

Study of Aircraft Fueling System: An Application of Refueling Operation

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Abstract

An aircraft fuel system enables fuel to be loaded, stored, managed and delivered to the propulsion system of an aircraft. Fuel systems differ greatly from aircraft to aircraft due to the relative size and complexity of the aircraft in which they are installed. In basic form, a fuel system consists of a single, gravity feed fuel tank with the associated fuel line connecting it to the aircraft engine. In a modern, multi-engine passenger or cargo aircraft, the fuel system is likely to consist of multiple fuel tanks which may be located in the wing or the fuselage (or both). Each tank is equipped with internal fuel pumps and has the associated valves and plumbing to feed the engines, allow for refueling and defueling, isolate the individual tanks and in some applications, allow for fuel dumping or for optimization of aircraft's centre of gravity. This paper focuses on various aspects of the Aircraft Fuel Systems from the refuel source to the delivery of fuel to the engine(s) for both commercial and military aircraft including: The refuel/defuel process and associated fuel storage issues; all aspects of fuel handling, fuel transfer and fuel feed systems; fuel measurement and management systems; aerial refueling systems; fuel properties and fuel system components; design practices associated with the protection of fuel systems from electromagnetic, electrostatic and lightning strike hazards.

Keywords: Aircraft Fuel System, internal fuel pumps, aircraft's centre of gravity.

1. Introduction

While aircraft fuel systems are not regarded as one of the glamorous feature of an aircraft functionality they are an essential feature of all aircraft. Their implementation and functional characteristics play a critical role in the design, certification and operational aspects of both military and commercial planes. In fact the impact of fuel system design on an aircraft operational capabilities encompasses a range of technologies that are much more significant than the non-specialist would at first realize, particularly when considering the complexities of large transport and high speed military aircraft applications. An aircraft fuel system may be defined as a system which enables the fuel to be loaded, stored, managed and delivered to the propulsion system (engine(s)) of an aircraft. Fuel systems differ greatly from aircraft to aircraft due to the relative size and complexity of the aircraft in which they are installed. In the most basic form, a fuel system will consist of a single, gravity feed fuel tank with the associated fuel line connecting it to the aircraft engine. In a modern, multi-engine passenger or cargo aircraft, the fuel system is likely to consist of multiple fuel tanks which may be located in the wing or the fuselage (or both) and, in some cases, the empange. Each tank will be equipped with internal fuel pumps and have the associated valves and plumbing to feed the engines, allow for refueling and defueling, isolate the individual tanks and, in some applications, allow for fuel dumping or for optimization of aircraft's center of gravity.

2. Classification of Fuel Systems Based on the Relative Size and Complexity of the Aircrafts

2.1 Light Single Engine Aircraft:

Small piston-engine powered aircraft are installed with fuel system consisting of a single tank. On newer aircraft two fuel tanks, with one in each wing, are more common. A two tank system requires additional components to allow controlled provision of fuel to the single engine. Fuel tank boost pumps may or may not be incorporated depending upon the location of the tanks. The fuel is piped from the tanks through fuel lines to a fuel control valve which is referred to as the fuel selector valve. This valve serves several functions and will potentially have Left, Right, Both and off selections. Left, Right and Both allow for fuel to be fed to the engine from either the Left tank or the Right tank individually or from both at the same time. This facility allows the pilot to balance the fuel tanks or to "trim" the aircraft laterally. The Off selection provides for a fuel shut off valve in the event of an engine fire or to prevent unwanted fuel migration when the aircraft is not in operation.

2.2 Light Twin Engine Aircraft:

Adding a second engine to an aircraft, by necessity increases the complexity of the fuel system and its management. Additional features normally found in small multi-engine aircraft include in-tank fuel pumps, a more robust fuel quantity indicating system and the provision for fuel "cross-feed". Refueling is still normally accomplished on a tank

by tank basis. Cross-feed allows for fuel from one wing tank to be burned by the engine on the other wing. In some cases, the fuel is routed directly from the tank to the engine while in others, it is transferred from one wing tank to the opposite wing tank before feeding to the engine. The cross-feed provision allows the pilot to use all of the fuel on board and to maintain lateral balance limitations in the event of single engine operations.

2.3 Multi-engine Turbo Prop and Turbo Jet Aircraft:

Increasing the size and complexity of an aircraft will normally result in corresponding changes to the fuel system. These changes will include advances in automation, the number and location of fuel tanks, specific direction from the manufacturer on fuel distribution and the sequence in which the tanks are to be filled or emptied, a robust indicating and warning system, provisions for "single point" re-fuelling and de-fuelling and, in some applications, provisions for fuel dumping and/or for center of gravity optimization.

3. Components of an Aircraft Fuel System

Fuel tanks: fuel tanks as the name suggest are mainly used to store fuel and manage fuel flow. in an aircraft there are two kinds of fuel tanks one for storage and other to feed the engine.

Fuel-lines and fittings: fuel line must be installed and supported to prevent excessive vibration and to withstand loads due to fuel pressure and accelerated flight conditions. They must be flexible and should be able to resist high temperatures.

Fuel valves: Selector valves are installed in the fuel system to provide a means for shutting off the fuel flow, for tank and engine selection, for cross-feed, and for fuel transfer.

Fuel pumps: fuel pump is also used to transfer fuel from one tank to another, to supply fuel under pressure for priming when starting the engine, and, as an emergency unit, to supply fuel to the carburetor in case the engine driven pump fails. Fuel pump is always turned on during takeoffs and landings to ensure a positive supply of fuel.

Fuel filters: a fuel strainer, or filter, is installed between the fuel tank outlet and the inlet of either the fuel metering device or an engine driven positive displacement pump, whichever is nearer the fuel tank outlet. It performs a dual function of preventing the foreign matter from entering the carburetor, and trapping any small amount of water that may be present in the system. In multi-engine aircraft, one main strainer is usually installed in each engine nacelle.

Fuel Gauges: A fuel gauge is an instrument used to indicate the level of fuel contained in a fuel tank. The gauge consists of two parts: a sensing unit and an indicator.

The sensing unit usually uses a float connected to a potentiometer. As the tank empties, the float drops and slides a moving contact along the resistor, increasing its resistance. In addition, when the resistance is at a certain point, it will also turn on a

"low fuel" light on some aircrafts. Meanwhile, the indicator unit measures and displays the amount of electrical current flowing through the sending unit. When the tank level is high and maximum current is flowing, the needle points to "F" indicating a full tank. When the tank is empty and the least current is flowing, the needle points to "E" indicating an empty tank.

4. Classification of Fuel Feed Mechanisms

There are mainly three types of feed mechanisms used to transfer fuel from fuel tanks to the engine:

Gravity feed system:

This is mainly used in high-wing aircraft. In this, with the tanks above the engine, gravity is used to transfer the fuel. As it doesn't involve any fuel pump, it is the simplest aircraft fuel system.

Pump feed system:

It is mainly used in low and mid wing single reciprocating aircrafts which cannot utilize gravity feed system as the fuel tanks are not located above the engine. Instead in this, one or more fuel pumps are used for fuel migration.

Fuel injection system:

This is mainly used in high wing, high performance single engine general aviation aircrafts. In this, instead of carburetor, we use fuel injection method. In this, the system sprays fuel into intake or directly into the cylinder. For a smooth, continuous operation, fuel without any air mixed in it is the primary condition of this system.

5. Refueling Process of Aircrafts

An important factor in the efficient turnaround of an aircraft is refueling. Refueling, as the word indicates, means to refuel an aircraft. Often, this aspect is underestimated, but is the most significant factor of the aircraft fuel system each fuel truck needs to travel between the fuel depot and the planes dozens of times a day, and only by optimizing delivery and reacting to constantly changing demands can the job be done efficiently. There are mainly two types of refueling involved in aircraft fuel system:

Ground refueling system: It is the system which supplies fuel to the aircraft at high enough flows and pressures to allow refueling of the aircraft in a short period of time. It is performed prior to almost every flight. The fundamental need for a pressure refueling of an aircraft is to provide a safe, quick aircraft turn-around-time. It increases profitability and provides superior customer service. For both commercial and military aircrafts the ground refueling system are the same, except small unmanned aircraft.

Aerial refueling: It has become vital part for modern day air warfare. It is usually required in situations where the aircrafts have to strike the places which are quite far

from the refueling bases. There are two different aerial refueling systems in operation today

Probe drogue system which involves the deployment of tension controlled fuel hose with attached drogue coupling from tanker aircraft and receiver aircraft receives it by maintaining the proper altitude. There is a simple fuel pressure assisted spring loaded mechanical latching mechanism in the drogue that holds the probe in place during refueling. On completion of refueling process receiver aircraft simply drops back to detach the probe.

The second type of refueling system is the **Flying boom system** in which the receiver aircraft has female coupling (receptacle) and tanker aircraft flies the boom with its interfacing nozzle into receiver receptacle. The receiver receptacle latches onto the boom nozzle using hydraulic pressure supplied by the receiver aircraft.

6. Conclusion and Future Aspect

Aviation is a sector that grows year on year, the increasing number of budget airlines and routes inspiring passenger numbers to hit record levels. These increases have necessitated radical infrastructural developments, and the need to get aircraft into the air is more crucial than ever. Planes sitting on the tarmac are not profitable, cause queues and stop the smooth flow of passengers. Nowadays magneto-resistance type fuel level sensors are being commonly used in small aircraft applications because of the potential alternative they offer for automotive use. These are highly accurate, and the electronics are completely outside the fuel. The non-contact nature of these sensors address the fire and explosion hazard, and also the issues related to any fuel combinations or additives to gasoline or to any alcohol fuel mixtures. Magneto resistive sensors are suitable for all fuel or fluid combinations, including LPG and LNG. The fuel level output for these sensors can be ratio-metric voltage or preferable CAN bus digital. These sensors also fail-safe in that they either provide a level output or nothing.

References

- [1] John W.R. Taylor: *The Lord of Flight*, London: Universal Books Ltd., 1990. ISBN 0-9509620-1-5.
- [2] Dietrich Kuchemann: *The Aerodynamic Design of Aircraft*, Pergamon Press, Oxford, 1978.
- [3] P. Madhavan (September 2004): "*Filtration Technology for Aircraft Gas Turbine Engine Fuel and Lubrication Systems*", Aircraft Technology and Maintenance, 2005 Engine Year Book.

