL AREA:
The entire surface area of a porous medium, whether effective or not, in a filter element.

WOUND MEDIUM:
A filter medium comprised of layers of crossed helical wraps of a continuous filament or strand of roving.

ABBREVIATION

EDX: Energy Dispersive X-ray analysis

EPMA: Electron Probe Microanalysis (EPMA) spectrometer used to identify the chemical composition of the contamination

ESEM: Environmental Scanning Electron Microscope

FTIR: Fourier Transform Infrared (FTIR) spectrometer used to identify the molecular bonding of the chemical composition

GC-MS: Gas Chromatography –Mass Spectrometry spectrometer

PSI: Pounds per square inch, a unit of pressure

PSID: Pounds per square inch differential

SEM: Scanning Electron Microscope

SEM/EDX: Scanning Electron Microscope and X-Ray emission spectroscopy analysis for chemical elemental composition

TGA: Thermal Gravimetric Analysis

X-RAY DIFFRACTOMETER: Crystallographic information on the contamination

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1 Summary

1.1 Conclusions

Results of tests and analyses performed by various laboratories confirm that super absorbent polymer (SAP) migration from filter monitors and contamination of aviation fuel has occurred in commercial aircraft, but only in trace quantities (compared with other contaminants found on blocked engine fuel filters). Results did not conclusively establish a correlation between SAP migration and engine fuel filter impending by-pass indication**.**

A test using copper sulphate proved determinant in the detection of SAP. None of the analytical techniques including microscopic examination, Scanning Electron Microscope and X-Ray emission spectroscopy (SEM/EDX) analysis or even Fourier Transform Infrared Spectroscopy (FT-IR) gave any evidence of SAP presence. This confirms that SAP could only be found in trace quantities.

Although SAP migration, as observed during the investigation, does not appear to affect flight operations, there is consensus that testing for SAP should be a requirement and the industry needs to better understand the mechanism(s) of SAP migration from filter monitors and its impact on aircraft fuel systems. The Task Force recommends that the engine OEMs work towards defining permissible levels of SAP in aviation fuel.

The Task Force recognises the operational limitation of filter monitors with regards to their use in fuel with the FSII additive. It is known that the FSII additive may contribute to the decomposition of filter monitor media and the release of SAP downstream. The Task Force unequivocally endorses the position of the filter monitor manufacturers, which states that their monitors should not be used in fuel containing FSII.

Other recommendations include greater fuel quality control and surveillance through tighter operational checks on filter monitors and aircraft engine filters; the need for improved and/or alternative filter monitor designs; the introduction of new and more accurate fuel quality monitoring devices; and the establishment of an industry committee to oversee all commercial aviation fuel quality issues; and to recommend any revision to the current regulations as deemed necessary.

1.2 *Executive Summary*

1.2.1 Objective & Mandate

The IATA Fuel Filter Monitor Task Force set out to investigate the probable release and migration of Super Absorbent Polymer (SAP) material from filter monitors in service onto commercial aircraft engine fuel filters.

The Task Force mandate was threefold to investigate if filter monitor media was migrating to commercial aircraft; to suggest mitigation measures in view of reducing the associated risks faced by the airlines; and finally to develop a communication plan with aviation regulatory authorities. The investigation required the establishment of a common testing protocol where all laboratories used the same procedures and analytical techniques.

1.2.2 Background

There has never been a report of a commercial aircraft engine fuel filter clogging attributed to SAP contamination.

The investigation was triggered essentially by incidents documented by the U.S Air Force after three T-37 aircraft in summer of 2005 experienced single engine flame-out while in flight. The U.S Air Force's own investigation of the incidents revealed that 'large amounts of SAP and debris' had been trapped in the aircraft engine filters and fuel control hardware thereby blocking fuel flow. It is noted that filter monitors qualified in accordance with the industry standard applicable at the time (API/IP 1583 4th edition) should not have been in use in fuel containing Fuel System Icing Inhibitor (FSII).

Although the Air Force directed the removal of filter monitors from the equipment used to refuel aircraft at all Air Force Bases, the FAA did not recommend this action, as per FSAW 06-04 bulletin (see Appendix 1) released in March 2006, for commercial aviation fuel facilities due to differences in commercial aviation refuelling equipment and the selective use of the FSII additive, which can affect filter monitor performance. However, the revised FSAW 06-04A released in December 2006 acknowledges the warning issued to commercial airlines by the Energy Institute (see Appendix 2) in October 2006 stating that "water absorbent polymer in filter monitors may pass downstream from filter monitors into fuel, even in the absence of FSII", a fact recognised by all filter monitor manufacturers supplying filter elements qualified to IP 1583 4th edition.

FSAW 06-04A points out the necessity of reviewing the airlines jet fuel quality control procedures "with special emphasis on procedures intended to minimise the introduction of contaminants into Jet fuel supplies." In a similar vein, the oil companies and filter manufacturers had advised all operators about the need to tighten operational checks on filter monitors including the daily monitoring of filter monitor differential pressure, flow rate and water drainage of filter vessels, as well as maximum service life reduction of filter monitor elements from 3 years to 1 year.

1.2.3 Findings

The IATA Task Force investigation involved laboratory analyses of the material found on 67 serviced engine fuel filters from operators worldwide and the survey of fuel facilities at 46 International airports.

Filter monitors are commonly found at airports in the fuel distribution system. Some 887 filter monitor units were identified at the airports surveyed. Into-plane service providers typically use them as the final stage of their comprehensive systems to protect aviation fuel quality on refuelling vehicles.

Filter monitors at the airports surveyed showed normal operations in terms of flow rate and differential pressure. No use of the FSII additive was reported with filter monitors at those airports. Nozzle screens downstream of filter monitors showed no traces of SAP. However, membrane filtration analysis on 39 Millipore samples using the copper sulphate test showed trace quantities of SAP in more that half of the samples examined.

Serviced engine fuel filters came from both Boeing and Airbus aircraft. The microscopic examination for solid contamination/debris from filter elements and the Scanning Electron Microscope and X-Ray emission spectroscopy (SEM/EDX) analysis for chemical elemental composition did not give any evidence of SAP presence. The Fourier Transform Infrared Spectroscopy (FT-IR) for chemical elemental analysis/structure of the contamination was not conclusive either as the IR spectra of the solid debris did not match those of the reference SAPs.

However, about 80% of the serviced engine fuel filters examined showed SAP presence when using the copper sulphate method for detection. There is thus evidence of SAP on aircraft filters but these materials occur in low concentration and as discrete pieces. The SAP observed during testing appeared to behave as a small amount of particulate dirt contamination and did not contribute to filter plugging, relative to other identified contaminants.

The mechanism(s) of SAP migration is not well understood. It is also not known whether two-inch diameter filter monitors (with outside-to-inside fuel flow) and six-inch (6”) diameter filter monitors (with outside-to-inside, or inside-to-outside fuel flow formats) are equally prone to SAP migration. However, it is the contention of filter monitor manufacturers that the six-inch (6”) inside-to-outside flow format element is likely to be the most prone to SAP migration. Filter monitors incorporate a final filtration layer to prevent media migration, but the tightness varies between element types.

Although the use of the FSII additive is approved in the aviation fuel specifications, the location of the injection of the additive is not clearly addressed. Filter monitor manufacturers state that their monitors should not be used in fuel containing FSII. The monitor specification publisher, Energy Institute, has endorsed that position.

The contaminants identified on engine filters were predominantly silicates, sulphur, sulphurous material in the form of sulphides, sulphites and sulphates, salts and iron oxides. Aluminium, calcium and copper were also found. In some cases, the debris appeared to have a high level of Chlorine, indicating that the sodium may be present as common salt. In a few filters, some white cloth fibres were found on the filter surface and further fibres were present in material extracted from inside the filter. Although not an objective of this task force, the quantity and types of material found blocking the aircraft engine filters were noted.

1.2.4 Recommendations:

Quality Monitoring and Surveillance:

Manufacturers of fuelling equipment have a shared responsibility to ensure that contaminated fuel is not getting into the aircraft fuel tanks. Besides complying with all industry standards including those published by the API and EI, manufacturers should assess the impact of likely equipment-released contaminants on fuel and aircraft fuel systems.

The recommendations below are not directly related to the SAP issue; however, they are best practices that the Task Force believes should be highlighted:

Engine OEMs and Aircraft Manufacturers recommend reducing the engine filter change interval and time of water drain on a case by case basis only and for a limited period of time to prevent impending by-pass conditions during flight according to the operators experience and recent findings.

Diligence at airport **Fuel Farms, Distribution and Dispensing** systems should be maintained by the fuel supply and distribution industry in order to achieve the maximum aviation fuel quality and cleanliness, as well as maintaining the required fuel specifications.

Improve Communications:

The **IATA Filter Monitor Task Force** should inform the **filter monitor manufacturers** about the finding that SAP occurred on Millipore filters downstream of new elements and request that they evaluate the cleanliness of their manufacturing procedures and improve them to comply with API/IP 1583 4th edition, paragraph 1.7.2.1d.

Importantly, Aviation Authorities worldwide, including **FAA** and **EASA**, should be informed of the findings of the investigation conducted by the Filter Monitor Task Force. It is hoped that the filter monitor investigation effort will pave the way for a more systematic communication link with the Aviation Authorities on issues of fuel quality.

Make SAP Testing a Requirement:

The **Energy Institute** should request that the **filter monitor manufacturers** urgently develop and perform SAP migration tests on their existing products, and any new prototype models they develop.

The Energy Institute should include a new laboratory-testing requirement in IP 1583 for manufacturers to analyse for SAP downstream of filter monitor elements being tested (using a copper sulphate test) with the condition that none is detected.

A standard flushing procedure should be developed for filter monitors before they are put into service (either at point of manufacture or installation) to minimize SAP dust from migrating from the elements into the aircraft systems.

Other quality assurance field-tests besides the copper sulphate test for the detection of SAP should be researched. Because of the known effect of FSII on filter monitors, operators should perform the B/2 refractometer test (ASTM D 5006 or equivalent) for FSII detection as necessary.

Airframe manufacturers should revise their maintenance manuals to include the requirement that engine fuel filters should be inspected.

To establish whether SAP is migrating beyond the engine filters, the airlines should be requested to conduct analysis for the presence of SAP on failed fuel control units or other fuel system components that have been removed from the aircraft.

Improved Filter Monitor Designs:

The **fuel filter monitor manufacturers** should improve their designs or research and develop another water removal device that will eliminate the release of SAP and keep fuel free from contamination with SAP material. Any new design should be thoroughly evaluated.

The **oil and into-plane companies** should assess the viability of filter monitor removal from their aviation fuel systems and implement the use of alternate approved filter equipment such as filter water separators as per API 1581 for their operations. However, the users should also be aware of some of the filter water separator limitations as discussed in Chapter 3 and in section 9.1.

Introduce New Quality Monitoring Technology:

The recommendations below are not directly related to the SAP issue but are future developments that this Task Force believes should be considered:

The industry needs a more accurate way to gauge fuel cleanliness than the current white bucket, visijar and other approved tests. Airlines and into-plane fuel suppliers should determine how much contamination is currently going into the aircraft, establish baselines, and then determine if new limits are required.

Optical devices using particle counter technology, although still in the developmental phase, seem to be the most adapted and promising solution. However, other devices using different technologies may need to be considered to enable an 'all contamination type' detection and measurement. Any new devices should be thoroughly evaluated (laboratory and field).

It is noted that a new API/IP publication is in preparation, 1598 Draft Standard *Guidelines for selecting electronic sensors for monitoring aviation fuel quality*. It will outline the minimum operational performance requirements for electronic sensors (any type) for the detection of dirt and water in fuel.

New Standard: Adopt New Definition for Fuel Quality in Aviation Regulation and Airport Fuel Handling Standards:

All the industry airport fuel handling standards should be reviewed to state that the fuel quality and cleanliness requirements will be in accordance with the engine manufacturer's specification. In addition to prescribing the specific types of filtration to be used for the receiving or dispensing filtration, clear mention should be made in these manuals that filter monitors should not be used in fuel containing FSII additive. Fuel from defuelled aircraft should be treated in a 'defuel' chain separate from the aircraft fuel supply chain: this is to prevent any kind of contamination including FSII additive to migrate from a contaminated aircraft into the aircraft fuel supply chain.

The IATA-led effort to achieve **one global standard** for aviation fuel quality control under the SAE G-16 Committee is encouraged and its scope should be expanded to include the improved fuel quality requirement defined above.

The recommendations below are not directly related to the SAP issue, but are nonetheless best practices that this Task Force considers important to highlight:

Airlines should incorporate or reference Fuel Handling manuals and publications in their contractual agreements with their into-plane agents and fuel suppliers. This would reinforce the commercial aviation authority's confidence of industry's ability to control requirements on aviation fuel quality and handling.

An industry committee should follow up on the findings of this Task Force by organizing the industry to look for efficient routes to mitigate media migration by establishing cause and effect relationships. For example, it may happen that in-to-out filter monitors or monitors in wet service contribute a disproportionate share of media migration. A further goal of this group should be to coordinate with the Energy Institute to evaluate mitigation options for existing filter monitor installations.

Fuel Quality Surveillance & Oversight:

The recommendations below are not directly related to the SAP issue, but are future developments that this Task Force believes should be considered:

It is noted that fuel quality and cleanliness requirements can be defined more specifically in the current industry standards. Airlines cannot alone ensure that the current regulatory requirement of a fuel free from contamination is met. It is a shared responsibility involving many industry segments.

It is recommended that a **committee of all industry stakeholders be formed to establish** the requirements for fuel quality and cleanliness, and the methods to demonstrate compliance, at or before the aircraft's fuel tanks.

It is recommended that a committee of all industry stakeholders be formed to establish the requirements for fuel quality and cleanliness, and the methods to demonstrate compliance, at or before the aircraft's fuel tanks.

It is also recommended that this committee coordinate their efforts with aviation regulatory authorities with the objective of strengthening current regulations applicable to fuel quality surveillance and oversight.

2 Introduction

2.1 Background

In 2002, one international carrier whilst investigating performance degradation of filter monitors having suffered electrostatic damage as part of its Monitor Test Program, discovered that the water removal performance of filter monitors was degrading prematurely in the field for unknown reasons. In that same year, investigative work by the American Petroleum Institute (API) and the Energy Institute (EI) identified filter monitors from seven international locations that failed to meet the performance requirements for new filter monitors specified in API/IP 1583 3rd edition. The investigation confirmed that the water removal performance degradation occurred from monitors from all of the four global manufacturers that supplied monitors qualified to API/IP 1583. A significant amount of EI-funded laboratory analysis, and the use of a 'condition/experimentation facility' specially set up at O'Hare airport to replicate near field conditions, failed to identify an obvious cause of the degradation.

As a mitigation measure and pending full investigation of the problem, the industry, through various service bulletins from filter manufacturers and oil companies, advised the users about the reduction in the recommended service life of filter monitors from three years to one year and emphasised the necessity of tightening operational checks on filter monitors including the daily monitoring of filter monitor differential pressure, flow rate and water drainage of filter vessels.

In 2003, several airlines reported to IATA an increase in engine fuel filter bypass incidents. Airlines were reducing their fuel filter replacement intervals in order to prevent impending bypass conditions and to prevent expensive aircraft turn-backs or diversions. The affected airlines reported that they had reduced their fuel filter replacement intervals from 5000-6000 hours down to 2000 hours, and for a few the replacement intervals were reduced to below 1000 hours.

In the summer of 2005, the U.S Air Force (USAF) reported that three T-37 aircraft flying out of Sheppard Air Force Base (Texas) experienced single engine flame-out while in flight. The U.S Air Force's own investigation of the incidents revealed that large amounts of Super Absorbent Polymer (SAP) and debris had been trapped in the aircraft engine filters and fuel control hardware thereby blocking fuel flow. It is presumed that the SAP had migrated from the filter monitor to the aircraft fuel tanks during refuelling. To prevent any future incidents, the USAF decided to replace their 6 inch water absorbing filters with filter coalescers.

In a letter dated 23 September 2005 (see Appendix 3) the API alerted the FAA about the incidents at USAF and the measures the latter had taken. The API informed the FAA of the uniqueness of USAF fuel, but nevertheless were committed, together with various representatives of the aviation industry, to collect data and investigate this problem fully to ascertain if other segments of the aviation industry could be experiencing a similar phenomena.

Although the Air Force directed the removal of filter monitors from the equipment used to refuel aircraft at all Air Force Bases, the FAA did not recommend this action, as per FSAW 06-04 bulletin (FAA Flight Standards Information Bulletin for Airworthiness) released in March 2006 for commercial aviation fuel facilities due to differences in commercial aviation refuelling equipment and the selective use of the FSII additive, which is known to affect filter monitor performance. FSAW 06-04 points out the necessity of reviewing the airlines jet fuel quality control procedures "with special emphasis on procedures intended to minimise the introduction of contaminants into Jet fuel supplies."

In October 2005, the IATA Technical Fuel Group (TFG) shared data and the USAF flame-out experience with all participants at the TFG semi-annual meeting. This resulted in the setting up of the Filter Monitor Task Force chaired by Continental Airlines and comprised of specialists from various industry segments.

2.2 Objective & Mandate of IATA Task Force

The IATA Fuel Filter Monitor Task Force set out to investigate the probable release and migration of Super Absorbent Polymer (SAP) material from filter monitors in service onto commercial aircraft engine fuel filters.

The Task Force mandate was threefold;

1) To investigate if filter monitor media was migrating to commercial aircraft

2) To suggest mitigation measures in view of reducing the associated risks faced by the airlines

3) To develop a communication plan with aviation regulatory authorities

The investigation required the establishment of a common protocol where all laboratories used the same procedures and analytical techniques.

3 What are Filter Monitors?

A filter monitor is a vessel containing a number of filter monitor elements that contain water-absorbing media known as super-absorbent polymer (SAP). They are designed to continuously remove dirt and water from aviation fuels down to a level acceptable for servicing. It is intended to positively shut off the fuel flow if the concentration of water is unacceptable. As the water-absorbing material picks up water, it expands in volume, which reduces and finally stops the flow of fuel. The reduced flow (which causes an increase in differential pressure) warns the operator that the current batch of fuel may be unusually wet. Filter monitors also contain filtration layers to remove particulates from fuel. Blocking of the filtration layers by excessive amounts of particulate will also cause an increase in differential pressure, but blocking of filter monitors in service by particulate is unusual.

Filter monitors are not disarmed by fuel borne surfactants (surface active materials) known to interfere with the removal of free water by filter/water separators. For this reason, filter monitors are typically used by into-plane fuel suppliers at the aircraft wing refuelling point as a 'last line of defense' to identify the presence of water and particulate in jet fuel and prevent their entry into the aircraft fuel tanks. However, the presence of Fuel System Icing Inhibitors (FSII) may cause filter monitors to fail, permitting water transmission if high concentrations of DiEGME are present in free water. It was originally thought that this transmission would increase the differential pressure across the unit, but testing has proved there can be significant water transmission before the pressure begins to rise (CRC, 2004).

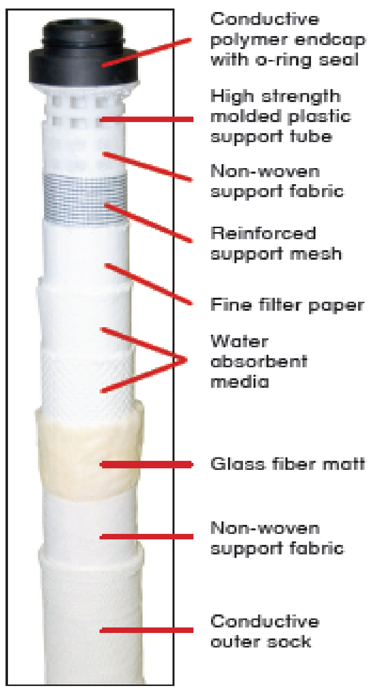


Figure 3-1 2"diameter (Out to In flow format) Monitor Element – Electrostatically Conductive. Picture: Courtesy Racor/Faudi

Figure 3-2 Water Absorbing Media Locations; Picture: Courtesy Continental Airlines

Figure 3-3 Inside View of Filter Monitor Vessel. Picture Courtesy ExxonMobil

4 Fuel Quality Oversight and Surveillance

FAA and EASA regulations stipulate a fuel 'free from contamination' for commercial aviation use:

FAA: 14 CFR 121.135(b)(18)

"Procedures for refuelling aircraft, eliminating fuel contamination, protection from fire (including electrostatic protection), and supervising and protecting passengers during refuelling."

EASA: Part M, subpart C, AMC M.A.301-1c
"a control that consumable fluids, gases, etc. uplifted prior to flight are of the correct specification, free from contamination and correctly recorded."

On the fuel handling side, unlike Maintenance organizations, contractors providing aircraft servicing activities as defined in Aircraft Maintenance Manuals ATA Chapter 12 (fuelling, de-icing/anti-icing, water, etc.) normally need not be approved by the Aviation Authority.

The responsibility for fuel quality rests with the operators and their suppliers:

JAR-OPS 1
Joint Air Worthiness Requirements (Operations), Section 2-B-8, AMC OPS 1.035, Paragraph 5.1.2 states that:

"The ultimate responsibility for the product or service provided by the sub-contractor always remains with the operator. A written agreement should exist between the operator and the subcontractor clearly defining the safety related services and quality to be provided. The sub-contractor's safety related activities relevant to the agreement should be included in the operator's Quality Assurance Manual."

FAR PART 121 REGULATIONS
FAR 121.131 states that:

"Each Air Carrier shall prepare and keep current a Manual for use and guidance of Flight and Ground Operations personnel conducting its operations."
"That the Manual must contain procedures for refuelling aircraft, eliminating fuel contamination, protection from fire(including electrostatic protection) and supervising and protecting passengers during refuelling."

As regards oversight and surveillance responsibilities, FAR 121.373 states that:

"Each Certificate Holder shall establish and maintain a system for continuing analysis and surveillance of the performance and effectiveness of its inspection program."

Although the services are contracted under conditions to the fuel companies, the ultimate responsibility for services provided by the fuelling company always remains with the operator. It is therefore up to the operator to ensure that the provided services are performed by the contractor, in accordance with all applicable requirements, standards and procedures.

The industry standards and guidelines are enshrined in the following documents:

API/IP 1540 Design, construction, operation and maintenance of aviation fuelling facilities
ASTM D 1655
ATA Specification 103
C.A.S.E Standard (Coordinating Agency for Supplier Evaluation)
Canadian Standard B836-00

DEF STAN 91-91
IATA Guidance Material for Aviation Fuel Turbine Specifications
IATA Guidance Material on Microbiological Contamination in Aircraft Fuel Tanks
International Fuel Quality Pool (IFQP) Standard
Joint Inspection Group (JIG) Guidelines
NFPA 407 (National Fire Protection Association)
Fuel distributor/supplier internal manuals

5 Review of Key Documents

5.1 Specifications

5.1.1 API/IP Specification 1583, 4th Edition: Specifications and Laboratory Tests for Aviation Fuel Filters with Absorbent Type Elements

Until recently, this was the industry specification for filter monitors. The publication prepared jointly by the Energy Institute (EI) and the American Petroleum Institute (API) provided the industry with general specifications and minimum laboratory test procedures (qualification requirements) for new filter monitor designs with absorbent type elements.

The specification applied specifically to 50 mm (2-inch) and 150 mm (6 inch) monitors but highlighted limitations, for example:

The qualification tests are not intended to necessarily predict the actual performance of the equipment in every environment that it may be exposed to."

The specification did not define service life of filter monitors.

The responsibility was on the filter manufacturer to "further define any application and/or performance limitations that affect the serviceability of filter monitor systems in aircraft servicing."

The specification recognized that:

"Performance testing of used elements from field service has shown that the water absorption performance of some elements has degraded to levels less than found for new elements."
"Performance of new elements may also be sensitive to environmental parameters such as temperature and salinity of free water."

The specification does not cover the operations and performance of filter monitors "in fuels containing Fuel System Icing Inhibitor (FSII)."

In fact, the 4th edition carried two important changes:

Filter monitors "should not be regarded as fail-safe. Instead they should be regarded as part of a comprehensive system to control aviation contamination."
Manufacturers are required "to advise purchasers and users of limitations in the application on and/or the performance of their filter monitor elements or system."

Both the American Petroleum Institute (API) and the Energy Institute (EI) have recognised the water removal performance degradation issues of filter monitors and have been actively researching water absorption in filter monitors. In December 2005, the API withdrew its support from the fourth edition of API/IP 1583 "Specification and Laboratory Tests for Aviation Fuel Filter Monitors with Absorbent Type Elements". The EI has continued to publish IP 1583. EI issued on 26 October 2006 a 'Warning on the use of Aviation Fuel Filter Monitors' confirming that the latter cannot be regarded as 'fail-safe' devices and recommending specific action to be taken by all filter monitor users. EI released in November 2006 the IP Draft Standard 1583 5th Edition "Laboratory Tests and Minimum Performance Levels for Aviation Fuel Filter Monitors" for technical review by industry stakeholders.

5.1.2 IP Draft Standard 1583 5th Edition "Laboratory Tests and Minimum Performance Levels for Aviation Fuel Filter Monitors

This is the fifth edition of this publication, which supersedes all earlier editions. With the publication of the fifth edition of IP 1583, the fourth edition was formally withdrawn from publication. The document is published as a Draft Standard as EI expects technical feedback on the content. IP 1583 5th edition will be reaffirmed, revised or withdrawn by 1st November 2008.

Highlights:

- Only "selected aspects of the performance of filter monitor elements and systems are addressed in this document." They are primarily those "where a laboratory test has been developed with sufficient experience to identify a minimum level of performance."

- The publication is issued as a 'Draft Standard' because of many unknowns:
    - It is not known whether products can be manufactured that can meet fully all of the laboratory test requirements for the new categories.
    - It is also not known what the effects will be of exposure of such products to the commercial aircraft fuelling environment.
    -
    - It has not been possible to evaluate all aspects of the new super-absorbent polymer (SAP) migration requirements described in the publication, although the provisions reflect the industry's knowledge on this topic at the time of publication.
    -
    - Thus, the use of filter monitors that meet the requirements of IP 1583 alone cannot provide assurance that water in fuel will be prevented from passing onto an aircraft

- The Draft Standard recognizes that:
    - It is not possible to replicate exactly in a laboratory the environmental and operational parameters to which a filter monitor system or elements may be exposed when in service in commercial aircraft fuelling applications.
    - Water absorption performance of filter monitors in service can suffer deterioration, although it has not been possible to identify with certainty the mechanisms that cause such deterioration in service.
    - Evidence also suggests that even the performance of new elements may be sensitive to environmental parameters.
    - Filter monitors are at best part of a comprehensive system to control aviation fuel contamination, and cannot be regarded as fail-safe devices on their own.

This edition of 1583 includes new laboratory testing requirements to confirm that no SAP occurs in fuel downstream of a filter monitor element under test. However, the caveat is the difficulty in replicating exactly the 'environmental and operational parameters to which a filter monitor system or elements may be exposed when in service'. As such, the use of filter monitors that meet the requirements of IP 1583 alone cannot provide assurance that water in fuel will be prevented from passing onto an aircraft, or that SAP migration from filter monitor elements will not occur.

5.1.3 Energy Institute Report to IATA Filter Monitor Task Force, 4 October 2006

The EI report (see Appendix 4) recognises the limitations of API/IP 1583, 4th edition specification which states in the main that laboratory tests are unable to replicate the operating conditions to which filter monitors are exposed when in service; and that filter monitor manufacturers have stated that SAP from filter monitor elements may pass downstream from filter monitors in fuel.

EI reports that all “size and flow formats of filter monitors are implicated, but the extent of SAP migration from them may vary. The six inch diameter in-to-out flow format element is considered by manufacturers and users to be the element most vulnerable to SAP migration, given the large quantity of SAP that it contains and the fuel flow direction.”

Besides the “Warning” communication to the industry and the publication of IP 1583 5th edition discussed in the preceding section, EI made a number of recommendations. These are discussed in section 9.5

5.2 Oil Companies Service Bulletins

Oil companies in general issued technical bulletins and advisories to inform their customers about the operational limitations of filter monitors and provided guidance in terms of procedures/actions to follow to handle fuel doped with anti-icing additive.

5.2.1 Shell Aviation Bulletin, July 2006: Filter Monitors: Restriction of Use

The Shell bulletin (see Appendix 5) reminds users to carry out diligently all routine checks of filter monitors, to notify users of the new restrictions covering jet fuel containing FSII, and to remind users that in-to-out-flow monitor (6-inch diameter) elements are not approved for Shell Group use. Shell recommends checks on filter monitors and reiterates filter manufacturers caution not to use filter monitors in the presence of FSII. However, where filter monitors are currently used for delivering jet fuel doped with FSII, specific actions are recommended. The bulletin also outlines procedures for some special situations like defuelling jet containing FSII and the inadvertent use of filter monitors with FSII.

5.2.2 ExxonMobil Technical Bulletin, 11 November 2005: Anti-Icing Additives and Filter Monitors

ExxonMobil Technical bulletin (see Appendix 6) recommends a review of all fuelling operations where an anti-icing additive is in use to determine if the fuel passes through a filter monitor after dosing with the additive. The bulletin specifies the action to be taken for any locations where this occurs. It recommends that where monitors are exposed to fuel containing the additive, fuelling through these filters must cease at the latest 6 months from the date of the bulletin.

To continue fuelling with the anti-icing additive ExxonMobil recommends two options:

1) Installation of injection systems on-board the fuelling vehicles downstream of the filter monitor cautioning against fuel being pre-blended with the additive prior to entering a vehicle using a filter monitor.

2) The conversion of filter monitor vessels to filter water separators qualified to API/IP 1581 5th Edition Class M service where on-board injection of the additive is not possible.

5.2.3 ConocoPhillips Technical Bulletin, 2 June 2006: Aviation Fuel Filter Monitors

ConocoPhillips Technical Bulletin (see Appendix 7) states that its own research in the 1980’s determined that filter monitors do not perform as well with aviation turbine fuel as filter/separators, whether or not it contains FSII. As such, ConocoPhillips has never recommended filter monitors as the primary filtration device on fuel farms or refuellers.

ConocoPhillips reinforces the importance of filter maintenance and water management at airport fuel facilities where rigorous quality control practices are essential to maintaining healthy fuel facilities. The bulletin outlines operational procedures for quality control and water management and specifies the conditions that warrant the replacement of the filter elements.

5.2.4 Air BP Technical Action Bulletins

In its Technical bulletin dated 6 January 2006 (see Appendix 8A), Air BP provides a listing of all important information regarding the use of filter monitors and filter/water separators with jet fuel containing FSII and specifies the following actions:

1) Review of all operations that include jet fuel and FSII to identify any sites where filter monitors are exposed to jet fuel containing FSII.

2) All identified sites shall be brought into compliance with this Technical action bulletin as soon as possible and certainly no later that June 1st 2006. Sites unable to comply with this will need to seek a Waiver as an interim measure.

In Technical bulletin dated 30 October 2006 (see Appendix 8B), Air BP reiterates the concern expressed in the warning note from the EI dated 26 Oct 2006. Moreover, Air BP believes that migration of SAP is most likely to occur when a new Filter Monitor cartridge of any size is first commissioned because it may contain loose manufacturing SAP debris which could be flushed out into the fuel.

Because of the potential for SAP migration, Air BP introduced two additional measures:

1) Increasing the frequency of inspection of all hose end strainers to monthly from quarterly

2) Inspection of the hose end strainers following the three minute flush after installing new Filter Monitor cartridges in any into-plane vessel. The presence of any gel in the hose end strainers will warrant the replacement of the Filter Monitor cartridges.

5.2.5 Chevron Bulletins

In its 2005/02 bulletin (see Appendix 9A) Chevron advised that, except under military contract, the jet fuel manufactured and handled by the company will not contain the FSII additive. Chevron recognises that filters used in the jet fuelling systems at airports that are the filter monitor type (IP 1583 formerly API/IP1583) are more prone to failure when jet fuel contains Di-EGME.

In its bulletin 2006/01-2/14/2006 (see Appendix 9B), Chevron highlights immediate actions to be taken at Chevron supplied or owned/operated facilities. These include water handling, quality checks and verification for correct application of additives to ensure product integrity; the conversion of all existing filter water separators housings from filter monitor elements back to filter water separators at commercial locations inside/outside the U.S.

5.3 Filter Manufacturers Service Bulletins

Most filter manufacturers have issued advisories on filter monitors. In the main, manufacturers have reduced the service life of filter monitors to a maximum of one year and cautioned users against their use in fuel additized with FSII.

5.3.1 FACET Technical Bulletin, March 13 2006: 1583 Monitor Specification Update

Facet technical bulletin (see Appendix 10) highlights the operational limitations of filter monitors as follows:

- FSII is not an approved monitor specification additive
- Facet cannot control the field conditions of proper additive injection or the condition of the neat FSII in operational storage
- It cannot assure that the proper sump draining procedures are in place.

For the above reasons, Facet cannot unconditionally guarantee performance of monitors in fuel with FSII. Facet issued the following caution:

"Full flow monitors should not be used with fuels containing fuel system icing inhibitors (FSII). The water removal performance of full flow monitors may be reduced with fuel containing FSII."

5.3.2 Velcon Service Bulletin, May 30 2006

Velcon recommends daily draining of vessel, change-out at 15 psid and the injection of anti-icing additives after filtration whenever possible. Velcon recognizes that in fuels containing anti-icing additive (Di-EGME, FSII, PRIST®), stagnant water bottoms can absorb large amounts of the anti-icing additive. This water/FSII solution can disarm water-absorbing elements allowing water to pass downstream.

In November 2003 Velcon issued a service bulletin that recommended that service life for all water absorbing cartridges should be one year. In May 2006, Velcon Filters Inc. recommended discontinuing the use of water absorbing cartridges with pre-mixed fuel containing anti-icing additives. The bulletin is provided in Appendix 11.

5.3.3 Racor Bulletin No. 73185

The Racor bulletin recognizes the phenomenon of SAP media degrading and migrating into the fuel tank under 'some operating conditions' as a result of which water and/or the super absorbent polymers themselves may enter into the aircraft fuel tank. The bulletin goes on to state that this 'may cause the engine of an aircraft to be inoperable leading to death, personal injury and property damage from the crash of the airplane.'

Parker Racor Division recommends changing out the filter monitor filter at least every 12 months or sooner when the differential pressure of the monitor housing reaches 25 psid. The complete bulletin is provided in Appendix 12.

5.3.4 Faudi Service Bulletin, December 13, 2003

Faudi mentions the presence of Sodium Chloride (salts) deposits in water absorbent media as one of the contributing factors for the degradation of water absorbent media performance. Faudi also recommended that the service life for all Faudi Aviation water absorbing monitor elements should be one year, unless otherwise advised by the operator's company directive or fuel handling procedures. The complete bulletin is provided in Appendix 13.

5.4 OEM's (Engine Manufacturers), 30 May 2006: Position on Engine Filter Impending By-pass Warning

OEMs recognize that some operators are reporting an increasing number of engine fuel filter impending by-pass indications**.**

Highlights

- Purpose of Engine Fuel Filters is to prevent dirt from getting into the close tolerance control and fuel nozzle components of the engine fuel system. The filters seem to be doing what they were designed to do.
- There is little evidence of SAP material in the engine filters. The inspection of filters returned from event engines seems to yield findings of dirt or clay materials, sulfur based materials, salts and iron oxides.
- Sudden increase in impending by-pass warnings would seem to suggest fuel is dirtier than in the recent past, nation wide and world-wide.

OEM's recommendations

1) IATA and ATA to work more diligently to achieve airport fueling systems that have cleaner fuel.

2) EI to determine if monitors need to be pre-conditioned and to work with IATA/ATA to ensure monitors are employed to work as they were conceived to work in airport fuel systems, last chance water removal, not as a major remover of water.

5.4.1 CFM, May 2006: CFM56 Fuel Filter Impending By-Pass Light Indication - Experience

CFM's fleet experience is that fuel system components are increasingly reliable in all CFM engine models although there has been an increase of engine fuel filter impending by-pass indication in the last 3 or 4 years. Fuel filter investigations have shown clogging. Very fine dark/brown particles sometimes associated with the presence of SAP were found on these clogged engine fuel filters. CFM fuel filters are designed to ensure fuel system components integrity and are performing well protecting engine fuel system.

CFM and Aircraft Manufacturers (see Appendix 14) recommend that operators reduce the filter change interval to prevent impending by-pass conditions during flight according to the operator experience.

The frequency of aircraft tank sumping should be increased to remove any SAP that may be present in water.

5.5 US Navy Fuel Monitor Status, May 31 2006

Prompted by the problems experienced by the US Air Force, the US Navy initiated a program to determine if and to what extent the Navy may experience similar problems. This came on the heels of a sampling program in which the Navy found that their filter monitors were losing effectiveness earlier than expected.

In a 'naval message' dated June 15 2005 (see Appendix 15), the Navy called for the removal of all Filter Monitors from service at their fuel facilities by 28 February 2007. Specific actions are defined to enable the Navy to achieve this objective.

The U.S Navy based its decision further to a risk assessment conducted by NAVAIR which indicated that Filter Monitors could be removed safely from service.

The U.S Navy provided its inputs to the Filter Monitor Task Force at the IATA Technical Fuel Group meeting in May 2006. A copy of U.S Navy presentation is provided in Appendix16.

5.6 US Air Force, August 2006: Update on the Status of Filter Monitor Technology in the US Air Force and Navy

The report (see Appendix17) outlines the efforts undertaken by both the US Air Force and US Navy further to the engine flame-out incidents experienced by the US Air Force on three T-37 aircraft in summer 2005

Further to the incidents at Sheppard Air Force Base, the US Air Force directed the removal of filter monitors from the equipment used to refuel aircraft at all Air Force Bases. Filter monitors were replaced with coalescing-type filtration hardware

The phenomenon of filter media migration is not new to the US Air Force. Acrylic type polymer material has been occasionally observed in fuel system sump samples.

A joint effort by US Air Force and Chevron to determine if SAP media migrates, under flow conditions that simulate the real-world situation, from filter monitors used by commercial aviation (all vendor types), showed that they all displayed some degree of SAP migration.

6 Investigation Methodology

The filter monitor investigation required the participation of various industry segments. It involved three parts, which are as follows:

1) Survey of airport fuel systems to determine the field application of filter monitors and the extent to which they are used in commercial aviation fuel

2) Laboratory analysis of serviced engine fuel filter elements to determine the presence of SAP

3) Laboratory analysis of membrane (Millipore) filtration test samples downstream of filter monitors to detect any presence of SAP and other particulates.

6.1 Airport fuel systems

A sample of international airports within the U.S and worldwide were surveyed by into-plane companies having global fuelling operations. The information sought was:

- The number of filter monitors used at the airport
- The precise location of filter monitors in the airport fuel supply system
- Operational parameters such as use of FSII, flow and differential pressure variances and abnormal nozzle screen findings

6.2 Laboratory Analysis

The serviced engine filters were provided by various airlines. As filters would be examined by a number of laboratories worldwide, guidelines for the examination of contamination (see Appendix18) had to be developed and a common protocol established so that all laboratories would be examining the serviced filter elements using the same procedures and techniques. The protocol was comprised of three stages:

1) Removal of contamination from the serviced engine filter element on to an analysis membrane, using a suitable solvent, followed by contamination identification via various analytical techniques including microscopic and Scanning Electron Microscope (SEM) examination, and X-ray emission spectroscopy (SEM/EDX), X-Ray fluorescence spectroscopy (XRF), X-Ray Diffraction (XRD), or Fourier Transform Infrared Spectroscopy (FT-IR) for chemical elemental analysis/structure of the contamination.

2) Extraction of the water soluble portion of the contaminant from a section of the filtration medium with water, followed by filtration through an analysis membrane to remove the insoluble portion. The filtrate was then evaporated and the non-volatile residue analyzed along with the non-volatile residue obtained from a water extract of the filtrate from step 1) above.

3) Immersion of the analysis membranes from 1) above in copper sulphate pentahydrate solution, followed by drying and microscopic examination for blue particulates which would represent SAP – copper sulphate adducts.

7 Into-Plane Survey Results

This chapter summarises the findings of the Into-plane companies who participated in the airport fuel system survey. The companies were Allied, ASIG and Swissport. The results of the filter membrane tests conducted on the Swissport and ASIG samples are also provided.

7.1 Allied findings (see Appendix19)

A total of 22 fuelling facilities comprising of 13 U.S, 7 Canadian and 2 South American airports were surveyed.

A total of 323 filter monitor vessels were found installed exclusively on the into-plane equipment. Some airports have more monitors installed than others. For example, Houston George Bush Airport and Toronto Pearson have 81 and 65 filter monitor vessels respectively. Some airports like JFK and LaGuardia in the U.S had no monitors installed.

All the U.S Airports had 100 mesh nozzle screens installed downstream of the filter monitors. Figure 7-1 below shows a typical fuel system filtration at DFW Airport.

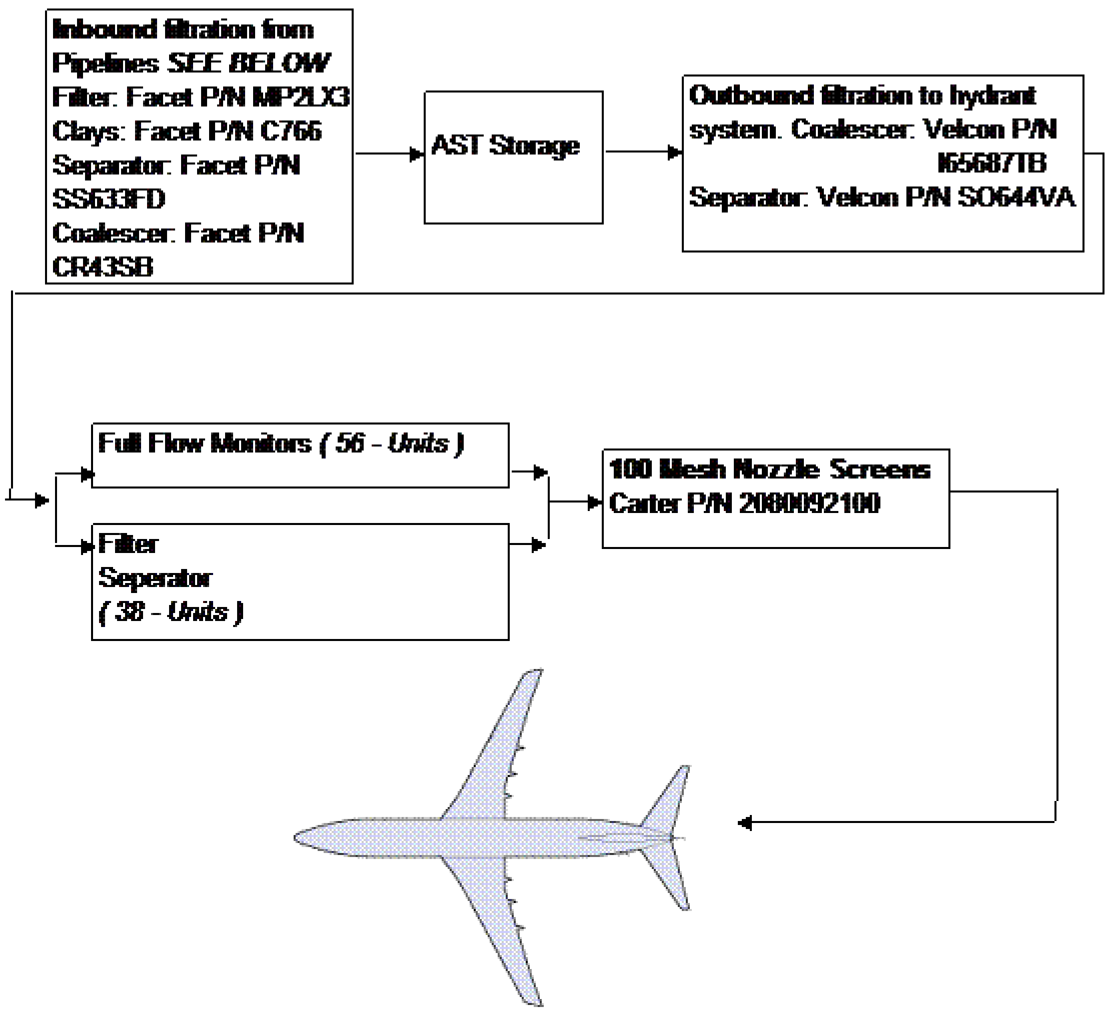


Figure 7-1 : US Dallas Fort Worth (DFW) Airport Fuel System Filtration.

There were no reports of abnormal operations in terms of reduced fuel flows and/or higher differential pressures at any of the stations surveyed.

7.2 ASIG findings (see Appendix 20)

ASIG surveyed 24 international airports in the US. Besides the parameters mentioned above, ASIG tested for FSII presence in the fuel and monitored abnormal nozzle screen findings.

A total of 564 filter monitor vessels were identified in use at the various airports. Three airports had no filter monitors installed. The filter monitors were invariably fitted on the into-plane equipment except at one location where it was also used to remove water at the facility filtration.

No FSII was reported being used or detected after tests and the filter monitor operations were normal at all 24 airports. At two stations, Bradley and Sarasota international airports, a few filter fibers were observed on the nozzle screen.

7.2.1 Membrane (Millipore) filtration test

Swissport and ASIG provided their Millipore samples to SwRI for them to be tested with copper sulphate to identify any presence of SAP. Of the 6 samples provided by Swissport, 4 Millipores contained some SAP.

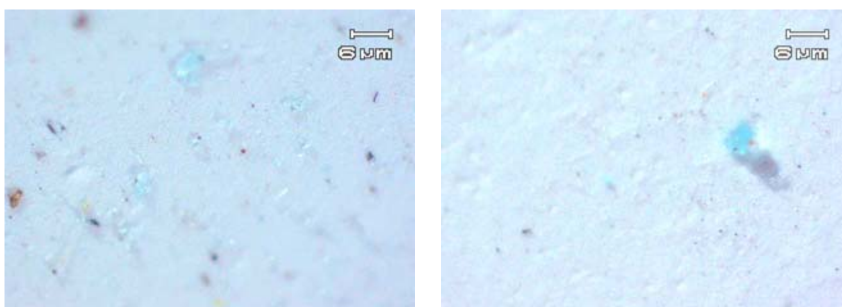


Figure 7-2 Swissport Millipore Analyzed by Copper Sulphate

Figure 7-3 shows Millipore test results from a few ASIG samples with varying levels of particulate contaminant and filter monitor fuel volume throughput. Approximately half of the 33 samples provided by ASIG indicated there was SAP presence. It is also noted that the ASIG samples were taken from both 2” and 6” diameter filter monitors and there was no significant difference in media migration between the two types.

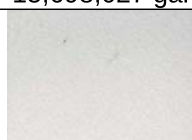
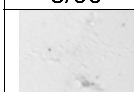
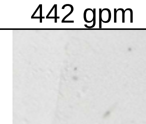
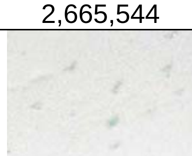
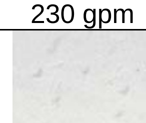
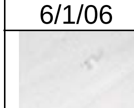
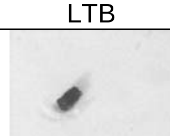
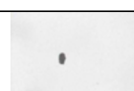
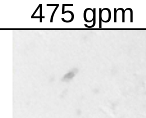
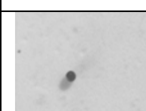
Airport, Last element change	**Manufacturer, Volume through monitors**	**Elements**	**Nozzle pressure, psi**	**ΔP @ Flow rate**	**Housing rated flow, gpm**	**SAP Present**
D 8/05	Velcon 15,698,027 gal	CDF-230K	36	6 psid @ 480 gpm	800	Trace
						
H 5/06	Velcon 524,564gal	CDF-230K	34	1 psid @ 442 gpm	810	High
						
L 9/08/05	Velcon 2,665,544	CDF-230K	20	2.0 psid @ 230 gpm	850	High
						
N 6/1/06	Velcon 2,943	CDF-230K	24	6 psid @ 300 gpm	300	Trace
						
R 1/10/06	Velcon 5,019,855 gal	ACI-63301 LTB	38	3 psid @ 475 gpm	605	None
						

Figure 7-3 Asig samples Millipore test results

8 Laboratory Analyses of Serviced Engine Fuel Filter Elements

The analyses were conducted by various laboratories using the test protocol outlined in section 6.2. Pall Corporation's evaluation is provided in its entirety as an example of the reports submitted. Other evaluations, including some which did not specify the analytical techniques used, are summarised in terms of their main findings and conclusions.

8.1 Pall's Evaluation

Pall Corporation evaluated 14 serviced engine fuel filter elements from power plants for both Boeing and Airbus aircraft. The serviced filter elements were submitted by operators located mostly in Europe or Asia and two North American operators. Most of the filter elements were removed on differential pressure indicator actuation. The details of the serviced filter elements are included in Table 1, below:

Table 1 Details of Serviced Engine Fuel Filter Elements

Operator	Filter Element ID	Location	Filter Element Service Time (Hours)	Filter Differential Pressure Indication	Tested for SAP?
A	A1	Europe	4020	N	Y
A	A2	Europe	4020	N	N
B	B1	Asia	Less than 5000	Y	Y
C	C1	North America	N/A	Y	Y
D	D1	Europe	3368	Y	Y
D	D2	Europe	2816	Y	N
E	E1	Asia	1678	Y	Y
E	E2	Asia	1678	Y	N
F	F1	North America	4675	Y	Y
G	G1	Europe	1463	Y	Y
G	G2	Europe	548	Y	N
G	G3	Europe	548	N	N
H	H1	Asia	N/A	N	N
H	H2	Asia	N/A	Y	Y

Note: Y = yes, N = no.

All 14 serviced filter elements were subjected to the procedure described in section 6.2(1). In addition, eight of the serviced filter elements were also evaluated for the presence of SAP, as indicated in Table 1, above, as per the procedure described in sections 6.2(2) and 6.2(3). The analyses were performed by external laboratories and the results of the evaluation are summarized in this report.

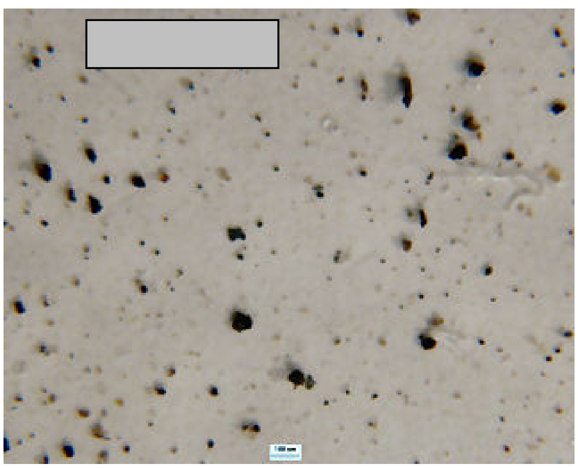
8.1.1 Summary of Results

8.1.2 Microscopic Examination for Solid Contamination from Filter Elements

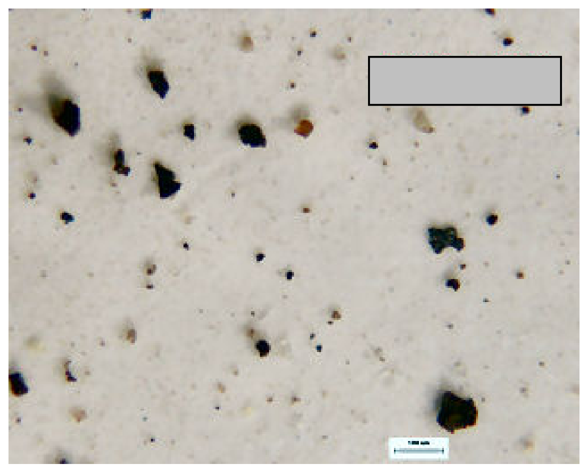
Microscopic examination of the contaminant on the analysis membranes, prepared by flushing contaminant from the submitted filter elements, showed the presence, predominantly, of four types of particulate contamination in varying amounts:

- Dark brown/black amorphous material
- Black particulate resembling oxidized ferrous material
- Shiny metallic particulate
- Translucent silica (sand) particulate

Figures 8-1 – 9 depict photomicrographs of representative contamination on the analysis membranes, corresponding to one of the submitted filter elements from each operator, at magnifications of 50X and 100X.

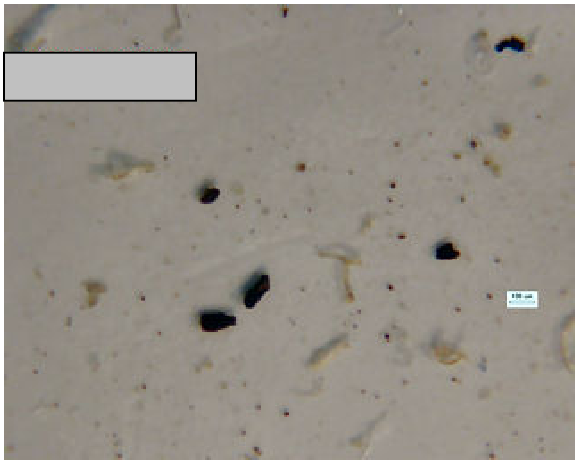


Magnification: ~ 50X
Scale: 100 µm

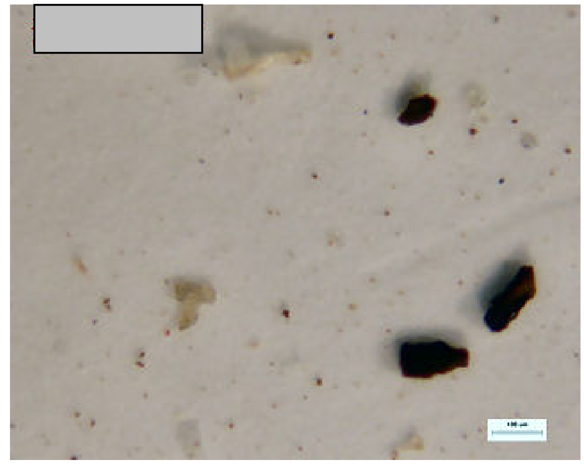


Magnification: ~ 100X
Scale: 100 µm

Figure 8-1 Photomicrographs depicting representative contamination on analysis membrane corresponding to engine fuel filter element A1, Operator A

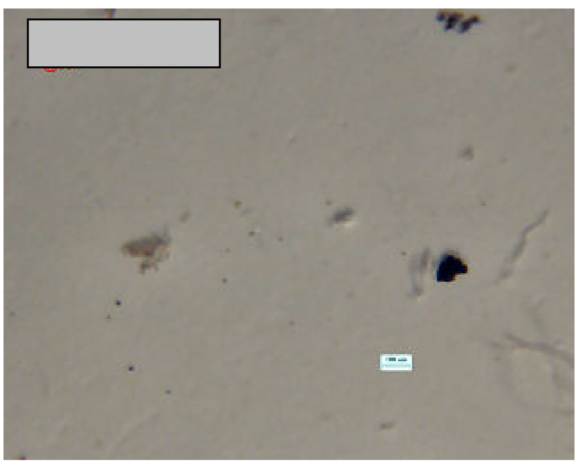


Magnification: ~ 50X
Scale: 100 µm

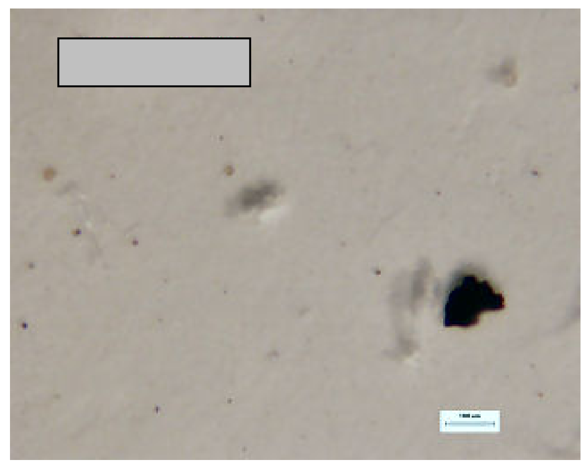


Magnification: ~ 100X
Scale: 100 µm

Figure 8-2 Photomicrographs depicting representative contamination on analysis membrane corresponding to engine fuel filter element B1, Operator B

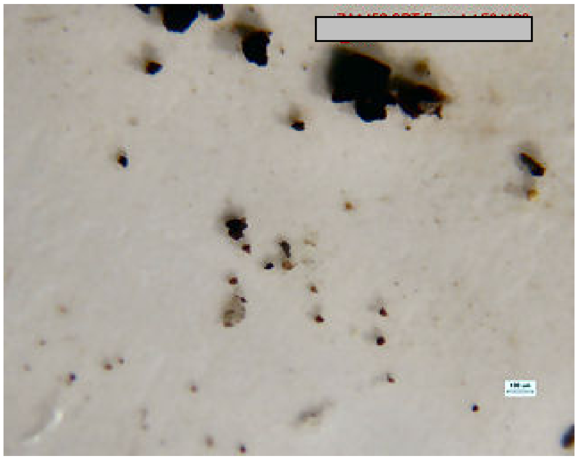


Magnification: ~ 50X
Scale: 100 µm

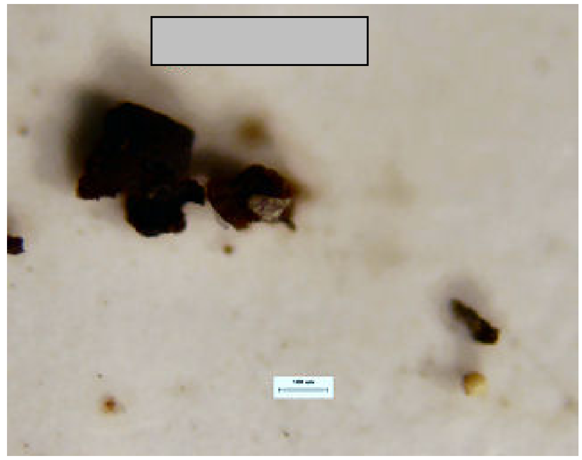


Magnification: ~ 100X
Scale: 100 µm

Figure 8-3 Photomicrographs depicting representative contamination on analysis membrane corresponding to engine fuel filter element C1, Operator C

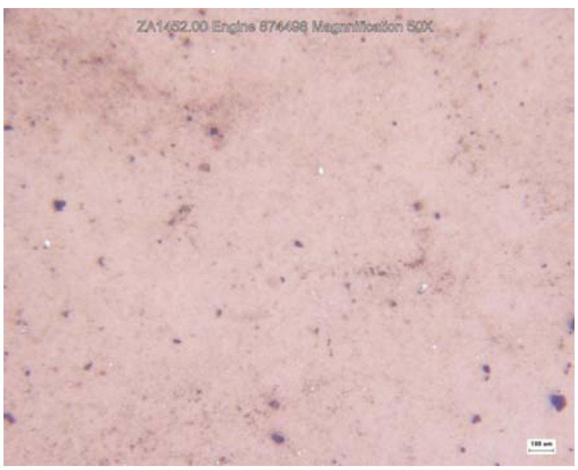


Magnification: ~ 50X
Scale: 100 µm

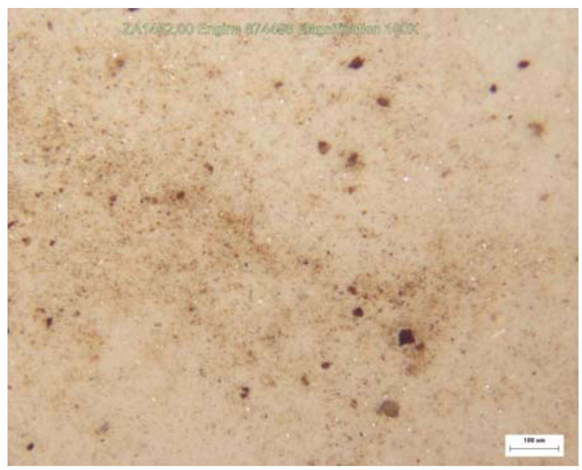


Magnification: ~ 100X
Scale: 100 µm

Figure 8-4 Photomicrographs depicting representative contamination on analysis membrane corresponding to engine fuel filter element D1, Operator D

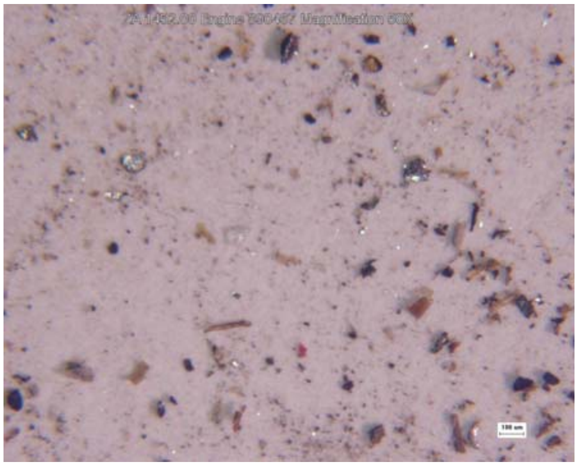


Magnification: ~ 50X
Scale: 100 µm

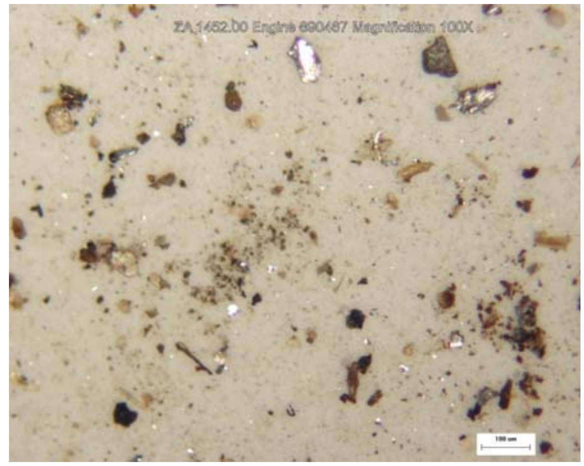


Magnification: ~ 100X
Scale: 100 µm

Figure 8-5: Photomicrographs depicting representative contamination on analysis membrane corresponding to engine fuel filter element from E1, Operator E

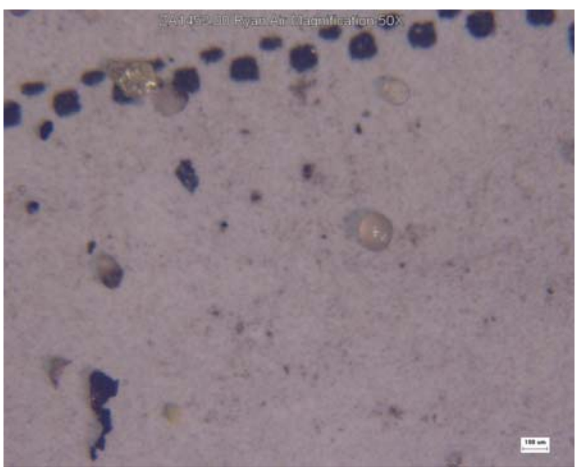


Magnification: ~ 50X
Scale: 100 μm

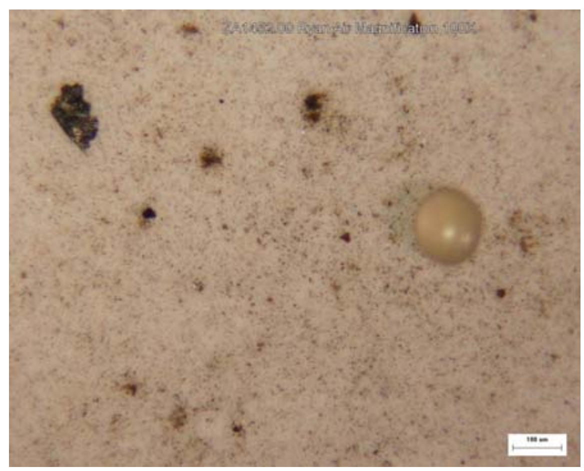


Magnification: ~ 100X
Scale: 100 μm

Figure 8-6 Photomicrographs depicting representative contamination on analysis membrane corresponding to engine fuel filter element F1, Operator F

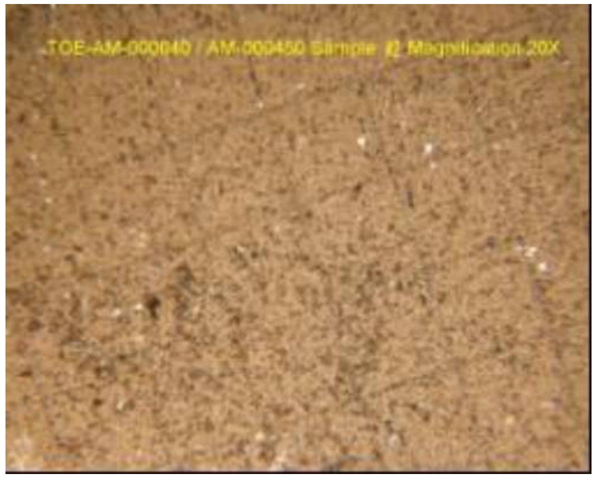


Magnification: ~ 50X
Scale: 100 μm



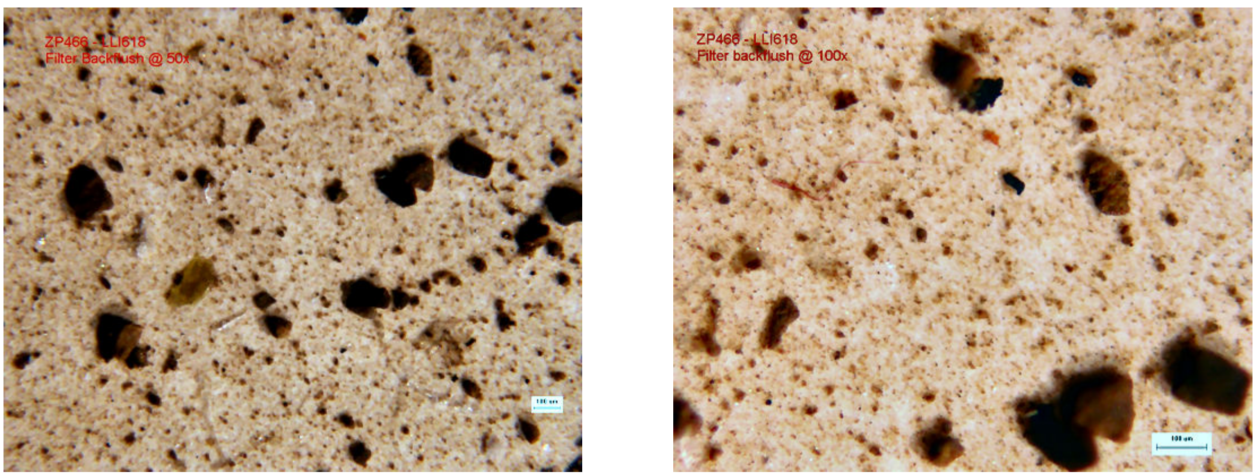
Magnification: ~ 100X
Scale: 100 μm

Figure 8-7 Photomicrographs depicting representative contamination on analysis membrane corresponding to engine fuel filter element G1, Operator G



Magnification: ~ 20X

Figure 8-8 Photomicrograph depicting cake of brown contaminant material removed from filter element G2, Operator G



Magnification:	~ 50X	Magnification:	~ 100X
Scale:	100 μm	Scale:	100 μm

Figure 8-9 Photomicrographs depicting representative contamination on analysis membrane corresponding to engine fuel filter element H2, Operator H

8.1.3 Percent Metallics and Particle Size Distribution

The particulate contamination on the analysis membrane was examined with incident (perpendicular) and oblique light under the optical microscope at 50X magnification. The relative percentage of particulates reflecting light with a metallic sheen was reported as the Percent Metallics. It should be noted that the Percent Metallics is based on the fraction of contaminant on the analysis membrane that exhibits a metallic sheen. Dark oxidized metallic particles may not exhibit a metallic sheen, and certain non-metallic particulates may exhibit a metallic sheen. Thus the Percent Metallics only provides a crude estimate of the percentage of metallic particulates.

The particle size distribution was determined, utilizing an Olympus BH-2 optical microscope, at a magnification of 400X. A total of 300 particles were sampled on the analysis membrane and sized; the longest dimension was recorded as the particle size.

It should be noted that the particle size distribution analysis of particulates in filter elements comprised of 'depth' type fiber matrix media may not provide a reliable estimate of the size distribution of the contaminant within the filter element. This is due to the potential non homogeneous distribution of contaminant within the filtration medium matrix, coupled with the very limited sampling of the contaminant in the filter element. Particle size distribution analyses are most reliable for homogeneous solid powders and solid contamination suspended homogeneously in liquids. Thus the particle size distribution analysis is of qualitative significance, at best.

The results are summarized in Table 2, below.

Table 2 Percent Metallics and Particle Size Distribution of Particulate Contamination

Filter ID	Percent Metallics (%)	Particle Size Distribution (Percentage of particles in indicated size range)				
		2–5 μm	5-15 μm	15-25 μm	25-50 μm	> 50 μm
A1	45-50	62.0	30.0	4.7	2.3	1.0
A2	50-55	61.4	30.5	4.6	2.3	1.0
B1	60-65	62.1	31.1	4.2	1.9	0.6
C1	40-45	70.4	25.4	2.9	1.0	0.3
D1	50-60	64.6	31.8	3.0	0.7	< 0.1
D2	60-65	58.9	32.7	5.3	2.3	0.7
E1	10	57.0	21.0	14.0	6.0	2.0
E2	50	47.1	33.3	10.0	5.4	4.2
F1	80	56.0	27.0	14.0	2.6	0.4
G1	30	49.0	32.0	11.0	3.0	5.0
G2	10	80.7	17.8	0.6	0.9	0.1
G3	60	54.7	31.7	10.3	2.2	1.1
H1	25	77.9	19.9	1.4	0.3	0.6
H2	< 5	39.0	41.0	9.0	5.0	6.0

8.1.4 SEM/EDX Analysis for Chemical Elemental Composition

The chemical composition of the solid particulate contamination, based on SEM/EDX analysis, is summarized in Table III, below.

Table 3 Chemical Elemental Composition of Particulate Contamination in Submitted Filter Elements

Filter Element ID	Chemical Elemental Composition of Contamination in Filter Element		
	Major Peaks	**Moderate Peaks**	**Minor Peaks**
A1	sulphur	iron, silicon, lead	zinc, silver
A2	sulphur	iron, aluminum, silicon, carbon, lead	zinc
B1	iron, silicon	aluminum, calcium, carbon	-
C1	sulphur, silicon, carbon	iron, aluminum	copper, zinc
D1	sulphur, iron	silicon, carbon	chromium
D2	sulphur, iron	aluminum	silicon, copper, calcium, cadmium
E1	sulphur	copper	iron, aluminum, cadmium, lead,
E2	sulphur, iron	silicon	aluminum, chromium
F1	aluminum, titanium, sulphur	silicon	lead, barium, calcium, chromium
G1	aluminum, Chlorine, sulphur	silicon	-
G2	sulphur, iron	calcium, carbon, aluminum, copper	silicon, Chlorine
G3	sulphur, iron	-	carbon, aluminum
H1	sulphur	iron, aluminum, copper	silicon, calcium, carbon, Chlorine
H2	sulphur, iron	carbon	silicon

8.1.5 Conclusions – solid contamination in filter elements

The predominant contaminant in the vast majority of plugged filter elements was a brown/black sulphurous material, often containing iron. In several instances the brown/black material formed a thick, 'sticky' cake when rinsed off the filter on to an analysis membrane. The sulphurous material may be sulfides, sulfites, sulphates, or sulfonates, possibly of iron or calcium

Aluminum, silicon, calcium and copper were also found, variously, in many of the filter elements, but in lower amounts.

The particle size distribution showed 90+ % of the particulate contamination to be below 25 μm, and 80+ % of the particulate contamination to be below 15 μm. With a few exceptions, less than 2 % of the particulate contamination was above 50 μm.

8.1.6 Non-volatile Residue from Water Extract of Contamination in Filter Elements

Eight of the filter elements, identified in Table 1, were evaluated per Appendix11. The samples were sent to an external laboratory for evaluation.

8.1.7 SEM/EDX Analysis for Chemical Elemental Composition

The chemical composition of the non-volatile residue from the water extract of the filter contamination, based on SEM/EDX analysis, is summarized in Table 4, below. The corresponding EDX spectra are included in Appendix 21. For a rough estimate of the relative elemental concentration of the main constituents in the debris, Table 4 lists the results of the semi-quantitative EDX analyses.

Table 4 Element Analysis of Non-volatile residue Samples by SEM-EDX. (Results normalized to 100% without carbon)

Filter Element ID	%O	%Na	%Mg	%Al	%S	%Cl	%K	%Ca	%Mn	%Fe	%Cu	%Zn
A1	**43.1**	**24.2**	0.3	0.3	**25.1**	1.7	**2.4**	2.5	0.4	--	--	--
B1	**37.9**	**19.4**	1.3	0.6	**21.0**	10.0	**2.3**	2.7	0.5	0.4	1.8	2.1
C1	**48.2**	**11.6**	5.3	0.4	**24.9**	1.0	**1.4**	4.2	0.4	0.3	1.1	1.1
D1	**41.6**	**20.2**	1.4	0.5	**20.3**	10.8	**2.2**	1.1	0.6	0.4	--	0.9
E1	**44.5**	**14.3**	2.0	0.8	**22.7**	6.0	**2.7**	3.6	--	1.3	0.6	1.4
F1	**41.0**	**12.3**	--	0.4	**19.3**	15.1	**3.6**	3.5	--	--	1.3	3.5
G1	**32.4**	**20.1**	1.4	0.4	**14.5**	22.9	**1.6**	3.1	0.2	0.6	1.1	1.7
H2	**44.2**	**15.6**	1.4	--	**23.6**	2.1	**1.7**	5.4	0.6	--	2.0	3.3

8.1.8 FT-IR Spectroscopic Analysis for Organic Functional Groups

Figure 8-10 shows the FT-IR spectra acquired for the eight samples. In addition to the vibrations noted on each spectrum (possibly indicating carboxyl groups), each residue spectrum also contains strong bands between 1000-1200 cm^{-1}. Vibrations in this region may be caused by sulphur to oxygen bonding, such as seen in sulphates. Note the EDX analyses detected a large concentration of sulphur and oxygen in all the residues.

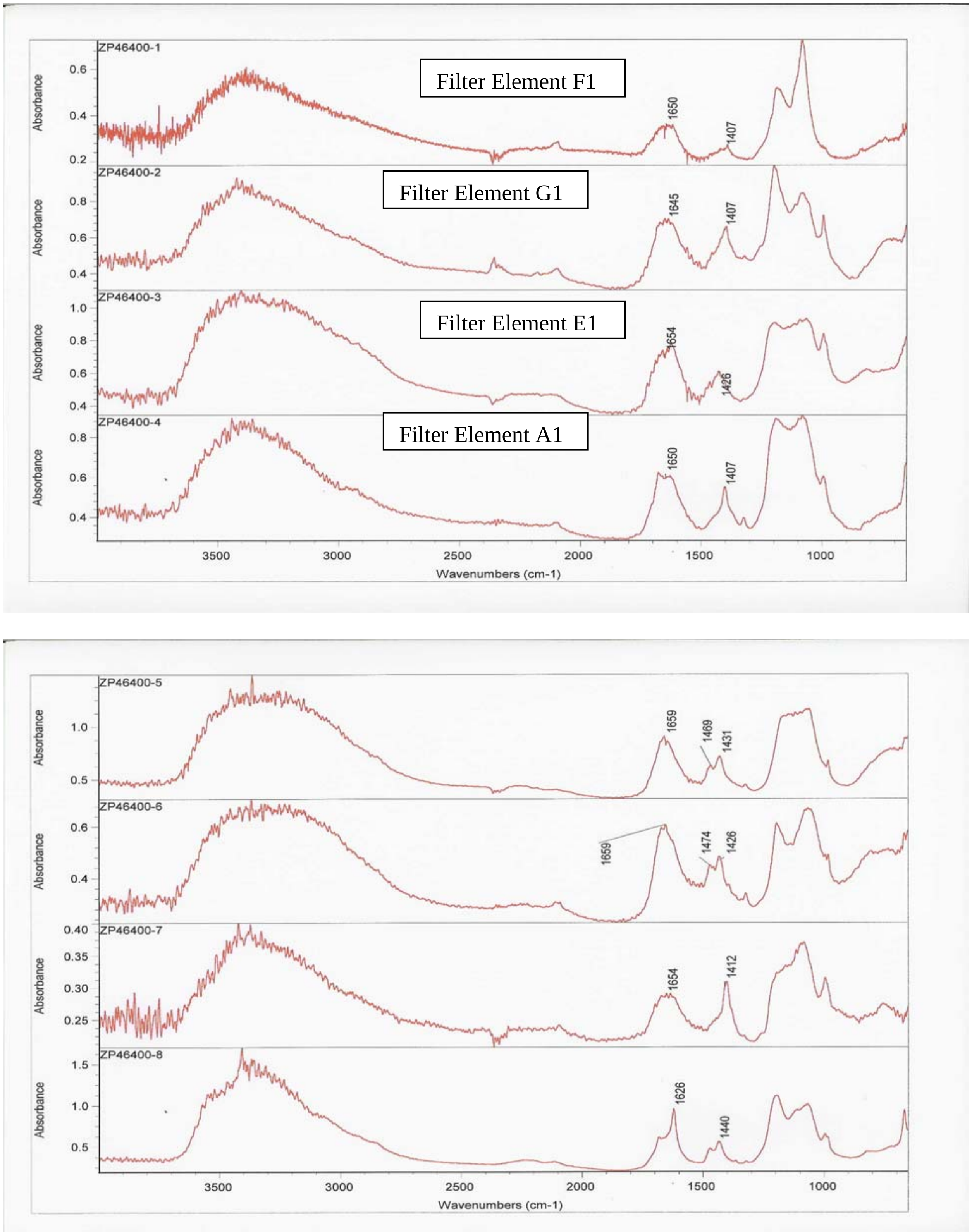


Figure 8-10 FT-IR Spectra of Non-volatile Residue Samples from the Water Extract.

8.1.9 Copper Sulphate Test for SAP in Filter Contamination

The first five filter elements, A1 – E1 were evaluated using the copper sulphate test. The contamination from A1 showed the most blue adduct (attributed to SAP) while the contamination from B1 had the least. Filter elements C1 –E1 exhibited amounts in between the two, roughly the same in each case. Photomicrographs showing the blue copper sulphate adduct (attributed to SAP) are depicted in Figures 8-11 – 8-15, below:

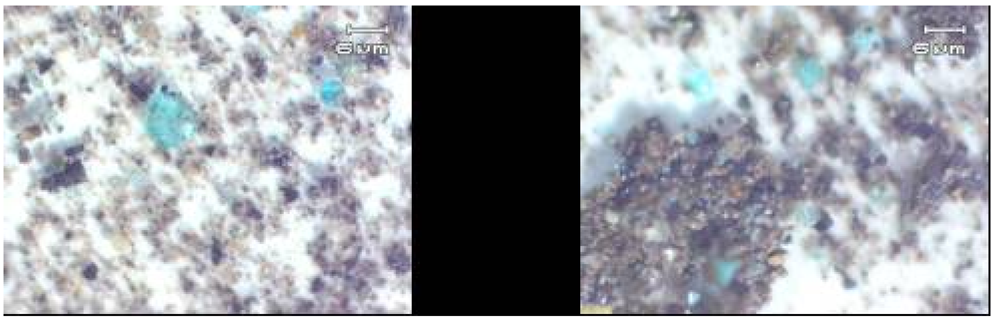


Figure 8-11 Photomicrographs depicting blue copper sulphate adduct (attributed to SAP) in engine fuel filter element A1

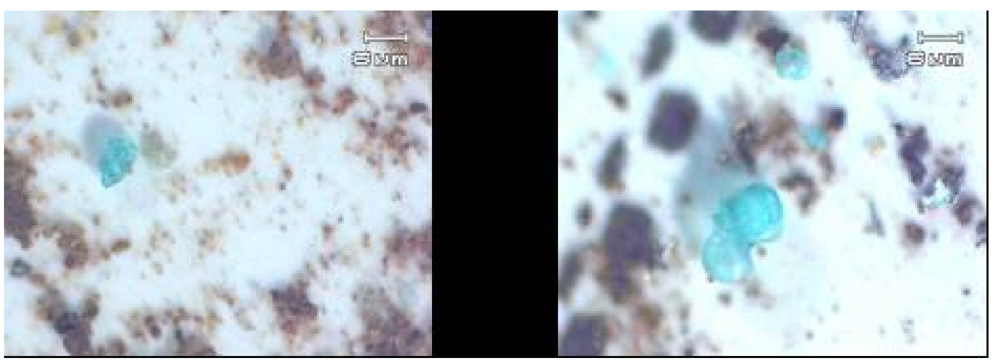


Figure 8-12 Photomicrographs depicting blue copper sulphate-SAP adduct (attributed to SAP) in engine fuel filter elements B1 (Left) and C1 (Right)

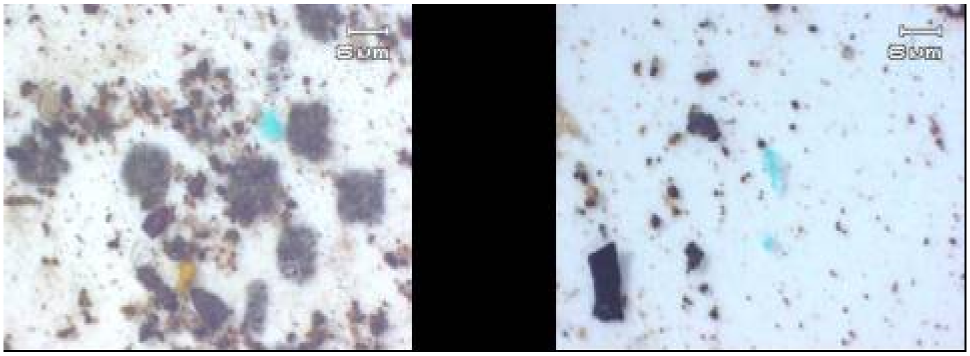


Figure 8-13 Photomicrographs depicting blue copper sulphate-SAP adduct (attributed to SAP) in engine fuel filter elements D1 (Left) and E1 (Right)

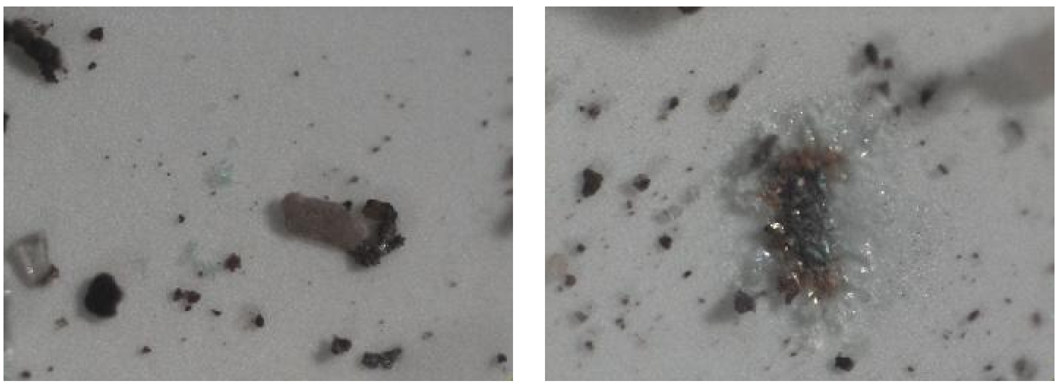


Figure 8-14 Photomicrographs depicting blue copper sulphate – SAP adduct (attributed to SAP) in engine fuel filter elements F1 (Left) and G1 (Right)

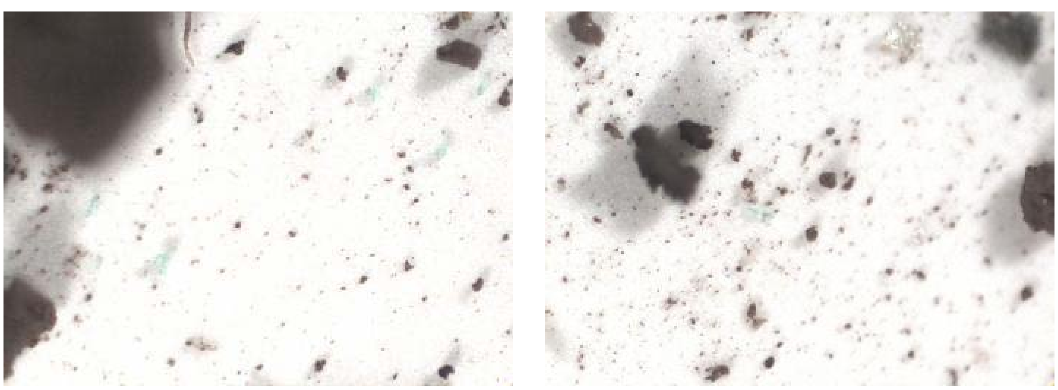


Figure 8-15 Photomicrographs depicting blue copper sulphate-SAP adduct (attributed to SAP) in engine fuel filter elements H1 (both pictures)

8.1.10 Conclusions – Non-volatile Residue from Water Extract of Contamination in Filter Elements

The non-volatile residue showed amounts of sodium along with lesser amounts of potassium. The FT-IR spectra showed peaks in the 1400 ± 40 cm^{-1} and 1620 ± 60 cm^{-1} wave numbers that could be indicative of carboxyl functional groups in carboxylic acid salts. The presence of sodium and potassium in conjunction with the above peaks may be suggestive of the presence of SAP.

In addition to the above, significant amounts of sulphur and oxygen were found in the non-volatile residue, and the FT-IR spectra also showed peaks in the 1000-1200 cm^{-1} region. The above may be indicative of sulphur-oxygen compounds such as sulphates.

The copper sulphate test showed varying amounts of blue copper sulphate adduct (attributed to SAP), with filter element A1 exhibiting the highest concentration and filter element B1 exhibiting the lowest concentration of the five filter elements A1 – E1.

8.2 Air BP Filter Debris Analysis

Air BP provided analysis on four used engine fuel filters from Operator P. Three of the filters were from Boeing 737 aircraft and one from Boeing 767. The engine fuel filter impending by-pass warning light illuminated during the flight, indicating increase differential pressure across the filter. The analysis was conducted to determine whether SAP and any other solids were present in the filter folds. The next section discusses the main findings of the analysis. A full report is provided in Appendix 22.

8.2.1 Analysis of Filter Blockage

Initial examination of the filter indicated that some white fibrous material was present in the folds. Figure 8-16 shows fibers from the filter surface. Some of this was removed with forceps, rinsed with pentane (a solvent) and analysed using Fourier Transform Infrared Spectroscopy, Light Microscopy and Scanning Electron Microscopy.

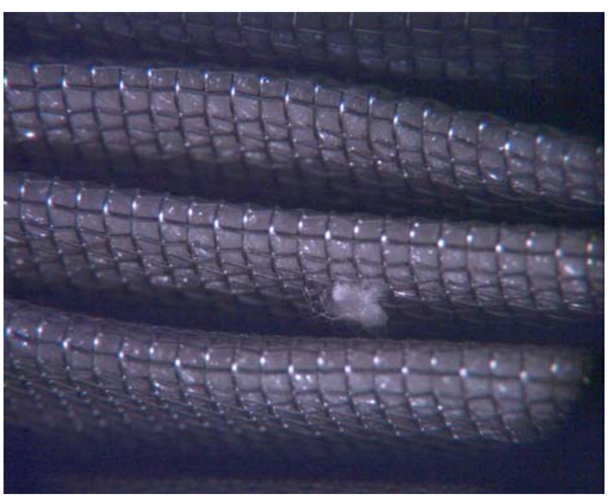


Figure 8-16 White fibrous material in filter fold

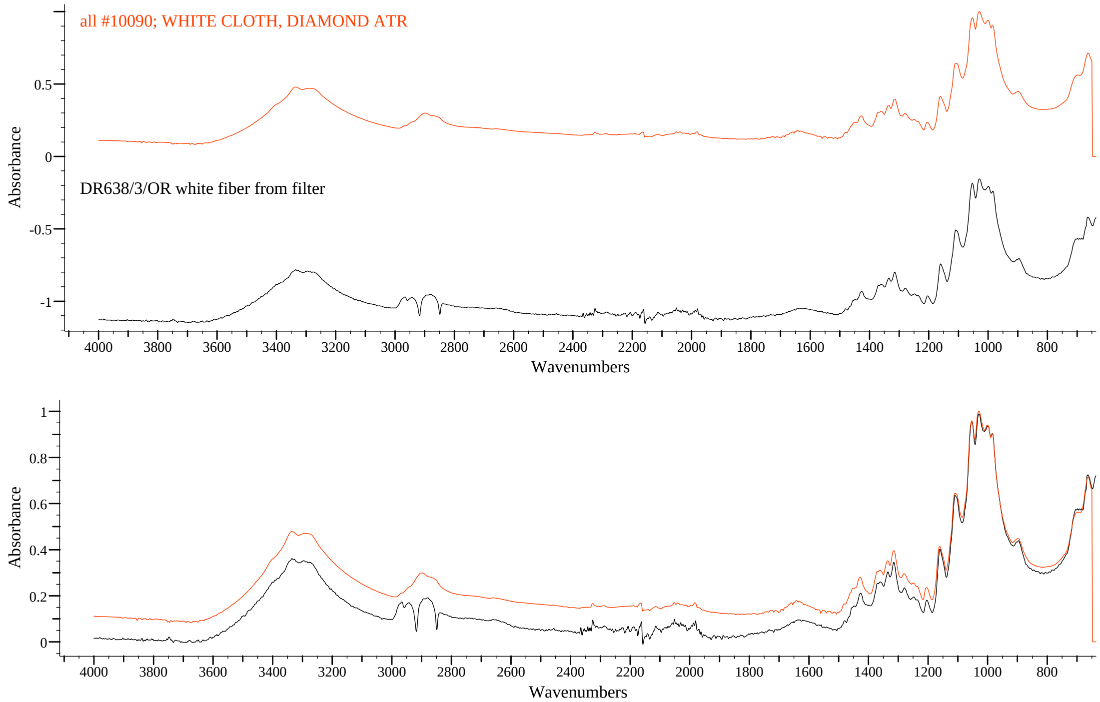


Figure 8-17 IR spectrum of white fibers taken from filter folds compared with white cloth, spectra collected on diamond ATR

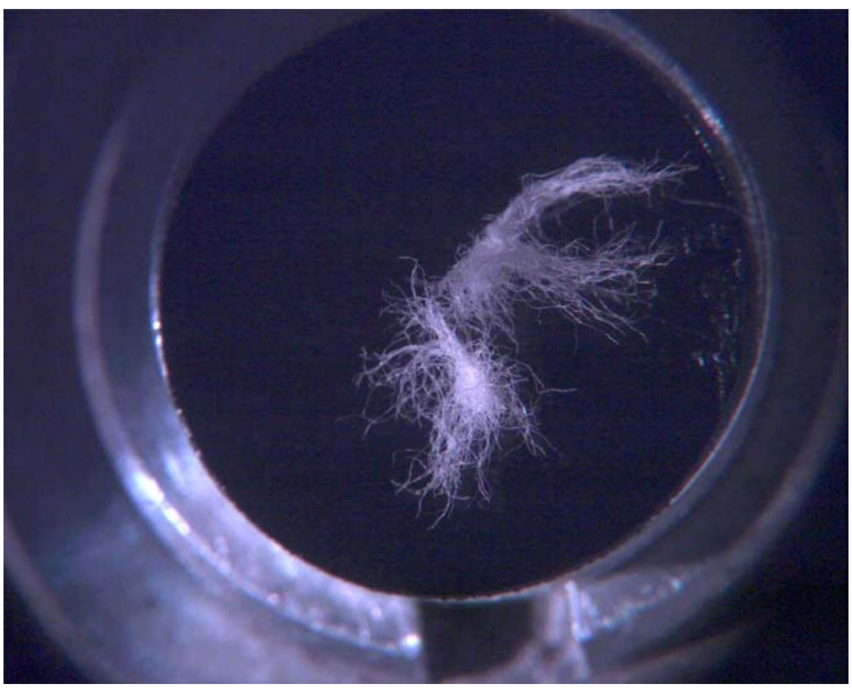


Figure 8-18 Light microscope image of white fibres on SEM stub (Stub diameter = 140mm)

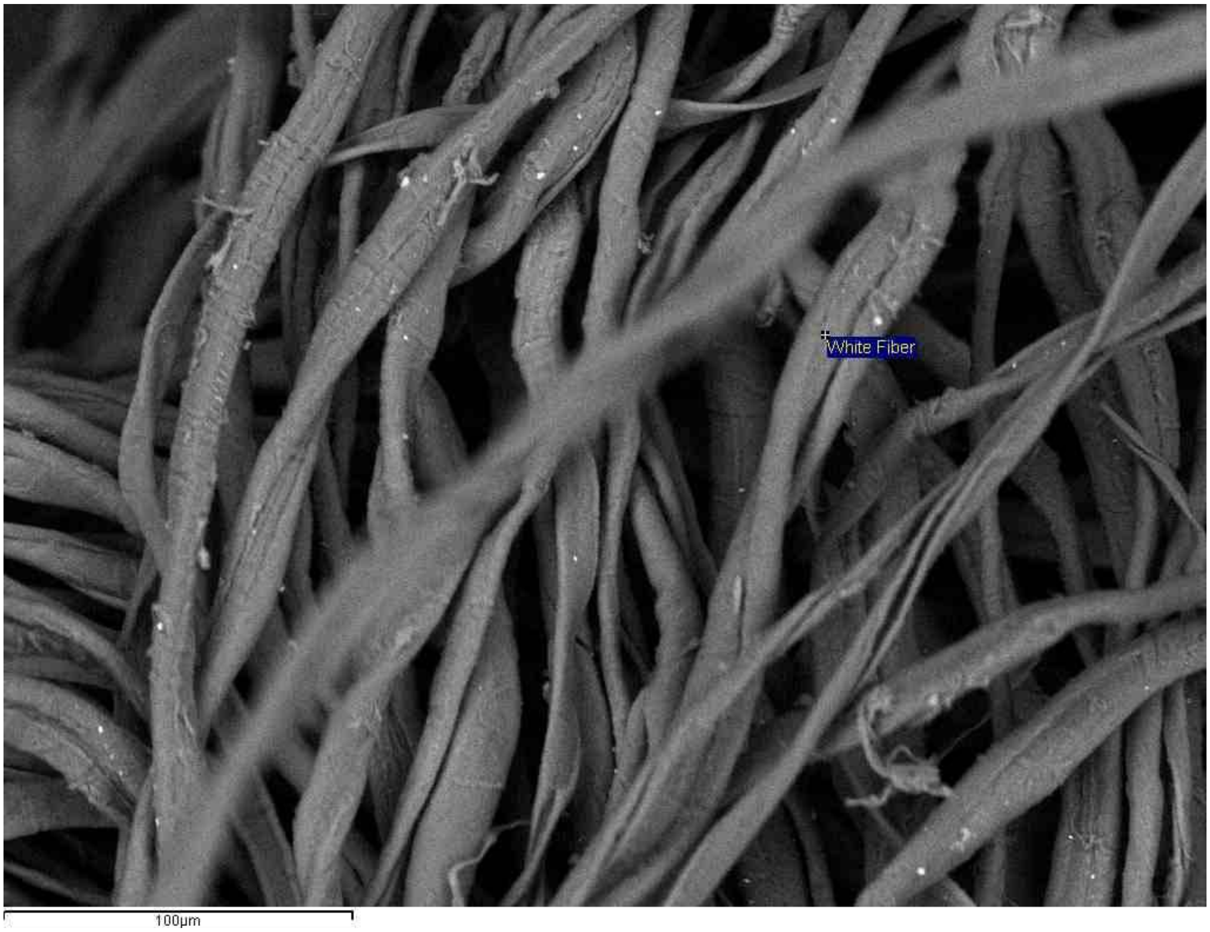


Figure 8-19 Electron Microscope Image of White fibres.

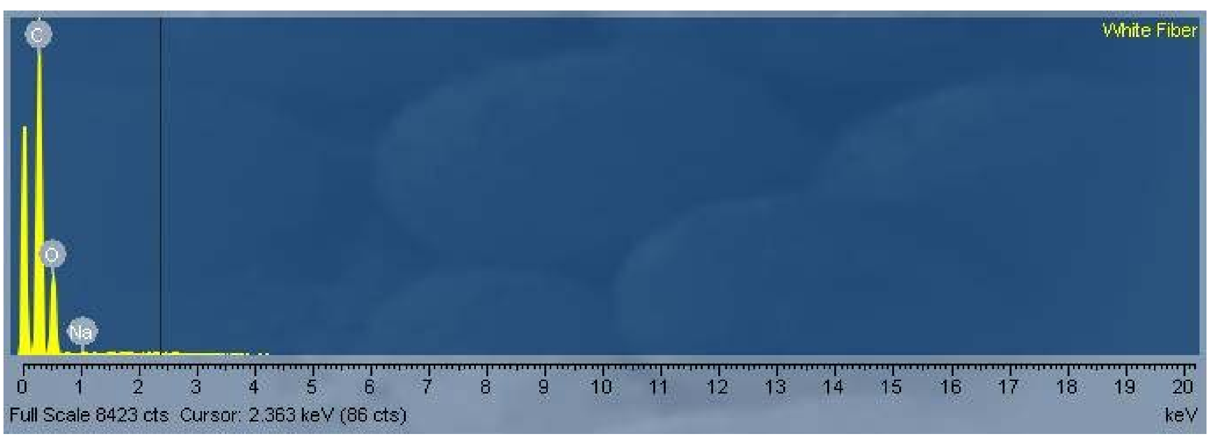


Figure 8-20 X-ray spectrum of white fibre

Result: The white fibers differ in size, shape and composition to the reference SAPs. The white fibers appear to be cloth fragments.

8.2.2 IR Spectrum Analysis

IR spectra were collected of the solid debris on a diamond ATR crystal. The three solid debris samples show very similar spectra to each other. The IR spectra of the solid debris (Fig. 8-21) do not match those of the reference SAPs (Fig. 8-22)

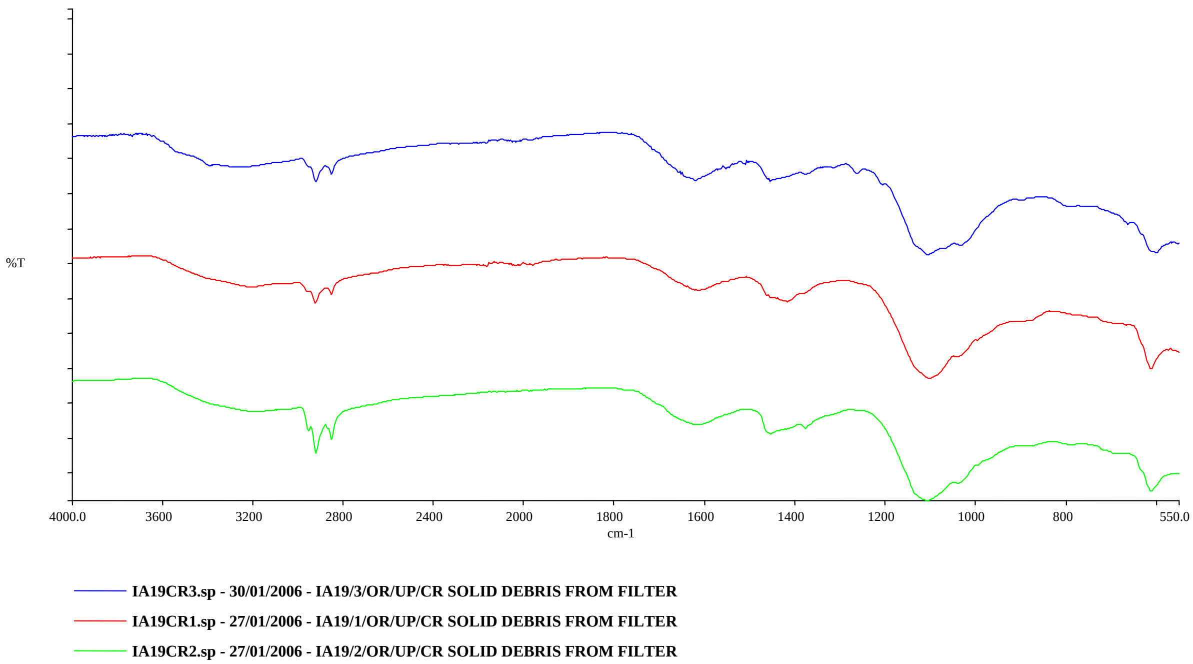


Figure 8-21 IR spectra of solid debris from the three filters

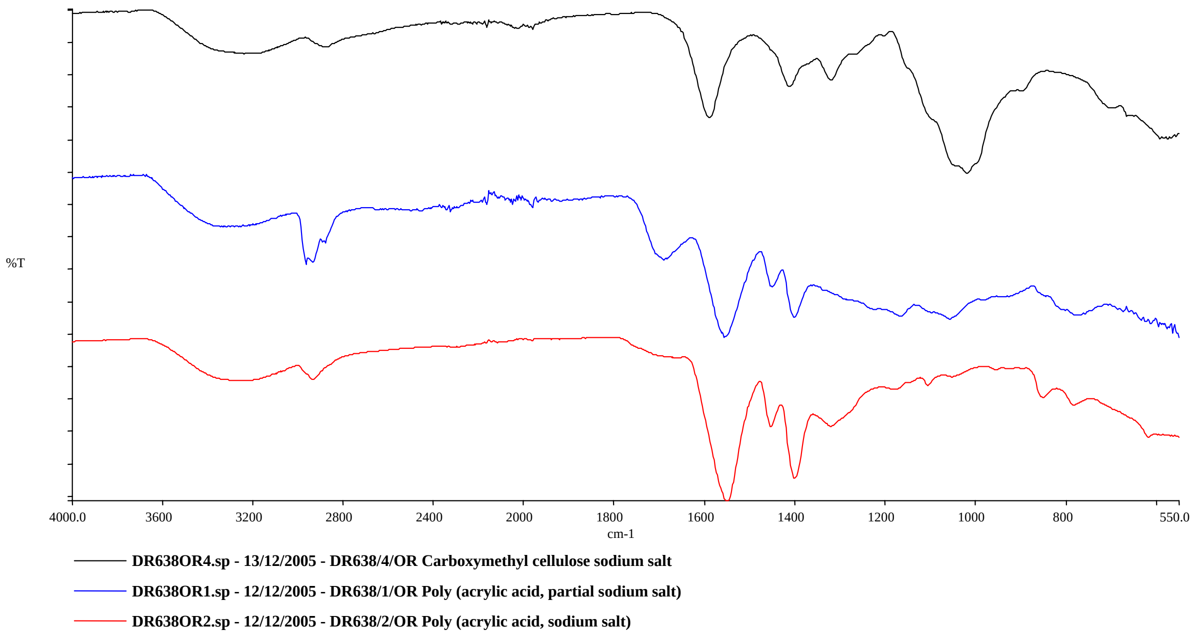


Figure 8-22 IR spectra of reference SAP materials, collected on diamond ATR

8.2.3 Conclusions:

Some white cloth fibers were present on the filter surface. Further fibers were present in material extracted from inside the filter.

Analysis of the filter extract indicates that amorphous solid debris appears to make up the bulk of the blockage. While this contains sodium, there is no evidence for the presence of SAP in the IR spectrum analysis of the debris.

The debris appears to have a high level of Chlorine, indicating that the sodium may be present as common salt.

Iron seems more abundant than Sodium, both by ICP and SEM. Ferrous corrosion salts may be at least partly responsible for the blockage. Some of the other elements such as silicon and aluminium could be due to dust.

8.3 Chevron/South West Research Institute (SWRI) Engine fuel filter Debris Analysis

SWRI analyzed 34 used filters provided by 5 international carriers. Of the 34 engine fuel filters analyzed, 5 did not have positive proof of presence of SAP. For 2 filters, it was unknown, as the copper sulphate tests were not performed. 27 filters had positive indication of SAP. The main contaminant was sand, clays, sulphates with SAP a very minor constituent.

The next sections discuss the main findings from a typical sample that showed positive indication of SAP. A summary of the results and the individual analysis for the 34 filters are provided in Appendix 23

8.3.1 Operator R Sample:

Sample: SwRI CL # 06-0145
Airline – Operator R
Aircraft ID – R8399
Engine ID – GE90-94B
Filter time on aircraft, hours – 3,418
Filter Part Number – AC9227F1740
Comments – 2,690 cycles

8.3.2 Debris Analysis

Toluene Acetone Methanol soluble materials, wt% - 11.72 %

Table 5 Elemental Analysis –filter – wt%

Element	wt %
Carbon, C	---
Sodium, Na	9.61
Magnesium, Mg	4.46
Aluminum, Al	15.33
Silica, Si	17.01
Phosphorus, P	---
Sulphur, S	27.47
Chlorine, Cl	1.84
Potassium, K	2.1
Calcium, Ca	4.69
Titanium, Ti	0.84
Chromium, Cr	1.33
Manganese, Mn	---
Iron, Fe	14.26
Nickel, Ni	---
Copper, Cu	---
Zinc, Zn	1.05
Cadmium, Cd	---
Barium, Ba	---

Strontium, Sr	---
Vanadium, V	---
Tin, Sn	---

Table 6 Elemental Analysis – water wash –wt%

Element	wt %
Carbon, C	---
Sodium, Na	21.08
Magnesium, Mg	4.25
Aluminum, Al	1.55
Silica, Si	---
Phosphorus, P	---
Sulphur, S	43.93
Chlorine, Cl	7.64
Potassium, K	2.29
Calcium, Ca	4.86
Titanium, Ti	---
Chromium, Cr	---
Manganese, Mn	0.46
Iron, Fe	2.4
Nickel, Ni	0.29
Copper, Cu	0.24
Zinc, Zn	2.61
Cadmium, Cd	---
Barium, Ba	---
Strontium, Sr	---
Vanadium, V	---

Table 7 Compositional Analysis - XRD

Compositional Analysis	Major Presence
Carbon	---
Aluminum, Al	X
Iron, Fe	X
$CaCO_3$	---
SiO_2	X
Ca_2SiO_4	---
$FeSO_4$	---
$CuSiO_3$	---
Fe_2SO_4	---
Na_2SO_4	X
$CaSO_4$	---
FeS	X
$Na_4Ca(SO_4)$	---
$MgCO_3$	---

$Na_2Ca_3Al_2O_6$	---
$NaHSO_4$	---
$NaZnSO_4$	---
FeO(OH)	---
Na_2CO_3	---
NaCl	---
$FeCO_3$	---
$NaCS_3$	---
KSCN	---
K_2FEO_4	---
$Na_6(CO_3)_2SO_4$	---
$K_3Fe(CN)_6$	---
$ZnSO_4$	---

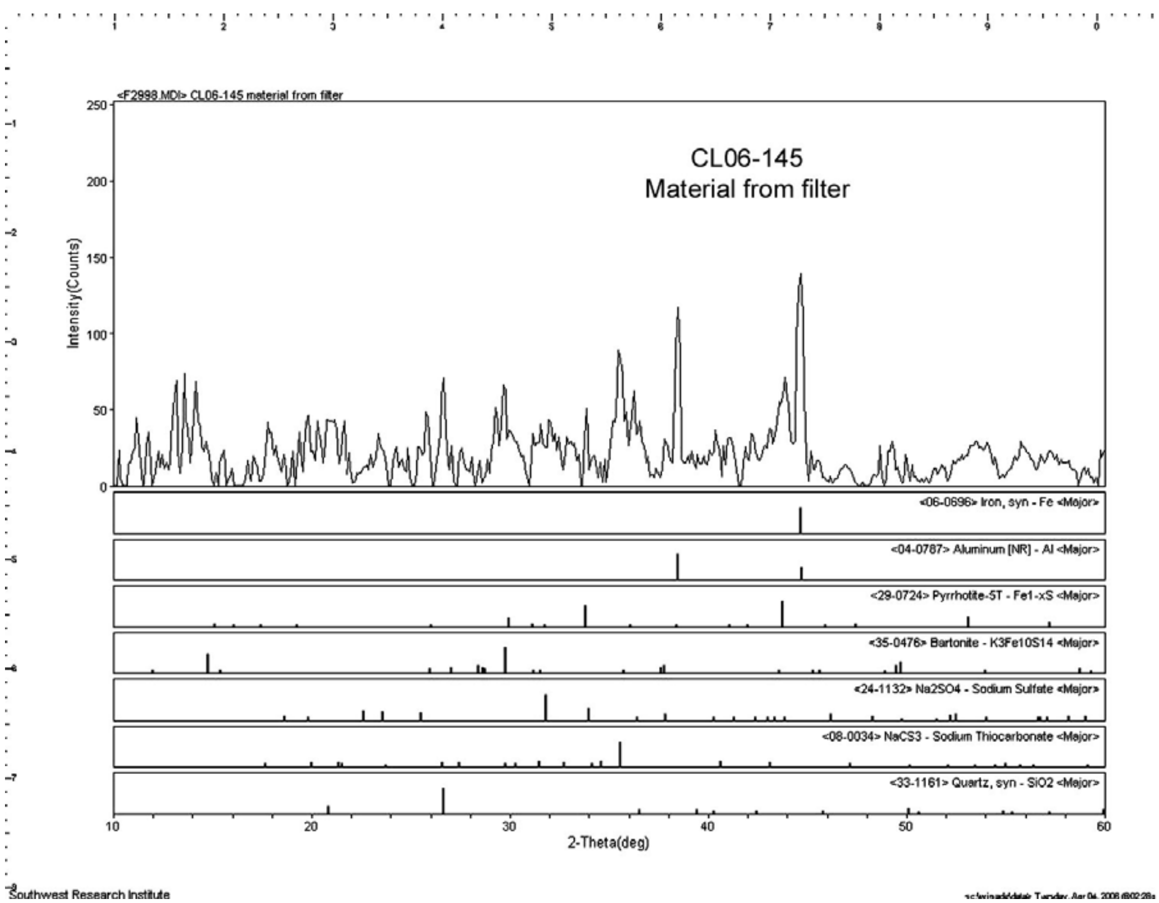


Figure 8-23 XRD Analysis

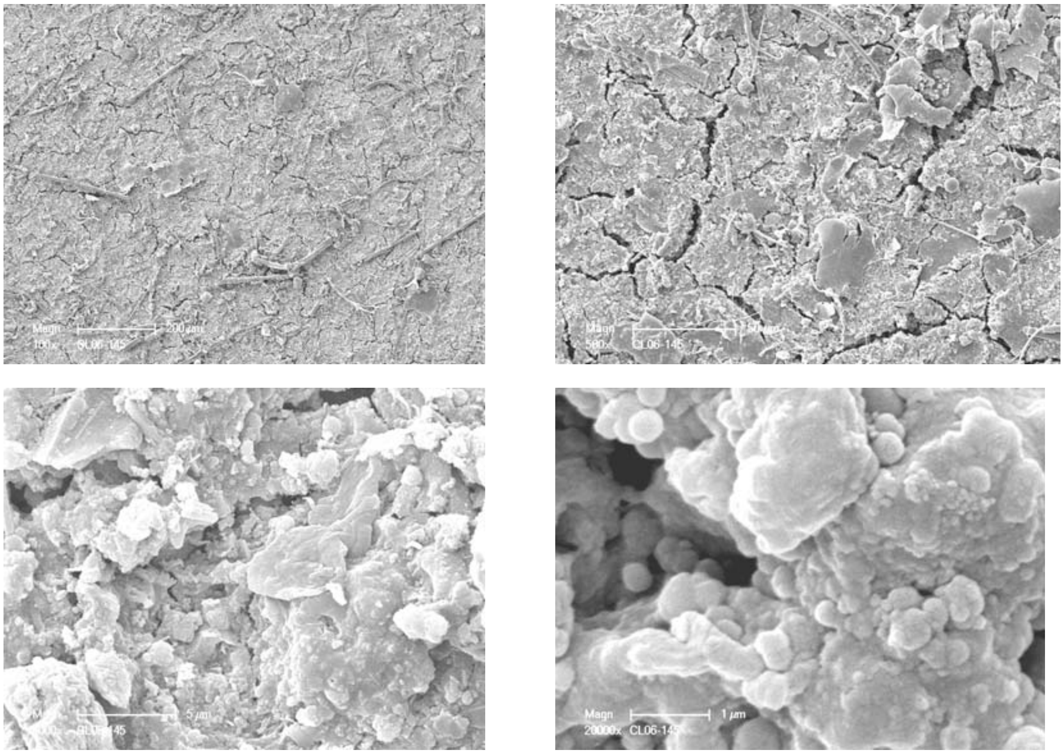


Figure 8-24 Scanning Electron Microscope Images

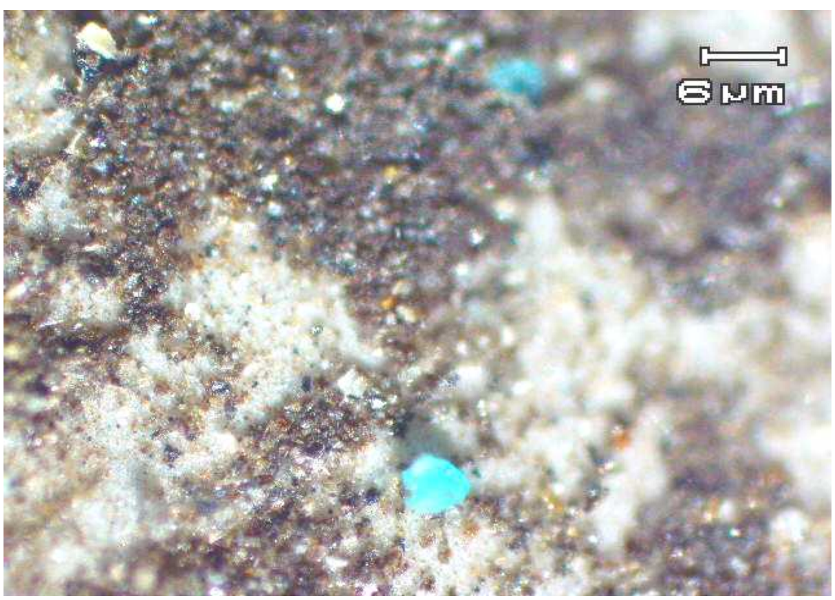


Figure 8-25 Optical Picture – Copper Sulphate Exposure

8.4 SwRI Report on Analysis of Operator Q's Used Engine fuel filters (see Appendix 24)

SwRI examined 5 used filters submitted by Operator Q. The following analyses were performed:

- Visual inspection
- XRF and SEM
- XRD
- FTIR
- Optical documentation
- FTIR and XRF on water wash
- NMR

The main constituents plugging the subject engine fuel filters appeared to be sands and clays. However, based on NMR, XRF, and FTIR data, there were water-soluble contaminants present in all supplied engine fuel filters.

8.5 ExxonMobil Used Aircraft Filter Analysis

ExxonMobil Research and Engineering (EMRE) conducted a comprehensive investigation of 2 plugged filters taken from aircraft which had been fueled through monitors. These filters were provided by Operator Q. In addition, SwRI and EMRE collaborated to determine the presence/absence of SAP in field samples, in-house testing, and on an aircraft filter which showed evidence of polymer.

Laboratory tests were conducted to:

1) Assess the composition of materials plugging the filters and
2) Demonstrate the presence/absence of SAP.

The main findings of the EMRE investigation are summarised below. The full report is provided in Appendix 25.

8.5.1 Conclusions

- Test results indicate that the material plugging Operator Q's filters is mainly composed of sulphur, sodium, and silicon. Sulphur and silicon are elements which are not present in SAP. Currently it is unknown where the bulk of these materials come from.
- There is evidence of SAP on aircraft filters but these materials occur in low concentration and as discrete pieces. Therefore the bulk of the filter constriction is from unidentified materials, not SAP.
- Based on these studies, the SAP appears to behave as a small amount of particulate dirt contamination and does not significantly contribute to filter plugging
- Debris was initially extracted through sonication of each filter in a variety of solvents. The extracted debris was filtered, dried, and submitted for XRF/IR analysis. The debris was also soaked in a CuSO4/water solution. There was no indication of SAP in either of Operator Q's filter.
- There was indication of a few blue specks in the SwRI aircraft filter debris.
- De-ionized water was also used to extract any water soluble materials in the filters. The solutions were filtered and the resulting fluid (free of large dirt particles) was dried. A residue resulted upon drying of the filtrate. The residue was analyzed with XRF/IR and was also soaked in a CuSO4 solution. One of Operator Q's filters had no visible sign of SAP upon CuSO4 treatment; however, a small blue speck was discovered in the debris of the second filter.

- The SwRI residue also contained a small amount of blue specks upon $CuSO_4$ treatment.
- The FTIR spectra of both Operator Q's water residue samples showed a peak at 1634 cm^{-1}.This carbonyl peak can be an indication of SAP. The water extract was methylated and the peak shifted to a position of 1734 cm-1. This indicates an acid was present and provides evidence of the presence of SAP.
- There were a small number of blue specks which were visible upon $CuSO_4$ treatment of the SwRI residues. SwRI had found more particles of SAP in their analysis of the same filter. It is believed that the variance in the results is due to the non-homogeneous distribution of SAP specks in the different samples tested. The blue specks which were discovered through EMRE analysis were separated from the debris and analyzed by microscopic IR. The samples IR contained peaks that are also found with pure polymers such as polyacrylate and carboxymethyl cellulose. This indicates the blue material present on the filter is SAP and may be a mixture of polymers.

8.6 Boeing Test Results

Between January and June 2006, Boeing tested 3 engine fuel filters in house using the same testing techniques used by PALL and SwRI. The filters were examined under a microscope, solvent and water were used to extract materials, then EPMA and FTIR analysis were used to identify the elements and organic compounds. The copper sulphate test was not performed on the Boeing filters, because it had not been implemented for use at that time.

None of these filters produced the correct FTIR signature for SAP. The Boeing test results are shown in Appendix 26.

Filters tested before January 2006 were not examined for SAP. It should be noted that all filters tested by Boeing have shown silicates, sulphates, salts, and iron oxides.

Four types of contaminates have been found on every filter Boeing has tested for the past 10 years. They are:

- Silicates; basically dust, dirt, and sand. The silicate particles are typically 0.5 to 5 microns in size.

- Sulphates; (water soluble, polar molecules. Sulphates can be produced from microbial growth (Anaerobic Bacteria) found in storage tanks, fuel delivery systems and aircraft fuel tanks.

- Iron oxide; rust. is associated with rusting tanks and piping from the ground based fuelling system; note that the airplane uses aluminium tubing.

- Salts; sodium or potassium chloride. Salts are often associated with salt dryers or contamination from salt water or salt laden air.

8.7 Sofrance Test Results

Sofrance investigated contaminates on engine fuel filter elements received during 2006 from various operators. Its examination sequence involved gravimetry, granulometry and particle identification. Observations of the media using a microscope showed that the media is clogged with organic mud particles. The remaining contaminants were typical of fuel contamination found in other tests such as metal, oxide, sand and paint. It is to be noted that a high distribution of contaminants was observed between 5 to 50 µm and principally between 5 to 15 µm. The report from Sofrance is provided in Appendix 27.

8.8 U.S Air Force and U.S Navy

The Air Force and Chevron initiated a joint effort to determine if SA polymer media migrates from the type of filter monitors used by commercial aviation. This work was performed by the Southwest Research Institute and involved the operation of an Air Force filter monitor housing containing 22 of the 2-inch diameter commercial aviation monitors. These monitors were exposed to a 20% rated flow of clean Jet-A fuel (without FSII (fuel system icing inhibitor) additive) with stop/starts taking place at evenly spaced intervals in order to simulate a real-world scenario. A side stream of this flow was directed through a membrane filter to trap a sample of any solid materials that may have become entrained in the fuel. The results of this work suggested that commercial filter monitors from a variety of vendors all displayed to some degree the migration of SA polymer media under these flow conditions.

The U.S Navy utilized a single element test rig to investigate the potential for SA polymer media migration from 2-, 4-, and 6-inch diameter filter monitor elements from a variety of manufacturers. The analyses of water and fuel samples were referenced to known standards for carboxymethylcellulose and polyacrylate polymers. The analyses revealed that all downstream water samples and some downstream fuel samples contained media that had migrated from the monitors. The Navy has concluded that the migration of SA polymer media can indeed occur.

The experiences and investigative work of the US Air Force and US Navy have demonstrated that SA polymer media can migrate from filter monitors either in the presence or absence of FSII. Moreover, experimental work has suggested that this migration can occur in both military and commercial-type monitors under the real-world conditions of refuelling operations. Efforts to quantify the amount of this media in engine filters or sump samples even under controlled conditions have proven to be very difficult. Additionally, the presence of this media could be masked by any accompanying inorganic and/or microbial contamination.

8.9 Neste Oil Results

Neste Oil analysed an in-service engine fuel filter from an MD11 provided by Operator S and compared the results with the analysis performed on a test filter that was installed at a refueller downstream of the filter monitor. The in-service filter from the MD11 had been used for 1169 flying hours with about 3 million liters of jet fuel having been filtered through it. The test filter element mounted on the refueller was similar as the filter element of the MD11
About 3 million liters of jet fuel was filtered through this filter during the test period. During the same period, 31 of November 2005 to 15 February 2006, as the test filter was installed, the MD 11 aircraft had been refueled internationally for 340 times.

The differential pressure over the refueller test filter was monitored, only nominal rise was found. Amount of impurities on the test filter was very low in comparison with the impurities found on the aircraft filter. The main impurities are sulphonic acids, sulphonates and sulphates, but no potassium. The report concluded that jet fuel of Neste Oil does not contain abnormal amounts of sulphonic acids, sulphonates and sulphates and that foreign jet fuels contain more sulphonic acids, sulphonates and sulphates. Moreover, according to the report, the formation of sulphonic acids, sulphonates and sulphates take places mainly in the plane because the heating of jet fuel in the aircraft accelerates oxidation of sulphur compounds. Neste Oil's report is provided in Appendix 28

8.10 Results from Operator T

The international airline established a “Clogged Fuel Filter Management’ unit within the Engineering department and investigated independently the clogged filter events since November 2005. Operator T had 14 events of clogged filters involving B737, B767, A319, A320, A321 aircraft. The tests were conducted at various laboratories. Over all the contamination was not water or bacteria. On the B 767 filters the contaminants were found to be ‘clay-like’ material and ‘glass beads (airport signage material)’. On the fuel samples taken from the B737 where fuel quantity indications problems were observed, the contaminant was a ‘thick material’ identified as dipropylene glycol. The service life of clogged filters ranged from 815-2904 hours. Consequently the airline reduced its filter change interval as follows:

Table 8 Operator T Filter Change Interval

Aircraft type	Filter change interval
B737	5600 hrs => 1500=> 750
B767	4000 => 2000
A319/320/321	6000 => 1650
B757	6000 => 2000
A330	5600 => 1800

9 Stakeholders Recommendations

The results of the surveys and analyses prompted the following recommendations by the Task Force members and the various industry segments they represent. Their inputs and key recommendations are summarised in this chapter.

9.1 Airlines

The participating airlines contributing to the Airline Report (see Appendix 29) are the Air Transport Association, American Airlines, British Airways, Continental Airlines, Finnair, Frontier Airlines, Japan Airlines, Lufthansa, My Travel, Southwest Airlines and US Airways.

1) A committee should be established that would be responsible for overseeing the developments and define the standard by which to evaluate requirements for fuel quality and cleanliness at or before the airplane's fuel tanks. This development should include evaluating the benefits of further industry actions as well as the potential costs of achieving such actions.

2) The fuel filter monitor manufacturers should work to possibly improve their designs or research and develop another water absorbent type of element that will eliminate the release of monitor media (SAP), or replace this design type of water absorbent media.

3) An alternative to water absorbent filtration method is to use filter water separators on the fueling equipment. If the existing fueling equipment is designed to fit filter water separators, service providers should install the water separators at next fuel filter monitor change period. However, the industry should provide to the airlines adequate assurance that this modification will not restate the pre-fuel filter monitor era with surfactant releases and microbial growth contamination issues.

4) A sensitive aviation fuel contamination detection system should be developed, and thoroughly tested prior to its implementation. It should be able to interrupt and possibly shutdown the airplane's refuelling process.

5) An aviation fuel filtration device should be developed, and thoroughly tested prior to its implementation. It should be able to capture and hold debris and contamination that is no greater than five microns without restriction to the refuelling process flow. It should also include the capability of interrupting and possibly shutting down the airplanes refuelling process. The preferred location of such a device should be prior to the airplane's refuelling adaptor.

6) Listed below are some of the affected documents that the committee should consider examining and possibly revising in order to enhance fuel quality and cleanliness at the airport depots, distribution systems, and airplane tanks:
    a. Based on the current industry's knowledge regarding aviation fuel and it's powerlessness (inability) to eliminate specific contaminations, the FAR 14 CFR, 121.135, paragraph (b) (18) and EASA Part M, subpart C, AMC M.A.301-1(c) regulations should be revised accordingly.
    b. Note: Example of an acceptable statement is: "The uplifted fuel on an aircraft should be in accordance with the engine manufacturer's specification, quality and cleanliness requirements."
    c. AC150/5230 should be revised to state in the applicability section that the aviation fuel requirements should be in accordance with the aircraft engine

manufacturer's specification, quality and cleanliness requirements. IATA Fuel Filter Monitor Media Migration Task Force Airline Report

d. AC150/5230 should be revised to include the worldwide industry approved publications; Joint Industry Group's (JIG) Guidelines for Quality & Operating Procedures for Airport Depots and Joint Into-Plane Fuelling Services, IATA's Guidance Material for Aviation Turbine Fuel Specifications and ATA Specification 103-Standard for Jet Fuel Quality Control at Airports that are currently used by air carriers and air operators. Also, the SAE G16 specification that is currently under development should be mentioned since it will harmonize the worldwide specification requirements.
e. The CAA, Air Navigation Order, Article 137, should add a note to clarify the current wording for the aviation fuel "fit for use".
f. Note: Example of an acceptable statement is: "The uplifted fuel on an aircraft should be in accordance with the engine manufacturer's specification, quality and cleanliness requirements."

7) The harmonization of any action with US and non-U.S. regulatory authorities before a new requirement is proposed is essential for its adaptability and overall benefit for the airlines and the affected aviation fuel companies.

8) Diligence at airport Fuel Farms, Distribution and Dispensing systems should be maintained by the fuel supply and distribution industry in order to achieve the maximum aviation fuel quality and cleanliness, as well as maintaining the required fuel specifications.

9) If the committee should determine that there is an urgency to take a regulatory action, the proposed rule should be redefined to require practical measures to limit possible airline flight operation disruptions due to fuel supply or distribution interruptions.

9.2 Airframe Manufacturers:

9.2.1 Airbus

1) Airbus suggests that the Joint Industry Guidelines (JIG) become mandatory and enforceable. The industry (into-planes companies) should monitor the current level of contamination in uploaded fuel for all known contaminations (particulate' size above ½ micron) in order to build a database and set new standards for the fuel cleanliness. This could be achieved by introducing new testing devices that enables 'in line' monitoring. Optical devices seem to be the most adapted technology available but microwave or sound devices should also be considered as the three technologies would enable 'all contamination type' detection and measurement system.

2) Filter monitor manufacturers should investigate the possibility to develop new filter types down stream of the filter monitor on fuel uplift vehicles. This would provide a last barrier to prevent solid particles from entering the aircraft fuel tanks. This filter should be able to stop the particles that are predominant in the aircraft filter, causing filter blockage. Therefore, according to the aircraft filter analysis currently available, 0.5 micron absolute would be a suitable limit. The design should not adversely affect the electrostatic charge of the uploaded fuel and prevent any pressure increase in the refuel system.

3) The failed aircraft fuel system component downstream of the aircraft engine fuel filter should be tested for SAP in order to assess the potential impact of these particulates on the aircraft fuel system

4) Each time an operational interruption of an aircraft occurs due to fuel contamination (at the exclusion of fuel contamination from production and maintenance activities) the related analysis costs (filters, fuel samples, etc) should be supported by the fuel suppliers in order not to generate additional costs due to poor fuel quality to the airlines. For information, the Russian authorities are currently applying this principle.

9.2.2 Boeing

1) Determine the average amount of water and particulates being uplifted into aircraft using new technology optical devices. Industry needs a more accurate way to gauge fuel cleanliness than the current white bucket, visijar and other approved tests. Airlines and uplift companies must determine how much contamination is currently going in to aircraft, establish baselines, and then determine if new limits are required.

2) Test for SAP on failed fuel control units and other fuel system components that have been removed from aircraft. Agreement from the engine companies and their suppliers will be required. This sampling of data will help to determine if SAP is getting past the engine fuel filters, and if so, what the consequences are. The testing could be as simple as using the copper sulphate test.

3) Put new fuel cleanliness requirements into the fuel handling specifications. Since there is activity to standardize these requirements across the aviation industry, distribution of this information should be easier. The current requirements are ATA 103, JIG's Guidelines for Aviation Quality Control, and IATA Guidance Material.

4) Work with SAE to examine the possibility of new requirements to install a new filter down stream of the water monitor on uplift vehicles. This filter should be ½ micron absolute and designed such that it does not affect the electrostatic charge or the pressure drop.

5) Work with SAE to modify the current filter cartridges to ensure optimal flow through the monitors. This can be achieved by turning on or off individual monitors as required within the housing. Pressure activated vales and new plumbing will be required.

9.3 Engine OEMs

1) IATA and ATA, as Associations representing the airlines, to work more diligently to achieve cleaner fuel in the airport fueling systems.

2) Request that the EI determine if monitor elements need to be pre-conditioned and make this a standard operating procedure if so: Work with IATA/ATA to ensure that monitors are employed to work as they were intended to in airport fuel systems, as last chance water removal, not as the major remover of water.

3) Filter monitor manufacturers to work together to design or redesign monitor elements so that they do not release SAP downstream into the fuel, or failing that, redesign the monitor to have downstream filtration to recapture liberated SAP.

4) Engine OEM's will continue to recommend changes in engine filter replacement interval to the affected airlines to manage (reduce) Impending By-pass Warning in the field.

5) Inform the airlines, through IATA and ATA, that aircraft fuel tank sumping interval should be reduced as SAP released to the aircraft would tend to settle into the tank water bottoms and could be trapped out (removed) with more frequent sumping.

6) That the Airlines be requested, at a time and a place convenient to their regularly scheduled maintenance, to use the copper sulphate test to determine if any SAP is present in control or HMU units removed from the engines. This is to verify or refute that SAP is getting downstream of the engine fuel filters.

7) That the Fuel Supply industry (refiners, transporters and airport suppliers), the airframe and the engine OEMs set up a committee to begin the process of defining fuel cleanliness standards for the aviation industry. These standards to be incorporated into salient fuel handling documents that are available to industry public (e.g. JIG, ATA 103, IATA Guidance Material, etc.).

9.4 Oil Companies

The contributors to the Oil Company report (see Appendix 30) are BP, Chevron, ConocoPhillips, ExxonMobil and Shell.

1) Modify Filter Monitor Manufacture: The finding of SAP on Millipore filters downstream of elements has been communicated to filter monitor manufacturers with a request that they evaluate the cleanliness of their manufacturing procedures and improve them to comply with IP 1583 5th edition. Note: IP 1583 5th edition has a zero SAP migration tolerance.

2) Use of Particle Detection Technology:

    a. Oil company industry associations, specifically the Energy Institute, are developing particle counter/detection technology and encourages all stakeholders to support and participate in the development. This standard will be issued as API/IP 1550.
    b. Into-plane companies (non-oil companies) should also evaluate the use and installation of this technology.

3) Use of Alternate Filter Equipment: Individual oil companies and into-plane companies (non-oil companies) should risk assess the use of alternate approved non-SAP containing filter equipment for their operations. The individual oil companies and into-plane companies (non-oil companies) should assist the filter manufacturers in assessing new SAP-free technology that can be fitted to existing filter monitor vessels

4) Equipment Selection: Individual oil companies and into-plane companies (non-oil companies) should assess the use of filter monitors and where possible select the construction and flow format that reduces the risk of media migration. Adopt IP 1583 5th edition elements as they become available.

5) New Equipment: Recommend that all new refuellers and hydrant servicers are designed to reduce or remove the risk of SAP media migration.

6) Modification of Airport Fuel Handling Standards: Revise documents used to define acceptable fuel quality such as the i) Joint Industry Group's (JIG) Guidelines for Aviation Fuel Quality & Operating Procedures for Airport Depots and Joint Into-Plane Fuelling Services, ii) IATA's Guidance Material for Aviation Turbine Fuel Specifications and iii) ATA Specification 103-Standard for Jet Fuel Quality Control at Airport.

    a. Add specific language regarding the appropriate introduction of Fuel System Icing Inhibitors (FSII) in jet fuel. Add further procedures covering filter requirements especially more restrictions with regards to the use of 6" monitors that are in-to-out flow. Include an unequivocal statement that FM's SHALL NOT be exposed to fuel containing FSII.

b. Add cautionary statements on filter monitor SAP migration

c. Include statements that equipment used on-airport should not only comply with standards defined by aviation industry bodies such as API and EI but that equipment manufacturers also have responsibility to ensure that any leaching or release of trace impurities from their equipment does not contaminate the fuel and fuel properties shall remain within the prescribed limits of the relevant fuel specification.

d. Add a procedure for flushing newly installed filter monitor elements. An acceptable approach is for equipment manufacturers to implement a management of change procedure to evaluate the impact of trace impurities on finished product quality and on aircraft systems. Other approaches may also be acceptable to the airline and/or aircraft system manufacturers

7) Oil companies recognise IATA's efforts in developing a new harmonized airport fuel handling standard through SAE's G-16 committee. This committee should also include similar fuel quality descriptors suggested in subsection 6 above.

8) Compliance to Airport Fuel Handling Standards: Oil companies recommend that airlines include all or most of the Airport Fuel Handling Standards listed above in contractual agreements with their into-plane agents and fuel suppliers. This would reinforce the commercial aviation authority's confidence of industry's ability to control requirements on aviation fuel quality and handling.

9.5 Into- Plane Service Providers

Three Major Into-Plane Service Providers, Allied Aviation, ASIG and Swissport Fueling participated in and contributed information (see Appendix 31) to the IATA Fuel Filter Monitor Task Force. Their recommendations are as follows:

1) ATA 103 does not dictate specific types of filtration to be used for the receiving or dispensing filtration. (Micronics, Clays, Coalescer/Separator, Hay Packs, Salt Dryers and Fuel Filter Monitors) The Airlines and the Airline Energy Committee need to modify ATA 103 to specify filtration and Quality Assurance Standards.

2) The Airlines and the Air Transport Association Fuel Committee need to work with airports to insure that certain Filtration Systems and Quality Assurance Testing are incorporated at all Airports in the Operating Agreements for the Maintenance and Operations and Into-Plane Operators.

3) In a standard time frame operators should perform B/2 refractometer test for FSII. Spot checks for corrosion inhibitors and drag reducers might also be advisable. Defuelling procedures should be evaluated to minimize the possibility of off-loading FSII-containing fuel into tankers utilizing filter monitors

4) To truly understand at what point SAP dust no longer migrates from newly installed fuel filter monitors, additional testing will need to be performed. A standard flushing procedure should be developed requiring a specific amount of fuel to be passed through the filter monitors before they are put into service to prevent SAP dust from migrating from the elements into the aircraft systems

5) Currently only the Copper Sulphate test is available to detect SAP. Additionally other quality assurance tests for the detection of SAP should be researched

9.6 Energy Institute Recommendations:

1) EI research on filter monitors: The EI has requested that the filter monitor manufacturers urgently develop and perform SAP migration tests on their existing products, and any new prototype models they develop. In addition the EI will contract an independent laboratory to undertake SAP migration tests on currently available filter monitors.

2) Preparation of a new API/IP specification 1599 for laboratory tests for a 2" diameter filter that does not have water holding capacity (no SAP):

3) A new publication is being prepared to encourage the provision of a new type of 2" diameter filter that is not designed to have water holding capability (and therefore not contain SAP) but can be retro fitted into existing 2" monitor vessels. Such a device would be intended for use in conjunction with an alternative means of water detection. The publication will be published in 1Q 2007.

4) Preparation of a new API/IP publication 1598 Draft Standard Guidelines for selecting electronic sensors for monitoring aviation fuel quality:

5) A new publication is being prepared that outlines the minimum operational performance requirements for electronic sensors (any type) for the detection of dirt and water in fuel. Laboratory verification tests to investigate selected aspects of performance are also to be included. It is hoped that the publication will encourage manufacturers to offer products suitable for the aviation fuel handling market. It is anticipated that such devices could be used downstream of filtration systems. The publication is expected by end 2Q 2007.

6) Research into performance of electronic sensors: EI-funded research will be undertaken into the performance verification of electronic sensors (offered by manufacturers as being suitable for the application, as described in API/IP 1598) for dirt and water contamination, on a suitable aviation fuel test rig. Results will be available by end 2Q 2007.

7) Preparation of a new API/IP Recommended Practice 1550: In addition to the above work on laboratory test specifications, and associated research for components used in the fuel handling system, the EI and API are preparing jointly. *The maintenance and delivery of clean aviation fuel*. The publication is anticipated by end 2Q 2007.

10 Appendices

Appendix	Description
1A	FAA FSAW 4
1B	FAA FSAW 4A
2	EI Warning on the use of Aviation Engine fuel filter Monitors
3	API letter dated 23 September Alerting FAA about the incidents at USAF
4	EI Report to IATA Filter Monitor Task Force
5	Shell Aviation Bulletin
6	ExxonMobil Technical bulletin
7	ConocoPhillips Technical Bulletin
8A	Air BP Technical Bulletin, January 2006
8B	Air BP Technical Bulletin, October 2006
9A	Chevron Bulletin 2005
9B	Chevron Bulletin 2006
10	Facet Technical bulletin
11	Velcon Service Bulletin
12	Racor Service Bulletin
13	Faudi Service Bulletin
14	CFM56 Fuel Filter Impending By-Pass Light Indication –Experience
15	US Navy Fuel Monitor Status, May 2006
16	US Navy Inputs to the IATA Filter Monitor Task Force
17	US Air Force Update on the Status of Filter Monitor Technology, August 2006
18	Guidelines for Examination of Contamination
19	Allied Findings
20	ASIG Findings
21	SEM/EDX Analysis for Chemical Elemental Composition
22	Air BP Filter Debris Analysis
23	Chevron/South West Research Institute (SWRI) Engine fuel filter Debris Analysis
24	SwRI Report on Analysis of Operator Q's Used Engine fuel filters
25	ExxonMobil Used Aircraft Filter Analysis
26A	Boeing Test Results
26B	Boeing Test Results
26C	Boeing Test Results
27	Sofrance Test Results
28	Neste Oil Results
29	Airlines Recommendations
30	Oil Companies Recommendations
31	Into-Plane Service Providers Recommendations

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ORDER: 8300.10

APPENDIX: 4

BULLETIN TYPE: Flight Standards Information Bulletin for Airworthiness (FSAW)

BULLETIN NUMBER: FSAW 06-04

BULLETIN TITLE: Aviation Fuel Filter Monitors with Absorbent Type Elements and Aviation Fuel Cleanliness

EFFECTIVE DATE: 03-29-06

TRACKING NUMBER: N/A

APPLICABILITY:

M/M	ATA Code	14 CFR	PTRS
NA	NA	121, 135	3638,5638

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1. PURPOSE. This bulletin provides information and guidance to Airworthiness principal inspectors (PIs) for Title 14 of the Code of Federal Regulations (14 CFR) part 121 and 135 air carriers operating turbine-engine powered aircraft. It also provides information to all aviation safety inspectors (ASIs) who perform surveillance activity code 3638 or 5638, Monitor Operators Refueling Procedures.

2. BACKGROUND.

A. The American Petroleum Institute (API) recently contacted the Federal Aviation Administration regarding United States Air Force (USAF) turbine engine flameouts on T37 aircraft. These incidents were attributed to particulate contamination from decomposition of filters installed in ground-based filter monitor units. The decomposition has been linked to the presence of fuel system icing inhibitor (FSII), also called Prist or DiEGME. Consequently, the American Petroleum Institute has withdrawn their filter monitor industry specification due to concerns with media migration.

B. The USAF has taken action to replace the filter monitors with filter/separators that do not use the super absorbent polymer that the filter monitors use. However, this action is not recommended for civil aviation fuel facilities at this time due to differences in civil refueling equipment and the selective use of FSII. Civil aircraft also typically have filter impending bypass alerts, transmitted to the cockpit that are intended to prevent filter bypass or fuel flow blockage during the flight.

C. Despite the apparently low susceptibility to the media migration problem, civil transports have recently been experiencing impending bypass indications at an increasing rate. Airlines have reduced scheduled filter replacement intervals and established an International Air Transport Association (IATA) task force to investigate premature filter clogging. The FAA has specified actions in this bulletin for the purpose of supporting the airline investigation and resolution of this problem.

4. ACTION. PIs should perform the following actions with their assigned air carriers:

A. PIs should review the air carrier's jet fuel quality control procedures, with special emphasis on procedures intended to minimize the introduction of contaminants into jet fuel supplies, such as:

(1) Periodic cleanliness checks of fuel facilities are performed daily, monthly, quarterly and annually. These checks should encompass facility areas such as storage tanks sumps, filter sumps, nozzle screens, and filter elements. Reference ATA Specification 103, Standard for Jet Fuel Quality Control at Airports, section 2-5.

(2) Periodic cleanliness checks of aircraft fueling equipment are performed daily, monthly, quarterly and annually. These checks should encompass inspections of filter sumps, tanker sumps, nozzle screens, tanker interiors, and should include schedule filter element replacements. Reference ATA Specification 103, Standard for Jet Fuel Quality Control at Airports, section 2-8.

B. PI's should periodically witness white bucket tests (ref. ATA Specification 103, section 3-7) for fuel cleanliness at various locations in the airport fuel distribution system, including:

(1) Storage tank filter housings (both upstream and downstream of filter).

(2) Tanker truck sumps.

(3) Hydrant locations (using uplift vehicles).

5. INQUIRIES. The Air Carrier Maintenance Branch, AFS-330, developed this bulletin to address concerns expressed by the API. Contact Frank Wiederman, AFS-330, at 202-267-5012 with any questions or comments regarding this bulletin.

6. EXPIRATION DATE. This bulletin will remain in effect until superseded or canceled.

ORIGINAL SIGNED BY

David E. Cann, Manager
Aircraft Maintenance Division

ORDER: 8300.10

APPENDIX: 4

BULLETIN TYPE: Flight Standards Information Bulletin for Airworthiness (FSAW)

BULLETIN NUMBER: FSAW 06-04A

BULLETIN TITLE: Aviation Fuel Filter Monitors with Absorbent Type Elements and Aviation Fuel Cleanliness

EFFECTIVE DATE: 03/29/06

AMENDED DATE: 12/14/06

TRACKING NUMBER: N/A

APPLICABILITY:

M/M	ATA Code	14 CFR	PTRS
N/A	N/A	121, 135	3638,5638

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1. PURPOSE. This bulletin provides information and guidance to Airworthiness principal inspectors (PI) for Title 14 of the Code of Federal Regulations (14 CFR) parts 121 and 135 air carriers operating turbine-engine powered aircraft. The information in this bulletin applies to all aviation safety inspectors (ASI) who monitor operators' refueling procedures using Program Tracking and Reporting Subsystem (PTRS) activity code 3638 or 5638.

2. BACKGROUND.

A. The American Petroleum Institute (API) recently contacted the Federal Aviation Administration (FAA) regarding United States Air Force (USAF) turbine engine flameouts on T37 aircraft. These incidents were attributed to particulate contamination from decomposition of filters installed in ground-based filter monitor units. The decomposition has been linked to the presence of fuel system icing inhibitor (FSII), also known as DiEGME (diethylene glycolmonomethyl ether) or Prist®. Consequently, the API has withdrawn their filter monitor industry specification because of concerns with media migration.

B. The USAF has taken action to replace the filter monitors with filters/separators that do not use the super absorbent polymer that the filter monitors use. This action is not recommended for civil aviation fuel facilities at this time because of differences in civil refueling equipment and the selective use of FSII. Civil aircraft also typically have filter impending bypass alerts transmitted to the cockpit, intended to prevent filter bypass or fuel flow blockage during the flight.

C. Despite the apparently low susceptibility to the media migration problem, civil transports have recently experienced impending bypass indications at an increasing rate. Airlines have reduced scheduled filter replacement intervals and established an International Air Transport Association (IATA) task force to investigate premature filter clogging. The FAA has specified actions in this bulletin to support the airline investigation and help resolve this problem.

D. On October 26, 2006 the Energy Institute issued a warning on the use of aviation fuel filter monitors (fuses) qualified to the Institute of Petroleum (IP) test method, IP 1583 4th edition, or earlier editions. Of particular importance is the statement: “The water absorbent polymer in filter monitors may pass downstream from filter monitors into fuel, even in the absence of FSII. All aviation fuel filter monitor manufacturers providing elements qualified to IP 1583 4th edition have stated that unknown quantities (possibly undetectable) of water absorbent polymer may pass into fuel even when filter monitors are operated in civilian fuel not containing FSII.” The warning goes on to state, “Assessment, impact and mitigating action by commercial airlines on this issue is the subject of current study by the International Air Transport Association working with industry stakeholders including the Energy Institute.” A copy of this warning can be found on the Energy Institute’s Web site at: http://www.energyinst.org.uk/content/files/EIwarning.pdf.

3. ACTION. PIs should perform the following actions with their assigned air carriers:

A. Review the air carrier’s jet fuel quality control procedures, focusing on procedures intended to minimize the introduction of contaminants into jet fuel supplies, such as:

(1) Periodic cleanliness checks of fuel facilities performed daily, monthly, quarterly and annually. These checks should encompass facility areas such as storage tank sumps, filter sumps, nozzle screens, and filter elements. Reference ATA Specification 103, Standard for Jet Fuel Quality Control at Airports, section 2-5.

(2) Periodic cleanliness checks of aircraft fueling equipment performed daily, monthly, quarterly and annually. These checks should encompass inspections of filter sumps, tanker sumps, nozzle screens, tanker interiors, and should include scheduled filter element replacements. Reference ATA Specification 103, section 2-8.

B. Periodically witness white bucket tests (reference ATA Specification 103, section 3-7) for fuel cleanliness at various locations in the airport fuel distribution system, including:

(1) Storage tank filter housings (both upstream and downstream of filter).

(2) Tanker truck sumps.

(3) Hydrant locations (using uplift vehicles).

4. INQUIRIES. The Air Carrier Maintenance Branch, AFS-330, developed this bulletin to address concerns expressed by the API. Direct any questions or comments regarding the information in this bulletin to Frank Wiederman, at 202-267-5012.

5. EXPIRATION. This bulletin will remain in effect until superseded or canceled.

ORIGINAL SIGNED BY
Ferrin Moore for

Ricardo Domingo, Acting Manager
Aircraft Maintenance Division

26th October 2006

WARNING ON USE OF AVIATION FUEL FILTER MONITORS (FUSES) 'QUALIFIED TO' IP 1583[1] 4TH EDITION OR EARLIER EDITIONS

Aviation fuel filter monitors (fuses) containing water absorbent polymer have been used for many years to prevent water and dirt being delivered to aircraft during refuelling operations.
In recent years it has been determined that **FILTER MONITORS 'QUALIFIED TO' IP 1583 4TH EDITION OR EARLIER EDITIONS CANNOT BE REGARDED AS FAIL-SAFE DEVICES FOR PREVENTING WATER BEING DELIVERED TO AIRCRAFT.**
IT HAS ALSO BECOME APPARENT THAT WATER ABSORBENT POLYMER FROM SUCH ELEMENTS MAY MIGRATE DOWNSTREAM.
However, in many operations filter monitors continue to form one component in the comprehensive system to control dirt and water in aviation fuel.

RECOMMENDED ACTION TO BE TAKEN BY FILTER MONITOR USERS

- Always operate filter monitors in strict accordance with manufacturer's instructions.
- Do not use filter monitors in fuel containing any Fuel System Icing Inhibitor (FSII), also known as DiEGME (diethylene glycol monomethylether) or Prist®.
- Do not use filter monitors where any free water in aviation fuel may contain high concentrations of salts.
- Seek assurance from the filter monitor manufacturer that, in addition to meeting the laboratory qualification requirements of IP 1583 4th edition, filter monitors are suitable for your intended service application.
- Ensure that where a filter monitor is used it forms only one part of a comprehensive system to control dirt and water in aviation fuel. A comprehensive system includes housekeeping procedures and quality assurance checks during into-plane fuelling.
- Users concerned about filter monitor performance should consider the use of different technology, or combinations of different technologies, but should assess the limitations of such alternatives on an individual basis.

ADDITIONAL INFORMATION

- **Filter monitor elements 'qualified to' IP 1583 4th edition or earlier editions should not be solely relied upon to ensure that water in fuel is prevented from passing onto aircraft.** The water removal performance of filter monitor elements 'qualified to' IP 1583 4th edition or earlier editions may deteriorate in service, to the extent that a filter monitor may not effectively shut off fuel flow or register a rise in differential pressure sufficient to alert the operator to the passage of water. Despite significant collaborative research and investigations by industry representatives it has not been possible to identify with certainty the causes of such deterioration in service. **WATER IN AIRCRAFT FUEL TANKS MAY AFFECT AIRCRAFT OPERATIONS**.
- Filter monitors that are 'qualified to' IP 1583 4th edition or earlier editions must never be used with aviation fuel containing FSII. **THE PERFORMANCE OF FILTER MONITOR ELEMENTS IS SIGNIFICANTLY IMPAIRED WHEN THEY ARE USED IN FUELS CONTAINING FSII. FILTER MONITOR ELEMENTS ARE ALSO MORE VULNERABLE TO WATER ABSORBENT POLYMER MIGRATION IN FUELS CONTAINING FSII.**
- **The water absorbent polymer in filter monitors may pass downstream from filter monitors into fuel, even in the absence of FSII.** All aviation fuel filter monitor manufacturers providing elements 'qualified to' IP 1583 4th edition have stated that unknown quantities (possibly undetectable) of water absorbent polymer may pass into fuel even when filter monitors are operated in civilian fuels not containing FSII. All size and flow formats of filter monitors are implicated, but the extent of migration from them may vary. **Assessment, impact and mitigating action by commercial airlines on this issue is the subject of current study by the International Air Transport Association working with industry stakeholders including the Energy Institute.**

1 IP Specification 1583 *Specifications and laboratory tests for aviation fuel filter monitors with absorbent type elements*, 4th edition, September 2004. Published by the Energy Institute.

Limitations of the laboratory test methods included in IP 1583 4th edition and earlier editions:

- IP 1583 4th edition is not a product specification. It provides general requirements for filter monitor elements and systems, and a series of laboratory tests to measure selected aspects of performance of new unused filter monitor elements.
- Laboratory tests alone cannot replicate the operating conditions to which filter monitors are exposed when in service, and therefore are of limited utility in predicting in-service performance.
- Filter monitors in current use that are 'qualified to' IP 1583 4th and earlier editions, may meet the requirements of the selected laboratory tests, but may not meet 1.7.2.1 d, which states:

"**1.7.2 Performance features**
1.7.2.1 A filter monitor shall have the following general features:

(d) It shall not contaminate the fuel and fuel properties shall remain within the prescribed limits of the relevant fuel specification."

ENERGY INSTITUTE DEVELOPMENTS

The Energy Institute (publisher of IP 1583 4th edition) is currently developing a 5th edition of IP 1583 for publication in November 2006. Laboratory tests will be included to measure SAP migration with the requirement that none is detected as the limit for qualification. It is not known at this time whether filter monitors meeting this limit will be developed.

CONTACTS

- For further information on the use of filter monitors contact your filter monitor manufacturer/ supplier.
- For any clarification on the content of this warning contact Martin Hunnybun, Technical Manager – Distribution & Aviation, Energy Institute, 61 New Cavendish Street, London, W1G 7AR. Tel +44 (0)20 7467 7133; +44 (0)77 9527 2368; mh@energyinst.org.uk

American Petroleum Institute

1220 L Street, Northwest
Washington, DC 20005-4070
Tel: 202-682-8157
Fax: 202-962-4797
E-mail: soffrind@api.org

David E. Soffrin
Manager, Downstream
Standards Programs

September 23, 2005

Mr. David Mandell
Chief of Staff
Office of the Administrator
Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591

Dear Mr. Mandell:

Recently, the American Petroleum Institute was informed that the U.S. Air Force (USAF) had instructed its facilities to remove all water absorbing filters from equipment being used to refuel aircraft at Air Force installations and to replace them with filter coalescers within 30 days. The USAF decision was based on an incident at Sheppard Air Force Base in Texas where three T-37 aircraft flamed out.

On August 4, a meeting was held at API headquarters in Washington DC with the USAF, U. S. Navy, and representatives from various segments of the aviation industry to discuss the basis for the USAF actions. At that meeting, the attached two presentations were provided, one from the U.S. Air Force Petroleum Office, and the second, from Southwest Research Institute. The data from these presentations indicate that it is possible that the USAF airplane engine fuel filters were experiencing clogging due to media migration from water absorbent filter monitor material. Since the USAF fuel is unique, all of the parties at the meeting believe that additional data is needed to determine whether the other segments of the aviation industry might be experiencing similar phenomena.

API intends to assist all parties in the investigation of this issue. The next meeting of the interested parties will be scheduled for the fall, to review additional data being collected on aircraft operational experiences and ground fueling practices. We would welcome Federal Aviation Administration involvement in these discussions and would be glad to meet with and brief the appropriate individuals at the administration before the next industry meeting.

I can be reached at 202-682-8157. Questions concerning the USAF data should be directed to Mr. Jack Lavin, Deputy Director, U.S. Air Force Petroleum Office at 703-767-9893.

Sincerely,

David E. Soffrin

Enclosures

ENERGY INSTITUTE REPORT TO IATA FILTER MONITOR MEDIA MIGRATION TASK FORCE

4th October 2006

1) Limitations of IP 1583 *Specifications and laboratory tests for aviation fuel filter monitors with absorbent type elements*, 4th edition

- IP 1583 4th edition is not a product specification. It provides general requirements for filter monitor elements and systems, and a series of laboratory tests to measure selected aspects of performance of new unused filter monitor elements.
- Laboratory tests alone cannot replicate the operating conditions to which filter monitors are exposed when in service, and therefore qualification against those tests is only part of the process of confirming that a monitor design will be suitable for its intended service.
- Filter monitors in current use that have met the laboratory test requirements of IP 1583 4th, editions and earlier, may not meet 1.7.2.1 d (in relation to super-absorbent polymer (SAP) migration when in service), which states:

  "**1.7.2 Performance features**

  1.7.2.1 A filter monitor shall have the following general features:

  (d) It shall not contaminate the fuel and fuel properties shall remain within the prescribed limits of the relevant fuel specification."

- Any filter monitor that contaminates fuel (e.g. by releasing SAP) does not meet fully the requirements of IP 1583 4th edition.

2) SAP from filter monitor elements may pass downstream from filter monitors in fuel

- Representatives from all aviation fuel filter monitor manufacturers have acknowledged at an Energy Institute meeting (open to all interested stakeholders) that unknown quantities (possibly undetectable) of SAP may pass into the fuel stream from filter monitors in service, even when filter monitors are operated in accordance with manufacturers' instructions. The extent of SAP migration is unknown and difficult to quantify.
- All size and flow formats of filter monitors are implicated, but the extent of SAP migration from them may vary. The six inch diameter in-to-out flow format element is considered by manufacturers and users to be the element most vulnerable to SAP migration, given the large quantity of SAP that it contains and the fuel flow direction.

3) Action being taken by the Energy Institute

3.1 Warning Communication to Industry

- A warning notice to communicate the above issue will be distributed by the EI to all relevant stakeholders.

3.2 Publication of IP 1583 5th edition before end November 2006

A 5th edition of 1583 will be published by EI by no later than the end of November 2006 that will incorporate the following modifications from the 4th edition:

- Explicit text that it is an in-service performance requirement for there to be no SAP from a filter monitor passing into fuel.

- A new laboratory testing requirement for manufacturers to measure SAP media migration with the requirement that none is detected. (Note: It is considered that this new test will lead to consistent media migration protection across all element types).
- Water test procedures will be amended to encourage manufacturers to develop new designs of element that may not suffer from SAP migration, and therefore meet the performance requirements of 1.7.2.1 d).

Despite these developments the limitations of laboratory testing in relation to in-service operating conditions should be appreciated.

In order to accelerate the development by manufacturers of new products that are capable of meeting the new requirements of IP 1583 5th edition, it will be published as a 'Draft Standard for Trial Use' with a maximum publication period of two years. The publication will supersede IP 1583 4th edition, with the recommendation that any filter monitor models qualified to IP 1583 4th edition should be requalified to the requirements of 5th edition.

3.3 EI research on filter monitors

The EI has requested that the filter monitor manufacturers urgently develop and perform SAP migration tests on their existing products, and any new prototype models they develop. In addition the EI will contract an independent laboratory to undertake SAP migration tests on currently available filter monitors.

3.4 Preparation of a new API/IP specification 1599 for laboratory tests for a 2" diameter filter that does not have water holding capacity (no SAP)

A new publication is being prepared to encourage the provision of a new type of 2" diameter filter that is not designed to have water holding capability (and therefore not contain SAP) but can be retro fitted into existing 2" monitor vessels. Such a device would be intended for use in conjunction with an alternative means of water detection. Publication is expected by end Q4 2006.

3.5 Preparation of a new API/IP publication 1598 Draft Standard for Trial Use Guidelines for selecting electronic sensors for monitoring aviation fuel quality

A new publication is being prepared that outlines the minimum operational performance requirements for electronic sensors (any type) for the detection of dirt and water in fuel. Laboratory verification tests to investigate selected aspects of performance are also to be included. It is hoped that the publication will encourage manufacturers to offer products suitable for the aviation fuel handling market. It is anticipated that such devices could be used downstream of filtration systems. Publication is expected by end Q4 2006.

3.6 Research into performance of electronic sensors

EI-funded research will be undertaken into the performance verification of electronic sensors (offered by manufacturers as being suitable for the application, as described in API/IP 1598) for dirt and water contamination, on a suitable aviation fuel test rig.
Results will be available by end Q1 2007.

3.7 Preparation of a new API/IP Recommended Practice

In addition to the above work on laboratory test specifications, and associated research for components used in the fuel handling system, the EI and API are preparing jointly a new *Recommended Practice for the implementation and operation of aviation fuel filtration systems*. The key concepts to be conveyed by the publication are outlined in Figure 1.
Publication is anticipated by April 07 latest.

The relationship between the existing and forthcoming publications, discussed in 3.2 to 3.7 is shown in Figure 1.

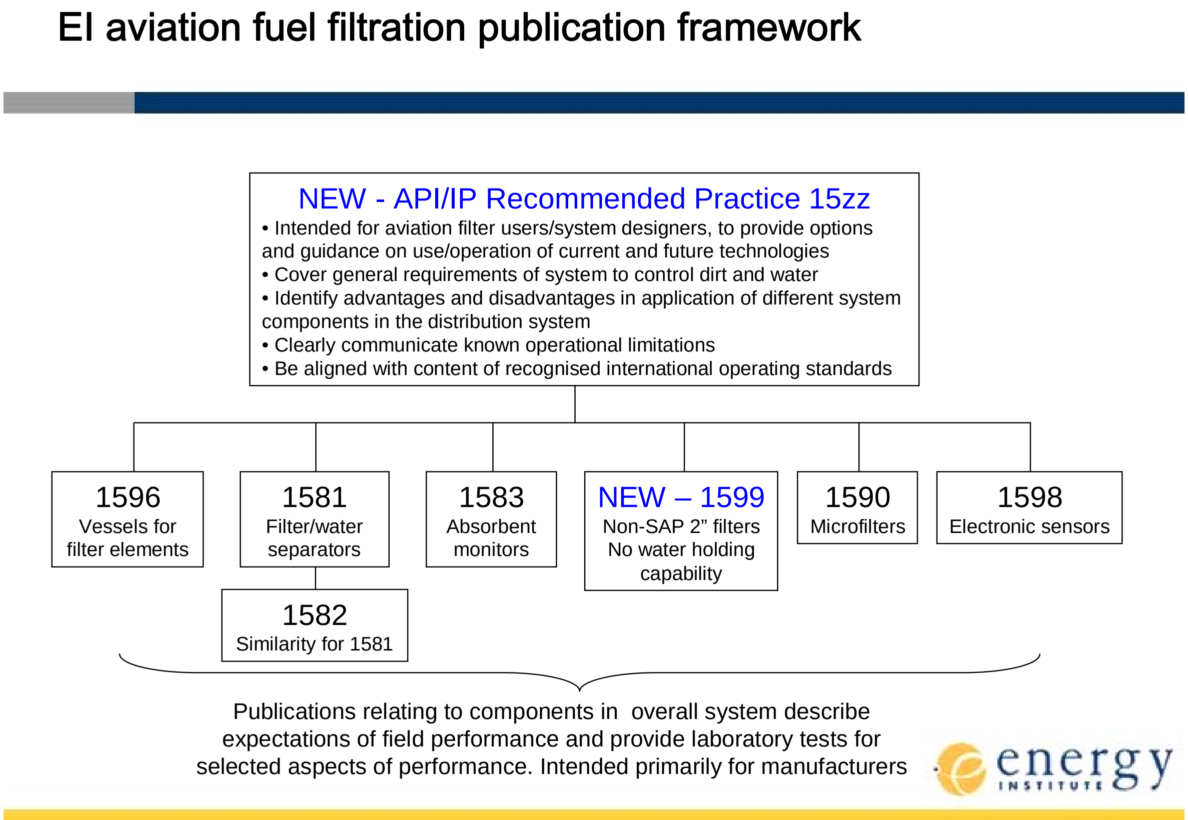


Figure 1 – EI aviation fuel filtration publications

The involvement/participation of any interested industry stakeholders in the preparation of Energy Institute publications (including joint API/IP publications) is most welcome. For further details please contact Martin Hunnybun (mh@energyinst.org.uk; +44(0)20 7467 7133; +44(0)77 9527 2368.

Shell Aviation

AOTB 2006/03 July 2006

Distribution	**SAV, All Regional Operations Managers** **SAV, All Global Operations & Engineering Staff** **TSA Customers**
Action	**All Airports under Shell Operational Control** **All Airports operated by Shell to JIG standards**

Filter Monitors: Restrictions of Use

1 Background

Filter monitors are currently the preferred filter type for into-plane use because of their ability to remove dirt and absorb water from fuel. However, recent performance issues have led to further restrictions on their use, in particular the requirement to avoid using filter monitors with jet fuels doped with FSII.

This bulletin serves to remind users to carry out diligently all routine checks of filter monitors, to notify users of the new restrictions covering jet fuel containing FSII, and to remind users that in-to-out-flow monitor (namely 6-inch diameter) elements are not approved for Shell Group use.

2 Checks on Filter Monitors

Operational checks on filter monitors were tightened in 2003 in response to performance degradation issues. It is essential that all users of filter monitors continue to carry out the necessary checks on monitors, and ensure that:

A) filter monitor vessels are drained of water at least daily;

B) the filter differential pressure is checked, corrected for flow rate and recorded daily

C) the elements are changed when the DP reaches 22psi, when the DP drops by 5psi or after a service life of one year.
NOTE: Filter monitor elements in service must always remain fuel-wetted and never allowed to dry out.

3 Jet Fuels containing Fuel System Icing Inhibitor (FSII)

It has long been known that FSII, which contains di-EGME (di-ethylene glycol monomethyl ether) can reduce the effectiveness of filter monitors. As a result, earlier recommendations were that monitor elements exposed to FSII were changed at the lower DP of 15psi.

However, filter manufacturers now recommend that filter monitors are not used in the presence of FSII, and as a result this practice is no longer allowed.

FSII is present in several branded commercial additives eg 'Prist', 'Fizzy' and military additives, such as AL48, AL41.

4 Action Required

Filter monitors (all types) must not be used for delivering jet fuel doped with FSII.

Where filter monitors are currently used for delivering jet fuel doped with FSII, the following is required:

A) Where pre-mixed FSII is delivered, replace the FSII pre-mix arrangement with an additive injection system installed downstream of the filter monitor (note that the standard arrangement for Shell Aerojet systems requires the injection point to be downstream of the filter, and so is already compliant with this bulletin);

Or

B) Stop adding FSII altogether and liaise with the customers so that they can make their own arrangements regarding additive use;

Or

C) Replace the filter monitor elements/vessel with an approved filter water separator, FWS, (note that the larger size of a FWS compared to a monitor of equivalent flow rate means that this option may not be straightforward for fuelling vehicles with limited space. The FWS is required to meet the latest 5th edition of IP/API 1581 and is required to be fitted with a sump water detection system – see SAOM 03.04.02)

This change applies to all filter monitor elements (2-inch, 6-inch, spin-on etc from all manufacturers) and all applications (vehicles, fixed facilities).

5 Special situations - Defuelling

Where jet fuel containing FSII, eg Aerojet, is defuelled from an aircraft, it must not be refueled through a filter monitor.

If it is **certain** that jet fuel contains FSII, for example if the defuelling is a load adjustment following delivery of Aerojet, then the defuelled product may not be redelivered through a filter monitor. Such defuelled product should, subject to the normal controls (SAOM 06.03.00), be redelivered through an approved filter water separator, or disposed of.

If it is **suspected** that defuelled jet fuel contains FSII, eg from the aircraft technical log, its concentration must be checked using a refractometer (eg Gammon B/2HB Test Kit). If FSII is detectable, the defuelled product may not be redelivered through a filter monitor. If the concentration is below the detection limit for FSII (0.05%) the defuelled product may be deemed to be undoped and may be delivered through a filter monitor.

6 Inadvertent use of filter monitors with FSII

If jet fuel containing FSII is inadvertently delivered through a filter monitor, the elements must be changed immediately.

7 6-inch diameter in-to-out flow filter monitor elements

This bulletin serves as a reminder that in-to-out flow 6-inch monitor elements (eg Velcon ACI series elements) are **not** approved for use by Shell Aviation. These elements are occasionally recommended by filter manufacturers for use in filter-water separator vessels that have been converted to filter monitors. Where in-to-out monitors are in use, these must be removed and alternative filtration arrangements made.

These changes are effective immediately and must be implemented before the end of October 2006. Until the changes are carried out, please ensure that all the current operating procedures for filter monitors are diligently carried out, particularly those contained in Section 2 above.

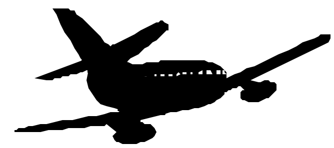
8 Further information

Section 03.03.02 (ii) of the SAOM will be amended in due course.

For further information, contact John Buxton at j.buxton@shell.com or Phil Rugen at phil.rugen@shell.com .

End of Bulletin

ExxonMobil Aviation



TECHNICAL BULLETIN

TITLE: Anti-Icing Additives and Filter Monitors

BULLETIN NO. ATB-38A-2005 **DATE: NOVEMBER 11, 2005**

Recent reports from the US Air Force at a number of industry forums (IATA, API) have suggested that aviation turbine fuel containing a Fuel System Icing Inhibitor additive (FSII, DiEGME, Prist, D-ICE etc.) can cause 4" and 6" API/IP 1583 type filter monitors to release media into the downstream fuel supply under certain circumstances.

Background

- **To date, this media migration has been observed using 4" or 6" inside-to-outside flow filter monitors in the presence of an anti-icing additive. This caused aircraft fuel filter blocking on 3 military aircraft resulting in emergency landings.**
- **Media migration from filter monitors has not been observed when using commercial Jet A-1 fuel that does not contain FSII.**
- **Advice following on from the US Air Force investigation into the 'Apple Jelly' incidents of ~5 years ago recommended anti-icing additives be injected on-board fuelling vehicles downstream of filter monitors.**

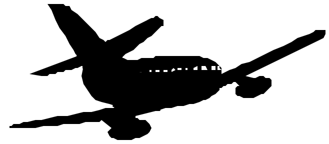
Recommended Actions

- **A review must be completed of all fuelling operations where an anti-icing additive is in use to determine if the fuel passes through a filter monitor after dosing with the additive.**
- **For any locations where this occurs, notify the fuel supplier(s) and consider action as below.**
- **In cases where monitors are exposed to fuel containing the additive, fuelling through these filters must cease at the latest 6 months from the date of this bulletin.**
- **One of the options below shall be adopted in order to continue fuelling with the anti-icing additive:**

1. Install injection systems on-board the fuelling vehicles downstream of the filter monitor. Fuel cannot be pre-blended with the additive prior to entering a vehicle using a filter monitor.

2. Where on-board injection of the additive is not possible, convert filter monitor vessels to filter water separators qualified to API/IP 1581 5th Edition Class M service. This may involve purchase of a new vessel.

ExxonMobil Aviation



TECHNICAL BULLETIN

Notes:-

a) All makes of filter monitor (2", 4" and 6") in FSII service will need to be converted to 5th Edition filter water separators within 6 months from the date of this bulletin.

b) 3rd edition or 5th edition Category C filter water separators in FSII service to need to be changed to API/IP 1581 5th edition Category M service.

c) Although filter water separators qualified to API/IP 1581 5th edition Category M100 have been qualified in the presence of anti-icing inhibitor some ongoing industry research work suggests that the Category M qualification is more severe. At this time, ExxonMobil Aviation only recommends the use of a specific API/IP 1581 5th edition Category M qualified element for fuels containing Fuel System Icing Inhibitor. These elements are estimated to be available from early December 2005.

Any questions relating to this bulletin should be addressed to the ExxonMobil Aviation Technical Group.

Please note that while the advice and recommendations given in this technical bulletin has been developed using the best information currently available from sources indicated at the commencement of this bulletin, it is intended purely as a guidance. No responsibility is accepted by ExxonMobil Aviation International Limited and its affiliated and parent companies who or which has been in any way concerned with the compilation or publication of this bulletin, for the accuracy of any information or advice given herein or for any omission herefrom or for any consequences whatsoever resulting directly or indirectly from compliance with or adoption of the recommendations contained herein.

ConocoPhillips

June 2, 2006

Technical Bulletin: Aviation Fuel Filter Monitors

The purpose of this Advisory is to promote understanding of issues our customers may face associated with filter monitors and to advise of actions to be taken, either required or recommended.

ConocoPhillips Company distributes aviation turbine fuel pre-blended at the terminal with the approved fuel system icing inhibitor, FSII (Also known as PFA 56, diethylene glycol monomethyl ether or DiEGME), to assure that the additive is dissolved in the fuel at the specified concentration. Operational experience has shown that FSII also provides benefits under normal conditions as preventative maintenance against biological activity resulting in cleaner fuel systems. After extensive testing in the 1980's, ConocoPhillips determined that filter monitors do not perform as well with aviation turbine fuel as filter/separators, whether or not it contains FSII. Therefore ConocoPhillips has never recommended filter monitors as the primary filtration device on fuel farms or refuelers.

The American Petroleum Institute (API), United States Air Force (USAF) and Federal Aviation Administration (FAA) have recently distributed information regarding quality control issues associated with the use of fuel filter monitors in aviation turbine fuel. The USAF demonstrated that three T-37 flame outs were due to the migration of the water absorbing materials, or super absorbent polymer (SAP), contained in filter monitors into the aircraft fuel filters. The incidents were linked to problems with filter monitors on three different airport refuelers delivering JP-8+100. In response, the USAF has removed all filter monitors from use.

Incidents have also been reported in civilian operations when filter monitors failed to prevent the passage of water laden fuel to aircraft. Although these failures are not well understood, they have led to the removal of the term "fail-safe" from the API/IP standard. Subsequently, the API and filter manufacturers shortened the recommended filter element replacement period to one year.

Degradation of the water absorbing material in filter monitors, or SAP, has been linked to fuel containing mixtures of water and FSII, and also potentially to impurities, *independent of FSII,* that often collect in water, such as acids, salts and biological activity. Although filter monitors have been used for decades, concerns about the degradation and migration of the water absorbing material downstream of filter monitors indicate that they may not be suitable for use with aviation turbine fuel, *with or without FSII*.

The American Petroleum Institute (API) withdrew from publication the fourth edition of API/IP 1583 *Specifications and Laboratory Tests for Aviation Fuel Filter Monitors with Absorbent Type Elements.* However the Energy Institute is maintaining its support for IP 1583 in Europe until further review of the media migration issues. The API will consider the publication of a new edition of the filter monitor standard when these technical issues have been adequately resolved.

These issues reinforce the importance of filter maintenance and water management at airport fuel facilities. Rigorous quality control practices are essential to maintaining healthy fuel facilities and preventing the issues discussed above. Operations supervisors are requested to review the use of filter monitors and operating procedures concerning the items outlined below:

<u>Service Life</u>
Filter elements should be replaced when:
- Differential pressure exceeds 15 psi
- Unusual trends in differential pressure are observed, such as low differential pressures or decreases in differential pressure
- Filter Membrane Test (Millipore) result in ratings greater than 2 when dry or 3 when wet
- Daily sump samples indicate the presence of water, haze, surfactant, microbial growth or solid contaminants
- Free water tests indicate that elements are not performing adequately
- The 12 month service life has expired

<u>Quality Control and Water Management</u>
Diligent quality control and water management practices are essential to maintaining healthy fuel facilities. A few of the required activities are given below:
- Check tank and filter sumps with a white bucket test on a daily basis
- Daily filter differential pressure checks
- Monthly free water tests downstream of filter vessels, membrane filter tests and nozzle screen inspections
- Check fuel prior to accepting delivery into the fuel farm

Required Action: Replace filter monitors with an acceptable filter/separator designed for use with aviation turbine fuel. Until this change can be made, increased scrutiny should be used when checking filter vessel sumps, tanks sumps and nozzle screens. Stop delivering fuel, clean the affected systems and replace filter elements if excessive particulates, significant accumulations of water or other contaminants are observed.

Note: Filter/separator vessels at the fuel farm and on refuelers should include a sump drain, differential pressure gauge, pressure relief valve, automatic water slug shutdown system, air eliminator and membrane filter test ports. If an automatic water slug shutdown system is not present then filter vessel sumps should be checked after fueling each aircraft. Filter/separators meeting API/IP 1581 5th Edition specifications are recommended for future installations. Filter monitors have never been recommended by ConocoPhillips as a primary filtration device for jet fuel and are no longer acceptable for use as a secondary filtration device on fuel dispensers.

ConocoPhillips has always recommended filter/separators over filter monitors as the primary filtration equipment on fuel farms and refueling vehicles that handle aviation turbine fuel. That's why all Phillips 66-branded refuelers are equipped with filter/separators for jet fuel service. Please take time to inspect and, if necessary, upgrade the filtration equipment at your facility.

Your focus on quality and safety are always appreciated. Please contact Ken McCarley by phone at 918-661-9776 or e-mail Ken.C.McCarley@ConocoPhillips.com if you have any questions.

2006/02/A

Technical **action** bulletin

Filters and fuel system icing inhibitor (FSII)

Listing of all important information regarding the use of filter monitors and filter/water separators with jet fuel containing FSII

During the ongoing investigation of the deterioration in performance of filter monitors in service, it has become clear that fuel system icing inhibitor (FSII) in jet fuel adversely affects the water removal properties of filter monitors to an extent not previously recognised.

There are other, not yet fully understood, mechanisms which affect the performance of filter monitors in jet fuel not containing FSII and these are subject to ongoing investigation.

None of the filter monitor manufacturers approved by Air BP unconditionally recommend that their products are suitable to be used in jet fuel containing FSII as they were not designed for this application. The specifications and laboratory tests for aviation fuel filter monitors with absorbent type elements, EI specification 1583, (formerly API/IP specification 1583), specifically excludes FSII as this additive is unique and makes unusually difficult demands on filtration and water separation/removal devices.

If FSII is injected on board fuelling vehicles then the injection shall be downstream of (after) the filter vessel regardless if it is a filter monitor or a filter / water separator.

If FSII is injected into the fuel at a point upstream of (before) the fuelling vehicle filter vessel, then the filter used has to be a filter / water separator of a type specifically approved for this purpose by Steve Anderson or Nic Mason. Similarly, any fixed filter / water separator vessels that jet fuel containing FSII pass through in distribution systems must be subject to this approval process.

This Technical action bulletin supersedes Air BP Regulations fuelling & quality control section AD.7.6 (iii) which shall be amended in due course. Further advice in cases involving upstream addition of FSII can be provided by the Technical Function.

Actions:

1. Review all operations that include jet fuel and FSII to identify any sites where filter monitors are exposed to jet fuel containing FSII.

2. All identified sites shall be brought into compliance with this Technical action bulletin as soon as possible and certainly no later than June 1st 2006. Sites unable to comply with this will need to seek a Waiver as an interim measure.

Yours faithfully

for Air BP Limited

Roald Skjaeveland

Global Ops Integrity Manager

2006/26/A

Technical Action Bulletin

Energy Institute Warning on use of Aviation Fuel Filter Monitors Qualified to IP 1583

Attached is a warning note (dated 26th October 2006) that has been issued by the Energy Institute (formerly the Institute of Petroleum) regarding the use of Filter Monitors in Aviation Fuel handling systems. Air BP has already issued a number of Technical Action Bulletins that introduced additional measures to minimise the potential problems that could be encountered due to the performance issues affecting Filter Monitors. These Technical Action Bulletins, which remain in force, are:

- 2002/16/A Dried out Filter Elements
- 2002/27/A Electrostatic Discharges in 2" Filter Monitors
- 2003/08/A Performance Issue Surrounding Filter Monitors
- 2003/09/A Performance Issue Surrounding Filter Monitors Update1
- 2003/15/A Performance Issue Surrounding Filter Monitors Update 2
- 2003/41/A Performance Issue Surrounding Filter Monitors Update 3
- 2006/01/A Filters and Fuel System Icing Inhibitors (FSII)

As stated in the Energy Institute warning, an additional concern that has become apparent, is that super absorbent polymer (SAP) from all types of Filter Monitors may migrate downstream (after the filter) in the fuel flow during service. This phenomenon is believed most likely to occur when a new Filer Monitor cartridge of any size is first commissioned because it may contain loose manufacturing SAP debris which could be flushed out into the fuel.

Because of the potential for SAP migration, two additional measures are to introduced as follows:

- The frequency of inspection of all hose end strainers shall be monthly (from quarterly; see Air BP Regulations IP.4.16).
- Following the three minute flush after installing new Filter Monitor cartridges in any into-plane vessel (see Air BP Task Breakdown M3), the hose end strainers should be inspected. If any gel is discovered in the hose end strainers; then the Filter Monitor cartridges need to be replaced. The presence of any gel type material encountered in any of these strainer inspections should also be reported to the Technical Function, to Nic Mason by e-mail – nic.mason@uk.bp.com.

Actions:

1. Ensure all technical/operations and sales/marketing staff are aware of the attached Energy Institute Warning.
2. Ensure all the additional procedures included in the above list of Air BP Technical Action Bulletins are fully implemented.
3. Introduce the additional hose end strainer inspections with immediate effect – equipment that has not received a hose end strainer inspection this month should do so upon receipt of this bulletin and then all equipment monthly thereafter.

Yours faithfully
for Air BP Limited

Roald Skjaeveland
Global Ops Integrity Manager

26th October 2006

WARNING ON USE OF AVIATION FUEL FILTER MONITORS (FUSES) 'QUALIFIED TO' IP 1583[1] 4TH EDITION OR EARLIER EDITIONS

Aviation fuel filter monitors (fuses) containing water absorbent polymer have been used for many years to prevent water and dirt being delivered to aircraft during refuelling operations.
In recent years it has been determined that **FILTER MONITORS 'QUALIFIED TO' IP 1583 4TH EDITION OR EARLIER EDITIONS CANNOT BE REGARDED AS FAIL-SAFE DEVICES FOR PREVENTING WATER BEING DELIVERED TO AIRCRAFT.**
IT HAS ALSO BECOME APPARENT THAT WATER ABSORBENT POLYMER FROM SUCH ELEMENTS MAY MIGRATE DOWNSTREAM.
However, in many operations filter monitors continue to form one component in the comprehensive system to control dirt and water in aviation fuel.

RECOMMENDED ACTION TO BE TAKEN BY FILTER MONITOR USERS

- Always operate filter monitors in strict accordance with manufacturer's instructions.
- Do not use filter monitors in fuel containing any Fuel System Icing Inhibitor (FSII), also known as DiEGME (diethylene glycol monomethylether) or Prist®.
- Do not use filter monitors where any free water in aviation fuel may contain high concentrations of salts.
- Seek assurance from the filter monitor manufacturer that, in addition to meeting the laboratory qualification requirements of IP 1583 4th edition, filter monitors are suitable for your intended service application.
- Ensure that where a filter monitor is used it forms only one part of a comprehensive system to control dirt and water in aviation fuel. A comprehensive system includes housekeeping procedures and quality assurance checks during into-plane fuelling.
- Users concerned about filter monitor performance should consider the use of different technology, or combinations of different technologies, but should assess the limitations of such alternatives on an individual basis.

ADDITIONAL INFORMATION

- **Filter monitor elements 'qualified to' IP 1583 4th edition or earlier editions should not be solely relied upon to ensure that water in fuel is prevented from passing onto aircraft.** The water removal performance of filter monitor elements 'qualified to' IP 1583 4th edition or earlier editions may deteriorate in service, to the extent that a filter monitor may not effectively shut off fuel flow or register a rise in differential pressure sufficient to alert the operator to the passage of water. Despite significant collaborative research and investigations by industry representatives it has not been possible to identify with certainty the causes of such deterioration in service. **WATER IN AIRCRAFT FUEL TANKS MAY AFFECT AIRCRAFT OPERATIONS**.
- Filter monitors that are 'qualified to' IP 1583 4th edition or earlier editions must never be used with aviation fuel containing FSII. **THE PERFORMANCE OF FILTER MONITOR ELEMENTS IS SIGNIFICANTLY IMPAIRED WHEN THEY ARE USED IN FUELS CONTAINING FSII. FILTER MONITOR ELEMENTS ARE ALSO MORE VULNERABLE TO WATER ABSORBENT POLYMER MIGRATION IN FUELS CONTAINING FSII.**
- **The water absorbent polymer in filter monitors may pass downstream from filter monitors into fuel, even in the absence of FSII.** All aviation fuel filter monitor manufacturers providing elements 'qualified to' IP 1583 4th edition have stated that unknown quantities (possibly undetectable) of water absorbent polymer may pass into fuel even when filter monitors are operated in civilian fuels not containing FSII. All size and flow formats of filter monitors are implicated, but the extent of migration from them may vary. **Assessment, impact and mitigating action by commercial airlines on this issue is the subject of current study by the International Air Transport Association working with industry stakeholders including the Energy Institute.**

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1 IP Specification 1583 *Specifications and laboratory tests for aviation fuel filter monitors with absorbent type elements*, 4th edition, September 2004. Published by the Energy Institute.

Limitations of the laboratory test methods included in IP 1583 4th edition and earlier editions:

- IP 1583 4th edition is not a product specification. It provides general requirements for filter monitor elements and systems, and a series of laboratory tests to measure selected aspects of performance of new unused filter monitor elements.
- Laboratory tests alone cannot replicate the operating conditions to which filter monitors are exposed when in service, and therefore are of limited utility in predicting in-service performance.
- Filter monitors in current use that are 'qualified to' IP 1583 4th and earlier editions, may meet the requirements of the selected laboratory tests, but may not meet 1.7.2.1 d, which states:

"**1.7.2 Performance features**
1.7.2.1 A filter monitor shall have the following general features:

(d) It shall not contaminate the fuel and fuel properties shall remain within the prescribed limits of the relevant fuel specification."

ENERGY INSTITUTE DEVELOPMENTS

The Energy Institute (publisher of IP 1583 4th edition) is currently developing a 5th edition of IP 1583 for publication in November 2006. Laboratory tests will be included to measure SAP migration with the requirement that none is detected as the limit for qualification. It is not known at this time whether filter monitors meeting this limit will be developed.

CONTACTS

- For further information on the use of filter monitors contact your filter monitor manufacturer/ supplier.
- For any clarification on the content of this warning contact Martin Hunnybun, Technical Manager – Distribution & Aviation, Energy Institute, 61 New Cavendish Street, London, W1G 7AR. Tel +44 (0)20 7467 7133; +44 (0)77 9527 2368; mh@energyinst.org.uk

Distribution – Distribution – Aviation Regional Asset & Operations Managers, Global Refining, PSAT, Global Marketing – PERT, Global Marketing – COF, Chevron Aircraft Services with copies to ALT, COE, Gen Aviation Ops & CAL

Operations Bulletin

Chevron

Bulletin 2005/ 02 – Jet Fuel and Fuel System Icing Inhibitor (FSII)

Author: Tracy Boval, Product Quality Manager Date: 28 December 2005

Chevron Global Aviation advises that jet fuel manufactured, traded, exchanged or purchased by the Company and supplied to customers such as airlines, general aviation Fixed Based Operators (FBOs) and Consumer Accounts shall NOT contain FSII of the type known as Diethylene Glycol Monomethyl Ether (DiEGME) except if under military contract.

Filters used in the jet fuel fuelling systems at airports that are the filter monitor type (IP 1583 formerly API/IP 1583) are more prone to failure when jet fuel contains DiEGME. The recognized failure modes that result from passing DiEGME dosed jet fuel through a monitor may render the jet fuel not fit-for-purpose. DiEGME or FSII is commonly known by the trade name, PRIST®. Filter monitors are also sometimes known in the field as "fuses" or Aquacons®.

If specific aircraft which are non-military require FSII per their aircraft operating manual, then FSII shall be added by the injection cart method at the aircraft wing downstream of the filter. Addition of FSII via a spray can into the aircraft wing is not an acceptable method.

Compliance

This directive is to take effect immediately for all PSAT traders. PSAT should ensure by contract and/or review of 3rd party Refinery Certificates of Quality and shipping documents that jet fuel batches do not contain FSII.

For Global Aviation's Supply & Logistics: A plan shall be in place by 13 Jan 2006 to remove pre-blended FSII from jet fuel in the supply chain (refinery to terminal rack) in the United States.

For General Aviation: A plan shall be in place by 31 Jan 2006 to eliminate all pre-blended FSII in jet fuel from the United States Distributor supply chain and convert airport facilities/equipment to enable FSII injection at the aircraft wing.

Other Information

Most aircraft used by commercial airlines do not require FSII, specifically DiEGME. There are some aircraft that require FSII as defined in the aircraft operating manual. Based on design, military-type aircraft normally require FSII.

FSII is an approved jet fuel additive in Jet A or JetA-1 per latest issues of jet fuel specifications (ASTM D1655 or UK Defence Standard 91-91). Allowable ranges are 0.02% min by volume to 0.15% max by volume. A field test per ASTM D5006 can be used to spot check the concentration. If the DiEGME concentration is less than 0.02% by volume, it is considered negligible and does not require purchaser agreement and/or notification.

This direction is based on current aviation industry technical information and issues.

Global Aviation

Our Family of Brands

Operations Bulletin

COE Bulletin 2006/ 01 – 2/14/2006
[Filter Monitors]

Author: Phil Wetmore

After recent engine "flameouts" on three United States Air Force T-37 training aircraft in May 2005 and the subsequent withdrawal of API 1583 4th edition specification, Chevron Global Aviation is concerned about fuel handing safety and distribution systems using water absorbent filter monitor systems.

The Energy Institute (formally the Institute of Petroleum (IP)) has agreed to maintain the EI 1583 standard for filter monitors. The EI will support this standard as long as a majority of the committee members support this filtration standard. If new information or laboratory testing reveals a flight safety risk or fuel contamination issue then the EI committee will meet and consider withdrawal or a significant modification of the EI 1583 standard.

This bulletin will outline the action items we must take to insure that our fuel handling process and our equipment deliver on specification fuels to our customers.

Filter Monitor Issues

Over the past 2-years a significant amount of testing on filter monitors been conducted by the Aviation Filtration Committee (AFC). At this time there are two key areas for concern with filter monitors.

1) **Degradation in the field** - There is concern that filter monitors will not build enough pressure differential to shut off fuel flow during operation when slugged with water. Laboratory data has confirmed this is possible when using monitors. At the time of issue of this bulletin, the root cause of this problem has not been determined.

2) **Media Migration-Super Absorbent Polymer (SAP) –**There is a concern that SAP media could migrate outside of the filter monitor housing and onto the aircraft. Military data has confirmed this has occurred in the presence of DiEGME (FSII). Commercial aircraft testing is underway to see if migration occurs with Jet A and JetA1 without fuel additives.

API/IP 1583 4th edition-

This specification does not support fuels that have DiEGME passing through water absorbing filter monitors. DiEGME has been identified to degrade the performance of the filter monitors. The 4th edition has language that filter monitors should not be considered "Fail Safe". The 4th edition also covers a number of failure modes for the active ingredient in the filter monitors (SAP): sea water, low temperatures, strong ionic compounds, etc. can degrade the monitor performance in the field.

Immediate Actions to be taken at CGA supplied or owned/operated facilities:

- **Water handling and quality checks**
  Product Integrity and facility routine inspections need to focus on water handling. Verify that **all** water removal procedures are being followed.
- **Additive injection systems**
  Product integrity and facility routine inspections need to verify and document that the correct amount of additive is being injected downstream of filtration equipment. If new injection systems are required then contact Phil Wetmore or Edson Gould for a manufacturer recommendation.
- **Commercial locations inside/outside the US:**
  Converting all existing filter water separators housings from filter monitor elements back to filter water separators. Make sure and install water defense equipment also.
- **Military fueling operations**
  For any location that is under a military contract or provides military fuels (JP8, JP5 etc.) verify that your location is in compliance with current military bulletins and guidance information.
- **General Aviation:**

  Chevron is discontinuing all supply arrangements which may have involved fuel pre-blended with DiEGME and require our various FBO's and distributors to do likewise. This will include discontinuing any arrangements for pre-blending of DiEGME into transport trucks or airport storage tanks. Verify that fuels do not contain DiEGME when received. If a customer requires DiEGME then it can be automatically injected (using commercially available additive injectors) or added into the fuel by the aircraft operator only after the final filtration process and before going into the aircraft. For any location that is under a military contract or provides military fuels (JP8, JP5 etc.) verify that your location is in compliance with current military bulletins and guidance information.

If you have questions concerning this alert please contact Phil Wetmore @832-854-5978 or email philwetmore@chevron.com

Facet
a CLARCOR company

March 13, 2006

Subject: TECHNICAL BULLETIN - IP 1583 Monitor Specification Update

Recent incidents in the aviation industry have indicated Fuel System Icing Inhibitor (FSII) adversely affects the water removal properties of filter monitors and has also been implicated in media migration.

Facet realized the difficulty presented by FSII on monitor performance testing. The API/IP 1583 specification does not include FSII as a test additive however, knowing that monitors could be used with FSII, our 3rd and 4th Edition monitors were designed to withstand not only qualification testing with FSII but also the much more severe 50:50 FSII: Water slug tests. Instead of ignoring that FSII was an approved fuel additive (ASTM D-1655), Facet showed due diligence by fielding monitors that not only were qualified to the API/IP 1583 specification but also passed supplemental testing with FSII.

Facet can not unconditionally guarantee performance of monitors in fuel with FSII for the following reasons: FSII is not an approved monitor specification additive; we can not control the field conditions of proper additive injection or the condition of the neat FSII in operational storage, and can not assure that the proper sump draining procedures are in place.

Facet advises caution with using monitors in fuel containing FSII. As stated in API/IP 1583 4th Edition, paragraph 1.1 SCOPE, "Operators using such additives in aviation fuels are recommended to ensure for themselves the performance capabilities of filtration equipment …". If your company policy allows for the use of monitors in fuel with FSII, be sure that the FSII is clean and dry, proportionally injected upstream of a pump into fuel that is also clean and dry. As additional precautionary measure, limit the maximum corrected differential pressure to 15 psi with FSII.

The following is a summary of recent monitor events:

The USAF identified problems with monitors in JP-8 fuel and had aircraft incidents related to media migration of CMC, an absorbent not present in Facet monitors.

A subsequent U. S. Army investigation revealed evidence of SAP (absorbent material in monitors produced by all manufacturers) in on-board aircraft filters however, without any incident of filter by-pass or any other problems.

Commercial aircraft testing is underway to see if migration occurs with Jet A and JetA1 without fuel additives.

American Petroleum Institute co-sponsor for the API/IP 1583 withdrew support for the specification in December 2005. Reasons for the action by the API are currently being clarified.

The Energy Institute (formerly Institute of Petroleum) originator of the monitor specification does not support the API position and has stated that they will not be withdrawing this specification.

Numerous major oil companies have taken a similar position as ATA Specification 103, Standard for Jet Fuel Quality Control at Airports, Revision 2004.1 that has the following caution statement about the use of monitors:

"CAUTION: FULL FLOW MONITORS SHOULD NOT BE USED WITH FUELS CONTAINING FUEL SYSTEM ICING INHIBITORS (FSII). THE WATER REMOVAL PERFORMANCE OF FULL FLOW MONITORS MAY BE REDUCED WITH FUEL CONTAINING FSII. "

Facet as a member of the EI Aviation Committee and Filtration Sub-Committee will continue to work in resolving monitor issues, and keep you informed as information becomes available.

Facet USA, Inc. – 9910 E. 56th St. North – Tulsa, OK 74117-4011 USA
Phone: (800) 223-9910/ (918) 272-8700 – Fax: (918) 272-8787

Velcon Filters, Inc.

Service Bulletin

November 5, 2003 **Vol. 2 Number 7**

WATER ABSORBING CARTRIDGES SERVICE LIFE

Since our bulletin of May 22, 2003, Vol. 2 Number 3, there have been a number of important developments. These are summarized as follows.

1. A task force has been formed by API/IP to investigate the performance of water absorbing cartridges. The task force includes members of the oil industry, filter manufacturers, airlines and fixed base operators (FBO's).
2. Analytical work conducted by Velcon Filters, Inc. indicates the presence of sodium chloride (salt) on the water absorbing polymers and that this salt can degrade the performance of these water absorbing polymers. At this stage it is not clear as to how the salt is getting into the fuel system – further tests and analysis are being conducted.
3. Tests on six (6) inch cartridges also show, at some locations, that the performance of cartridges in service for over one year exhibit a similar degradation in performance to the two (2) inch monitors. Again, all poorly performing cartridges show a presence of salt on the water absorbing polymers. It should be understood that the Velcon cartridges that have performed poorly have all shown a high pressure differential (in excess of 25 psid) during our testing.
4. Although we believe that salt is a major factor, we continue to investigate other factors as well.

RECOMMENDATIONS – SERVICE LIFE

As recent test data indicates that six (6) inch cartridges can be affected, Velcon Filters, Inc. recommends the following:

> **Service life for all water absorbing cartridges, including two (2), five (5) and six (6) inch diameter cartridges, should be one (1) year, unless stated otherwise by your company's fuel handling procedures.**

Velcon Filters will continue to work with companies and operators who wish to extend service life beyond one year by testing cartridges that have been in service for one year or longer. Please contact Velcon Filters, Inc., at vfsales@velcon.com or fax us at 719-531-5690, if you wish to participate in this program.

We also continue to recommend that all operators continue to diligently conduct water removal procedures as outlined in our service bulletin of May 22, 2003. Please see our web site, http://www.velcon.com/doc/vol2no3.pdf for this bulletin.

Velcon

Service Bulletin is published by the Marketing Services Department of Velcon Filters, Inc.
Please address all comments or questions to Robin Mason.
4525 Centennial Blvd • Colorado Springs, CO 80919 • 719.531.5855 • FAX: 719.531.5690
• E-mail: vfsales@velcon.com

1897-R3 11/03
PN 09-094

Parker Hannifin Corporation
Racor Division
P.O. Box 6030
805 North West Street
Holly Springs, MS 38635

WARNING!

Aviation Fuel Monitor Vessels contain filter elements that remove particulates and prevent water from entering an aircraft fuel tank.

Parker Hannifin aviation fuel monitor filters are used in the fuel delivery system and are manufactured with super absorbent polymer media that may degrade and migrate into the fuel tank under some operating conditions. Degradation of the monitor filter may allow water and/or the super absorbent polymers themselves into the aircraft fuel tank.

The level of super absorbent polymer media degradation/migration depends upon factors including the fuel characteristics and the specific fueling application. These factors include fuel additives, the water level content and the technique used for fuel dispensing.

The aviation industry has not reached a consensus on all possible causes of media degradation/migration under field operating conditions.

Water or super absorbent polymers in the fuel tank may cause the engine of an aircraft to be inoperable leading to death, personal injury and property damage from the crash of the airplane.

To best avoid degradation of the super absorbent polymers and transmission of such super absorbent polymers and water into the aircraft fuel tank, Parker Racor Division recommends changing out the fuel monitor filter at least every 12 months or sooner when the differential pressure of the monitor housing reaches 25 psid. Further, strict adherence to proper aviation fuel quality control and filter maintenance guidelines including applicable industry standards is recommended.

Such guidelines and standards include:
Air Transport Association of America ATA 103 Standards for Jet Fuel Quality Control at Airports
IATA Fuel Quality Control and Fueling Service Guidance Material
Joint Inspection Group (JIG)
and other guidelines that are appropriate for your operation.

For additional information, please call Parker Racor Division Hydrocarbon Products Technical Service at 662-252-2656 or e-mail: racorengus@parker.com

Bulletin No. 73185

Service Bulletin
December 15, 2003 – Vol. 2

Water Absorbing / Monitor Element Service Life

Since our previous service bulletin in June this year regarding the concerns with service life of water absorbing elements there have been a number of further developments. These developments have shown without doubt that ALL manufactures are experiencing similar problem.

Importantly, a Task Force has been formed by API/IP to investigate this problem. This task force includes members of the Oil Industry, Airlines, Operators and ouf course the Filter Manufacturers.
Preliminary investigations by the Task Force have pointed at the presence of Sodium Chloride (Salt) deposits in the water absorbent media. This salt may degrade the performance of the water absorbing media and at this time it is not clear as to how the salt is getting into the supply system.
It is also not certain at this time that the salt is the sole cause and other possibilities are being investigated.

Tests by some manufacturers have indicated that similar problems exist with 6" Monitor elements and this is also being investigated as part of the working group.

RECOMMENDATIONS – SERVICE LIFE

In light of the recent Bulletins from various Manufacturers and End Users recommending a Service Life of One (1) Year for all Water absorbent Monitor elements, FAUDI Aviation are issuing the following advice to avoid confusion and hopefully help the Industry to be on a single footing;

> Service life for all FAUDI Aviation water absorbing monitor elements should be ONE (1) Year, unless otherwise advised by your Company's directive or fuel handling procedures.

This new 1 year Changeout recommendation by FAUDI Aviation will take effect immediately and will remain until the API/IP investigation is concluded and a proven solution found.

Please address all comments or questions to: Marcus Wildschütz
E-Mail: m.wildschuetz@faudi-aviation.com

THE POWER OF FLIGHT

CFM56 Fuel Filter Impending Bypass Light Indication - Experience -

May 2006

THE POWER OF FLIGHT

- **Background** :

  - Even thought a significant increase of Fuel Filter Delta P Switches MTBUR, Customers complain about Fuel Filter Indication System.

  - Numerous fuel filter impending bypass light indication reported on all CFM56 fleet:

    ATO / ATB / A/C diversion events reported in year 2006:

    - CFM56-7B : 7 ATB's & 2 A/C's diversion
    - CFM56-5A: 1 ATB
    - CFM56-5B: 2 ATB's
    - CFM56-5C: 0 ATB/ATO
    - CFM56-3: 4 ATB

THE POWER OF FLIGHT

- **Specific Study on CFM56-7B:**

  - On CFM56-7B, with the 737NG WTT team a specific study was launched June 05 to determine Fuel Filter Impending bypass Indication root causes in field and establish the rate of indication problems from the rate of true clogging (Critical Issue Team - CIT 004 - a joint Airlines / Boeing / CFM Team).

  - The first step of the CIT 004 consists in collecting parts (both Fuel Filter and Fuel Filter Delta P Switch) and a questionnaire form (troubleshooting information) completed from field event with Fuel Filter Indications, to investigate Fuel Filter Indication System.

  - Since CIT 004 was launched many customers have started reporting true fuel filters clogging.

THE POWER OF FLIGHT

- **CFM56-7B CIT 004 Fuel Filter Investigations status:**

  - 17 filters elements from the CIT 004 investigated at fuel filters manufacturers:
    - 13 filters from Pall
    - 4 filters from Sofrance

  - All 17 filters investigated confirmed to be clogged and showed similar contamination (presence of dark/brown material) :
    - 80 to 99 % of contaminants are within 2 to 25 µm size
    - Chemical composition major elements identified: major sulfur, iron, silicon , carbon, aluminum, (copper),…

Dark/brown material could be iron sulfide or sulfur oxides (sulfites, sulfates…)

- **CFM56-7B CIT 004 Fuel Filter Investigations status** (cont'd):

7B Engine	TYPE	Time on filters (Hours)	Particles Identifications	Particles size & Distribution (microns)
875633	18350/ACC462F2038M	4020	Major sulfur, some iron,silicon & lead	96,7% range from 2 to 25 - 45% -50% metallics
874610	18350/ACC462F2038M	4020	Major sulfur, some iron, silicon, alu,carbon and lead	96,5% range from 2 to 25 - 50% -55% metallics
874888	18350/AC-C331F-2038	less than 5000 hrs	Major iron & silicon	97,4% range from 2 to 25 - 60% -65% metallics
876334	18350/ACC462F2038M	?	Major sulfur, carbon and sulfur, some alu & iron	98,7% range from 2 to 25 - 40% -45% metallics
891334	18350/ACC462F2038M	3368	major sulfur & iron,some silicon & carbon	99,4% range from 2 to 25 - 50% -60% metallics
860152	18350/ACC462F2038M	2816	major sulfur & iron,some aluminum	96,9% range from 2 to 25 - 60% -65% metallics
875520 - # 1	18350/ACC462F2038M	1678	major sulfur, some copper (presence of dark/brown, black particulates resembling oxidized ferrous, shiny metallic and some translucent silica (sand)	92% range from 2 to 25 - 10% metallics
874498	18350/ACC462F2038M	1678	major sulfur, iron and some silicon (presence of dark/brown, black particulates resembling oxidized ferrous, shiny metallic and some translucent silica	90,4% range from 2 to 25 - 50% metallics
890467	18350/ACC462F2038M	4675	major alu,titanium & sulfur,some silicon	97% range from 2 to 25 - 80% metallics
888154 - # 2	18350/ACC462F2038M	?	Major: sulfur with major/minor iron Some carbon, aluminum, and copper One particle had major calcium, one had major chlorine,and one had major silicon	2 - 5 um: 77.9 % 5 - 15 um: 19.9 % 15 - 25 um: 1.4 % 25 - 50 um: 0.3 % > 50 um: 0.6 % % Metallics: 25
876383, # 2 - ATB	18350/ACC462F2038M	548	Major: sulfur, iron Some carbon, sodium	2 - 5 um: 54.7 % 5 - 15 um: 31.7 % 15 - 25 um: 10.3 % 25 - 50 um: 2.2 % > 50 um: 1.1 % % Metallics: 60
876381- # 1	18350/ACC462F2038M	548	Major: sulfur, iron, carbon Some aluminum, calcium, copper One particle had major sodium	2 - 5 um: 80.7 % 5 - 15 um: 17.8 % 15 - 25 um: 0.6 % 25 - 50 um: 0.9 % > 50 um: < 0.1 % % Metallics: 10
890696- # 1	18350/ACC462F2038M	1463	One particle had major lead	Metallics: 30%, 92% range from 2 to 25
890218, # 2	CH0697101552N00	1763		96% of size particle between 5-15 um , contamination type : 100% mud particles
888620	CA01962B	?		67,9% of size particle between 5-15 um , contamination type : 90% brown organic particles
891779	CA01962B	?		85,6% of size particle between 5-15 um , contamination type : 95% mineral mud (can be sand)
876412 - # 2	CA01962B	4043		84,2% of size particle between 5-15 um , contamination type : 100% mineral mud (can be sand)

- **CFM56-7B CIT 004 Results & Customer reports:**
  - Operators are reporting an increasing number of fuel filter bypass indication.
  - However fuel contamination becoming a significant concern:
    - All CFM56-7B fuel filter elements investigated found clogged and contaminated with similar very fine particles.
    - Many CFM56 Customers report an increase of fleet events with very fuel filter low time.
  - Contamination source not identified (atmospheric pollution, quality fuel from suppliers (Tank, truck , water, bacteria …)
  - Customers report that water is a contributor of fuel filter clogging but CFM56 fuel filters are not a coalescent filter.
  - CFM56 fuel filters are making a good job to protect engine fuel system.

- **CFM and Aircraft Manufacturers recommendations:**

  - CFM and Aircraft Manufacturers recommend to Reduce the filter change interval to prevent impending bypass conditions during flight according to the operator experience and to Reduce time of water drain.

  - CFM and Aircraft Manufacturers recommend customers to joint the IATA group team formed to investigate fuel contamination and recommend customers to work with their fuel suppliers.

CFM56 Fuel Filter Impending Bypass Light Indication - Experience -

May 2006

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874610	18350/ACC462F2038M	4020	Major sulfur, some iron, silicon, alu,carbon and lead	96,5% range from 2 to 25 - 50% -55% metallics
874888	18350/AC-C331F-2038	less than 5000 hrs	Major iron & silicon	97,4% range from 2 to 25 - 60% -65% metallics
876334	18350/ACC462F2038M	?	Major sulfur, carbon and sulfur, some alu & iron	98,7% range from 2 to 25 - 40% -45% metallics
891334	18350/ACC462F2038M	3368	major sulfur & iron,some silicon & carbon	99,4% range from 2 to 25 - 50% -60% metallics
860152	18350/ACC462F2038M	2816	major sulfur & iron,some aluminum	96,9% range from 2 to 25 - 60% -65% metallics
875520 - # 1	18350/ACC462F2038M	1678	major sulfur, some copper (presence of dark/brown, black particulates resembling oxidized ferrous, shiny metallic and some translucent silica (sand)	92% range from 2 to 25 - 10% metallics
874498	18350/ACC462F2038M	1678	major sulfur, iron and some silicon (presence of dark/brown, black particulates resembling oxidized ferrous, shiny metallic and some translucent silica	90,4% range from 2 to 25 - 50% metallics
890467	18350/ACC462F2038M	4675	major alu,titanium & sulfur,some silicon	97% range from 2 to 25 - 80% metallics
888154 - # 2	18350/ACC462F2038M	?	Major: sulfur with major/minor iron Some carbon, aluminum, and copper One particle had major calcium, one had major chlorine,and one had major silicon	2 - 5 um: 77.9 % 5 - 15 um: 19.9 % 15 - 25 um: 1.4 % 25 - 50 um: 0.3 % > 50 um: 0.6 % % Metallics: 25
876383, # 2 - ATB	18350/ACC462F2038M	548	Major: sulfur, iron Some carbon, sodium	2 - 5 um: 54.7 % 5 - 15 um: 31.7 % 15 - 25 um: 10.3 % 25 - 50 um: 2.2 % > 50 um: 1.1 % % Metallics: 60
876381- # 1	18350/ACC462F2038M	548	Major: sulfur, iron, carbon Some aluminum, calcium, copper One particle had major sodium	2 - 5 um: 80.7 % 5 - 15 um: 17.8 % 15 - 25 um: 0.6 % 25 - 50 um: 0.9 % > 50 um: < 0.1 % % Metallics: 10
890696- # 1	18350/ACC462F2038M	1463	One particle had major lead	Metallics: 30%, 92% range from 2 to 25
890218, # 2	CH0697101552N00	1763		96% of size particle between 5-15 um , contamination type : 100% mud particles
888620	CA01962B	?		67,9% of size particle between 5-15 um , contamination type : 90% brown organic particles
891779	CA01962B	?		85,6% of size particle between 5-15 um , contamination type : 95% mineral mud (can be sand)
876412 - # 2	CA01962B	4043		84,2% of size particle between 5-15 um , contamination type : 100% mineral mud (can be sand)

- **CFM56-7B CIT 004 Results & Customer reports:**
  - Operators are reporting an increasing number of fuel filter bypass indication.
  - However fuel contamination becoming a significant concern:
    - All CFM56-7B fuel filter elements investigated found clogged and contaminated with similar very fine particles.
    - Many CFM56 Customers report an increase of fleet events with very fuel filter low time.
  - Contamination source not identified (atmospheric pollution, quality fuel from suppliers (Tank, truck , water, bacteria …)
  - Customers report that water is a contributor of fuel filter clogging but CFM56 fuel filters are not a coalescent filter.
  - CFM56 fuel filters are making a good job to protect engine fuel system.

- **CFM and Aircraft Manufacturers recommendations:**

  - CFM and Aircraft Manufacturers recommend to Reduce the filter change interval to prevent impending bypass conditions during flight according to the operator experience and to Reduce time of water drain.

  - CFM and Aircraft Manufacturers recommend customers to joint the IATA group team formed to investigate fuel contamination and recommend customers to work with their fuel suppliers.

US Navy Fuel Monitor Status

IATA -Fuel Filter Monitor Workshop Meeting
May 31, 2006

Jack Buffin/John (Jack) Krizovensky
Naval Air Systems Command
Phone: (301) 757-3406/301-757-3405
Fax: (301) 757-3614
Email: john.buffin@navy.mil/john.krizovensky@navy.mil

Navy Fuel Monitor Applications

- Naval Air Stations - 3rd Stage Filtration
  - Truck Fill Stands
  - Refueling Trucks
  - Direct Fueling Stations
  - Skid Mounted
- Helicopter In Flight Refueling (HIFR)
- Shipboard Aircraft-Aircraft Fuel Transfer Cart
- Fuel Monitors Not Used In Navy Shipboard Aircraft Refueling Systems

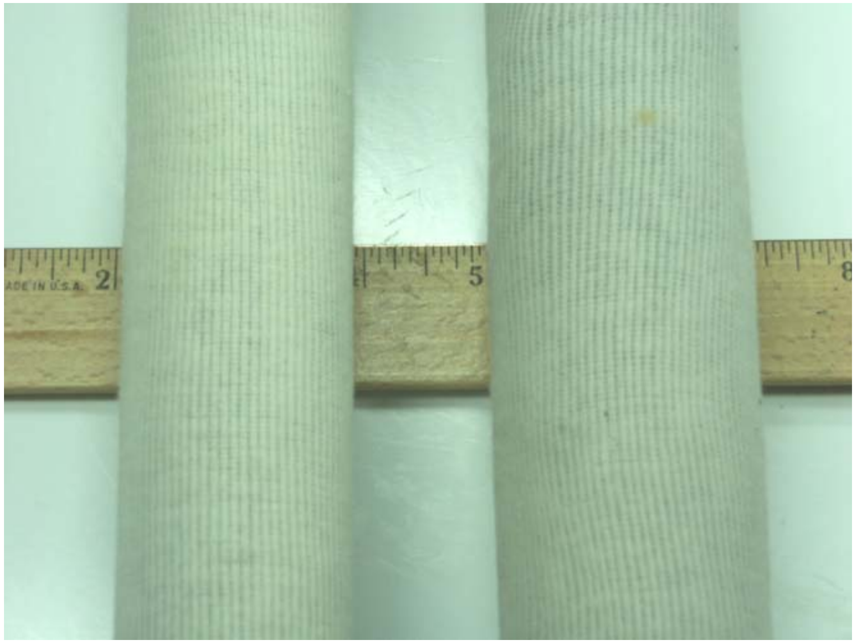
Monitor Media Migration

- Monitor Media Migration Reported by Air Force and Commercial Operators – Navy Initiated Investigation

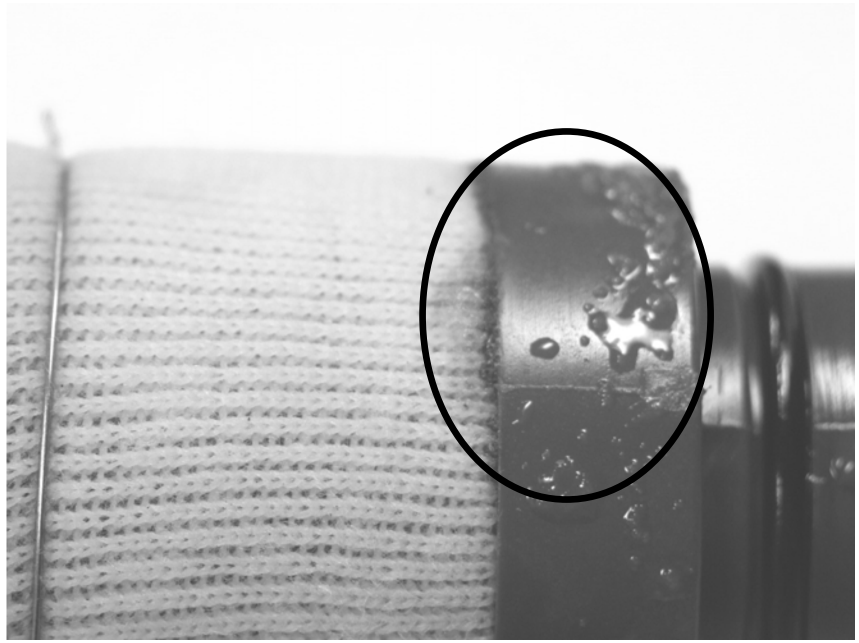
- Single Element Testing – New and Used Elements
  - 2"X20"; 2"X30"; 4"X20"; 6"X33"
  - Fuel and Water Phases Analyzed for Media
    - FTIR/ICP/GC-MS/GPC
    - Reference Standards-CMC&PA - Mnfrs/Chem Supply
    - Qualitative Method - FTIR
    - Quantitative Method Could Not be Established
      - MIL-PRF-81380 Specification Limits Cannot Be Established

  - All Downstream Water Samples Contained Media
  - Some Media Found in Fuel Samples

Monitor Water Slug Test + Static Soak

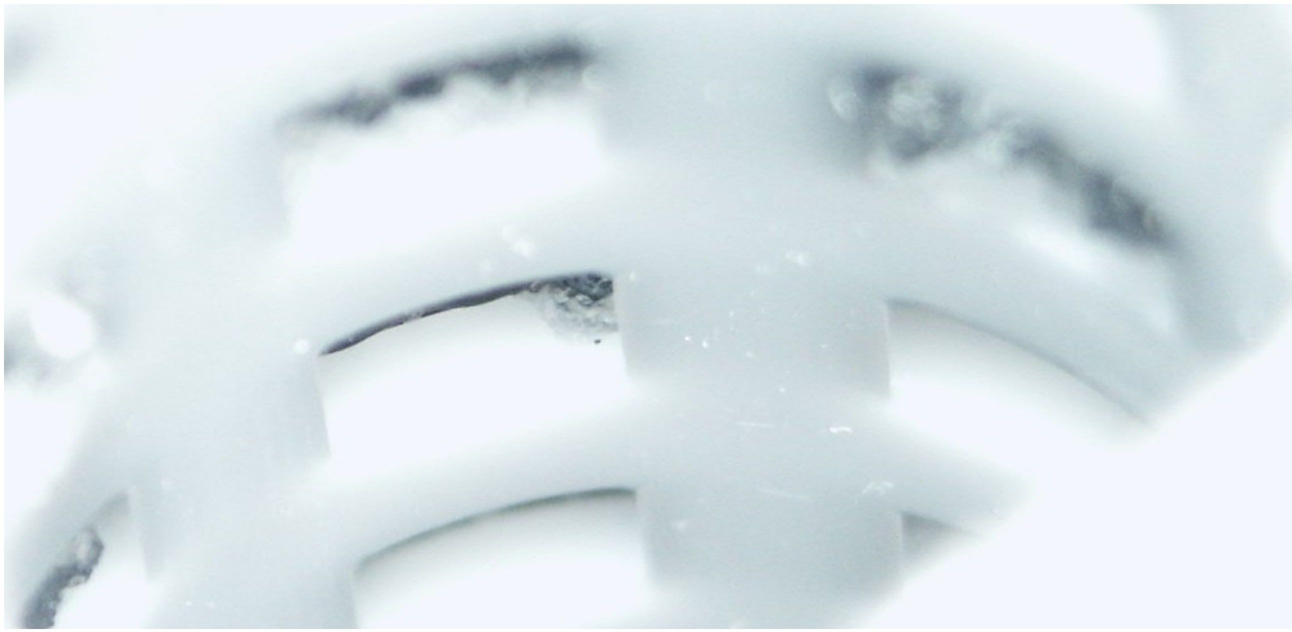


Swollen Monitor*



Media Migration*

In-house Laboratory Techniques - Extrusion



NAVY Position

- Media Migration Can Occur
- Currently Conducting Risk Assessment
  - (1) status quo - monitors remain in place; (2) removal of monitors without replacement; (3) removal of monitors and replacement with new water sensing technology
    - Field Monitor Replacement History
    - A/C EIs/Filter History
    - Cost – Savings/Expenditures
  - Completion - 30 June 2006

Appendix 16

U.S Navy Inputs to IATA Filter Monitor Task Force

MSGID/GENADMIN/COMNAVAIRSYSCOM//
REF/A/MSGID:DOC/NAWCAD/YMD:20050615//
POC/JOHN CUMMINGS/GS-13/445/LOC:PATUXENT RIVER MD/TEL:301-757-3410/-
/EMAIL:JOHN.CUMMINGS@NAVY.MIL// AMPN/REF A IS NAVAIR 00-80T-109, AIRCRAFT REFUELING NATOPS MANUAL (JUNE 2005)// GENTEXT/REMARKS/

1. FUEL QUALITY MONITORS SHALL BE TAKEN OUT OF SERVICE BY ALL NAVY/MARINE CORPS AIR STATIONS AND TACTICAL FUELS UNITS AS SOON AS PRACTICABLE BUT NOT LATER THAN 28 FEB 2007.

2. ALL NAVY/MARINE CORPS AIR STATION FUEL DIVISIONS SHALL TAKE THE FOLLOWING ACTIONS:

A. REMOVE FUEL QUALITY MONITOR ELEMENTS FROM ALL FIXED FUELING FACILITY FUEL QUALITY MONITOR VESSELS. FUEL QUALITY MONITOR VESSELS SHALL BE LEFT IN PLACE PENDING FURTHER GUIDANCE.

B. REMOVE FUEL QUALITY MONITOR ELEMENTS FROM ALL GOVERNMENT OWNED MOBILE REFUELING EQUIPMENT. FUEL QUALITY MONITOR VESSELS SHALL BE LEFT IN PLACE. REPLACEMENT MOBILE REFUELING EQUIPMENT SHALL BE ACQUIRED WITHOUT FUEL QUALITY MONITORS.

C. ENSURE THAT DAILY EQUIPMENT FUEL QS TESTS ARE PERFORMED IAW REF A SECTION 9.2.3. NOTE THAT THE THIRD BULLET UNDER "NOTE" IN THIS SECTION NO LONGER APPLIES.

D. CONDUCT A RISK ASSESSMENT OF THEIR FACILITY IAW THE SECOND BULLET UNDER "NOTE" IN REF A SECTION 9.2.3. IF ASSISTANCE IS REQUIRED TO CONDUCT THE RISK ASSESSMENT CONTACT THE AIR 4.4.5.1 POC.

E. FOR THOSE AIR STATIONS HAVING CONTRACTED IN-TO-PLANE FUELING SERVICES, COORDINATE WITH THE CONTRACTOR'S ON-SITE MANAGER TO HAVE FUEL QUALITY MONITOR ELEMENTS REMOVED FROM ALL CONTRACTED AIRCRAFT REFUELING EQUIPMENT.

3. FOR MARINE CORPS SYSTEMS COMMAND, COORDINATE WITH ALL TACTICAL FUELS UNITS TO REMOVE TAFDS/HERS FUEL QUALITY MONITOR VESSELS FROM SERVICE AND REMOVE FUEL QUALITY MONITOR ELEMENTS FROM ALL MOBILE REFUELING EQUIPMENT EQUIPPED WITH SUCH ELEMENTS.

4. FOR NFESC AND NAVFAC ATLANTIC. RECOMMENDED CHANGES TO AFFECTED UNIFIED FACILITY CRITERIA AND UNIFIED FACILITY GUIDE SPECIFICATIONS WILL BE SUBMITTED FROM NAVAIR VIA SEPARATE CORRESPONDENCE.

5. FOR NOLSC PETROLEU. USN/USMC AIR STATION IN-TO-PLANE FUELING SERVICE CONTRACTS WILL NEED TO BE MODIFIED TO REFLECT THIS CHANGE IN MINIMUM EQUIPMENT REQUIREMENTS FOR MOBILE REFUELING EQUIPMENT.

6. BACKGROUND

A. A NAVAIR CONDUCTED STUDY OF FUEL QUALITY MONITOR ELEMENTS LED TO A REDUCTION IN ELEMENT USE LIFE (IE. A MORE FREQUENT ELEMENT CHANGE OUT

CRITERIA) THAT WAS PROMULGATED VIA REF A.

B. THROUGH CONTINUED RESEARCH (TO INCLUDE WORK DONE BY THE COMMERCIAL AVIATION SECTOR)NAVAIR HAS DETERMINED THAT THERE ARE NO CURRENTLY AVAILABLE TEST METHODS THAT CAN QUANTITATIVELY DETERMINE THE AMOUNT OF SUPER ABSORBENT POLYMER (THE WATER ABSORBING COMPONENT OF FUEL QUALITY MONITOR ELEMENTS) THAT MIGRATES DOWNSTREAM.

C. BASED ON THE ABOVE AND A REVIEW OF ALL AVAILABLE DATA FROM THREE USAF INCIDENTS INVOLVING FLAME-OUTS AT ALTITUDE ATTRIBUTED TO FILTRATION MATERIAL MIGRATING DOWNSTREAM OF FUEL QUALITY MONITORS, NAVAIR HAS CONDUCTED AN ANALYSIS OF THE RISK TO AIRCRAFT OF REMOVING FUEL QUALITY MONITOR EQUIPMENT FROM SERVICE.

D. THE RISK ANALYSIS INDICATED THAT FUEL QUALITY MONITOR EQUIPMENT COULD BE SAFELY REMOVED FROM SERVICE. ANY RESIDUAL RISK OF THE DELIVERY OF EXCESSIVE AMOUNTS OF FREE WATER TO AIRCRAFT CAN BE MITIGATED BY ADHERENCE TO THE FUEL QUALITY CONTROL PROCEDURES IN REF A SECTION 9.2.3.

E. THE RISK ANALYSIS ALSO CONCLUDED THAT, DESPITE MORE THAN TWENTY YEARS OF PROBLEM FREE SERVICE WITHIN THE NAVY/MARINE CORPS, FILTER/MONITOR MEDIA MIGRATION DOES PRESENT A POTENTIAL RISK TO AIRCRAFT OPERATIONS.

7. AN INTERIM CHANGE TO REF A IS BEING COORDINATED AND WILL BE DISSEMINATED BY THE END OF CY-06.

8. THE CONTINUED USE OF MONITOR ELEMENTS WITH HELICOPTER IN-FLIGHT REFUELING EQUIPMENT IS BEING INVESTIGATED SEPARATELY.

9. ONGOING FUEL QUALITY SURVEILLANCE RESEARCH EFFORTS. CURRENT R&D EFFORTS ARE DEVELOPING TECHNOLOGIES THAT CAN MEASURE FREE WATER AND PARTICULATES IN FUEL IN REAL-TIME. AN IN-LINE SYSTEM IS UNDERGOING FIRST ARTICLE TESTING FOR INSTALLATION ABOARD NAVY CARRIERS. A TRIAL INSTALLATION OF THE SYSTEM AT AN AIR STATION IS SCHEDULED FOR THE 3RD OR 4TH QUARTER FY07. A TRUCK MOUNTED SYSTEM HAS BEEN DEVELOPED AND IS CURRENTLY BEING TRIALED IN A COMMERCIAL REFUELING TRUCK. A PORTABLE UNIT BASED ON THE SAME TECHNOLOGY AS THE FIXED SYSTEMS IS UNDER DEVELOPMENT AND IS SCHEDULED TO BE TESTED NEAR THE END OF FY07.

10. AIR 4.4.5.1 POC FOR FUEL QUALITY SENSING EQUIPMENT IS JACK BUFFIN, 301-757-3406, FAX 301-757-3614, E-MAIL JOHN.BUFFIN@NAVY.MIL. THE AIR

4.4.5.1 POC FOR QUESTIONS CONCERNING AIRCRAFT REFUELING NATOPS ISSUES IS JOHN CUMMINGS, 301-757-3410, DSN 757-3410, FAX 301-757-3614, E-MAIL JOHN.CUMMINGS@NAVY.MIL//

UPDATE ON THE STATUS OF FILTER MONITOR TECHNOLOGY IN THE US AIR FORCE AND NAVY

August 2006

Det 3, WR-ALC/AFTT
WEAPON SYSTEMS SUPPORT BRANCH
AIR FORCE PETROLEUM OFFICE
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433-7632

INTRODUCTION

Within the past two years various reactions and initiatives by the US Air Force and US Navy have been directed toward defining the future role of filter monitor technology within the US military. This has to a great extent been motivated by multiple aircraft incidents experienced by the Air Force.

In the summer of 2005, three T-37 aircraft flying out of Sheppard Air Force Base (Texas) experienced single engine flame-out while in flight. Attempts to air-restart failed in all cases. The ensuing investigation found that large amounts of carboxymethylcellulose/potassium super absorbent (SA) polymer had been trapped in the aircraft engine filters and fuel control hardware blocking the flow of fuel. The manufacturer of the filter monitor equipment in use at that time confirmed that polyacrylate and carboxymethylcellulose neutralized potassium slats were contained in the SA polymer media of these filter monitors. Further investigative efforts resulted in the identification of the same SA polymers in aircraft filters taken from several other bases within the continental US. In order to ensure safety of flight, the Air Force directed the removal of filter monitors from the equipment used to refuel aircraft at all Air Force activities. Filter monitors were replaced with coalescing-type filtration hardware and interim safety supplements were processed to remove all reference to filter monitor elements within all pertinent manuals and Technical Orders.

The identification of SA polymer in the T-37 and other US Air Force aircraft engine filters prompted the initiation of several follow-on efforts by both the US Air Force and US Navy. Some of this work remains ongoing. The work by the US Air Force has the purpose of determining the mechanism by which the SA media migrates from the filter monitor and to determine if the migration of this media only takes place in certain types or designs of filter monitors. The US Navy is working to determine if this same media migration takes place in US Navy systems and if so, to what extent. The disposition and findings of these follow-on efforts are described in the following.

US AIR FORCE

Long before the T-37 incidents in 2005, the Air Force Petroleum Office Technical Division located at Wright Patterson Air Force Base was occasionally finding what appeared to be an acrylic type polymer material often located in and with other polymeric materials, inorganic substances, and microbial growth products found in fuel system sump samples. For example, polyacrylate was identified in at leaset five samples from five different bases in 2004. Since it was known that polyacrylate polymers were used as part of the filter monitor media, these findings prompted an exploration, albeit very limited, of potential mechanisms by which polyacrylate filter monitor media could be depolymerized and migrate away from the monitor during use.

The actual structures of the SA polymers utilized by the various filter monitor vendors have always been regarded as proprietary information and have never been disclosed to the Air Force. This of course has greatly hampered efforts to determine the chemical reaction mechanisms that may be responsible for the apparent depolymerization and migration of the SA polymer.

Based on the scant amount of information that has been made available by vendors, a potential mechanism was devised. In this mechanism, the sodium ion is first released by interaction with an organic acid. This is then followed by a nucleophilic substitution reaction breaking the cross-link between individual polymer molecules of the SA material. Multiple breaks in cross-link bonding would result in portions of the SA polymer detaching from the bulk material and becoming entrained in the downstream flow of fuel. The validity of this and other potential mechanisms such as the hydrolysis of ester or amide linkages cannot be firmly established with any great degree of certainty without knowing the actual structure of the SA polymer.

Following the T-37 incidents in 2005, the Air Force and Chevron initiated a joint effort to determine if SA polymer media migrates from the type of filter monitors used by commercial aviation. This work was performed by the Southwest Research Institute and involved the operation of an Air Force filter monitor housing containing 22 of the 2-inch diameter commercial aviation monitors. These monitors were exposed to a 20% rated flow of clean Jet-A fuel (without FSII (fuel system icing inhibitor) additive) with stop/starts taking place at evenly spaced intervals in order to simulate a real-world scenario. A side stream of this flow was directed through a membrane filter to trap a sample of any solid materials that may have become entrained in the fuel. The results of this work suggested that commercial filter monitors from a variety of vendors all displayed to some degree the migration of SA polymer media under these flow conditions. Although a number of different analytical techniques have been used in making this assessment, the development of other analytical techniques could prove to be useful in further substantiating these results.

US NAVY

Prompted by the problems experienced by the US Air Force, the US Navy initiated a program to determine if and to what extent the Navy may experience similar problems. This came on the heels of a sampling program in which the Navy found that their filter monitors were losing effectiveness earlier than expected.

As part of this ongoing Navy program, an attempt was made to use gel permeation chromatography to quantify the amounts of SA polymer media that might be present in engine filters or sump samples. The Navy found that, due to poor repeatability and detection limits, this technique would not be able to provide this type of information.

This illustrates the great difficulty that exists in quantifying the amount of media present in field samples.

The Navy utilized a single element test rig to investigate the potential for SA polymer media migration from 2-, 4-, and 6-inch diameter filter monitor elements from a variety of manufacturers. The analyses of water and fuel samples were referenced to known standards for carboxymethylcellulose and polyacrylate polymers. The analyses revealed that all downstream water samples and some downstream fuel samples contained media that had migrated from the monitors. The Navy has concluded that the migration of SA polymer media can indeed occur. In light of this, they are currently performing an assessment of the risk associated with the removal of filter monitor hardware from their refueling systems.

The Navy also plans to continue work by developing a media migration test that can be included in their filter monitor specification MIL-PRF-32148. This will then work to ensure that filter monitors purchased to this military specification will not shed SA polymer media during use.

CONCLUSIONS

The experiences and investigative work of the US Air Force and US Navy have demonstrated that SA polymer media can migrate from filter monitors either in the presence or absence of FSII. Moreover, experimental work has suggested that this migration can occur in both military and commercial-type monitors under the real-world conditions of refueling operations.

Efforts to quantify the amount of this media in engine filters or sump samples even under controlled conditions have proven to be very difficult. Additionally, the presence of this media could be masked by any accompanying inorganic and/or microbial contamination. For these reasons, additional work to further substantiate and quantify this migration of SAP from commercial type monitors will require a significant investment and cooperation between monitor vendors and users.

Guide for examination of contamination in aviation fuel filters

1. Scope

1.1 This document covers types of contamination or debris typically encountered in fuel filters and provides a routine for the examination of these filters in the form of a series of sequenced steps. This examination protocol is a combination of best practices currently in use by a variety of laboratories and will provide an in-depth analysis of contaminants while minimizing the time and expense required to obtain this analysis.

1.2 Since there is a wide range of applications and environments, additional analytical methods maybe utilized to meet any special user requirements.

1.3 The categories used to classify the contaminants were derived from a great deal of previous experience analyzing numerous and varied samples in a variety of laboratories.

1.4 Classification of the contaminants is based on the results of many samples from various laboratories.

2. Referenced Documents

ASTM Standards

D 1356 Standard Terminology Relating to Sampling and Analysis of Atmospheres

D 3282 Standard Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes

D 2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

D 653 Standard Terminology Relating to Soil, Rock, and Contained Fluids

D 5120 Standard Test Method for Inhibition of Respiration in Microbial Cultures in the Activated Sludge Process

D 4310 Standard Test Method for Determination of the Sludging and Corrosion Tendencies of Inhibited Mineral Oils

E 1839 Standard Test Method for Efficacy of Slimicides for the Paper Industry – Bacterial and Fungal Slime

SAE Standards

SAE J1124 Glossary of Terms Related to Fluid Filters and Filter Testing

SAE ARP1827 Measuring Aircraft Gas Turbine Engine Fine Fuel Filter Element Performance

ISO Standards

ISO 4405 – Hydraulic fluid power – Fluid contamination – Determination of particulate contamination by the gravimetric method

ISO 4406 – Hyraulic fluid power – fluids – Method for coding the level of contamination by solid particles

ISO 11171 – Hydraulic fluid power – Calibration of automatic particle counters for liquids

3. Terminology

Filters encounter a variety of chemical contaminants that sometimes may produce unusual forms of agglomeration and conglomeration, for instance, microbial sludges or inorganic slurries that can be described differently. In this sense, the classification of contaminants presented in this document follows the general terminology accepted in most cited technical literature such as ASTM documents and popular college dictionaries. Please note different references may define the terms in a different way to meet the application.

i. Definitions related to filters

Filter – A device having a porous medium for collecting particulate matter. The major filter components are the housing and the element.

Filter element – A sub-assembly of a filter which contains the filter medium or media.

Filter housing – A ported enclosure which contains the filter element and directs fluid through it.

Filter medium – The porous material which performs the process of particulate separation and retention.

Filter mesh – A sieve-like arrangement of interlocking metal links or wires.

Filter paper – A porous paper, matted or felted sheet of fibers.

Pleats – A series of folds in the filter medium used to increase effective filter area within a given space.

Root – The inner fold of a pleat.

Surface Medium – A filter medium that primarily separates and retains contaminant on the influent surface face.

Total area – The entire surface area of a porous medium, whether effective or not, in a filter element.

Wound Medium – A filter medium comprised of layers of crossed helical wraps of a continuous filament or strand of roving.

ii. Definitions related to contamination

Agglomerate – A group of two or more particles combined, joined, or clustered, by any means.

Aggregate – A relatively stable assembly of dry particles formed under the influence of physical forces.

Conglomerate – A group of two or more particles or particulates of heterogeneous materials joined or clustered by any means.

Clay – a firm, fine-grained earth composed chiefly of hydrous aluminum silicate minerals.

Clean Element – A new or re-conditioned filter element which is essentially free of contamination introduced during manufacture, assembly, storage, or use.

Clogged Element – A filter element which has collected a quantity of contaminant, such that it cannot maintain rated flow without excessive differential pressure

Contaminant – Any material or substance which is unwanted in a system.

Particle – A minute piece of matter with observable length, width, and thickness; usually measured in micrometers.

Particles size – The maximum dimension of the particle.

Particulate – *adj.* 1. of, pertaining to, or composed of distinct particles. – *n*. 2. a particle. 3. a material composed of particles.

Sand particle – A particle of the soil within the size range of 75 microns to 4.76 mm

Silt – Fine particulate matter with particles smaller than sand and larger than clay.

4. Types of contaminants frequently encountered in fuel filters

Contaminants typically observed in fuel filters fall into the following general categories (by visual appearance, texture and size):

- Distinctive particles, flakes and chips of various metals, paints, coatings, plastics and rubbers of various colors
- Distinctive particles of sand, clay and their mix frequently referred to as dust or airborne particles
- Distinctive fibers including fibers of the filter's media
- Rust-like particles and flakes
- Dry agglomerates/conglomerates of the particles described above, homogeneous and/or heterogeneous
- Sludge-like (wet) (or dirt-like) agglomerates/conglomerates of the particles described above, homogeneous and/or heterogeneous.
- Slime-like substances, usually of dark or tan-brownish color.
- Oily and greasy substances
- Gelled (gelatinous, jelly-like) particulates of various colors, shapes and sizes
- Brownish/reddish, scaly or gritty deposits on the filter's meshes and/or conglomerates in the filter's media

5. Airline Data Requested for Filter Analysis

- Filter time on aircraft (in aircraft engine operating hours)
- Indication problem or actual filter problem
- Did bypass light go on?
- Airplane routing history
- Filter brand & part number
- Aircraft identification (line number, S/N, etc.)
- Is this a single event or multiple events on the airplane or fleet

6. Apparatus

- Stereo Microscope (minimum 8X magnification) with digital imaging system
  - Used to classify large particles and fibers and select samples for SEM and FTIR analysis
- Electron Probe Microanalysis (EPMA) spectrometer
  - Used to identify the chemical composition of the contamination
- X-ray diffractometer
  - Crystallographic information on the contamination
- Fourier Transform Infrared (FTIR) spectrometer
  - Used to identify the molecular bonding of the chemical composition
- Gas Chromatography –Mass Spectrometry (GC-MS) spectrometer
- Scanning Electron Microscope (SEM)
- Environmental Scanning Electron Microscope (ESEM)
- Thermal Gravimetric Analysis (TGA)
- X-ray Fluorescence spectrometer
  - Elemental analysis of the contamination
- Vacuum oven
- Ultrasonic bath
  - Used to vibrate contaminates off the filter media during solvent wash
- Air vacuum source
  - Used to draw solvent wash through filter pad
- 0.4 – 5 microns 25 – 47 mm filter pads
  - Used to capture fine particulates from solvent wash

7. Filter preparation

At the time of examination, some filters may still contain residual fuel and/or be in a “wet” condition. They are usually delivered in sealed plastic bags and fuel, if present, is collected on the bottom of the bags. If possible, drain the fuel into a glass container (flask, vial) for further analysis, if needed. It is desirable to let “wet” filters dry at normal (room temperature) conditions in a ventilated hood for at least overnight.

8. Examination of filters for contamination

Below is a description of the sequence of the examination steps needed to get the contamination analysis done.

1. Visually inspect the filter.
2. Sonicate element in filtered iso-octane, heptane or other appropriate solvent in an ultrasonic bath for a minimum of 15 minutes. Alternately back flush element using air and sonication to remove debris.
3. Remove element from solvent.
4. Filter solvent/debris through preweighed 0.8-μm cellulose acetate analysis membranes. (Note: More than one set of membranes may be required). Retain solvent for further analysis.
5. Wash the debris to remove any residual fuel products.
6. Dry the prepared analysis membrane(s) in a dessicator and weigh the membrane(s) to constant weight. Calculate the mass of the debris on each analysis membrane.
7. Perform the following analysis, as applicable, on the debris: Optical microscopic examination, SEM/EDX, FTIR, EPMA, and XRD.
8. Optional analysis can include TGA if it appears there is any carbonaceous debris.
9. Take 100 mL of filtrate from Step 4 and add 25 mL of de-ionized water in a 125 mL separatory funnel. Shake vigorously for 10 minutes and let the fuel and water separate. Decant the water into a clean beaker.
10. Remove a section of the filter medium and place it in a beaker of de-ionized water. The recommended filter medium sample size is 10 pleats X 3”. Sonicate the sample for 15 minutes. Remove and drain the medium from the water. Filter the water and debris through Whatman GF/F membranes. This filtration is only to remove any dirt/debris.
11. Evaporate the water from steps 9 and 10 in a vacuum oven until resultant residue is dry. NOTE: Be careful not to over heat the sample to “burn” the water-soluble residue. Remove residue and perform FTIR[1] and XRF. You may have to use a KBr pellet to get acceptable results. The XRF is used to determine if large quantities of K or Na are present as this will be an indication of whether water absorbent SAP is present.

[1] FTIR peaks that possibly indicate carboxyl content are at 1600±60 and at 1400±40 cm^{-1}. Another peak that may indicate the presence of SAP are at 1725 cm^{-1}.

12. A method used by the SAP manufacturers to determine the SAP distribution on a diaper is wetting the material with a copper sulfate solution which allows the copper ion to ion exchange with the metal present in the SAP, thereby turning the SAP blue. The procedure for determining the presence of SAP in the aircraft fuel filter debris is shown below.
    - Mix 5 gram of Copper (II) sulfate pentahydrate to 1 liter of de-ionized water
    - Soak membrane containing fuel debris from aircraft fuel filter with copper sulfate solution.
    - Allow membrane to dry.
    - Determine if SAP is present by use of an optical microscope.
    - SAP will be "blue"
13. An additional method utilized to verify if SAP is present to use a strong acid to wash the debris from the fuel filter in addition to the de-ionized water wash. Using an acidic solution with a pH equal to approximately 3 will cause the SAP salt to be converted to an acid, thereby shifting the FTIR peaks at 1600 and 1400 cm^{-1} to the left (to approximately 1700 and 1450 cm^{-1}.

A. Limitations Analytical Techniques for filter contamination analysis

Limitations of FTIR and EPMA as instrumental techniques are well known and documented. EPMA measures elemental composition and structure (through Secondary electron images) of solid materials such as metal alloys, thin films, minerals, various particles and so on. It can detect only elements with atomic number greater than or equal to 5 (boron). The identification of SAP by FTIR can be greatly facilitated by first establishing a reference library standard for the type of SAP of interest. Precise analysis is limited to flat, polished specimens. Uneven geometries such as individual particles, powders, biological specimens can be analyzed only qualitatively with greater uncertainty. EPMA cannot distinguish organic materials.

FTIR is a great technique for identification of mainly organic and some classes of inorganic compounds. However, exact material identification is strongly dependent on the presence of the reference spectra in the database. In the absence of such reference spectra, FTIR can provide information on structure and characteristic chemical bonding.

Regarding identification of contamination in fuel filters, contaminants are rarely clean and pure from a chemical standpoint. They are typically mixtures of heterogeneous and complex compounds which contaminate each other and /or complex by-products of chemical and biological reactions in fuel tanks and filters. In this sense, there are virtually no databases with reference spectra available. Both EPMA and FTIR provide enough information to identify contaminants by element composition and characteristic chemical bonding and structures and classify them as belonging to some particular chemical family. If further and deeper analysis is needed, it can be obtain with other techniques such as GC-MS and X-Ray diffraction and fluorescence. The FTIR may pick up binder resins or even filtration media such as polymeric media, and this could interfere in some cases.

B. Microbiological analysis

If a filter shows signs of biological contamination, such as carbohydrates, there is a strong possibility that the aircraft fuel tank has microbial contamination that resulted in the filter clogging. It is possible to take a culture sample of the material deposited on the filter media. However, if more than 24 hours has passed since the filter was removed from the aircraft engine, the microbes will have either died or become replaced with anaerobic bacteria. A culture test will probably not give an indication of the actual conditions inside the fuel tanks.

9. Analysis Results

Stereo Microscope:

If the filter has a large number of metal chips, this is an indication of ….

Fuel Tank maintenance activity
Failures of the airplane boost pump or engine driven pump

Paint chips or sealant, rags, and miscellaneous foreign objects

Maintenance activity

Extremely Fine particulates

Sand, dirt, dust contamination. A "sticky" compound is required to bind these particulates together.

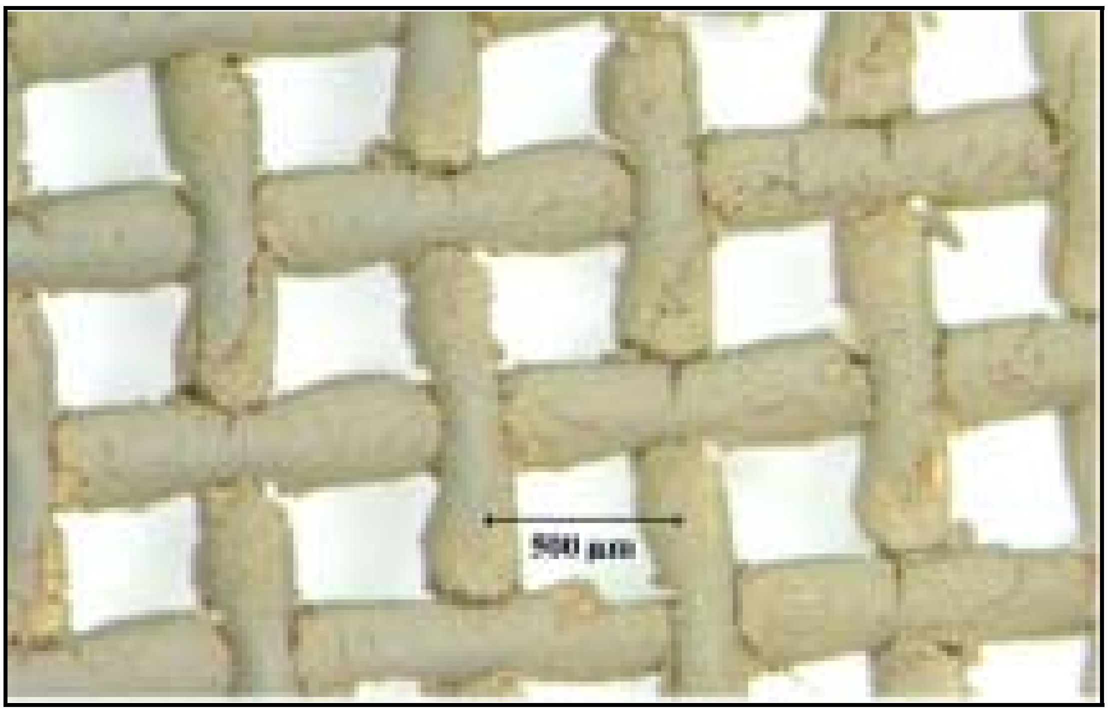


Figure 1: Stereo Microscope Example, Filter Screen

Figure 2: Stereo Microscope Example: Filter Screen

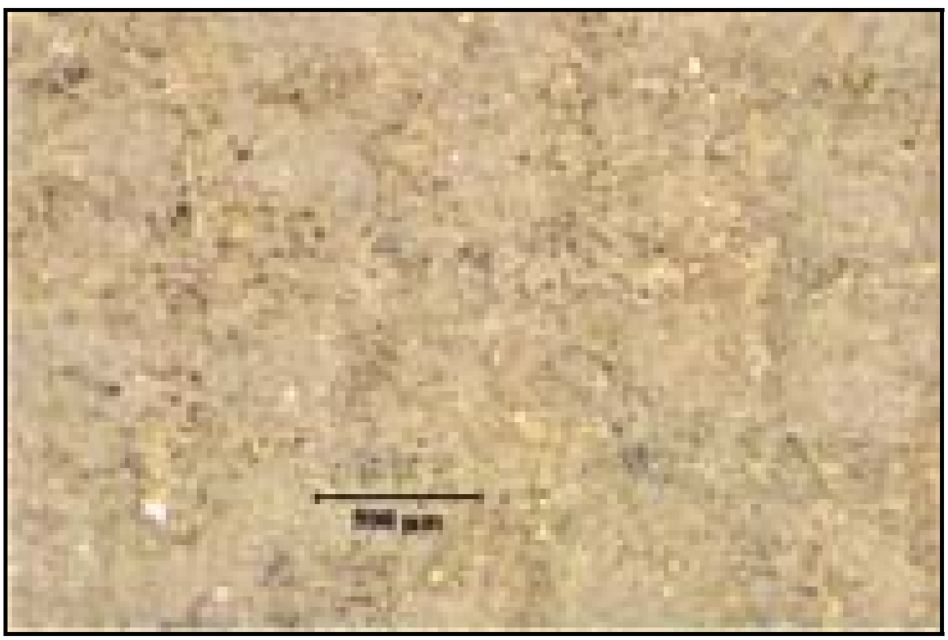


Figure 3: Stereo Microscope Example, Filter Media

EPMA:
The EPMA will show relative quantities of elements composing the contamination. Typically, these may include carbon, sulfur, sodium, potassium, iron, and trace metals. The sulfur atoms are typically bonded to other elements to form sulfates, sulfites or sulfonates. This sulfur is not associated with the sulfur found in jet fuel.

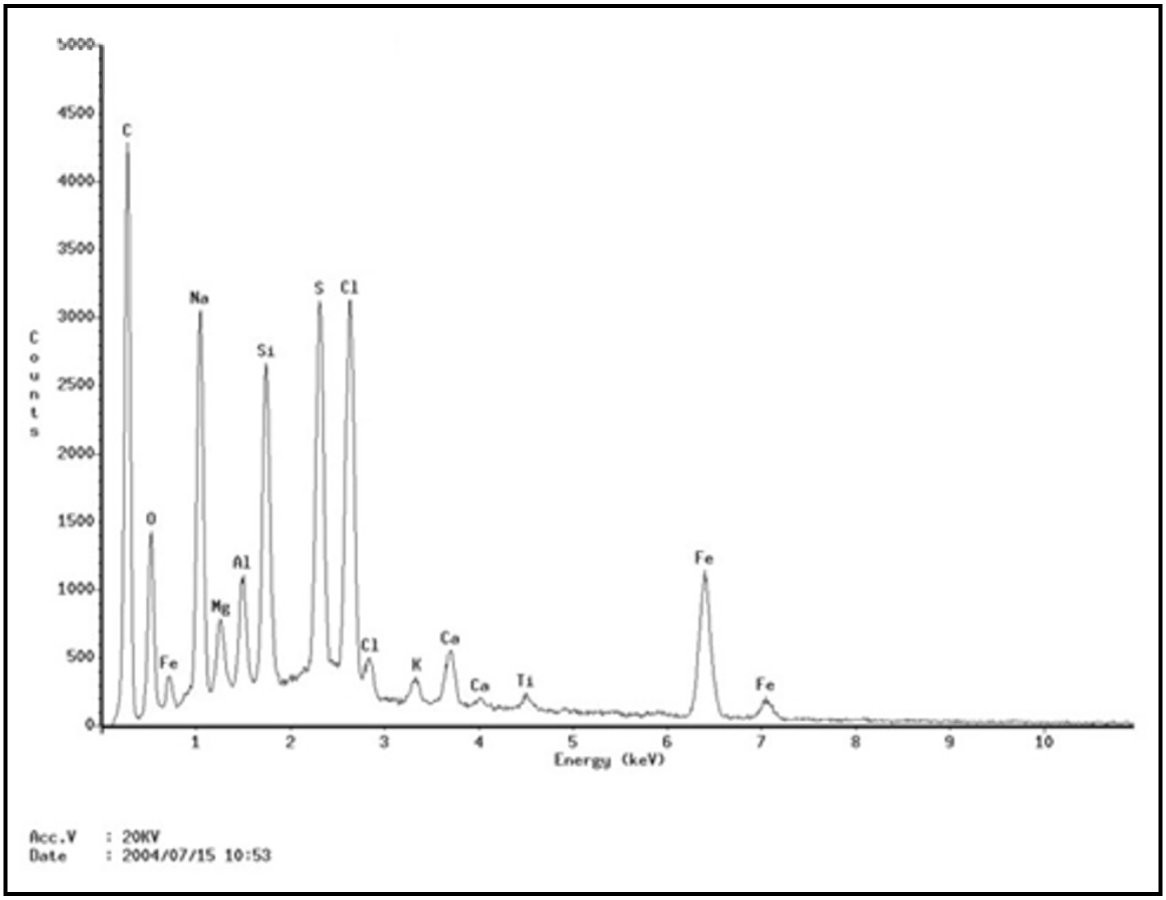


Figure 4: EPMA Example

FTIR Results:

The FTIR provides information on how the elements are bonded together….

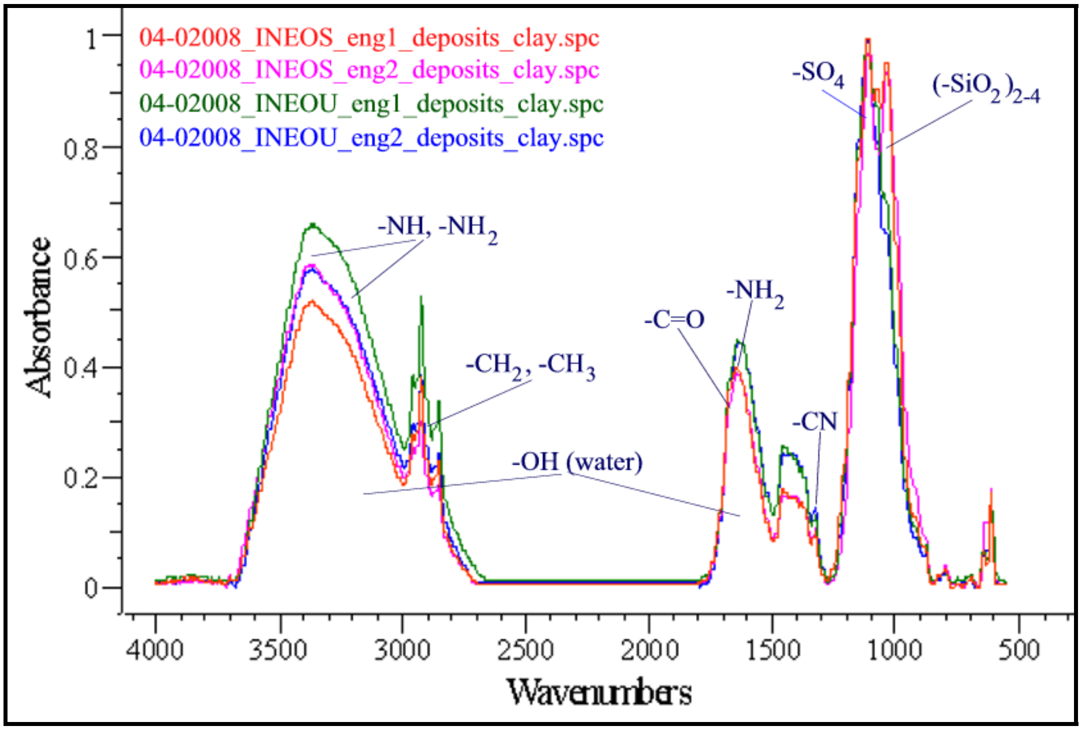


Figure 5: FTIR Example

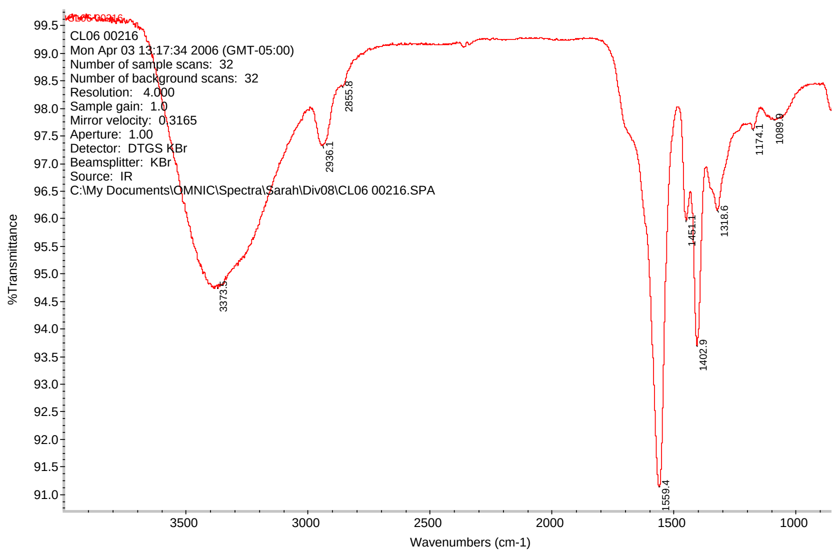


Figure 6. FTIR of water soluble contamination

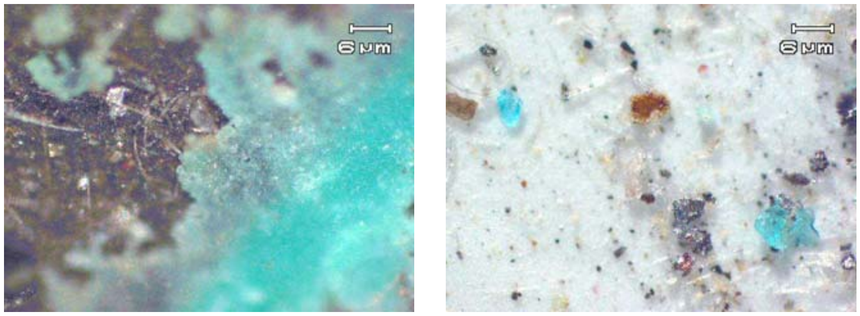


Figure 7. Copper Sulfate Indicator

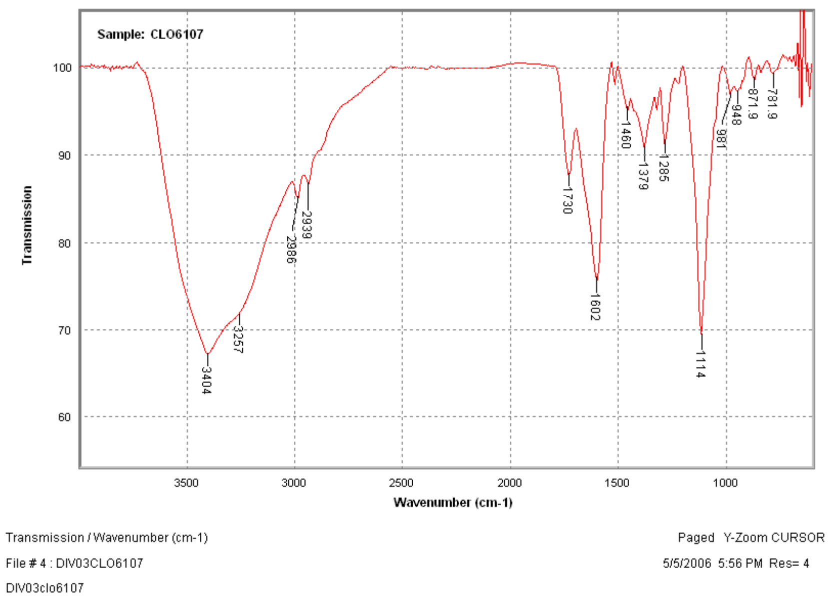


Figure 8. Acid Wash FTIR

GOST Contaminant Classification

1. Basic information

1. Filter brand

2. Filter part number

3. Airline

4. Aircraft identification (line number, S/N, etc.)

5. Engine identification (line number, S/N, etc.)

6. Filter time on aircraft (in aircraft engine operating hours)

2. Result of investigations

Table 1. General characteristics of contamination

№	Determined parameters	Result
1	**Appearance**	
2	**Total weight of contamination**	
3	**The nature of contamination, (% mass)** 3.1. Organic substances 3.2. Inorganic substances	
4	**Component structure of contamination (% mass)** 4.1 Substances, insoluble in organic solvents and water 4.2 Gum-like substances, soluble in organic solvents 4.3 Water-soluble substances	

Table 2**.** The characteristic of substances, insoluble in organic solvents and water

№	Determined parameters	Result
1	**Appearance**	
2.	**Weight of contamination**	
3	**Element structure of substances, %** Carbon Hydrogen Nitrogen Chlorine Cindery elements	
4	**The structure of cindery elements (% of weights):** Silicon Aluminium Magnesium Calcium Iron Manganese Titanium Copper Lead Zinc Tin Phosphorus ……. …….	

Table 3. The characteristic of gum-like substances, soluble in organic solvents

№	Determined parameters	Result
1	**Appearance**	
2	**Weight of contaminations**	
3	**Element structure of substances, %** Carbon	

№	Determined parameters	Result
	Hydrogen Sulphur Nitrogen Chlorine Cindery elements	
3	**Group structure gum-like substances (FTIR)**	

Table 4. Characteristics of water-soluble substances

№	Determined parameters	Result
1	**Appearance**	
2	**PH**	
3.	**Weight of contaminations**	
5	**Element structure of substances, %** Carbon Hydrogen Sulphur Nitrogen Chlorine Cindery elements	
6	**The structure of cindery elements (% of weights):** Silicon Aluminium Magnesium Calcium Iron Manganese Titanium Copper Lead Zinc Tin Phosphorus ……… ………	

3. Discussion

4. Conclusions

Signature

Allied Station	(Inbound) Facility Filteration Type	(OutBound) Facility Filteration Type	Monitors used to remove water at Facility Filteration
DAL - Dallas / Love Field - US	Filter/Seperator/Clay	Filter/Seperator	No
DCA - Reagan National - US	Filter/Seperator/Clay	Filter/Seperator	No
DFW - Dallas - US	Filter/Seperator/Clay	Filter/Seperator	No
EWR - Newark Liberty - US	Filter/Seperator	Filter/Seperator	No
IAH - Houston George Bush - US	Filter/Seperator/Clay	Filter/Seperator	No
JFK - John F Kennedy - US	Filter/Seperator/Clay	Filter/Seperator	No
LGA - LaGuardia - US	Filter/Seperator/Clay	Filter/Seperator	No
MCI - Kansas City - US	Filter/Seperator/Clay	Filter/Seperator	No
MIA - Miami International - US	Filter/Seperator/Clay/Hay Paks	Filter/Seperator	No
SAN - Lindbergh Field - US	Filter/Seperator	Filter/Seperator	No
SAT - San Antonio - US	Filter/Seperator	Filter/Seperator	No
SMF - Sacramento Airport - US	Filter/Seperator/Clay	Filter/Seperator	No
STL - Lambert Field - US	Filter/Seperator/Clay	Filter/Seperator	No
YQX - Gander - Canada	Filter/Seperator	Filter/Seperator	No
YQY - Sydney - Canada	N/A	N/A	N/A
YWK - Wabush - Canada	N/A	N/A	N/A
YDF - Deer Lake - Canada	Filter/Seperator	Filter/Seperator	No
YUL - Dorval - Canada	Filter/Seperator	Filter/Seperator	No
YMX - Mirabel - Canada	Filter/Seperator	Filter/Seperator	No
YYZ - Toronto - Canada	Filter/Seperator	Filter/Seperator	No
MAG - Albrook Field - Latin America	Filter/Seperator	Filter/Seperator	No
PTY - Tocumen - Latin American	Filter/Seperator/Clay	Filter/Seperator	No

(Into-Plane)Equipment Filteration Totals		Any slow flow fueling	Are monitors flowed at normal	Any use of FSII with monitors	Any abnormal DP's recorded
Monitors	Filter/Seperators				
2	14	No	Yes	No	No
14	7	No	Yes	No	No
50	20	No	Yes	No	No
22	51	No	Yes	No	No
81	27	No	Yes	No	No
0	155	No	Yes	No	No
0	8	N/A	N/A	N/A	No
8	17	No	Yes	No	No
N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	No	No
5	8	No	Yes	No	No
13	1	No	Yes	Yes	No
4	40	No	Yes	No	No
6	3	No	Yes	No	No
N/A	N/A	N/A	N/A	N/A	N/A
N/A	N/A	N/A	N/A	N/A	N/A
2	1	No	Yes	No	No
24	5	No	Yes	No	No
3	0	No	Yes	No	No
65	6	No	Yes	No	No
6	0	No	Yes	No	No
18	3	No	Yes	No	No

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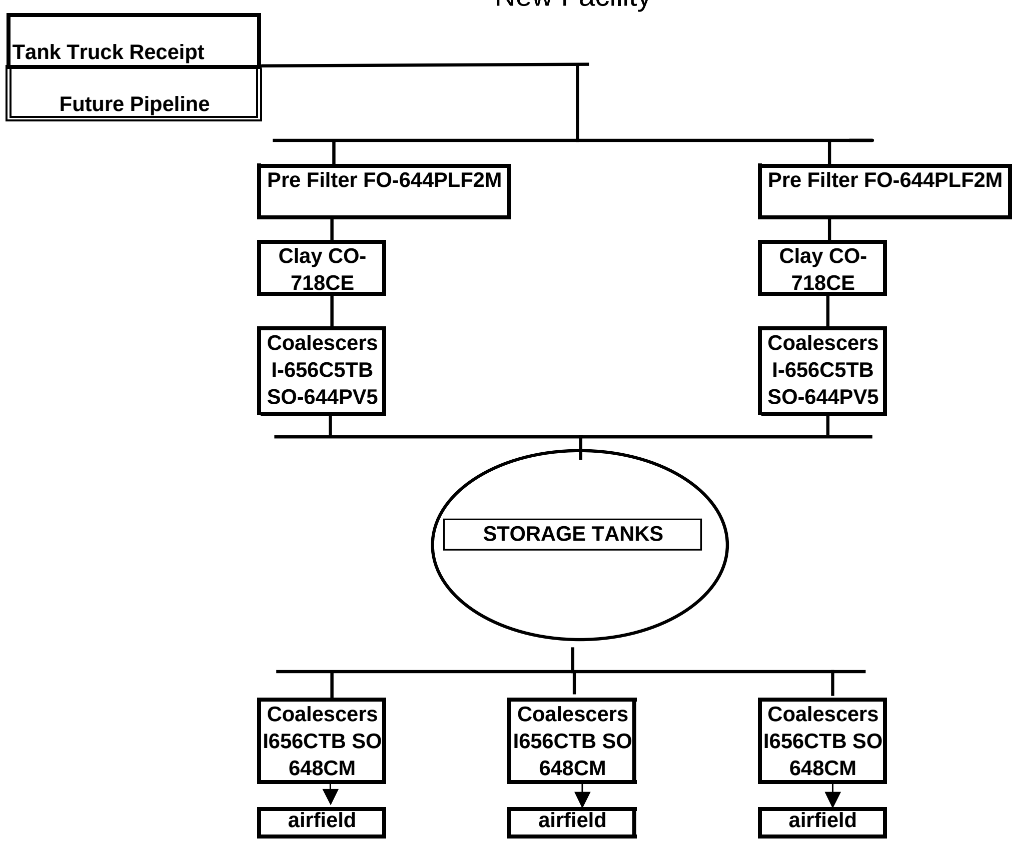
IATA Fuel Monitor Task Force

ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
ABQ													
New Facility	Pre-Filter, Clay, F/S	NA	F/S	No	N/A	N/A	N/A	N/A	No	No	NA	No	No
Old Facility	F/S	NA	Monitor, F/S	Yes	N/A	N/A	N/A	N/A	No	No	NA	No	No
Fuel Facility Filtration													

New Facility



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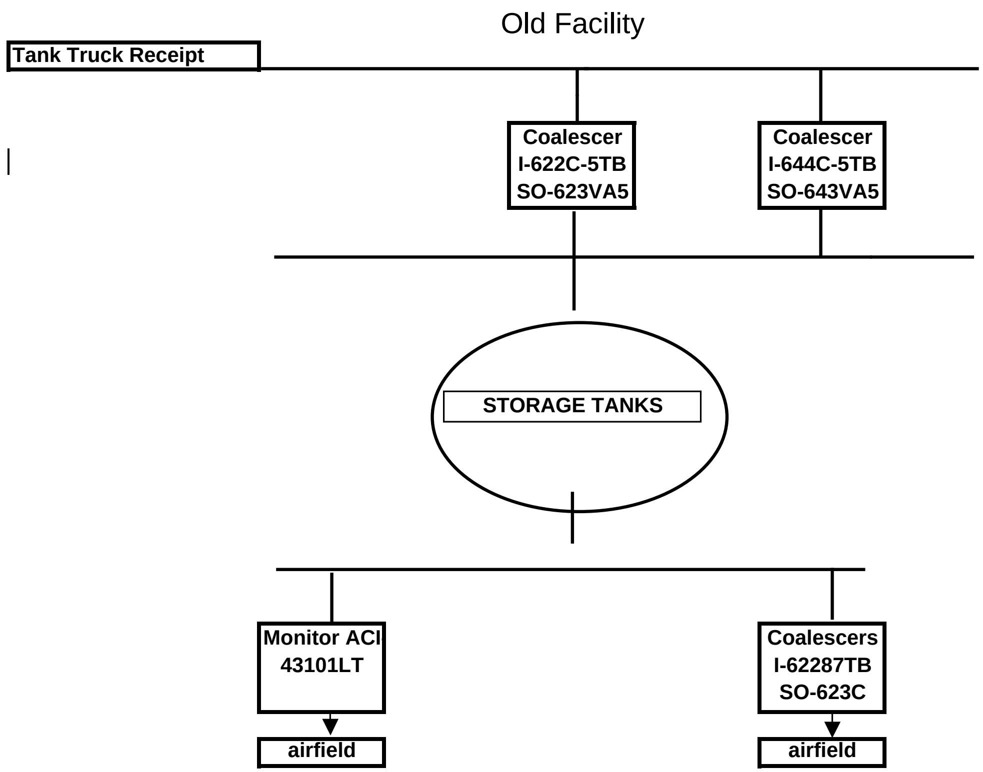

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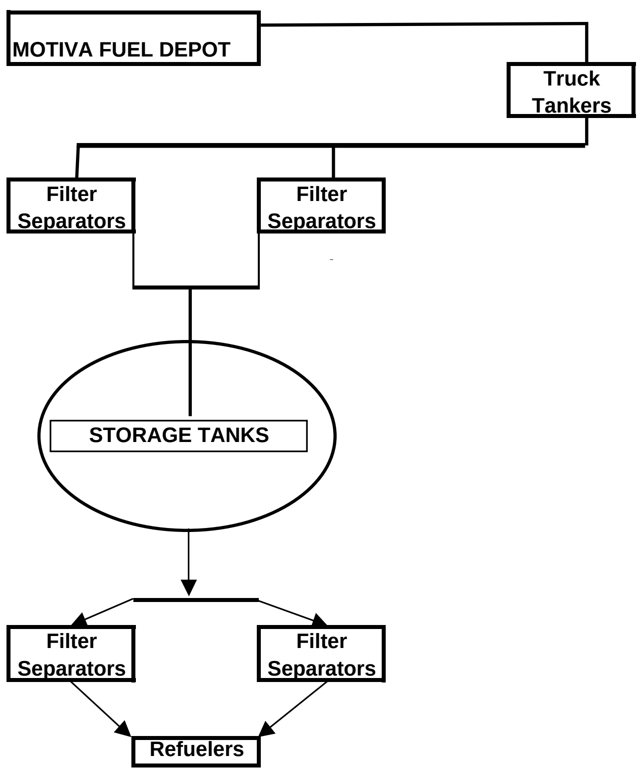
					Monitors	F/S			with monitors	Testing	Additives Found		
AFW	F/S	NA	F/S	No	27 CDF230K	36/F | 21/S	No	Yes	No	No	NA	No	No
Fuel Facility Filtration													



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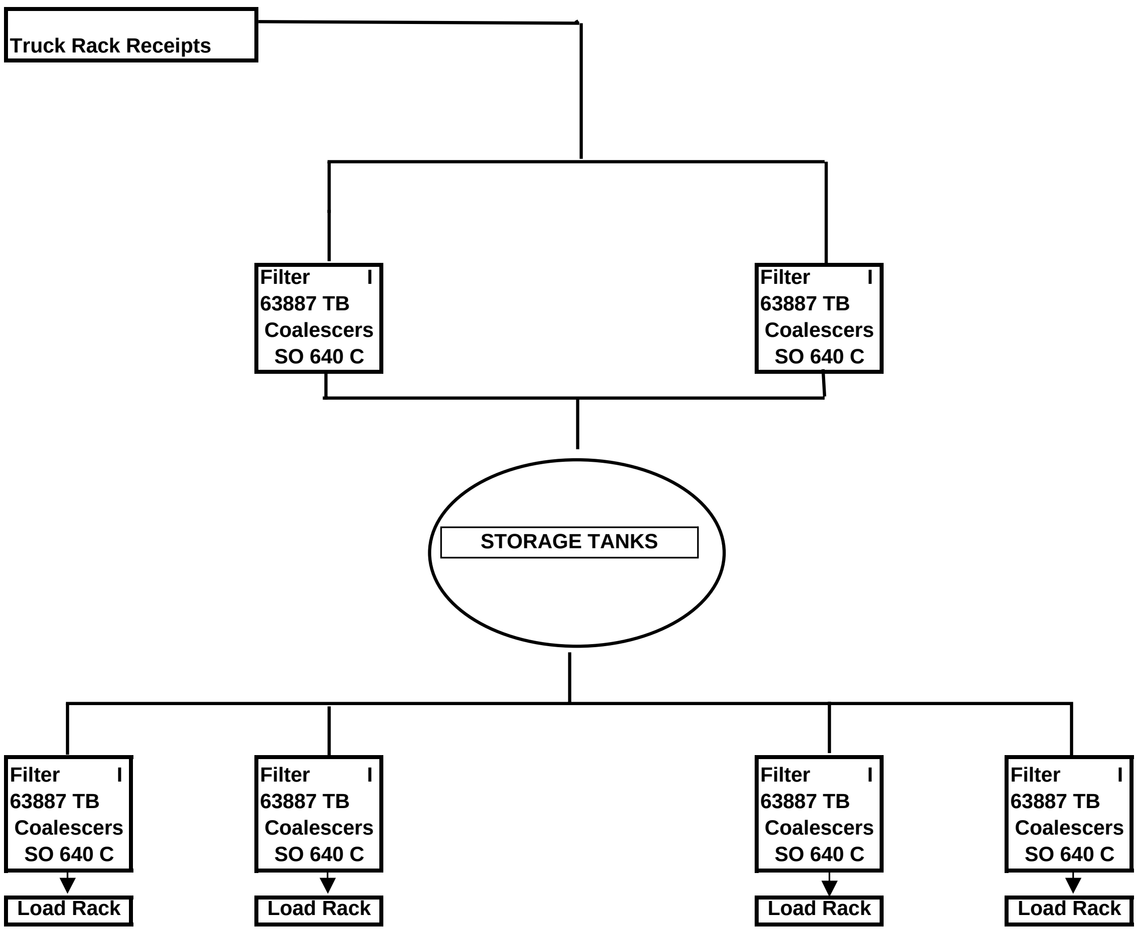
					Monitors	F/S			with monitors	Testing	Additives Found		
AUS													
Fuel Facility Filtration	F/S	N/A	F/S	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No



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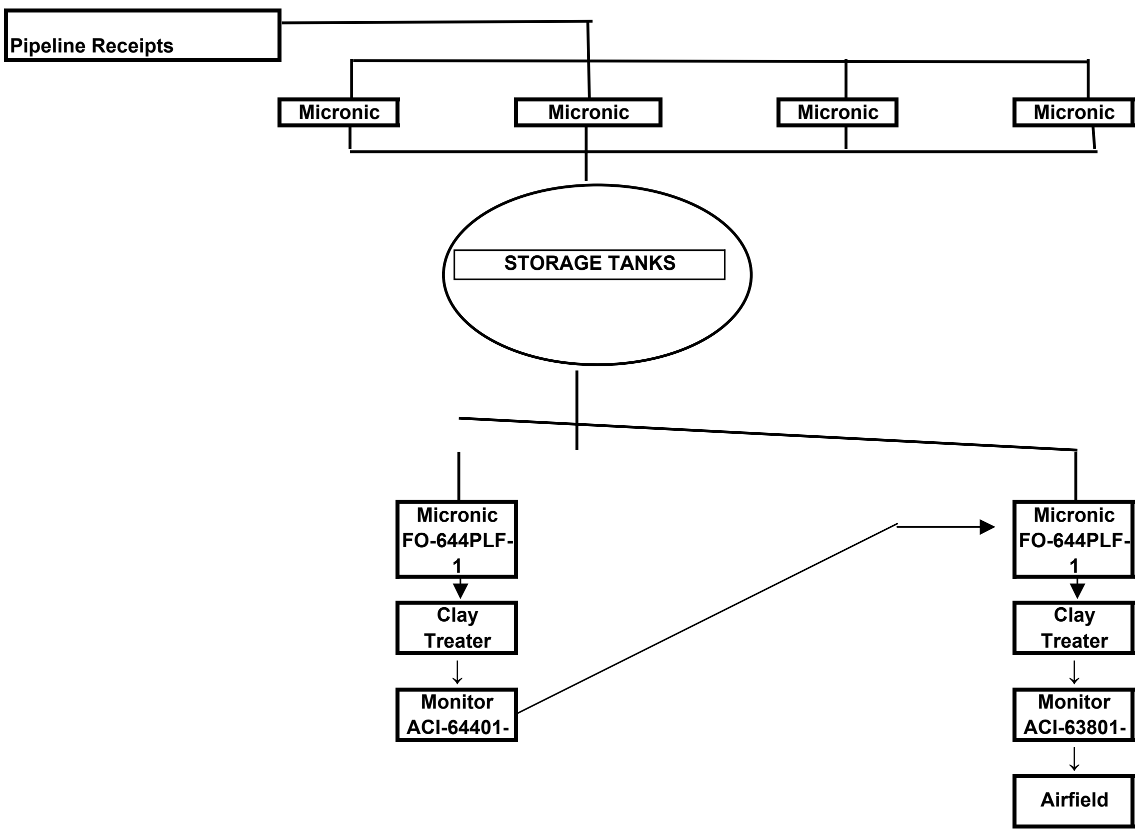
					Monitors	F/S			with monitors	Testing	Additives Found		
BDL	Micronic	NA	Micronic Clay Treater Monitor	Yes	10	0	No	Yes	No	No	NA	Truck 100 7/05 Water in truck	Filter Medium in truck 100 screen 7/05

Fuel Facility Filtration BDL 425



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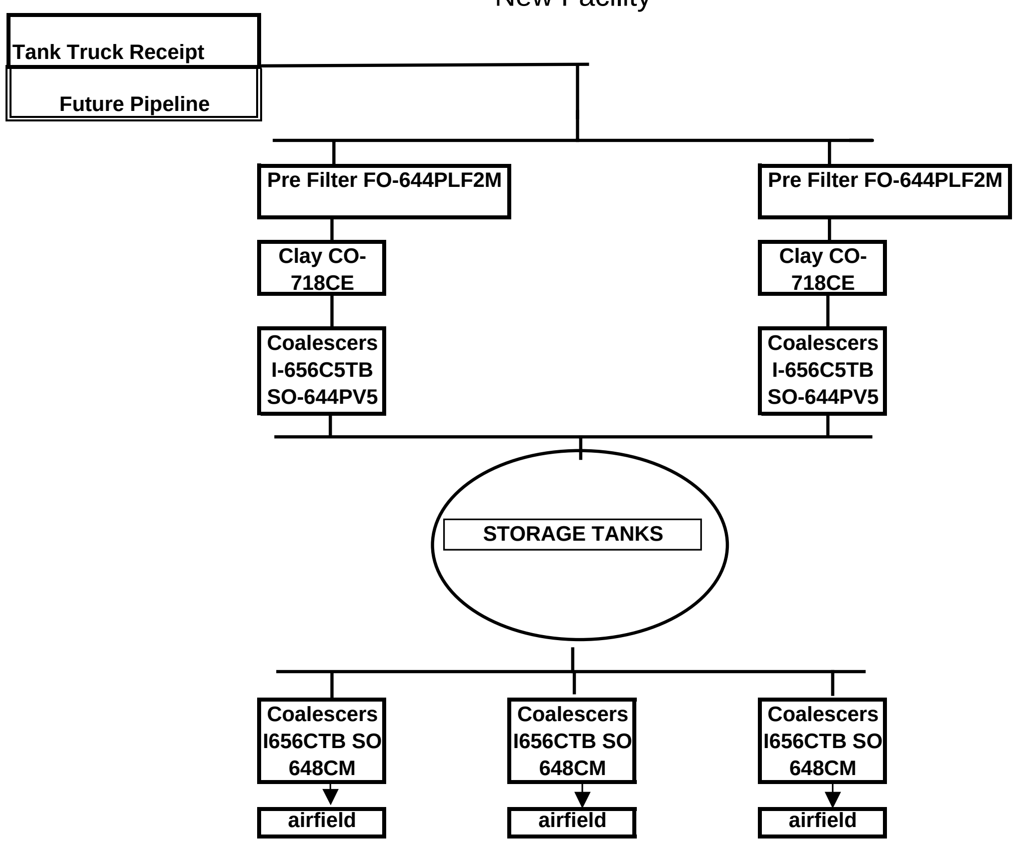
ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
ABQ													
New Facility	Pre-Filter, Clay, F/S	NA	F/S	No	N/A	N/A	N/A	N/A	No	No	NA	No	No
Old Facility	F/S	NA	Monitor, F/S	Yes	N/A	N/A	N/A	N/A	No	No	NA	No	No
Fuel Facility Filtration													

New Facility



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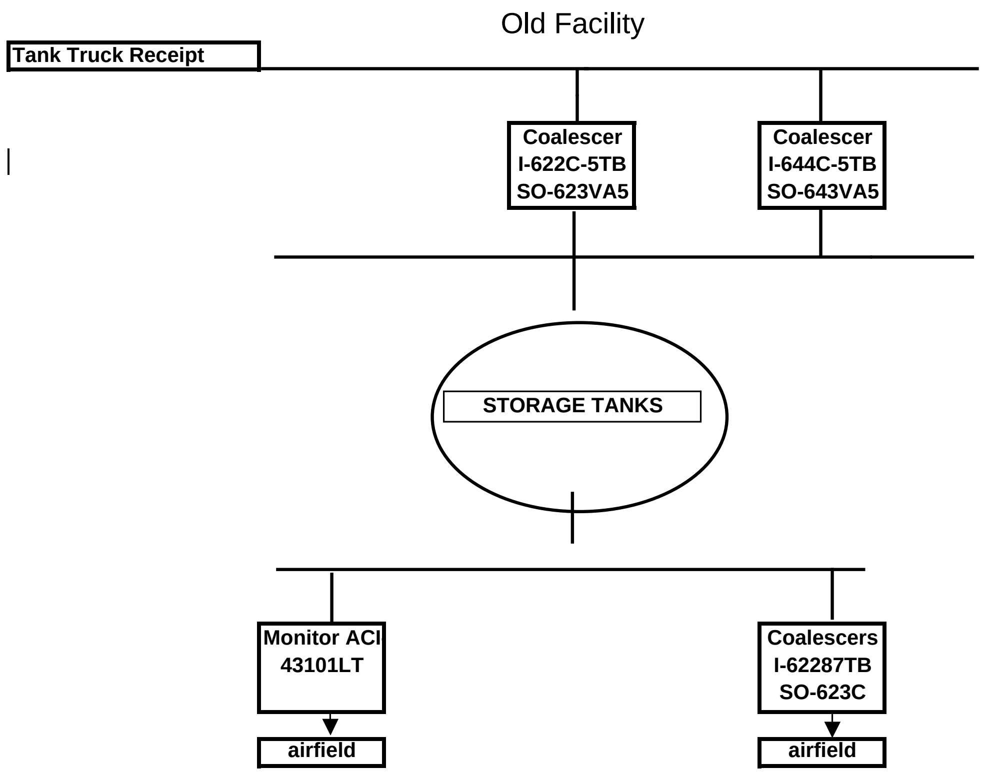

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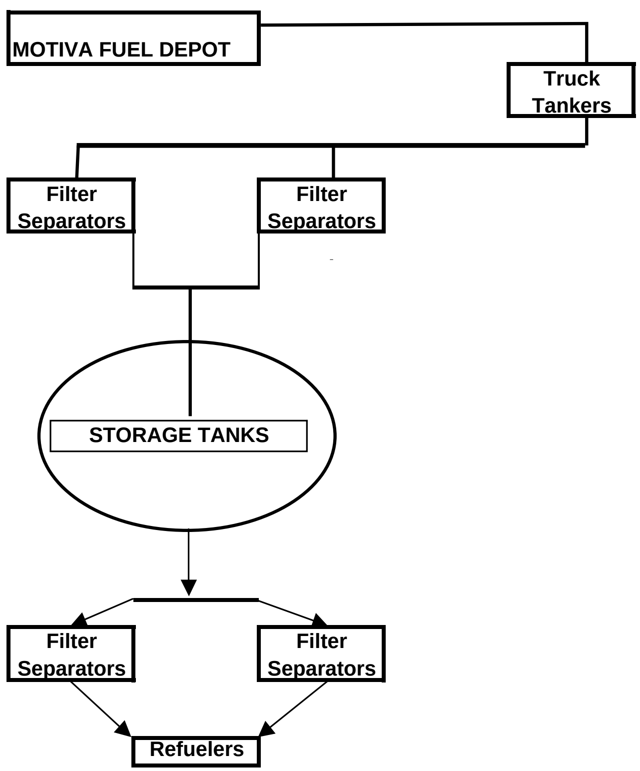
					Monitors	F/S			with monitors	Testing	Additives Found		
AFW	F/S	NA	F/S	No	27 CDF230K	36/F | 21/S	No	Yes	No	No	NA	No	No
Fuel Facility Filtration													



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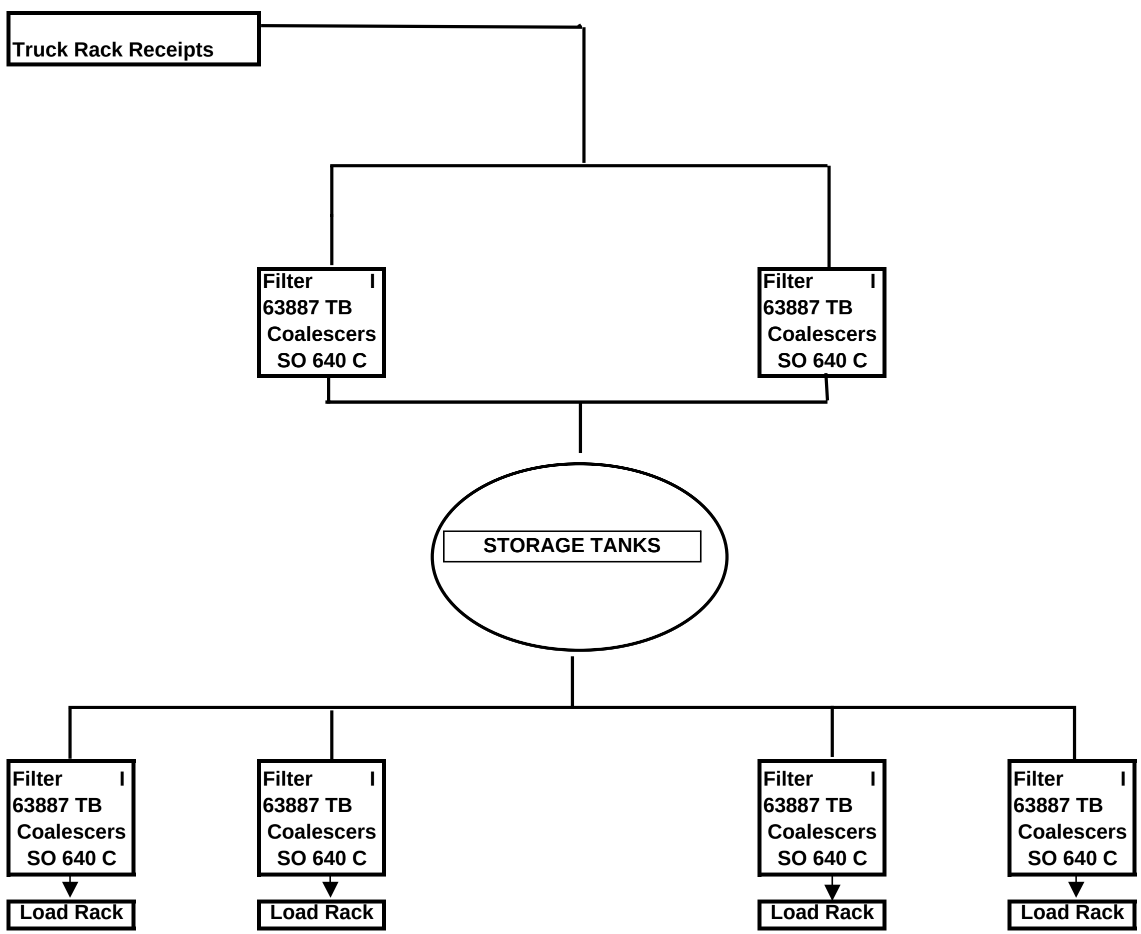
					Monitors	F/S			with monitors	Testing	Additives Found		
AUS													
Fuel Facility Filtration	F/S	N/A	F/S	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No



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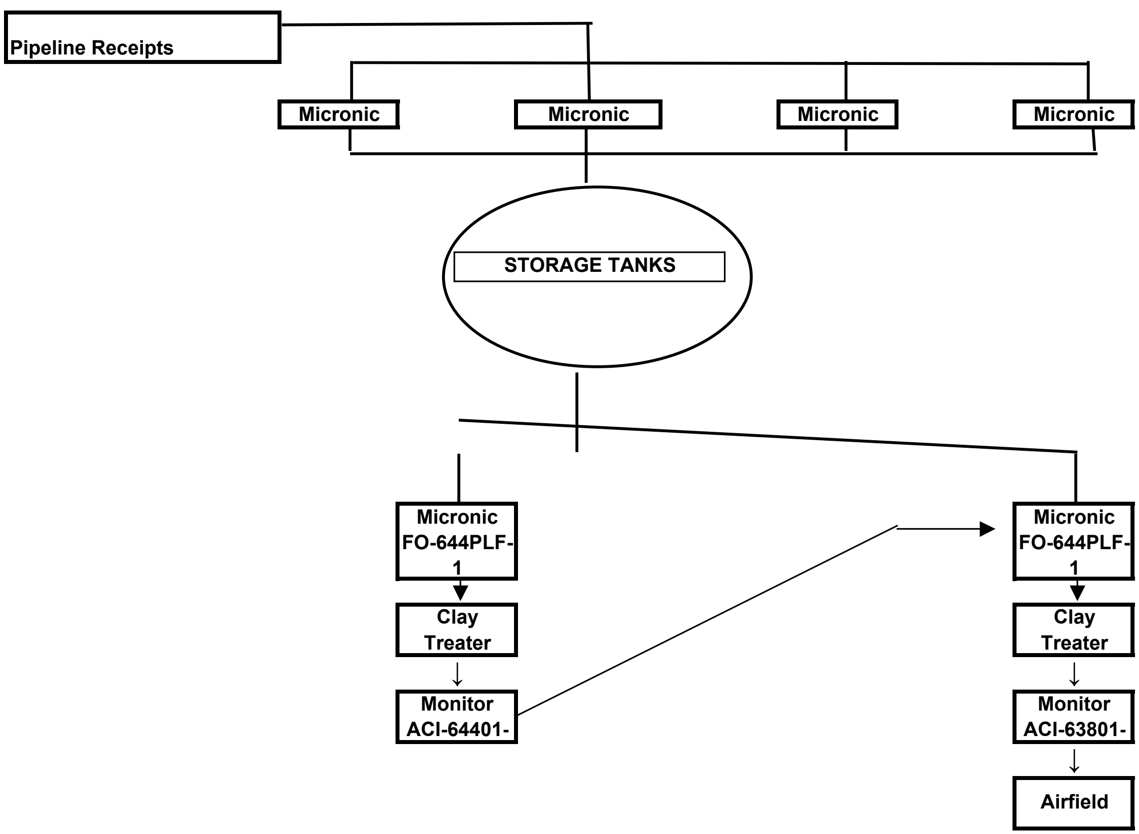
					Monitors	F/S			with monitors	Testing	Additives Found		
BDL	Micronic	NA	Micronic Clay Treater Monitor	Yes	10	0	No	Yes	No	No	NA	Truck 100 7/05 Water in truck	Filter Medium in truck 100 screen 7/05

Fuel Facility Filtration BDL 425



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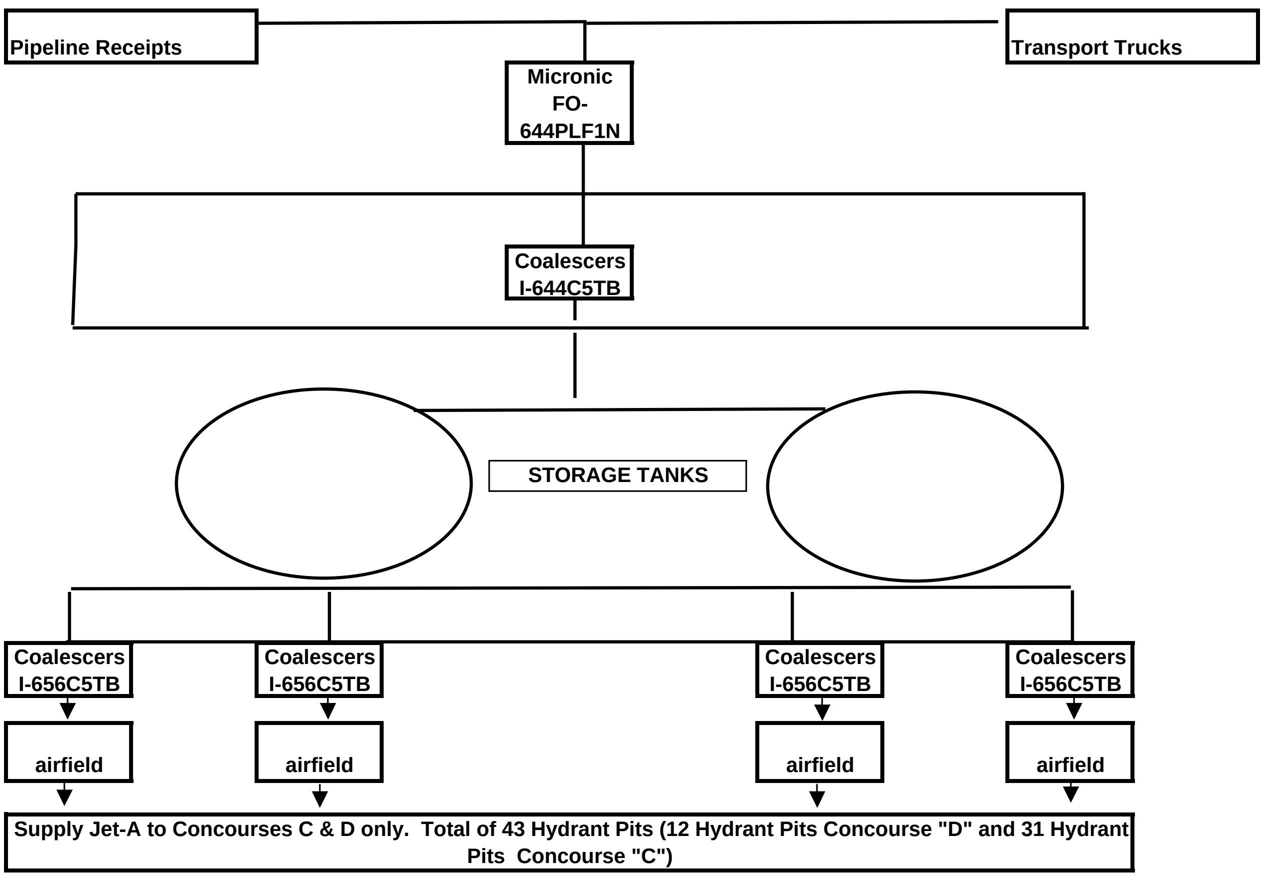
ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
CLE 504 Fuel Facility Filtration	Micronics; F/S	N/A	F/S	No	38	0	No	Yes	No	No	N/A	No	No



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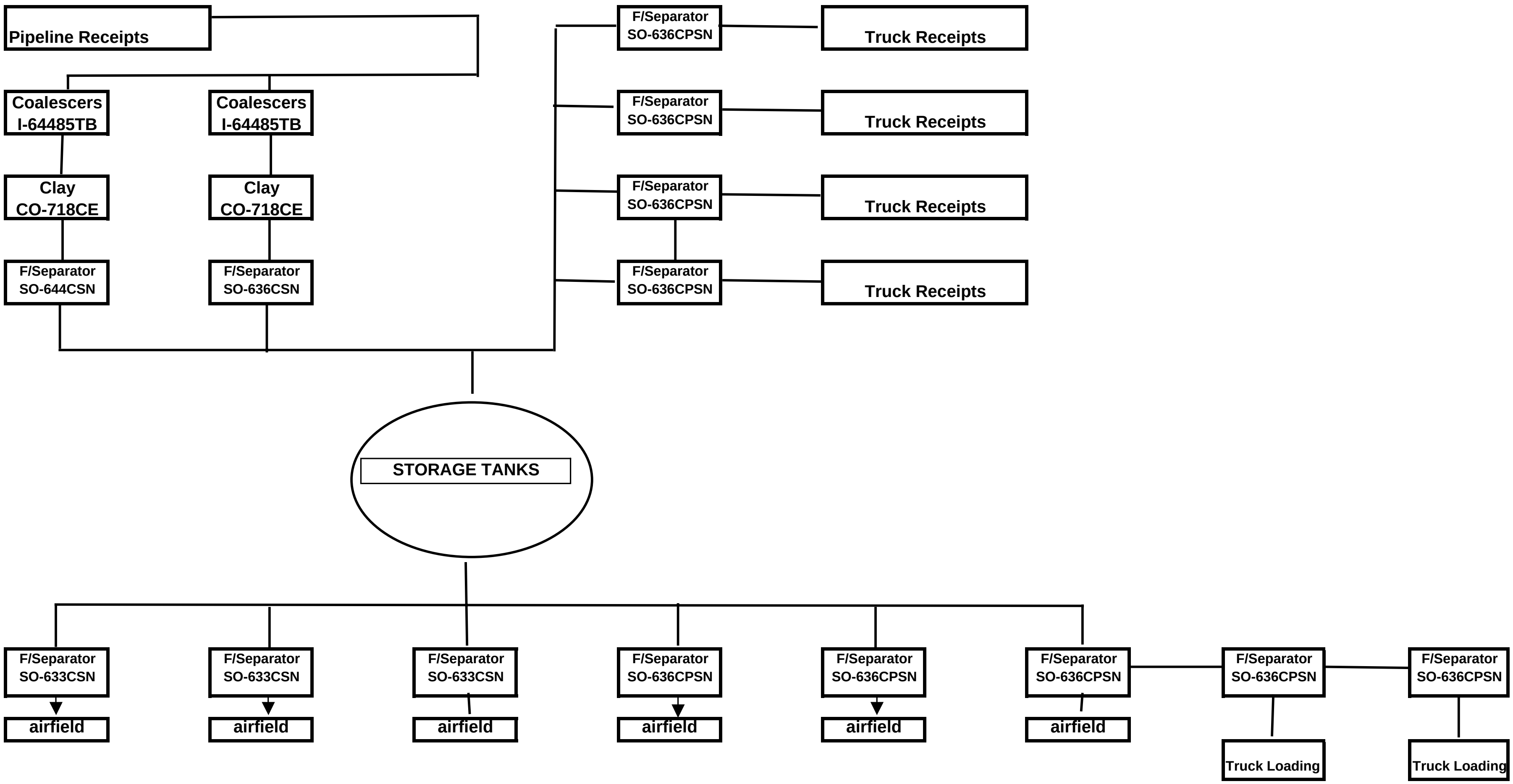
ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
CVG Fuel Facility Filtration	coalescer; Clay; F/S	F/S	F/S	No	15	0	No	Yes	N/A	N/A	N/A	No	No



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ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
DCA	NA	NA	NA	NA	28	0	No	Yes	No	No	NA	No	No

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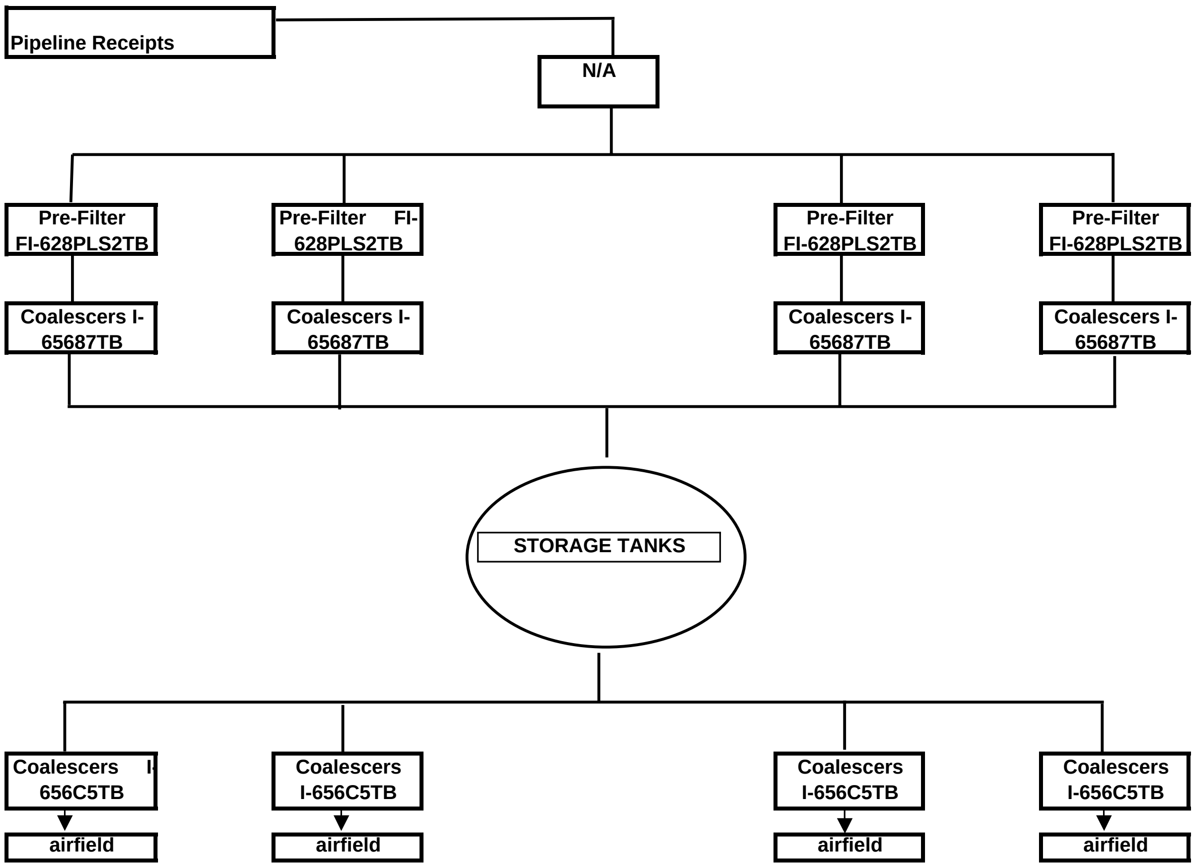
ASIG Base Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
DEN													
Fuel Facility Filtration (538)	Micronics; Pre-Filter; F/S	N/A	F/S	No									



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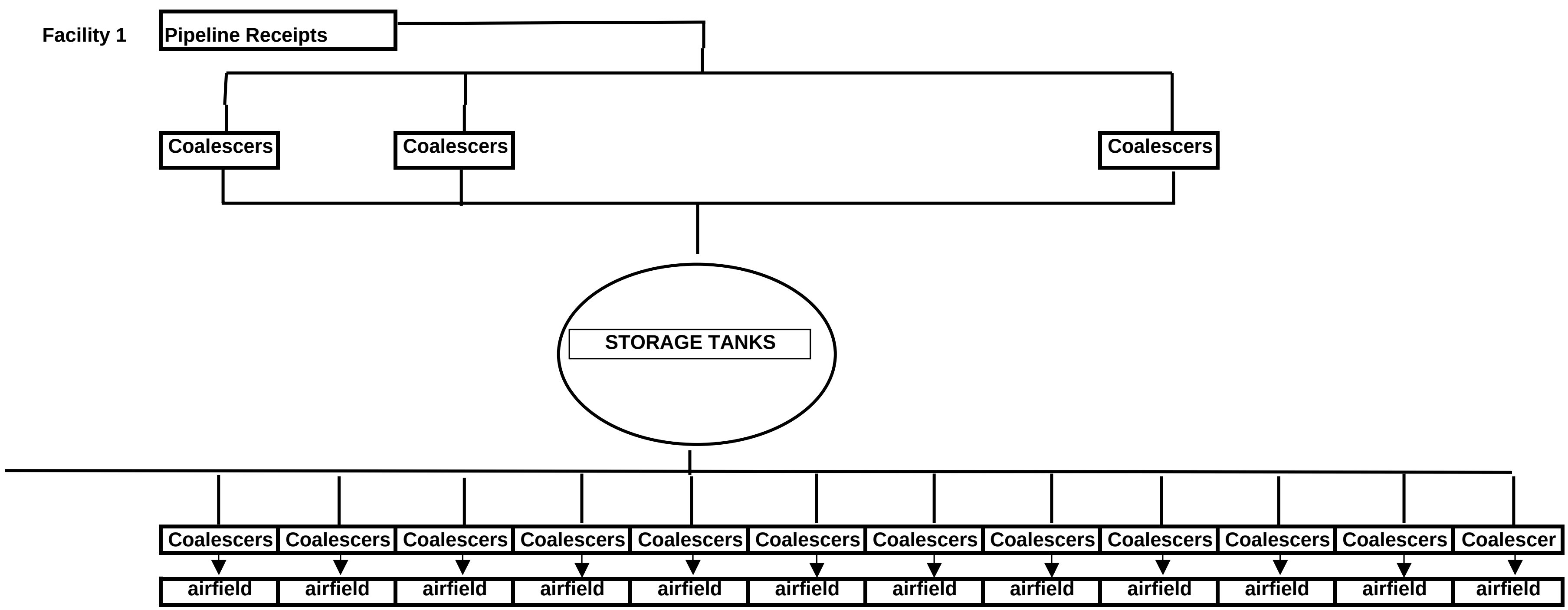
ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
DTW	N/A	N/A	N/A	N/A	12	0	No	Yes	No	No	NA	No	No
Fuel Facility 1 Filtration	F/S	N/A	F/S	No	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fuel Facility2 Filtration	Monitor	N/A	Monitor	Yes	N/A	N/A	No	Yes	No	No	N/A	No	No

Note: The first line applies to aircraft fueling equipment. Facility 1 is the main airport storage and is not operated by ASIG. Facility 2 serves ASIG retail and United Parcel intoplane.



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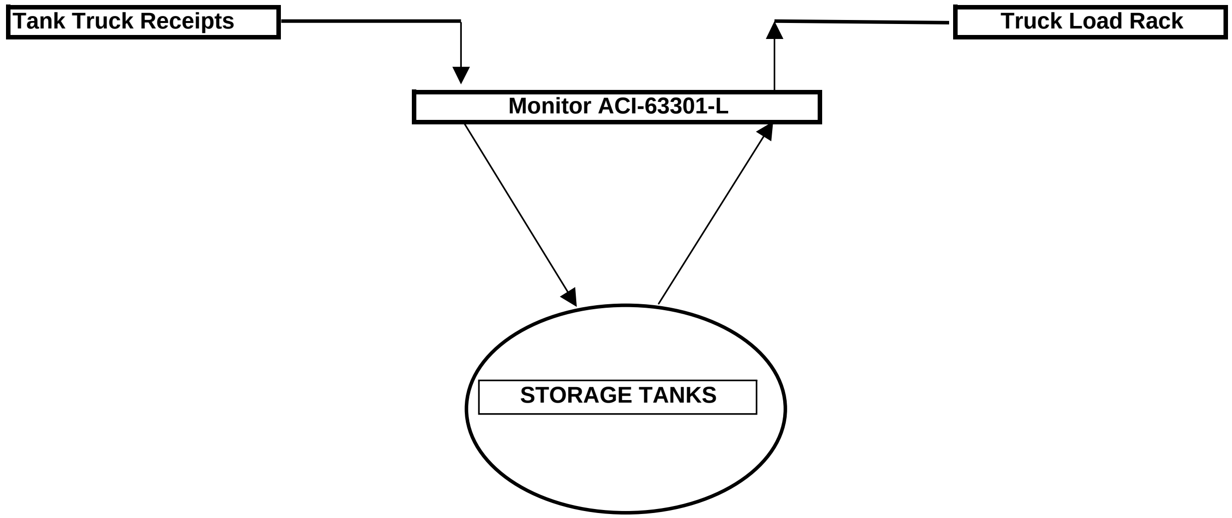
Facility 2



ASIG Fuel Filter/Monitor Survey
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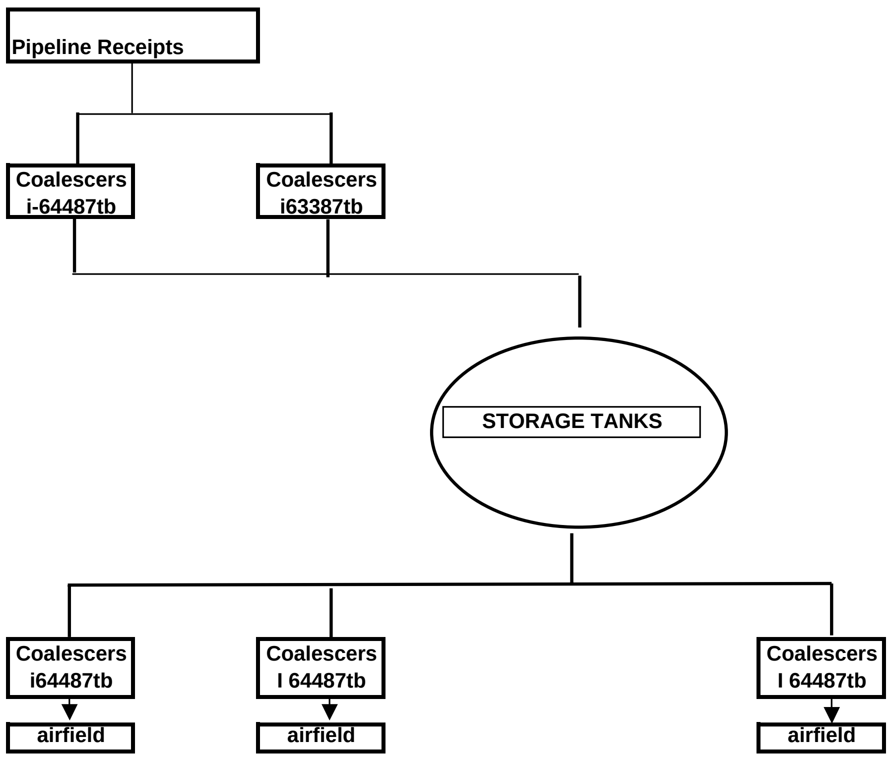
ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
FAI 527	Coalescers	NA	Coalescers	No	8	0	NA	NA	No	No	NA	No	No
Fuel Facility Filtration													



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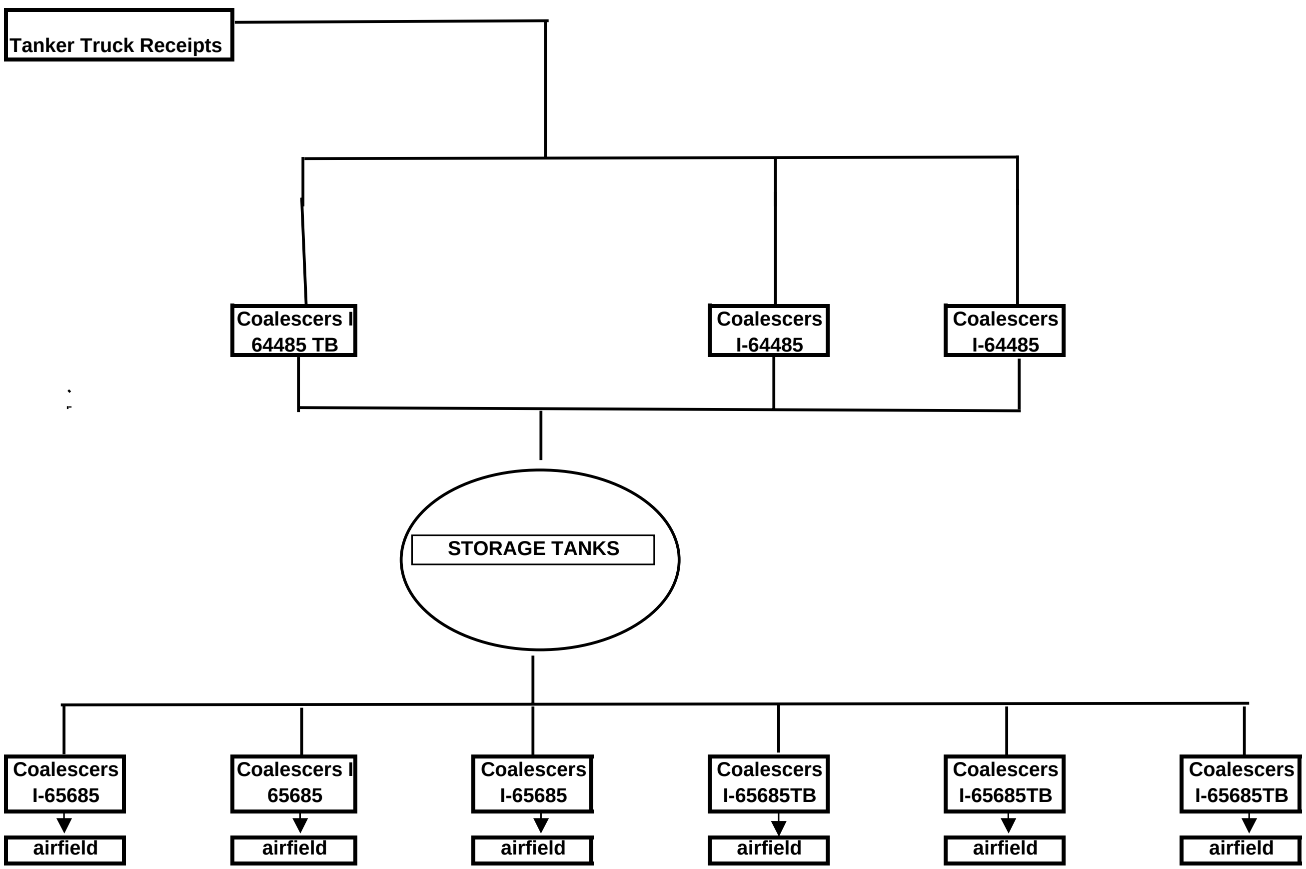
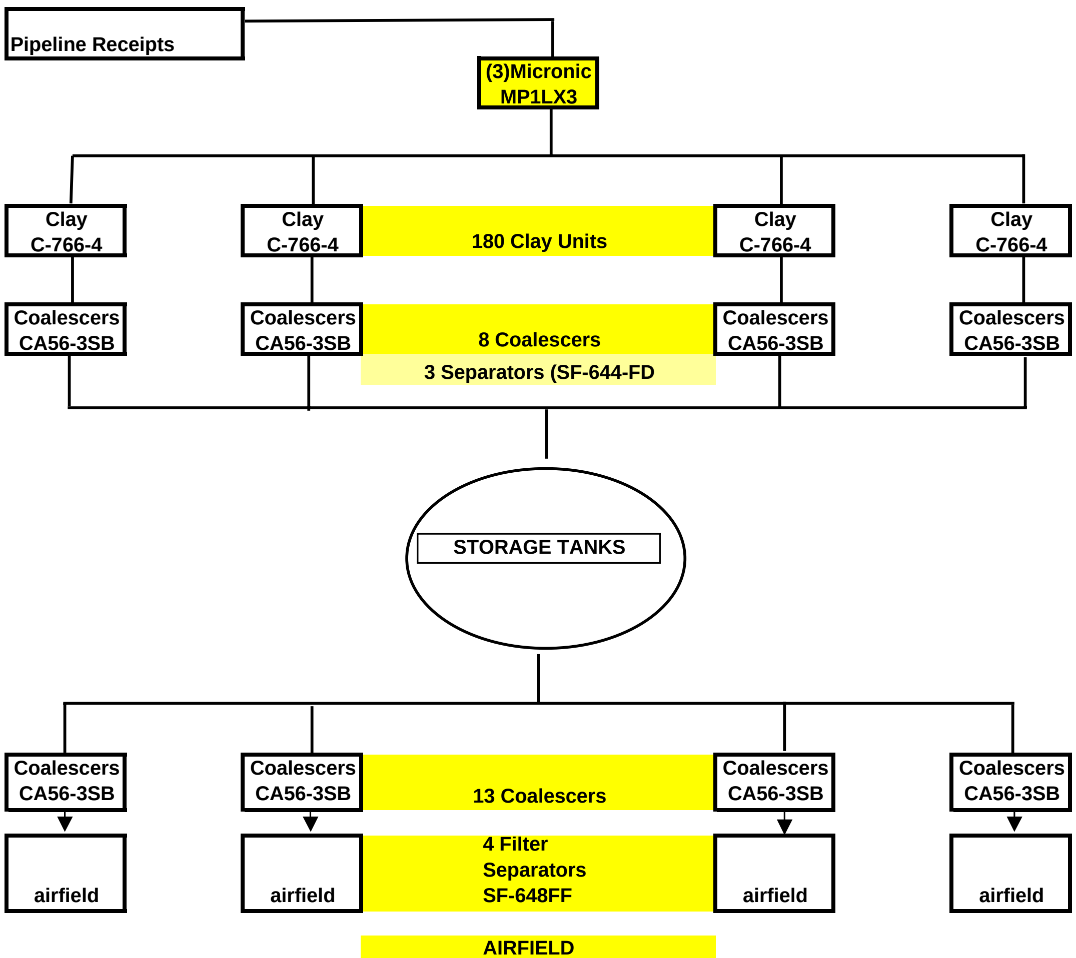
ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
GUM-476	F/S	F/S	F/S	No	4	8	No	Yes	No	No	NA	No	No
Fuel Facility Filtration													



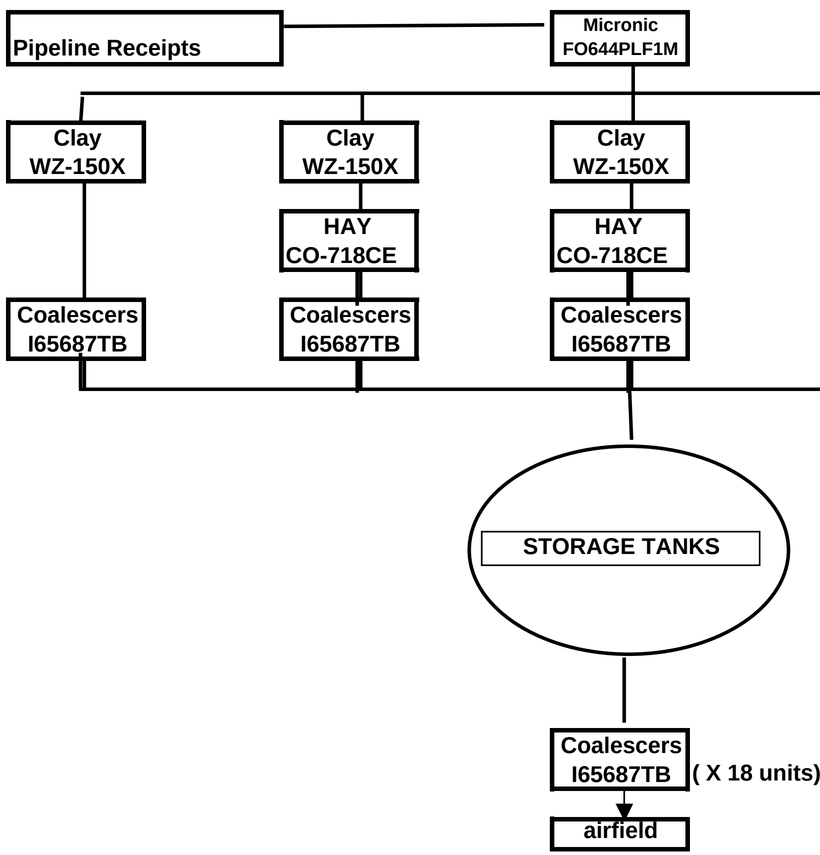
ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
LAS 410	Micronics; Clay; F/S	NA	F/S	No	44	0	No	Yes	No	No	NA	No	No
Fuel Facility Filtration													



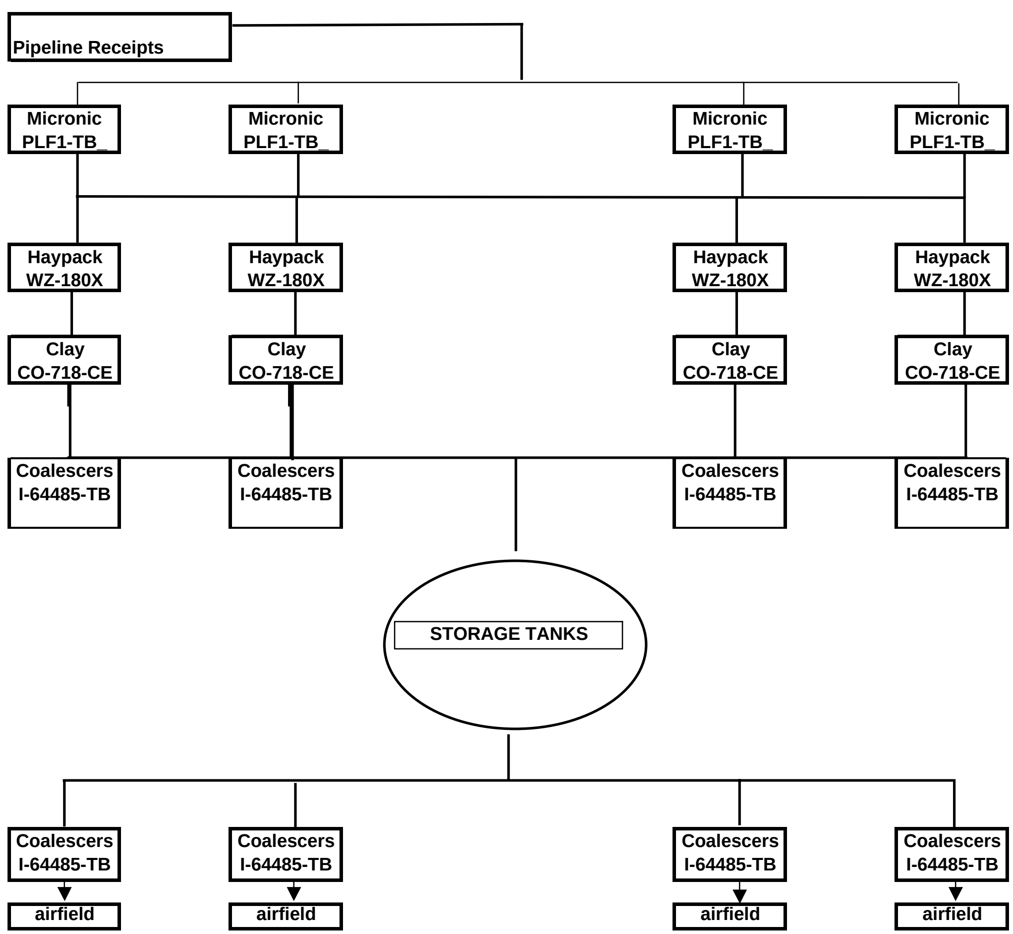
ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings
					Monitors	F/S			with monitors	Testing	Additives Found		
LAX													
Fuel Facility Filtration	Micronics; Hay, Clay; F/S	NA	F/S	No	NA	NA	NA	NA	NA	NA	NA	No	No



ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
MCO	Micronics; Haypack; Clay; F/S	NA	Two Stage F/S	No	24	0	NO	YES	NO	NO	N/A	NO	NO
Fuel Facility Filtration													



ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(Outbound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal nozzle screen findings recorded
					Monitors	F/S			with monitors	testing	additives found		
MEM 510	**Clay F/S**	**N/A**	**F/S**	**No**	**75 (9 RJ's) (66 HC's)**	**2 (RJ's)**	**No**	**Yes**	**No**	**No**	**N/A**	**No**	**No**

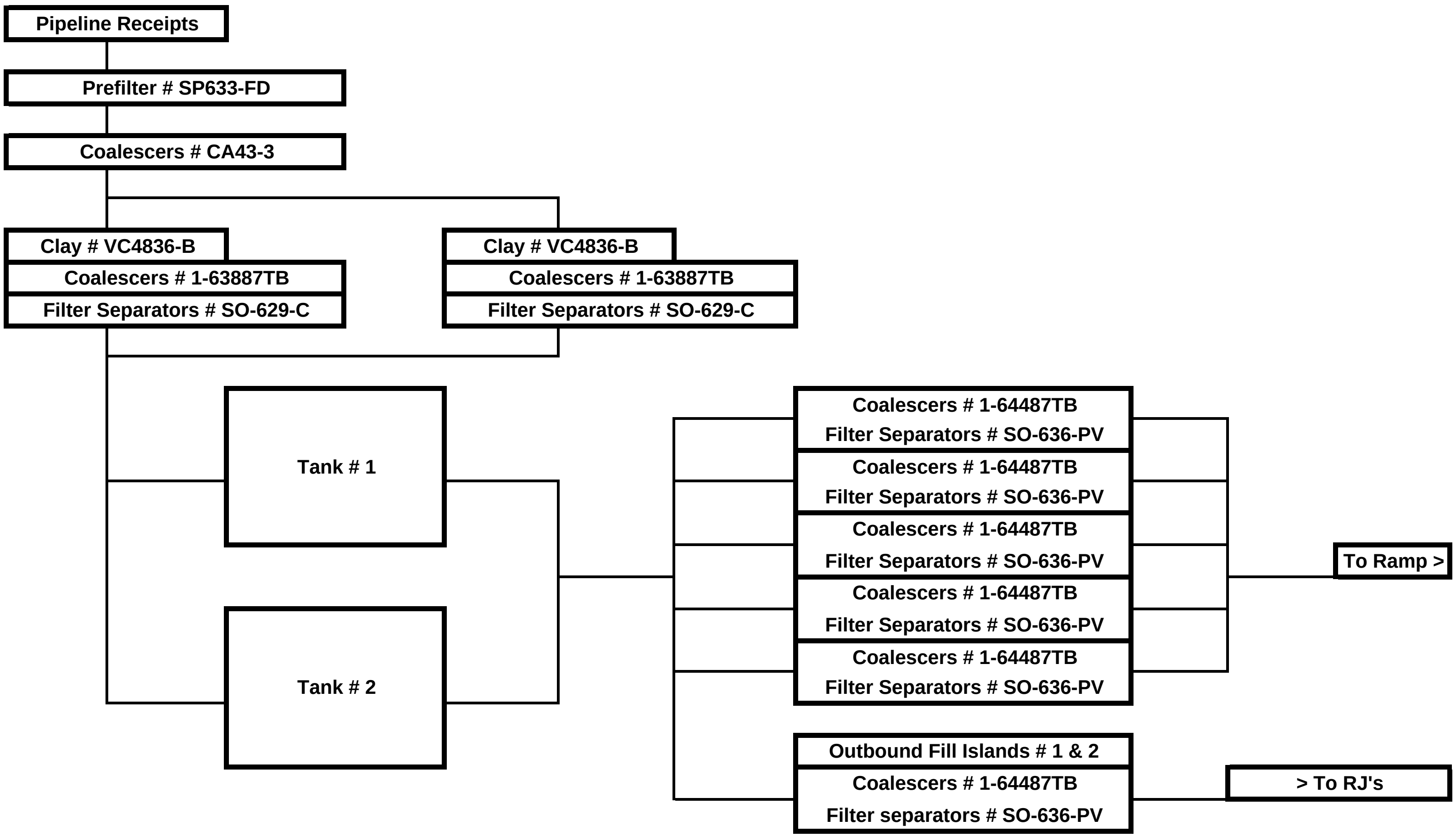
All Hydrant Carts	**Monitors**	**CDF-230-K**

All Trucks (RJ's)	**Monitors**	**ACI-62901-LTB** **ACI-63301-LTB** **ACI-63387-TB** **ACI-63801-LTB** **ACI-64401-LTB**
	Filter Separators	**SO-436-V** **SO-624-VA**

Fuel Facility	**Clay**	**VC-4836-B**
	Coalescers	**CA-43-3** **I-63887-TB** **I-64487-TB**
	Filter Separators	**SO-629-C** **SO-636-CA** **SO-636-PV**

ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

ASIG-MEM Fuel Facility Block Diagram

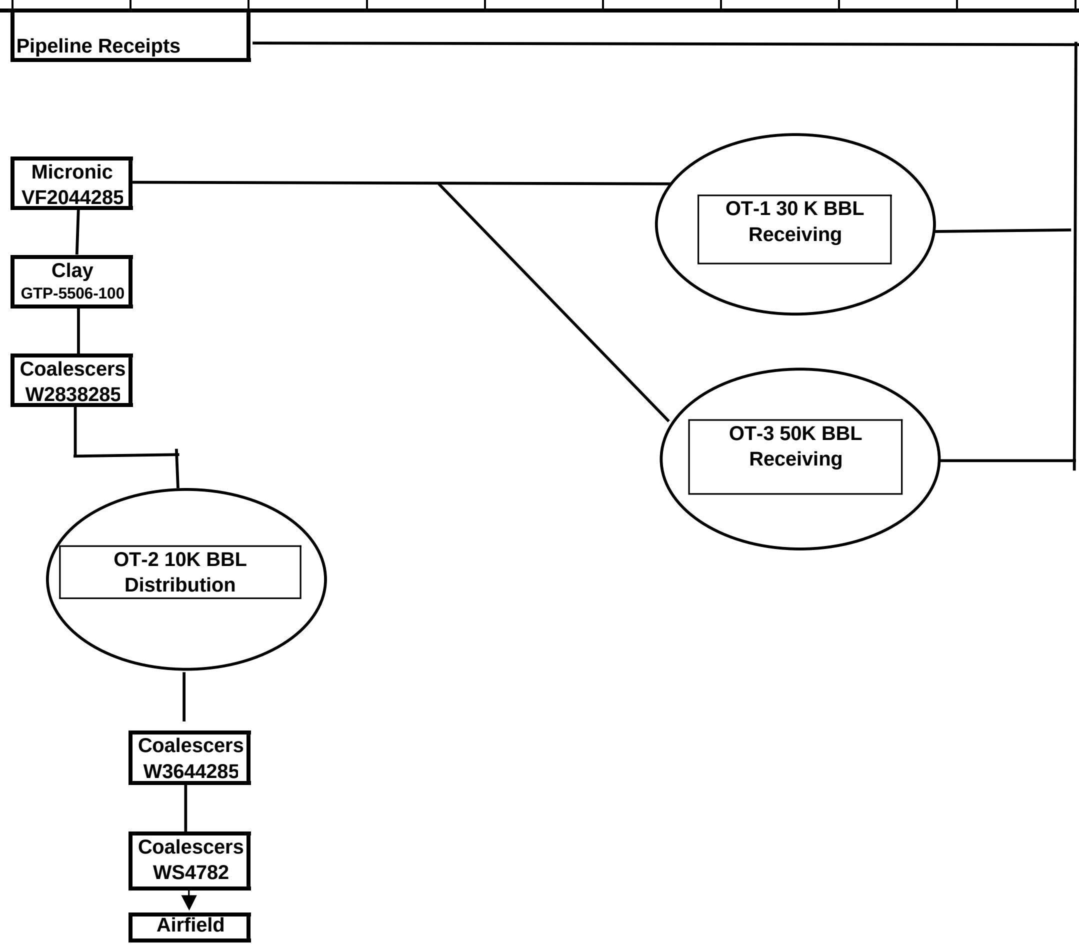


ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
MIA	Micronics; Clay; F/S	UNK	UNK	UNK	15	0	No	Yes	No	No	NA	No	No

ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

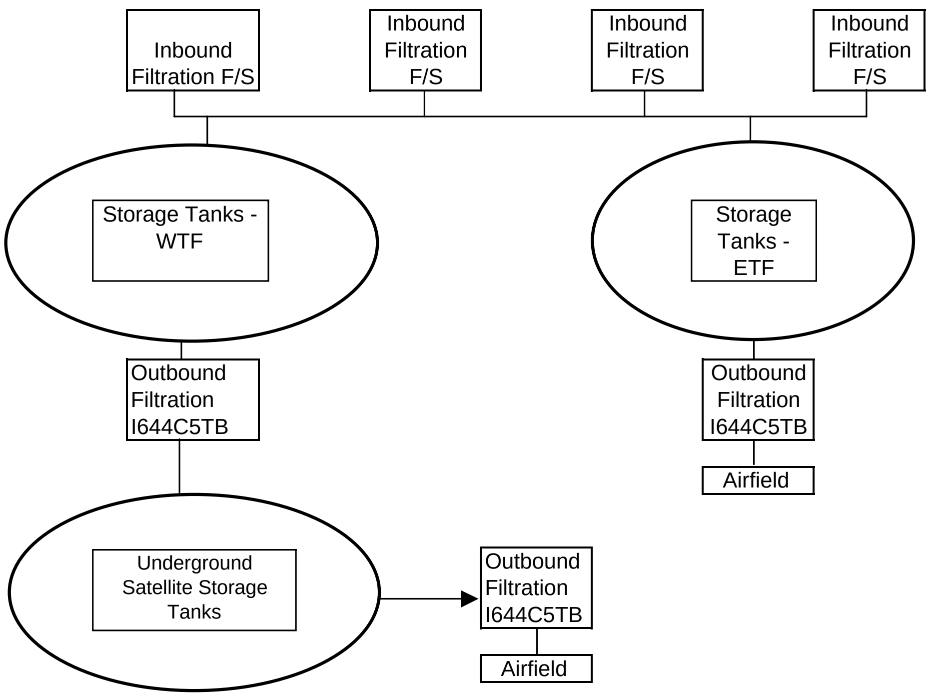
ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
ONT	N/A	Micronics; Clay; F/S	F/S	No	2	9	No	Yes	No	No	NA	No	No
Fuel Facility Filtration													



ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

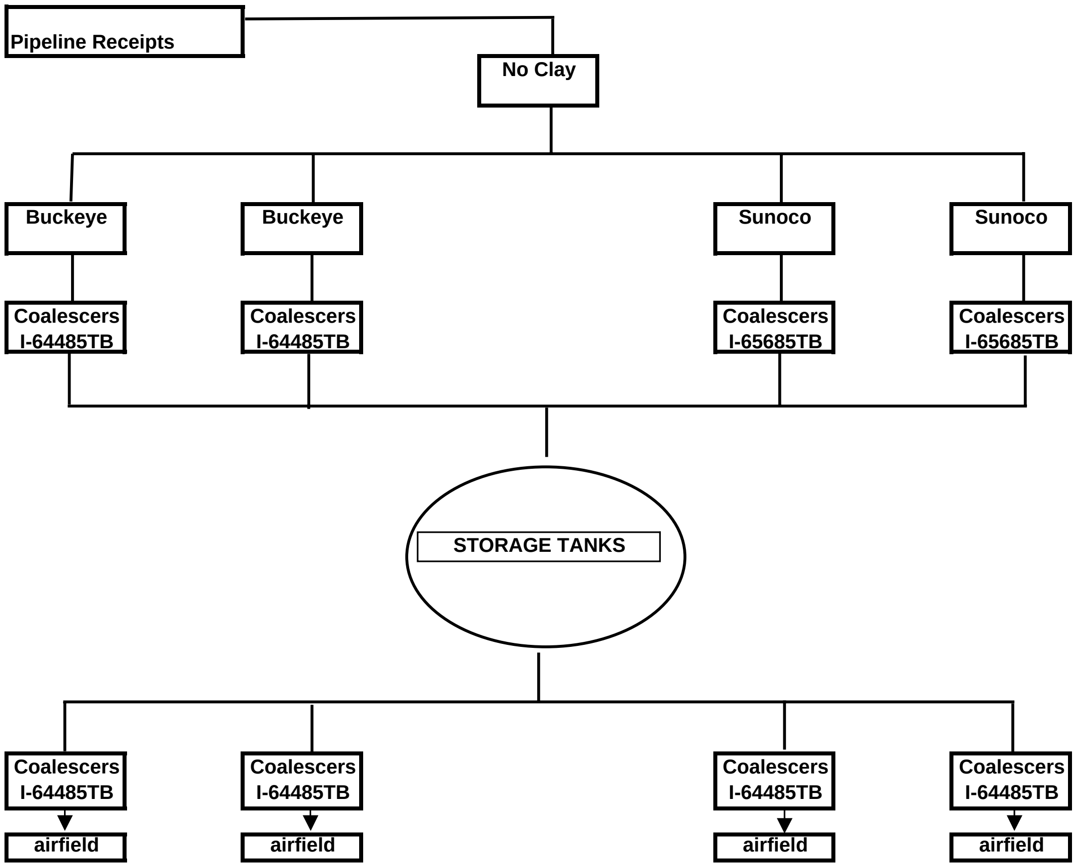
Chicago ORD 474 M&O

ASIG Station Code - ORD	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility	(Into-Plane) Equipment Filtration		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings
					Monitors	F/S			with monitors	Testing	Additives Found		
Fuel Facility Filtration	F/S	N/A	F/S	No	N/A	1	N/A	N/A	N/A	N/A	N/A	No	No
ASIG IntoPlane					5	0							
American Airlines Intoplane					2	31							
American Eagle Intoplane					0	11							
Servisair Shell Intoplane					67	0							



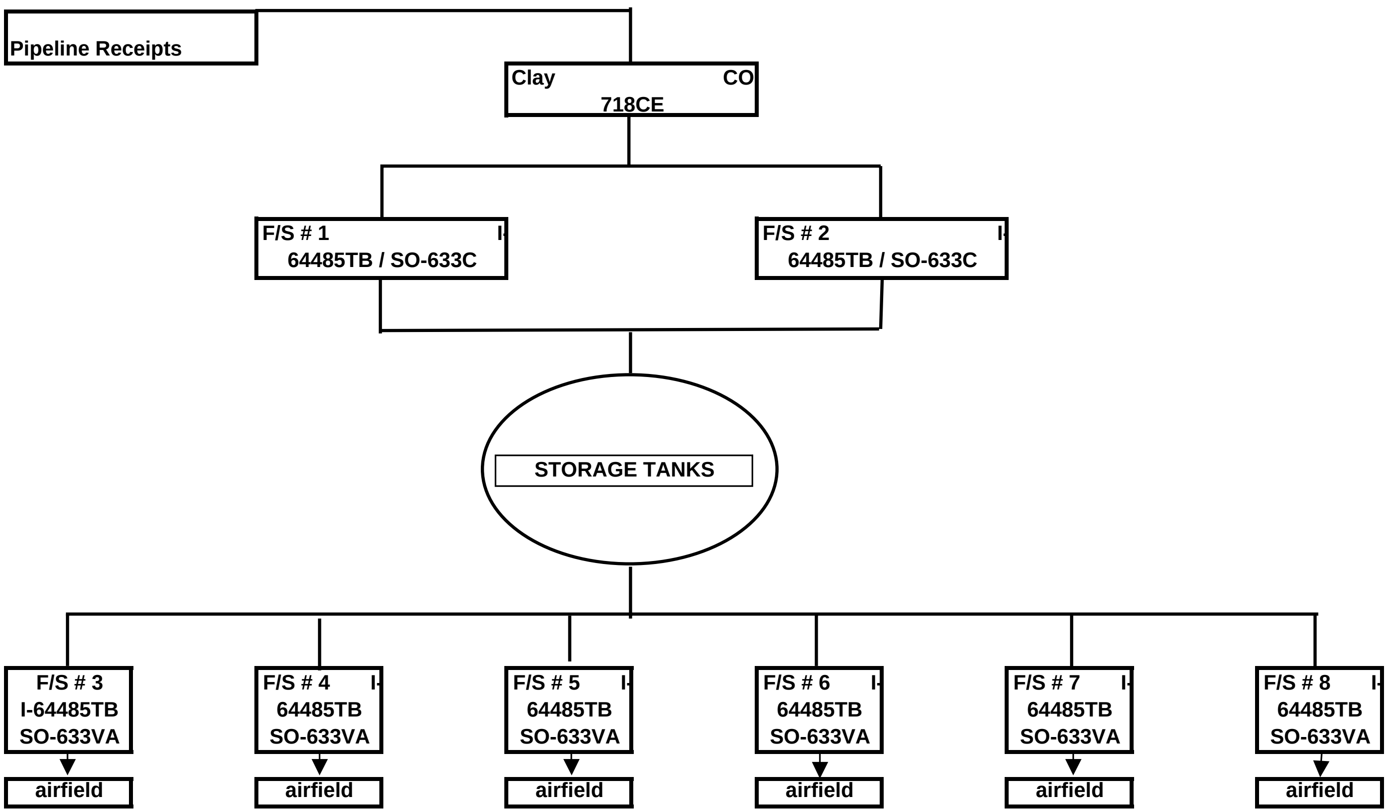
ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
PHL 518					39	0	No	Yes	No	No	N/A	No	No
PHL 539	F/S	NA	F/S	No									



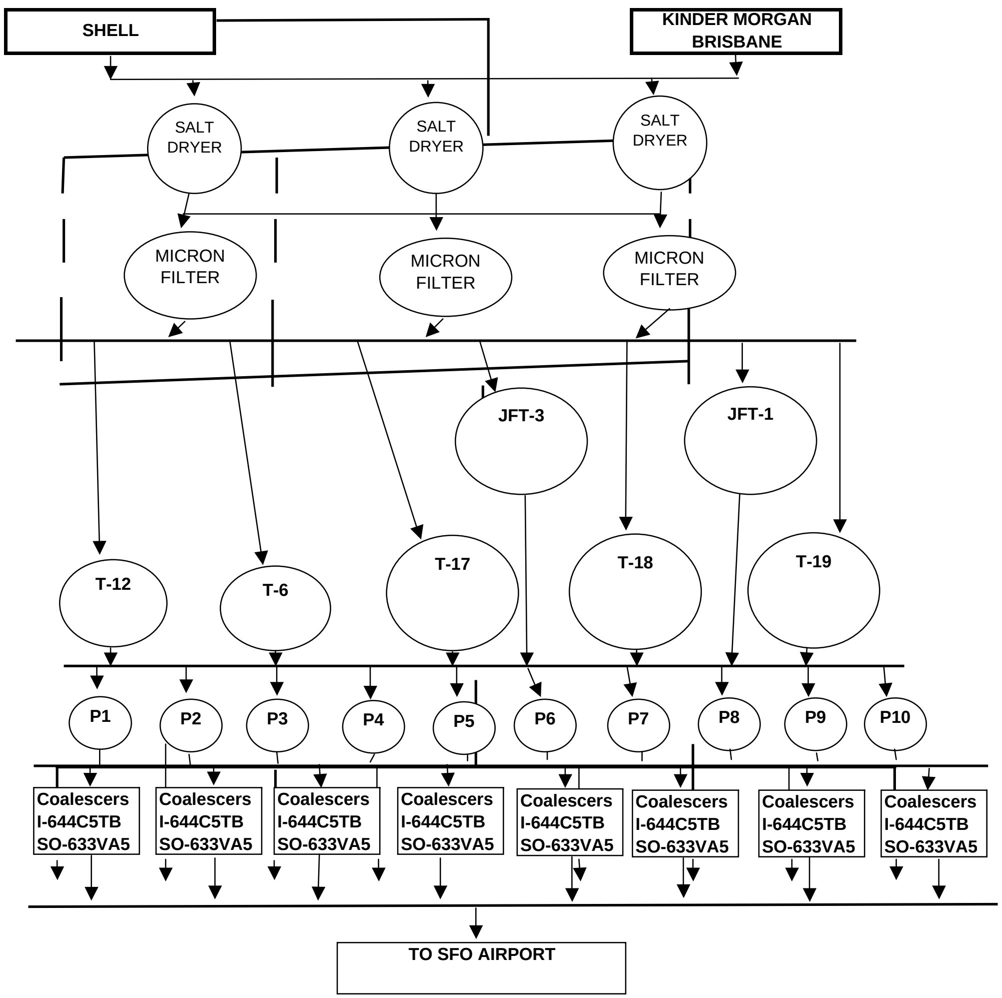
ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
PIT	F/S Monitor	NA	F/S	N/A	30	3	N/A	N/A	N/A	N/A	N/A	No	No
Fuel Facility Filtration	Clay :F/S	NA	F/S	No	N/A	Clay 180 F/S 98 / 50	N/A	N/A	N/A	N/A	N/A	No	N/A



ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

ASIG Station Code	(Inbound) Facility Filtration Type	(Receiving Tanks to Dispensing Tanks) Filtration Type	(OutBound) Facility Filtration Type	Monitors used to remove water at Facility Filtration	(Into-Plane) Equipment Filtration Totals		Any slow flow fueling with monitors	Are monitors flowed at normal rate	Any use of FSII	Fuel Tested for FSII using B/2 Test Kit		Any abnormal DP's recorded	Any abnormal Nozzle Screen findings recorded
					Monitors	F/S			with monitors	Testing	Additives Found		
Example	Micronics; Clay; F/S	NA	F/S	No	13	6	No	Yes	No	No	NA	No	No
Fuel Facility Filtration	F/S	N/A	F/S	NO	44	5	NO	YES	NO	NO	N/A	NO	NO



ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

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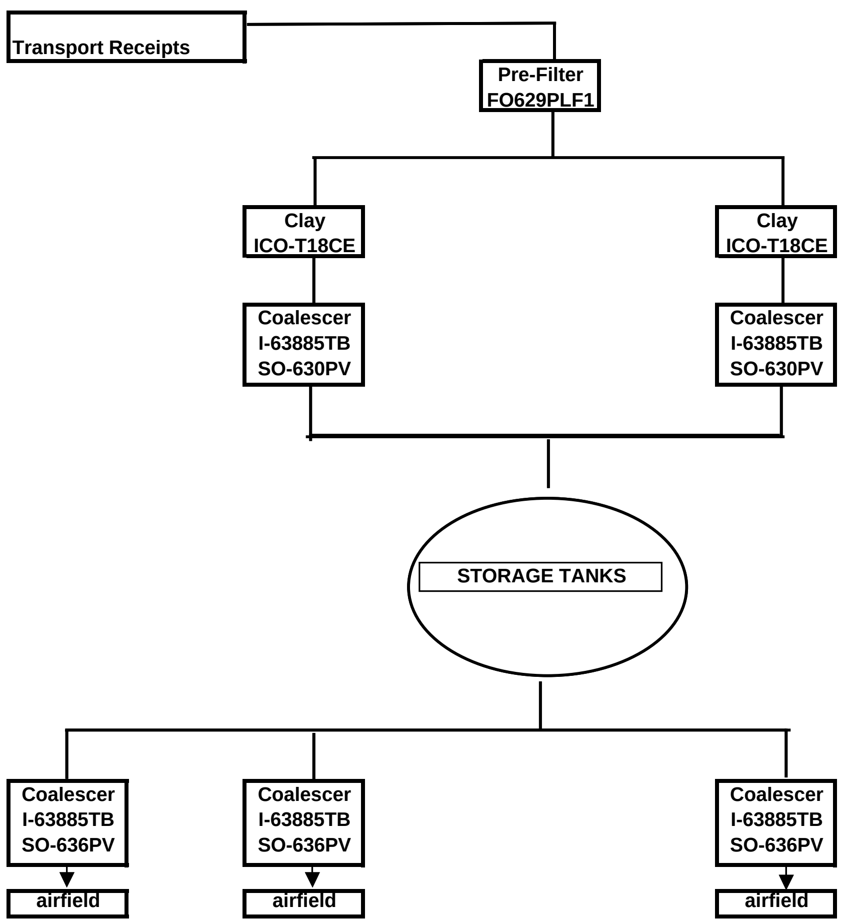
					Monitors	F/S			with monitors	Testing	Additives Found		
SNA					12	0	yes	Yes	no	No	NA	No	No
Fuel Facility Filtration	Pre-filter, Clay, F/S	N/A	F/S	No							N/A	No	No



ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

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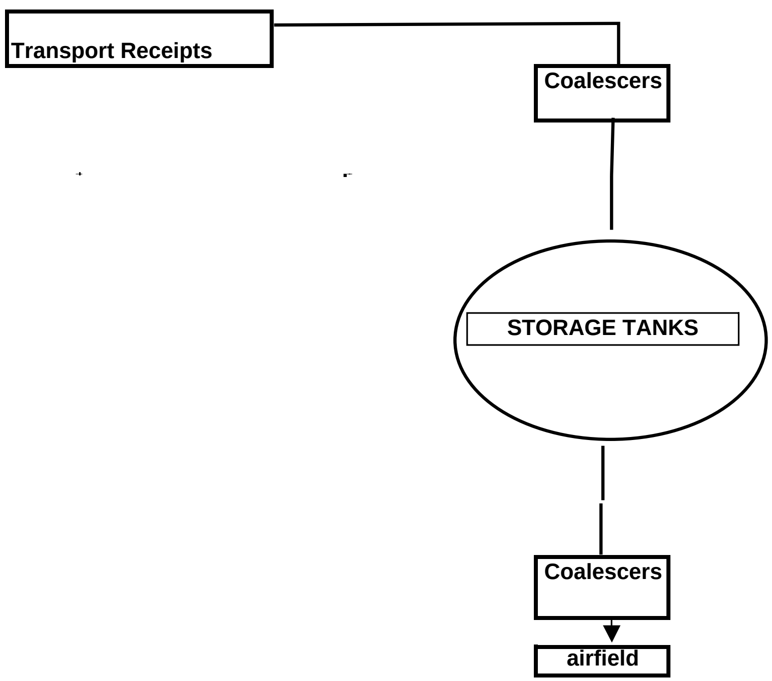
					Monitors	F/S			with monitors	Testing	Additives Found		
SRQ													
Fuel Facility Filtration	F/S	NA	F/S	No	22	0	Yes	Yes	No	No	NA	No	Yes Observed few filter fibers



ASIG Fuel Filter/Monitor Survey
IATA Fuel Monitor Task Force

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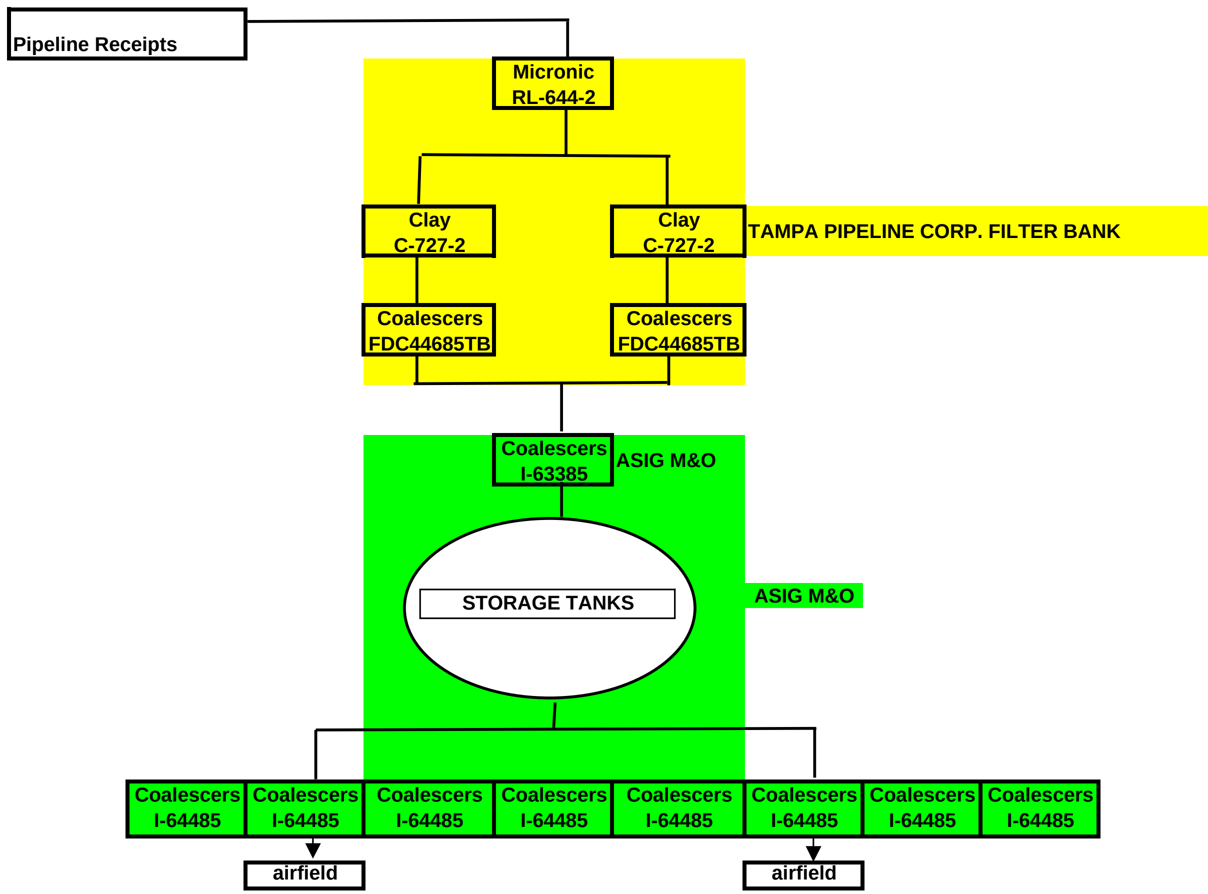
					Monitors	F/S			with monitors	Testing	Additives Found		
TPA	Micronics; Clay; F/S	NA	F/S	No	28	N/A	no	no	N/A	N/A	NA	no	no
Fuel Facility Filtration													



EDX Spectra of Non-Volatile Residue Samples from Water Extract.

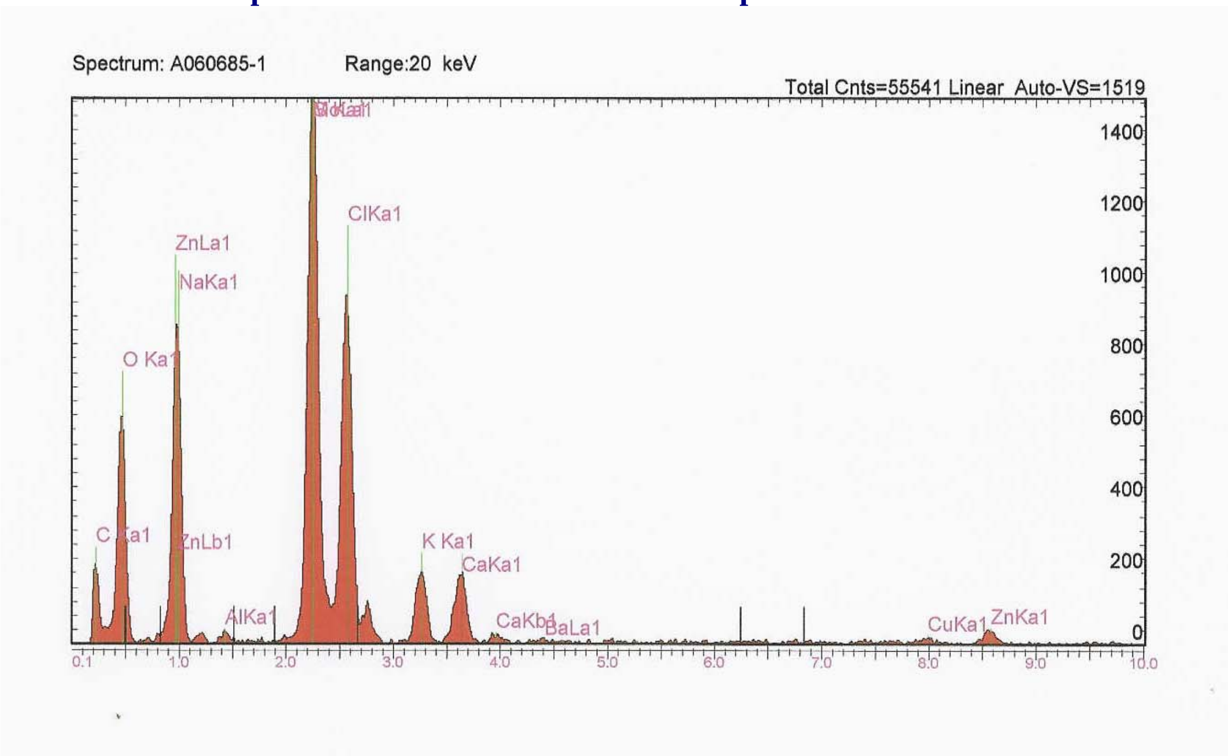


Figure A1. EDX spectrum of non-volatile residue from water extract of filter element F1.

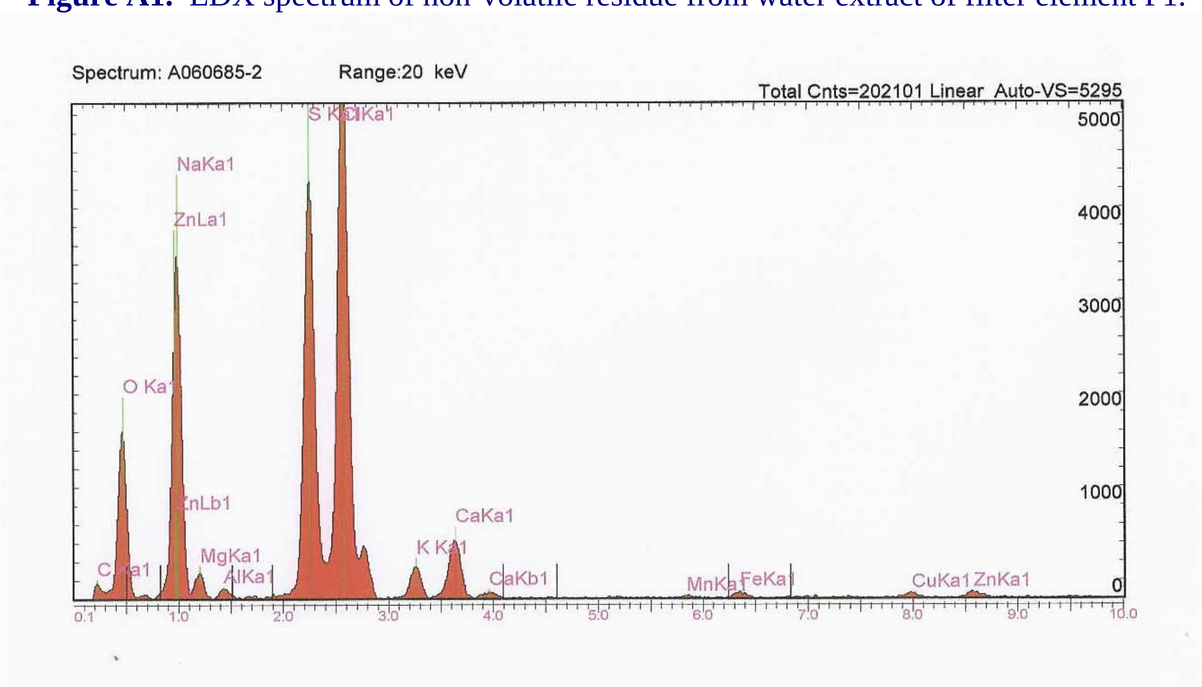


Figure A2. EDX spectrum of non-volatile residue from water extract of filter element G1.

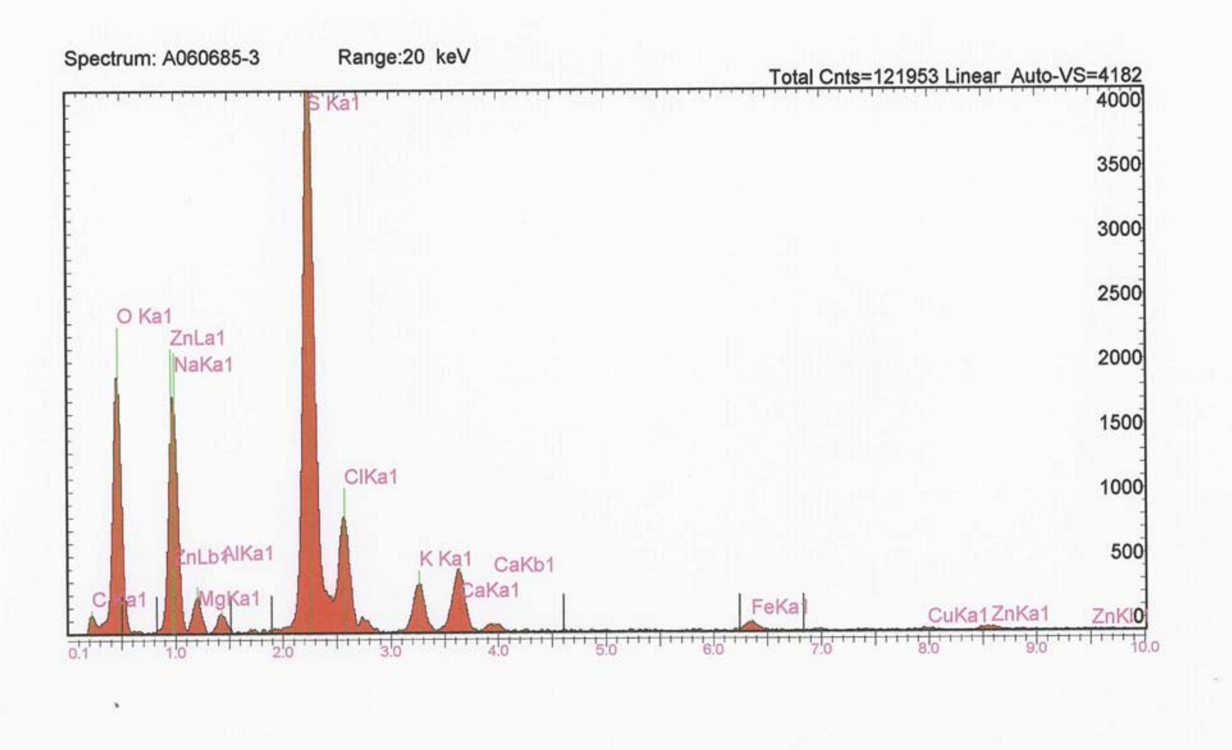


Figure A3. EDX spectrum of non-volatile residue from water extract of filter element E1.

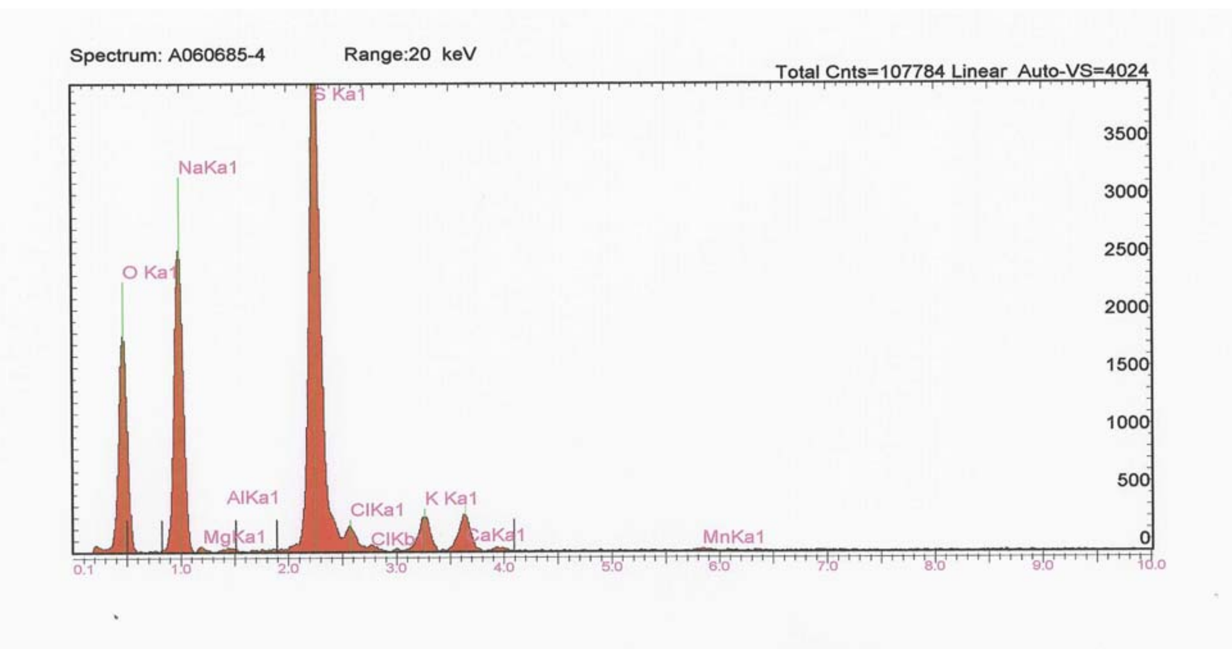


Figure A4. EDX spectrum of non-volatile residue from water extract of filter element A1.

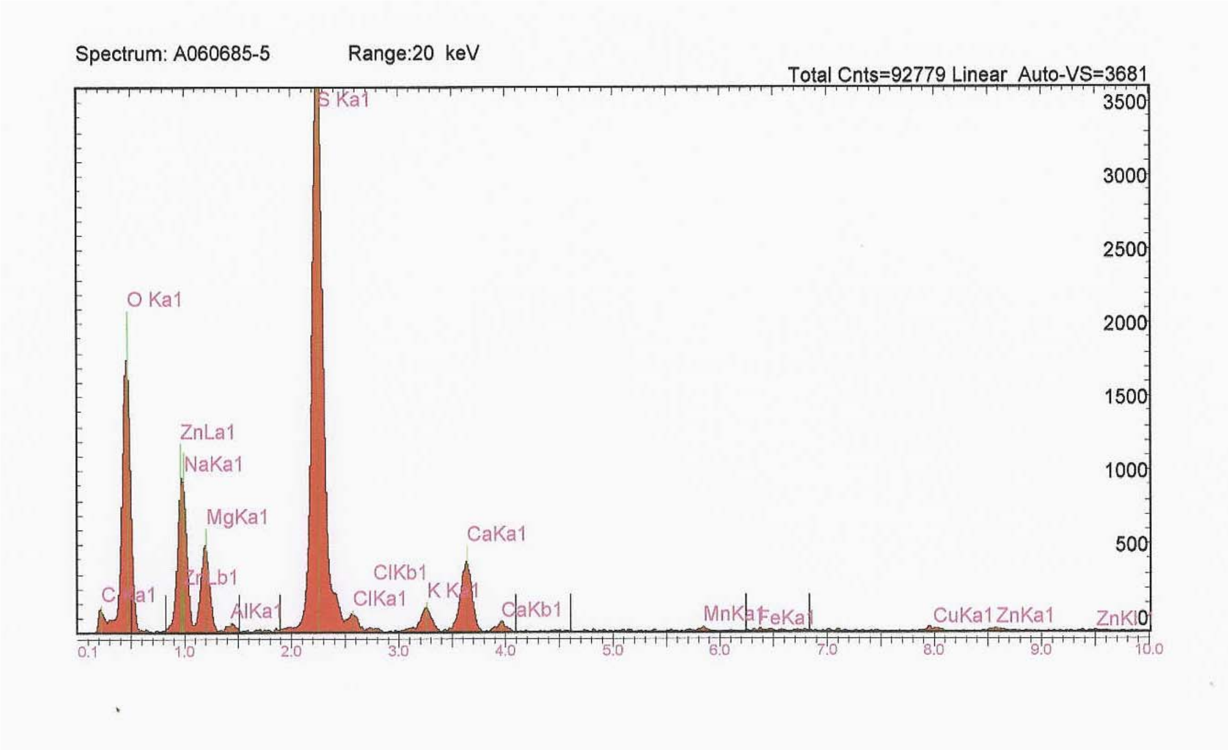


Figure A5. EDX spectrum of non-volatile residue from water extract of filter element C1.

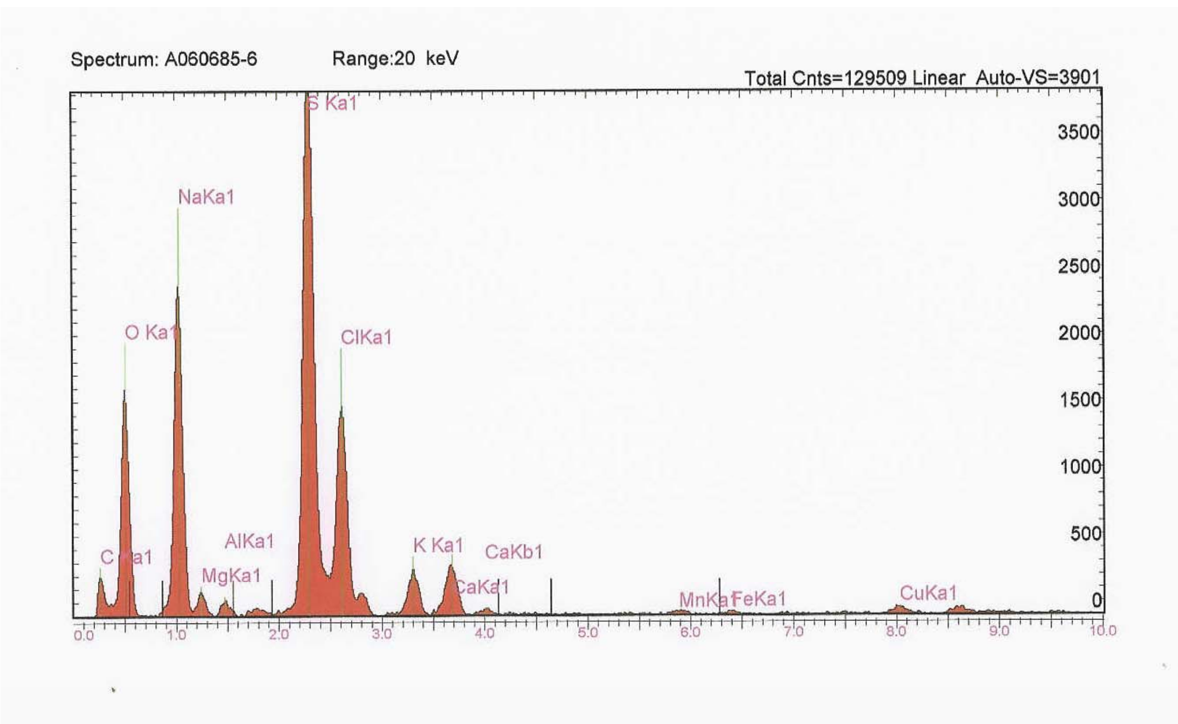


Figure A6. EDX spectrum of non-volatile residue from water extract of filter element B1.

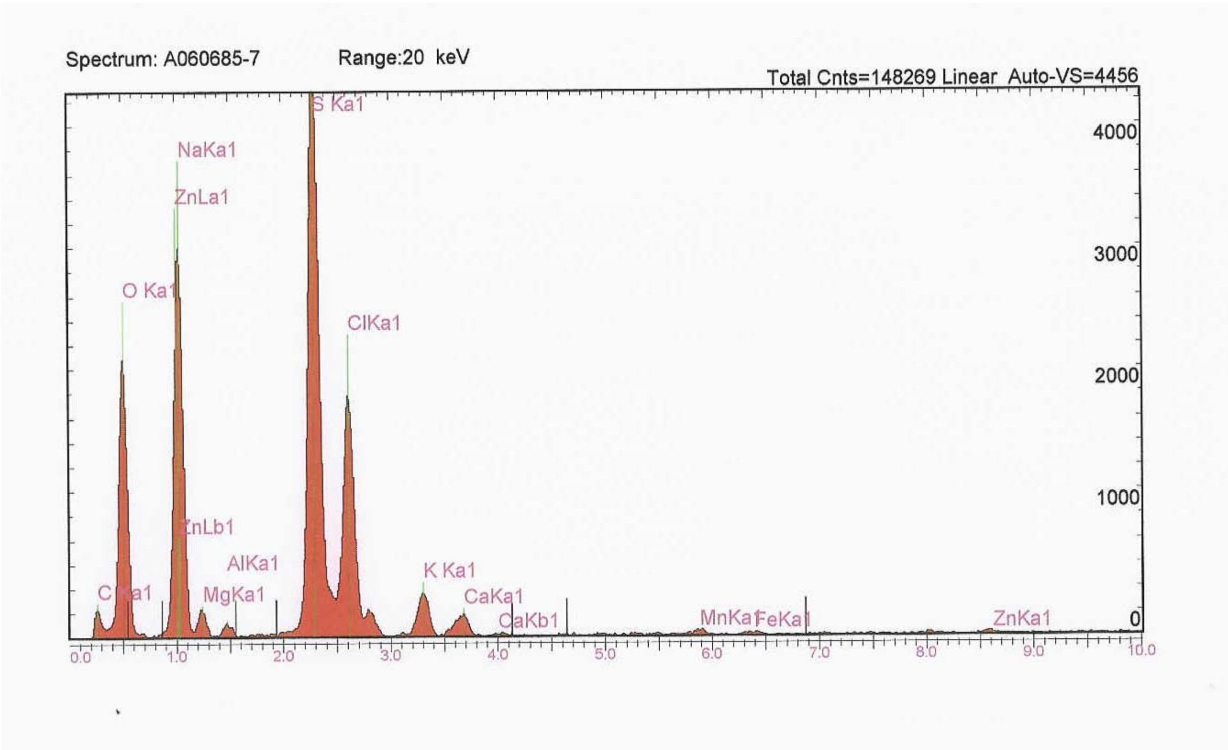


Figure A7. EDX spectrum of non-volatile residue from water extract of filter element D1.

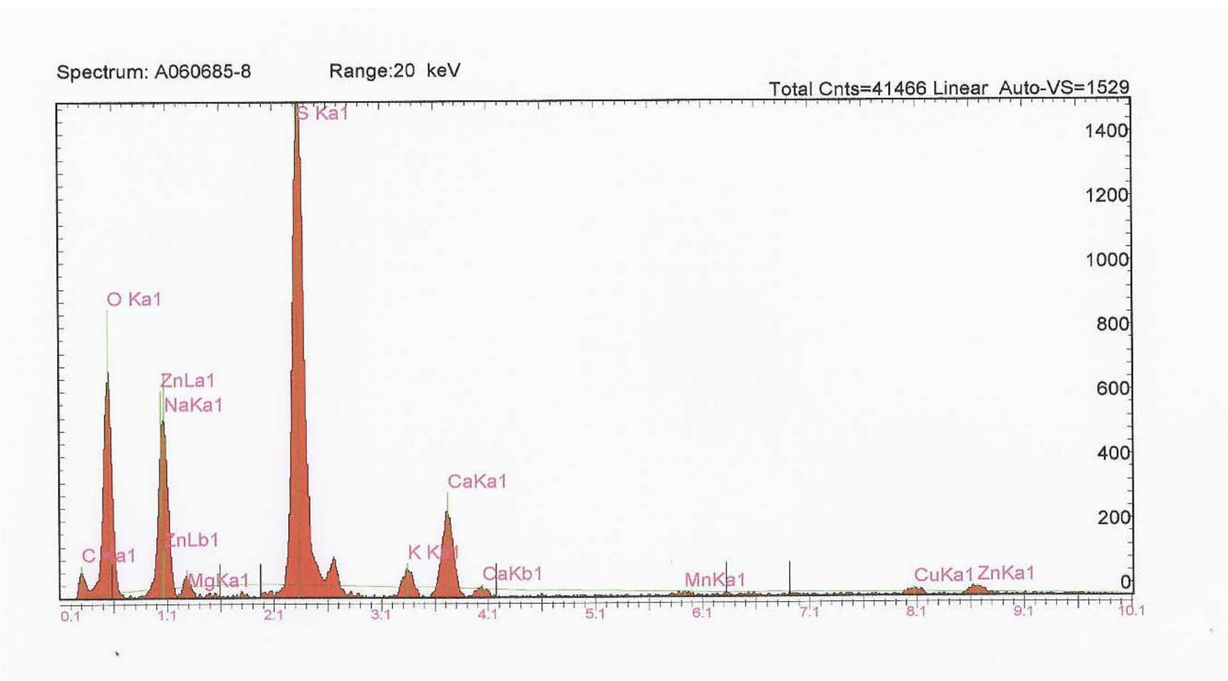


Figure A8. EDX spectrum of non-volatile residue from water extract of filter element H2.

Air BP Filter Debris Analysis

Air BP provided analysis on four used fuel filters from Operator P. These were from Boeing 737 aircraft and one from a Boeing 767 aircraft. The analysis is provided below.

Report Details

Title	Boeing 737 Filter Blockage ex Operator P		
Report Type	Investigation		
Report ID	DR638	Section	Investigational Analysis
Author	Mr X	E mail	mailto:leetchdr@bp.com
Issue Date	20/12/05	Status	Completed
Effort	Hours		

Customer Details

Name	Mr Y
Company	Castrol
Department	Fuels
Cost Code	GFT

Scope

The fuel filter bypass warning light illuminated during the flight, indicating loss of flow through the filter. The filter was submitted for determination of the nature of the blockage if any.

Analysis was conducted to determine:

1. Whether SAP (super absorbent polymer) was present in filter folds

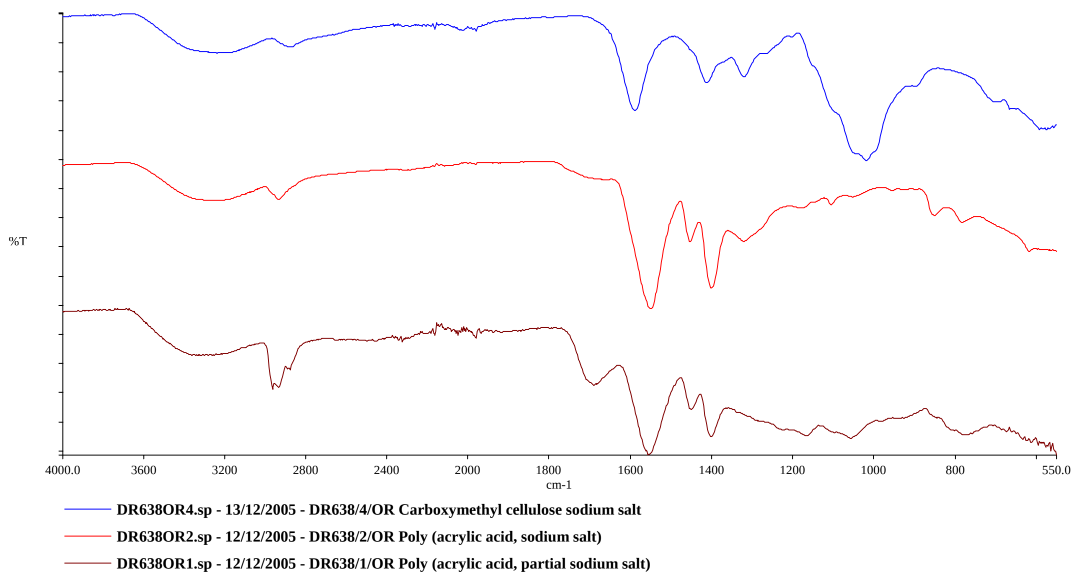
2. To identify any other solids present in the filter folds.

Samples

Analysis Code	Description	Purpose
DR638/1/OR	Poly(acrylic acid), partial sodium salt lightly cross linked	SAP reference
DR638/2/OR	Poly(acrylic acid, sodium salt)	SAP reference
DR638/3/OR	Blocked Filter	For investigation of blockage
DR638/4/OR	Carboxymethylcellulose, sodium salt	SAP reference

Reference Data

1. Infrared Spectroscopy



Technology Centre, Pangbourne

Fig 1: IR spectra of reference SAPs, collected on diamond ATR

2. Scanning Electron Microscope (SEM) Images

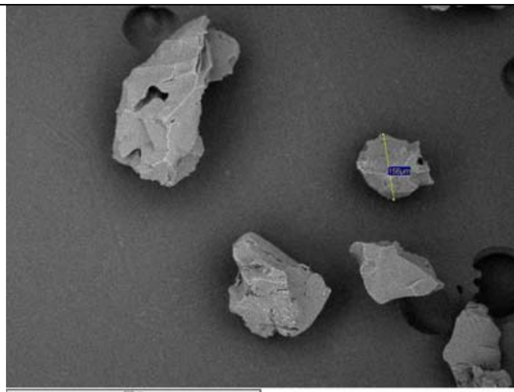


Fig 2: DR638/1/OR large irregular angular particles typically greater than 150μm

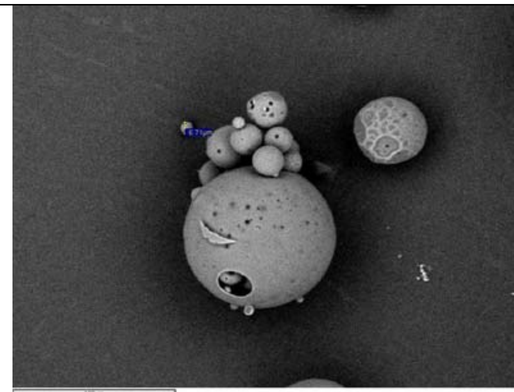


Fig 3: DR638/2/OR spherical particles with a large range of diameters (approx 5 to 150μm)

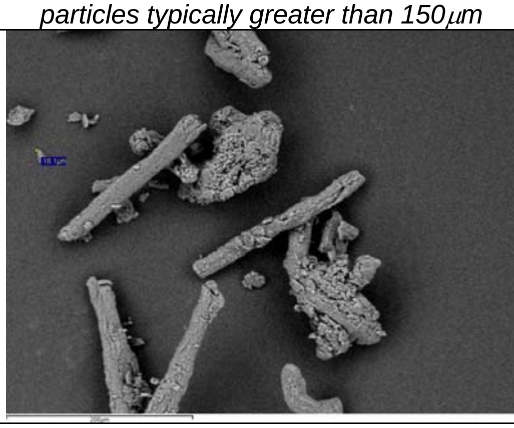


Fig 4: DR638/4/OR Textured lumps and rods. Fragments range in size from approx 15 to 250μm

3. X-ray Spectra (Elemental analyzer attached to the Electron Microscope)

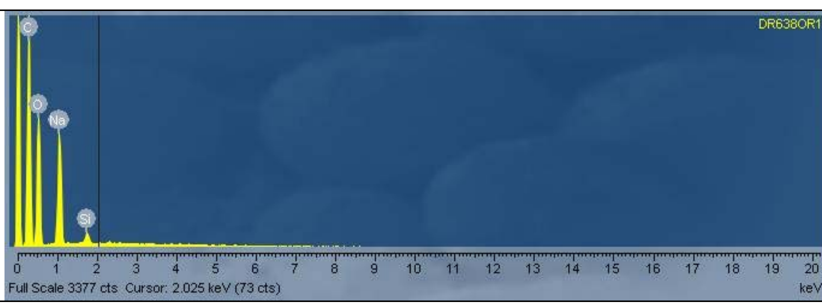
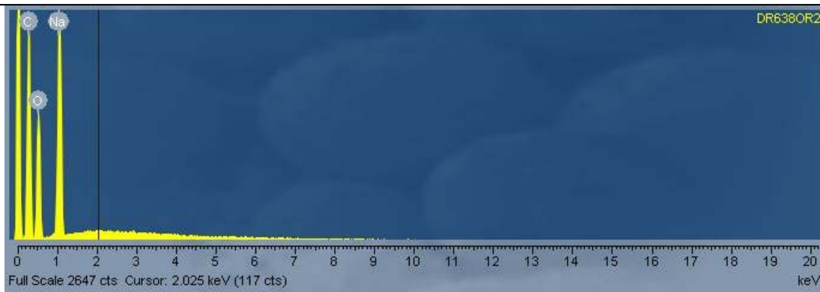
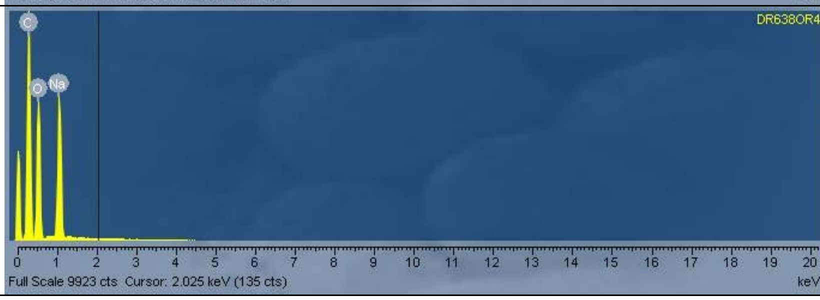


Fig 5: X-ray spectrum from sample DR638/1/OR

	*Fig 6: X-ray spectrum from sample DR638/2/OR*
	*Fig 7: X-ray spectrum from sample DR638/4/OR*

All three SAP samples show strong Sodium (Na) peaks.

<u>Analysis of Filter Blockage</u>

1. **Fibers from Filter Surface**

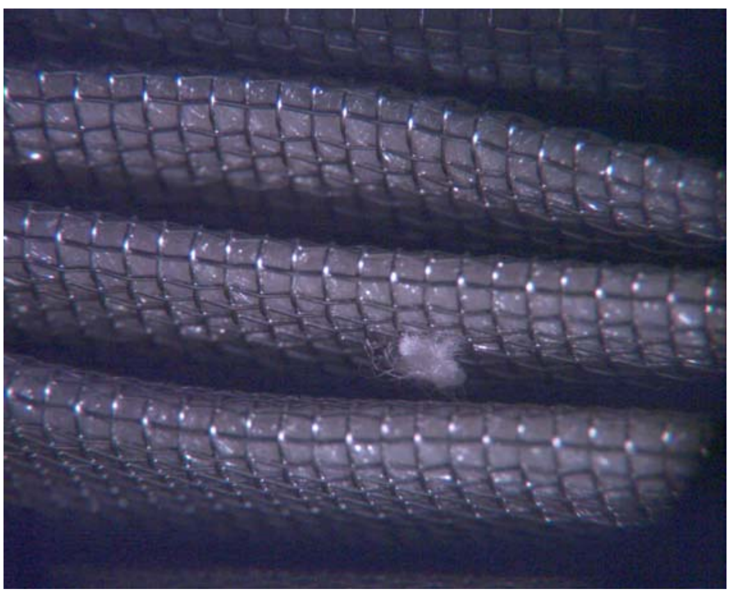


Fig 8: White fibrous material in filter fold

Initial examination of the filter indicated that some white fibrous material was present in the folds. Some of this was removed with forceps, rinsed with pentane (a solvent) and analysed using Infrared Spectroscopy, Light Microscopy and Scanning Electron Microscopy.

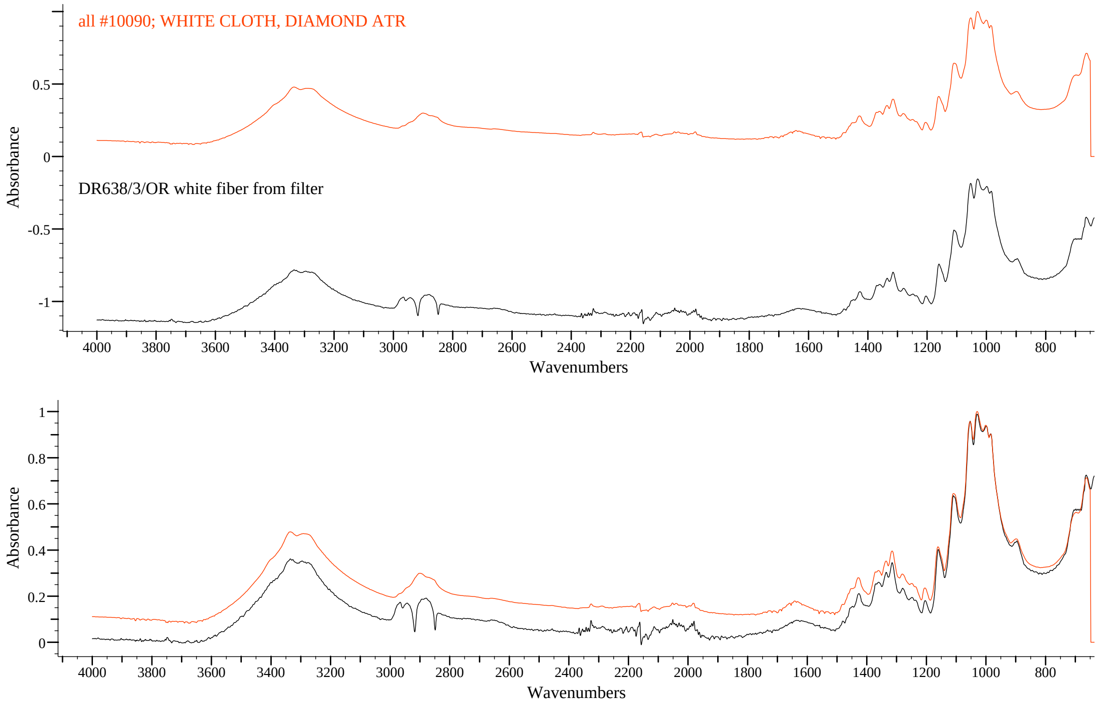


Fig 9: IR spectrum of white fibers taken from filter folds compared with white cloth, spectra collected on diamond ATR

Fig 10: Light microscope image of white fibers on SEM stub (Stub diameter = 140mm)

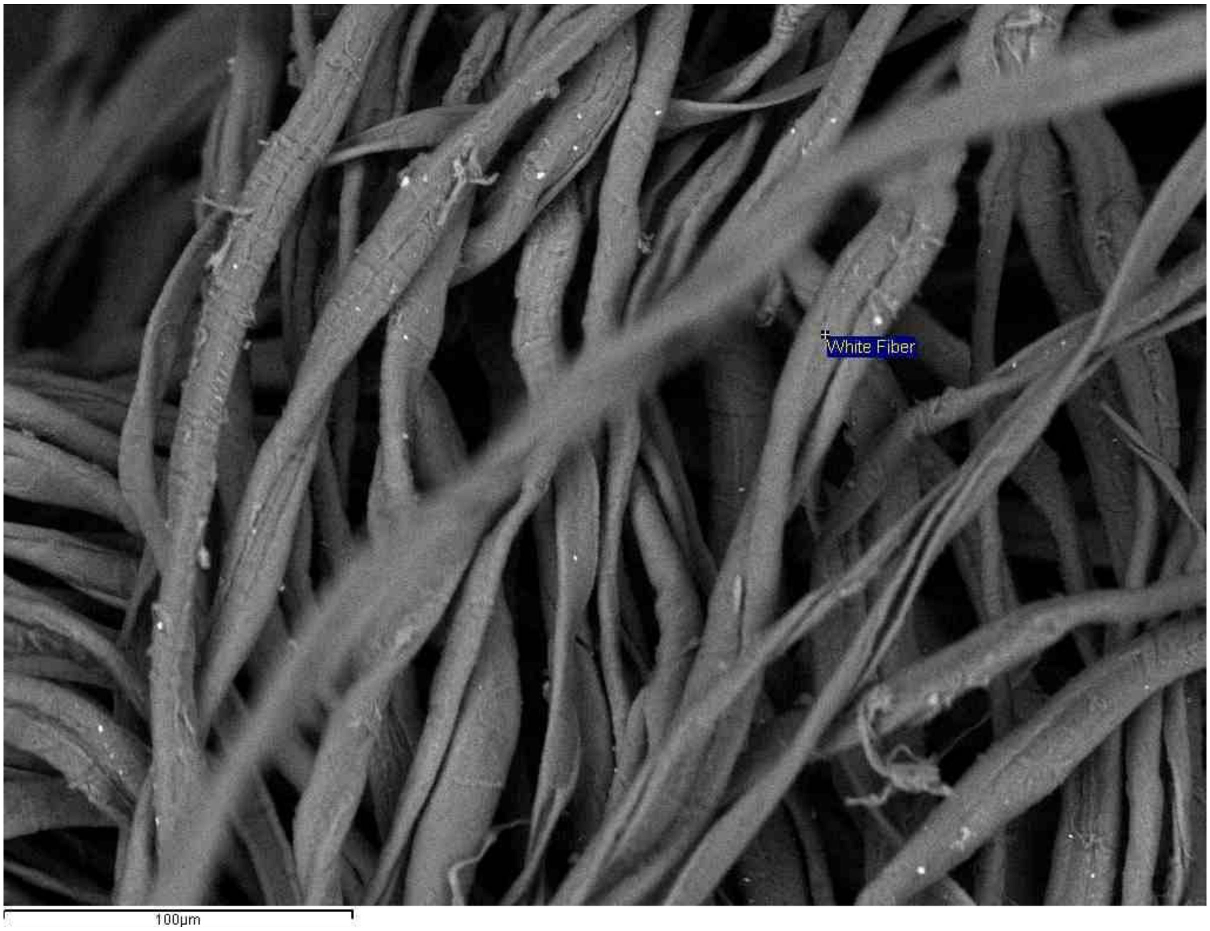


Fig 11: Electron Microscope Image of White fibers

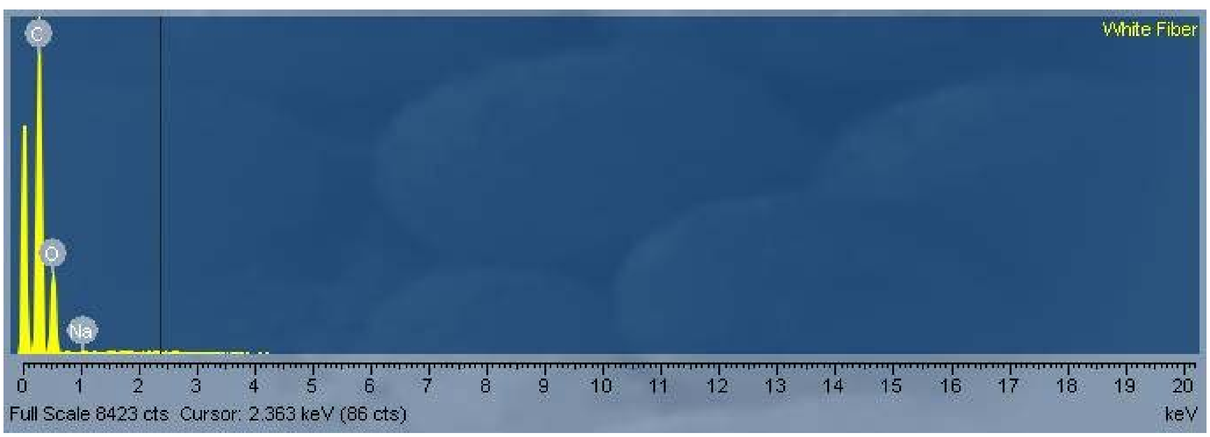


Fig 12: X-ray spectrum of white fiber

The white fibers differ in size, shape and composition to the reference SAPs.

<u>The white fibers appear to be cloth fragments</u>

2. Trapped Solid Debris

The filter was placed in a large beaker and immersed in pentane. The beaker was placed in an ultrasonic bath and was shaken for 15 minutes. The pentane was evapourated to leave jet fuel with suspended solids.

A sample of dirty jet fuel was retained for elemental analysis (ICP and XRF). The rest was centrifuged to remove the suspended solids for further analysis.

Fig 13: Fuel with suspended solids (right), Fuel after removal of solids by centrifugation (left)

ICP Elements ppm	Fuel with Suspended Solids	Fuel with Solids Removed
Calcium	3	<1
Magnesium	1	<1
Phosphorus	2	1
Sulphur	563	548
Zinc	1	<1
Aluminium	3	<1
Boron	<1	<1
Barium	<1	<1
Cadmium	<1	<1
Chromium	<1	<1
Copper	<1	<1
Iron	23	<1
Manganese	<1	<1
Molybdenum	<1	<1
Nickel	<1	<1
Lead	<1	<1
Silicon	4	<1
Tin	<1	<1
Titanium	<1	<1
Vanadium	<1	<1

Sodium	11	<1
***XRF Chlorine ppm**	49	<5

*XRF Chlorine figures are likely to be much less accurate than ICP

The centrifuged solids were analysed by Scanning Electron Microscopy to determine composition.

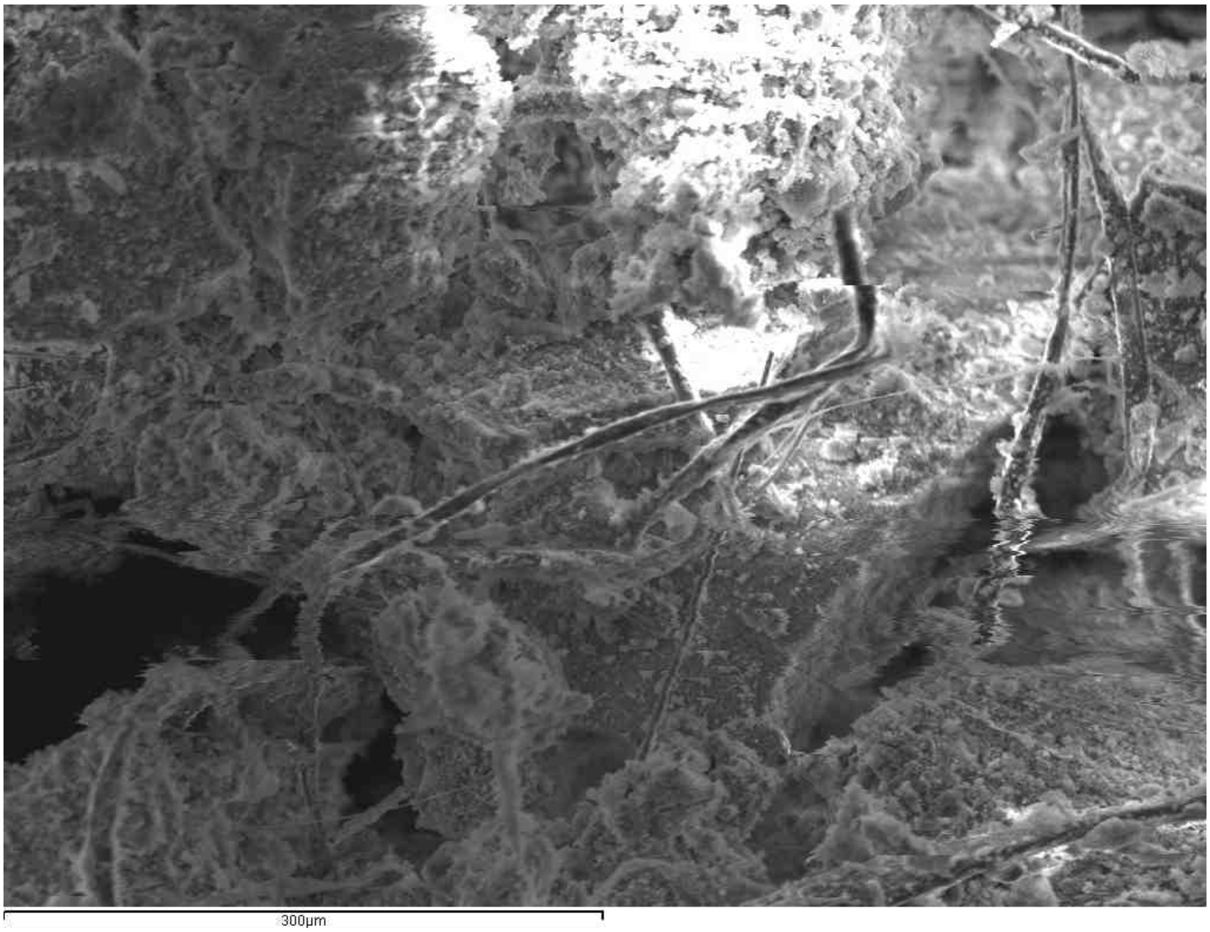


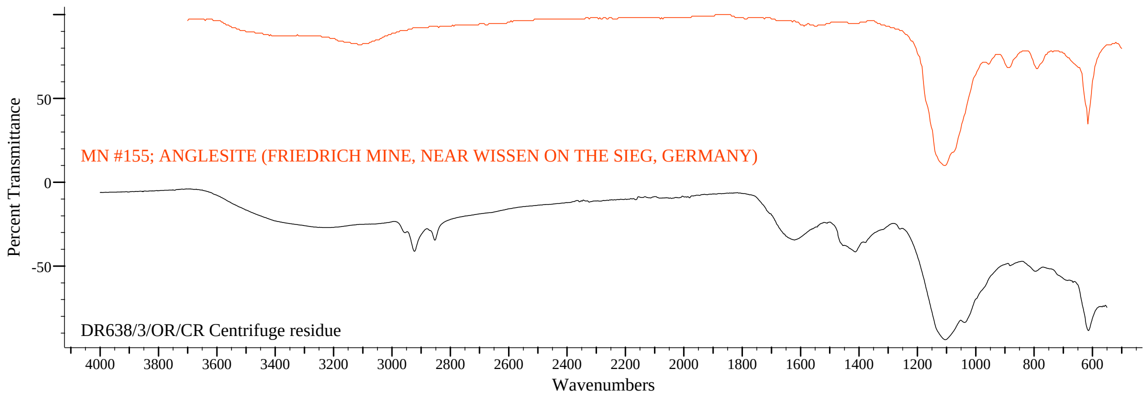
Fig 14: Debris extracted from Fuel Filter

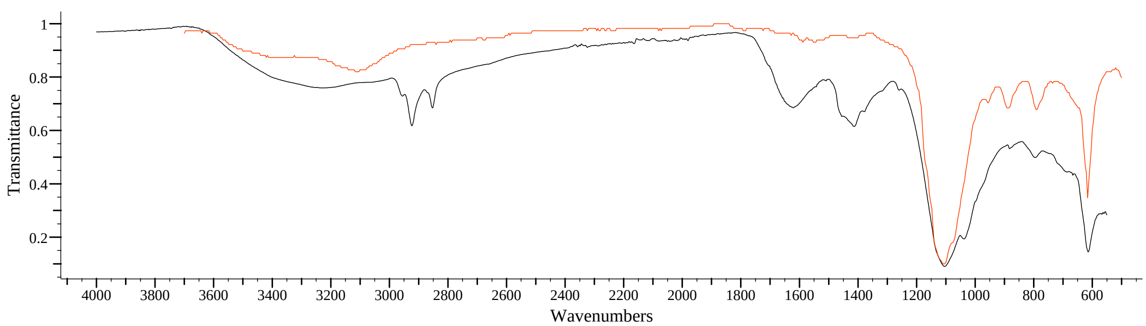
The debris extracted from the filter included some fibers and small agglomerated amorphous particles. The general composition was determined semi-quantitatively using the X-ray analyzer.

Results in weight %

	C	O	Na	Mg	Al	Si	S	Cl	K	Ca	Fe	Total
Mean Composition	38.91	34.00	3.85	0.37	2.36	2.81	4.08	1.48	0.30	1.20	10.63	100.00

Infrared Analysis of the filter extract proved inconclusive.





"lead sulphate, also other sulphate like copper have similar features to this spectrum. This is a difficult region where sulphate, phosphates and silicates absorb"

Conclusions

Some white cloth fibers were present on the filter surface. Further fibers were present in material extracted from inside the filter.

Analysis of the filter extract, indicates that amorphous solid debris appears to make up the bulk of the blockage. While this contains sodium, there is no evidence for the presence of SAP either in the IR spectrum or by examination of the morphology* of the debris.

***Note that the morphology of the SAPs in the filter monitor are not currently known. The reference materials may not match those in general use.**

The sodium may be present simply as common salt, note presence of chlorine.

Iron seems more abundant than Sodium, both by ICP and SEM. Ferrous corrosion salts may be at least partly responsible for the blockage. Some of the other elements such as silicon and aluminum could be due to dust.

Recommendations

Some further characterization of the filter extract may be possible using techniques such as X-ray Diffraction (XRD).

Reference knowledge on the morphoplogy of SAPs in general use in filter monitors may be useful for future investigations.

1.1.1

Report Details

Title	Operator P Filter Investigation		
Report Type	Investigation		
Report ID	IA19	Section	Investigational Analysis
Author	Mr X	E mail	mailto:leetchdr@bp.com
Issue Date	30/01/06	Status	Completed
Effort	Days		

Customer Details

Name	Mr Y
Company	BP
Department	Air BP
Cost Code	440061100002

Scope

3 fuel filters were analysed to determine whether SAP (super absorbent polymer) or SAP derivatives were present in the filter debris.

Analysis Code	Description
IA19/1/OR	BA 737 Fuel Filter no 2 engine 1st change out
IA19/2/OR	BA 737 Fuel Filter no 2 engine 2nd change out
IA19/3/OR	BA 767 Fuel Filter ex aircraft NWN No 1 Engine

Sample Preparation

The filters were photographed in the received condition. Each was placed in a beaker filled with pentane and left in an ultrasonic bath for 15 mins. Pentane was evaporated from the filter extracts to leave jet fuel and solid debris. Small samples of the dirty jet fuels extracted from the filters were analysed by ICP and XRF to determine the elemental composition. The remaining fuels were centrifuged to isolate the solid debris for analysis by Infrared Spectroscopy and Scanning Electron Microscopy. The elemental compositions of the fuel samples after centrifugation were compared with the dirty fuels by ICP and XRF.

Fig. 1: IA19/1/OR

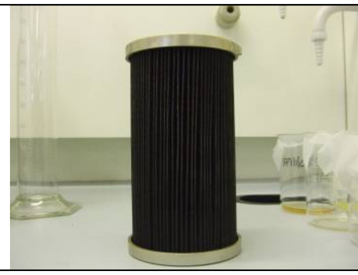


Fig. 2: IA19/2/OR

Fig. 3: IA19/3/OR

Filters IA19/1/OR and IA19/3/OR appeared clean. Filter IA19/2/OR was darker and appeared more dirty.

Fig 4: IA19/1/OR/UP

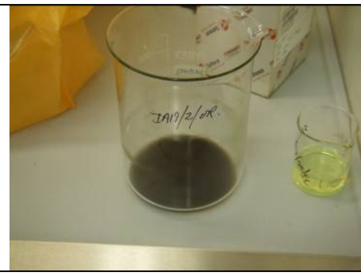


Fig 5: IA19/2/OR/UP

Fig 6: IA19/3/OR/UP

The jet fuel extracts IA19/1/OR/UP and IA19/3/OR/UP were fairly clean with only minimal suspended solids. Extract IA19/2/OR/UP was very dirty.

	IA19/1/OR/UP	**IA19/1/OR/UP/CG**	**IA19/2/OR/UP**	**IA19/2/OR/UP/CG**	**IA19/3/OR/UP**	**IA19/3/OR/UP/CG**
All values in ppm	Fuel with suspended solids	Fuel with solids removed	Fuel with suspended solids	Fuel with solids removed	Fuel with suspended solids	Fuel with solids removed
ICP Elements						
Calcium	1	1	15	<1	<1	<1
Magnesium	<1	<1	6	<1	<1	<1
Phosphorus	3	<1	2	2	<1	1
Sulphur	423	425	758	649	1465	1462
Zinc	<1	<1	3	<1	<1	<1
Aluminium	<1	<1	13	<1	<1	<1
Boron	<1	<1	<1	<1	<1	<1
Barium	<1	<1	<1	<1	<1	<1
Cadmium	<1	<1	<1	<1	<1	<1
Chromium	<1	<1	<1	<1	<1	<1
Copper	<1	<1	3	<1	<1	<1
Iron	4	2	193	3	<1	<1
Manganese	<1	<1	2	<1	<1	<1
Molybdenum	<1	<1	<1	<1	<1	<1
Nickel	<1	<1	<1	<1	<1	<1
Lead	<1	<1	3	<1	<1	<1
Silicon	<1	<1	17	<1	<1	<1
Tin	<1	<1	<1	<1	<1	<1
Titanium	<1	<1	<1	<1	<1	<1
Vanadium	<1	<1	<1	<1	<1	<1

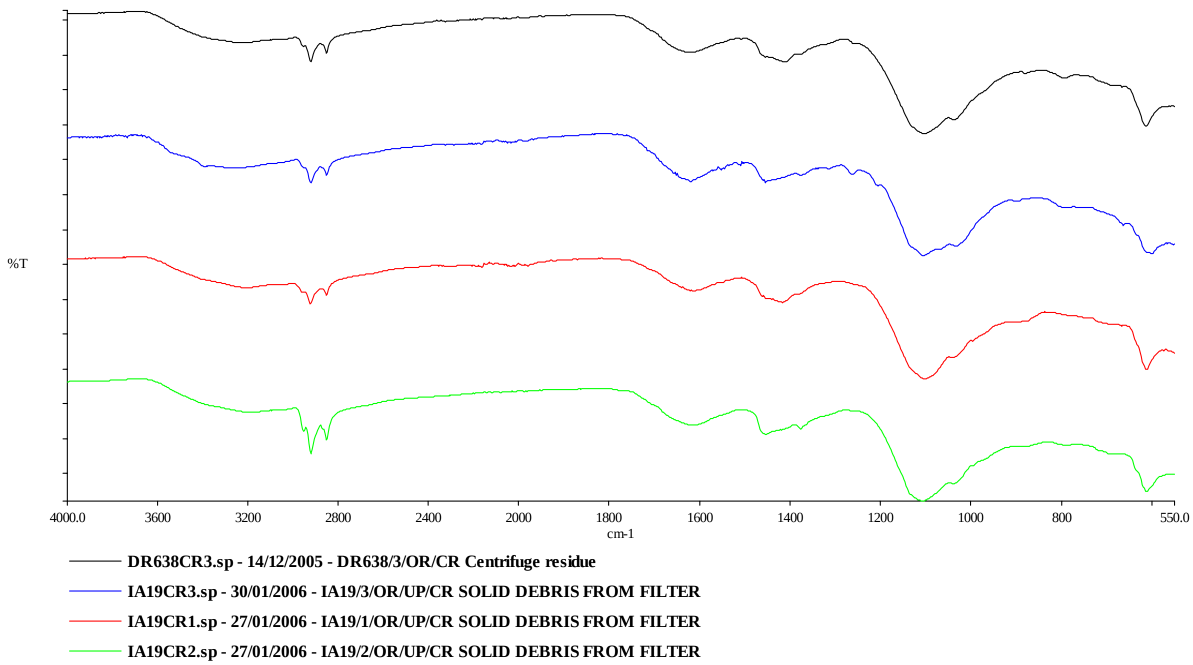
Sodium	2	1	78	<1	<1	<1
XRF Chlorine	8.2	2.9	476.1	3.6	<1	1.4

The ICP and XRF results show a clear difference in composition between the dirty fuel extract and the centrifuged fuel for filter IA19/2/OR. This suggests that the suspended solids contain significant levels of iron, chlorine, sodium and sulphur. Together with some silicon, aluminum, calcium etc.

Solid debris from each filter was weighed:

Debris	**Weight g**
IA19/1/OR/UP/CR	0.0381
IA19/2/OR/UP/CR	0.1310
IA19/3/OR/UP/CR	0.0250

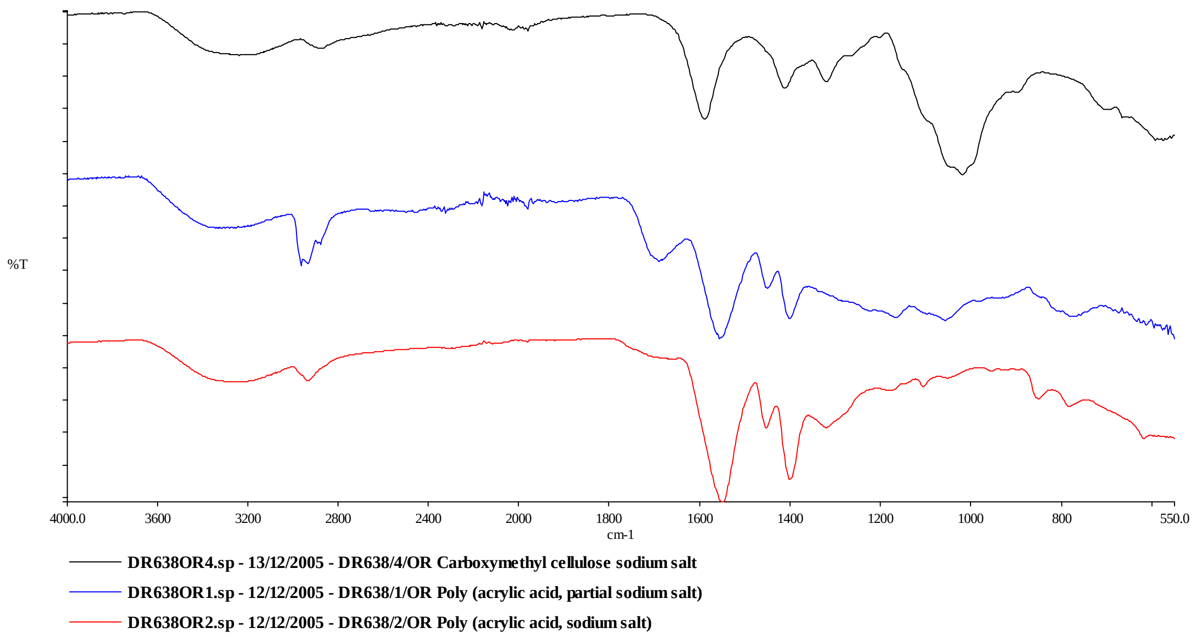
IR spectra were collected of the solid debris on a diamond ATR crystal.



Castrol International

Fig. 7: IR spectra of solid debris from the three filters, compared with debris from report DR638

The three solid debris samples show very similar spectra to each other and to debris from a fuel filter analysed in report DR638. In this previous report, Infrared analysis was inconclusive "*lead sulphate, also other sulphates like copper have similar features to this spectrum. This is a difficult region where sulphate, phosphates and silicates absorb*"



Castrol International

Fig. 8: IR spectra of reference SAP materials

The IR spectra of the solid debris (Fig. 7) do not match those of the reference SAPs (Fig. 8)

The general composition of the filter debris was determined semi quantitatively using the X-ray analyzer attachment of the electron microscope.

Results in weight %

	C	O	Na	Mg	Al	Si	P	S	Cl	K	Ca	Fe
ID: IA19/1/OR/UP/CR	37.45	33.53	5.96	0.56	0.80	0.81	0.53	6.69	1.19	0.46	0.98	11.03
ID: IA19/2/OR/UP/CR	45.32	32.79	3.92	0.28	1.44	0.44	0.10	5.09	1.24	0.22	0.60	8.57
ID: IA19/3/OR/UP/CR	56.32	32.52	1.81	0.21	1.67	0.52	0.00	3.03	0.27	0.17	0.92	2.55

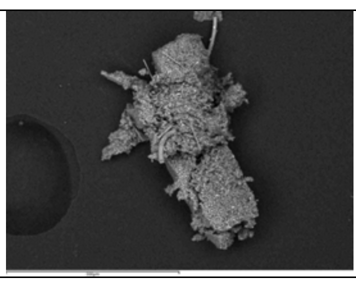


Fig. 9: IA19/1/OR/UP/CR

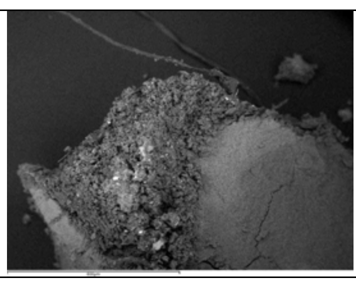


Fig. 10: IA19/2/OR/UP/CR

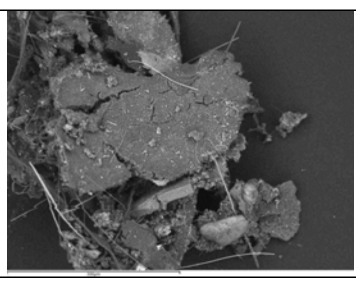


Fig. 11: IA19/3/OR/UP/CR

The solid debris from each filter was composed of agglomerated amorphous particles together with some fibers, possibly from the filter itself.

Conclusions

The three filters each contain broadly similar debris to that extracted during the previous investigation (DR638).

While the trapped solids from the filters contain significant sodium levels, there is no evidence to suggest that this is present as SAP. The debris appears to have a high level of chorine, indicating that the sodium may be present as common salt. The level of iron is high in the solid debris indicating that Ferrous corrosion salts are likely to be present.

Other elements such as silicon and aluminum are likely to be from dust or sand.

SwRI CL#	05-631	05-684	05-0689	05-0700	05-0734	06-0088	06-0089	06-0094	06-0095	06-0096	06-0105	06-0106	06-0107	06-0108	06-0133	06-0134
Basic Information																
Filter Brand																
Filter Part Number															721580	721580
Airline	**Operator Q**	**Operator Q**	**Operator Q**	**Operator Q**	**Operator Q**	**Operator R**	**Operator R**	**Operator S**	**Operator R**	**Operator R**	**Chevron**	**Chevron**	**Chevron**	**Chevron**	**Operator R**	**Operator R**
Aircraft Identification				A/C 0014		A/C 801	A/C 801		A/C 802	A/C 802	72649	649	576		907	907
Engine Identification				Engine #2		Left Engine	Right Engine		Right Engin	Left Engine	Position #2	Position #1	Position #2		#2 Engine Filt	1 Engine Filt
Filter time on aircraft, hours																Re
Comments														Suspected oil contaminati		
Debris Analysis Results																
TAM Soluble Materials, %	**8.90%**	**10.50%**	**11.72%**	**11.40%**	**10.90%**	**0%**	**0%**	**5.49%**	**8.99%**	**4.40%**	**10.10%**	**3.20%**	**12.50%**	**53.70%**	**0**	**0**

Elemental Analysis																
Filter																
Carbon, C	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Sodium, Na	20.4	---	5.54	9.71	6.45	3.97	4.66	9.78	10.45	6.28	2.44	1.62	4.11	6.02	---	---
Magnesium, Mg	3.85	2.58	0.88	1.94	1.7	0.83	0.89	1.52	2.61	2.52	1.96	2.39	1.98	2.18	1.93	2.53
Aluminum, Al	2.32	5.07	5.23	4.94	5.61	9.49	10.41	16.26	9.79	11.67	32.3	39.5	29.59	29.59	7.92	7.7
Silica, Si	1.94	4.55	7.48	4.39	6.66	29.91	42.46	26.4	47.66	53.58	11.01	13.73	16.22	19.75	14.72	16.91
Phosphorus, P	0.34	1.83	1.01	2.12	1.52	---	---	---	---	0.21	---	---	0.94	1.25	---	---
Sulfur, S	40.3	37.79	34.88	49.92	41.46	13.81	4.55	24.37	10.43	8.1	24.97	14.15	20.13	17.62	21.97	21.2
Chlorine, Cl	1.05	2.06	1.15	1.84	1.3	0.57	0.57	0.59	---	0.2	0.88	0.92	0.85	1.29	0.49	---
Potassium, K	1.19	1.44	1.36	1.25	0.79	4.96	6.03	3.62	2.74	3.37	1.13	---	1.21	1.53	6.36	3.16
Calcium, Ca	3	4.05	5.82	3.36	4.92	7.39	5.98	4.99	5.23	6.27	7.84	6.11	7.38	6.5	6.1	5.4
Titanium, Ti	0.56	0.89	0.92	0.32	0.81	---	---	---	---	1.53	0.75	0.88	0.72	1.59	----	1.69
Chromium, Cr	0.62	1.03	1.45	0.42	0.53	2.3	1.26	0.72	1.27	1.08	1.61	1.79	1.96	1.07	2.66	2.84
Manganese, Mn	0.58	0.52	---	0.24	---	---	---	---	---	0.31	0.82	0.58	0.83	0.36	0.58	---
Iron, Fe	19.52	30.25	29.45	16.93	23.17	5.34	2.44	6.5	3.74	3.17	8.38	9.46	9.73	8.11	7.12	7.51
Nickel, Ni	0.2	---	0.9	---	---	0.49	---	0.65	---	---	0.73	---	1.11	---	0.75	0.51
Copper, Cu	2.8	6.09	1.79	1.34	2.1	9.31	3.8	---	---	---	0.72	---	---	---	17.1	20.73
Zinc, Zn	2.37	3.54	2.14	1.27	0.95	4.87	5.94	1.44	2.68	1.72	4.49	5.59	3.25	3.14	4.5	4.34
Cadmium, Cd	---	---	---	---	2.04	---	---	---	---	---	---	---	---	---	2.98	3.81
Barium, Ba	---	---	---	---	---	6.76	11.01	3.15	3.4	---	---	---	---	---	4.65	1.65
Strontium, Sr	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Vanadium, V	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0.15	---
Tin, Sn	---	---	---	---	---	---	---	---	---	---	---	3.26	---	---	---	---

Elemental Analysis																
Water Wash																
Carbon, C	---	---	---	---											---	---
Sodium, Na	29.87	25.31	24.57	22.87	27.46	16.11	17.97	9.72	16.28	22.43	8.22	10.25	39.68	19.21	9.46	7.03

Magnesium, Mg	2.56	2.54	2.51	2.68	1.46	1.23		2.01	1.25	1	1.23	2.63	1.73	1.76	2.62	2.38
Aluminum, Al	3.64	4.86	3.41	3.45	2.81	---	---	0.68	0.7	0.53	0.58	0.68	0.97	1.02	---	---
Silica, Si	0.13	0.35	0.3	0.23	---	2.31	19.22		0.74	0.79	0.66	0.81	0.65	1.3	---	---
Phosphorus, P	---	---	---	---	---	---	---							1.46	---	---
Sulfur, S	49.65	48.1	47.5	49.8	51.08	48.73	19.67	53.15	36.74	38.03	37.96	25.03	13.1	37.15	44.33	50.35
Chlorine, Cl	2.94	4.35	4.57	3.93	2.41	9.43	25.78	5.42	17.57	23.18	24.27	24.75	22.89	13.96	7.62	6.79
Potassium, K	1.86	1.64	2.43	2.5	1.91	11.71	11.34	5.07	10.31	7.29	6.08	6.83	5.82	5.7	20.41	13.47
Calcium, Ca	3.95	2.57	2.65	3.09	8.87	4.36	6.02	5.23	6.33	3.42	9.06	11.79	7.52	8.99	7.85	7.76
Titanium, Ti	---	---	---	---	---	---	---	---	---			---	---	---	---	---
Chromium, Cr	---	---	---	---	---	---	---	---	---			---	---	---	---	---
Manganese, Mn	0.58	0.82	1.01	0.95	0.44	0.58	---	0.81	0.79	0.42	0.33	---	1.31	---	0.95	0.95
Iron, Fe	3.58	5.91	5.05	3.55	2.19	1.19	---	2.92	0.85			---	---	1.15	0.47	0.76
Nickel, Ni	---	---	0.41	0.2		---	---	4.17	0.78			---	---	---	0.56	0.65
Copper, Cu	---	---	---	---		1.96	---		2.72	1.52		---	---	---	---	0.77
Zinc, Zn	1.24	3.55	5.6	6.74	1.07	2.38	---	10.83	4.93	1.4	11.6	17.23	6.32	8.29	2.94	5.37
Cadmium, Cd	---	---	---	---	0.31	---	---	---	---	---	---	---	---	---	---	---
Barium, Ba	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Strontium, Sr	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2.79	3.71
Vanadium, V	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Compositional Analysis																
Carbon	**X**	---	---	---	**X**	**Amorphou**	**Amorphou**	**Amorphou**	---	---	---	---	---	---	---	---
Aluminum, Al	---	**X**	---	---	**X**	---	---	---	---	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Iron, Fe	---	---	**X**	---	---	---	---	---	---				---	---	**X**	**X**
$CaCO_3$	---	---	**X**	**X**	---	---	---	---	---	**X**	**X**	**X**	---	**X**	---	---
SiO_2	---	---	---	---	---	---	---	---	---	**X**	**X**		**X**	**X**	---	---
Ca_2SiO_4	---	**X**	**X**	---	---	---	---	---	---	---	---	---	---	---	---	---
$FeSO_4$	---	**X**	**X**	**X**	---	---	---	---	---	---	---	---	---	---	---	---
$CuSiO_3$	---	**X**	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Fe_2SO_4	---	**X**	**X**	---	---	---	---	---	---	---	---	---	---	---	---	---
Na_2SO_4	**X**	---	---	**X**	---	---	---	---	---	---	---	---	---	---	---	---
$CaSO_4$	---	---	---	**X**	**X**	---	---	---	---	---	**X**	---	**X**	**X**	---	---
FeS	---	---	---	**X**	**X**	---	---	---	---	---	---	---	---	---	---	---
$Na_4Ca(SO_4)$	**X**	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
$MgCO_3$	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
$Na_2Ca_3Al_2O_6$	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
$NaHSO_4$	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
$NaZnSO_4$	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
FeO(OH)	**X**	---	---	---	---	---	---	---	---	**X**	**X**	---	---	---	---	**X**
Na_2CO_3	---	---	**X**	---	---	---	---	---	**X**	---	**X**	**X**	---	**X**	---	---
NaCl	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
$FeCO_3$	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
$NaCS_3$	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
KSCN																
K_2FEO_4																
$Na_6(CO_3)_2SO_4$																
$K_3Fe(CN)_6$																
$ZnSO_4$																
											---	---	---	---	---	---
Presence of SAP	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**No**	**Yes**	**No**	**Unknown**	**Unknown**

06-0135	06-0136	06-0137	06-0138	06-0144	06-0145	06-0146	06-0160	06-0184	06-0185	06-0186	06-0187	06-0188	06-0189	06-0190	06-0191	06-0216
											Pall	Pall	Pall	PTI		
721580	721580	176820	721580	CC153F323	C9227F1740			CA01962B M870170 04/03	CA01962B M008670 09/04	CA-1962B M079610 04/05	AC-C153F-3235	AC-C153F-3235	AC-C153F-3235	05228-7581187	18350/AC-B006F-2474Y6	
Operator R	**Operator R**	**Operator R**	**Operator R**	**Operator P**	**Operator P**	**Operator P**	**Operator Q**	**Operator S**	**Operator S**	**Operator S**	**Operator Q**	**Operator Q**	**Operator Q**	**Operator Q**	**Operator Q**	**Unknown**
935	935	934	934	JA702J	JA8399			737-700	737-700	737-300		A/C 015	A/C 011	A/C 062	A/C 208	
Hand Engine	Right Hand Engine #2 Filter	Engine #1 Old Part	Engine #2 Fuel Filter	GE90-94B ESN 900388	CF6-80C2B4	Left Engine	Right Engine						Engine #2	Right Engine	Right Engine	
emoved 2/27/06		Removed 2/06	emoved 2/6/	10,285	3,418											
				3478 cycle	2,690			Filter had a strong odor with a								Debris was only soluble in water
1.02%	**0**	**0**	**0.60%**	**12.64%**	**11.72%**	**18.00%**	**11.80%**	**23.90%**	**20.30%**	**14.80%**	**19.60%**	**11.80%**	**15.00%**	**13.10%**	**21.10%**	**0**
---	---	---	---	---	---	---	---	---	---	---						---
---	---	---	---	18.86	9.61	10.77	12.08	7.71	8.82	7.46	14.45	15.16	8.34	5.96	12.61	---
1.19	1.07	1.15	1.24	1.95	4.46	2.98	2.65	2.18	2.7	2.34	2.14	1.85		1.79	1.67	---
15.82	12.68	13.33	13.78	4.17	15.33	15.92	11.66	11.79	10.66	8.51	7.36	7.42	5.04	6.8	11.06	---
26.51	25.32	22.18	27.39	5.22	17.01	14.97	27.66	47.67	38.6	40.44	13.13	3.73	7.01	13.37	13.76	---
---	---	---	---	1.83	---	1.24	---		---	---	1.18		1.68		0.93	---
17.6	19.21	20.84	15.16	38.92	27.47	25.58	16.35	11.12	16.92	15.43	37.83	44.92	46.12	41.47	28.36	---
0.72	0.57	0.37	0.51	1.38	1.84	1.04	0.5		---	---	1.4	2.58	1.84	2.24	1.32	---
3.06	2.78	2.57	3.44	1.79	2.1	1.63	3.4	3.17	2.78	4.99	2.16	1.44	1.9	1.55	3.79	---
5.25	5.75	5.05	6.3	2.92	4.69	3.76	6.1	5.56	4.65	5.78	4.37	2.74	3.06	5.27	4.51	---
2.51	2.11	2.26	2.62	0.54	0.84	1.02	1.95	0.54	0.69	0.95	0.24		0.76	0.77	2.44	---
3.58	3.44	3.85	4.48	---	1.33	1.34	1.68	0.74	0.98	0.65	0.69	1.13	0.7	0.73	1.12	---
0.52	0.47	---	0.55	---	---	---	---		---	---					0.27	---
7.87	8.08	8.67	9.41	21.42	14.26	17.98	7.38	3.61	5.32	3.34	12.06	15.94	18.38	12.49	7.16	---
0.48	0.8	0.86	1.05	---	---	---	---		0.34							---
6.53	9.49	11.67	4.41	1	---	---	0.88		0.52	1.56	1.04	3.09	3.63	1.74	2.72	---
3.43	3.12	2.88	3.42	---	1.05	1.77	5.37	1.78	2.43	2.28	0.9		1.54	1.07	3.89	---
2.68	2.48	2.15	2.81	---	---	---	1.84	1.37	2.64	3.54				4.74	2.69	---
2.25	2.64	2.15	3.43	---	---	---	---	2.76	1.96	2.72	1.04				1.72	---
---	---	---	---	---	---	---	---	---	---	---						---
---	---	---	---	---	---	---	---	---	---	---						---
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---	---	---	---	---	---	---	---		---	---						---
19	17.07	19.69	18.6	24.82	21.08	24.42	21.38	13.79	4.5	6.13	19.71	16.58	20.76	20.37	22.3	---

0.96	1.18	0.65	0.96	2.16	4.25	3.03	2.29	1.25	0.85	1.44	1.97	2.22	2.64	1.74	4.03	---
---	---	0.17	0.25	2.12	1.55	0.58	2.34	3.4	4.36	0.78	1.38	3.55	2.77	7.25	0.72	0.74
---	---	1.05	0.62	---	---	1.57	---	0.36	0.81	---	0.45	0.57	0.37	0.45	0.41	1.01
---	---			---	---	0.84	---		---	---						0.31
38.1	47.77	32.96	22.55	49.42	43.93	24.64	42.59	51.1	56.05	34.99	50.27	51.76	53.73	49.46	40.99	1.76
17.62	11.79	24.23	34.09	3.31	7.64	23.42	4.85	5.93	8.28	24.86	9.93	4.94	2.6	6.41	12.36	1.51
10.35	8.98	8.52	14.49	3.17	2.29	5.58	6.39	4.6	3.49	7.68	4.45	3.93	3.53	0.85	14.2	75.44
5.12	6.01	5.64	3.66	3.17	4.86	11.97	4.12	1.99	1.11	---	2.57	3.46	4.87	2.16	1.97	2.03
---	---	---	---	---	---	0.3	---		---	---						
0.44	---	0.34	---	---	---	---	---		0.41	---				0.4	0.14	0.28
0.58	0.71	0.3	0.47	1.05	0.46	---	---		---	---		1.35	1.03	1.1	0.26	---
0.26	0.24	0.35	---	5.1	2.4	0.69	2.16	3.54	3.69	0.62	2.08	5.43	1.94	5.43	0.7	2.36
0.42	0.5	0.36	---	0.15	0.29	---	0.57	1.39	2	2.23		0.67	0.55		0.34	1.09
0.78	0.37	0.4	---	0.97	0.24	0.77	---		---	---						---
1.65	2.69	1.2	1.46	4.56	2.61	2.18	8.99	10.4	11.1	17.35	7.19	5.54	5.21	2.09	1.58	12.15
1.53	---	---	---	---	---	---	4.29	2.25	3.35	3.92				2.3		---
---	---	2.27	0.87	---	---	---	---		---	---						---
3.24	2.7	1.87	1.98	---	---	---	---		---	---						---
---	---	---	---	---	---	---	---		---	---						---

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X	X	X	X	---	X	---	---	X	X	X		X	X	X	X	
X	X	X	X	---	X	---	---	X	X	X		X	X	X	X	
---	---	---	X	---	---	---	---									
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X	X	---	---	---	---	---	---									
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---	---	---	---	X	---	---	---						X			
---	---	---	---	X	---	---	---									
										others						
												X				
---	---	---	---	---	---	---	---									
Yes	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**No**	**Yes**

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FUELS AND LUBRICANTS RESEARCH DIVISION
U.S. ARMY TARDEC FUELS AND LUBRICANTS RESEARCH FACILITY (SWRI)
WWW.SWRI.ORG

FAX No. 210/522-3270
ISO 9001 Certified
ISO 14001 Certified

January 10, 2006

Subject: Southwest Research Institute® (SwRI®) Letter Report 08-11186, entitled, "Analysis of Used Fuel Filters from an Operator Q Aircraft"

Dear Mr. Q:

The subject aviation fuel filters were furnished to SwRI for analysis of the contaminants plugging the filter. The following analyses were performed:

- Visual inspection
- XRF and SEM
- XRD
- FTIR
- Optical documentation
- FTIR and XRF on water wash
- NMR

The filters furnished to date include:

1. APM P/N 18350/AC-C153F-3235
2. APM P/N 18350/AC-C153F-3235, GE90-75B/76B1-8513 Turbofan engines
3. APM P/N 18350/AC-C153F-3235
4. Pall APM P/N 18350/AC-C153F-3235, Lot # 696620, Work card provided
5. FAA PMA replacement for AC 9227F1740, S/N 55872, 05228-7581187

Visual Inspection

A visual inspection was performed to determine if there was any apparent structural damage to the filter or obvious indication of microbial activity. Neither structural damage nor microbial activity was found with these fuel filters.

Determination of Fuel Degradation Products, Weight Percent

Each fuel filter was submerged in a beaker of iso-octane and sonicated for approximately 15 minutes. The solvent and the contaminant removed from the filters was filtered through two 0.45-μm nylon membrane of known weight. The amount of debris was measured and recorded. The nylon membranes were then washed with a tri-solvent containing toluene-acetone-methanol (TAM) to remove any TAM soluble materials that include fuel degradation products. The quantity of TAM soluble material for each filter is shown in Table 1. This indicates the thermal or storage stability of the aviation fuel is not the major cause of filter plugging.

Table 1. Degradation Products

Sample	Fuel Degradation Products, wt%
1	8.9
2	10.5
3	11.7
4	11.4
5	10.9

XRF and Scanning Electron Microscopy (SEM)

Elemental Analysis by XRF

The elemental analysis of the contaminants as determined by XRF is provided in Table 2. The XRF plots are provided in Appendix A.

Table 2. Elemental Analysis of Contaminants by XRF

Element	#1	#2	#3	#4	#5
Na	20.40	----	5.54	9.71	9.92
Mg	3.85	2.58	0.88	1.94	2.48
Al	2.32	5.07	5.23	4.94	7.36
Si	1.94	4.55	7.48	4.39	8.40
P	0.34	1.83	1.01	2.12	1.74
S	40.30	37.79	34.88	49.92	45.77
Cl	1.05	2.06	1.15	1.84	1.30
K	1.19	1.44	1.36	1.25	0.71
Ca	3.00	4.05	5.82	3.36	4.35
Ti	0.56	0.89	0.92	0.32	0.60
Cr	0.62	1.03	1.45	0.42	0.36
Mn	0.58	0.52	----	0.24	---
Fe	19.52	30.25	29.45	16.93	14.68
Cu	2.80	6.09	1.79	1.34	1.17
Zn	2.37	3.54	2.14	1.27	0.51
Ni	0.20	----	0.90	----	---
Cd	---	---	---	---	0.64

The XRF analysis for the water-soluble contaminant is provided in Table 3.

Table 3. Elemental Analysis on Water-Soluble Contaminants

Element	#1	#2	#3	#4	#5
Na	29.87	25.31	24.57	22.87	27.46
Mg	2.56	2.54	2.51	2.68	1.46
Al	3.64	4.86	3.41	3.45	2.81
Si	0.13	0.35	0.30	0.23	---
S	49.65	48.10	47.50	49.80	51.08
Cl	2.94	4.35	4.57	3.93	2.41
K	1.86	1.64	2.43	2.50	1.91
Ca	3.95	2.57	2.65	3.09	8.87
Mn	0.58	0.82	1.01	0.95	0.44
Fe	3.58	5.91	5.05	3.55	2.19
Ni	---	----	0.41	0.20	---
Zn	1.24	3.55	5.60	6.74	1.07
Cd	---	---	---	---	0.31

<u>Scanning Electron Microscopy (SEM)</u>
SEM photos were taken of the debris to determine the size and shapes of the contaminants. Figures 1-5 illustrate the types of contaminants removed from the fuel filters. A complete set of SEM photos is provided in Appendix B.

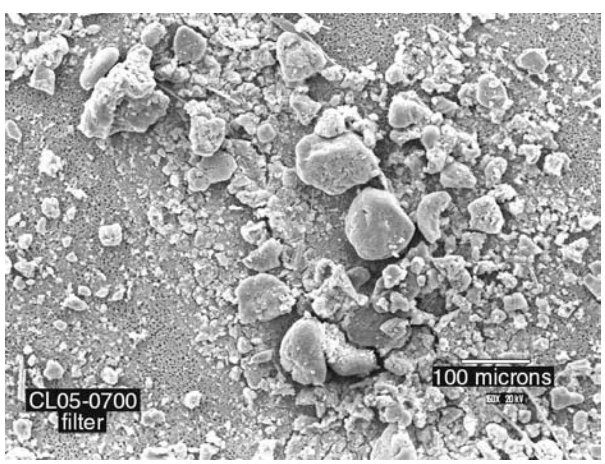

Figure 1. SEM of Contaminants from Fuel Filter #5

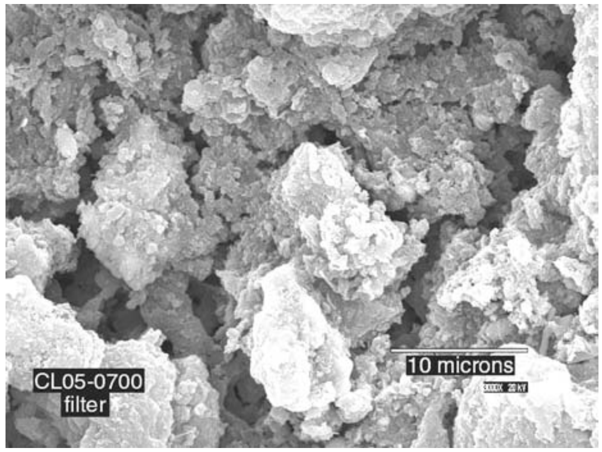

Figure 2. SEM of Contaminants from Fuel Filter #5

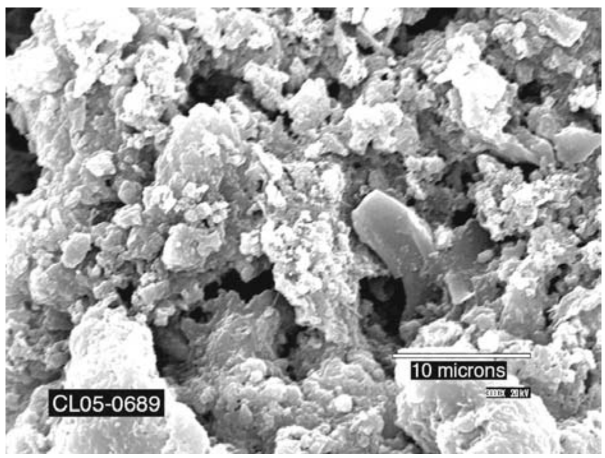

Figure 3. SEM of Contaminants from Fuel Filter #3

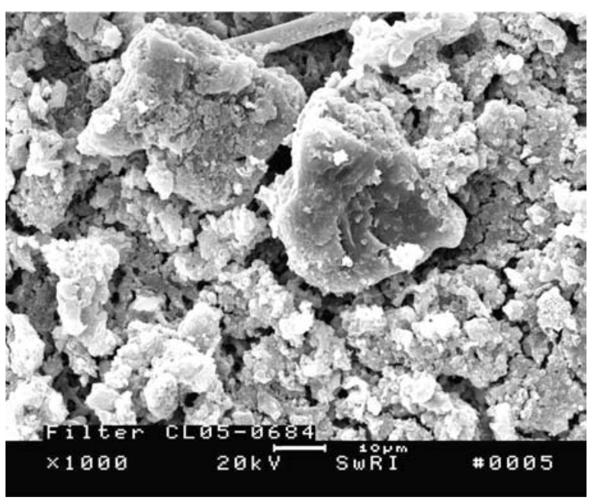

Figure 4. SEM of Contaminants from Fuel Filter #2

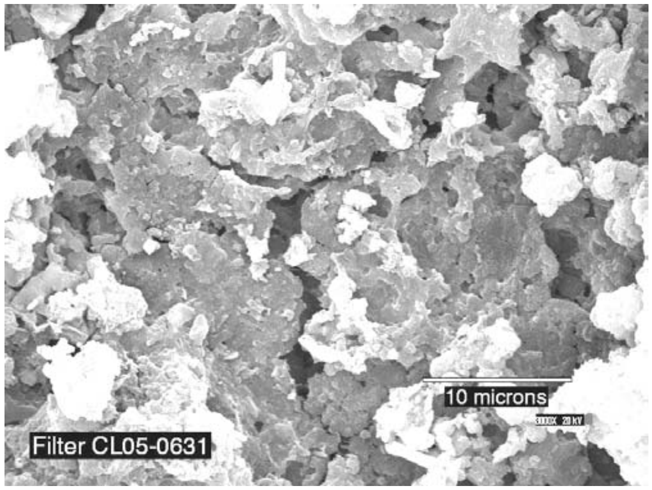

Figure 5. SEM of Contaminants from Fuel Filter #1

These pictures illustrate the larger captured particles (approximately 20-μm) with many smaller (<5-μm) particles adhering to the larger particles. Figure 6 shows a closer view of this adhesion.

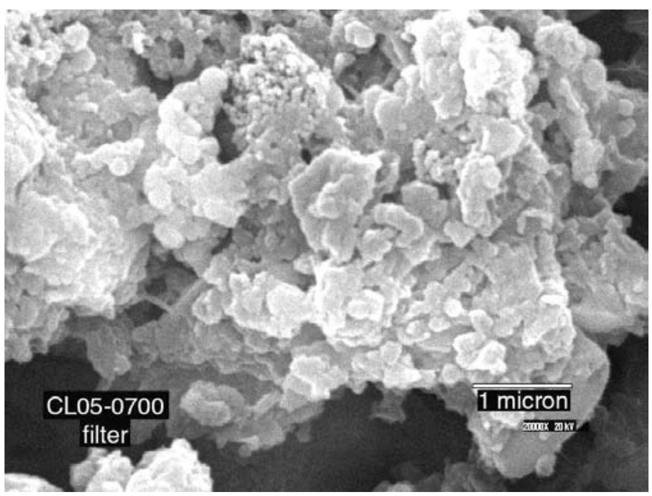

Figure 6. SEM of Contaminant from Fuel Filter #4

Diffractive X-Ray (XRD)

XRD analysis was performed on the above debris to help determine some of the oxides and mineral compositions. Figure 7 presents a typical XRD scan with the suggested minerals. Please note that the listed minerals are the best fit from the software library and may be other minerals. For example, Rutile, TiO_2 is typically paint. A list of the various compositions is provided in Table 4.

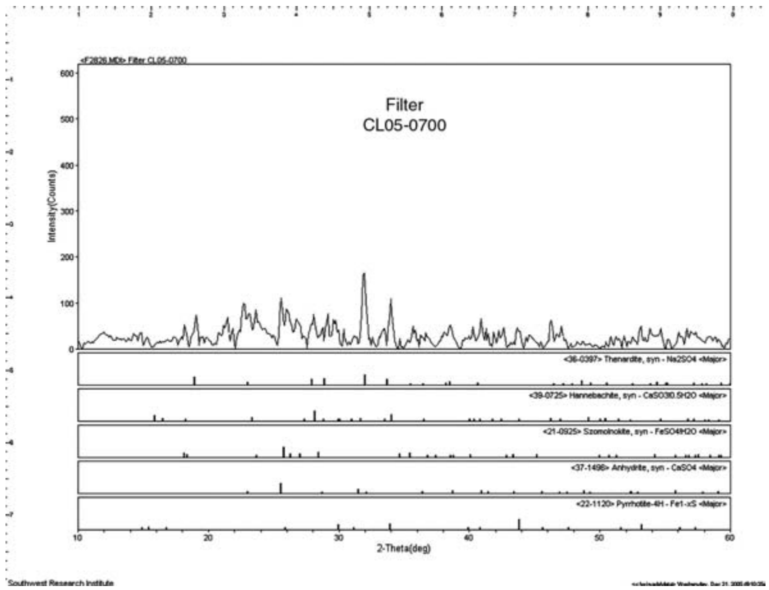

Figure 7. XRD Analysis of Contaminant from Fuel Filter #4

Table 4. XRD Results

Compound	Fuel Filter #1	Fuel Filter #2	Fuel Filter #3	Fuel Filter #4	Fuel Filter #5
Na_2SO_4	Major			Major	
$CaSO_3 \bullet 5H_2O$				Major	
$FeSO_4 \bullet H_2O$			Major	Major	
$CaSO_4$ (Gypsum)				Major	Major
FeS				Major	Major
Al		Major	Major		Major
Ca_2SiO_4		Major	Major		
$CaCO_3$			Major		
$Fe_2Al_4Si_5O_{18}$			Major		
$Na_2CO_3 \bullet H_2O$			Major		
Fe			Major		
$Fe_2(SO_4)_3 \bullet 11 H_2O$		Major			
$CuSiO_3 \bullet H_2O$		Major			
$Na_2Ca(SO_4)_2 \bullet 4H_2O$	Major				
FeO(OH)	Major				
C (graphite)	Major				Major

Fourier Transform Infrared (FTIR)
Figures 8-14 illustrate the FTIR spectra on the contaminants from the media. Since FTIR spectra only provides a "footprint", these spectrum could represent fuel or other hydrocarbons instead of polyacrylate. In addition to the FTIR analysis, we included XRF analysis to determine if either potassium or sodium were present in high concentrations. If both the FTIR spectrum and XRF had positive results, then we have a higher confidence level that water absorbing polyacrylate is present.

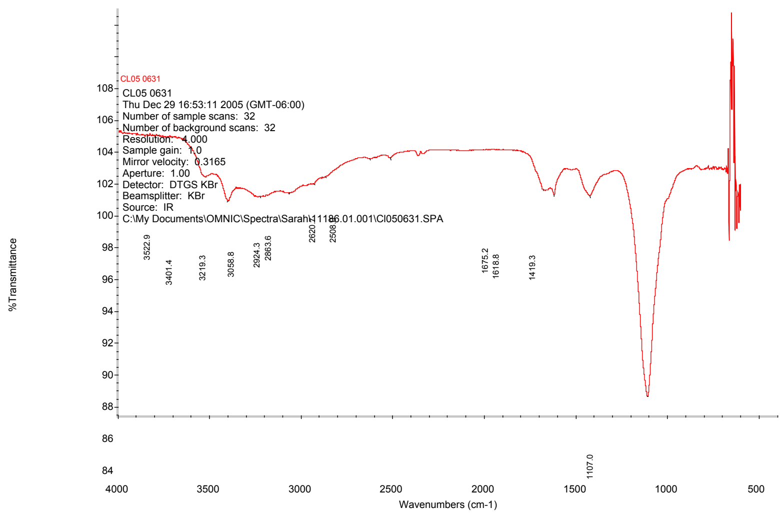

Figure 8. FTIR Spectra for Contaminant from Fuel Filter #1

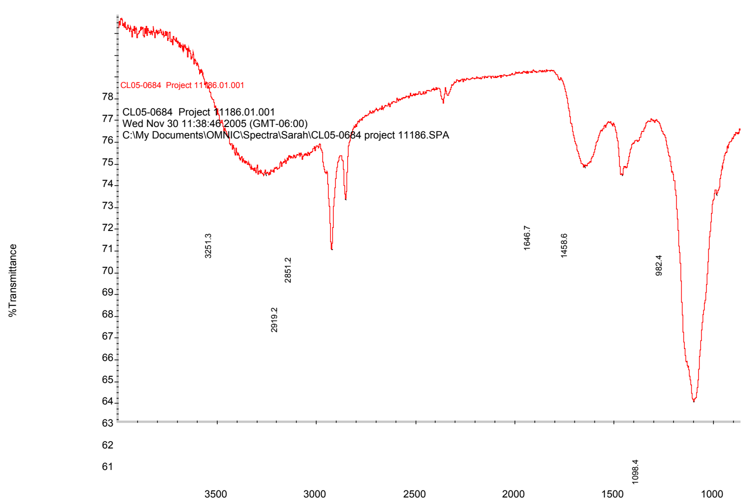

Figure 9. FTIR Spectra for Contaminant from Fuel Filter #2

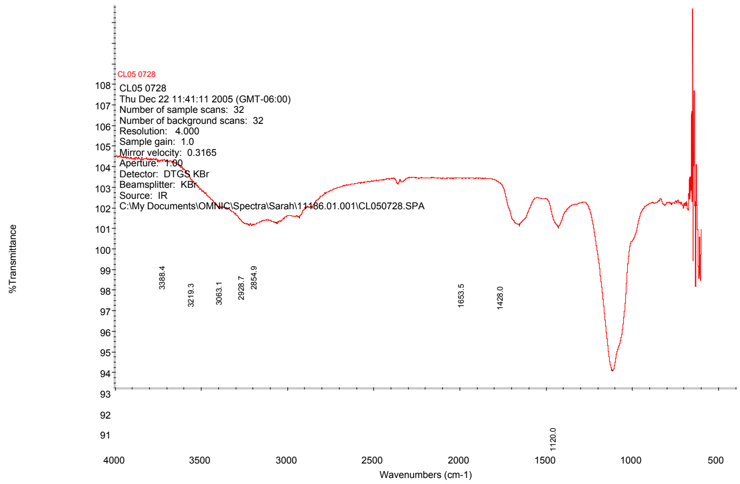

Figure 10. FTIR Spectra for Water-Soluble Contaminant from Fuel Filter #2

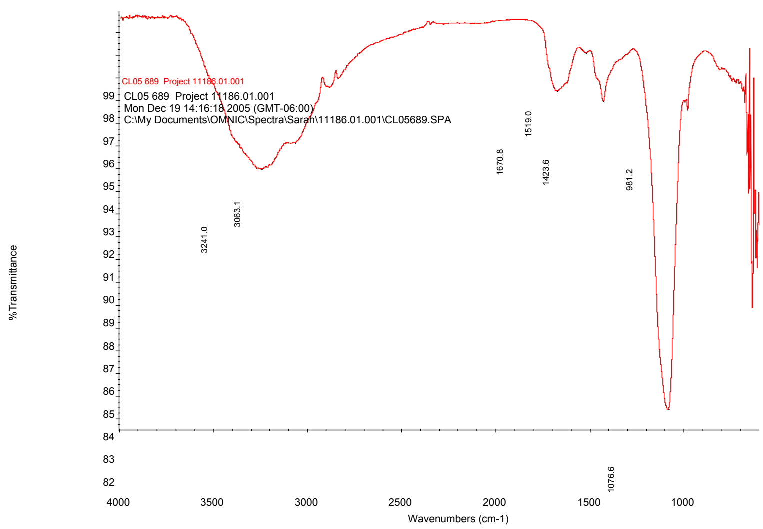

Figure 11. FTIR Spectra for Contaminant from Fuel Filter #3

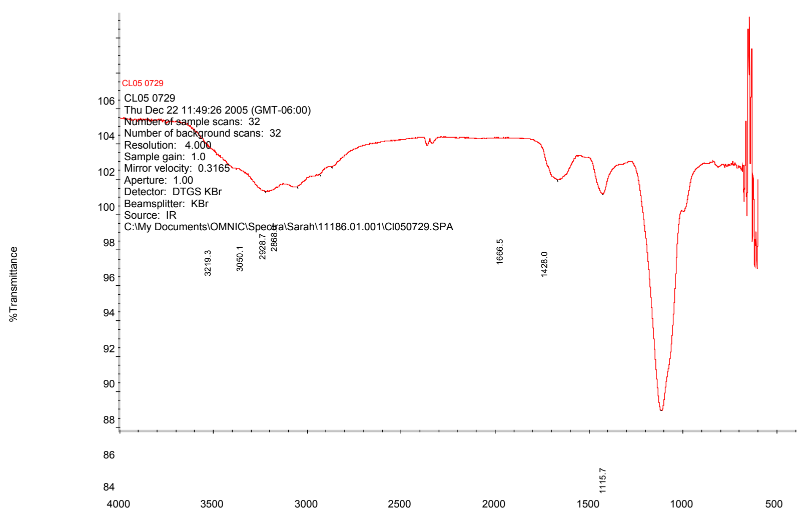

Figure 12. FTIR Spectra for Water-Soluble Contaminant from Fuel Filter #3

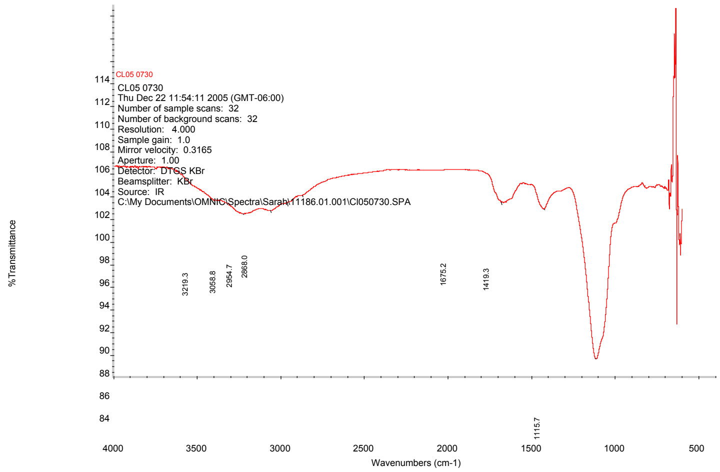

Figure 13. FTIR Spectra for Water-Soluble Contaminant from Fuel Filter #4

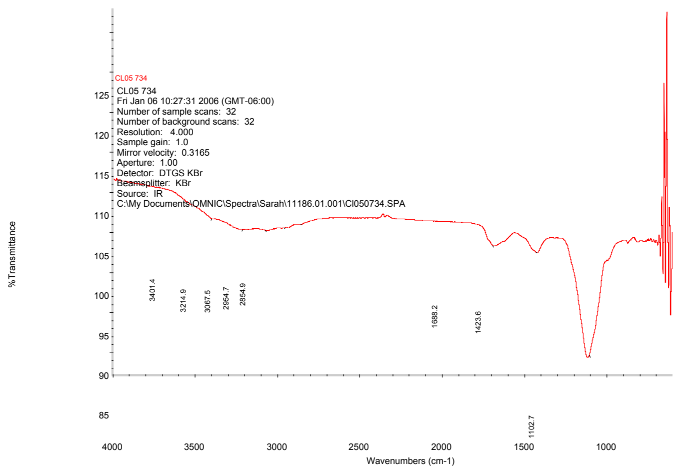

Figure 14. FTIR Spectra for Water-Soluble Contaminant from Fuel Filter #5

The water-soluble conte … ure 15.

Figure 15. Water Soluble Debris from Aircraft Fuel Filters

Carboxylate anions have two characteristic infrared stretching vibrations. An antisymmetric stretching vibration generally occurs in the 1600 ± 60 cm^{-1} range while the symmetric stretching vibration occurs in the 1440 ± 40 cm^{-1} range. These result from a shift in frequency of the carbonyl (C=O) and C-O absorptions, respectively. The frequency shift occurs upon conversion of a carboxylic acid to a carboxylate salt (the material found in water absorbent fuel filters and baby diapers). The large absorption near 3300 cm^{-1} is likely the result of absorbed water.

NMR Results

NMR was performed on the water-soluble contaminant from fuel filters #1 and #2, Figures 16 and 17, respectively. These results were compare to a standard made from Aldrich poly (acrylic acid) 65% wt solution, Figure 18.

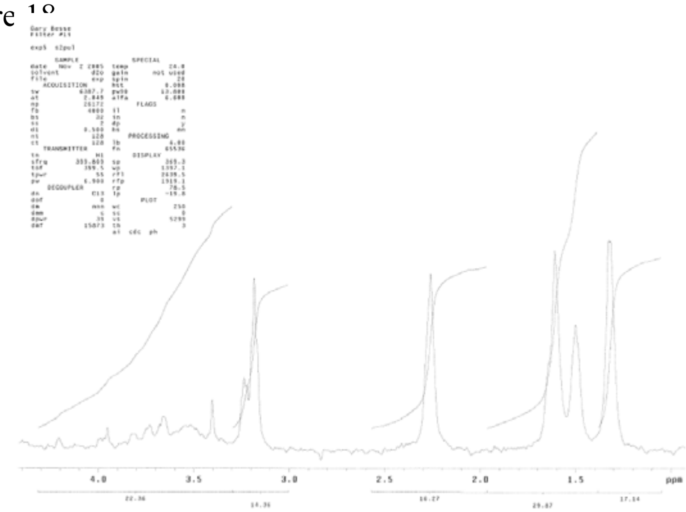

Figure 16. NMR on Water-Soluble Contaminant from Fuel Filter #1

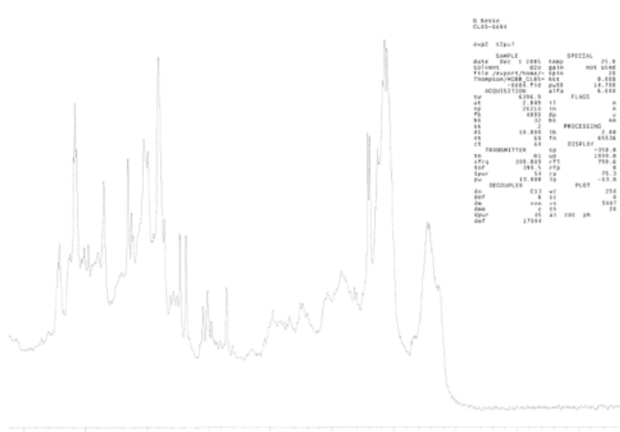

Figure 17. NMR on Water-Soluble Contaminant from Fuel Filter #2

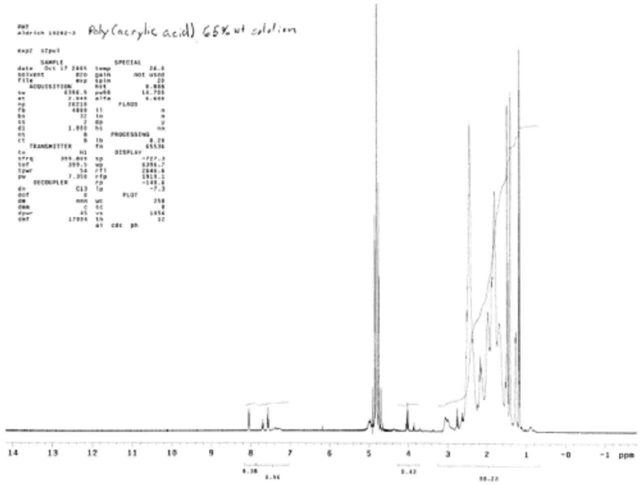

Figure 18. NMR on Aldrich poly(acrylic acid) 65% wt solution

The broad base of the peaks indicates this material is polymeric in composition. Comparing the baseline poly acrylic acid to the spectra from the water-soluble contaminants from fuel filters #1 and #2 confirms the contaminant is similar to the poly acrylic acid.

Conclusions

The main constituents plugging the subject fuel filters appear to be sands and clays. Based on NMR, XRF, and FTIR data, there are water-soluble contaminants present in all supplied fuel filters. Please note that we are not able to verify what fuel was used for each application.

If you have any questions, please contact me at 210 522 6941 or email me at gbessee@swri.org.

Approved:

Edwin C. Owens
Director
Fuels and Lubricants Technology

Sincerely:

Gary B. Bessee
Manager
Filtration, Logistics & Fluids Research

GBB/lmd
Enclosure(s)
cc: SwRI: Dolores Hobart (08). R. V. Lemes (08)

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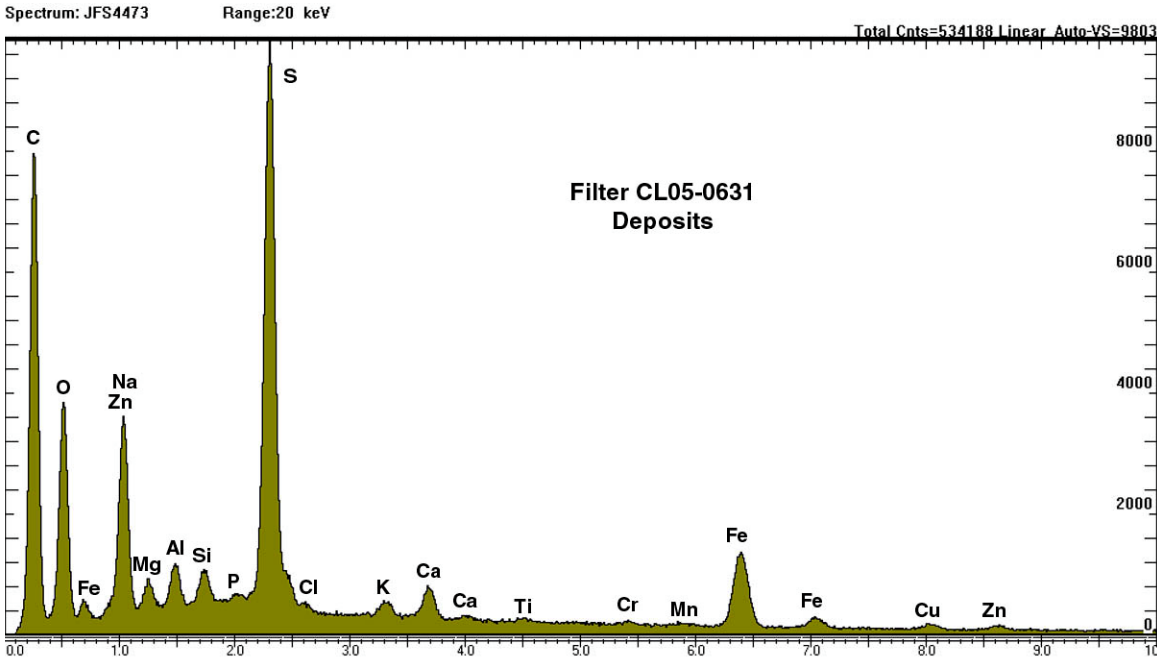
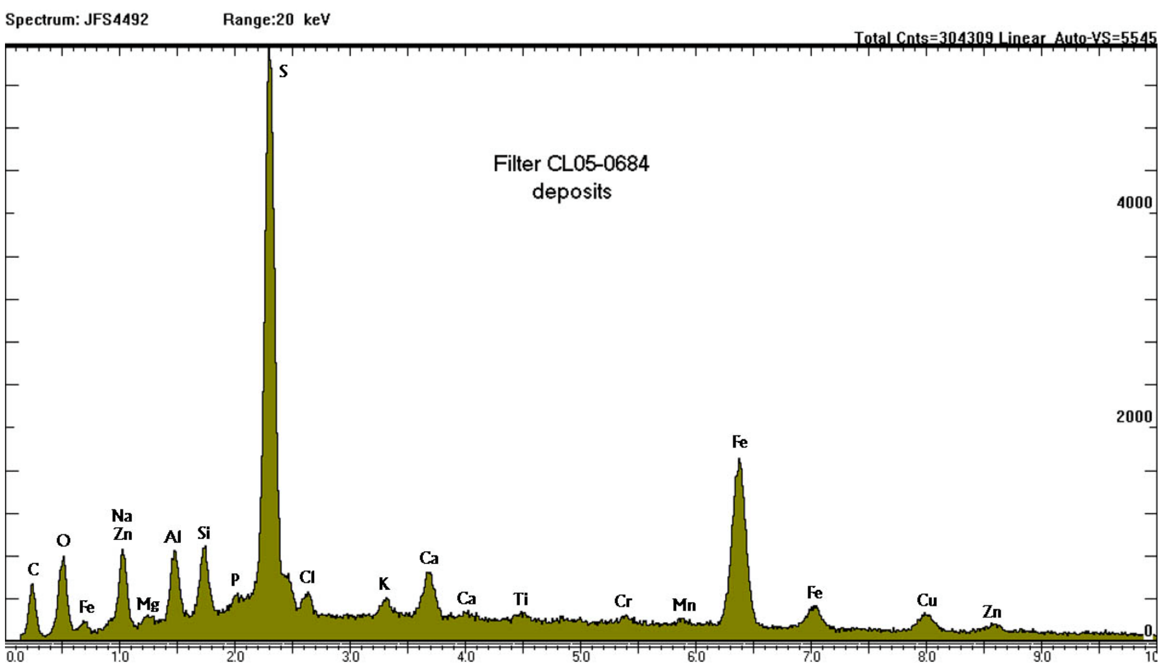
Appendix A

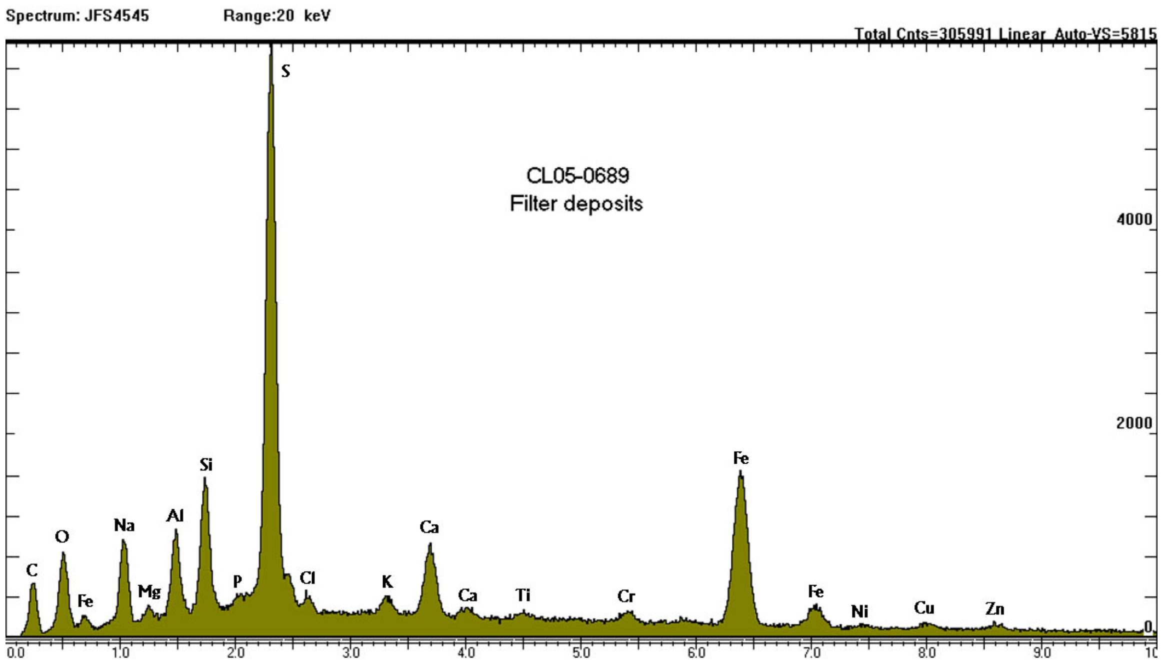
XRF of Fuel Filter Contaminant



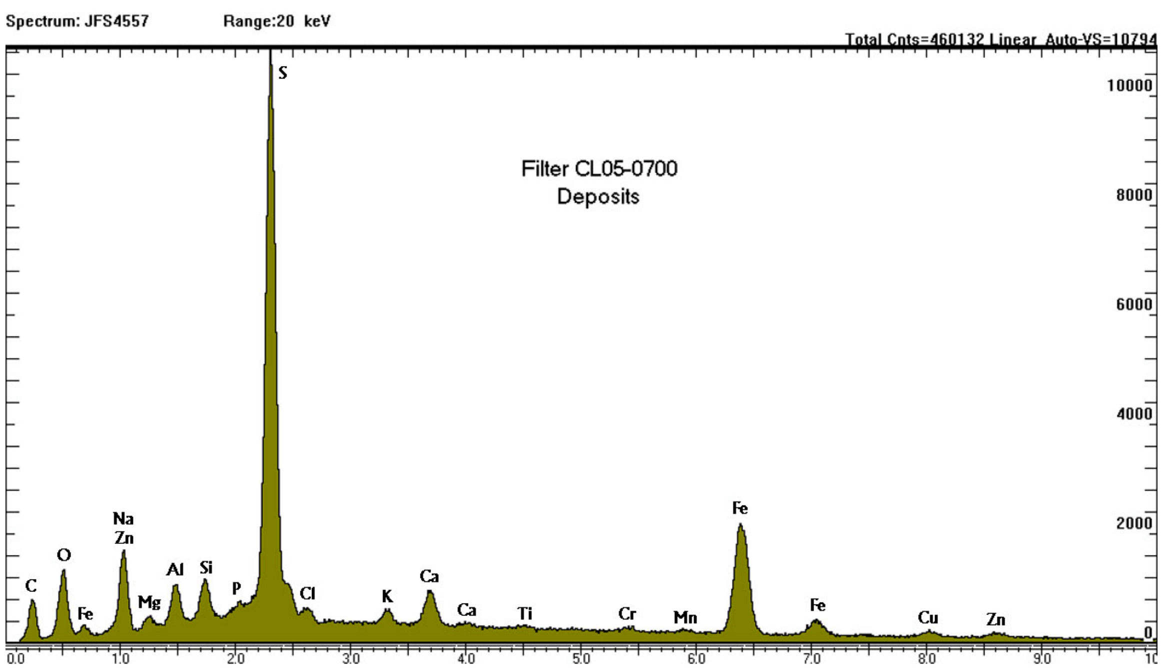
A1. XRF of Fuel Filter #1 Contaminant



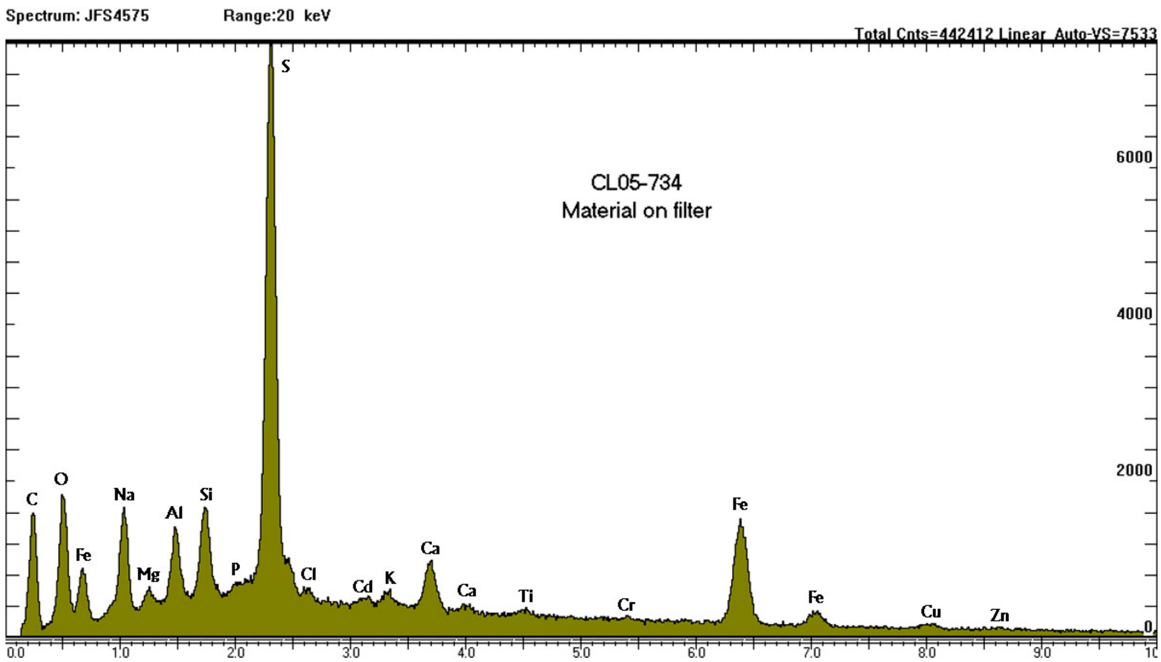
A2. XRF of Fuel Filter #2 Contaminant



A3. XRF of Fuel Filter #3 Contaminant



A4. XRF of Fuel Filter #4 Contaminant

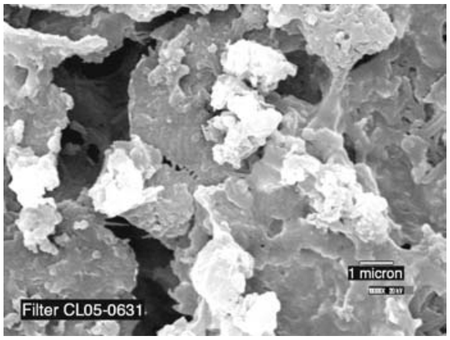


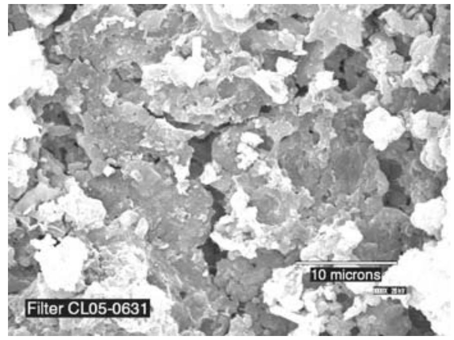
A5. XRF of Fuel Filter #5 Contaminant

Appendix B

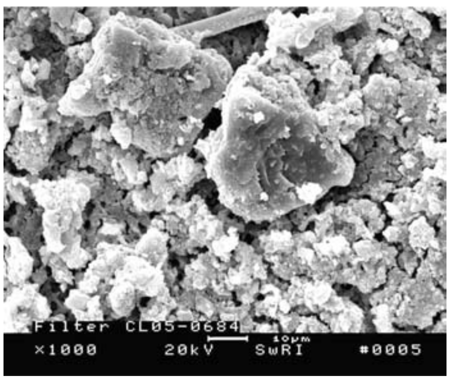
SEM Photographs

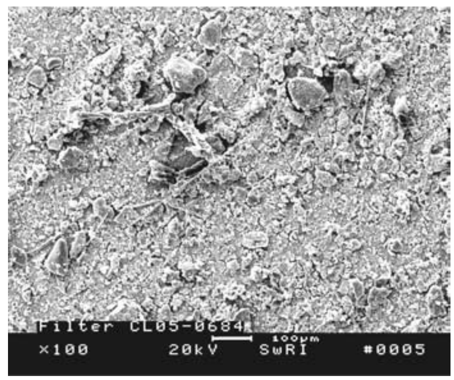
Fuel Filter #1



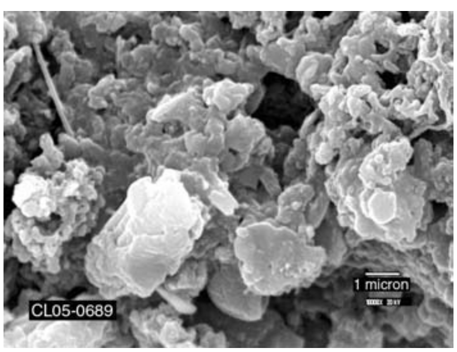


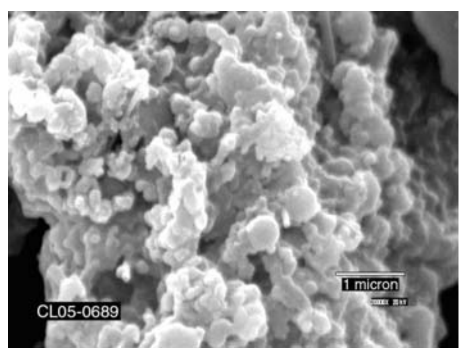
Fuel Filter #2

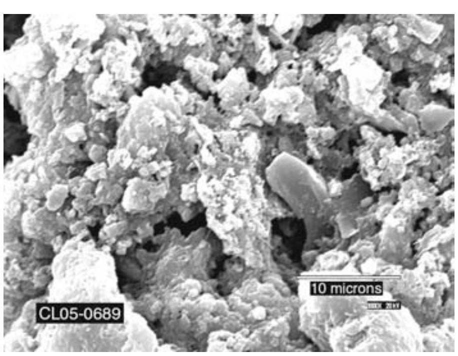


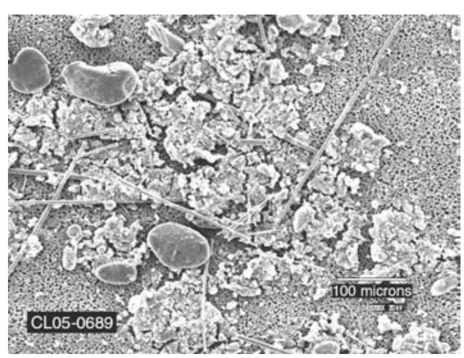


Fuel Filter #3

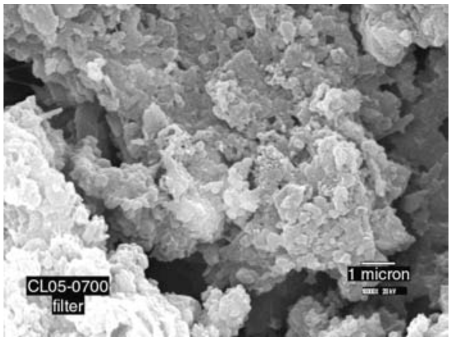


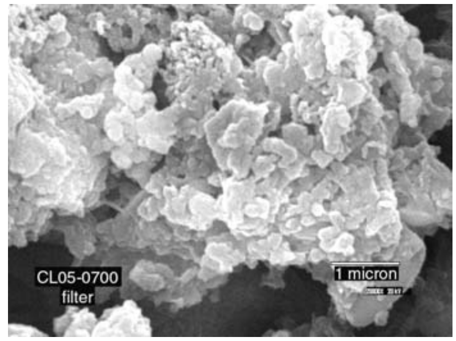


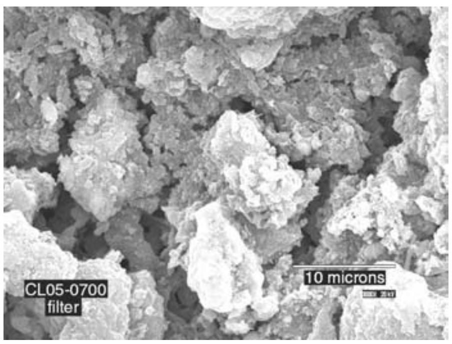


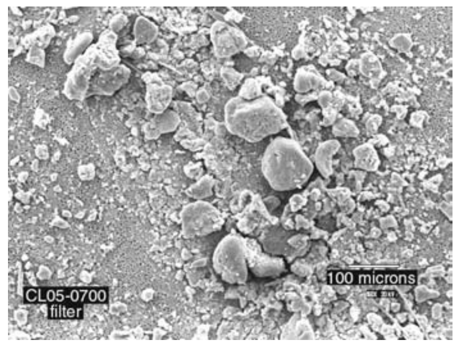


Fuel Filter #4









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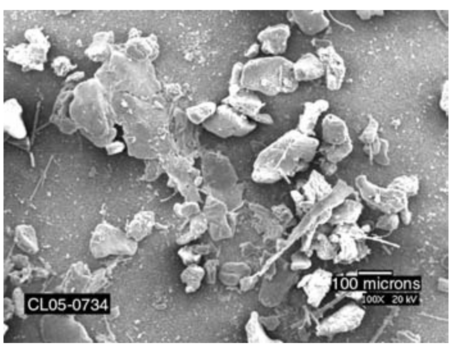

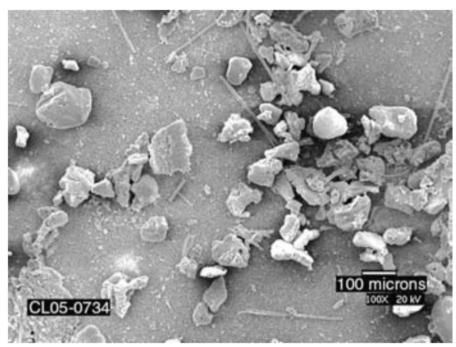

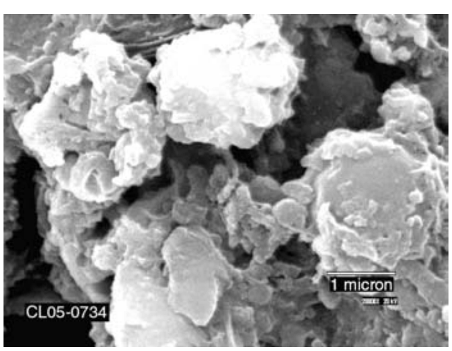

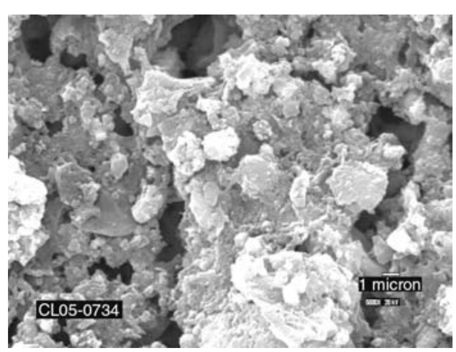

ExxonMobil Research
and Engineering Company
600 Billingsport Road
Paulsboro, NJ 08066-0480
856-224-2603 Telephone
856-224-3614 Fax
krystal.b.russell@exxonmobil.com Email

Krystal B. Russell
Fuel Products & Operations Division

ExxonMobil Research and Engineering

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IATA Task Force
600 Jefferson #HQJSM
Houston, TX 77002

USED AIRCRAFT FILTER ANALYSIS

The Aviation Industry has expressed concern over shortened aircraft filter life. They are interested in determining 1) the composition of the material plugging the filter and 2) if SAP (Super Absorbent Polymer) has migrated from the filter monitor and contributed to the debris causing filter plugging. This memorandum summarizes results of work recently undertaken to assess the materials present on the filter and what role, if any, SAP has in the plugging (media migration). The Operator Q provided EMRE with 2 plugged filters taken from aircraft which had been fueled through monitors. In addition, SwRI and EMRE collaborated to determine the presence/absence of SAP in field samples, in-house testing, and on an aircraft filter which showed evidence of polymer. Laboratory tests were conducted to 1) assess the composition of materials plugging the filters and 2) demonstrate the presence/absence of SAP.

CONCLUSIONS

- Test results indicate that the material plugging the Operator Q filters is mainly composed of sulfur, sodium, and silicon. Sulfur and silcon are elements which are not present in SAP. Currently it is unknown where the bulk of these materials come from. As indicated below, there is evidence of SAP on aircraft filters but these materials occur in low concentration and as discrete pieces. Therefore the bulk of the filter constriction is from unidentified materials, not SAP. Based on these studies, the SAP appears to behave as a small amount of particulate dirt contamination and does not significantly contribute to filter plugging.
- Debris was initially extracted through sonication of each filter in a variety of solvents. The extracted debris was filtered, dried, and submitted for XRF/IR analysis. The debris was also soaked in a $CuSO_4$/water solution. There was no indication of SAP in either Operator Q filter. There was indication of a few blue specks in the SwRI aircraft filter debris.

- Deionized water was also used to extract any water soluble materials in the filters. The solutions were filtered and the resulting fluid (free of large dirt particles) was dried. A residue resulted upon drying of the filtrate. The residue was analyzed with XRF/IR and was also soaked in a $CuSO_4$ solution. One Operator Q filter had no visible sign of SAP upon $CuSO_4$ treatment; however, a small blue speck was discovered in the debris of the second filter. The SwRI residue also contained a small amount of blue specks upon $CuSO_4$ treatment.
- The FTIR spectra of both Operator Q water residue samples showed a peak at 1634 cm^{-1}. This carbonyl peak can be an indication of SAP. The water extract was methylated and the peak shifted to a position of 1734 cm^{-1}. This indicates an acid was present and provides evidence of the presence of SAP.
- There were a small number of blue specks which were visible upon $CuSO_4$ treatment of the SwRI residues. SwRI had found more particles of SAP in their analysis of the same filter. It is believed that the variance in the results is due to the non-homogeneous distribution of SAP specks in the different samples tested. The blue specks which were discovered through EMRE analysis were separated from the debris and analyzed by microscopic IR. The samples IR contained peaks that are also found with pure polymers such as polyacrylate and carboxymethyl cellulose. This indicates the blue material present on the filter is SAP and may be a mixture of polymers.

USED AIRCRAFT FILTER ANALYSIS

Operator Q Plugged Aircraft Filters

- The first Operator Q aircraft filter was cut by machinists at the top, bottom, and center, creating two equal pieces. In the initial screening, a section of approximately 40 pleats X 3" was analyzed. The filter was assessed qualitatively by use of an optical microscope. It looked to be plugged primarily by dirt, however small particles of different sizes, color, and nature were also present on the screen filtration layer. It was noted that there were blue specks of glue located throughout the debris. This glue comes from a wrap used to hold the filter tightly together. It is unknown whether the glue had come off in-flight or during machining/cutting. After the initial observations, the filter was sonicated for 60 minutes in a filtered isooctane solution. The remaining solvent/debris mixture was kept for further analysis.
- The solvent/debris mixture was filtered through a 0.8 µm nitrocellulose Millipore filter. Two Millipores were required to filter the entire solution. The debris captured on the filters was weighed and observed under the optical microscope. The total debris captured was 0.75 grams per 40 pleats X 3" section. The first filter had a thin layer of what appeared to be dirt particles. The second filter had captured a cake of debris. The filtered debris was then observed qualitatively under an optical microscope. The caked debris appeared to be made up of: large dirt particles, paint chips, small rock-like particles, metal from the filter screen, and an unknown shiny fiber-like substance which was dispersed throughout. Figures 1 and 2 are pictures taken of the extracted debris.

Figure 1: Debris from Cut Filter

Figure 2: Debris from Cut Filter

- The aircraft filter was also sonicated in deionized water for 60 minutes. The solution was filtered through a 0.8µm Millipore nitrocellulose filter and a cake of debris was captured.
- The debris was then analyzed using XRF and FTIR. XRF data is shown in Table 1. The XRF analysis shows that the majority of traceable materials are sulfur, sodium, metals, and silicon. The metal content may be due to filter debris which came off during the cutting of the filter. The FTIR spectrums of the filtered debris can be found in Figures 3, 4, and 5.

Table 1: Elemental Data of Debris from Operator Q Filter 1 [1]

XRF Uniquant, wt%	Solid Removed With Isooctane (Filter 1)	Loose Solid Removed With Isooctane (Filter 2)	Solid Removed With H_2O Extraction
S	4.03	2.60	3.85
Na	2.55	1.35	2.72
Fe	1.53	2.24	1.20
Si	0.56	1.28	1.53
Al	0.94	0.64	0.79
Mg	0.19	0.67	0.74
Ca	0.30	0.49	0.38
Cl	0.20	0.18	0.26
K	0.19	0.10	0.13
Zn	0.15	0.34	0.11
Cu	0.19	0.34	0.18
P	0.07	0.05	0.07
Ti	0.04	0.22	0.09
Cr	0.06	0.17	0.05
Mn	0.04	0.05	0.02
Ni	0.02	0.05	0.02
V	0.01	0.02	0.007
D5291, wt%			
C	--	--	31.38
H	--	--	4.92
N	--	--	3.31

[1] XRF is a semi -quantitative assessment of metals in the debris, it is not all-inclusive. The remainder of the material is hydrocarbons, nitrogen, and oxygen.

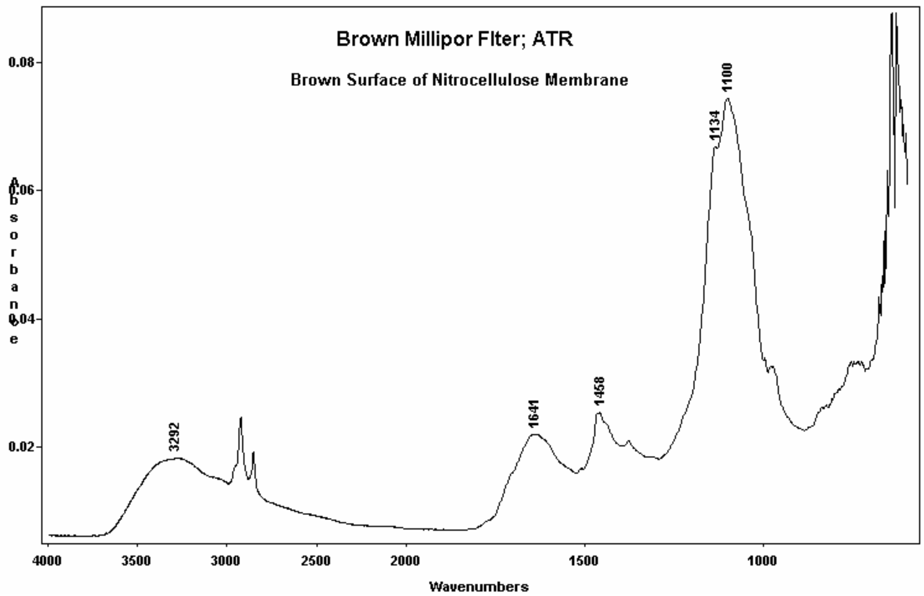


Figure 3: FTIR for Operator Q l Filter 1 - Solid Removed after Isooctane Sonication

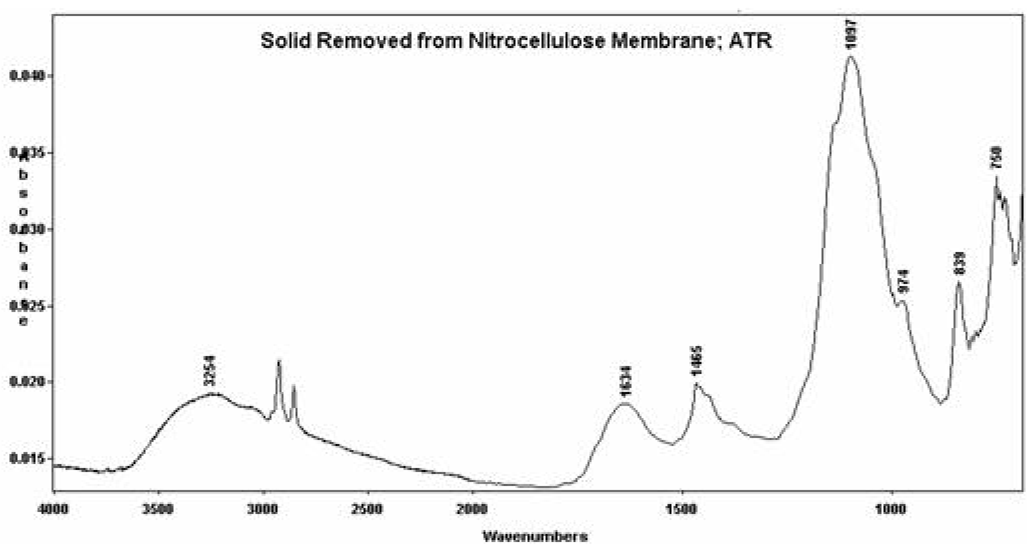


Figure 4: FTIR from Operator Q Filter 1 – Loose Solid Removed after Isooctane Sonication

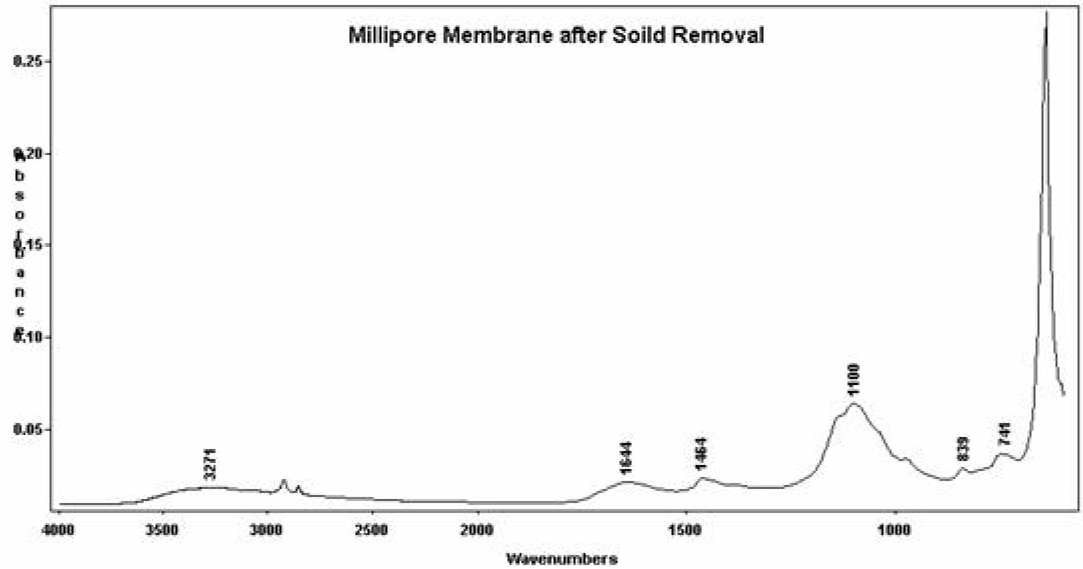


Figure 5: FTIR for Operator Q Filter 1 – Solid Removed after Water Sonication

- The FTIR shows a very large peak in all instances at 1100cm^{-1}. This peak could be representative of sulfates/sulfoxides. It also has a shoulder at ~1150cm^{-1} that could be from silicon. There are broad peaks at 3200 and 1635 cm^{-1} which could be amide functionality. The peak at 1635 cm^{-1} could also be indicative of SAP, however further analysis was needed to confirm SAP presence.
- A portion of each debris sample was then subjected to a $CuSO_4$/water treatment. A $CuSO_4$/water soak has been identified as a method to determine the presence/absence of SAP. The SAP takes on a bright blue color when placed in the solution. In this test case, upon submersion, there were no observed blue SAP particles in solution. The mixtures were then filtered again through a 0.8 μm nitrocellulose Millipore filter and the filter was observed under an optical microscope. Again, there were no observed blue SAP particles.
- Due to the inability to distinguish between debris that was on the filter before and after cutting, a similar analysis was done on a whole filter.
- Initially, the intact Operator Q filter was sonicated in heptane for 60 minutes. The mixture was then filtered through an 8 μm nitrocellulose membrane. A brown solid film remained on the membrane. Figure 6 shows the FTIR spectrum for this material. Table 2 shows the XRF data. The XRF and FTIR of this material look similar to the first filter/debris analyzed.

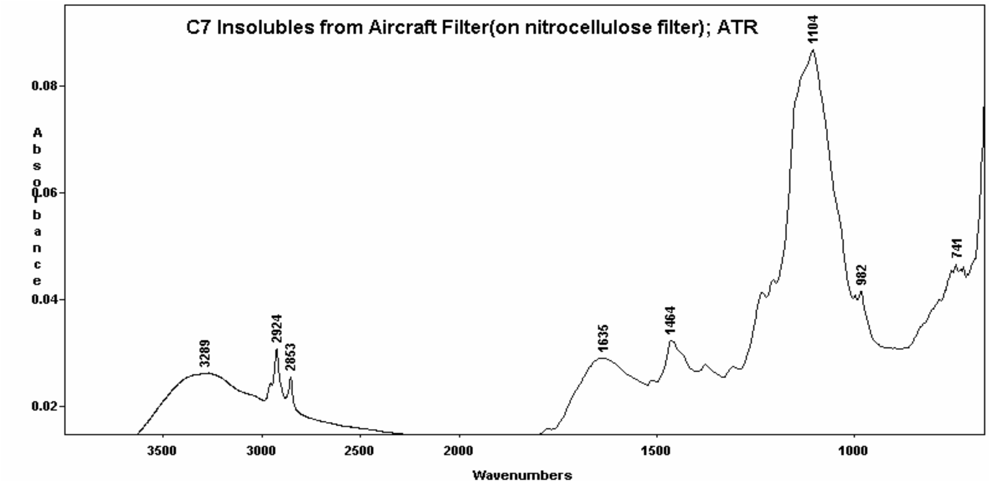


Figure 6: FTIR of Operator Q Filter 2 - Solid Remove After Heptane Sonication

Table 2: Elemental Data of Debris from Operator Q Filter 2

XRF Uniquant, wt%	**Solid Removed With Heptane**	**Solid Removed With CH_2Cl_2**	**Solid Removed With H_2O Extraction**
S	3.30	2.08	14.75
Na	2.53	0.25	5.92
Fe	0.92	0.57	1.04
Si	0.88	0.02	ND
Al	0.52	0.03	0.96
Mg	0.31	0.07	0.92
Ca	0.24	0.02	2.65
Cl	0.23	0.18	3.17
K	0,10	0.03	1.28
Zn	0.09	0.14	3.04
Cu	0.07	0.06	0.18
P	0.07	0.02	0.009
Ti	0.03	ND	ND
Cr	0.02	0.007	0.02
Mn	0.02	0.02	0.64
Ni	0.01	0.02	0.17
V	0.003	0.007	ND
D5291, wt%			
C	--	56.16	8.10
H	--	9.11	2.90
N	--	4.46	3.54

- The intact filter was then subjected to sonication in a methylene chloride solution. The solution was evaporated and the resulting black solid was swirled in heptane and filtered through an 8 µm nitrocellulose membrane. Two and a half grams of black solid were isolated. The XRF on this material shows the presence of sulfur but less sodium than the other samples. The FTIR of the $CHCl_2$ extract in Figure 7 looks similar to previous samples with a sulfate/sulfoxide peak at 1100 cm^{-1}. This spectrum also shows evidence of hydrocarbon presence (2924, 2854, 1465, and 1378 cm^{-1}). In addition, the FTIR of the material shows a peak at 1634 cm^{-1}. This again, has been indicative of SAP in past samples.

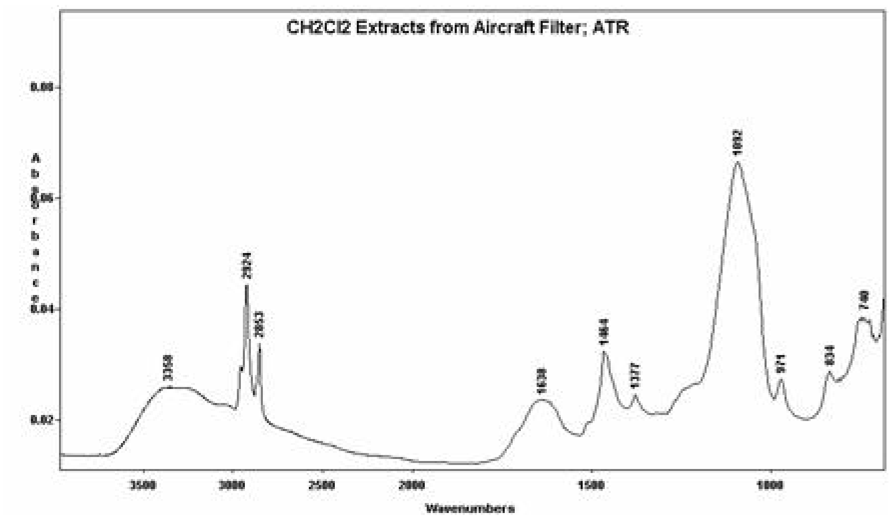


Figure 7: FTIR for Operator Q l Filter 2 - Solid Removed After $CHCl_2$ Sonication

- The intact filter was finally sonicated in water. The water was evaporated and a brown solid residue resulted. XRF analysis of this material shows a higher level of sulfur and sodium than the others (see Table 2). The FTIR shown in Figure 8 has a strong sulfate/sulfoxide peak at 1100 cm^{-1} and no evidence of hydrocarbon presence. This filter was also treated with a $CuSO_4$/water solution. Upon soaking, one small blue dot was discovered. This may be indicative of SAP presence.

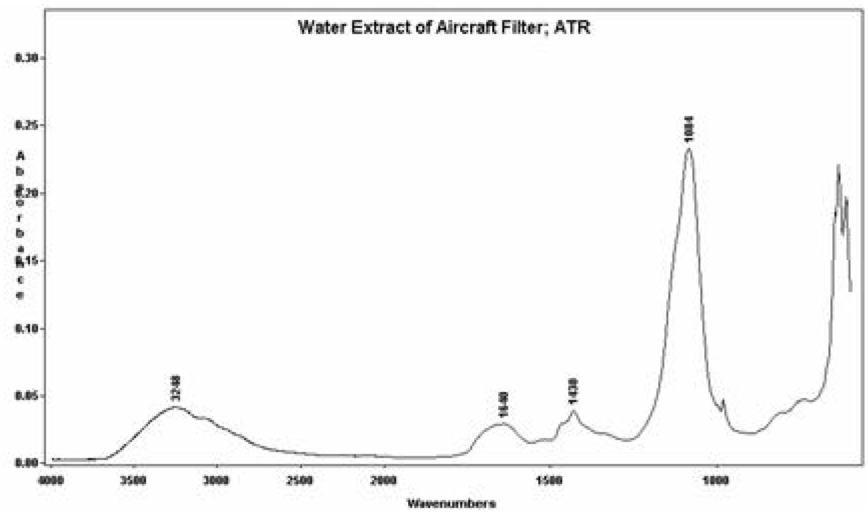


Figure 8: FTIR of Operator Q Filter 2 - Solid Removed After Water Sonication

SAP Identification

- A small peak at approximately 1600 cm^{-1} was found on the FTIR of each debris sample. This peak can represent a carbonyl. If this is so, when methylated, the peak will shift to approximately 1700 cm^{-1}. Two reference samples, sodium polyacrylate and polyacrylic acid, were treated with MeOH/NaOH and BF_3/MeOH solutions. This treatment represents standard conditions for hydrolyzing and esterifying triglycerides. After treatment, the materials were run on FTIR and there was a strong peak located at 1733 cm^{-1} for each reference material. This shift shows that an acid is present and provides evidence of the presence of SAP. Figures 9 and 10 show the reference spectrums.

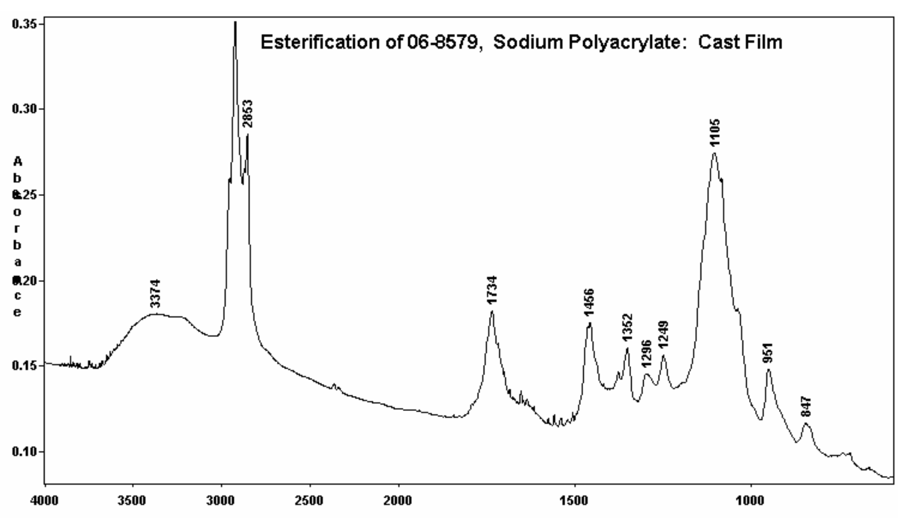


Figure 9: FTIR of Reference Sodium Polyacrylate after Esterification

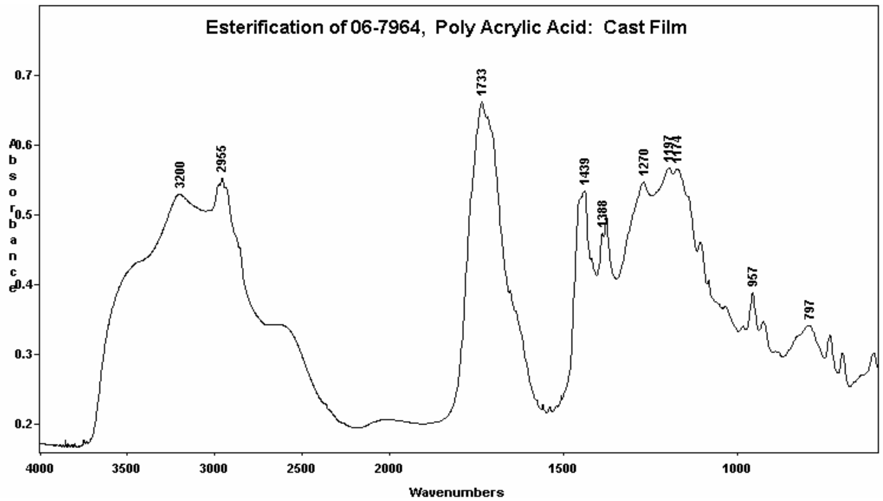


Figure 10: FTIR of Reference Polyacrylic Acid after Esterification

- After the reference samples were run, the water extract from the intact Operator Q filter was methylated. An FTIR was taken of the material and there was a very small peak located at 1736 cm^{-1}. This peak shift is similar to the reference samples. This indicates that there may be SAP present in the deposit; however it is at a very low concentration. Figure 11 shows the spectrum.

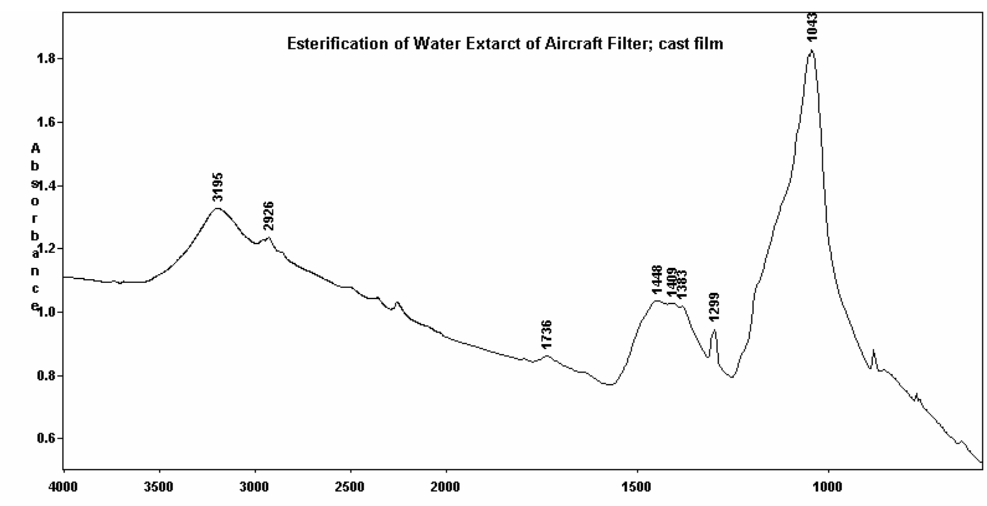


Figure 11: FTIR of Esterified Water Extract from Operator Q Filter 2

Reference Spectrums

- Figure 12 shows the reference spectrum for a nitrocellulose membrane. Figure 13 shows the reference spectrum for pure sodium polyacrylate. This spectrum was used as a basis of comparison for SAP peak shifts.

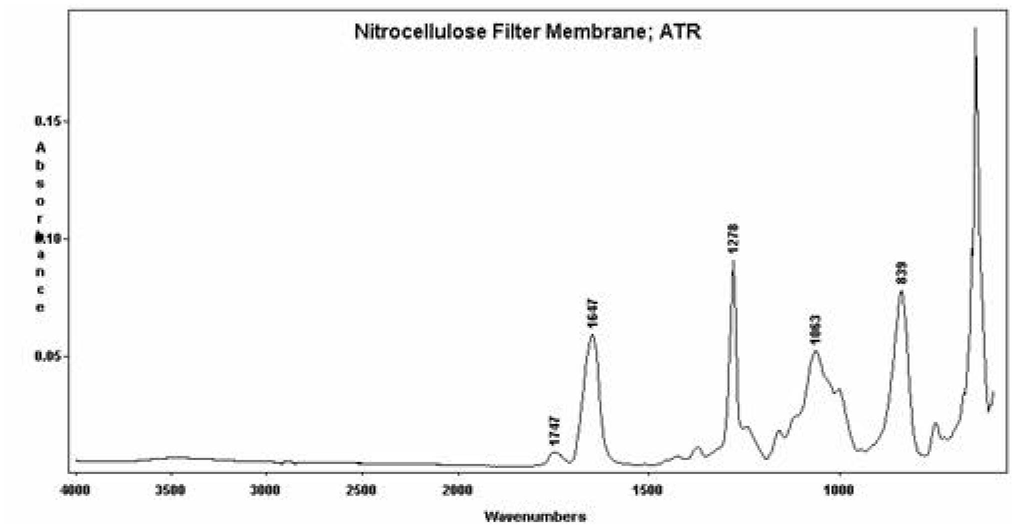


Figure 12: Reference FTIR of Nitrocellulose Filter

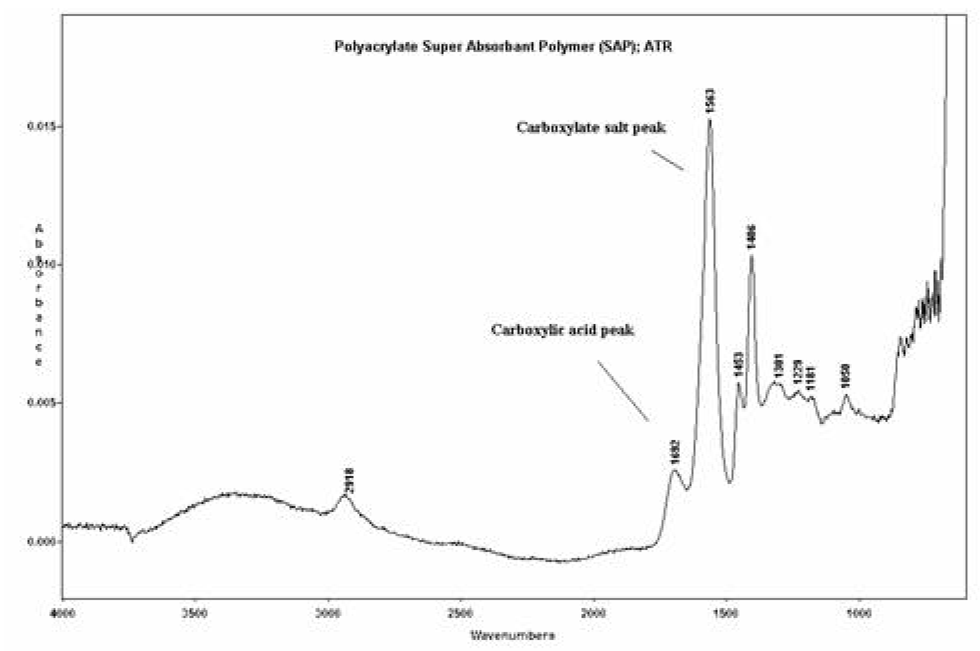


Figure 13: Reference FTIR of Polyacrylate

SwRI Filter Work

Field Test

- SwRI sent two Millipore filters which were believed to contain SAP to EMRE. These filters were routine Millipore samples taken from Swissport refuelers. The first sample was taken downstream of a vessel rated at 440 gpm that contained 6" monitors. Approximately 2,900 gallons of fuel had been dispensed through it. The second sample was taken downstream of a vessel rated at 710 gpm that contained 6" monitors. Approximately 30,200 gallons of fuel had been dispensed through it.

- SwRI received the filters from Swissport and treated each with a $CuSO_4$/water solution. The first filter had visible blue debris and the second had one small blue particle. These filters were then sent to EMRE for further analysis.

- EMRE ran FTIR on the sample. Figure 14 shows the spectrum of the material on the first filter.

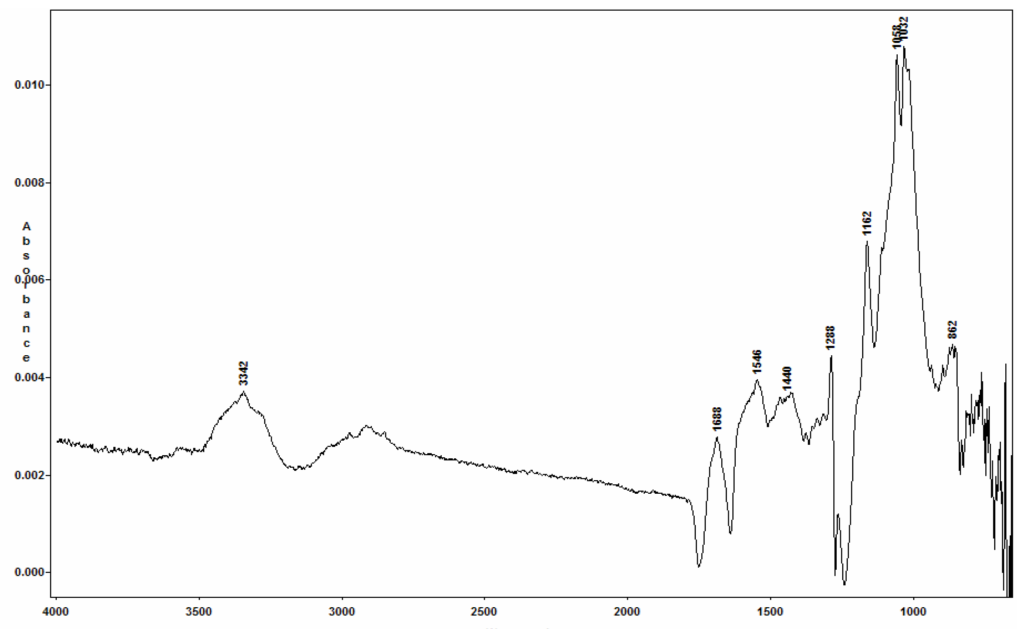


Figure 14: FTIR of Swissport Filter #1

- The FTIR shows peaks at 1688, 1546, 1440, 1288, 1162, 1058, and 1032 cm^{-1}. These peaks are very close to those of polyacrylate type polymers (see Figure 13). EMRE also had FTIR run on various pure polymers after they had been soaked in a $CuSO_4$/water solution. Figure 15 shows the reference spectrum for $CuSO_4$/water treated carboxymethyl cellulose. Figure 16 shows the reference spectrum for $CuSO_4$/water treated polyacrylate.

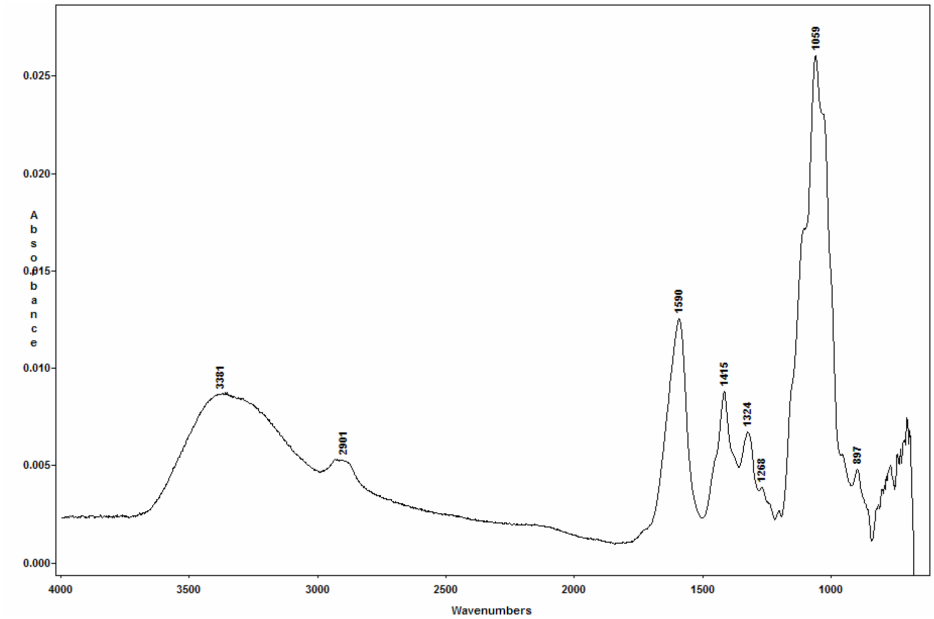


Figure 15: FTIR of Reference Carboxymethyl Cellulose after CuSO4/water Treatment

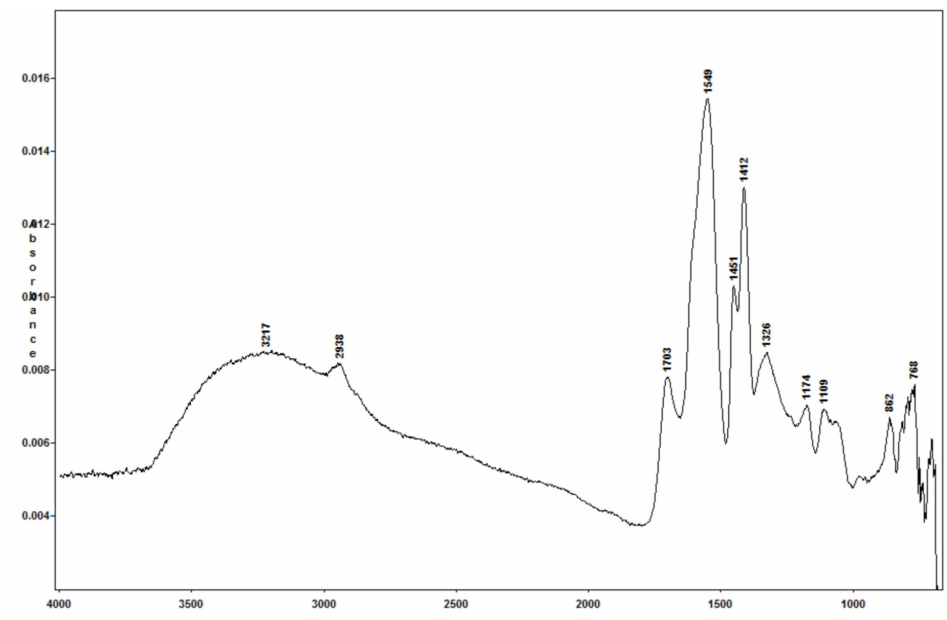


Figure 16: Reference FTIR of $CuSO_4$/water treated Polyacrylate Polymer

- The debris on the Millipore filter from Swissport closely resembles those of polyacrylate SAP. EMRE was unable to find any particles on the second filter, so no further analysis was done.

In-House Testing

- SwRI completed in-house testing using 22 x 2" monitors. The fuel was run at 20% of rated flow and had 50,000 gallons of wet/dry fuel dispensed through it. During this process, a Millipore sample was taken continuously downstream of the vessel. This filter was then treated with a $CuSO_4$/water solution. There were visible blue particles on the filter. This filter was then sent to EMRE for further analysis.

- EMRE ran FTIR on the filter. An FTIR was also run on a reference sample of pure polyacrylate which had been immersed in a $CuSO_4$/water solution. The spectrum of the filter sample is shown in Figure 17. The spectrum of the reference material is shown in Figure 16.

- The FTIR shows peaks at 1703, 1610, 1566, 1449, 1415, 1324, 1173, and 1103 cm^{-1}. The reference spectrum shows peaks at 1703, 1549, 1451, 1412, 1326, 1174, and 1109 cm^{-1}. Based on this comparison, the material on the filter is polyacrylate polymer.

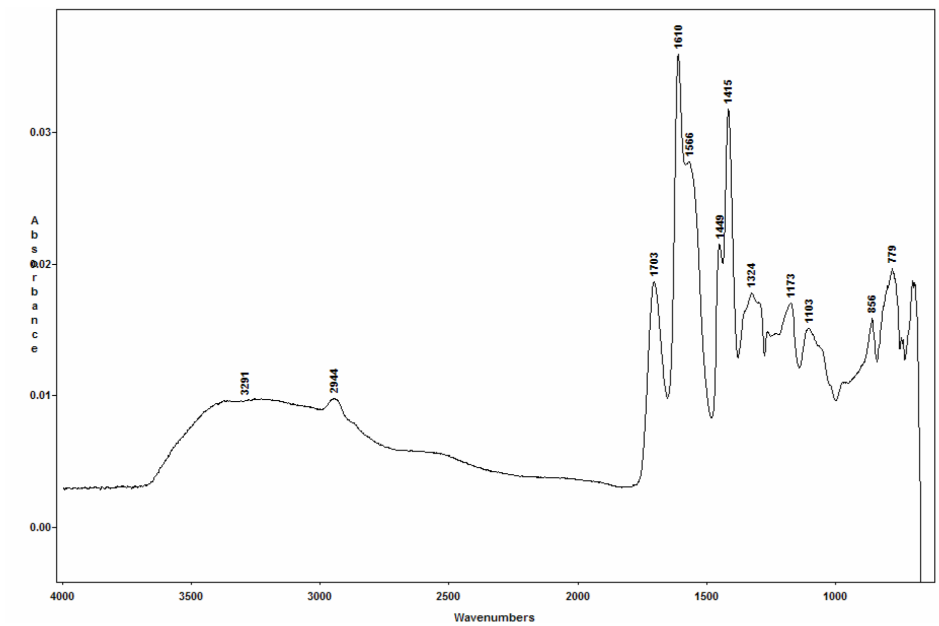


Figure 17: FTIR of Sample Taken from SwRI In-house Testing

Aircraft Filter

- SwRI supplied EMRE with an aircraft filter. It was the intent of EMRE to sonicate this filter and immerse the debris in a $CuSO_4$/water solution to find SAP. SwRI had found large amounts of blue particles from a sample they had taken from the same filter.

- EMRE cut a sample from the filter and sonicated it, first in filtered isooctane and second in water. Each solution was then filtered through a 0.8 µm membrane and the resulting filtrate was dried in an oven. Before $CuSO_4$ treatment, each portion of debris was observed under an optical microscope. There were no visible blue particles present. Each Millipore was then soaked in $CuSO_4$/water and placed under an optical microscope. At this point, there were blue particles present on the filters. Any blue particle that was visible was separated from the debris and placed onto a clean filter.

- In addition, the filtrate of the isooctane sonication was dried, however there was no significant debris residue. The water filtrate was also dried and there was a large amount of debris which was treated with $CuSO_4$/water. A small number of blue particles, relative to the debris, were found during this treatment as well.

- In all, very few blue particles were found. SwRI had discovered more particles of SAP in their analysis of the same filter. It is believed that the variance in these results is due to the non-homogeneous distribution of SAP in the different samples tested. There was a greater number of SAP particles than what had been seen on the Operator Q filters, however not a sufficient amount to obtain clear FTIRs. EMRE pursued to do microscopic IR in order to determine the composition of the blue particles. Figures 18, 19, and 20 show the microscopic IR spectrums[2]. Figure 18 represents the blue debris that was captured during the cutting of the filter. Figure 19 represents the blue debris that was captured during isooctane filtration. Figure 20 represents the blue debris that was captured during water filtration.

- Figures 18, 19, and 20 show peaks in the same regions of the IR. All three spectrums are comparable to a mixture of polyacrylate and carboxymethyl cellulose.

[2] The area from 4000 to 2000 cm^{-1} was removed on the spectrums shown in Figures 18, 19, and 20.

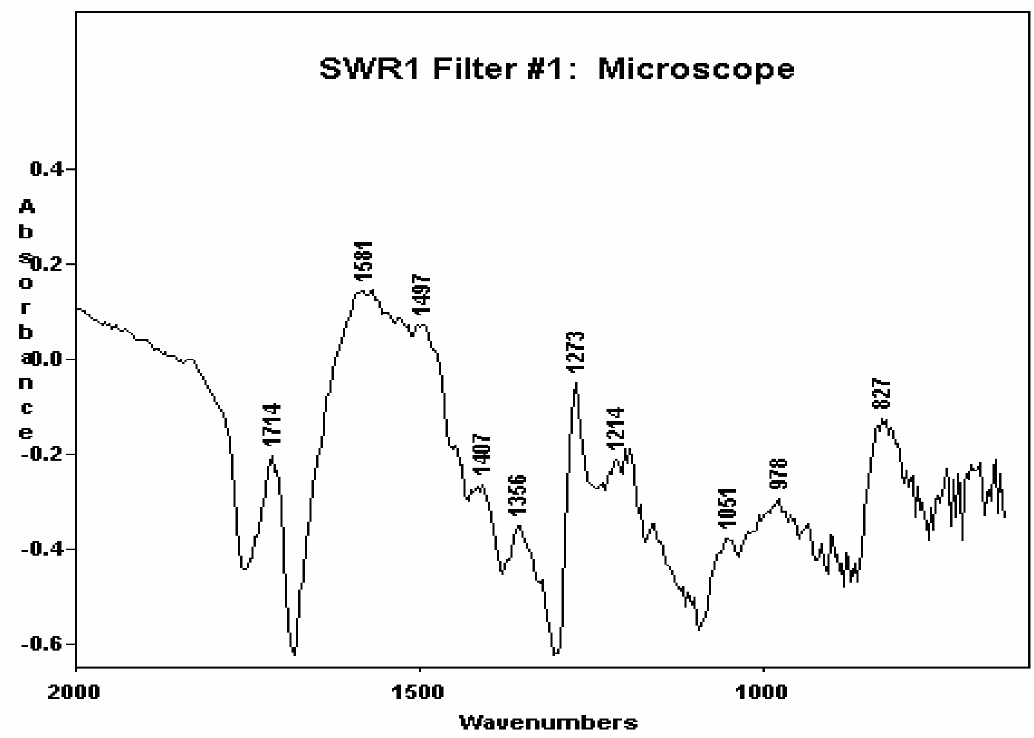


Figure 18: FTIR of Blue Particles from Loose Debris

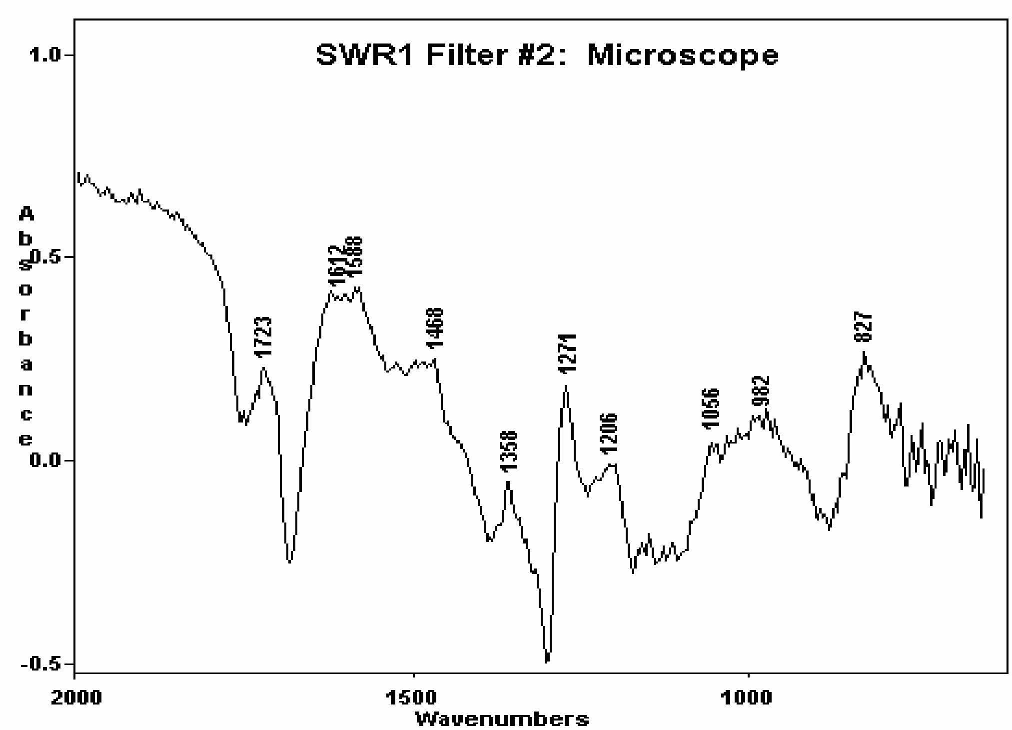


Figure 19: FTIR of Blue Particles from Debris after Isooctane Sonication

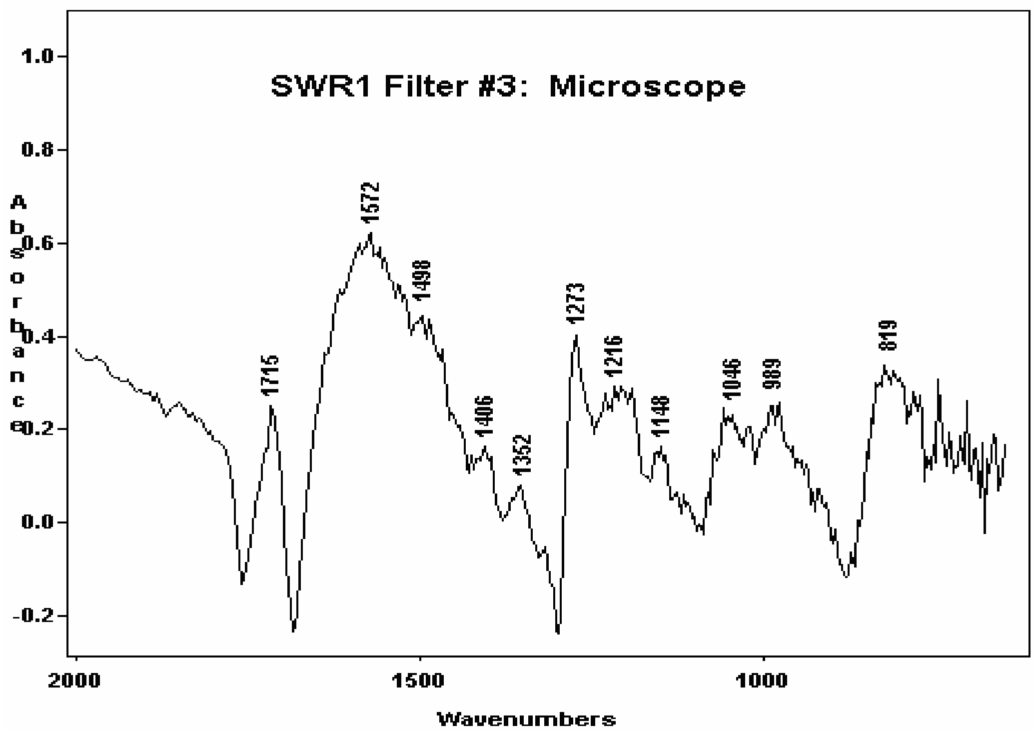


Figure 20: FTIR of Blue Particles from Debris after Water Sonication

M&PT
Material & Process Technology

FLUIDS & LUBRICATION TECHNOLOGY GROUP (66-Z6-20C5)

INFORMAL REPORT WR 200600267-S00 DATE: 02/06/2006

TO:	**Gaskey, Brian P**	**04-EC**	**425-342-6440**
CC:	**Plagemann, Walter L**	**73-45**	**425-234-3025**
	Hadaller, Oren J	**67-MH**	**425-234-5203**
	Jones, Michael D	**67-MH**	**425-237-9937**
FROM:	**Ponomarev, Sergey G**	**73-47**	**425-234-1622**

SUBJECT: Analysis of the deposits in a fuel filter from US Air 767 (VE151)

Background: A fuel filter from the airplane VE151 was submitted to the Fluids and Lubrication Technology Group for analysis of the deposits collected in the filter. Upon visual examination, the filter's media was found significantly contaminated with fine clay-like particles especially in the fold areas and next to them along with a characteristic brown material deposited on the meshes' wires (Fig.1 and 2). Fine, nano and micro size, clay particles clogging the filters' media and the brown material on the meshes have been found in many fuel filters analyzed in the lab over the last three years. The brown material was identified as mixed sodium-ammonium sulfate, one of the main constituents of the clay and readily soluble in water. Aggregation and accumulation of these fine clay particles in the filter's media has been determined as the cause of the filters' clogging.

In this VE151 filter, in addition to the clay-like particles, numerous glass- or plastic-like beads were noticed amid the deposits (Fig.3 and 4). The fold areas of the filter have also accumulated various fibers, paint and plastic chips and fragments that are typical manufacturing debris or debris originated from maintenance activities.

Light microscopy, Fourier Transform Infrared (FTIR) spectroscopy and Electron Probe Micro Analysis (EPMA) technique with Scanning Electron Microscopy (SEM) were performed for analysis of the samples of the contamination deposits, their extracts in heptane, acetone and water suspensions, and beads.

Results

<u>The clay-like deposits</u> were confirmed to be a mixture of aluminum silicates, iron oxides and mixed ammonium-sodium sulfates. Their EPMA and FTIR spectra (Fig.5 and 7) showed the elemental composition and chemical groups typical for

clays composed of silicates, oxides and sulfates – well pronounced peaks of aluminum, silicon, sodium, sulfur, calcium, magnesium, oxygen and iron. Water soluble ammonium-sodium sulfate was identified as one of the main constituents of this clay composition which was found to be quite similar to the clays identified as contaminants in many fuel filters such as one from a TTT 777 (Fig.7).

Aggregation of these clay particles in the filter's media appeared to be the major reason of the filter's clogging.

<u>The numerous small beads</u> found in the filter's media (Fig.3 and 4) were found to be composed mainly of three elements, sodium, carbon and oxygen (Fig.6) that points out an organic material. Strong hydroxy (alcohol), carbonyl, carbon-oxygen, amine and nitro groups were identified in the bead's material (Fig.8). The chemical composition of the beads showed a basic similarity with melamine types of compounds and a good match with some additives in the water phase of the JP-8 fuel mixture, sample P47, previously tested in the lab (BMT summary report SR 10270, 02/22/2002).

EPMA and FTIR spectra are on file.

Acknowledgements: Jeff Wessel – EPMA and SEM
Tom Plank – sample preparation and testing
Steve Millett, Mike Parr - review

Fig.1 Upper mesh of the filter with debris and clay deposits on the wires

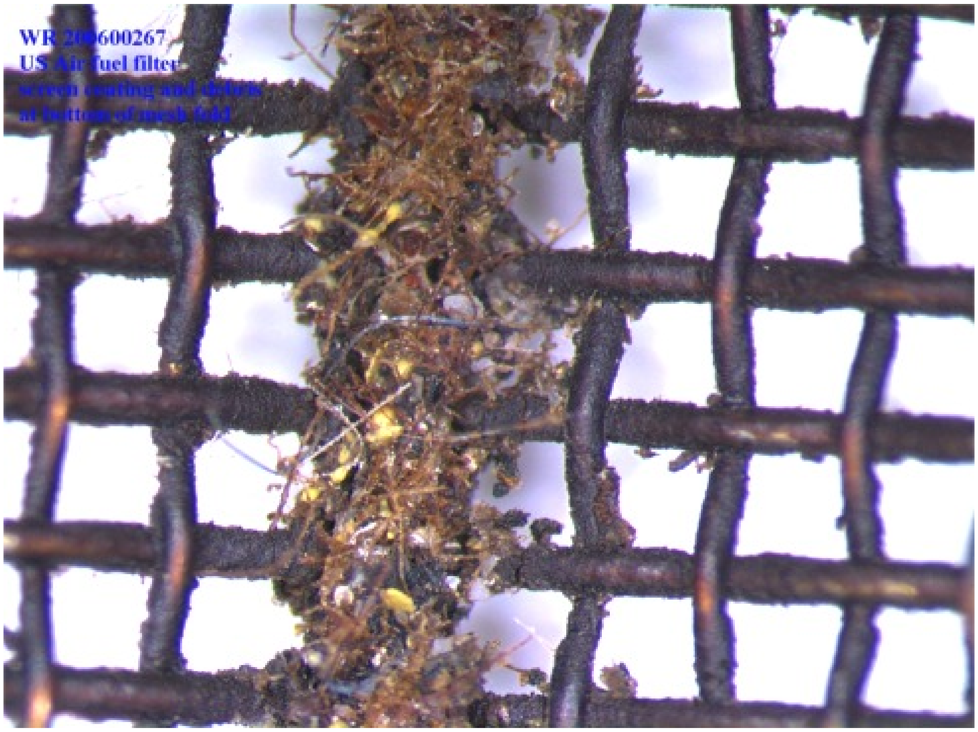


Fig.2 Filter's media clogged with clay, mineral particles and plastic-like beads

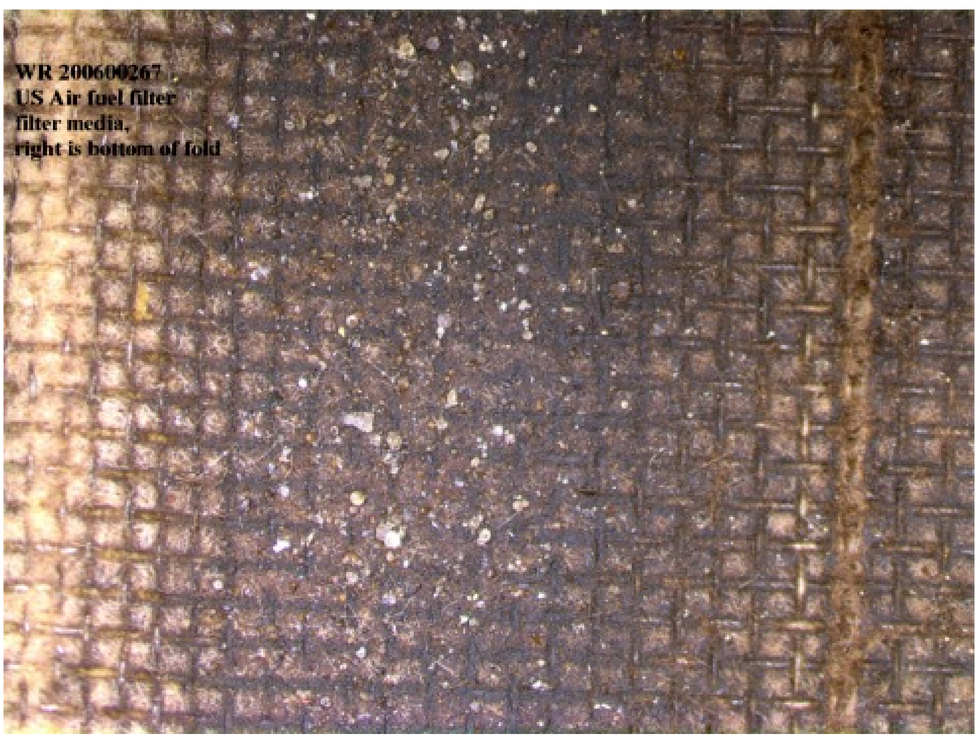


Fig.3 Clay deposits and plastic-like beads in the filter's media

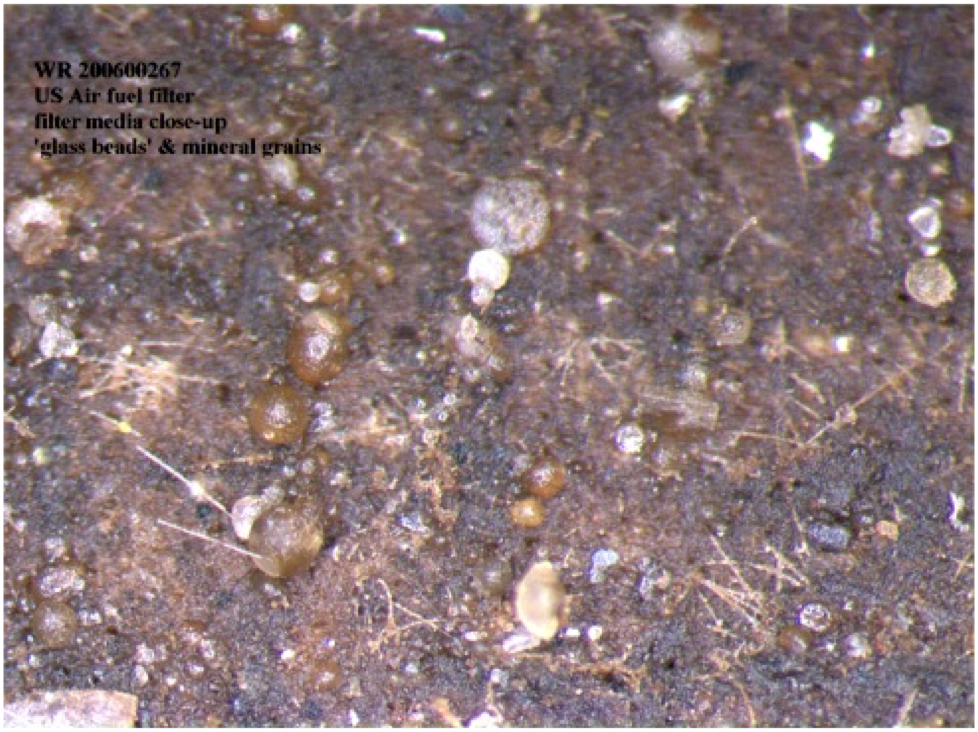


Fig.4 SEM micrograph of the beads and clay particles in the filter's media

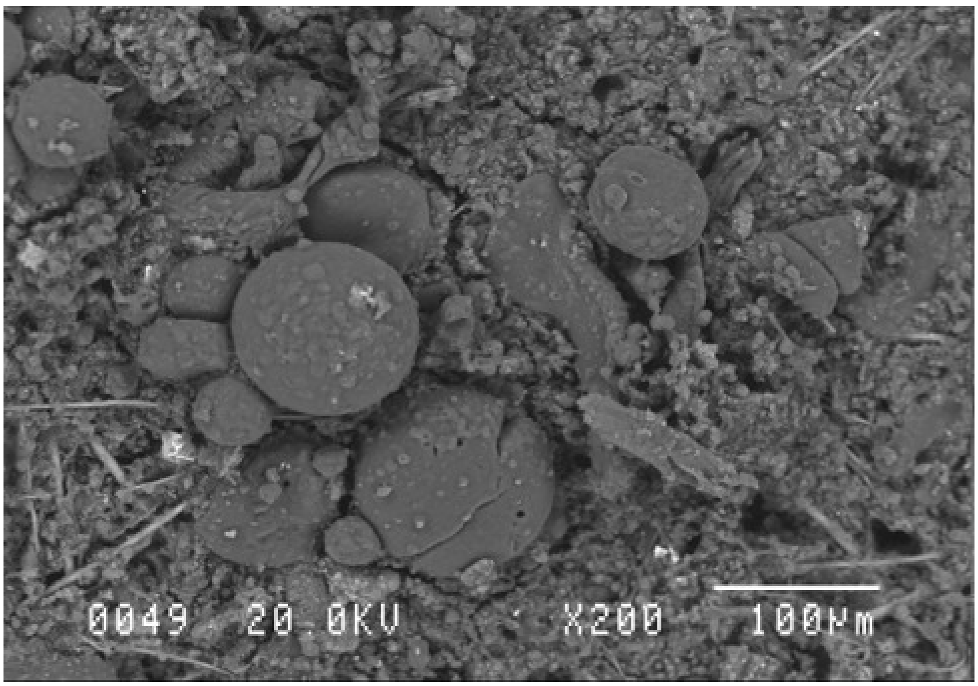


Fig.5 EPMA spectrum of the clay deposits and beads

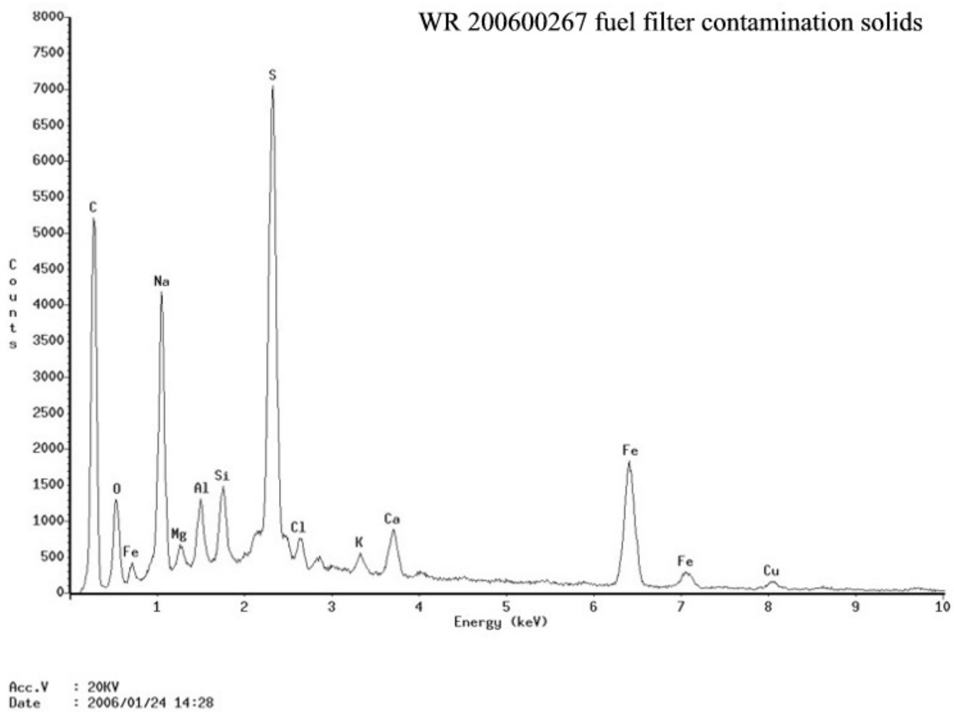


Fig.6 EPMA spectrum of the plastic beads

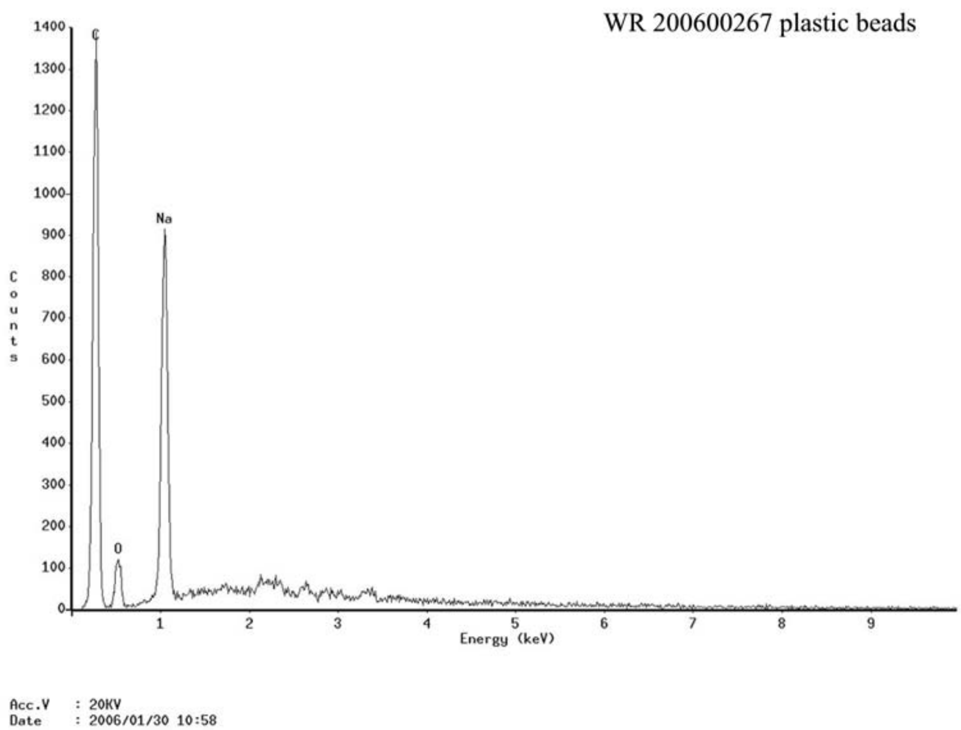


Fig.7 FTIR spectra of the water extract of the filter's clay deposits and beads and reference mixed sodium-ammonium sulfate of the clay water extract of the filter from a TTT 777 (WR 200304248)

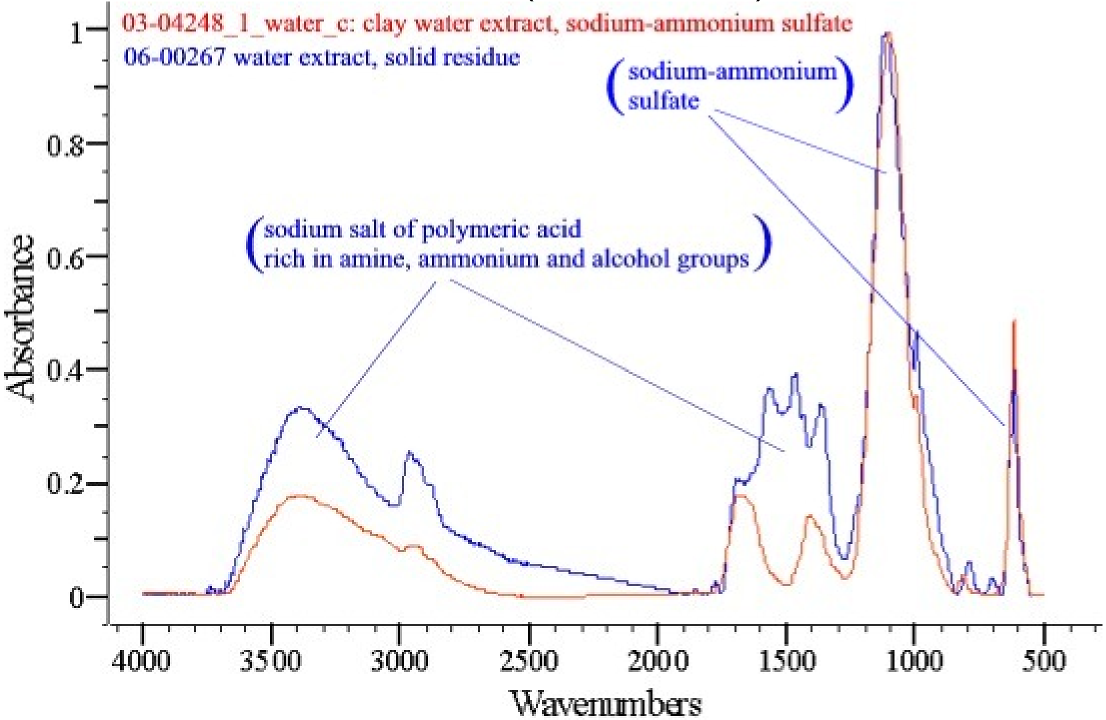
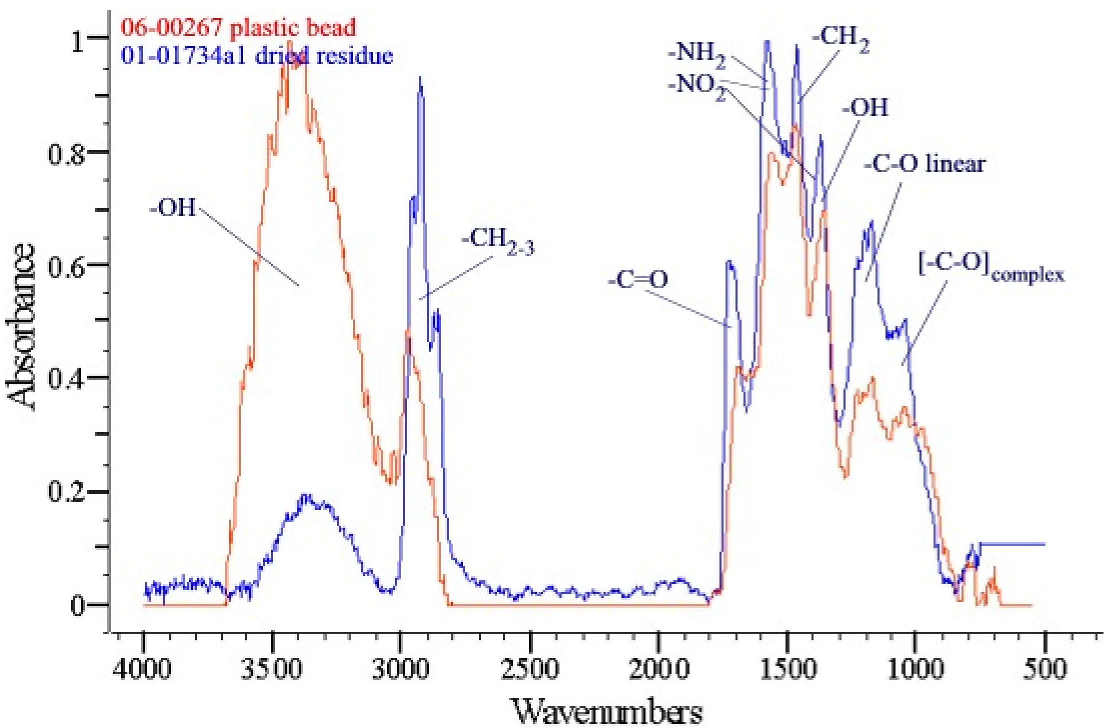


Fig.8 FTIR spectra of a plastic bead and reference dried residue of the water phase of the JP-8 fuel sample P47



M&PT
Material & Process Technology

FLUIDS & LUBRICATION TECHNOLOGY GROUP (66-Z6-20C5)

INFORMAL REPORT WR 200600307-S00 DATE: 02/06/2006

TO:	**Gaskey, Brian P**	**04-EC**	**425-342-6440**
CC:	**Plagemann, Walter L**	**73-45**	**425-234-3025**
	Hadaller, Oren J	**67-MH**	**425-234-5203**
	Jones, Michael D	**67-MH**	**425-237-9937**
FROM:	**Ponomarev, Sergey G**	**73-47**	**425-234-1622**

SUBJECT: Analysis of the deposits in a fuel filter from US Air 767 (VE144)

Background: A fuel filter from the airplane VE144 was submitted to the Fluids and Lubrication Technology Group for analysis of the deposits collected in the filter. Visual examination of the filter revealed that it had trapped the same types of particulates that were found in the fuel filter from the airplane 767 VE151 (WR 200600267-S00). The filter's media was significantly contaminated with fine clay-like particles especially in the fold areas and next to them along with a characteristic brown material deposited on the meshes' wires (Fig.1 and 3)[1].

In addition to the clay-like particles, plastic or glass-like beads similar to those found in the VE151 filter were also noticed amid the deposits (Fig.2 and 4). In the folds areas, the filter had accumulated various fibers, paint and plastic chips and fragments (Fig.1), typical debris commonly found in fuel filters. Several fold areas of the filter's upper mesh was significantly clogged with long cotton-like fibers (Fig.8).

Light microscopy, Fourier Transform Infrared (FTIR) spectroscopy and Electron Probe Micro Analysis (EPMA) technique with Scanning Electron Microscopy (SEM) were performed for analysis of the samples of the contamination deposits, their extracts in heptane, acetone and water suspensions, beads, and fibers.

Results

The clay-like deposits were identified as a mixture of aluminum silicates, iron oxides and mixed ammonium-sodium sulfates. Their EPMA and FTIR spectra (Fig.5 and 6) were typical for clays composed of aluminum silicates, iron oxides and water soluble ammonium-sodium sulfates.

[1] The brown material has been previously identified as mixed sodium-ammonium sulfate soluble in water and one of the main constituents of clays.

Aggregation of these sulfates in the filter's media along with the incorporation of the silicates and oxides appeared to be the major reason of the filter's clogging.

The numerous small beads noticed in the filter's media and stuck on the meshes' wires (Fig.2 and 4) were found to be composed mainly of three elements, sodium, carbon and oxygen (Fig.7), quite similarly to the beads found in the filter VP151 and that indicates organic nature of the beads' material as well. The FTIR tests of the beads also yielded the spectra almost identical to those of the beads from the VP151 filter (Fig.8). Analysis of the chemical composition of the beads suggested the material is similar to melamine compounds rich in alcohol, amine, and ammonium groups (see WR 200600267-S00 report).

The cotton-like fibers found in several folds of the filter's upper mesh (Fig.9) were confirmed to be of cellulose type of material (Fig.10).

EPMA and FTIR spectra are on file.

Acknowledgements: Jeff Wessel – EPMA and SEM
Tom Plank – sample preparation and testing
Mike Parr - review

Fig.1 Upper mesh of the filter with debris and clay deposits on the wires

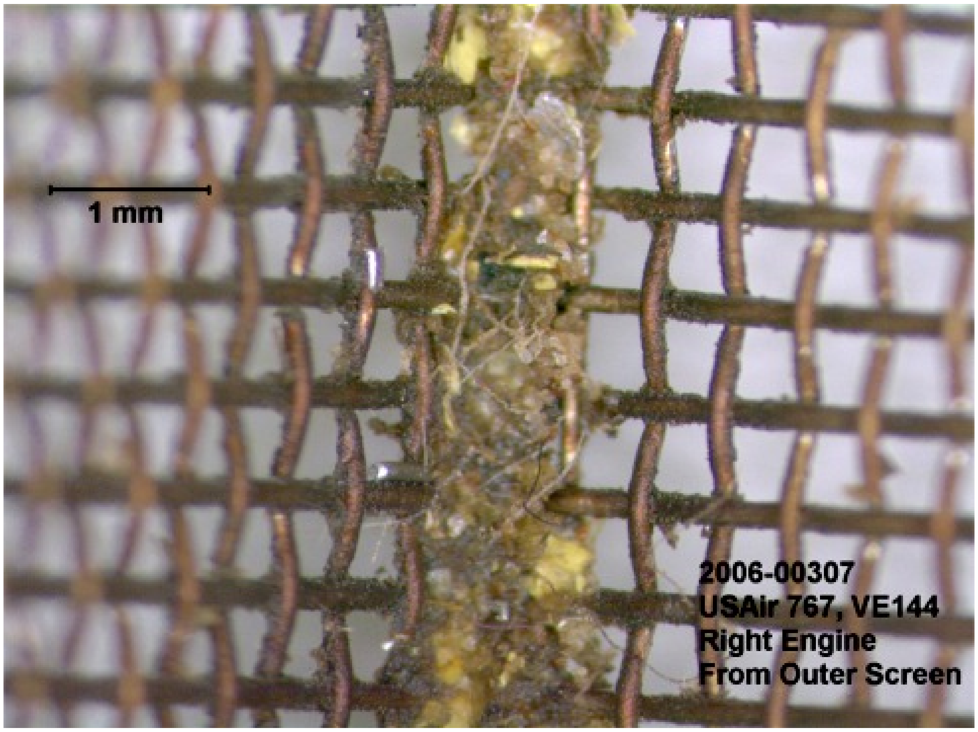


Fig.2 Upper mesh of the filter, plastic-like beads in the debris

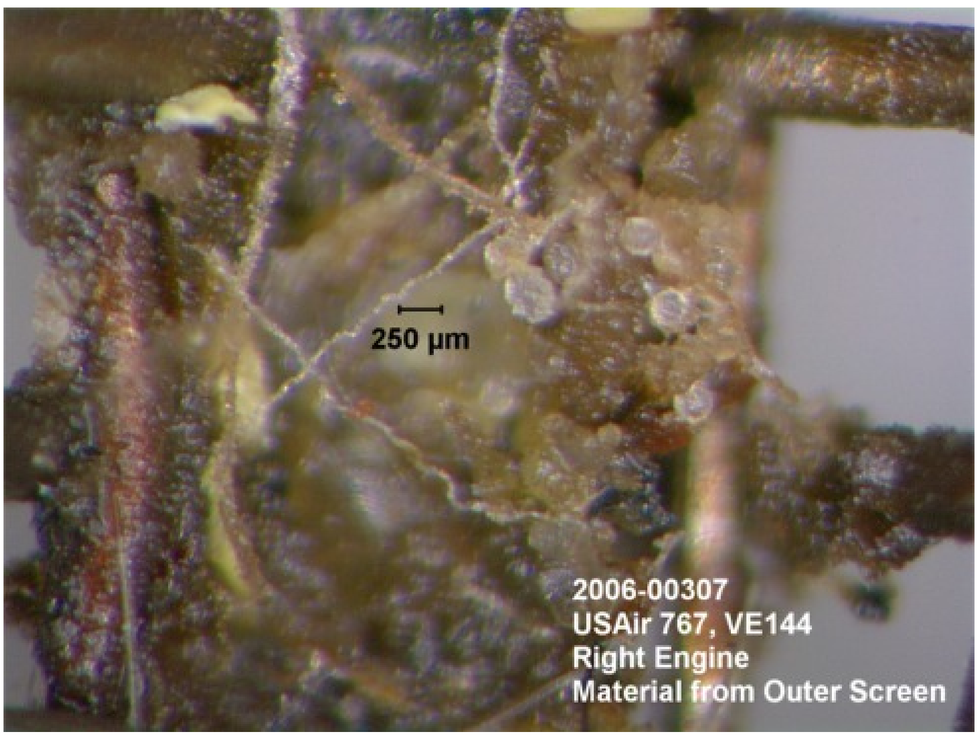


Fig.3 Filter's media clogged with clay, mineral particles and plastic-like beads

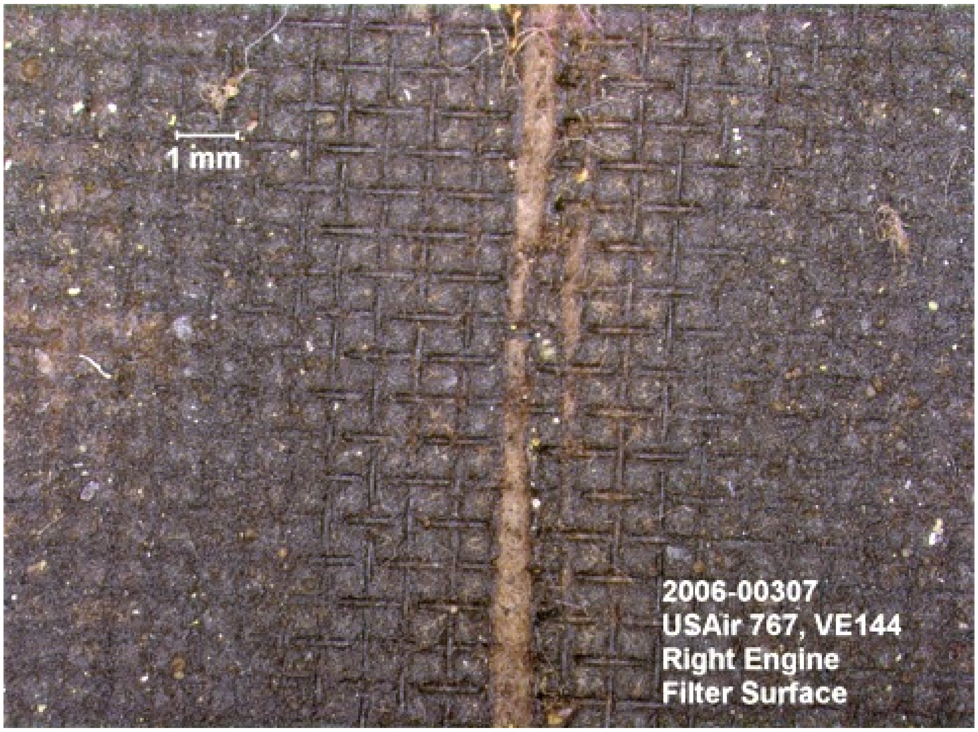


Fig.4 Clay deposits and plastic-like beads in the filter's media

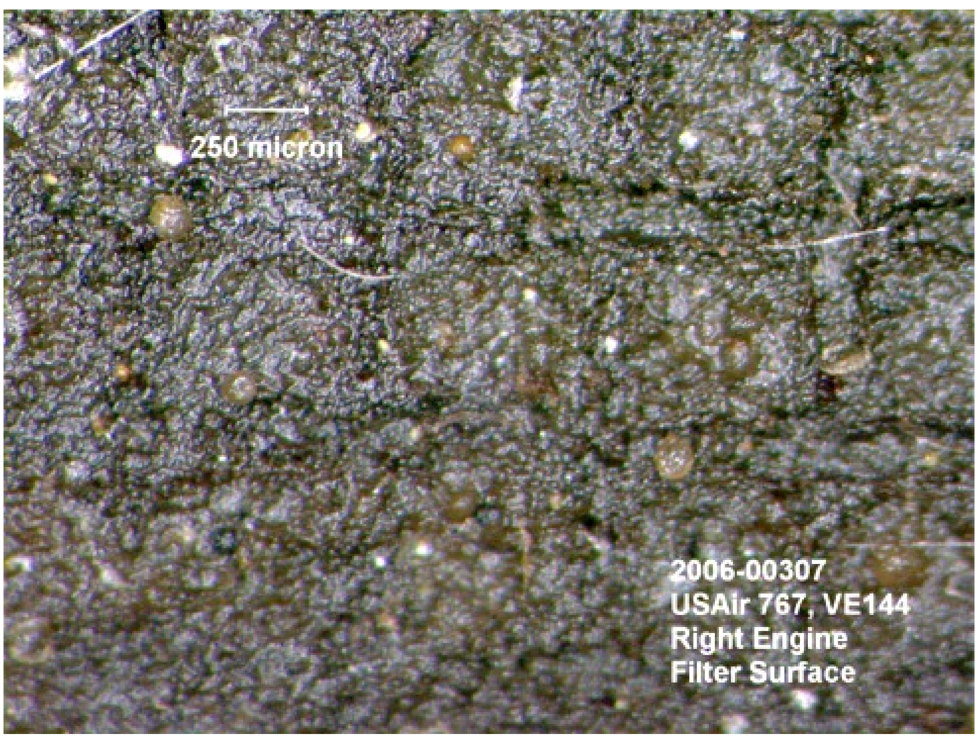


Fig.5 EPMA spectra of water soluble components of the filter's deposits and the deposits filtered with acetone

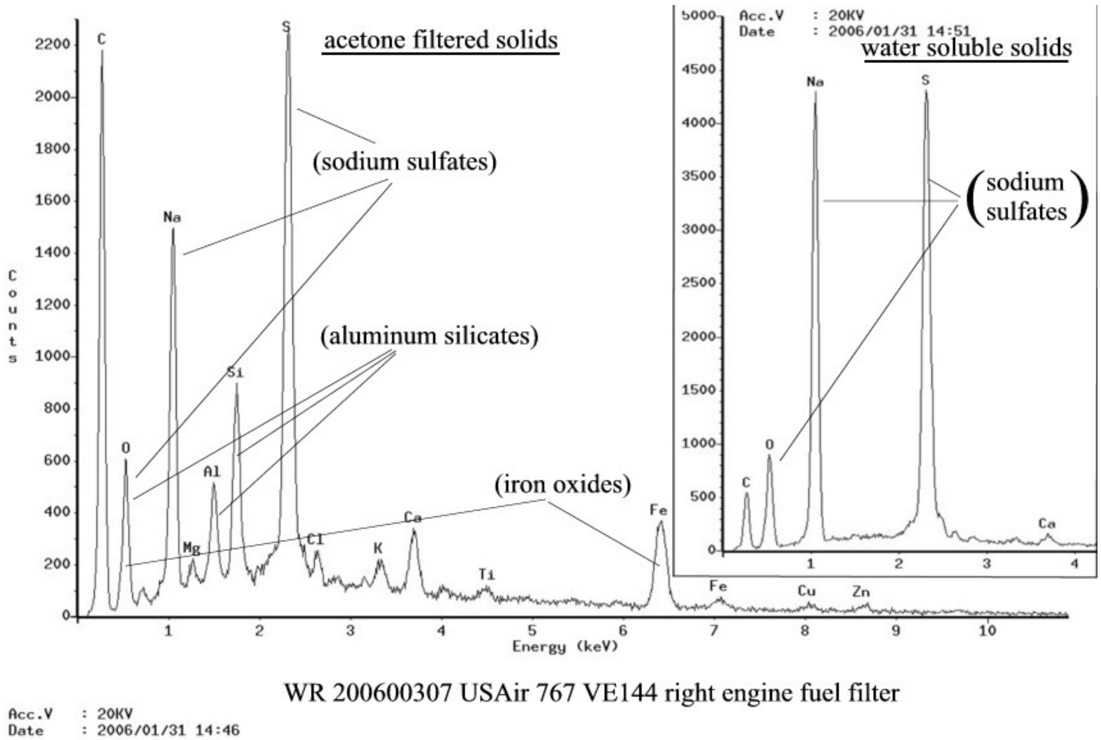


Fig.6 FTIR spectra of water soluble components of the filter's deposits and the deposits filtered with acetone

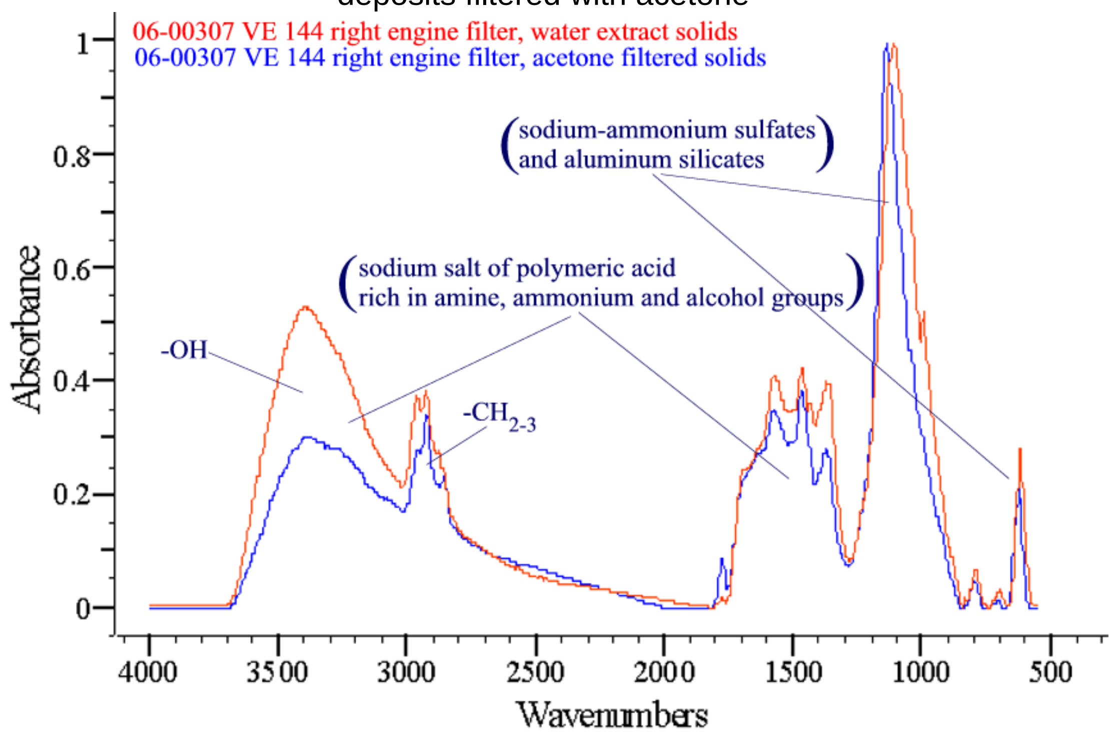


Fig.7 EPMA spectra and SEM micrograph of the plastic beads

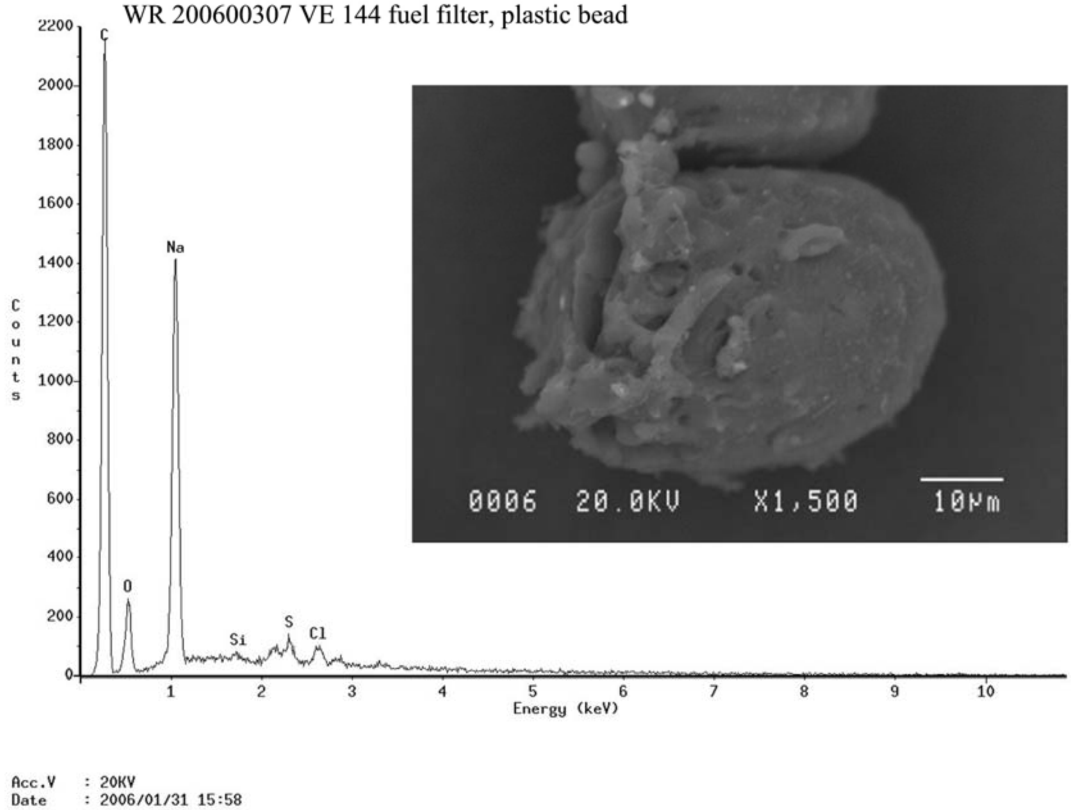


Fig.8 FTIR spectra of the beads and sulfates from the fuel filters VE151 and VE144

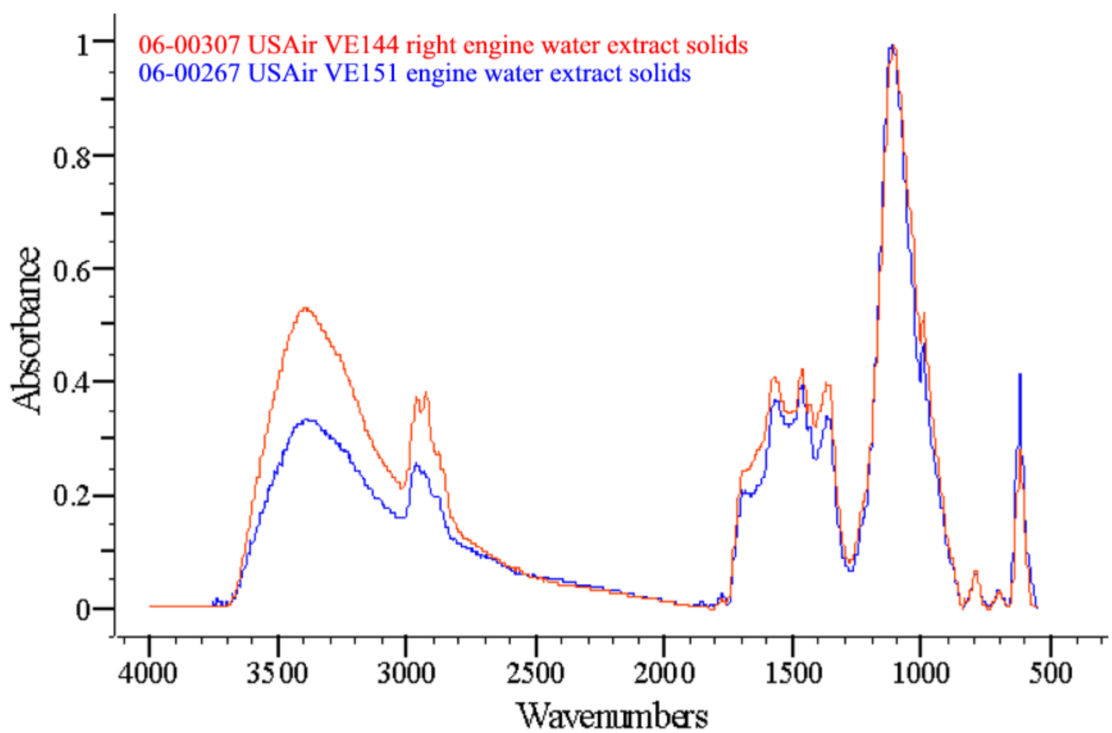


Fig.9 Fibers trapped in the upper mesh of the filter

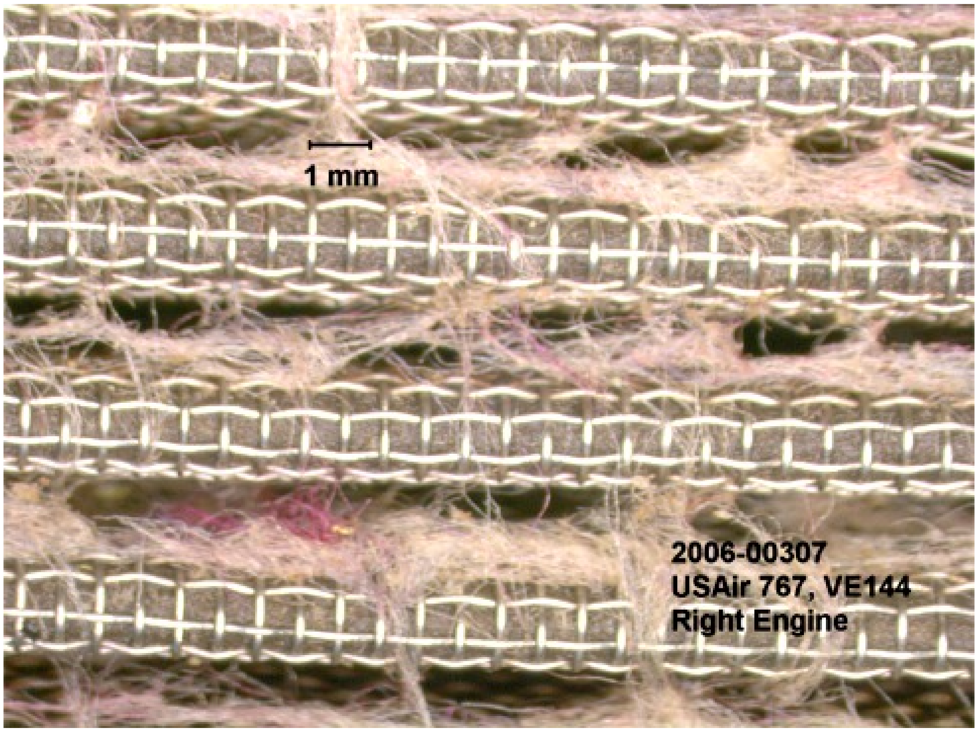
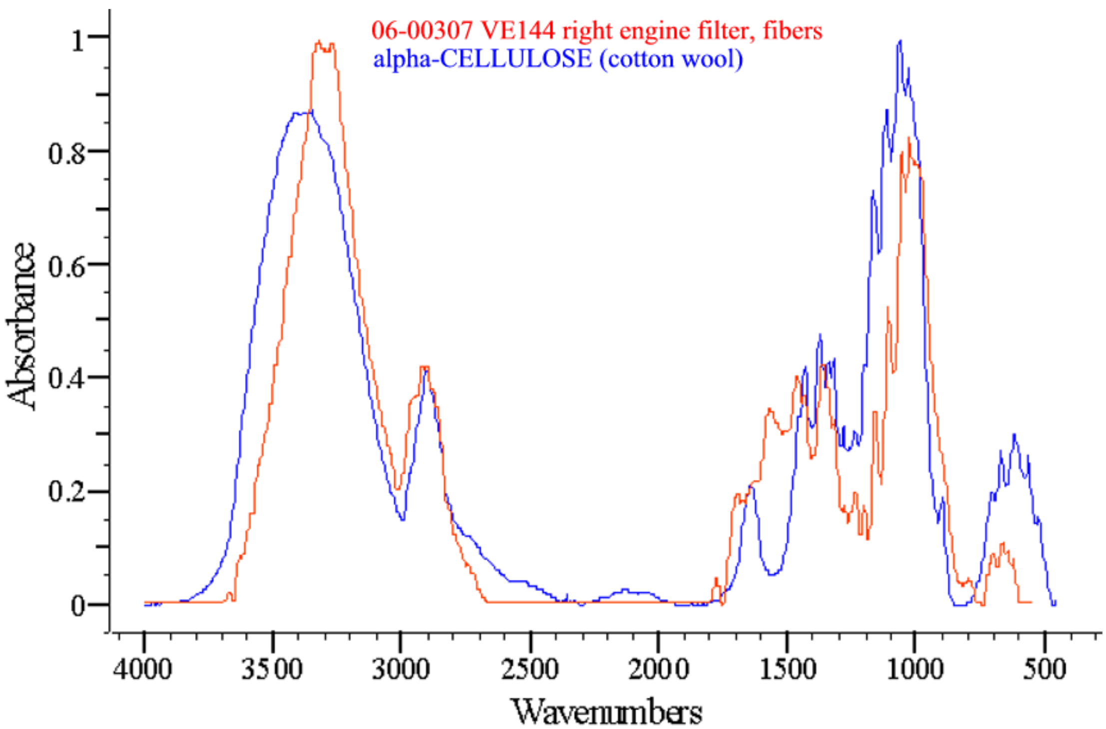


Fig.10 FTIR spectra of the fibers from the filter's upper mesh and reference cotton material



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Material & Process Technology

FLUIDS & LUBRICATION TECHNOLOGY GROUP (66-Z6-20C5)

INFORMAL REPORT WR 200600307-S00 **DATE: 02/07/2006**

TO:	**Morris, Gary L**	**2L-85**	**206-766-4351**
CC:	**Plagemann, Walter L**	**73-45**	**425-234-3025**
	Mountain, Bill	**92-17**	**425-237-1579**
FROM:	**Ponomarev, Sergey G**	**73-47**	**425-234-1622**

SUBJECT: Analysis of the deposits in a fuel filter from US Air 737 (A/P PP052) (FedEx Tracking Number 814392502622, service request ID 1-151676043)

Background: A fuel filter from #1 Left Engine of airplane PP052 was submitted to the Fluids and Lubrication Technology Group for analysis of the deposits trapped in the filter. The only ID was the FedEx Tracking Number. Upon visual examination, the filter's meshes and media were found relatively clean with no visible deposits of clay and other common contaminants such as fibers and paint chips (Fig.1 and 2). A very small amount of metallic and carbon-like particles were noticed in the media. Along with the color of the filter's media, dark-gray-to-brown, it is typical for in-service filters to change color over time and trap dust particles and wear debris. In such amounts as in this filter, they do not cause filters' blockage. To determine what material had been trapped in this filter, extracts of the filter's media in acetone, heptane and water were prepared and analyzed by means of Fourier Transform Infrared (FTIR) spectroscopy and Electron Probe Micro Analysis (EPMA) technique with Scanning Electron Microscopy (SEM).

Results

The only liquid material extracted out of the filter's media was a straight hydrocarbon compound similar to jet fuels.

The recovered solid residues of the extracts were found to be mainly composed of some organic material with a high content of magnesium, carbon and oxygen, and minor amounts of aluminum, silicon, sulfur, calcium, sodium and chlorine. (Fig.3). These are typical elements of airborne dust (clay) particles such as aluminum silicates, sulfates, and sodium chloride.

The EPMA spectra of the water filtered solids (Fig.3) and the FTIR analysis of the material (Fig.4) confirmed that the solids trapped in the filter were of long chain hydrocarbon types of compounds with strong hydroxy (alcohol) and fatty ester groups. Along with the high content of magnesium, the analysis suggested a magnesium salt of a fatty acid such as ricinoleic. Water soluble components of the residues were identified as sodium chloride, sulfates, and nitrates.

Conclusion

The fuel filter of the airplane PP052 was confirmed to be mainly contaminated with a soap-like material, likely magnesium salt of a fatty acid, and with minor amounts of sulfates and nitrates.

EPMA and FTIR spectra are on file.

Acknowledgements: Jeff Wessel – EPMA and SEM
Tom Plank – sample preparation and testing
Mike Parr - review

Fig.1 US Air 737 PP052 left engine fuel filter, upper mesh

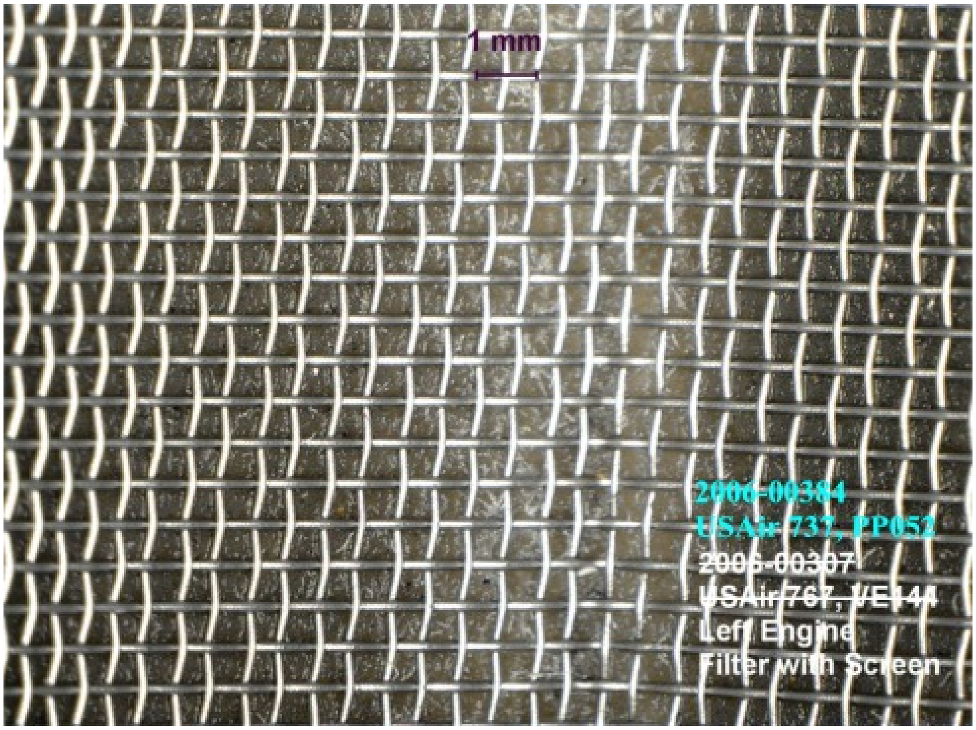


Fig.2 US Air 737 PP052 left engine fuel filter, filter's media

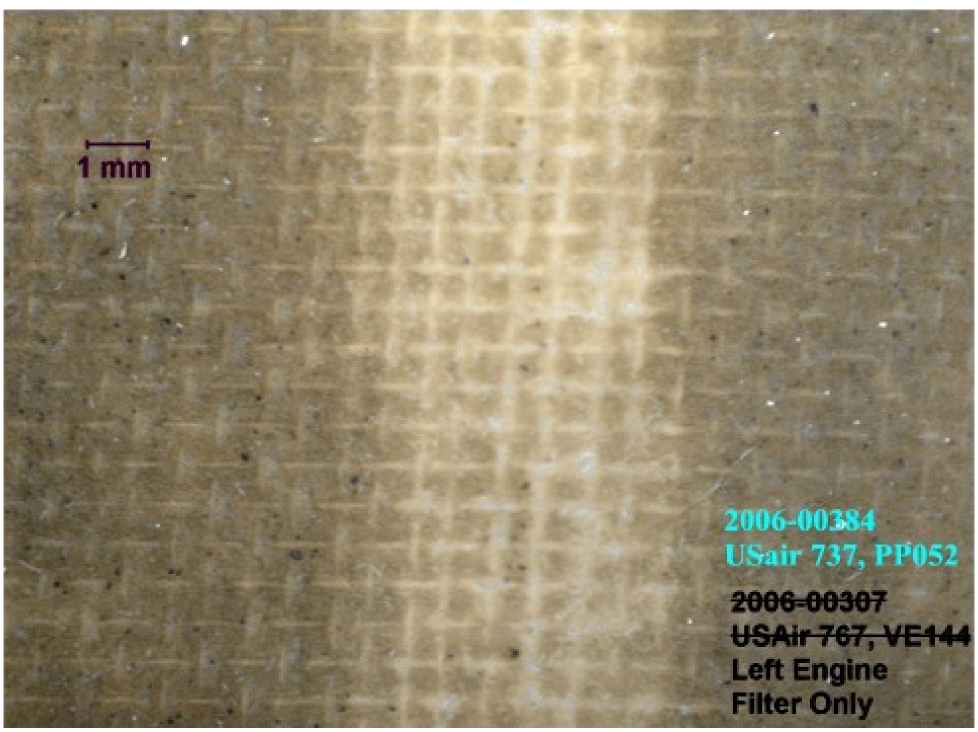


Fig.3 EPMA spectra of the filtered solids from the US Air 737 PP052 left engine fuel filter

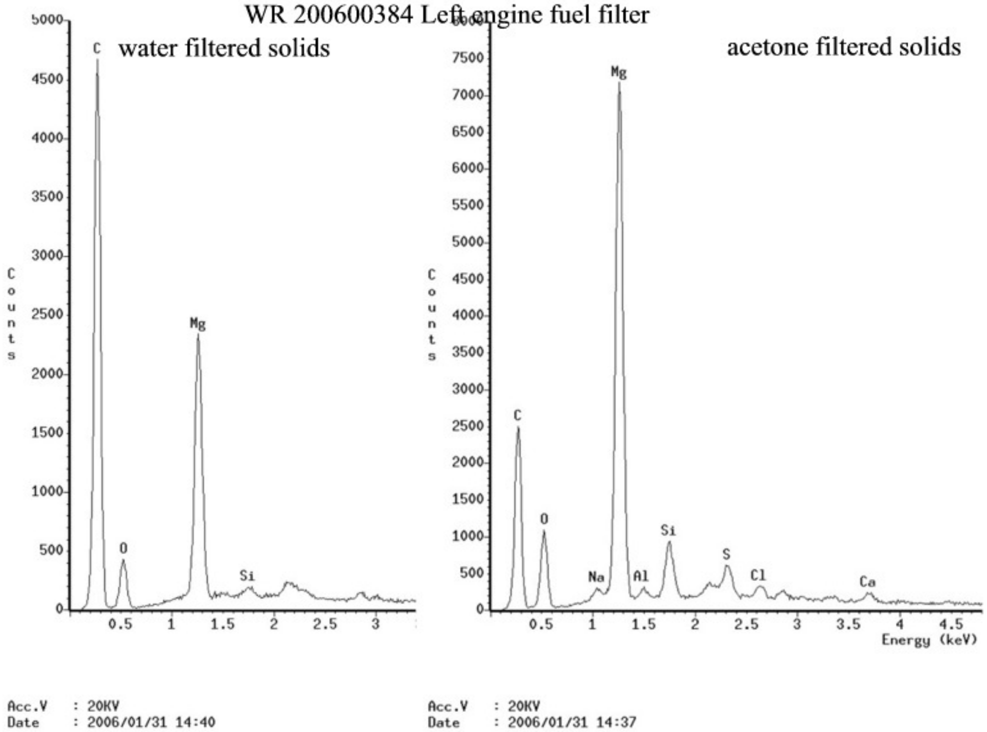
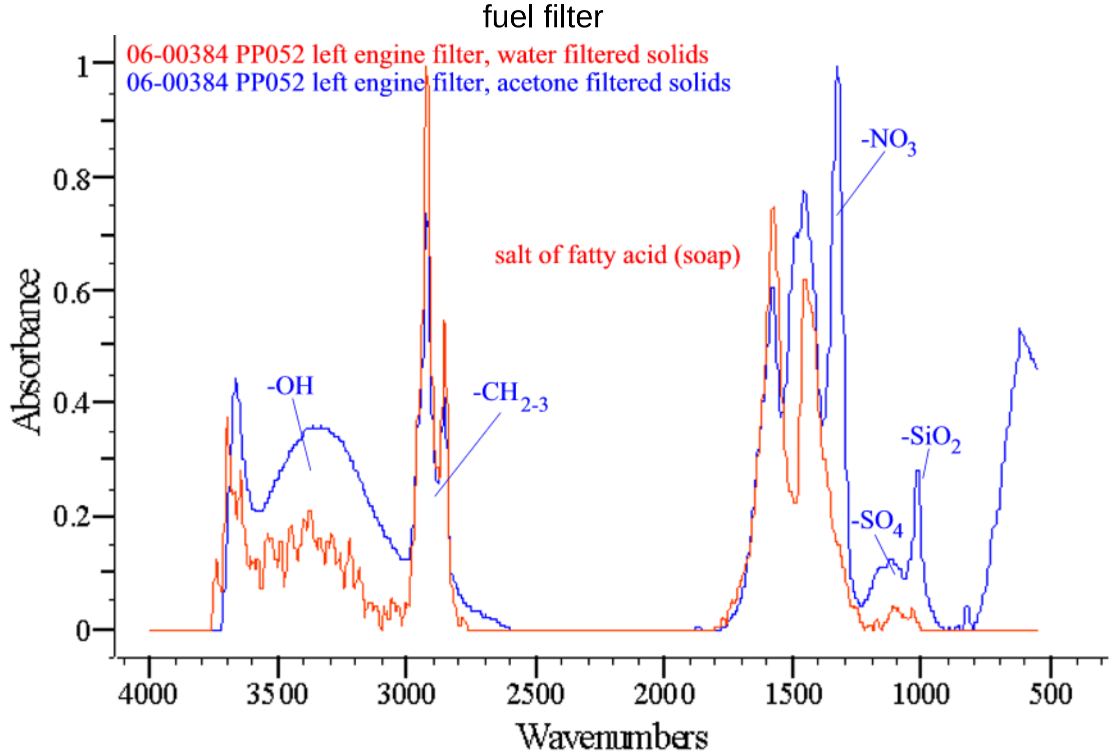


Fig.4 FTIR spectra of the filtered solids from the US Air 737 PP052 left engine fuel filter



SOFRANCE	DOC SUMMARY REPORT	Page : 1

DOC N° : D E 0 0 8	Ind. / *Rev.* 00	Réf. matériel / *P/N* : Main fuel filter element

Titre / *Title* : **Summary of particles size distribution of the contamination found during the analysis of main the fuel filter elements received in 2006**

CHAPITRE / *Chapter*	Page

DIFFUSION INTERNE / *Internal distribution*						DIFFUSION EXTERNE / *External Distribution*	
Recherche et Développement	-	Production	-	Service du Personnel	-	DGA/DPM/SQ	-
Bureau d'Études	-	Méthodes Assemblage	-	Informatique	-	GSAC	-
Études Avancées	-	Méthodes Mécanique	-	Commercial Aéro.	-	FOURNISSEUR/*Supplier*	-
Chef de Projet	-	Assemblage	-	Commercial Industrie	1	**IATA**	-
Laboratoire - Qualification	-	Usinage	-	Support Client	-		
Qualité Opérationnelle	-	Gestion de Production	-	Autres : INTRANET	-		
Qualité Environnement	-	Achats	-		X	**VISA** Client/C*ustomer* ou Fournisseur/S*upplier*	

1. Subject

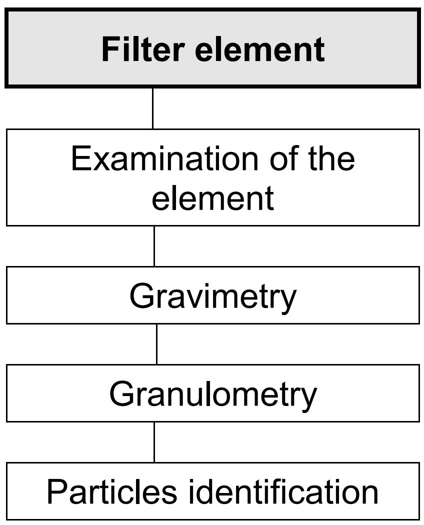
This document presents a summary of particle size distribution found during the investigation performed on fuel filter elements received by Sofrance during 2006.

2. Investigation

RESPONSIBLE FOR THE TESTS :

The investigation is performed at SOFRANCE by the Laboratory Department - Qualification (phone: 05.55.58.50.29).

2.1. Examination sequence



2.2. Analysis of the contamination collected on the element

The contamination is collected from the element by ultrasonic operation during 30 min in an ultra-filtered solvent (contamination class of the solvent : 00).

The cleaning fluid of the element is filtered thanks to a 1,2 µm DMP membrane which has been beforehand weighed, and after drying, weighed again in order to determine the mass of the collected polluting agent.

The size particle and the type of the contamination are determined after the run of a little quantity of the cleaning fluid over a second DMP membrane of 1,2 µm.

Mass of collected pollution *	Particle size distribution by microscope (%)					Major contaminant	Clogging Indication
	[5 - 15[µm	[15 - 25[µm	[25 - 50[µm	[50 - 100[µm	>100µm	Organic mud particles	No
0.071	89.1	6.6	3.2	0.7	0.4	Organic mud particles	Yes
0.738	88.7	7.4	3.4	0.4	0.1	Organic mud particles	Yes
2.001	87.8	8	3.6	0.4	0.2	Organic mud particles	Yes
1.312	88.9	6.8	3.8	0.4	0.1	Organic mud particles	No
2.126	91.9	5.3	2.2	0.4	0.2	Organic mud particles	No
0.459	92.1	4.6	2.2	0.8	0.3	Organic mud particles	Yes
0.047	79.6	9.5	7.8	1.8	1.3	Synthetic fibres	NA
0.442	86.9	7.9	4.3	0.6	0.3	Organic mud particles	No
0.778	92.6	4.6	2.3	0.46	0.04	Organic mud particles	No
1.17	94.1	4	1.4	0.3	0.2	Organic mud particles	No
4.04	94.6	3.96	1.32	0.1	0.02	Organic mud particles	NA
5.31	93.1	4.8	1.7	0.3	0.1	Organic mud particles	NA
4.33	85.6	8.1	5.5	0.7	0.1	Organic mud particles	NA
1.56	84.2	8.5	5.1	1.7	0.5	Mineral mud	NA
0.988	91.9	4.8	3.1	0.18	0.02	Organic mud particles	NA
2.16	92.3	5.2	2.3	0.15	0.05	Organic mud particles	NA
1.26	94.8	3.9	1.24	0.05	0.01	Organic mud particles	NA
3	96.5	2.4	1	0.07	0.03	Organic mud particles	NA
1.31	92.1	6.2	1.5	0.18	0.02	Organic mud particles	NA
1.44	86	7.2	5.6	1.1	0.1	Mineral mud	NA

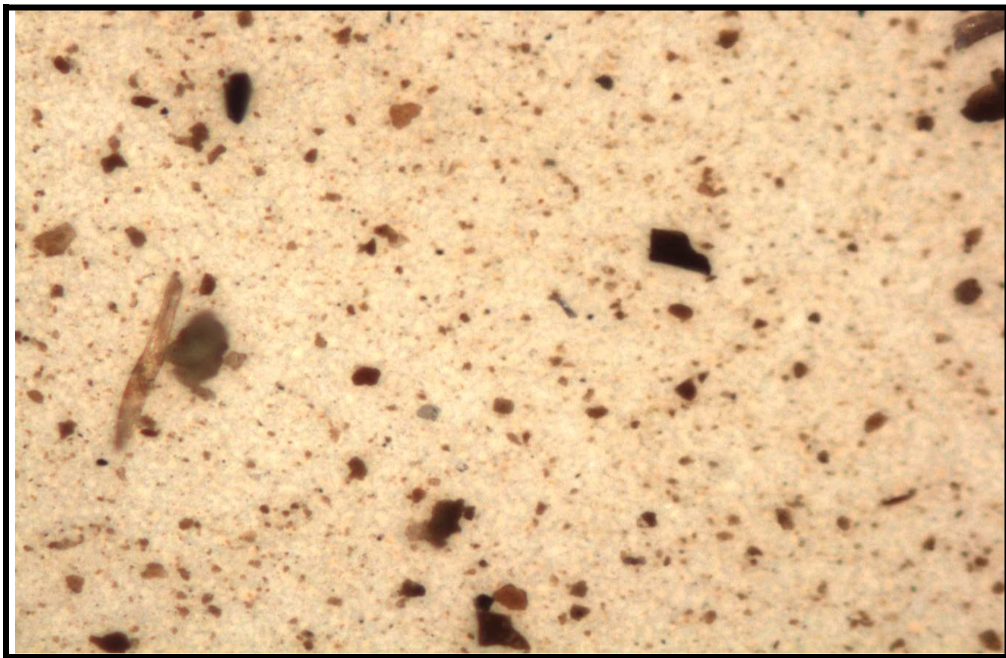
(*) The measured gravimetries do not represent the total of the contamination issued from the element, the ultrasonics operation only enabling the extraction of one part of this contamination

3. Conclusion

Observation taken with microscope of the media showed that the media is clogged with organic mud particles. The reminder of pollution is typical of fuel contamination: metal, oxide, sand, paint…

We can observe a high distribution of contaminants between 5 to 50 µm and principally between 5 to 15 µm.

ANNEX

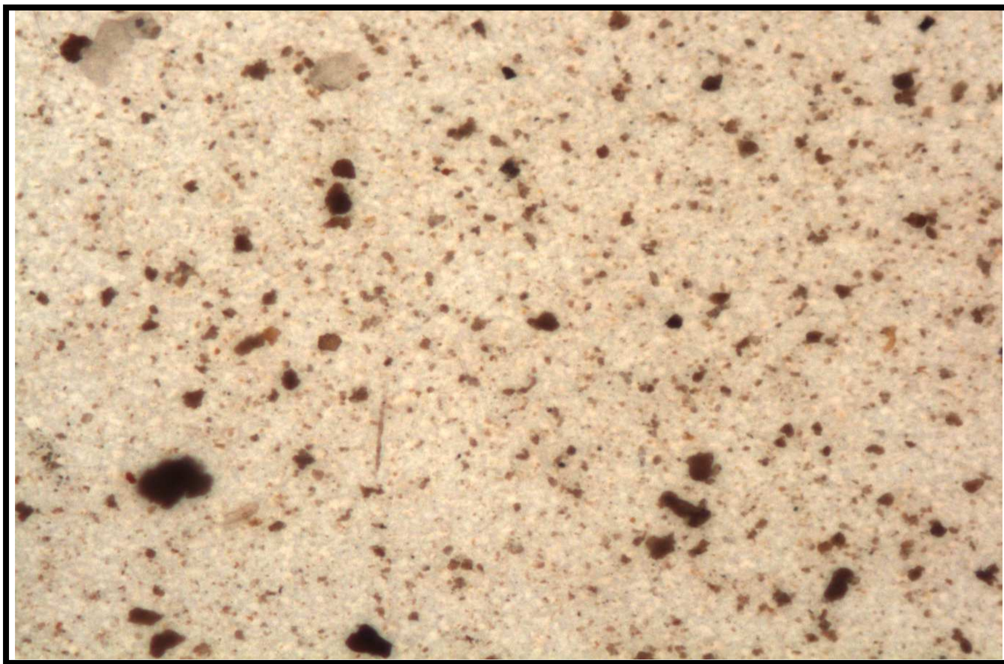


80 % Organic mud particles
10 % Brown mineral particles
5 % Synthetic fibers
3 % White crystals
2 % Metal -metallic balls - metallic salts

Photograph of the membrane Magnification : X 300	Identification of the particles

80 % Organic mud particles
15 % White crystal
3 % Metal
1 % Synthetic fibres
1 % Green particles (it can be paint or sealing product)

Photograph of the membrane Magnification : X 300	Identification of the particles

	90 % Organic mud particles 4 % Synthetic fibre 2 % Translucent balls 2 % White crystals 1 % Metallic particles – chips-metallic oxides 1 % Green particles (it can be paint or sealing products)
Photograph of the membrane **Magnification : X 300**	**Identification of the particles**

	50 % White crystals 20 % Syntetic fibre 20 % Cellulose fibre 4 % Metallic oxidised 4 % Metal - metallic balls - metallic chips 1% Green particles: it can be paint or sealing products 1 % Gels
Photograph of the membrane **Magnification : X 150**	**Identification of the particles**

Development & Laboratories / 23 May 2006 42/LXI

Subject	Aircraft filters
Customer	**Operator S**
Project code	TFIAI3 and T42641

Distribution **Cc**

Appendixes Photos of filters and its parts

Approved (name/position/tel.) Researcher, 010 45 83402

Samples:		**Bar Code:**	
	1. Test filter element 2. OH-LGD fuel filter element		00377956
Date received:	24.2.2006	**Date analysed:**	20-30.3.2006
Analysed by:	Sirpa Nordling		
Task:	What kind of impurities there are on the filters?		
Method(s):	FTIR		

Background information:

The test filter element was similar as the filter element of Operator S MD11 OH-LGD (P/N AC9227F-1740). The test filter system was installed at the refueller, just next to the monitor filter. The subject refueller is supplying jet fuel from airfield reservoir area to airplanes. After the test filter there is only a fluid flow meter, fuel hose and the refuelling connector. About 3 million liters of jet fuel was filtered trough this filter during the test period. The differential pressure over the test filter was monitored, only nominal rise was found. Maximum filtering flow was about 130 l/minute. This refueller (number 6308) is operating only at the air field of Helsinki-Vantaa.

The fuel filter of MD11 (OH-LGD) (P/N AC9227F-1740), had been used for 1169 FH, and was taken to analyse for comparison reasons. About 3 million liters of jet fuel had been filtered trough it. Maximum flow through the element is about 160 l/minute at T/O thrust.

At the same period, 31 of November 2005 to 15 February 2006, as the test filter was installed, the subject aircraft was refuelled as follows:

155 times in Helsinki , 75 times in Bangkok, 20 times or less of refuelling had been carried out in Canton, Shanghai, Hong Kong, Tokyo, Osaka, New York, Singapore and Malaga, all together 90 times.

Analysis and result(s):

The filters were let to dry about two weeks in room temperature. Exactly measured pieces of both the surface filter mesh and pleated filter paper of both filters were taken. The pieces were cut from the middle area of the filters.

Filter mesh and filter paper were extracted with solvent of different polarity starting with non polar heptane, then toluene, chloroform and at last with polar methanol. All the extracts were weighted and analyzed with FTIR.

On the tables below there are the amounts of extracts (mg) as calculated for the whole filters and the compounds identified from extracts:

Extracts of the whole filters (mg):

	heptane	toluene	chloroform	methanol
OH-LGD, filter mesh	126	84	252	147
Test filter, filter mesh	≈ 0	<20	<20	<20
OH-LGD, filter paper	126	84	179	273
Test filter, filter paper	≈ 0	84	42	116

Compounds identified from extracts:

	heptane	toluene	choroform	methanol
OH-LGD, filter mesh	neopentyl glykol- or pentaerytritol ester-oil	sulphonates	sulphonates, sulphonic acids	ammonium sulphates/-sulphonates
Test filter, filter mesh	mainly paraffin wax	sulphonates	sulphonates	sulphates, little epoxy resin
OH-LGD, filter paper	polystyrene, ester compound	sulphonates	sulphonic acids sulphates	ammonium sulphates /-sulphonates
Test filter, filter paper	mainly paraffin wax	sulphonates	bisphenol-A-epoxy resin, little sulphonates	bisphenol-A-epoxy resin, little sulphonates / sulphates

Summary:

1. Amounts of some extracts are very low but in every case some compounds have been identified.
2. Only very small amounts of material had been filtered on the filter mesh of test filter. Respectively the amounts were considerably higher on the filter of MD11 OH-LGD.
3. The amounts of the impurities on the paper filter of OH-LGD are considerably higher than on the test filter.
   An epoxy resin was found clearly on the test filter but not on the filter of OH-LGD. Could this resin be a binding agent of that element?
4. Sulphonates, sulphonic acids and sulphates could be found in the different extracts. The cation part is not always known. A detailed organic structure of these sulphur compounds is not known.
5. Plenty of ammonium sulphonates and sulphates were found in methanol extracts of OH-LGD.
6. Ester oil found in an extract of OH-LGD must be an oil of this aircraft.
7. Polystyrene found on the filter of OH-LGD is difficult to explain.
8. In photos enclosed can be seen how dirty/clean filters are.

Conclusions:

1. Amount of impurities on the test filter is very low.

2. Amount of impurities on the filter of OH-LGD is clearly higher than on the test filter.

3. Main impurities are sulphonic acids, sulphonates and sulphates, <u>no</u> potassium.

Hypothesis:

1. Jet fuel of Neste Oil does not contain abnormal amounts of sulphonic acids, sulphonates and sulphates.
2. Foreign jet fuels contain more sulphonic acids, sulphonates and sulphates?
3. Formation of sulphonic acids, sulphonates and sulphates take places mainly in the plane?
4. Heating of jet fuel in the aircraft accelerates oxidation of sulphur compounds? (Ref. IDG Oil cooler/ Fuel heater at MD11 CF6-80 engine)
5. The difference between the two filter elements was very clear, and could not be explained by any difference at the installation, the flow used etc.

P/N AC9227F-1740 P/N AC9227F-1740

Photo 1. Filters

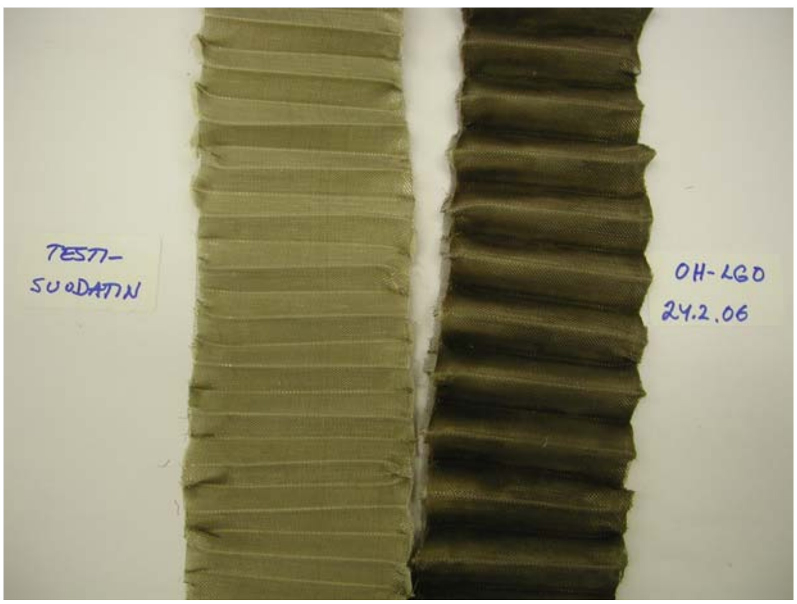


Photo 2. Filter mesh + paper filter

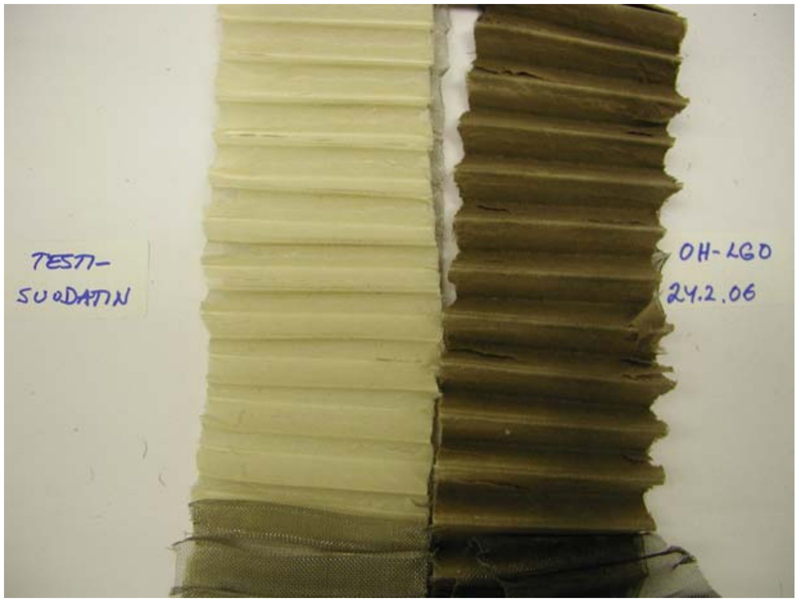


Photo 3. Paper filter

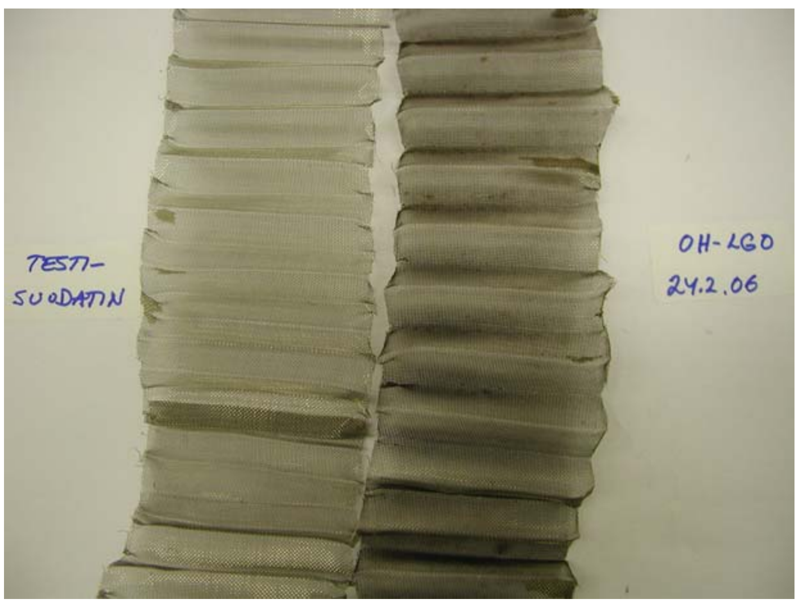


Photo 4. Filter mesh

Task Force - Purpose

To understand if filter monitor media is migrating to commercial aircraft, to identify mitigation procedures reducing associated risks faced the airlines, to develop an approach and communication link with Aviation Authorities on this matter.

Comments

1. In response to recent engine fuel filter clogging events, air carriers have instituted more frequent filter change intervals. They have identified traces of fuel filter monitor media (Supper Absorbent Polymer) migration on transport airplane engine fuel filters.

2. The cause of the increased engine fuel filter impending bypass warning indication primarily on GE/CFMI engines, has been identified as the tighter mesh manufacturing requirements by comparison to the equivalent on other manufacturer engine filters.

3. The engine fuel filter element inspections have revealed debris and contaminations mostly by particles not associated to an aircraft design (iron sulfide, sulfites, sulfates, sulfur oxides), as well as traces of fuel filter monitor media (SAP).

4. The SAP travels with and sometimes is attached to the debris and contamination. The sizes of most common debris found in the filters have size equal or less than five microns.

5. There has never been a report of fuel filter clogging attributed solely to SAP contamination.

6. Analyses of Millipore tests conducted by fueling service providers have revealed the presence of SAP water-absorbent media. These tests contacted by the industry as part of the action items established after the May 31, 2006 industry’s meeting at Houston, Texas. The release of SAP, water absorbent media, is found at various stages, regardless of the fuel quantity passed thru the filter monitors. Also, the Millipore test data has identified and indicated normal filter monitor differential pressure.

7. The jet fuel specification is established by the American Society for Testing and Materials (ASTM) specification D-1655. This is a consensus standard committee with a membership made up of Airframe and Powerplant manufacturers as well as other industry experts. However, the aviation fuel specification used by air carriers is regulated by the operational requirements established, and listed in each of the engine manufacturer's service bulletins.

8. Aviation fuel quality and cleanliness, as well as eliminating fuel contamination, is currently the responsibility of the airlines who establish procedures for handling and dispensing of their fuel under the authority given to them by 14 CFR 121.135, paragraph (b) (18) and EASA Part M, subpart C, AMC M.A.301-1(c).

9. The SAP migration is generated from ground fuel filtration units commonly known as 'Fuel-Flow Monitors' or 'Water-Absorbent Filters' operated by an airline or a consortium of airlines, contracted fuel service providers in the US or oil companies elsewhere in the world.

10. The fuel filter monitor's operational design specification requirements are to not contaminate the fuel and remove any possible traces of water and debris escaped downstream by water separators or other filtration devices in the airport fuel distribution system. They have not been designed to be the primary and the only water removal device from the fuel at the fuel farms or the airport distribution systems. Refer to IP 1883 specification document paragraph 1.7.2.1 "Performance Features".

11. The current airport fuel dispersing units are not equipped with a filtration or ultra sensitive contamination detection devices to prevent fuel contamination (such as SAP) from entering the airplanes fuel tanks.

12. There are no specific dispersing requirements for fuel anti-icing, like FSII, or any other fuel additives that may contribute to the decomposition of the filter monitor media, and release SAP downstream of the fuel filter monitors. Some of the fuel additives, like FSII, are approved by ASTM-D 1655 and DEF STAN 91-91 fuel specification but not the location of their injection into the fuel.

13. Although the maintenance of fuel quality and cleanliness requires constant attention by everyone concerned with the handling and distribution of aviation fuel, in order to prevent contaminations (such as with SAP), the airport certification manual (ACM) checklist section 321, addresses only fuel Hazmat requirements and has omitted quality and cleanliness.

14. The AC 150/5230 that identifies standards and procedures for storage, handling and dispersing of aviation fuel on airports, pertains only to fire safety and storage. It excludes fuel quality and cleanliness that are essential requirements. Refer to Flight Standards Information Bulletin for Airworthiness (FSAW 06-04)

15. The AC 150/5230 refers to National Air Transportation Association (NATA) publication for refueling and quality procedures. It does not refer to the aviation fuel filter monitor specification of the worldwide industry approved publications; Joint Industry Group's (JIG) Guidelines for Aviation Fuel Quality & Operating Procedures for Airport Depots and Joint Into-Plane Fuelling Services, IATA's Guidance Material for Aviation Turbine Fuel Specifications and ATA Specification 103-Standard for Jet Fuel Quality Control at Airport that are currently used by air carriers and air operators. EI/IP 1583 should be maintained by the EI organization until all investigations, research and possible developments are completed.

16. The fuel filter monitor manufacturers should work together to possibly improve their designs or research and develop another water absorbent type of element that will eliminate the release of monitor media (SAP), or replace this design type of water absorbent media.

17. For your reference, listed below are the regulatory documents that possible affected by the subject issue and need clarification and/or revision:
    a. 121.105 (proper servicing)
    b. 121.123 (proper servicing)
    c. 121.135 (b) (18) (eliminating contamination)
    d. 121.635 (dispatch from regular airports)
    e. 121.639 (enough fuel) (regardless the fuel specification, quality or cleanliness)
    f. 121.645 (same as 121.639)
    g. 139.201 (Airport Certification Manual) (no reference to fuel specification, quality or cleanliness)
    h. 139.203 (Airport Certification Manual) (no reference to fuel specification, quality or cleanliness)
    i. 139.321 (protection of persons and property during handling and storing hazardous material) (no reference to fuel specification, quality or cleanliness)
    j. EASA Part M, subpart C, AMC M.A.301-1(c)
    k. CAA, CAP 748
    l. CAA, The Air Navigation Order, Article 137

18. IP 1583 Performance Specifications for Water-Absorbing Monitors allow an average solids transmission rate of 0.3 mg/liter (1.1 mg/U.S. Gal) average; 0.5mg/liter (1.9 mg/U.S. Gal); free water limit is 15 ppm (v);Media Migration Rate of 10 fibers/liter
19. An alternate water absorbent filtration method is to use filter water separators on the fueling equipment. If the existing fueling equipment is designed to fit filter water separators, service providers should install the water separators at next fuel filter monitor change period. However, the industry should provide to the airlines adequate assurance that this modification will not restate the pre-fuel filter monitor era with surfactant releases and microbial growth contamination issues.

Recommendations

1. A sensitive aviation fuel contamination detection system should be developed, and thoroughly tested prior to its implementation. It should be able to interrupt and possibly shutdown the airplane's refueling process.

2. An aviation fuel filtration device should be developed, and thoroughly tested prior to its implementation. It should be able to capture and hold debris and contamination that is no greater than five microns without restriction to the refueling process flow. It should also include the capability of interrupting and possibly shutting down the airplanes refueling process. The preferred location of such a device should be prior to the airplane's refueling adaptor.

3. A committee should be established that will be responsible for overseeing the developments and define the standard by which to evaluate requirements for fuel quality and cleanliness at or before the airplane's fuel tanks. This development should include evaluating the benefits of further industry actions as well as the potential costs of achieving such actions.

4. Listed below are some of the affected documents that the committee should consider examining and possibly revising in order to enhance fuel quality and cleanliness at the airport depots, distribution systems, and airplane tanks:

   a. Based on the current industry's knowledge regarding aviation fuel and it's powerlessness (inability) to eliminate specific contaminations, the FAR 14 CFR, 121.135, paragraph (b) (18) and EASA Part M, subpart C, AMC M.A.301-1(c) regulations should be revised accordingly.

      Note: Example of an acceptable statement is: "*The uplifted fuel on an aircraft should be in accordance with the engine manufacturer's specification, quality and cleanliness requirements.*"

   b. AC150/5230 should be revised to state in the applicability section that the aviation fuel requirements should be in accordance with the aircraft engine manufacturer's specification, quality and cleanliness requirements.

c. AC150/5230 should be revised to include the worldwide industry approved publications; Joint Industry Group's (JIG) Guidelines for Aviation Fuel Quality & Operating Procedures for Airport Depots and Joint Into-Plane Fuelling Services, IATA's Guidance Material for Aviation Turbine Fuel Specifications and ATA Specification 103-Standard for Jet Fuel Quality Control at Airports that are currently used by air carriers and air operators. Also, the SAE G16 specification that is currently under development should be mentioned since it will harmonize the worldwide specification requirements.

d. The CAA, Air Navigation Order, Article 137, should add a note to clarify the current wording for the aviation fuel "fit for use".

Note: Example of an acceptable statement is: "*The uplifted fuel on an aircraft should be in accordance with the engine manufacturer's specification, quality and cleanliness requirements.*"

5. The harmonization of any action with US and non-U.S. regulatory authorities before a new requirement is proposed is essential for its adaptability and overall benefit for the airlines and the affected aviation fuel companies.

6. Diligence at airport Fuel Farms, Distribution and Dispensing systems should be maintained by the fuel supply and distribution industry in order to achieve the maximum aviation fuel quality and cleanness, as well as maintaining the required fuel specifications.

7. If the committee should determine that there is an urgency to take a regulatory action, the proposed rule should be redefined to require practical measures to limit possible airline flight operation disruptions due to fuel supply or distribution interruptions.

Participated Airlines

Air Transport Association
American Airlines
British Airways
Continental Airlines
Finnair
Frontier Airlines
Japan Airlines
Lufthansa
MyTravel
Southwest Airlines
US Airways

Oil Company– Final Report – 16 December 2006
IATA Fuel Filter Monitor Task Force

Participants:

BP, Chevron, ConocoPhillips, ExxonMobil, Shell

Scope:

Oil companies are focused on answering the following items per this task force's Terms of Reference.

1. Determine if the filter monitor media is migrating to commercial aircraft.

2. Identify mitigation steps if SAP migrates that assist the airlines in reducing associated risks.

Not included in scope of the IATA task force: any initiatives of the American Petroleum Institute (API) or the UK Energy Institute (EI) to address SAP migration.

Assessment:

We concur with the task force findings that the filter monitor media, super absorbent polymer (SAP) is at times migrating to commercial aircraft. However, there is no conclusive data identifying the extent of migration and the mechanism is still not fully understood.

- We recognise that the SAP was a very small part of the total material found on aircraft filters. We also know that:
  - The amount of SAP appeared too small to play a significant role in aircraft filter clogging.
  - The SAP was found as discrete translucent particles.

- We recognise that SAP is not a chemical found in the manufacturing of jet fuel.

- We recognise that SAP is a malleable chemical and unlikely to directly cause abrasive wear.

- We recognise that SAP should be considered as a fuel contaminant, that it appears to behave like the generally accepted and controlled dirt contaminant, but has not specifically been approved.

- We recognise that the following parameters may increase SAP migration from filter monitors:

- Operation-

1. Use of monitors at high dPs may cause media migration
2. Deviating from filter manufacturer's recommendations

- Manufacturer – there are at least 3 different manufacturers of filter monitors who use differ materials, processes & designs for making filter monitors
- Filter monitor type – 3 types of filter monitors (2", 6" in-to-out, and 6" out-to-in) are used in aviation. The 6" designs contain much more SAP than the 2" designs. It is more difficult to constrain the SAP in the in-to-out flow design than the out-to-in.
- Flushing protocols when putting new monitors into service.
- Fuel type – FSII-water mixture can extract SAP

Recommendations:

We support broad-based approaches for mitigation as detailed below but also recommend that IATA organize a new task group to determine if media migration can be correlated to any of the above parameters, which could lead to efficient mitigation.

Based on the assessment above, we recommend the following for mitigation.

1. Modify Filter Monitor Manufacture
The finding that SAP was found on Millipore filters downstream of elements has been communicated to filter monitor manufactures with a request that they evaluate the cleanliness of their manufacturing procedures and improve them to comply with IP 1583 5th edition. Note: IP 1583 5th edition has a zero SAP migration tolerance.

2. Use of Particle Detection Technology

a. Oil company industry associations, specifically the Energy Institute, are developing particle counter/detection technology and encourages all stakeholders to support and participate with the development. This standard is filed as IP 1550.

b. Into-plane companies (non-oil companies) should also evaluate the use and installation of this technology.

3. Use of Alternate Filter Equipment
Individual oil companies and into-plane companies (non-oil companies) should risk assess the use of alternate approved non-SAP containing filter equipment for their operations.

The individual oil companies and into-plane companies (non-oil companies) should assist the filter manufacturers in assessing new SAP-free technology that can be fitted to existing filter monitor vessels.

4. Equipment Selection

Individual oil companies and into-plane companies (non-oil companies) should assess the use of filter monitors and where possible select the construction and flow format that reduces the risk of media migration. Adopt 5th edition elements as they become available.

5. New Equipment

Recommend that all new refuelers and hydrant servicers are designed to reduce or remove the risk of SAP media migration.

6. Modification of Airport Fuel Handling Standards

Revise documents used to define acceptable fuel quality such as the a) Joint Industry Group's (JIG) Guidelines for Aviation Fuel Quality & Operating Procedures for Airport Depots and Joint Into-Plane Fuelling Services, b) IATA's Guidance Material for Aviation Turbine Fuel Specifications and c) ATA Specification 103-Standard for Jet Fuel Quality Control at Airport.

a. Add specific language regarding the appropriate introduction of Fuel System Icing Inhibitors (FSII) in jet fuel. Add further procedures covering filter requirements especially more restrictions with regards to the use of 6" monitors, that are in-to-out flow. Include an unequivocal statement that FM's SHALL NOT be exposed to fuel containing FSII.

b. Add cautionary statements on filter monitor SAP migration.

c. Include statements that equipment used on-airport should not only comply with standards defined by aviation industry bodies such as API and EI but that equipment manufacturers also have responsibility to ensure that any leaching or release of trace impurities from their equipment does not contaminate the fuel and fuel properties shall remain within the prescribed limits of the relevant fuel specification.

d. Add procedure for flushing newly installed filter monitor elements.

   An acceptable approach is for equipment manufacturers to implement a management of change procedure to evaluate the impact of trace impurities on finished product quality and on aircraft systems. Other approaches may also be acceptable to the airline and/or aircraft system manufacturers.

7. We recognise IATA's efforts in developing a new harmonized airport fuel handling standard through SAE's G-16 committee. This committee should also include similar fuel quality descriptors suggested in #6 above.

8. Compliance to Airport Fuel Handling Standards
We recommend that airlines include all or most of the Airport Fuel Handling Standards listed in the above list in contractual agreements with their into-plane agents and fuel suppliers. This would reinforce the civil aviation authority's confidence of industry's ability to control requirements on aviation fuel quality and handling.

Closing Remarks:

We thank IATA for the opportunity to finance many of the aircraft fuel filter analysis used to determine if super absorbent polymer (SAP) was present on commercial aircraft fuel filters.

We also thank the Task Force Chairman, George Zombanakis from Continental Airlines, for his enthusiasm and diligence in coordinating the task force's work.

Into-Plane Fuel Service Providers Report
Fuel Filter Monitor Task Force

Three Major Into-Plane Service Providers, Allied Aviation, ASIG and Swissport Fueling participated in and contributed information to the IATA Fuel Filter Monitor Task Force. The information gathered by the into-plane Companies is as follows:

Inbound Filtration

The majority of the fuel facilities that ASIG, Allied Aviation and Swissport Fueling have the following for inbound fuel filtration into storage, Micronic elements, Clay Treater and Coalescer/Separator elements.

ASIG reported that two stations are also using Hay Packs and one station is using Salt Dryers at the fuel receiving station.

The remaining fuel facilities are using only Coalescer/Separators elements for filtration. None of the three participants are using fuel filter monitors for inbound filtration.

Outbound Filtration

All of the fuel facilities that Allied Aviation and Swissport Fueling operate utilize Coalescer/Separators for outbound filtration to either a truck reloading facility or a hydrant system. ASIG reported one fuel facility, Bradley International Airport (BDL) is using fuel filter monitors for outbound filtration.

Refueling Equipment Filtration

The majority of ASIG, Allied Aviation and Swissport Fueling locations are using fuel filter monitors as their primary filtration. Filter Coalescer/Separators are also used but mainly in older model mobile tanker equipment and motorized hydrant vehicles. Note, some of the older vehicles have been converted to fuel filter monitors. On all the mobile tanker equipment purchased by the Port Authority at EWR & JFK Coalescer/Separators elements, water detection probes and fuel filter monitors are utilized. The majority of the motorized hydrant vehicles have Coalescer/Separators with the exception a select few that have fuel filter monitors, at the terminals where Operators are serviced.

Slow Rate Fueling

Allied Aviation and Swissport Fueling reported NO slow flow fueling with fuel filter monitors. All fuel filter monitors are flowed at normal rate.

ASIG reported that one location does flow at a slow rate but does not use FSII (Fuel System Icing Inhibitor).

FSII with Fuel Filter Monitors

ASIG, Allied Aviation and Swissport Fueling reported there was no use of FSII with fuel filter monitors at their facilities.

Fuel Tested for FSII

Allied Aviation and Swissport Fueling have conducted testing on the fuel in their fuel facilities using a B/2 Test Kit for detecting FSII. These tests did not detect presence of FSII.

ASIG to date has not conducted testing at their fuel facilities for FSII.

Differential Pressure Readings

ASIG, Allied Aviation and Swissport Fueling reported NO abnormal filter differential pressure readings.

Nozzle Screens

ASIG, Allied Aviation and Swissport Fueling reported NO traces of SAP (Super Absorbent Polymer) in the nozzle screens. The nozzle screen is 100 mesh and would only capture a 150-micron particle. The largest particle of SAP that has been found in an aircraft fuel filter is 5 microns.

Filtration Diagrams

Allied Aviation and Swissport Fueling provided Filtration Diagrams for their respective fuel facilities and into-plane operations showing the receiving filtration facility, dispensing filtration facility and refueling equipment filtration, which included filter element model numbers.

ASIG provided Filtration Diagrams for the majority of their fuel farms and into-plane operations showing the receiving filtration facility, dispensing filtration facility and refueling equipment filtration, which included filter element model numbers. Additional data will be added to the report, as it becomes available.

Millipores

All three major Into-Plane Companies, Allied Aviation, ASIG and Swissport Fueling agreed to provide millipore samples for testing of SAP. Southwest Research Institute will be the prime laboratory for the testing.

Swissport Fueling submitted six millipores for testing and the test results showed small traces of SAP on one of the millipore samples. The remaining five millipores were tested with no findings of SAP being present. The millipore that did show small traces of SAP was taken from a stationary hydrant cart where the Monitors were recently replaced. 2,896 gallons were flowed through the cart prior to the collection of this one- (1) gallon millipore sample. The Monitors that were installed are a six- (6) inch cartridge with an outside-in flow.

Allied Aviation and ASIG are in the process of providing millipores to Southwest Research Institute. ASIG has provided 32 millipores to Southwest Research Institute. The results of the testing will be available in the near future.

Fuel Service Providers (FSPs)

Commercial Into-Plane and Maintenance & Operations Fuel Service Providers (FSPs) are employed at the discretion and under the direction of Commercial Passenger and Cargo Air Carriers (Airlines) or through agreements with Consortiums, Committees, and Suppliers. As such, the FSPs serve as “agent-of” the certificated Airline thereby extending all of the airline’s FAA-approved fuel handling, storage, and delivery practices and procedures to the vendor. In addition to each Airline’s specific Fueling Manual, the FSPs may also be governed by myriad QA/QC specifications (ATA 103, JIG, CASE 2A, etc); industry standards (NFPA, IP, API, ASTM, etc); and Federal, State, local, and airport laws, regulations, and ordinances.

Contractual obligations generally exist between the FSP and the contracting Airline and between the FSP and the airport in the form of operating agreements/licenses. Fuel quality criteria are dictated solely by the contracting airline. Generally, the FSP will provide services to a number of varied customers. Accordingly, the FSP will likely adopt the most stringent quality/performance standard in order to ensure its compliance with this standard, as well as with all lesser, similar requirements.

FSPs are charged with ensuring that fuel receiving, storage, and distribution facilities and equipment meet or exceed the minimum requirements and specifications. The FSP will order and receive fuel as specified by the airlines. The FSP will also conduct limited sampling and analysis of fuel during receipt, however, pursuant to existing quality standards the impetus is on each supplier to provide full certification of the quality of their fuel, respectively. In some instances, the FSP may be required to re-certify received fuel. Recertification testing is generally limited to items listed in the specification and anticipated cross-contaminants. After receipt, the fuel will be handled in accordance with the prescribed methods of the contracting airlines. Likewise, fuel will be delivered into aircraft based upon each customer's specific operating procedures for each type aircraft.

Regarding fuel filter media migration, conventional wisdom holds that mobilization of the contaminant (SAP) may be due to several contributing factors: 1) additives in fuel, 2) manufacturing dust, 3) sub-par filter performance, and 4) excessive pressures. With the exception of excessive differential pressure, there are currently no obligations or requirements for the FSP to monitor or manage any of these issues. While it may be simple enough to accomplish, neither the industry nor the Airlines have stipulated any mitigation measures beyond the traditional scope of work and/or contractual terms and conditions.

Recommendations

- ATA 103 does not dictate specific types of filtration to be used for the receiving or dispensing filtration. (Micronics, Clays, Coalescer/Separator, Hay Packs, Salt Dryers and Fuel Filter Monitors) The Airlines and the Airline Energy Committee need to modify ATA 103 to specify filtration and Quality Assurance Standards.

- The Airlines and the Air Transport Association Fuel Committee need to work with airports to insure that certain Filtration Systems and Quality Assurance Testing are incorporated at all Airports in the Operating Agreements for the Maintenance and Operations and Into-Plane Operators.

- In a standard time frame operators should perform B/2 refractometer test for FSII. Spot checks for corrosion inhibitors and drag reducers might also be advisable. Defueling procedures should be evaluated to minimize the possibility of off-loading FSII-containing fuel into tankers utilizing fuel monitors.

- To truly understand at what point SAP dust no longer migrates from newly installed fuel filter monitors, additional testing will need to be performed. A standard flushing procedure should be developed requiring a specific amount of fuel to be passed through the fuel monitors before they are put into service to prevent SAP dust from migrating from the elements into the aircraft systems.

- Currently only the Copper Sulfate test is available to detect SAP. Additionally other quality assurance tests for the detection of SAP should be researched.

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