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AIRCRAFT PROTECTION AGAINST LIGHTNING AND STATIC ELECTRICITY

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Abstract: *The aircraft safety is one of the most important things when thinking of designing and manufacturing the airplane. During the flight, there is a probability of lightning occurrence which may cause catastrophic consequences. In order to avoid potential aircraft damage, the aircraft must be protected against lightning effects. Metallic components should be bonded to the airframe, while the airplane design must secure that possible lightning strike would not endanger the plane, the crew and the passengers. In this paper, the compliance of „Sova“ aircraft design with certification requirements regarding lightning protection will be analyzed and shown.*

Keywords: *lightning, protection, airframe bonding, metallic components, safety.*

1. INTRODUCTION

The „Sova“ aircraft was designed by UTVA Aircraft Industry Research & Development team in compliance with certification specifications [1] and [2].

During designing and manufacturing of the aircraft, along with analizing structure, controls, avionics and other systems, engineers must be aware of potential occurences during the flight, such as lightning strike.

Certification specifications include requrements concerning aircraft protection against lightning effects.

In this paper, the compliance with requrements concerning electrical bonding and protection against lightning and static electricity, as well as fuel system lightning protection will be demonstrated.

2. CERTIFICATION

2.1 Electrical bonding and protection against lightning and static electricity:

The paragraph CS 23.867 [1] defines the corresponding requirements:

(a) The aircraft must be protected against the catastrophic effects from lightning.

(b) For metallic components, compliance with sub-paragraph (a) may be shown by bonding the components properly to the airframe; or Designing the components so that a strike will not endanger the aircraft.

(c) For non-metallic components, compliance with sub-paragraph (a) may be shown by Designing the components to minimise the effect of a strike; or Incorporating acceptable means of diverting the resulting electrical current so as not to endanger the aircraft.

On „Sova“ aircraft, metallization was carried out on the structure, control surfaces and all systems, so that protection of the aircraft and crew from lightning strikes is enabled, the stability and uninterrupted operation of electronic equipment is ensured, the risk of fire is prevented, and sparkling caused by static electricity is eliminated.

„Sova“ is all metal structure except engine cowling, wingtips, rudder tips and elevator tips. Protection of the metal components of „Sova“ aircraft against lightning was achieved by bonding the components through mass in an appropriate manner to the aircraft structure.

The metallization of the metal elements of „Sova“ aircraft structure is defined in the technical documentation. Aircraft assemblies with number of bonding positions are specified in Table 1.

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Table 1. Aircraft metallization

Assemblies	Quantity
Wing	32
Flaps	1
Empennage	6
Elevator controls	4
Flap controls	9
Aileron controls	6
Aileron Trimmer	1
Fuel installation	5
Hydraulic installation	14
Ellectrical installation	1
Antennas	2

Special screws for metallization are installed on the wings, and on the funnel for pouring fuel into the tanks there are defined points for attaching clips for metallization.

Also, the aircraft was successfuly tested according to the Technical conditions for determining the quality of installation, testing and acceptance of electronic equipment and installation (insulation resistance of electronic equipment, transient resistance) and the Technical conditions for determining the quality of installation, testing and acceptance of electrical equipment and installation (electrical resistance of the insulation of the installation, ohmic resistance of the aircraft structure, transient resistances and metallization).

As for non-metallic aircraft parts, design ensures the protection of the following surfaces made of composite from the catastrophic consequences of a lightning strike:

• wingtips,

• rudder tips,

• elevator tips.

The redirection of the resulting electric current, which occurs as a result of a lightning strike, is carried out in such a way that the safety of the aircraft is not endangered:

• by applying an epoxy film LORD UltraConductiveTM coating with high electro conductivity on the wingtips,

• by installing the Micropoint Trailing Discharger, P/N 11-16630, in the zone of the trailing edge of the tips.

The design solution for the protection of the tips zone on „Sova“ aircraft from the catastrophic consequences of a lightning strike demonstratess the compliance of the solution with certification requirements.

2.2 Fuel system lightning protection requirements

For the purposes of certification of „Sova“ aircraft in accordance with certification specifications [1] and [2], it was necessary to design the fuel system so that it meets the corresponding requirements.
The paragraph CS 23.954 [1] defines the requirements concerning fuel system lightning protection:

The fuel system must be designed and arranged to prevent the ignition of fuel vapour within the system by – (a) Direct lightning strikes to areas having a high probability of stroke attachment;

(b) Swept lightning strokes on areas where swept strokes are highly probable; and

(c) Corona or streamering at fuel vent outlets.

SWEPT - "sweeping" strikes occur when a lightning strike is deformed due to interaction with aerodynamic forces and is formed in a unique way due to the material and shape of aircraft surfaces. It is a series of continuous contact of lightning with the surface of the aircraft that is formed due to the aircraft movement through the air.

CORONA – light discharge that occurs as a result of the difference in electric potential between the aircraft and the external atmosphere.

STREAMERING – is a branch-like ionized path that occurs in the presence of a direct lightning strike or under conditions that prevail immediately before the strike.

ARC & SPARK – An arc and a spark are the same thing, but the spark usually lasts a very short time. However, when that spark remains continuous for a long time, then it is called an arc.

A lightning strike on aircraft can occur during flight and/or in the vicinity of a thunderstorm. In addition, due to flying in the vicinity of the lightning strike area, CORONA or STREAMER formation may occur on the aircraft. For this reason, it is necessary that the fuel vapors generated inside the fuel system are protected from ignition in the case of flight in conditions of a large difference in electrical potential between the aircraft and the atmosphere, as well as in the case of a direct lightning strike in zones with a high probability of a strike.

According to document [4], it is necessary to first define the zones on the aircraft that have a high probability of a direct lightning strike, as well as of a "Swept" strike. Figures 1 and 2 show the orthogonal and side projection of Sova aircraft with marked zones.

Zone 1B represents the surfaces that have a high probability of a direct lightning strike and are marked in yellow in figures 1 and 2. These are the extremities on the trailing edges of the control surfaces - wings, elevator, rudder, as well as the tips of the wings and the horizontal and vertical stabilizer. Since the trailing edge of the tip is made of composites (glass fibers) that are electrically conductive, then the 1B zone extends forward to the nearest electrically conductive surface. Also, this zone is extended laterally by 0.5 [m] due to possible "Swept" channels, and also in the event of a local scattering of points from a direct lightning strike.

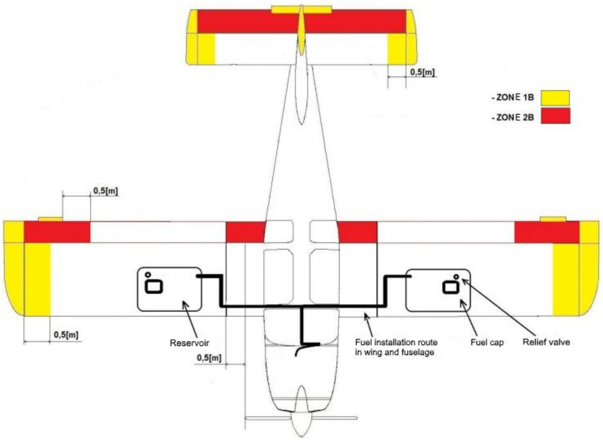

Figure 1. Sova aircraft top view

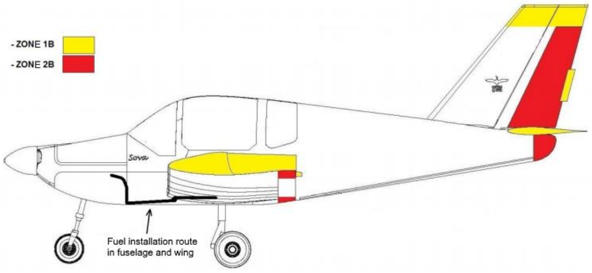

Figure 2. Sova aircraft side view

Zone 2B represents the surfaces that have a high probability of a "Swept" impact and are marked in red in figures 1 and 2. These are the trailing edges of the wings, horizontal and vertical control surfaces, as well as the top of the fuselage. Since the control surfaces of Sova aircraft are made of aluminum (electrically conductive materials), then the specified zone will not extend forward to the nearest electrically conductive surface. Since there is no fuel installation (pipelines and components) or reservoirs that could be exposed to a direct or "swept" lightning strike in the above-mentioned zones, it is concluded that Sova aircraft meets the certification requirements.

In order to meet the certification requirements, it is necessary to show that the fuel system is designed in such a way that the possibility of ignition of fuel vapors inside it is prevented in the event of the appearance of "Corona" or "Streamering" on the exhaust valves installed in the wings of Sova aircraft.

In manual [3], a Lockheed study examined three different types of exhaust valves. The testing concluded that the openings that are directed in the direction of the air flow have a more "diluted" mixture of fuel vapors at the exit, that is, the least flammable area compared to the other cases that were examined. The non-flammable mixture is 1D and more from the exhaust valve, which means that a lightning strike or "Streamering" must occur very close to the edge of the exhaust tube to ignite the fuel vapors. Tests have shown that it is only possible to ignite the vapors when the "Arc" is directly directed at the outlet of the exhaust valve.

It was also mentioned that during the reports collected until then, there was no record of a direct lightning strike on the exhaust valve, although on many aircraft these openings are located on the winglets, which have a high probability of a direct lightning strike.

In Newman's test during 1966-1967, a 48kA ignition source was released on a Boeing 707 aircraft. During the test, a direct lightning strike on the vent occurred only once in 34 times at a wind speed of 90 knots. At a speed of 200 knots and 200 attempts, not once did a simulated direct lightning strike occur on the opening itself.

When the strikes last longer, so-called "swept" strikes are formed. During the above test out of 15 attempts, fuel vapors ignited 11 times. Based on this, it is concluded that exhaust valves should not be installed in 1B zones that have a high probability of "Swept" or direct impact.

The exhaust valve assembly on „Sova“ aircraft is shown in Figure 3. It is connected to the air deflector. Its position on the wing is shown in Figure 1 where it can be seen that the opening is far enough from the zones where there is a high probability of a strike that could ignite the fuel vapors.

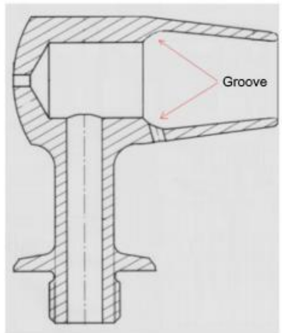

Figure 3. Exhaust valve air deflector

Positioning the vent in Zone 3 (where the exhaust valve is installed) will provide the highest level of protection, according to manual [3] point 7.3.4.(6). Since the air deflector directed directly in the direction of the air flow, then a much more diluted mixture of fuel vapors appears at its exit than usual, so the probability of ignition is minimal. Besides, the valve is made of aluminumwhich has good electrical conductivity. The pipe groove is recommended, because the pipe itself could later become a source of "Corona" or "Streamering" that can occur when the aircraft is flying in a strong electric field. For this reason, there is a groove on the air deflector, shown in Figure 3. In this way, the possibility of "CORONA" being transferred directly to the exhaust valve and igniting the fuel vapors was prevented.

Based on the above explanation, it is concluded that the exhaust valve on „Sova“ aircraft fulfills all the proposed recommendations from the used literature, and in this way the possibility of ignition of fuel vapors, and in the cases mentioned, also the lightning strike zone, is reduced to a minimum. Also, there are no fuel system components and pipelines in areas that have a high probability of lightning strikes, so it can be concluded that the fuel system on „Sova“ aircraft is designed to meet the certification requirements.

3. CONCLUSION

Utva Aviation Industry is approved by Civil Aviation Directorate of Republic of Serbia as a Design and Production organization under Part 21 regulations.

Also, „Sova“ aircraft is certified under CS-23 regulations.

Those approvals and certificates carry along high resposibility when designing and manufacturing the aircraft. There are plenty of certification requirements that the aircraft must comply.

Showing compliance of the aircraft with all those requirements meant hard work and effort. However, for some paragraphs, analizing and testing were interesting, such as in the case of lightning protection.

References

[1] Certification Specifications for Normal, Utility, Aerobatic and Commuter Category Aeroplanes CS 23, Amendment 3 Book 1

[2] Certification Specifications for Normal, Utility, Aerobatic and Commuter Category Aeroplanes CS 23, Amendment 3 Book 2

[3] DOT/FAA/CT-89/22 Aircraft Lightning Protection handbook

[4] DOT/FAA/CT-83/3 User’s Manual for AC-20-53A Protection of Airplane Fuel System Against Fuel Vapour Ignition Due to Lightning