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Flow Test to Analyze Fuel Filter Element of an Aircraft

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ABSTRACT

This project briefly covers the fuel filter clogging test setup and warning signal to alerts the aircraft crew. TheFUEL FILTER CLOGGING TEST SETUP designed by using catia v5 R19 software. The designed model is fabricated to the dimensions.The fabricated model is to be tested in the airframe lab.

The pressure variation between two pressure gauges where theFuel filter impending bypass indicator alerts the crew by indicating in case of clogging of fuel filter. This indication allows the fuel automatically to flow through the pressure relief valve .The bypassed fuel will be sent through another filter for safety purpose. Then there will not be blockage and the flow will be continuous.Then the fabricated fuel filter clogging test setup is fit to serve its purpose.

I. INTRODUCTION

The fuel system is the essential part of an aircraft while the problem may arise that the 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.

Fuel filter clogging element is designed and fabricated with the known dimensions. Testing is carried out on the fabricated model by applying pressure from fuel pump to manually clog the filter by blocking screw method and the impending bypass indicator rise the red signal while the pressure relief valve automatically opened for the safety purpose. The differential pressure is noted and calculated from before and after clogging. Further the fuel filter clogging results are found, the literature survey and conclusions are made.

A fuel filter is a filter in the fuel line that screens out dirt and rust particles from the fuel, normally made into cartridges containing a filter paper. They are found in most internal combustion engines.

Fuel filters serve a vital function in today's modern, tight-tolerance engine fuel systems. Unfiltered fuel may contain several kinds of contamination, for example paint chips and dirt that has been knocked into the tank while filling, or rust caused by moisture in a steel tank. If these substances are not removed before the fuel enters the system, they will cause rapid wear and failure of the fuel pump and injectors, due to the abrasive action of the particles on the high-precision components used in modern injection systems. Fuel filters also improve performance, as the fewer contaminants present in the fuel, the more efficiently it can be burnt.

A fuel pumpis a frequently essential component on a car or other internal combustion engine device. Many engines (older motorcycle engines in particular) do not require any fuel pump at all, requiring only gravity to feed fuel from the fuel tank through a line or hose to the engine. But in non-gravity feed designs, fuel has to be pumped from the fuel tank to the engine and delivered under low pressure to the carburettor or under high pressure to the fuel injectionsystem. Often, carburetted engines use low pressure mechanical pumps that are mounted outside the fuel tank, whereas fuel injected engines often use electric fuel pumps that are mounted inside the fuel tank (and some fuel injected engines have two fuel pumps: one low pressure/high volume supply pump in the tank and one high pressure/low volume pump on or near the engine).

II. FUEL FILTER

The paper used for fuel filters is a crepe paper with controlled porosity, which is pleated and wound to cartridges. The raw material for filter paper used in fuel filters are made of a mixture of hardwood and softwood fibres. The basis weight of the paper is 50 - 80 g/m^2.

Types of Diesel Filters

- Cloth Type (Primary)
- Coil Type (Secondary)
- Star Type (Secondary)

Cloth Type (Primary)

- Consists of several layers of cloth wound over a layer of link cloth on a perforated metal tube
- Flow direction - From outside to inside
- Filtered fuel collects in the centre tube and is delivered to the pump
- Removes non-dissolving impurities like dust, foreign particles etc.

Coil Type (Secondary)

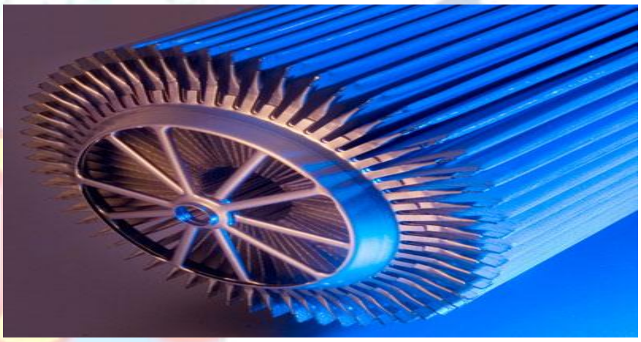
- Consists of a corrugated filter paper around a central tube with alternative layers glued
- Flow direction - Radial and axial
- Dual particles are held in the v-shaped folds

Star Type (Secondary)

- Formed out of pleated filter paper
- Paper is pleated along the breadth to provide a framework for filter dust
- Flow direction - Radial from outside to inside
- Filtered fuel collects at the centre and is delivered to the pump
- Dust particles are deposited on the filter paper or settle down as sediments at the bottom of the filter housing
- Removes impurities of less than 2 microns

Advantages

- Integration of water separation, fuel heating and fuel cooling in one module
- Pressure stability at very high injection pressures
- Special filter media achieves high storage capacity and separation of fine particles
- Effective water separation from fuel prevents corrosion damage



III. FUEL PUMP

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Types of Fuel Pump

- Mechanical pump
- Electric pump
- Turbo pump

a) MECHANICAL FUEL PUMP

The mechanical fuel pumps to transfer fuel from the fuel tank into the fuel bowls of the carburettor. Most mechanical fuel pumps are diaphragm pumps, which are a type of positive displacement pump. Diaphragm pumpscontain a pump chamber whose volume is increased or decreased by the flexing of a flexible diaphragm, similar to the action of a piston pump. A check valve is located at both the inlet and outlet ports of the pump chamber to force the fuel to flow in one direction only. Specific designs vary, but in the most common configuration, these pumps are typically bolted onto the engine block or head, and the engine's camshaft has an extra eccentric lobe that operates a lever on the pump, either directly or via a pushrod, by pulling the diaphragm to bottom dead centre. In doing so, the volume inside the pump chamber increased, causing pressure to decrease. This allows fuel to be pushed into the pump from the tank (caused by atmospheric pressure acting on the fuel in the tank). The return motion of the diaphragm to top dead center is accomplished by a diaphragm spring, during which the fuel in the pump chamber is squeezed through the outlet port and into the carburettor. The pressure at which the fuel is expelled from the pump is thus limited (and therefore regulated) by the force applied by the diaphragm spring.

The carburettor typically contains a float bowl into which the expelled fuel is pumped. When the fuel level in the float bowl exceeds a certain level, the inlet valve to the carburettor will close, preventing the fuel pump from pumping more fuel into the carburettor. At this point, any remaining fuel inside the pump chamber is trapped, unable to exit through the inlet port or outlet port. The diaphragm will continue to allow pressure to the diaphragm, and during the subsequent rotation, the eccentric will pull the diaphragm back to bottom dead center, where it will remain until the inlet valve to the carburettor reopens.

Because one side of the pump diaphragm contains fuel under pressure and the other side is connected to the crankcase of the engine, if the diaphragm splits (a common failure), it can leak fuel into the crankcase.

The pump creates negative pressure to draw the fuel through the lines. However, the low pressure between the pump and the fuel tank, in combination with heat from the engine and/or hot weather, can cause the fuel to vaporize in the supply line. This results in fuel starvation as the fuel pump, designed to pump liquid, not vapour, is unable to suck more fuel to the engine, causing the engine to stall. This condition is different from vapour lock, where high engine heat on the pressured side of the pump (between the pump and the carburettor) boils the fuel in the lines, also starving the engine of enough fuel to run. Mechanical automotive fuel pumps generally do not generate much more than 10-15 psi, which is more than enough for most carburettors.

b) ELECTRIC FUEL PUMP

The fuel pump is usually electric and located inside the fuel tank. The pump creates positive pressure in the fuel lines, pushing the gasoline to the engine. The higher gasoline pressure raises the boiling point. Placing the pump in the tank puts the component least likely to handle gasoline vapour well (the pump itself) farthest from the engine, submersed in cool liquid. Another benefit to placing the pump inside the tank is that it is less likely to start a fire. Though electrical components (such as a fuel pump) can spark and ignite fuel vapours, liquid fuel will not explode (see explosive limit) and therefore submerging the pump in the tank is one of the safest places to put it. In most cars, the fuel pump delivers a constant flow of gasoline to the engine; fuel not used is returned to the tank. This further reduces the chance of the fuel boiling, since it is never kept close to the hot engine for too long.

The ignition switch does not carry the power to the fuel pump; instead, it activates a relay which will handle the higher current load. It is common for the fuel pump relay to become oxidized and cease functioning; this is much more common than the actual fuel pump failing. Modern engines utilize solid-state control which allows the fuel pressure to be controlled via pulse-width modulation of the pump voltage. This increases the life of the pump, allows a smaller and lighter device to be used, and reduces electrical load.

Cars with electronic fuel injection have an electronic control unit (ECU) and this may be programmed with safety logic that will shut the electric fuel pump off, even if the engine is running. In the event of a collision this will prevent fuel leaking from any ruptured fuel line. Additionally, cars may have an inertia switch (usually located underneath the front passenger seat) that is "tripped" in the event of an impact, or a roll-over valve that will shut off the fuel pump in case the car rolls over.

Some ECUs may also be programmed to shut off the fuel pump if they detect low or zero oil pressure, for instance if the engine has suffered a terminal failure (with the subsequent risk of fire in the engine compartment).

The fuel sending unit assembly may be a combination of the electric fuel pump, the filter, the strainer, and the electronic device used to measure the amount of fuel in the tank via a float attached to a sensor which sends data to the dash-mounted fuel gauge. The fuel pump by itself is a relatively inexpensive part. But a mechanic at a garage might have a preference to install the entire unit assembly. Replacing just the fuel pump by itself presents much additional labour, as well as the problem of compatibility of parts.

c) TURBO FUEL PUMP

A turbo pump is a propellant pump that comprises basically two main components: a rot dynamic pump and a driving gas turbine, usually both mounted on the same shaft, or sometimes geared together. The purpose of a turbo pump is to produce a high pressure fluid for feeding a combustion chamber or other use.

An axial turbo pump designed and built for the M-1 rocket engine A turbo pump can comprise one of two types of pumps: centrifugal pump, where the pumping is done by throwing fluid outward at high speed; or axial flow pump, where alternating rotating and static blades progressively raise the pressure of a fluid.

Axial flow pumps have small diameters, but give relatively modest pressure increases, and multiple compression stages are needed, but work well with low density fluids. Centrifugal pumps are far more powerful for high density fluids, but require physically large diameters for low density fluids.

Turbo pumps operate in much the same way as turbo units for vehicles. Higher fuel pressures allow fuel to be supplied to higher-pressure combustion chambers for higher performance engines.

IV. TERMINOLOGY FOR PRESSURE RELIEF DEVICES

A.1 Pressure Relief Devices

A pressure relief device is a device designed to prevent internal fluid pressure from rising above a predetermined maximum pressure in a pressure vessel exposed toemergency or abnormal conditions.

A.2 Flow Capacity Testing

Testing of a pressure relief device to determine itsoperating characteristics including measured relievingcapacity.

A.3 In-Service Testing

Testing of a pressure relief device while protecting thesystem on which it is installed to determine some or allof its operating characteristics using system pressuresolely or in conjunction with an auxiliary lift device or
Other pressure source.

A.4 Bench Testing

Testing of a pressure relief device on a pressurizedsystem to determine set pressure and seat tightness.

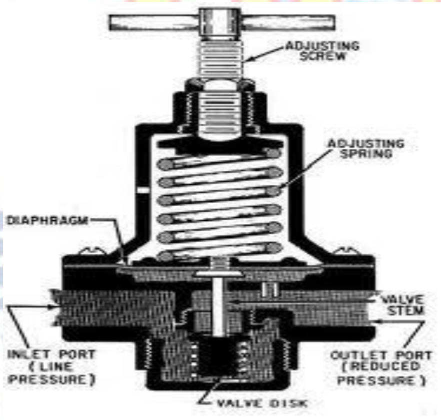
TERMINOLOGY

Pilot-Operated Pressure Relief Valve.A pilot operatedpressure relief valve is a pressure relief valvein which the major relieving device is combined withand is controlled by a self-actuated auxiliary pressurerelief valve.

Power-Actuated Pressure Relief Valve.A power actuatedpressure relief valve is a pressure reliefvalve in which the major relieving device is combinedwith and controlled by a device requiring an externalsource of energy.

Temperature-Actuated Pressure Relief Valve.A temperature-actuated pressure relief valve is a pressurerelief valve which may be actuated by external orinternal temperature or by pressure on the inlet side.

Vacuum Relief Valve.A vacuum relief valve is apressure relief device designed to admit fluid to preventan excessive internal vacuum; it is designed toreclose and prevent further flow of fluid after normalconditions have been restored.



V. FUEL SYSTEM PROBLEMS

A. LEAKS

Major leaks in the fuel system are a concern to the flight crew because they may result in engine fire, or, eventually, in fuel exhaustion. A very large leak can produce engine flameout. Engine instruments will only indicate a leak if it is downstream of the fuel flowmeter. A leak between the tanks and the fuel flow meter can only be recognized by comparing fuel usage between engines, by comparing actual usage to planned usage, or by visual inspection for fuel flowing out of the pylon or cowlings. Eventually, the leak may result in tank imbalance.

In the event of a major leak, the crew should consider whether the leak needs to be isolated to prevent fuel exhaustion.

It should be noted that the likelihood of fire resulting from such a leak is greater at low altitude or when the airplane is stationary; even if no fire is observed in flight, it is advisable for emergency services to be available upon landing.

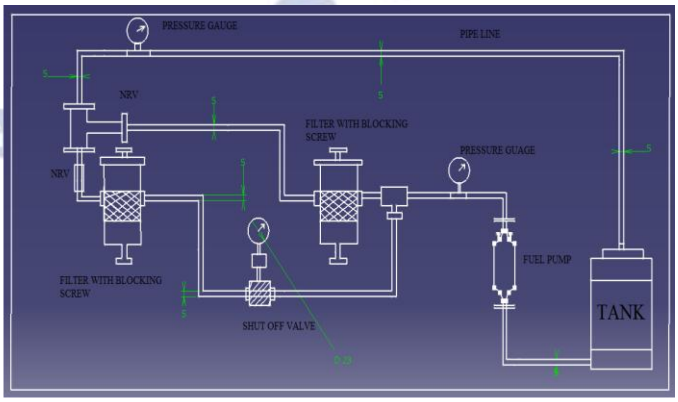
B. INABILITY TO SHUT DOWN ENGINE

If the engine fuel shut-off valve malfunctions, it may not be possible to shut the engine down by the normal procedure, since the engine continues to run after the fuel switch is moved to the cutoff position. Closing the spar valve by pulling the fire handle will ensure that the engine shuts down as soon as it has used up the fuel in the line from the spar valve to the fuel pump inlet. This may take a couple of minutes.

FUEL FILTER CLOGGING

Fuel filter clogging can result from the failure of one of the fuel tank boost pumps (the pump generates debris which is swept downstream to the fuel filter), from severe contamination of the fuel tanks during maintenance (scraps of rag, sealant, etc., that are swept downstream to the fuel filter), or, more seriously, from gross contamination of the fuel. Fuel filter clogging will usually be seen at high power settings, when the fuel flow through the filter (and the sensed pressure drop across the filter) is greatest. If multiple fuel filter bypass indications are seen, the fuel may be heavily contaminated with water, rust, algae, etc. Once the filters bypass and the contaminant goes straight into the engine fuel system, the engine fuel control may no longer operate as intended. There is potential for multiple-engine flameout. The Airplane Flight or Operating Manual provides the necessary guidance.

LINE DIAGRAM OF TEST SETUP



FABRICATED FUEL FILTER CLOGGING ELEMENT

CATIA DIAGRAM OF FABRICATED TEST SETUP

Fabrication as an industrial term refers to building metal structures by cutting, bending, and assembling. The cutting part of fabrication is via sawing, shearing, or chiselling (all with manual and powered variants); torching with handheld torches (such as oxy-fuel torches or plasma torches); The bending is via hammering (manual or powered) or via press brakes and similar tools. The assembling (joining of the pieces) is via welding, binding with adhesives, riveting, threaded fasteners, or even yet more bending in the form of a crimped seam. Structural steel and sheet metal are the usual starting materials for fabrication, along with the welding wire, flux, and fasteners that will join the cut pieces. As with other manufacturing processes, both human labour and automation are commonly used. The product resulting from (the process of) fabrication may be called a fabrication. Shops that specialize in this type of metal work are called fab shops. The end products of other common types of metalworking, such as machining, metal stamping, forging, and casting, may be similar in shape and function, but those processes are not classified as fabrication.

TESTING

The fuel filter clogging element is fully fabricated and then subjected to testing process. The fuel is poured into the fuel tank and the fuel pump electrical connections are to be made by the 12v DC adapter. Whenthe adapter is switched on and the whole setup will start to function. The fuel pump will draw fuel from the tank to the filter.The pressure gauge will indicate pressure betweenthe fuel pump and the fuel filter. The indicated pressure is noted as P1.

Case 1: If there is no clogging in the fuel filter the fuel will return to the fuel tank,the pressure in the return line (between fuel filter and fuel tank) is noted as P2.

Case 2: If there is clogging in the fuel filter the pressure between fuel pump and the fuel filter becomes high (compare to case1 the case2 pressure is high) the indicated pressure noted as p1, while the high pressured fuel is automatically bypassed through the pressure relief valve.The emergency light will indicate the system run by the alternate filter. The indicated pressure p2 is zero during the clogging condition.

CALCULATION FORMULAE:

DIFFERENTIALPRESSURE

$\Delta P = P1 - P2$

Difference between the (static) pressures measured at the wall pressure tapping, one of which is on the upstream side and the other of which is on the downstream side of a primary device (or in thethroat for a Venturi tube) inserted in a straight pipe through which flowoccurs, when any difference in height between the up-stream anddownstream tapping has been taken into account.

1. PREESURE BEFORE CLOGGING

$\Delta P = P1 - P2$

$= 40 - 34.5$

$\Delta P = 5.5$ psi

2. PRESSURE WHILE CLOGGING

$\Delta P = P1 - P2$

$= 48 - 0$

$\Delta P = 48$ psi

VI. CONCLUSION

The apparatus for fuel filter clogging test had been studied, to fabricate an apparatus for our aircraft systems and instrumentation lab. The fabricated apparatus can be used to carry out different pressure test to overcomecontamination of filter by warning signal. The apparatus functions without any technical glitches.

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