EFFECTS OF IN-FLIGHT FIRE EXPOSURE OF ALUMINUM AND COMPOSITE FUSELAGE MATERIALS

Modern civilian transport aircraft are being constructed with increasingly greater portions of the aluminum fuselage being replaced with composite materials. The Boeing 787 is a nearly all composite aircraft. Composite materials consist of layers of fiber material held together with a resin binder. Composite materials have many benefits for the aircraft

manufacturer in terms of fabrication strength and weight savings. However, the performance of these materials under in-flight and post crash fire conditions is essentially unknown. Aircraft have been constructed with aluminum skin and structure for decades. The performance of this material when exposed to an in-flight or post crash fire is well known. Aluminum is essentially non-flammable, conducts heat very well and has a high thermal radiation coefficient. Aluminum also melts at a relatively low temperature. These properties cause the aluminum hull material to behave very differently during an in-flight fire versus a post crash fire. During in-flight fire exposure of the fuselage, the aluminum skin and structure are cooled by the flow of air around the fuselage. This keeps the metal below its melting point and preserves the structural integrity of the aircraft. There has never been a documented case of hull penetration due to in-flight fire in an aluminum aircraft.

A series of tests were performed in the FAA Technical Centers Airflow Induction Facility to determine the relative performance of both aluminum and composite hull materials when exposed to an internal fire while in flight. A test fixture was designed to simulate in-flight airflow over the test panels. The underside of the fixture was fitted with an enclosed box that housed the heat sources. Two heat sources were utilized to expose the underside of the test panel, an electric heater and a live fire. The electric source was used to determine the relative heat conduction properties of each type of material under ground and in-flight conditions The live fire intensity was sized to expose the test panels to a condition that was severe enough to melt through the aluminum panel under ground conditions, but not in-flight. The aluminum and composite test panels were exposed to each of these heat sources under airflows that simulated both ground and in-flight conditions. The heat transfer and conduction properties were measured with both thermocouples and FLIR infrared cameras.

The results from these tests show that there is no significant loss in fuselage structural integrity during an in-flight fire due to the use of composite construction verses aluminum construction. The materials conduct and transmit heat very differently; however the resistance to burn through is similar. The aluminum panels behaved as observed from experience in full scale aircraft fire tests. The aluminum transmits heat in a radial direction very effectively. Aluminum is also very effective at convective transfer of heat to air, more so in a moving air stream. If sufficient heat is applied to overwhelm these characteristics, the panels become plastic and deform when nearing the melting temperature of 1220 DegF. Once this temperature is reached, the metal turns to liquid, leaving a hole in the panel. Burn through under our test conditions occurred in 12-15 minutes. Burn-through is not an issue during in-flight conditions. The air stream is sufficient, even at the relatively low 200 mph in these tests, to cool the top surface of the metal and prevent it from reaching the melting point. This has been demonstrated in real world aircraft fires; burn through occurs on the ground once the relative airflow has stopped. Although omposite panels do not appear to effectively transmit heat in a radial direction, they do transmit heat normal to the surface. The panels are effective at preventing burn through, even though the resin is flammable because they have some insulating effect. Topside temperatures in the static tests were roughly half of the underside temperatures. The fire does damage the exposed face of the panel, burning the resin away and exposing the fiber. Once the outer layer of resin is burned away, however, the exposed fiber material acts like a fire blocking layer, limiting further damage. Burn through did not occur within the time frame of these tests, up to 25 minutes. Airflow over the panel during in-flight conditions is very effective at cooling the top surface of the composite material. The top surface temperature was lowered by more than 200 DegF in a 200 mph airflow. Off gassing from the heated composite panel did produce a flammable mixture in the box resulting in a flash fire. Further work in this area is necessary to determine the magnitude of this hazard and the implications on safety.

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