AIRLINES MUST WORK WITH THEIR FUEL SUPPLIERS TO ENSURE THAT LOCAL FUEL HANDLING PROCEDURES ARE BEING FOLLOWED.

Engine Fuel Filter Contamination

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Dirty fuel is the main cause of engine fuel filter contamination. Although it's a difficult problem to isolate, airlines can take steps to deal with it, including auditing fuel suppliers to ensure that they are following applicable fuel handling requirements and replacing engine fuel filters more often.

Fuel contamination can take many forms, but the result is often the same: a fuel filter bypass indication that may cause delays if the pilot elects to return to ground or divert to have the fuel filter inspected or replaced. This article addresses contamination of the engine fuel filter.

BACKGROUND

In 2003, the International Air Transport Association (IATA) Technical Fuel Group formed a team comprising airlines, airframe manufacturers, and fuel suppliers to study the reasons behind an increase in the number of reported fuel filter impending bypass indications and more frequent filter replacements being reported by airlines. The team examined many reports of contaminated fuel filters but could not determine a single cause of the problem. The majority of the fuel filters examined were filled with silicates (i.e., dirt), sulfates, iron oxide (i.e., rust), and salts (see fig.1). The team could not draw a specific conclusion but suspected that the contamination was being uplifted with the fuel. The team also suspected that the fuel technically would pass the ATA 103 fuel handling specification for cleanliness.

An impending bypass indication will show when the differential pressure switch in the engine fuel filter is actuated (10.5 to 12.5 pounds per square inch on the CFM53-3 engine). On the Boeing 737, the FILTER light on the P5-2 panel and MASTER CAUTION indicator will illuminate when this differential pressure switch is actuated. The Boeing 757, 767, 777, and 747-400 will show an engine fuel filter message on the Engine Indicating and Crew Alerting System.

FUEL FILTER BYPASS INDICATION

Fuel filter bypass indications are required by the Federal Aviation Administration (FAA). In its publication *Airplane Turbofan Engine Operation and Malfunctions — Basic Familiarization for Flight Crews,* the FAA explains, "If the fuel filter at the engine fuel inlet becomes clogged, an impending bypass indication will alert the crew for a short while before the filter actually goes into bypass."

The filter and indication system are designed so that the mission can be completed under normal levels of particulate contamination in the fuel. Most impending bypass indications occur during the takeoff roll or climb because this is the phase of flight that typically has the highest fuel flow through the filter, and greatest delta pressure across the filter.

If a flight crew receives a fuel filter bypass indication during a flight, procedures do not

CONTAMINATION TRAPPED BY A FUEL FILTER
Figure 1

A visual inspection of a fuel filter reveals a variety of contaminants.

CONTAMINATED FUEL FILTER CAUSES LOSS OF POROSITY
Figure 2

When the engine fuel filter medium becomes clogged with contaminates, it loses its porosity, leading to a fuel filter bypass indication. This filter medium is loaded with silicates and sulfates.

The individual particulates found on fuel filters are very small, often less than 1 micron in size. However, these particulates become bound together on the filter medium and filter screen.

specifically call for a diversion or return to airport. It is up to the flight crew to return to ground, divert, or continue with the flight. If there are adequate alternate airports along the route of flight, and only a single engine fuel FILTER BYPASS light is illuminated, with no abnormal operation, the captain may make the decision to proceed with the flight. A fuel FILTER BYPASS light with any abnormal engine operation should be cause for a diversion. In addition, an immediate diversion should be performed if *both* engine bypass lights are illuminated or have illuminated during the flight.

In any case, it's important to keep in mind that the alert is an *impending* bypass indication: the filter can still handle several more grams of material before the bypass valve opens and it is unlikely an actual filter bypass would occur during that flight. At this point, if contamination gets past the filter, it is possible for the engine to shut down. However, Boeing has not had any reports of an engine shutdown due to dirt contamination.

ENGINE FUEL FILTER OUTER SCREEN AT 30X MAGNIFICATION
Figure 3

This filter screen is contaminated with particulates and a gum residue.

MICROBIAL CONTAMINATION IN A WING TANK
Figure 4

The brown-black debris on the bottom of this tank is made up of fungus and bacteria. Fuel microbial growth can clog fuel filters, causing the airplane fuel quantity indication system to read incorrect values, and eventually cause structural corrosion of the aluminum stringers and wing skin. Operators can greatly reduce the chance of microbial growth by draining water from airplane fuel tanks weekly and by testing for microbes annually.

SOURCES OF CONTAMINATION

Contamination can enter the airplane wing from either the uplifted fuel or through the fuel vent systems. Atmospheric dust storms could be contributing to filter contamination; however, Boeing has been unable to correlate engine fuel filter blockage with any airplane pneumatic system problems due to dust storms. If dust storms were contributing to filter contamination, Boeing would expect problems with the airplane bleed system or environmental control system packs.

The individual particulates found on fuel filters are very small, often less than 1 micron in size. However, these particulates become bound together on the filter medium and filter screen. Boeing believes that the sulfates, such as calcium sulfate dihydrate, which are water soluble and polar, are helping to bind these very small particulates together, preventing the material from passing through the filter. Filtration used in fuel uplift vehicles is typically between 0.5 and 1 micron absolute.

Locating the source of engine fuel filter contamination can be very difficult. If an airport is in the process of building or modifying a fuel hydrant system, airlines should ensure that the system is properly flushed before it is put into use. Large quantities of relatively large particulates are an indication that the filtration at an airport is not adequate.

CATEGORIES OF CONTAMINATION

An IATA Technical Fuel Group team is working to standardize the testing procedures for contaminated fuel filters. This procedure will be available from IATA later this year. One of the key efforts in this standardizing testing procedure was to categorize the types of contaminates found on a fuel filter. The IATA team has classified four categories of contaminants:

Category 1: Foreign Objects. This category is for any material found on the filter from a maintenance activity or degradation of the airplane or ground fuel system. Foreign objects include paint chips, paper, aluminum chips, sealant chips, composite materials, and O-rings and gasket materials (see figs. 2 and 3).

Category 2: Clays and Rust. Clays and dirt comprise very fine particulates that are black, brown, or reddish in color. They are most often associated with dirt in uplifted fuel. Poor filtration processes at airports is the most common source of the dirt. Rust is associated with oxidation of steel piping in either the uplift vehicle or the airport fuel distribution system.

Category 3: Gumlike Residues. This category is for shiny, slimy, jelly-like materials, including microbial contamination and oil and coke deposits (see fig. 4).

BOEING FUEL FILTER MAINTENANCE RECOMMENDATIONS
Figure 5

These are the official Boeing recommendations for scheduled maintenance for fuel filters, as cited in the relevant Maintenance Planning Data manual.

AIRPLANE MODEL	RECOMMENDED FUEL FILTER MAINTENANCE
717	No interval or check established
737 Classic	1C Check
Next-Generation 737	Fuel filter replacement at 6,000 flight-hours (FH)
747-400	Fuel filter replacement at 7,500 FH or 18 months (whichever comes first)*
757	Fuel filter replacement at 3,000 FH
767	Fuel filter replacement at 3,000 FH
777	Fuel filter inspection at 2,000 FH

Category 4: Unknowns. This category includes anything not listed in the first three categories. These materials may require additional laboratory procedures to identify.

Almost every filter examined by Boeing and other laboratories contains the following contaminates:

- Silicates, including clay and dirt with very small particulate sizes.
- Sulfates.
- Salts, primarily sodium chloride and potassium chloride.
- Iron oxides (rust from steel).
- Aluminum chips (due to fuel tank maintenance).
- Tank primer (due to fuel tank maintenance).
- Fibers (from rags left in the tank).
- Trace elements such as magnesium contained in soil.
- Microbial contamination.

Less frequently, filters contain the following contaminates:

- Grease.
- Glycols from cleaning fluids or wing de-icing fluids.
- Polymer from airport water monitors. (This polymer has been found on a number of engine fuel filters, but it is not known whether it has caused any problems with the engine fuel system.)

IMPROVED METHODS ON THE HORIZON

For many airlines, the current fuel filtration methods at airports are not adequate to prevent airplane fuel filter contamination for the replacement interval recommended by engine manufacturers. But new technologies are emerging that will provide more accurate assessments of the amount of particulates and water in uplifted fuel.

For example, in-line optical devices may be able to alert operators to potential problems with fuel contamination before the fuel is pumped into the airplane. These devices measure the index of refraction: if the fuel contains particulates or water, the index of refraction changes and the system will notify the airport ground crew to take action. It is anticipated that optical devices could detect particulates a few microns in size while fuel is

AIRPLANE MODEL	RECOMMENDED FUEL FILTER MAINTENANCE
DC-8	1C Check
DC-9	1C Check
DC-10	General Electric: No Interval — Fuel Filter Bypass "Clog" Indication System determines filter change Pratt & Whitney: 2A Check*
MD-11	1C Check
MD-80	1C Check
MD-90	1C Check

*Every 150 hours for the first 1,000 hours following airplane delivery or major airplane fuel tank repair.

flowing to the airplane. It may take several more years before this new equipment is installed at the majority of airports.

RECOMMENDATIONS

Because many instances of fuel contamination can be traced to uplifted fuel, it's important that airlines ensure that their fuel suppliers are following proper fuel handling requirements by performing periodic audits of their facilities. The fuel supply should contain less than 0.5 milligrams of particulates per liter.

If an operator is experiencing a large number of air turnbacks or rejected takeoffs because of fuel filter bypass indications, it may want to consider replacing fuel filters more frequently than the recommended scheduled maintenance interval (see fig. 5). Many airlines are replacing fuel filters at 2,000 hours or fewer, compared to the published scheduled maintenance intervals of up to 7,500 hours. If an airline suddenly has filter contamination problems on many airplanes, it is a sign of poor filtration at an airport facility and the airline should investigate the fuel suppliers.

SUMMARY

It's important that airlines work with their fuel suppliers to ensure that local fuel handling procedures are being followed. If the source of the contamination cannot be found, the only alternative is to replace the fuel filters more frequently.

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