Statement of
Roger Dinius
Flight Safety Director
GE Aviation

Before the

SPACE AND AERONAUTICS SUBCOMMITTEE
Committee on Science and Technology
U.S. House of Representatives

Hearing on

Mitigating the Impact of Volcanic Ash Clouds on Aviation

Wednesday, May 5, 2010

Roger Dinius
Director, Aviation Safety, GE Aviation
Testimony before the Space and Aeronautics Subcommittee,
Committee on Science and Technology,
U.S. House of Representatives

Wednesday, May 5, 2010

Mitigating the Impact of Volcanic Ash Clouds on Aviation-What Do We Need to Know

Madame Chair, Members of the Committee, I am Roger Dinius, Director, Aviation Safety for GE Aviation. Thank you for providing us this opportunity to present our views and observations to the Subcommittee today.

GE aircraft engines and CFM International engines fly approximately 50 million flight hours per year worldwide. Every 2 seconds, a GE or CFM-powered airplane is taking off somewhere in the world. At any given moment, more than 2,200 of these aircraft are in flight, carrying between 50 and 300 passengers. That's more than 300,000 people, right now, who are depending on our engines.

In order to appreciate the potential hazard posed by volcanic ash on commercial aviation, and in particular on aviation gas turbine engines powering these aircraft, one has to have a basic understanding of how these engines operate. The modern turbofan engines that power today's commercial airliners are complex machines that contain more than 10,000 individual parts. In today's commercial aviation operations, the engine is expected to remain on the wing for 20,000 hours, or about 5 years. Therefore, the engines have to be very reliable while being capable of operating in all kinds of environments.

Each commercial engine is certified to 14 CFR part 33. This regulation requires specific design characteristic, design analysis, and testing be completed and approved by the FAA prior to being certified for installation on a commercial aircraft. There are currently ingestion requirements for birds, ice, rain and hail, but no requirement for volcanic ash ingestion. Sand ingestion is no longer a certification requirement, since effects of sand ingestion are more of a longer-term maintenance issue and not a flight safety issue typically. Volcanic ash ingestion is not a certification requirement for commercial engines. Historically, engines have not been required to meet a specific volcanic ash threat as a result of the relatively infrequent encounters.

Before I discuss GE Aviation's experience with volcanic ash ingestion, a short lesson on engine technology is needed. A gas turbine engine is comprised of five basic sections: the fan, compressor, combustor, high-pressure turbine and low-pressure turbines.

The fan brings in a large amount of air from the outside and pressurizes it. This is either exhausted directly to product thrust, the force that pushes an airplane through the air, or passes it to the compressor. The fan is typically made up of a single row of blades (airfoils - wings) to pressurize the air.

The compressor takes the air from the fan and pressurizes it further. This compressed air is passed to the combustor. The compressor is typically made up of 9 to 14 rows of blades (airfoils) to pressurize the air. Each one of these blade rows contains between 30-76 blades (airfoils). These compressor blades are aerodynamically shaped for efficient air pressurization. Additionally the compressor provides air for cooling hot metal parts in the turbine stages of the engine, enabling long reliable life.

The combustor takes the air, mixes a portion of it with fuel and then burns it to increase the temperature of the air stream. Since the fire in the combustor is so hot, the remainder of the compressors supplied air is typically used to cool the metal liner of the combustor and first stage turbine nozzle and blades. Without this cooling the combustor liner would crack and subsequently lead to a rupture failure, and engine shutdown.

The high-pressure turbine takes the hot high-pressure air from the combustor and takes work out of the air stream to drive the compressor. The high-pressure turbine is comprised of two main components: the turbine nozzles and turbine blades. The turbine nozzles set the area behind the combustor to maintain the pressure and turn the air to efficiently interact with the rotating turbine blades. The turbine nozzle section is a row of stationary vanes (airfoils). The turbine blades are typically one or two rows of airfoils that receive the discharged hot high-pressure air from the turbine nozzles and convert it to rotational force to turn the compressor. The turbine is like a waterwheel in operating concept, or a windmill. The high-pressure turbine operates at very high temperatures, in excess of 2500 degrees Fahrenheit. At these temperatures the base materials lose their strength properties, so in order to survive under these conditions and provide long reliable life, the blades and nozzles are cooled with un-burned compressor discharge air.

The low-pressure turbine receives the air exhausted from the high-pressure turbine and takes work out of the air stream to drive the fan. The low-pressure turbine is comprised of both nozzles and blades similar to the high-pressure turbine, except the low-pressure turbine is typically not cooled or cooling is limited to structural frames and nozzles.

For a jet engine to operate properly and produce continuous thrust, it is imperative that the air continuously flows from the fan section and proceed to exit the low-pressure turbine. When this continuous flow of air is disrupted in the compressor, the engine is said to "stall". To maintain the continuous flow of air it is important that the airfoils, both stationary and rotating, maintain their shape.

With this understanding of the engine, we can now look at how and why volcanic ash poses a hazard to aviation. Volcanic ash can hazard an aircraft if the encounter is of high enough concentration and long enough duration. There have been a number of engine temporary power losses due to volcanic ash cloud encounters. GE's first experience with volcanic ash came in 1989 when we supported the investigation after a KLM 747-400 experienced a multi-engine power loss while encountering severe volcanic ash. In this event, approximately a minute after the aircraft entered a dense volcanic ash cloud, a multi-engine power loss occurred. After exiting the volcanic ash cloud, the engines restarted and the aircraft landed safely. The volcanic ash damaged the engines, causing power loss as well as a permanent performance loss from the engines. It should be noted that while this is an extreme case, there are many cases of minor volcanic ash encounters that go unnoticed by the crew, but contribute to reduced engine on-wing life.

Industry wide experience with the volcanic ash threat has been acceptable because when aircraft avoid volcanic ash clouds, the airborne hazards are mitigated. This is a result of worldwide weather services, Air Traffic Control, and proper flight planning. Volcanic ash advisories occur across the globe on a weekly basis. Operators respond to these advisories by avoiding the troublesome area.

Volcanic ash damages engines and can lead to engine failure. The volcanic ash impacts the engine in at least three significant ways: erosion of compressor blades, plugging of cooling circuits, and accumulation on turbine nozzles.

Of these three failure modes, the volcanic ash deposits on turbine nozzles is the least understood and most impactful on engine operation as a result of high concentrations of volcanic ash. Volcanic ash can melt as it passes though the combustor and is then deposited on turbine nozzles, leading to a reduction in flow area, making the compressor work harder and resulting in subsequent engine stall (loss of airflow and thrust). This

failure mode was likely the most operationally disruptive on the KLM 747/CF6 event for which GE has detailed data. In this event, the ash accumulated on the high-pressure turbine nozzles in approximately one minute, which led to the engine stall. The rate of ash accumulation on turbine nozzles in a specified volcanic ash environment (estimated to be 2 grams per cubic meter in this event) is unknown and likely a function of volcanic ash density in the atmosphere, volcanic ash chemical make-up, engine design, and engine power setting.

The next most impactful failure mode is airfoils erosion. Volcanic ash, like sand, erodes compressor blades, changing their shape. This change in shape reduces the efficiency of the airfoil and reduces its aerodynamic capability to maintain the airflow. Taken to the engines limit, erosion will lead to an engine stall (loss of airflow and thrust). Depending on the volcanic ash density in the environment and particle size of the volcanic ash encountered this can be more severe, from an erosion stand point, than a sand storm.

The last of the most impactful failure modes is the disruption in airflow in the hot section cooling circuits. Long life of the turbine hardware is predicated on maintaining the temperatures within design limits. As volcanic ash passes through an engine it will find its way into the cooling circuits and deposit, which results in limiting, or loss of, cooling flow. This loss of cooling will lead to premature combustor, turbine blade and/or turbine nozzle failure.

Additionally, volcanic ash contaminates oil systems, air conditioning systems, erodes flowpath hardware and piping, and deposits ash in the combustor. While these failure modes are real, and impact engine operation, they're not typically the most significant failure modes from a time to failure standpoint when exposed to significant volcanic ash density. These are expected to be longer-term failure modes resulting from light to moderate levels of volcanic ash exposure.

The week following the eruption of the Eyjafjallajokull volcano, GE provided support to our customers to minimize disruptions in service, and supported US agencies and European agencies to establish safe guidelines for the resumption of operations in European airspace while volcanic ash may be present.

On April 14, following the eruption of Eyjafjallajokull volcano, GE initiated efforts to ensure airlines had information to continue operations with a volcanic ash threat. The following day, we issued an update to all operators to inform airlines of procedures to inspect and maintain engines post-exposure to volcanic ash. Also on that day, the UK Civil Aviation Authority (CAA) suspended flight operation, due to volcanic ash in the environment.

On April 16, we received an invitation from the FAA New England Regional Office to participate in an international teleconference to deal with the European volcanic ash issue. GE initiated efforts to understand past volcanic ash events with engines. On April 17 and 18, we supported additional international phone calls hosted by the UK CAA.

Actual ash concentration predicted based on the UK National Weather Service (MET) office model for volcanic ash concentration was discussed and the group worked to establish an appropriate level to prevent a hazardous environment for civil flights. GE freely shared our knowledge, observations and experience on this potential safety matter with agencies, airframers and other engine companies (Pratt & Whitney, & Rolls-Royce). We researched records to gather relevant data on past volcanic ash encounters with engines. The UK CAA was acting on guidance within the International Civil Aviation Organization (ICAO) "Manual on Volcanic Ash, Radioactive Material, and Toxic Chemical Clouds" DOC 9691, which states in paragraph 3.4.8 : "... the recommended procedure in the case of volcanic ash is.... regardless of ash concentration – AVOID AVOID AVOID".

The group worked to understand the UK MET office model and its validation. The UK MET office initiated flights to support model validation. On April 19th, there were further phone calls to establish consensus on the concentration level of volcanic ash an engine could tolerate without causing a safety hazard.

On April 20th, engine manufacturers (RR, P&W, & GE) reached consensus with FAA NE office that flights in volcanic ash would be acceptable up to volcanic ash concentration levels of up to 2milligrams per cubic meter and in absence of visible volcanic ash. Additionally the London Volcano Area Advisory Center (VAAC) would issue volcanic ash advisories for predicted concentration in excess of 0.2 milligrams per cubic meter. Operation in volcanic ash concentrations between 0.2 and 2 milligrams per cubic meter and clear of visible volcanic ash would be monitored to determine the long-term impact on engine operation. This consensus was based on industry experience and engineering judgment.

GE continues to support regulating agencies and airlines with volcanic ash inquires, and mature sampling plans. In addition, GE issued All Operator Wires and Service Bulletins to socialize the agreement above and to provide guidance for operators on sampling plans to access longer-term engine impact. In summary, government and industry working together determined that the Volcanic Ash threat can be mitigated as long as aircraft avoid visible volcanic ash.

Volcanic ash can pose a threat to safe aviation flights. It has caused engine failure within minutes of the encounter in severe volcanic ash cloud environments. Much work still needs to be done to understand the effects on aircraft gas turbine engines. The quantitative flight safety risk due to volcanic ash is dependent on a number of factors, some known and some unknown. These unknowns make establishing a quantitative limit on volcanic ash a challenge. GE provided and continues to provide support to our customers and regulatory agencies to maintain safe operation in light of the recent volcanic ash threat. The current best practice for abating the volcanic ash hazard is to avoid visible volcanic ash. GE supports further research to better define the volcanic ash threat and to establish working limits, that maintain safe environment for flight and provide meteorologists a metric to establish a forecast volcanic ash area to allow ATC and flight crews a known area to avoid.

Thank you again for the opportunity to discuss this issue with you.