**Doc. No 9974**

# FLIGHT SAFETY AND VOLCANIC ASH

*Risk management of flight operations with known or forecast volcanic ash contamination*

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## FOREWORD

This document provides guidance which States may recommend to operators and regulatory authorities where volcanic ash contamination may be a hazard for flight operations. The underlying assumption used is that the individual operator is responsible for such operations under the oversight of their respective State regulatory authority. The guiding principle for such operations is the use of a safety risk management approach, as described in this document.

This document is based principally on work undertaken by the ICAO International Volcanic Ash Task Force (IVATF) in 2010 and 2011and inputs from Members of the ICAO Operations Panel (OPSP). It was published to make existing information available as soon as possible. Several relevant initiatives continue to be undertaken and outcomes may be introduced, as appropriate, as they are completed.

Among the ongoing initiatives which may have relevance to the volcanic ash safety risk management approach is the information provided by the volcanic ash advisory centres (VAAC) within the framework of ICAO's international airways volcano watch. Work is underway to correlate the forecast output of the nine designated VAACs with the current avoidance guidance* to operators found in the *Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds* (Doc 9691) and the *Handbook on the International Airways Volcano Watch (IAVW) — Operational Procedures and Contact List* (Doc 9766) and to harmonize the content of the VAAC advisory information at regional interfaces. There is also work underway to enhance the information available to aircraft in flight and at the aerodrome to ensure utmost safety and optimal efficiency.

In the interests of flight safety, in the event of a volcanic eruption, distribution of this document is encouraged. It may not be offered for sale or used commercially without the written permission from ICAO.

*This document is published by ICAO following a collaborative endeavour among stakeholders with the objective of improving safety for flight operations in the event of a volcanic eruption. An arrangement of collaboration has been signed denoting the valued contribution and endorsement, including the use of the logo on this document, with the following organizations: Airports Council International (ACI), Civil Air Navigation Services Organisation (CANSO), International Air Transport Association (IATA), International Coordinating Council of Aerospace Industries Associations (ICCAIA), International Federation of Air Line Pilots' Associations (IFALPA) and International Federation of Air Traffic Controllers' Associations (IFATCA).*


* Current avoidance guidance refers to visible or discernable ash. There is a need to define these terms in a manner that facilitates their use both at dispatch and in the en route phase of flight (such as quantitative descriptors). This information is considered central to any operational procedures intended to be applied when flying in airspace subject to volcanic ash.

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## 1. DEFINITIONS

The terminology and acronyms used in this document are set out in Appendix H.

## 2. INTRODUCTION

Volcanic ash mostly consists of sharp-edged, hard glass particles and pulverized rock, which is very abrasive and, being largely composed of siliceous materials and has a melting temperature below the operating temperature of modern turbine engines at cruise thrust. A volcanic ash cloud may be accompanied by gaseous solutions of sulphur dioxide (when combined with water create sulphuric acid), chlorine (when combined with water create hydrochloric acid) and other chemicals which are corrosive to the airframe and hazardous to health. Given these facts, it is self evident, that volcanic ash in the atmosphere may pose a serious hazard to aircraft in flight. Thus, volcanic ash encounters by aircraft should be avoided.

Volcanic ash forecast serve to levy the probability, when performing a safety risk assessment, of the hazard of an aircraft encountering volcanic ash. The risk may be mitigated using effective in flight procedures. This document establishes guidelines which States may recommend to aircraft operators and regulatory authorities to adopt in order to assess the safety risk of flight operations in areas forecast to be affected by volcanic ash or aerodromes contaminated with volcanic ash.

### 2.1 Ash encounter indicators

In day VMC a precursor to a volcanic ash encounter will likely be a visual indication of a volcanic ash cloud or haze. If a flight crew observes a cloud or haze suspect of containing volcanic ash they should be alerted that a volcanic ash encounter is imminent and action should be initiated to avoid the contaminated airspace.

Indicators that an aircraft is encountering volcanic ash are related principally to odor, haze, changing engine conditions, airspeed, pressurization and static discharges.

- *Odor*. When encountering volcanic ash, flight crews usually notice a smoky or acrid odor that can smell like electrical smoke, burned dust or sulphur.
- *Haze.* Most flight crews, as well as cabin crew or passengers, see a haze develop within the aircraft cockpit and/or cabin. Dust can settle on surfaces.
- *Changing engine conditions*. Surging, torching from the tailpipe, and flameouts can occur. Engine temperatures can change unexpectedly, and a white glow can appear at the engine inlet.
- *Airspeed.* If volcanic ash fouls the pitot tube, the indicated airspeed can decrease or fluctuate erratically.
- *Pressurization.* Cabin pressure can change, including possible loss of cabin pressurization.
- *Static discharges.* A phenomenon similar to St. Elmo's fire or glow can occur. In these instances, blue-coloured sparks can appear to flow up the outside of the windshield or a white glow can appear at the leading edges of the wings or at the front of the engine inlets.

Any of these indicators should suffice to alert the flight crew of an ash encounter and appropriate action should be taken to vacate the contaminated airspace as safely and expeditiously as possible.

## 2.2 The hazard

The abrasiveness of volcanic ash[1] can be very detrimental to aircraft. The following non-exhaustive list provides examples of what can be expected in the event of an ash encounter which may affect the:

a) immediate safety of an aircraft:

- the malfunction or failure of one or more engines leading not only to reduction, or complete loss, of thrust but also to failures of electrical, pneumatic and hydraulic systems. Volcanic ash contains particles whose melting point is below modern turbine engine burner temperature; these then fuse in the turbine section reducing the throat area and efficiency leading to engine surge and possibly flame-out;

- the blockage of pitot and static sensors resulting in unreliable airspeed indications and erroneous warnings;

- windscreens can be rendered partially or completely opaque; and

- contamination of cabin air requiring crew use of oxygen masks.

b) the longer term safety and costs affecting the operation of aircraft:

- the erosion of external aircraft components;

- reduced electronic cooling efficiency and, since volcanic ash readily absorbs water, potential short circuits leading to a wide range of aircraft system failures and/or anomalous behaviour;

- flight crew manoeuvring for volcanic cloud avoidance may potentially conflict with other aircraft in the vicinity;

- deposits of volcanic ash on a runway resulting in a degradation of braking performance, especially if the volcanic ash is wet; in extreme cases, this can lead to runway closure; and

- the aircraft ventilation and pressurization systems can become heavily contaminated. In particular, cleaning or replacement may be required in response to air cycle machine contamination and abrasion to rotating components, ozone converter contamination and air filter congestion.

## 2.3 Ash encounter avoidance resources

The behaviour of erupting volcanoes ranges from the quiet, steady effusion of lava to highly explosive eruptions. The larger scale eruptions may eject many cubic kilometres of glass particles and pulverized rock (volcanic ash) and corrosive/hazardous gases high into the atmosphere, potentially over a wide area for timescales ranging from hours to weeks or even months. Volcanic eruptions may present a direct threat to the safety of aircraft in flight and major operational difficulties at aerodromes and in airspaces located downwind of the resulting volcanic ash cloud, in particular when eruptions are of high intensity and/or prolonged.

Consequently, the timely availability of reliable, consistent volcanic ash-related information (observations and forecasts) is essential to mitigate the safety risk of aircraft encountering volcanic ash. The availability

[1] Although the specific material being warned for is the ash contained in the volcanic cloud, it is understood that other elements of the cloud may also be undesirable to operate through and cause additional hazards

of such information plays an important role for strategic pre-flight planning and tactical in-flight re-planning in assessing the likelihood of encountering ash clouds.

The nine designated volcanic ash advisory centres (VAACs), which make available advisory information on the extent and movement of volcanic ash in the atmosphere, have at their disposal information from an array of ground-based, airborne and satellite-based remote-sensing systems that is used to initialize sophisticated numerical trajectory/dispersion models and validate the forecasts produced. Such tools are often also available at meteorological watch offices for use in the preparation of en-route SIGMET information. It is important to note that no matter how sophisticated observations and forecasts of volcanic ash may be, there is no definitive assurance on how volcanic ash will behave in the atmosphere.

### 2.4 Coordinating the response to a volcanic event

There are many other contributors to the overall volcanic risk mitigation system such as, Air Navigation Service Providers including Aeronautical Information Services and Air Traffic Flow Management Units, Meteorological Service providers including Meteorological Watch Offices, Volcanic Ash Advisory Centres and Volcano Observatories, and aircraft and engine type certificate holders (TCHs), supplemental type certificate (STC) holders and parts manufacturer approval (PMA) holders. Their cooperation in supplying States, operators and CAAs with the information necessary to support the pre-flight process and the in-flight and post-flight decision making process is essential to continuing safe operations.

Information on the procedures of these contributors in respect of operations in areas forecast to be or aerodromes known to be contaminated with volcanic ash is available in other ICAO documents such as:

- ICAO Annex 3 — *Meteorological Services for International Air Navigation*;
- ICAO *Procedures for Air Navigation Services (PANS) – Air Traffic Management* (Doc 4444);
- ICAO *Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds* (Doc 9691);
- ICAO *Handbook on the International Airways Volcano Watch – Operational Procedures and Contact List* (Doc 9766); and
- ICAO *Regional ATM contingency plans such as the Volcanic Ash Contingency Plan for the European and North Atlantic Region* (EUR Doc 019/NAT Doc 006 Part II).

This present document, in providing advice to States on addressing the role of the aircraft operator and of the operator's CAA, is complementary to the documents listed above.

To ensure effective coordination between all concerned, it is recommended that States encourage operators and their CAAs to participate in annual volcanic ash exercises (simulations) as are organized by ICAO in several ICAO Regions. In the European and North Atlantic (EUR/NAT) Region, for example, information on regular exercises is available on the ICAO EUR/NAT Office website http://www.paris.icao.int/.

## 3. THE STATE

The State of the Operator and/or State of Registry are required to maintain adequate ongoing surveillance of operators including their Safety Management Systems (SMS). In the event that a State has no SMS regulations in place, or is in the process of promulgating SMS regulations, it is expected that the same oversight and surveillance process will ensure that safety risk assessments, such as those for operating into airspace forecast to be or at aerodromes contaminated with volcanic ash, will be undertaken.

The safety control measures set out in this document are intended to be sufficiently robust that they facilitate acceptance by a State whose airspace is forecast to be affected by volcanic clouds without further investigation, confident in the ability of operators from other States to undertake operations safely in their airspace. However, pursuant to Article 16 of the Convention on International Civil Aviation

(Doc. 7300), other contracting States may inspect the certificates and other documents, prescribed by the Convention, of an operator on landing or prior to departure.

## 4. THE AIRCRAFT OPERATOR

ICAO's generic safety risk assessment process is described in ICAO Doc 9859[2]. An approach, aligned with an operator's SMS, would be equally appropriate. The material in this document is designed to provide States with information to support operators in developing the safety risk assessment, within their SMS, covering the volcanic cloud hazard.

### 4.1 Responsibilities

a) The operator is responsible for the safety of its operations.

b) In order to decide whether or not to operate into airspace forecast to be or aerodromes known to be contaminated with volcanic ash, the operator should have in place an identifiable safety risk assessment within its SMS.

***Note.—*** *Guidance on the production of a safety risk assessment is provided in Appendices A (guidelines on conducting a safety risk assessment), B (procedures to be included in a safety risk assessment) and C (risks to be considered). Each operator should develop its own list of procedures and hazards since these have to be relevant to the specific equipment, experience and knowledge of the operator, and to the routes to be flown.*

c) The operator should complete the safety risk assessment as part of the SMS before initiating operations into airspace forecast to be or aerodromes known to be contaminated with volcanic ash. During its normal oversight of its operators, a CAA should normally evaluate the safety risk assessment as an identifiable process of the operator's SMS.

d) An operator should have satisfied its CAA regarding the likely accuracy and quality of the information sources it uses in its SMS and its own competence and capability to interpret such data correctly in order to reliably and correctly resolve any conflicts among data sources that may arise.

e) The operator should revise its safety risk assessment when changes that are material to the integrity of the safety risk assessment occur.

f) The operator's safety risk assessment should take into account data published by the relevant TCHs regarding the susceptibility to volcanic cloud-related airworthiness effects of the aircraft they operate, the nature of these effects and the related pre-flight, in-flight and post-flight precautions to be observed by the operator.

g) The operator should ensure that those of its personnel needing to be familiar with the details of the safety risk assessments receive all relevant information (both pre-flight and in-flight) in order to be in a position to apply appropriate mitigation measures as specified by the safety risk assessments, especially when the situation deviates from any scenario contemplated in the safety risk assessments.

h) The operator should ensure that reports are immediately submitted to the nearest ATS unit using the VAR/AIREP procedures followed up by a more detailed VAR on landing together with, as applicable, an ASR and AML entry for:

[2] ICAO *Safety Management Manual* (Section 9, Issue 2, 2009).

1) any incidents related to volcanic clouds;
2) any observation of volcanic ash activity; and
3) anytime that volcanic ash is not encountered in an area(s) where it was forecast to be.

### 4.2 Procedures

a) The operator should have documented procedures for the management of operations into airspace forecast to be or aerodromes known to be contaminated with volcanic ash.

*Note 1.— Procedures should include crew action in the event that they encounter a volcanic ash cloud (related guidance material is being developed).*

Note *2.— Procedures should include collaboration with ATM and aerodrome operators to coordinate any delays and/or service recommencement on aerodrome(s) affected by volcanic ash.*

b) These procedures should ensure that, at all times, flight operations remain within the accepted safety boundaries, as established through the SMS, despite any variations in information sources, equipment, operational experience or procedures. Procedures should include those for flight crew, flight planners, dispatchers, operations, engineering and maintenance personnel such that they are equipped to evaluate correctly the risk of flights encountering airspace contaminated by volcanic clouds and to plan accordingly.

c) Maintenance and engineering personnel should be provided with procedures allowing them to correctly assess the need for, and execute, relevant maintenance or other engineering interventions.

d) The operator should retain, or, employ via a third party sufficient qualified and competent staff to generate well supported operational risk management decisions, and ensure that its staff is appropriately trained and current.

*Note.— It is not intended that the operator be precluded from securing necessary resources from other competent parties.*

e) The operator should make the necessary arrangements for its flight operations staff to take up opportunities to be involved in volcanic ash exercises conducted in their area of operations.

### 4.3 Information

Before and during eruptions, information valuable to the operator is generated by various meteorological and volcanological agencies worldwide. The operator's risk assessment and mitigating actions need to take account of, and respond appropriately to, the information likely to be available during each phase of the eruptive sequence from pre-eruption through to end of eruptive activity. Further material is provided in Appendix E.

## 5. THE TYPE CERTIFICATE HOLDER

In fulfilling its primary responsibility for the safety of operations, the operator is dependent on the Type Certificate Holders (TCH) of the equipment it operates for some information, such as maintenance monitoring, recognition of encounter, etc. necessary to inform its safety risk assessment when volcanic clouds are a hazard.

Therefore, TCHs should make available to operators a range of information important to the operator's safety risk assessment related to the hazards associated with volcanic clouds. This information should be kept updated as future knowledge is acquired.

*Note.— An indication of the range of information that an operator might require is provided in Section 3 and in Appendix B.*

## 6. THE CIVIL AVIATION AUTHORITY

ICAO's safety risk assessment process is described in the ICAO *Safety Management Manual (SMM* – Doc 9859). An approach, aligned with an organisation's approved SMS, would be equally appropriate. The State is advised that the CAA exercising oversight of an operator that intends to undertake operations into airspace forecast to be or aerodromes known to be contaminated with volcanic ash should establish a methodology for evaluating the safety risk assessment process particular to volcanic ash of the operator's SMS. The operator should not be prevented from operating through, under or over, airspace forecast to be affected by a VAA, VAG or SIGMET provided it has demonstrated in its SMS the capability to do so safely. The guidance set out in Appendix F indicates a process that the CAA can use to achieve this outcome.

## APPENDIX A
## GUIDELINES FOR COMPLETING A SAFETY RISK ASSESSMENT

### A.1 INTRODUCTION

ICAO's safety risk assessment process is described in the ICAO *Safety Management Manual* (Doc 9859, Section 9, Issue 2, 2009). Alternative approaches, aligned with an organisation's approved SMS, would be equally appropriate.

Implementation of an SMS, in accordance with State Regulation, is a key capability for an operator. The operator should develop any safety risk assessment in accordance with its authorised SMS risk management processes.

Where the SMS regulatory framework has yet to be promulgated by a State, then it should be possible for the State to accept a safety risk assessment provided the operator has implemented an SMS that, as a minimum:

a) identifies safety hazards;
b) ensures the implementation of remedial action necessary to maintain agreed safety performance;
c) provides for continuous monitoring and regular assessment of the safety performance; and
d) aims at a continuous improvement of the overall performance of the safety management system.

Risk is an assessment of the probability and severity of adverse consequences resulting from a hazard. To help an operator to decide on the probability of a hazard causing harm, and to assist with possible mitigation of any perceived safety risk, all pertinent information available should be taken into account and relevant stakeholders consulted.

The safety risk from each hazard should be assessed using a suitable safety risk assessment worksheet. The safety risk should be derived by considering the severity of the safety risk outcome arising from the hazard, together with the probability of that outcome.

The severity of any adverse consequences resulting from a particular hazard should be assessed using a suitable severity scale.

*Note.— Further guidance on safety risk assessments can be found in the* Safety Management Manual *(SMM – Doc 9859).*

### A.2 THE PROCESS STEPS

When made specific to the issue of intended flight into airspace forecast to be or aerodromes known to be contaminated with volcanic ash, then the process involves:

- Identifying the hazard (i.e. arising from the generic hazard of airspace or aerodromes with known or forecast contamination by volcanic ash clouds with characteristics harmful to the airworthiness and operation of the aircraft);
- Considering the seriousness of the hazard occurring (i.e. the actual level of damage expected to be inflicted on the particular aircraft from exposure to that volcanic ash cloud);
- Evaluating the probability of encountering volcanic ash clouds with characteristics harmful to the safe operation of the aircraft;

- Determining whether the consequent risk is acceptable and within the organisation's risk performance criteria;
- Taking action to reduce the safety risk to a level that is acceptable to the operator's Accountable Executive or equivalent.

### A.2.1 Hazard Identification

The generic hazard, in the context of this document, is airspace or aerodromes subject to contamination by volcanic ash with characteristics harmful to the airworthiness and operation of the aircraft.

Within this generic hazard is the specific hazard of an operator not having secured the information necessary to properly characterise that hazard and develop a robust assessment of the risk and likely success of any chosen mitigating actions. To assist operators in relation to this specific hazard, guidance on the list of procedures to be considered is given in Appendix B.

A list of suggested hazards and their associated risks is provided in Appendix C.

Neither of these lists is exhaustive; the operator should develop its own taking into account its specific equipment, experience, knowledge and type of operation.

### A.2.2 Risk severity

For each hazard, the potential adverse consequences or outcome should be assessed. Again, the results of this phase of the assessment should be recorded in a safety risk assessment worksheet, such as that reproduced at Appendix D.

### A.2.3 Risk probability

For each hazard, the probability of adverse consequences should be assessed, either qualitatively or quantitatively. When assessing probability, the following factors should be taken into account:

- Any uncertainties in available information;
- The duration of exposure to the hazard and associated severity;
- Any historic incident or safety event data relating to the hazard. This can be derived using data from TCHs, regulators, other operators, Air Navigation Service Providers, internal reports etc;
- The expert judgement of relevant stakeholders notably from TCHs.
- Operational environment in which flight operations are performed.

The results of this phase of the assessment should be recorded in a safety risk assessment worksheet, an example of which is at Appendix D.

### A.2.4 Risk tolerability

At this stage of the process, the safety risks should be classified acceptable or unacceptable.

It is recognised that the assessment of tolerability will be subjective based on qualitative data and expert judgement until specific quantitative data is available in respect of a range of parameters such as uncertainty in volcanic cloud forecast accuracy, the likely range of engine tolerability to ingestion of ash and other volcanic cloud elements with time and engine condition etc.

Appropriate mitigations for each unacceptable risk identified should then be considered, recorded on a safety risk assessment worksheet and implemented in order to reduce the risks to a level acceptable to the operator's Accountable Executive or equivalent.

Not all risks may be suitably mitigated; in such cases, the operation should not proceed.

### A.2.5 Mitigating actions

Mitigating actions by themselves can introduce new risks. An effective SMS should incorporate procedures for continuous monitoring of hazards and risk, with qualified personnel establishing the mitigating actions or halting affected operations.

Given the potential introduction of new risks, or a change of circumstances on which the original assessment was predicated changing, it is critical that an operator ensures that the safety risk assessment is repeated as necessary following any mitigation process and at regular intervals as part of its SMS activities.

## A.3 RECORDS

The results of the safety risk assessment should be documented. Mitigating actions should be completed and verified and supported by evidence prior to the start of operations.
Any assumptions should be clearly stated, and the safety risk assessment reviewed at regular intervals and as necessary, to ensure that the assumptions and decisions remain valid.

*Note.— Any safety performance monitoring requirements should also be identified and undertaken through the organisation's safety risk management system.*

## APPENDIX B

## PROCEDURES TO BE CONSIDERED BY AN AIRCRAFT OPERATOR WHEN CONDUCTING A SAFETY RISK ASSESSMENT

| **Considerations** | **Actions** |
|---|---|
| **Preparation** | |
| Type Certificate Holder | The operator should obtain advice from the TCHs of the aircraft and engines it operates concerning operations in potentially contaminated airspace and/or to/from aerodromes contaminated by volcanic ash. This advice should set out:<br>– the features of the aircraft or engine that are susceptible to airworthiness effects related to volcanic ash;<br>– the nature and severity of these effects;<br>– the effect of volcanic ash on operations to/from contaminated aerodromes;<br>– the related pre-flight, in-flight and post-flight precautions to be observed by the operator including any necessary amendments to Aircraft Operating Manuals, Aircraft Maintenance Manuals Master Minimum Equipment List/Despatch Deviation or equivalents required to support the operator;<br>– the recommended continuing airworthiness inspections associated with operations in volcanic ash contaminated airspace and to/from volcanic ash contaminated aerodromes; this may take the form of Instructions for Continuing Airworthiness or other advice. |
| Operator Personnel or their Service Providers | The operator should publish procedures for flight planning, operations, engineering and maintenance ensuring that:<br>– personnel responsible for flight planning are equipped to evaluate correctly the risk of encountering volcanic ash cloud-contaminated airspace, or aerodromes, and can plan accordingly;<br>– flight planning and operational procedures enable crews to avoid areas and aerodromes with unacceptable volcanic ash contamination;<br>– flight crew are aware of the possible signs of entry into a volcanic ash cloud and execute the associated procedures;<br>– engineering and maintenance personnel are able to assess the need for, and to execute, any necessary maintenance or other required interventions. |

| Considerations | Actions |
|---|---|
| **Operator procedures** | |
| Provision of Enhanced Flight Watch | The operator should:<br>– closely and continuously monitor VAA, VAR/AIREP, SIGMET, NOTAM and ASHTAM information, and information from its crews, concerning the volcanic ash cloud hazard;<br>– ensure that its Operations Unit, or equivalent, and its crews, have access to plots of the affected area from SIGMETs and NOTAMs;<br>– ensure that the latest information is communicated to its crews and planners in a timely fashion. |
| Flight Planning | The operator should develop a safety risk assessment for planned flights into areas forecast to be or aerodromes known to be contaminated with volcanic ash which the CAA should evaluate during normal oversight of the operator's SMS. The operator's process should be sufficiently flexible to allow re-planning at short notice should conditions change. |
| Departure, Destination and Alternates | For the airspace to be traversed, or the aerodromes in use, the operator should determine, and take account of:<br>– the degree of known or forecast contamination;<br>– any additional aircraft performance requirements;<br>– required maintenance considerations;<br>– fuel requirements for re-routeing and extended holding. |
| Routeing Policy | The operator should determine, and take account of,:<br>– the shortest period in and over the forecast contaminated area;<br>– the hazards associated with flying over the contaminated area;<br>– drift down and emergency descent considerations. |
| Diversion Policy | The operator should determine, and take account of:<br>– maximum allowed distance from a suitable alternate;<br>– availability of alternates outside the forecast contaminated area;<br>– diversion policy after an volcanic ash encounter. |
| Minimum Equipment List / Dispatch Deviation Guide | The operator should consider additional restrictions for dispatching aircraft with unserviceabilities which might affect:<br>– air conditioning packs;<br>– engine bleeds;<br>– pressurisation system;<br>– electrical power distribution system;<br>– air data computers;<br>– standby instruments;<br>– navigation systems;<br>– de-icing systems;<br>– engine driven generators; |

| | |
|---|---|
| | – Auxiliary Power Unit (APU);<br>– Airborne Collision Avoidance System (ACAS);<br>– Terrain Awareness Warning System (TAWS);<br>– Autoland systems;<br>– provision of crew oxygen; and<br>– supplemental oxygen for passengers.<br><br>(This list is not exhaustive) |

| **Considerations** | **Actions** |
|---|---|
| **Flight Crew Procedures** | |
| Standard Operating Procedures | The operator should ensure that crews are familiar with normal and abnormal operating procedures and particularly any changes regarding:<br>– pre-flight planning;<br>– in-flight monitoring of volcanic ash cloud affected areas and avoidance procedures;<br>– diversion policy;<br>– communications with ATC;<br>– in-flight monitoring of engine and systems potentially affected by volcanic ash cloud contamination;<br>– recognition and detection of volcanic ash clouds:<br>– in-flight indications of a volcanic ash cloud encounter;<br>– procedures to be followed if a volcanic ash cloud is encountered;<br>– unreliable or erroneous airspeed;<br>– non-normal procedures for engines and systems potentially affected by volcanic ash cloud contamination;<br>– engine-out and engine relight;<br>– escape routes; and<br>– operations to/from aerodromes contaminated with volcanic ash.<br><br>(This list is not exhaustive) |
| AML | The operator should ensure that crews:<br>– make an AML entry related to any actual or suspected volcanic ash encounter whether in-flight or at an aerodrome;<br>– confirm, prior to flight, completion of maintenance actions related to an AML entry for a volcanic ash cloud encounter on a previous flight. |
| Incident Reporting | The operator should specify crew requirements for:<br>– reporting an airborne volcanic ash cloud encounter (VAR);<br>– post-flight volcanic ash cloud reporting (VAR);<br>– reporting non encounters in airspace forecast to be contaminated;<br>– filing a mandatory occurrence report as required by the State. |

| Considerations | Actions |
|---|---|
| **Maintenance Procedures** | |
| Maintenance Procedures | An operator operating in, or near, areas of volcanic ash cloud contamination should:<br>– enhance vigilance during inspections and regular maintenance and make appropriate adjustments to maintenance practices;<br>– have produced a continuing airworthiness procedure to follow when a volcanic ash cloud encounter has been reported or suspected;<br>– ensure that a thorough investigation is carried out of any signs of unusual or accelerated abrasions or corrosion or of volcanic ash accumulation;<br>– co-operate in reporting to TCHs and the relevant authorities their observations and experiences from operations in areas of volcanic ash cloud contamination;<br>– comply with any additional maintenance recommended by the TCH. |

*Note.— The above list is not exhaustive; the operator should develop its own list taking into account its specific equipment, experience, knowledge and type of operation.*

**Appendix C: Hazards & Risks to be considered by Aircraft Operators**
(when conducting a Safety Risk Assessment for volcanic ash operations)

| 1) Process/ Activity | 2) Hazards | 3) Existing Defences | 4) Additional Defences (from this SRM exercise) | 5) Unsafe Event [UE] (and intermediate consequences) | | 6) Existing Recovery Measures (from UE) | 7) Additional Recovery Measures (from this SRM exercise) | 8) Ultimate (Worst) Consequence/ Risk |
|---|---|---|---|---|---|---|---|---|
| | | | | **UE** | **Intermediate Consequences** | | | |
| **Flight Planning** | Hazard #1- Regulatory or operator requirements concerning volcanic regions operations **not correctly incorporated** into the flight planning process | See Note | See Note | Inadvertent volcanic ash encounter (with intermediate consequences as indicated on the right ) | a) P/S probes blockage | See Note | See Note | Loss or erroneous indications from equipment dependent on the P/S signals, e.g. airspeed |
| | | | | | b) Severe Window abrasion | See Note | See Note | Loss or reduced vision through forward cockpit windshields |
| | | | | | c) Turbine and compressor damage (all engines) | See Note | See Note | Loss or reduced thrust on all engines/ Aircraft forced landing |
| | | | | | d) etc | See Note | See Note | |
| | Hazard #2- Information on volcanic ash concentration **not properly communicated** to crews at pre-flight briefing | See Note | See Note | | | See Note | See Note | |
| | Hazard #3 etc | See Note | See Note | | | See Note | See Note | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Volcanic ash communication with flight crew** | Hazard #1- Communication not transmitted to in-flight crew as required | | | Inadvertent volcanic ash encounter (with safety implications) | | | | Loss or reduced thrust on all engines/ Aircraft forced landing |
| | Hazard #2 – Communication not received by in-flight crew | | | Inadvertent volcanic ash encounter (with safety implications) | | | | Loss or reduced thrust on all engines/ Aircraft forced landing |
| | Hazard #3, etc | | | | | | | |
| **ETC** | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

Notes: Columns 3, 4, 6 & 7 to be addressed by Operator's SRM process on volcanic region operations.

## APPENDIX D

## EXAMPLE SAFETY RISK ASSESSMENT WORKSHEET

| | | | | Outcome (Pre-Mitigation) | | | | Outcome (Post-Mitigation) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No | Hazard Description | Hazard Consequence Description | Existing Controls | Severity | Probability | Risk Tolerability | Further Actions to Reduce Risk | Severity | Probability | Risk Tolerability | Risk Owners | Monitoring and Review Actions |
| 1 | Flying into area of volcanic ash cloud | Loss of thrust – all engines | Avoidance, existing crew procedures | High | Remote | Un-acceptable | Monitoring of NOTAMs, Flight planning to avoid flying into Danger Area, QRH drills for volcanic ash procedures, Notice to crew on in-flight volcanic ash encounters | High | Extremely Remote | Review | Flight Operations | Ensure latest information available to crew. Monitoring of pilot reports and review of revised flight planning and operating procedures |
| 2 | Flying into area of volcanic ash cloud | Damage to forward windscreen obscuring vision | Avoidance, existing crew procedures | Medium | Remote | Un-acceptable | Monitoring of NOTAMs, Flight planning to avoid flying danger Area, QRH drill for volcanic ash procedures, Notice to crew on in-flight volcanic ash encounters | Medium | Extremely Remote | Acceptable | Flight Operations | Ensure latest information available to crew. Monitoring of pilot reports and review of revised flight planning and operating procedures |
| 3 | Flying in proximity of airspace subject to volcanic ash | Undetected engine and airframe damage leading to system or component erroneous behaviour or failure | Pre-flight checks and walk-around checks, Scheduled maintenance | Medium | Possible | Un-acceptable | Enhanced reporting and flight tracking for flights into or close to Danger Area. Additional inspections of ash cloud contamination iaw TCH Instructions | Medium | Extremely Remote | Acceptable | Operations, Engineering | Monitoring of enhanced reporting system and engineering inspections |
| 4 | … | … | … | … | … | … | … | … | … | … | … | … |
| 5 | … | … | … | … | … | … | … | … | … | … | … | … |

## APPENDIX E

## GUIDELINES ON VOLCANIC ACTIVITY INFORMATION AND OPERATOR RESPONSE

### E.1 OVERVIEW

The material set out in this Appendix is intended to inform the operator about the range of volcanic activity information that may be available during an eruptive cycle and to indicate the operator's potential response. It is noted that eruptions rarely follow a deterministic pattern of behaviour.

### E.2 PRE-ERUPTION

a) The operator should have in place a robust mechanism for ensuring that it is constantly vigilant for any alerts of pre-eruption volcanic activity relevant to its operations. The staff involved need to understand the threat to safe operations that such alerts represent; some operators include this expertise within their "Operations Unit".

b) An operator whose routes traverse large, active volcanic areas for which immediate IAVW alerts may not be available, should define its strategy for capturing information about increased volcanic activity before pre-eruption alerts are generated.[3] Such an operator should also ensure that its crews are aware that they may be the first to observe an eruption and so need to be vigilant and ready to ensure that this information is made available for wider dissemination as quickly as possible.

### E.3 START OF AN ERUPTION

a) Given the likely uncertainty regarding the status of the eruption during the early stages of an event and regarding the associated volcanic cloud, the operator's procedures should include a requirement for crews to initiate or accept re-routes to avoid the affected airspace.

b) The operator should ensure that flights are planned to remain clear of the affected area and that consideration is given to available alternate aerodromes and fuel requirements.

c) It is expected that following initial actions will be taken:

- Determine if any aircraft in flight could be affected, alert the crew and provide advice re-routing as required;
- Alert management;
- Brief flight crew and revise flight and fuel planning in accordance with the safety risk assessment;
- Alert flight crew and operations staff to the need for increased monitoring of AIREP/VARs, SIGMETs and NOTAMs;
- Initiate the gathering of all data relevant to determining the risk;

[3] For example, an operator may combine elevated activity information with information concerning the profile and history of the volcano to determine an operating policy, which could include re-routing or restrictions at night. This would be useful when dealing with the 60% of volcanoes which are unmonitored.

*Note.— If the appropriate ATFM Unit organises regular data sharing teleconferences, the operator should make arrangements to participate*.

- Apply mitigations identified in the safety risk assessment process.

## E.4 ONGOING ERUPTION

a) As the eruptive event develops, the operator can expect the responsible VAAC to provide VAA/VAGs defining, as accurately as possible, the vertical and horizontal extent of areas and layers of volcanic ash clouds. As a minimum, the operator should monitor, and take account of, this VAAC information as well as of relevant SIGMETs and NOTAMs.

b) Other sources of information are likely to be available such as VAR/AIREPs, satellite imagery and a range of other information from State and commercial organisations[4]. The operator should plan its operations in accordance with its safety risk assessment taking into account also those of these additional sources of information that it considers accurate and relevant.

The operator should carefully consider and resolve differences or conflicts among the information sources, notably between published information and observations (pilot reports, airborne measurements, etc.).

c) Given the dynamic nature of the volcanic hazards, the operator should ensure that the situation is monitored closely and operations adjusted to suit.

d) The operator should be aware that, depending on the State concerned:

1) affected areas or danger areas may be established that differentiate between various levels of volcanic ash contamination such as the low, medium and high contamination thresholds currently being used in Europe;

2) affected areas or danger areas may be established covering airspace containing volcanic ash regardless of the level of contamination. If no graduation of the volcanic ash contamination is given, operators should treat the whole area as if it contains high volcanic ash contamination, unless the operator's safety risk assessment allows it to do otherwise safely.

e) The operator should require reports from its crews operating in or close to areas forecast to be affected, concerning any encounters with volcanic emissions, and ATC requirements. These reports should be passed immediately to the responsible authorities.

f) For the purpose of flight planning, the operator should treat the horizontal and vertical limits of the Danger Area to be over-flown as they would mountainous terrain, modified in accordance with their safety risk assessment. The operator should take account of the risk of cabin depressurisation or engine failure resulting in the inability to maintain level flight above a

[4] In the US, operators holding Enhanced Weather Information System (EWINS) approval are authorized to produce flight movement forecasts, adverse weather phenomena forecasts and other meteorological advisories, including those related to ash contamination, based on meteorological observations provided by the State.

volcanic ash cloud, especially when conducting EDTO operations. Additional MEL restrictions should be considered in consultation with the TCHs.

g) When the airspace is no longer contaminated by volcanic ash clouds, a NOTAMC cancelling the active NOTAM is likely to be promulgated. A new NOTAM/ASHTAM would then be promulgated to update the situation.

## APPENDIX F

## GUIDELINES FOR CAAs ON EVALUATING AN OPERATOR'S CAPABILITY TO CONDUCT FLIGHT OPERATIONS SAFELY INTO AREAS FORECAST TO BE OR AERODROMES KNOWN TO BE CONTAMINATED WITH VOLCANIC ASH.

### F.1 PROCEDURES

a) The aim of these guidelines is to assist the CAA of the State of Registry/Operator in its oversight of an operator intending to undertake operations into airspace forecast to be or aerodromes known to be contaminated with volcanic ash where the CAA requires the use of SMS.

b) The operator should complete the safety risk assessment as part of the SMS before initiating operations into airspace forecasted to be or aerodromes known to be contaminated with volcanic ash. During its normal oversight of its operators, a CAA should normally evaluate the safety risk assessment as an identifiable process of the operator's SMS.

c) The objective of the SMS is to provide a formal, robust and transparent method by which the operator can demonstrate to the CAA that it has the capability and competence to achieve a safe outcome from flight operations into areas forecast to be or aerodromes known to be contaminated with volcanic ash .

d) The CAA's evaluation under its normal oversight process should be considered satisfactory if the operator demonstrates its competence and capability to:

- understand the hazards associated with volcanic ash clouds and the effect on the equipment being operated;

- be clear on where these hazards may exceed acceptable safety risk limits;

*Note.— It is assumed that acceptable safety risk limits are exceeded when there is no longer a high level of confidence that the aircraft can continue to its intended destination or a planned alternate.*

- identify and implement mitigations including suspension of operations where mitigation cannot reduce the risk to within safety risk limits;

*Note.— This assessment is generally recorded in a formal safety risk assessment worksheet (example at Appendix D).*

- develop, and execute effectively, robust procedures for planning and operating flights through, or avoiding, potentially contaminated airspace safely;
- choose correctly information sources to use, to interpret the information correctly and to resolve correctly any conflicts among such sources;
- take account of detailed information from its TCHs concerning volcanic ash-related airworthiness aspects of the aircraft it operates, and the related pre-flight, in-flight and post-flight precautions to be observed;
- assess the competence and currency of its staff in relation to the duties necessary to operate safely in areas forecast to be or aerodromes known to be contaminated with volcanic ash and implement any necessary training;
- retain or employ via a third party, sufficient numbers of qualified and competent staff for such duties

*Note.— It is not intended that the operator be precluded from securing necessary resources from other competent parties.*

e) The CAA should consider:

- those of the operator's recorded mitigations of most significance to a safe outcome are in place;
- those of the operational procedures specified by the operator with the most significance to safety appear to be robust;
- that the staff on which the operator depends in respect of those duties necessary to operate safely in areas forecast to be or aerodromes known to be contaminated with volcanic ash are trained and assessed as competent in the relevant procedures.

f) Analysis of the operator's SMS allows the CAA to review its Hazard Analysis competency and Safety Culture in a coherent way, and provides the CAA with a degree of confidence. An example of one approach to a Safety and Risk Assessment Matrix is given at Appendix G to guide CAAs through the process of evaluating operator safety risk assessments. It is acknowledged that each CAA may modify this document to fit their SMS approach. It is acknowledged that the nature of this assessment is such that it does not lend itself to a substantive quantitative approach though such an approach would be welcome in due course.

g) As part of its regular oversight of the operator, the CAA should remain satisfied as to the continuing validity of a safety risk assessment accepted for operations into or avoiding areas forecast to be or aerodromes known to be contaminated with volcanic ash;

*Note.— Should an operator fail to maintain an acceptable safety risk assessment, and associated resources, knowledge and procedures, the CAA should prohibit operations into areas forecast to be or aerodromes known to be contaminated with volcanic ash.*

## F.2 CAPABILITIES

a) The CAA should have a thorough understanding of SMS principles and methodology.
b) The CAA should have the means to impose such restrictions on its operators as are necessary to minimise the volcanic ash safety risk.
c) The CAA should ensure those of its staff involved in evaluating operator's SMS are appropriately trained and current and strongly encourage them to take up any opportunity to be involved in such VOLCEX exercises as are conducted in their area of operations.
d) Where a CAA considers that it lacks the capability to assess an operator's SMS and the related safety risk assessment on volcanic ash, it should enlist the assistance of a CAA with this capability.

## APPENDIX G

## EXAMPLE OF A SAFETY AND RISK ASSESSMENT MATRIX

**THE OPERATION**

| | |
|---|---|
| **Operator** | |
| **AOC No** | |
| **Aircraft Type(s)** | |
| **Engines** | |
| **Number of aircraft** | |
| **Zones of Operation** | |

**AUTHORISATION**
*Any "NO" rating should cause the CAA to with-hold and withdraw acceptance of the safety risk assessment*

| | | |
|---|---|---|
| **Has the operator satisfactorily demonstrated:** | Adequate understanding of the nature and location of the hazards? | **YES/NO** |
| | Clarity as to its safety risk limits? | **YES/NO** |
| | Robust documented procedures to ensure that the operation stays within limits? | **YES/NO** |
| | Adequate competence and capability to reliably execute its documented procedures on an on-going basis? | **YES/NO** |

| | | |
|---|---|---|
| **Has this demonstration been documented by the operator?** | | **YES/NO** |
| **Authorisation** | Has the safety risk assessment been accepted thus signifying that the CAA is satisfied that the operator can operate, in accordance with its procedures, into areas forecast to be or aerodromes known to be contaminated with volcanic ash? | **YES/NO** |

**EVALUATION**

*Any "unacceptable" elements should result in operational restrictions up to and including prohibition or suspension of operations.*
*Any "unacceptable" elements could indicate an increased probability of failing to sustain acceptable standards and should result in the CAA enhancing its operator surveillance accordingly.*

| | **Evaluated As** | | | |
|---|---|---|---|---|
| **Factor** | **Unacceptable** | **Acceptable** | **Best Practice** | **Notes** |
| **Safety Policy**[5] | No policy in place, or poorly developed/ inappropriate | An appropriate safety policy is in place | Management commitment to the safety policy is evident in all that the operator does | |
| | No evidence of commitment to/ action in line with the policy | The policy is linked to other company practices/activities | Safety is integral to business improvement in all relevant aspects of the operator's activity | |

[5] The Safety Policy is one component of the operator's SMS and the subject of a mandatory ICAO Annex 6 requirement. Without an acceptable or best practice safety policy, it would be expected that the AOC of the operator would be suspended.

| | | | | |
|---|---|---|---|---|
| | Policy has not been approved at senior management level nor communicated effectively to staff | Policy has been approved and promulgated by senior management and is understood by all staff | Evidence that the policy has been approved and promulgated by senior management, is understood by all staff and staff understand and act on the policy in day to day business | |
| **Understanding Risks** | Operating procedures and practices do not reflect adequately the risks and hazards from this kind of activity | Operating procedures and practices reflect adequately the known risks/hazards of this type of activity | Evidence that the procedures and practices reflect well the known risks/hazards of this type of activity and the operator is proactive in receiving and sharing information regarding relevant risks/hazards with aviation community | |
| | No particular effort made to identify or assess hazards/risks specific to this particular operation | An adequate Hazard identification and prioritisation carried out for this specific operation | Clear evidence of a regular review and update of hazard/risk assessment in light of own and others' experience | |
| | No documented picture of risks/ hazards faced ("Safety Risk Profile") | Documented Safety Risk Profile is in place | Staff understand the Safety Risk Profile and demonstrate commitment to their part in risk control | |
| | Own experience not factored into any documented picture of risks/ hazards the operator faces | Own incident and occurrence experience is factored into picture of risks/hazards faced | Leaders in understanding of relevant risks, based on own knowledge and evidence from elsewhere | |

# APPENDIX H

# TERMINOLOGY

## H.1 Acronyms

| | |
|---|---|
| AIREP | Air Report |
| AML | Aircraft Maintenance Log or equivalent, e.g. Aircraft Technical Log |
| ASHTAM | Special series NOTAM notifying a change in activity of a volcano, a volcanic eruption and/or volcanic ash cloud that is of significance to aircraft operations |
| ASR | Air Safety Report - used by an operator to document its safety incidents |
| ATC | Air Traffic Control |
| ATFM | Air Traffic Flow Management |
| ATM | Air Traffic Management |
| CAA | Civil Aviation Authority |
| CDM | Collaborative Decision Making |
| EDTO | Extended Diversion Time Operations |
| ETOPS | Extended Range Operations by Turbine-engined Aeroplanes |
| FIR | Flight Information Region |
| IAVW | International Airways Volcano Watch |
| IVATF | International Volcanic Ash Task Force (of ICAO) |
| LIDAR | Light Detection and Ranging: an optical remote sensing technology counting among its capabilities that of detecting and measuring volcanic ash particle size and density |
| MEL | Minimum Equipment List |
| MET | Meteorology or Meteorological |
| MWO | Meteorological Watch Office |
| NOTAM | A notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations |
| PMA | Parts Manufacturer Approval |
| SIGMET | Information concerning en-route weather phenomena which may affect the safety of aircraft operations |
| SMM | Safety Management Manual ICAO Doc 9859 |
| SMS | Safety Management System |

| | |
|---|---|
| STC | Supplemental Type Certificate |
| TCH | Type Certificate Holder |
| VAA | Volcanic Ash Advisory |
| VAAC | Volcanic Ash Advisory Centre |
| VAG | Volcanic Ash Advisory in graphical form |
| VAR | Volcanic Activity Report from aircraft (the real-time part of the VAR is issued in the same manner as an AIREP Special) |
| VO | Volcano Observatory |
| VOLCEX | Regular ICAO volcanic ash exercises to validate and improve regional volcanic ash contingency plans and procedures. |

## H.2 Definitions

***Accountable Executive.*** The individual within a CAA-approved organisation who is accountable to that CAA for ensuring that the safety standards required by regulation, and any additional standards specified by the organisation, are met on an ongoing basis by the organisation.

***Affected Area.*** A volume of airspace, an aerodrome or another area on the ground, identified by VAA/VAG and/or SIGMET as being affected by known or forecast volcanic cloud contamination.

***(Aircraft) Operator.*** In the context of this document, references to the (aircraft) operator refer to those operators subject to ICAO Annex 6 Parts I, II and III being operators of aeroplanes or helicopters authorised to conduct International commercial air transport operations or involved in international general aviation.

***Danger Area.*** In the context of volcanic ash cloud contamination, a volume of airspace identified by NOTAM as being affected by levels of known or forecast volcanic cloud contamination which States judge merit publication to operators.

***Service Provider.*** In the context of this document, includes approved training organizations, aircraft operators and approved maintenance organizations, organizations responsible for type design and/or manufacture of aircraft, air traffic service providers, aerodromes, MWOs and VAACs.

***State of the Operator.*** The State in which the operator's principal place of business is located or, if there is no such place of business, the operator's permanent residence.

***State of Registry.*** The State on whose register the aircraft is entered.

***Volcanic Cloud.*** The sum of the material ejected from a volcano into the atmosphere and transported by winds aloft. It comprises volcanic ash, gases and chemicals[6] (refer section 2.1 of ICAO Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds - Doc 9691).

***Volcanic Ash.*** is comprised of minerals unique to the volcanic eruption. Minerals common to most volcanic ash are silica together with smaller amounts of the oxides of aluminium, iron, calcium and sodium. The glassy silicate material is very hard and extremely abrasive. Its melting point is below jet engine burner temperature which introduces additional hazards. (refer section 2.1 of ICAO Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds - Doc 9691).

———————

[6] Although the specific material being warned for used to be the ash contained in the volcanic cloud, it is understood that other elements of the cloud may also be undesirable to operate through