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Civil Aircraft Inerting and venting System Design

Adel Karami[1], AtefehGhasem nia[2], Majid Asli[3], AbloghasemMesgarpour Tousi[4]

1-Adel Karami, Institute of Space Science and Technology, Amirkabir University of Technology, Hafez str. Tehran Iran

2,3-Atefeh Ghasemnia&MajidAsli,Institute of Space Science and Technology, Amirkabir University of Technology, Hafez str. Tehran Iran

Abstract

Aircraft fuel systems are complex systems andthe fuel as an important part of the system needs some safe subsystems in order to maintain the fuel pressure and oxygen percentage in the safe range. The pressure and flammability of fuel may cause dangerous situation for an aircraft. The structural limits of the fuel tanks makes the designer to prepare some facilities to level vapor fuel pressure in the tanks, this is done by venting system. Furthermore the fuel flammabilityobligates the designer to level oxygen percentage via venting and inerting. In order to design a safe and reliable fuel system, there should be facilities preventing any differential pressure and ignition in the fuel system and tanks. The pressure between the tanks and each tank with atmosphere is adjusted via venting system. The venting is done by transferring fuel vapor to the surge tanks which are related to atmosphere through NACA duct. In some phases such as cruise, an open venting system can maintain oxygen percentage in the fuel vapor in a safe margin in order to prevent ignition in the tanks, yet it is not satisfied in all phases of flight. A noble system presented for this aim is inerting system in which by reducing and controlling oxygen percentage in a tank, any flame possibility is prohibited. The inerting system controls the fuel vapor oxygen percentage. This is done by discharging nitrogen enriched air in the fuel tanks. In this paper it is tried to describe the role and importance of these system and standards lead to utilizing these systems in a civil aircraft fuel system. Also it is tried to present the fuel system designed by the writers using venting and inerting in the tanks.

Keywords: *Fuel system, Venting, Vapor, Inerting*

Introduction

A civil aircraft fuel system includes various subsystem such as venting and inerting subsystems which play an important role in the fuel system. Venting system adjusts fuel pressure in the tanks via ventilating the vapor fuel to the atmosphere. This job is accomplished through venting pipes in the tanks. Every tank has an entrance transferring vapor fuel through pipe lines to the surge tank. The surge tank is related to atmosphere through NACA duct. The venting in some phases such as refuel/defuel or climb/landing has priority to the other phases. The oxygen percentage is almost maintained below enough preventing any ignition in the tanks, yet in some phases this is not satisfied. For the first time, in 1996, as a result of a fuel tank explosion due to high oxygen percentage in the tanks of B474 in flight, FAA tried to design a system which could maintain the oxygen percentage in the vapor fuel in safe range. This system was named inerting system which gets the air-fuel mixture and separates oxygen from it. Then, returns a rich nitrogen fuel gas to the tank and the separated oxygen is discharged to the atmosphere. This system is obligated to be installed on newly-manufactured aircrafts such as B737,B747, A340, A321by FAA. This systemhas been forced to be even installed on in-service aircraftsince 1992, as well.

Venting system for J+150 Aircraft

Venting system configuration depends on the aircraft type and number of tanks. J+150 aircraft consists of one center tank, two wing inner tanks and two outer tanks. Also there is one surge tank in each wing tip in order to collect over flow fuel and ventilation vapor fuel, these tanks are shown in Fig. 1. Each tank can use arbitrary number of entrance so that the venting operates sufficiently. The venting system designed for J+150 civil aircraft fuel system uses only one entrance for each tank expect the inner wing tank which uses two entrance. The vent pipe of the central tank connects the middle of central tank to surge tanks. This pipe has two ends which are open. The vent pipe of the inner wing tank has three ends, two of them are in inner tank and another is in surge tank. a float valve is connect toone of the ends in inner wing tank so in climb this valve get closed and fuel vapor can enter the pipe from another end. This pipe like the vent pipe of central tank, connects the vapor of inner wing tank to surge tank. The ends of vent pipes are at the top of the tank. Unlike the vent pipes of the central and inner wing tanks, vent pipes of Outer wing tank, connect this tank to related inner wing tank. A float valve is connected to the end of this pipe that is in outer wing tank. This float valve get mechanically closed when the outer wing tank is full of fuel, so the fuel cannot enter the vent pipe. Also when the tank is full, venting of it is not necessary.Hence the venting of center tanks and inner wing tanks are straightly to the surge tank and the venting of the outer cell tanks is directed to the inner wing tank. The layout of venting system designed for fuel system of J+150 is shown in Fig. 2.

As the fuel vapor in the tanks is over pressurized the vaporized fuel is transferred to the surge tank. The air is discharged to the ambient through NACA duct in the surge tank.Also surge tank is a temporary tank for when fuel overflowed, the fuel can enter it through vent pipes. This fuel is returned to the outer cell via jet-pumps.

Some check valves are installed at the lowest points of the vent pipes near every ends except two ends that connect to a float valve (one in inner wing tank and another in outer wing tank). The check valves let the fuel that has entered the wingtank vent system return to the related wing tank.

Also overpressure protectorshave been used in any tank in order to adjust pressure between tanks, these protectors can be used for adjusting tanks and ambient pressure when the venting lines are blocked or do not operate properly. A vent protector is installed in each surge tank, as well. This vent protector prevents ice formation and ignition of fuel vapor in surge tank. The whole components of venting system and their mechanism are presented in Table. 1.

Furthermore, the designed venting system is used to maintain vapor fuel oxygen percentage in a safe margin below 12 percent. But the system does not have sufficient performance in some phases of flight such as climb. Then another auxiliary system is need which was named inerting system and has been described in the next chapters.

Standards and compliance of them in Venting

In design of the venting system some standards should be considered. The standard related to the venting system presented by ICAO is CAD2508.975. This standard is about vent pipe position, operation and safety. For instance in this standard it is mentioned that the vent arrangement must prevent siphoning of fuel during normal operation. This requirement is satisfied in our design by using check valves. This valve let the fuel that has entered the wingtank vent system return to the related wing tank. So during normal operation fuel cannot enter vent pipes and release to out.

Inerting system for J+150 Aircraft

Any inerting system levels oxygen percentage of fuel vapor in the tanks via discharging Nitrogen enriched air in the tanks. This system can be used in any tank, but generally it is used in the center tank. The inerting system for J+150 is used for center tank and inner cell wing tanks. This system has two dependent sub-systems including CSAS(conditioned service air system) and IGGS(Inert gas generation system). The CSAS uses cooled pneumatic or bleed air and transfers it to IGGS. This subsystem involves various components in order to cool the inlet air and transfer to it to IGGS (see Fig.4). IGGS performs separation operation on the refined air sent from CSAS. A portion of oxygen separated is discharged to the atmosphere and the nitrogen enriched air is returned to the related tank. The simplified scheme of inerting system is shown in fig 3. In order to adapt this system to J+150 aircraft fuel system some points should be considered:

In returned manifold from Inerting to the tank:

- The air returned to the tanks from inerting system should not cross 200 degree of centigrade
- The tanks pressure should be controlled so that the inlet air from inerting may not damage the structure resulting from overpressure
- The fuel should not return to the inerting manifold by utilizing sufficient means

In air inlet from engine bleed or pneumatic to CSAS:

- In any unconventional low pressure in bleed air/pneumatic or high temperature of air and fuel tanks overpressure the inerting system should shut-down automatically

Sensors, valves and controllers used in the inerting system are arranged to insure these requirements (see Table. 2).

The functional protocol and components satisfying these parameters are presented separately for CSAS and IGGS in Fig. 4 & Fig. 5.

The air gotten from bleed air or Pneumatic is directed to the Ozone convertor to change air's oxygen to ozone as the isolation valve opens from CSAS Controller. Then, the air is cooled in an heat exchanger and is directed to the IGGSinlet air as a conditioned air. The temperature and pressure of the air is sent to the CSAS controller, as well (see Fig. 4. Also the flight phase is transmitted to the CSAS from SDAC. This information are transmitted to the IGGS controller,at the same time.

Inerting system interface with Fuel system

The nitrogen-enriched air returned from inerting (IGGS) should return to the related tank via inert manifold on the top of the tanks.This manifold in interface with the tank has a flap check valve which prevents fuel inlet to the inerting system. The nitrogen-enriched air discharged in the tank has an effect on the tanks pressure. On the other hand, the venting system adjusts the fuel vapor pressure in the tanks. Then the venting system function is affected on the function of inerting system. Hence the venting system and pipes should be designed so that could operate sufficiently in inerting condition. The functional protocol of inerting IGGS and components operation has been presented in Fig. 5.

Inerting system interface with Monitoring and indicating

The inerting system is an independent automatic system containing any control and monitoring system related within the system. And only the failures or malfunctions are transmitted to the cockpit. The failure is indicated in the Flight warning computer. Also massages are transmitted to the cockpit at the end of flight in order to specify the problem for required maintenance purposes. Each subsystems of inerting system (CSAS & IGGS) has a control unit.Any system fault leading to the lossof inerting capability generates acockpit and maintenance messageat the end of the flight. This faults from CSAS and IGGS control units are sent to flight warning computer (FWC) and maintenance computer through signals. The functional protocol of inerting system monitoring and indicating has been shown in Fig 6. The IGGS component Failure is transmitted to CSAS and then is indicated or announced. Engine fir is informed to the inerting system, as well. This function can be seen in inerting Block Diagram (see Fig 4.)

Inertingsystem operational modes

The operational modes of inerting system include low flow mode, high flow mode, and medium flow mode. The low flow mode is used in climb or cruise flight phase, medium flow is used in approach or slow approach and the high flow is used in decent.

In inerting system a dual flow shut-off valve (SOV) is used to control the nitrogen enriched air flow to thefuel tank and enables the system toswitch between low/mid/high nitrogen enriched air flows, and to isolate the IGGSfrom the fuel tank. This dual flow SOV has two branches; low branch and mid branch. In low flow mode, the low branch is open and the mid branch is closed. So, the inerting system develops least amount of nitrogen enriched air flow and consume least amount of bleed air in this mode. In high flow mode, both of branches are open and greatest amount of nitrogen enriched air is delivered to fuel tank. In medium mode, only the mid branch is open. The functional protocol of this system is shown in Fig.7.

Standards and compliance of them in Inerting

CAD 2508.981 presented by ICAO is about fuel tank ignition prevention. Sub-paragraph "C" of this standard state that design precautions must be taken to achieve conditions within the fuel tanks which reduce the likelihood of flammable vapors. The existence of the inerting system is Aircraft is a compliance with this sub-paragraph of the standard. Also this systemhas been forced to be installed on newly-manufactured aircraftsince 1992.

Conclusion

The venting system is an important sub-system of fuel system that should be exist in every aircraft.This venting system adjusts the fuel vapor pressure in fuel tanks which prevents extra structural loads to the tanks.Also it is used to prevent flammability in the tanks by controlling air and oxygen in the tanks. In this paper the venting system for J+150 is designed. The simplified schematic of this system and vent pipes is shown in figure 2. Some Provisions like over-pressure protectors, vent protector, check valves and float valves are provided and added to vent system in order to make sure that this system work property in any phases during flight or on ground. But the open vent system designed would not satisfy flame prevention possibility in all phases of flight. Then an Inerting system is utilized. This system is an outer system and is connected to the related tank through a twin flapper check valve. The functional protocol and components of the designed system are shown in Fig. 4 and Fig. 5. The inerting system designed can prevent any flame possibility in the tanks and provides a safe system. Hence, both vent and inerting systems are essential subsystems of fuel system playing an important role in a civil or military aircraft.

Tables

Table 1: Components for Venting

Components	*Mechanism*
Vent pipes	-
Over-pressure protector	Mechanically
Vent protector	Mechanically
Check valve	Mechanically
Float valve	Mechanically
NACA duct	-

Table 2: Components for Inerting

Components	*Mechanism*
Inert pipes	-
Heat Exchanger	Air Cooling
Ozone Separator	Mechanically
Isolation Valve	Electromechanical
Temp. Sensor	Electrical
Pressure Sensor	Electrical
Oxygen Sensor	Electrical
Bypass Valve	Electromechanical
ASM	Chemical
Air Filter	-
Dual Flapper Valve	Mechanical
CSAS Controller	-
IGGS Controller	-

Figures and Drawings

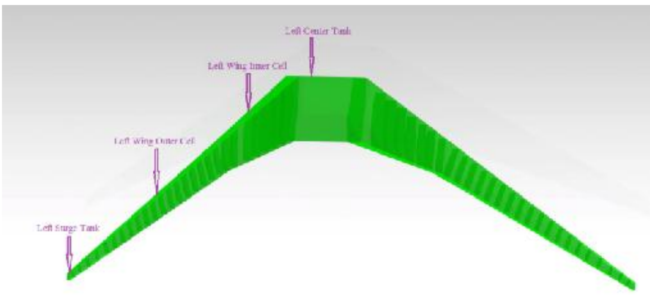

Fig. 1: J+150 Fuel Tank Arrangement

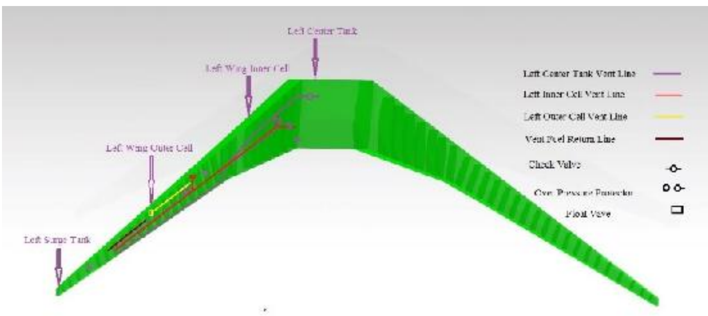

Fig. 2: The Venting System Lines For J+150 Civil Aircraft

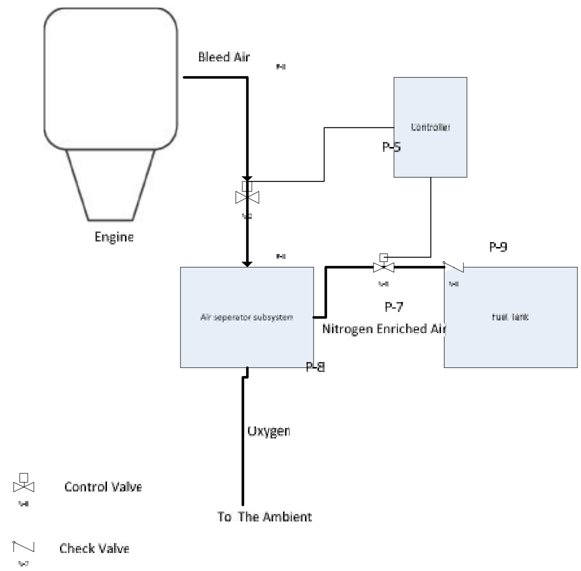

Fig. 3: A Generalized Inerting System Schematic

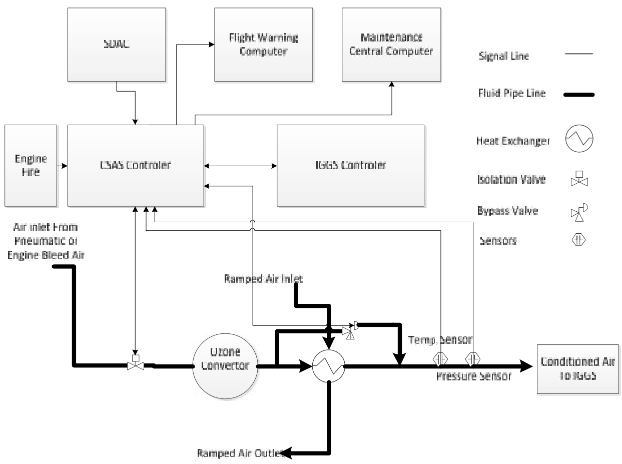

Fig. 4: J+150 Inerting CSAS Operational Block Diagram

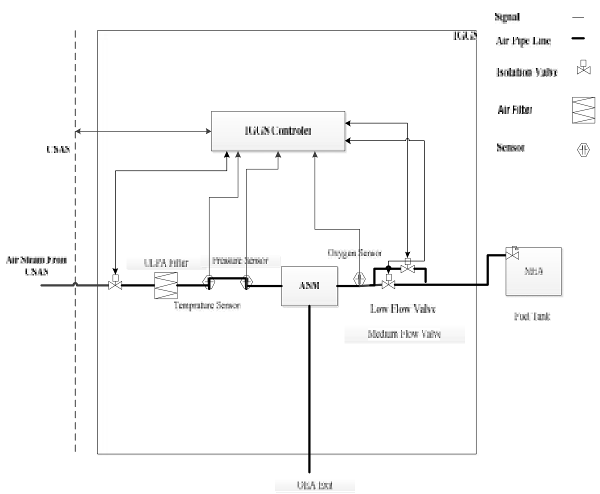

Fig. 5: J+150 Inerting IGGS Operational Block Diagram

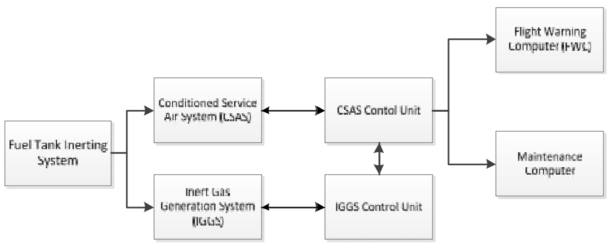

Fig. 6: Functional protocol of inerting system monitoring and indicating

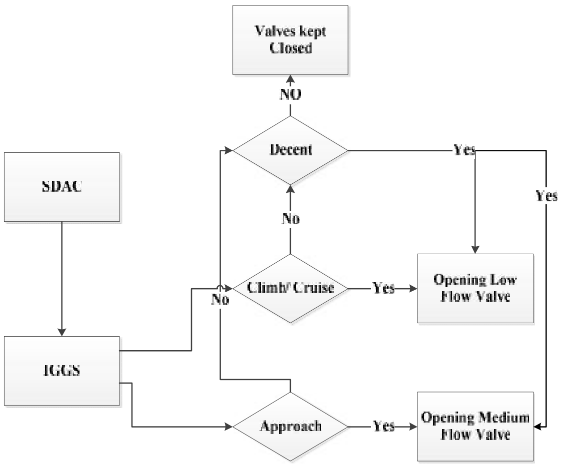

Fig. 7: Functional protocol of operational modes of inerting

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