DEPARTMENT OF THE AIR FORCE
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AIRWORTHINESS ADVISORY

VOLCANIC ASH EFFECTS ON AIRCRAFT AND PROCEDURES FOR ADDRESSING EXPOSURE

PURPOSE:

This airworthiness advisory addresses safety issues that may result from aircraft exposure to volcanic ash in-flight and on the ground and provides guidance on appropriate procedures for addressing detrimental exposure.

SCOPE:

This airworthiness advisory applies to all USAF aircraft, manned and unmanned, including those operated by the Air National Guard and the USAF Reserve.

REFERENCED DOCUMENTS:

1. USAFE/A3 Interim USAFE Flying Policy in the Wake of April 2010 Icelandic Volcanic Eruptions, dated 20 April 2010
2. Cleaning And Corrosion Prevention and Control, Aerospace and Non-Aerospace Equipment, T.O. 1-1-691, dated 19 October 2007
3. Maintenance Assistance, T.O. 00-25-107, dated 31 May 1999
4. Dunn, M. G., and Wade, D. P., 1994, Influence of Volcanic Ash Clouds on Gas Turbine Engines, in Casadevall, T. J. (ed.). "Volcanic Ash and Aviation Safety - Proceedings of the First International Symposium on Volcanic Ash and Aviation Safety," U.S. Geological Survey Bulletin 2047, p. 107-118
5. Aero, Advances in Volcanic Ash Avoidance and Recovery, (No. 9, 1999) a quarterly magazine published by Boeing Commercial Airplane Group
6. International Civil Aviation Organization, Manual on volcanic Ash, Radioactive Material and Toxic Chemical Clouds, Doc 9691, AN/954, Second Edition, 2007, http://www.icao.int/icao/en/9691.pdf
7. Special Airworthiness Information Bulletin (SAIB), "Turbine Engine Operation in Volcanic Ash Airspace," NE-10-28, dated 22 April 2010 http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgSAIB.nsf/(LookupSAIBs)/NE-10-28?OpenDocument
8. U.S. Department of Transportation, Federal Aviation Administration, Air Traffic Organization Policy, Order JO7110.65T, dated 11 February 2010 http://www.faa.gov/documentLibrary/media/Order/ATC.pdf
9. International Civil Aviation Organization, "Hazards of Volcanic Ash," ALSAFECOM, dated 5 October 2004

BACKGROUND:

1. The eruption of the Icelandic volcano Eyjafjallajökull has hampered both civil and military flight operations since 14 April 2010. The current, visible ash cloud extends southeast from Iceland toward Northern Europe; however a composite of the volcanic ash cloud from 14 April 2010 through 25 April 2010 shows that visible ash has covered a significant portion of the Northern Hemisphere extending from the United States to Northern Europe. It is reasonable to conclude that an area significantly larger than the current ash plume area may be subject to the accumulation of less visible or invisible ash debris. Ground and flight operations planning should account for this extended hazard area.
2. An ash cloud eventually dissipates in the atmosphere, and ash concentrations drop. It is known that ash clouds pose an extreme hazard to aircraft. However, the threshold concentration at which ash poses no harm to aircraft is not known, and indeed, may never fully be characterized for all situations involving aircraft. It is usually assumed that ash identifiable on satellite images continues to present a hazard to aircraft. Accordingly, the consensus of the aviation community is that if an ash cloud can be discerned, it **should be avoided**.
3. Flight operations by unprotected aircraft subject to ash fall out while on the ground must be preceded by appropriate inspections and maintenance actions. Experience has shown that damage can occur to aircraft surfaces, windshields and engines. Most aircraft systems are subject to some level of contamination from exposure to volcanic ash. Exposure could lead to system malfunction or failure. Partial or total engine power loss events caused by volcanic ash ingestion, while not frequent, are major safety concerns. As weather radar is not effective in detecting volcanic ash clouds, air crews must be informed by other means of the potential or effective presence of ash clouds on air routes and over air bases.

DISCUSSION:

1. Numerous instances of jet aircraft flying into volcanic ash clouds have demonstrated the serious damage that can be sustained. Ash particles are angular fragments having the hardness of a pocket-knife blade and, upon impact with aircraft traveling at speeds of several hundred knots, cause abrasion damage to forward-facing surfaces, including windscreens, fuselage surfaces, and compressor fan blades. Moreover, the melting temperature of the glassy silicate rock material that comprises an ash cloud is lower than the operating temperatures of modern jet engines; consequently, ingested ash particles can melt and then accumulate as re-solidified deposits in the engine. The overall result of an aircraft flying into an ash cloud can be degraded engine performance (including flame out), loss of visibility, and failure of critical navigational and operational instruments.
2. The ref. 1 USAFE/A4 Memo outlines flight operation limitations for USAFE controlled aircraft and appropriately identifies the ref. 2 and ref. 3 technical data for use in performing maintenance actions and cleaning/refurbishment procedures on aircraft systems exposed to corrosive and abrasive contaminant environments.
3. Experimental tests (study by Wade and Dunn, ref. 4) have shown potential adverse impacts to aircraft performance resulting from exposure to a volcanic ash cloud for numerous systems and components:
   a. Deposition of material on hot-section components
   b. Erosion of compressor blades and rotor-path components
   c. Blockage of fuel nozzles and cooling passages
   d. Contamination of the oil system and bleed-air supply

e. Opacity of windscreen and landing lights
f. Contamination of electronics
g. Erosion of antenna surfaces
h. Plugging of the pitot-static system which indicates the airspeed of the aircraft.

4. Component Abrasion: Because volcanic ash consists of highly abrasive particles, it can easily erode plastic, metal and even glass pieces. Service experience shows that aircraft can experience extensive damage to forward facing components, exposed surfaces and engine structure from an in-flight volcanic ash encounter. Service reports from such encounters typically identify damage to components such as:
   a. Windshields
   b. Forward cabin windows
   c. Navigation and landing lights cover
   d. Wing, stabilizer and fin leading edges
   e. Engine nose cowls and thrust reversers
   f. Pitot and static probes.
5. Engine Performance Deterioration: Ingestion of volcanic ash by engines may cause serious deterioration of engine performance due to erosion of moving parts and/or partial or complete blocking of fuel nozzles. Volcanic ash contains particles, whose melting point is below engine internal temperature. In-flight, these particles will immediately melt if they enter an engine. Melted materials progressing through the turbine are subject to rapid cooling and collection on the turbine vanes. The accumulation of these particles disturbs the flow of high-pressure combustion gases and can result in engine stall. In the event that specific T.O. data addressing volcanic ash contamination is not available, the following actions should be implemented for the indicated situations:
   a. The following actions are recommended for engines that have been exposed to volcanic ash environment but have not operated on the ground or in-flight and should be accomplished prior to the next engine start:
      i. Remove volcanic ash from the area in front of engine inlet and around the exhaust
      ii. Dry motor the engine at the typical motoring speed of N2 for 90 seconds to blow volcanic ash out of the engine. Observe starter duty cycle requirements in the applicable engine operating instruction manual.
      iii. Borescope inspect the Fan, HPC, HPT and LPT to look for foreign material
      iv. If loose material is observed, dry motor the engine again for 90 seconds and re-inspect
      v. Change the engine oil filters
      vi. Drain the oil system and refill with fresh oil.
   b. The following actions are recommended for engines that have been exposed to volcanic ash and operated on the ground or in-flight in a volcanic ash environment prior to the next engine start.
      i. Inspect the engine inlet and exhaust areas for damage or erosion
      ii. Borescope inspect the Fan, HPC, combustor, HPT, and LPT for evidence of erosion, foreign object damage, ash deposits and cooling hole-plugging
      iii. Change engine oil filters
      iv. Drain oil system and refill with fresh oil
      v. Schedule a repeat combustor, HPT and LPT Borescope inspection at the next aircraft phase inspection but no later than 100 flight hours

vi. Perform a ground high power assurance run.

c. USAF strongly advises against performing water washes for engines that have been operated in volcanic ash environment. Performing water washes with water alone or in concert with wash solvent may cause the foreign material to accumulate in the HPT and LPT nozzle and HPT and LPT blade cooling paths resulting in reduced cooling flow and performance loss. Fan, HPC, HPT and LPT rotor imbalance and performance loss may also result from accumulation of material settling and drying in the rotor spools if water washes are performed.

6. Bleed, Air Data and Electronic Systems Contamination: Volcanic ash is made of very fine particles (down to 1 micron) that can easily penetrate all but the most tightly sealed enclosures. It may carry high static charge that makes it difficult to remove from electronic components. Ash deposit easily absorbs water and can cause arcing, short circuits and intermittent failures of electronic components. Dense ash deposit can clog bleed system filters and may lead to total bleed loss, with associated loss of cabin pressurization. Pitot and static systems may also become obstructed by the dust.
7. Indications an aircraft has inadvertently entered a volcanic-ash cloud (ref. 5 and 6):
   a. Smoke or very fine dust in cabin
   b. Acrid odor (like electrical smoke)
   c. Low air-speed indications
   d. Cargo fire warnings (caused by ash triggering smoke detectors)
   e. Static discharges (St. Elmo's fire) around windscreen, or on wing, stabilizer, or fin tips
   f. White glow (searchlight effect) at engine inlets
   g. Multiple engine malfunctions (increasing EGT, power loss, stall or flameout).
8. The recommended in-flight procedures in the event of an ash-cloud encounter are summarized below (ref. 5 and 6):
   a. Exit the ash cloud as quickly as possible (e.g., a 180-degree turn). **DO NOT ATTEMPT TO CLIMB OUT OF THE ASH CLOUD**
   b. Disconnect auto-throttle
   c. Throttles at minimum, terrain permitting
   d. Ignition on
   e. Bleed air systems full on (air-conditioning, engine and wing anti-ice, etc.)
   f. Start auxiliary power unit when clear of ash cloud
   g. Monitor engine exhaust gas temperature (if hung start occurs, EGT will increase rapidly)
   h. Restart engine(s) if required. If an engine fails to start, try again immediately
   i. Monitor airspeed and pitch attitude
   j. Crew oxygen masks on 100%, if ash enters flight deck
   k. Declare an Emergency to ATC, if warranted
   l. Transmit Volcanic Activity Report
   m. Land at the nearest suitable airport.
9. Volcanic ash with high sulfur compounds may produce caustic material when exposed to moisture. Surfaces subject to the formation of condensate (such as cold surfaces) are susceptible to formation of these caustic materials leading to corrosion. Exposed surfaces, such as radomes and antennas, are subject to performance degradation under these conditions and thorough inspection and cleaning is essential following ash exposure.

GUIDANCE/RECOMMENDATIONS:

1. System Program Offices should be familiar with the information discussed, references provided and procedural options outlined in this advisory and should communicate this information to their operational customers.
2. The adequacy of each weapon system's -1 Flight Manual for clearly delineating in-flight emergency procedures for inadvertent flight operations into volcanic ash or air-borne contaminants should be reviewed and confirmed.
3. Flight operations checklists should be reviewed to establish that pre-flight and post-flight inspections are adequate for aircraft deployed to locations susceptible to ash fall-out or exposure to excessive airborne dust and abrasive contaminants.
4. System specific technical orders should be reviewed to ensure they adequately outline the general procedures documented in ref. 2 and ref. 3 for inspection, cleaning and maintenance of systems exposed to volcanic ash while conducting flight operations or ground deployed.
5. Commercial Derivative Aircraft (CDA) under FAA Regulations: The FAA has issued a Special Airworthiness Information Bulletin (SAIB), ref. 7, to owners and operators of aircraft equipped with turbine engines that operate in airspace where volcanic ash may be present. While there is no specific airworthiness safety concern that warrants an Airworthiness Directive (AD) at this time, the bulletin advises that owners and operators observe equipment manufacturer instructions for volcanic ash exposure. Ref. 8 was also recently issued by the FAA and provides information on ground operations in areas exposed to volcanic ash and provides additional reference material for flight operations in areas subject to volcanic ash. Users of CDA should regularly review the FAA website for updates.
6. Ref. 9 provides additional information on several of the topics treated in this advisory and can be consulted if other documentation is lacking. Program offices should consult with their prime contractor or aircraft original equipment manufacturer for additional guidance if current documentation is found to be lacking in specific operational, inspection and maintenance procedures.

POINTS OF CONTACT:

Contact Mr. Robert Fitzharris (ASC/ENSI, 937-255-7224, DSN 785-7224) to discuss airworthiness related questions/issues and Mr. Timothy Jennewine (ASC/ENF, 937-255-8610, DSN 785-8610) for the technical content of this document. For airworthiness publication issues contact the ASC/AFRL Engineering Standards Group (ASC/ENRS, (937) 255-6295, DSN 785-6295).

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