Banjul Accord Group Aviation Safety Oversight Organisation

Abuja – Nigeria

BAGASOO

ADVISORY CIRCULAR

AC 01-002

VOLCANIC ASH CLOUD AWARENESS

SECTION 1 POLICY & GENERAL INFORMATION

1.1 PURPOSE

A. This advisory circular provides guidance to states and international organizations regarding the hazards posed by volcanic ash cloud.

B. It also provides information concerning the requirements for the provision of warnings to aircraft of volcanic ash clouds and guidance regarding how these requirements may be satisfied.

1.2 STATUS OF THIS AC

This AC is an original issuance.

1.3 INTRODUCTION

Volcanic ash in the atmosphere is of little direct safety concern to anyone except aviation. It is incumbent on the aviation community, therefore, to take the lead in establishing and maintaining the essential channels of communication between volcano-observing sources and the relevant ACCs and MWOs and maintaining the currency of the local staff instructions and procedures.

Flying through an ash cloud should be avoided by all means due to the extreme hazard for the aircraft. Experience has shown that damage can occur to aircraft surfaces, windshields and powerplants. Aircraft ventilation, hydraulic, electronic and air data systems, can also be contaminated.

Partial or total engine power loss events caused by volcanic ash ingestion, while not frequent, are major safety concerns. Simultaneous power loss in all engines has occurred, where the crew succeeded in restarting the engines, after application of operational procedures.

As weather radar is not effective in detecting volcanic ash clouds, crews must be informed by other means of the potential or effective presence of ash clouds on air routes.

The aim of this Advisory Circular is to provide information about volcanic ash effects on aircraft and aviation community, and give operational guidelines to help prevent a volcanic ash cloud encounter.

1.3 BACKGROUND

Since the eruptions of Mt. Galunggung in Indonesia in 1982 there have been numerous explosive volcanic eruptions around the world, many of which have affected aircraft operations. With the occurrence of each new eruption, the opportunity has been taken to focus on and review the local and international arrangements for the issuance of information to pilots and, where necessary, fine-tune these arrangements based on actual operational experience gained in dealing with the impact of the eruptions on aircraft operation.
If an explosive eruption is observed or if the analysis of the monitoring data indicates that such an eruption is imminent, this information has to be sent quickly through pre-arranged channels of communication to an agreed list of recipients, including the civil aviation and meteorological authorities, and then to pilots of aircraft which could be affected.

This is the basis of the ICAO International Airways Volcano Watch (IAVW). Moreover, explosive eruptions have a tendency to occur with little or no warning from volcanoes which have not erupted for hundreds of years.

Pilots themselves are also an important source of information on volcanic activity and volcanic ash cloud, and in this regard ICAO has developed a format for a special air-report of volcanic activity which pilots are encouraged to use when reporting volcanic activity to air traffic services units.

1.3.1 Statistical Data

The Pacific region represents one of the biggest concentration of volcanoes in the world, with over 100 active volcanoes (See **Appendix F**). Active volcanoes are capable of sending volcanic ash up to altitudes greater than FL300 after explosive eruptions. Encounters affecting aircraft performance have occurred 2 400 NM from the ash source and up to 72 hours after the eruption.

Over 80 aircraft have reported to have flown into volcanic ash cloud between 1980 and 2000, with consequences ranging from increased wear of engines to simultaneous power loss in all engines.

Alert messages (volcanic ash SIGMET) are issued by a Meteorological Watch Office (MWO) for its area of responsibility. Nine Volcanic Ash Advisory Centers (VAAC) have been designated by international organizations to provide an expert advice to MWO regarding the location and expected movement of volcanic ash cloud.

1.4 APPLICABILITY

The guidance provided in this advisory circular is applicable to States, International Organisations, Pilots, Air Traffic Service Units, Meteorological Offices, Airport Authorities (Aerodrome Operators), Aircraft and Engine Manufactures.

1.5 RELATED REGULATIONS

ICAO Doc 9766 - Handbook On The International Airways Volcano Watch (IAVW) Operational Procedures And Contact List (2nd Edition).

- ICAO PANS ATM (Doc 4444) Appendix I – ICAO Special Air-report of Volcanic Activity Form (model VAR).

1.6 RELATED PUBLICATIONS

ICAO document *Preparation of an Operations Manual* (Doc 9376), Chapter 8 and Attachment K

ICAO document Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds (Doc 9691).

1.7 DEFINITIONS & ACRONYMS

1.7.1 DEFINITIONS

The following definitions are used in this document—

ASHTAM/NOTAM- Alert message issued by AIS to aviation when an ash cloud is detected and confirmed. It provides information on the status of activity of a volcano when a change in its activity affects flight preparation. The information includes location, extent, movement, air routes and flight levels affected by an ash cloud.

Ash cloud — A cloud of volcanic ash and pyroclastic fragments, often with gases and aerosols of volcanic origin, formed by volcanic explosion that is carried by winds away from an eruption column. Ash clouds are often dark-coloured brown to gray. Ash clouds may drift for hundreds to thousands of kilometres from their volcanic source.

Plume — Term often used to describe the elongated, downwind dispersed portion of an eruption cloud and ash-cloud.

Volcano — A vent or opening at the surface of the Earth through which magma erupts, also the landform that is produced by the erupted material accumulated around the vent.

Vulcanian eruption — A type of volcanic eruption characterized by the short duration, violent explosive ejection of fragments of lava. Vulcanian eruption columns may attain heights of 45 000 ft (14 km) or more.

VAAC - a group of experts responsible for co-ordinating and disseminating information on atmospheric volvanic ash clouds that may endanger aviation.

The VAAC was set up by ICAO and there nine VAACs worldwide. They are run as part of national weather forecasting organisations of the country where they are based.

Volvanic Ash- consists of small tephra, which are bits of pulverized rock and glass created by volcanic eruption less than 2mm in diameter.

Volcanic Ash Advisory- An alert message issued to aviation and meteorological offices when an ash cloud is detected in the atmosphere. It will provide information on: name of volcano, country, location, crater elevation of volcano, source of information, details of ash cloud including flight level, size, current movement, forecast movement for 6, 12, & 18 hours.

1.7.2 ACRONYMS & ABBREVIATIONS

ACC area control centre
AFTN aeronautical fixed telecommunication network
AIA Aerospace Industries Association of America
AIREP air-report
AIRMET information concerning en-route weather phenomena which may affect the safety of low- level aircraft operations
AIRS Alliance Icing Research Study
AIS aeronautical information service
ALPA American Airline Pilots Association
AMIC area manager-in-charge
AMSU-A advanced microwave sounding unit-A
AMSU-B advanced microwave sounding unit-B
ANC Air Navigation Commission
APU auxiliary power unit
ATOVS advanced TIROS observational vertical sounder
ATS air traffic services
AVHRR advance very high resolution radiometer
AVO Alaska Volcano Observatory
CCI Convention Information Structure
CNES Centre National d'Études Spatiales (the French space agency)
EGT exhaust-gas temperature
EOS Earth observing system
EPR engine pressure ratio
FIC flight information centre
FIR flight information region
GMS geostationary meteorological satellite
GOES geostationary operational environmental satellite
GTS global telecommunication system
HF high frequency

HIRS	high resolution infrared sounder
IAEA	International Atomic Energy Agency
IATA	International Air Transport Association
IAVCEI	International Association of Volcanology and Chemistry of the Earth's Interior
IAVW	international airways volcano watch
IFALPA	International Federation of Air Line Pilots'Association
ISCS	international satellite communications system
IUGG	International Union of Geodesy and Geophysics
JMA	Japanese Meteorology Association
LIDAR	light detection and ranging
MODIS	moderate resolution imaging spectroradiometer
MSU	microwave sounding unit
MTSAT	multi-functional transport satellites
MWO	meteorological watch office
NASA	National Aeronautics and Space Administration
NESDIS	National Environmental Satellite Data and Information System
NOAA	National Oceanic and Atmospheric Administration
NOF	international NOTAM office
NOTAM	notice to airmen
PANS	Procedures for Air Navigation Services
PIREP	pilot report (North America)
RSMC	Regional Specialized Meteorological Centre
SADIS	satellite distribution system for information relating to air navigation
SAR	synthetic aperture radar
SBUV	solar back scattered ultra violet
SEVIRI	spinning enhanced visible and infrared imager
SIGMET	information concerning en-route weather phenomena which may affect the safety of aircraft operations
SIGWX	significant weather
SITA	International Society for Aeronautical Telecommunications
SSU	stratospheric sounder unit
TAF	aerodrome forecast
TOMS	total ozone mapping spectrometer
UNDRO	United Nations Disaster Relief Organization
USGS	United States Geological Survey
UUA	urgent pilot request
UV	ultraviolet
VAAC	Volcanic Ash Advisory Centre
VAFTAD	volcanic ash forecast transport and dispersion
VAR	volcanic activity reporting
VAWSG	Volcanic Ash Warnings Study Group
VEI	volcanic explosivity index
VFR	visual flight rules
VHF	very high frequency
WAFC	world area forecast centre
WAFS	world area forecast system
WMO	World Meteorological Organization
WOVO	World Organization of Volcano Observatories

SECTION 2 GENERAL INFORMATION & GUIDANCE

2.1 Volcanic Ash Effects on Aircraft

2.1.1 Components Abrasion

Volcanic ash is highly abrasive particles that may damage aircraft components, particularly forward facing surface of external parts and engine components. They are made of sharp rock fragments that will easily erode plastic, metal and even glass pieces.

In service events show that aircraft may suffer from extensive damage after volcanic ash encounter. In some cases, all the following parts were removed and replaced, after they were sand blasted:

- Windshields
- Forward cabin windows
- Navigation and landing lights cover
- Wing, stabilizer and fin leading edges
- Engine nose cowls and thrust reversers
- All pitot and static probes

2.1.2 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 go through an engine. Going through the turbine, the melted materials are rapidly cooled down, stick on the turbine vanes, and disturb the flow of high-pressure combustion gases.

This disorder of the flow may stall the engine, in worst cases.

2.1.3 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.

2.2 IMPACT OF VOLCANIC ASH ON AVIATION OPERATIONAL AND SUPPORT SERVICES

2.2.1 AERODROMES

The effect of volcanic ash on an aircraft is similar to aerodromes. Aerodrome operator s should be aware that

1) Cooling, lubrication and filter systems could be contaminated and become clogged.

2) Ash which has been dampened by rain can cause short circuits, arcing and flashovers resulting in fires on electrical distribution system components.

3) Wet ash has the consistency of wet cement and when deposited on top of hangars can cause buildings to collapse.

4) Wet ash on parked aircraft can shift the C of G and cause the aircraft to tip over if not secured by a tail stick.

5) In heavy ash falls with very dry and windy conditions, broncho-pulmonary, opthalmic and skin medical problems can occur.

2.2.2 AIR TRAFFIC MANAGEMENT

2.2.2.1 GENERAL

Volcanic eruptions and the resulting ash cloud can cause major disruptions in air traffic operations and in some instances result in life-threatening situations for aircraft en-route.

2.2.2.2. DETECTION AND REPORTING

In order to avoid the risk of a major accident and the economic costs associated with aircraft re-routing, flight delays etc., the following worldwide standard message formats for the notification of volcanic eruptions and ash cloud have been developed:

(i) AIS- NOTAM or ASHTAM

(II) MET- METAR/ SPECI, VAR, SIGMET, AERODROME WARNING
(III) VULCANOLOGICAL AGENCY- VONA/ VAR (may include alert status color code)

(iv) PILOTS- Special PIREP, Urgent PIREP

(v) VAAC - VAAI in abbreviated plain language message

2.2.3 AIR TRAFFIC PROCEDURES FOR AN AREA CONTROL CENTRE (ACC)

If a volcanic ash cloud is reported or forecast in the FIR for which the ACC is responsible from any of the approved sources or VAACs, the following procedures should be followed:

a) Relay all information available immediately to pilots whose aircraft could be affected to ensure that they are aware of the ash cloud's position and the flight levels affected

b) Suggest appropriate re-routing to avoid area of known or forecast ash clouds

c) Remind pilots that volcanic ash clouds are not detected by airborne radar or traffic radar systems. The pilot should assume that radar will not give them advance warning or location of the ash cloud

d) If the ACC has been advised by an aircraft that it has entered a volcanic ash cloud and indicates that a distress situation exists:

(i)Tthe ACC should consider the aircraft to be in an emergency situation

(ii) The ACC should **not** initiate any climb clearances to turbine-powered aircraft until the aircraft has exited the ash cloud

(iii) The ACC should **not** attempt to provide escape vectors without pilot concurrence

Note* Experience has shown that the recommended escape manoeuvre for an aircraft which has encountered an ash cloud is to reverse its course and begin a descent if terrain permits. The final decision, however, rests with the pilot.

Air Traffic Controllers need to be informed that aircraft which encounter ash cloud may suffer serious consequences which can include complete loss of power to the turbine engines. ATCOs therefore need to be trained to handle such situations and each State must develop procedures which meet its circumstances.

2.2.4 RADIO AND GROUND NOTIFICATION

The Area Control Centre (ACC) is the communication link between the Pilot, Dispatcher and Meteo during episodes of volcanic ash clouds within the FIR.

The responsibility of ACC is as follows:

1. to provide the pilot with information on the flight levels that are affected by the ash cloud.

2. to provide the pilot with the projected trajectory and drift of the ash cloud.

3. to coordinate the pilot's alternative route to avoid the cloud based on the information provided in the volcanic ash SIGMET, the Volcanic Ash Advisory Message and the MWO Meteo Advice.

4. to provide dispatchers with NOTAM, ASHTAM, SIGMET, and special PIREPS for flight planning

2.2.5 METEOROLOGICAL SERVICES

With the onset of a volcanic eruption resulting in ash cloud, Volcanic Ash Advisory Messages are required to be made available via the following ICAO Satellite communication channels:

1. ISCS

2.SADIS

3. SITA

4. VAACAs Websites

5. SIGMET & NOTAM

6. SIGWX

PROCEDURE

1. MWO should immediately inform its associated ACC/ FIS so that aircraft which could be affected may be warned and diverted

2. MWO should notify its associated VAAC by telephone or fax and

(a) seek confirmation of the ash clouds from satellite data

(b) request trajectory forecasts based on initial information

(c)confirm height of the ash cloud

2.2.6 FLIGHT PLANNING, DESPATCH AND OPERATIONAL CONTROL

Flight dispatchers and Operational Control Centres must always consider the safety of the aircraft and its occupants when information on volcanic eruption or ash cloud is received.

The following factors must be considered during the flight planning

(i) carriage of additional fuel

(ii) off- loading of passenger or cargo

(iii) flight crew duty time limitation due technical stops

SECTION 3 FACTORS INVOLVED IN VOLCANIC ASH CLOUD ENCOUNTER

The following factors have an influence on volcanic ash detection in flight and on the consequences of volcanic ash encounter.

3.1 DETECTION

Night and IMC flights are more favorable to ash cloud encounter, as dust clouds cannot be detected by airborne weather radars

Low concentration of volcanic ash may not be detected by the crew.

Presence of the following elements can help recognize a volcanic ash cloud encounter:

- Acrid odor similar to electrical smoke

- Rapid onset of engine problems
- St. Elmo’s fire
- Bright white/orange glow appearing in the engine inlets
- Dust and smell in the cockpit
- Outside darkness
- Airspeed fluctuation
- Landing lights casting sharp, distinct, shadows.

3.2 CONSEQUENCES

Recent (within hours of eruption) volcanic clouds contain concentration of ash that can cause complete loss of engine power within one minute.

Engines operating at high thrust setting are more prone to suffer from ash deposit buildup in the turbine chamber, as internal engine temperature may exceed volcanic- glass material melting point.

In service events show that even low concentration of volcanic ash can cause expensive damage.

SECTION 4 PREVENTION STRATEGIES AND OPERATIONAL RECOMMENDATIONS

Prevention strategies and lines-of-defense should be developed to address the risk of volcanic ash encounter. The following communication links can be used to obtain timely up-dated information on the volcano eruptive activity:

4.1 Volcanic Watch Function

The Volcanic Watch Function consists in collecting, compiling, processing and up-dating detailed information regarding the active and pre-eruptive volcanoes likely to affect the company area of operation.

This function can be assigned to the following departments, as applicable:

- Flight Operations
- Flight Safety Office.

So as to assess the volcanic threat for each company route, the following information sources and communication links can be used:

- Air Information Service (AIS), for active NOTAM's
- Meteorologial Watch Offices, Airport Offices and Regional Area Forecast Centers for active SIGMET's
- On-site Aviation Authorities for additional information, such as data and maps related to the ash cloud observed and forecasted extension
- International organisations such as ICAO, IATA, IFALPA

4.2 Flight Crews Pre-flight Briefing and Documentation

All flight crews, operating a flight to/from/through an area likely to be affected by volcanic activity, should be provided with the following information and documents:

On a systematic basis

- Map(s) of active volcanoes and hazards area
- ICAO special air-report of volcanic activity form (model VAR).

As dictated by current volcanic eruptive activity:

- Last active NOTAM's,
- Last active SIGMET's
- Data or map(s) reflecting the observed ash cloud location, extension and/or trajectory forecast

- Upper wind analysis and forecast at selected flight levels
- Satellite images

4.3 EN-ROUTE INFORMATION UP-DATING

The activity of an erupting volcano usually features series of eruptions sometimes separated by only a few hours. En-route updating of the pre-flight briefing information is therefore of paramount importance to minimize the potential for volcanic ash cloud encounter.

The following communication links can be used to obtain timely up-dated information on the volcano eruptive activity:

- Company FLIGHT WATCH frequency
- ACARS
- VOLMET broadcasts (SIGMETs)
- FLIGHT Information Service (SIGMET's).

Detailed update should be solicited and obtained regarding the following aspects:

- Notification of new eruption(s)
- Location, height, extension and forecasted trajectory of volcanic ash cloud.
- Notification of airspace restrictions (closure of air routes, activation of contingency routes).

4.4 FLIGHT CREW TRAINING

So as to build-up a flight crew mind-set regarding the volcanic ash threat, volcanic ash awareness should be addressed as part of the flight crew initial and recurrent training, as follows:

- Understanding volcanic ash and volcanic ash clouds, as any other weather systems, and their threat to jet aircraft operation
- Highlighting the published procedures related to volcanic ash cloud avoidance, recognition of encounter and encounter recovery
- Placing a particular attention, during the simulator session related to the ALL ENGINE FLAME OUT procedure, to the slow engine acceleration characteristics to be expected upon engine restart after volcanic ash ingestion
- Stressing the instrumental contribution of flight crew air reports and the use of the ICAO special air-report of volcanic activity form (model VAR).

4.5 OPERATIONAL RECOMMENDATIONS

Flight crew operational procedures are published in respective aircraft manufacturers' documentation. Nevertheless, the following actions have been identified as being typical recommendations in case of volcanic ash encounter.

4.5.1 ON THE GROUND

Operation to or from airports contaminated with volcanic ash should be avoided, if possible. Should volcanic ash exposure be unavoidable, the following recommendations and procedures should be applied:

- Whenever an aircraft is planned to stay over at an airport contaminated with volcanic ash, engine inlet covers as well as other protective covers and plugs should be installed

- Have the aircraft cleaned before departure

− Ash layer may contaminate the lubricated parts, penetrate the seals or enter the engines gas path, air conditioning system, air data probes and other aircraft orifices.

- Dry crank the engines

− Before starting the engines, ventilate them by dry cranking at maximum motoring speed for two minutes.

- Do not use windshield wipers for ash dust removal.

- Restrict ground use of APU to engine starts

− Do not use APU for air conditioning and electrical power supply. Use external pneumatic supply for starting the engines, if it is available.

- Keep bleed valves closed for taxiing

- Taxi with minimum thrust

− Advance the levers smoothly to the minimum required for breakaway. Avoid making sharp or high-speed turns. All engines taxi should be preferred, to minimize thrust level on each engine.

- Allow ash and dust (if present) to settle on runway before starting the takeoff roll

- Use the rolling takeoff technique if possible

- Consider the runway as wet (for dry ash) or contaminated with slush (wet ash) for takeoff/landing performance calculation

− Braking efficiency may be degraded by the layer of ash on the runway.

4.5.2 IN FLIGHT

If a volcanic eruption is reported while in flight, the flight should remain well clear of the affected area and, if possible stay on the upwind side of the volcanic dust (typically 20 NM upwind of the erupting volcano). Should the volcanic ash encounter be unavoidable, the following general recommendations apply:

- Make a 180^{o} turn

− Pilots should exit the cloud as quick as possible. Generally, a 180^{o} turn will result in the fastest cloud exit, due to the possible extension of such clouds over hundreds of nautical miles

- Decrease the thrust

− High thrust settings increase the risk of glass particles melting and associated ash deposit buildup in the turbine chamber. Thrust should therefore be decreased, if conditions permit.

- Don the crew oxygen masks (100%)

- Report to the ATC

− Any observation of volcanic activity or any encounter with a volcanic ash cloud should be reported by immediate radio transmission or/and by filling the ICAO special air-report of volcanic activity form (model VAR).

- Increase bleed demand (wing and engine anti-ice ON)

− Increasing the bleed demand aims at increasing the fuel/air ratio in the engine combustor to limit the possibility of an engine surge and/or flameout.

- Start the APU

− The APU GEN will be available to supply the electrical network in case of engine flameout.

- Monitor engine parameters and airspeed indications

− The crew should be aware that volcanic ash may render airspeed indications unreliable.

SECTION 5 SUMMARY OF KEY POINTS

It is important to note the following key points:

- Airlines should provide exhaustive and updated information to crews flying in regions likely to be affected by volcano activity

* Flight crews should solicit updating of the preflight information when en route

* Flight Crews should report to the ATC any observation of volcanic activity or any encounter with a volcanic ash cloud

- If encounter with volcanic ash cannot be avoided, the flight crew should immediately applied the procedure recommended by the aircraft manufacturers' documentation.

APPENDIX A

RECOMMENDED PROCEDURES FOR THE MITIGATION OF THE EFFECT OF VOLCANIC ASH ON AIRPORTS

1. INTRODUCTION

1.1 Techniques for reducing the effects of volcanic ash can be grouped into three broad categories:

(1) Keeping the ash out,

(2) Controlling what gets in, and

(3) Disposing of the ash.

These categories are more illustrative than discrete, and some mitigation techniques will apply in all three cases. Mitigation actions will be required on a continuous basis as long as ash is present. Settled ash is easily re-entrained into the atmosphere, and a 2-mm layer can be as troublesome as a 50-mm layer.

1.2 The most effective technique for reducing ash-related damage or upset to equipment is to avoid using the equipment: shut down, close up, keep inside, or seal the area until the ash can be removed. This tactic is acceptable only for short periods of time because operations must be resumed at some point. In any case, disposal techniques will not eliminate all of the ash. A residue will remain on the ground and will be blown into the air by wind, passing vehicles and aircraft take-offs. Thus, an accelerated and intensive program of inspection, maintenance, cleaning and monitoring will be necessary during and after the main part of ash deposition.

1.3 Cleaning the ambient air — and keeping it clean — is the key to reducing operation and maintenance problems. Blowing ash off of a circuit board is useless if the ash is fine enough to remain suspended for several minutes. The difficulty of attempting to perform maintenance tasks in an already ash- contaminated atmosphere is obvious. “Clean-room” procedures can be used to isolate an area and keep it free of ash, but only under ideal circumstances. Some equipment — aircraft engines, for example — are too large for such treatment. Tents or tarps can be used to reduce gross contamination. However, the fine particles of volcanic ash can penetrate very small openings and seams; it is this property that makes volcanic ash so damaging to critical equipment.

1.4 Some mitigation procedures may cause additional problems or may actually be counterproductive, depending on the circumstances. For example, adding filtration to a computer system will reduce the amount of ash contamination, but it will also decrease the air flow. The resulting rise in temperature may change the operating characteristics of sensitive components or even cause damage. Adding a larger fan would increase the air flow, but not all computers, especially smaller units, can be easily modified. Another example is the use of moisture to control ash. Wetting carpets will increase relative humidity and help to keep the ash down; however, wet or even damp volcanic ash is conductive.

No single technique will be absolutely effective; a combination of techniques has been found to provide the best results for managing volcanic ash. Constant monitoring and reassessment of ash effects and the mitigation process will be required to achieve the most effective balance between operational requirements and the desired level of damage limitation. The following sections summarize ash mitigation techniques for selected aircraft and support systems.

1. AIRCRAFT SYSTEMS

2.1 The basic mitigation tactic to protect aircraft systems is avoidance of exposure to ash. The airports and airfields surveyed after the Mt. St. Helens eruption simply shut down for the duration of the ash problem or until the ash had been removed. Airlines rerouted traffic away from ash-impacted airports.

2.2 Sealing aircraft seams, ports, vents and other openings with duct tape will keep out the bulk of the ash, especially if the aircraft is under cover. Maintaining positive pressure within aircraft components would help to keep ash out, but it is difficult, if not impossible, to pressurize an aircraft on the ground without damaging ground equipment. Techniques include:

a) Blow or vacuum ash before washing, otherwise, ash tends to flow into ports, vents or control surfaces;

b) Flush or wash residue, do not scrub or sweep;

c) Wash gear, underside, air-conditioning intakes and engines;

d) Check pH of aircraft/engine surfaces for acidity; and

e) Neutralize acidic residue by adding petroleum-based solvent to the wash water.

2.3 All of the above techniques require large amounts of time, manpower and equipment. All have significant effects on the level and scope of continued operations. These techniques were tried under conditions of greatly reduced operating levels; however, there is some question as to their effectiveness during normal (or near-normal) operations. For example:

a) Sealing an aircraft would take 4-5 hours, and removing all seals and tape would take 1-2 hours. It is very hard to seal an aircraft completely because of numerous ports, vents, seams and joints;

b) Ash buildup in or around hatch seals could cause pressurization problems; and

c) Fuel tank vents must be open during loading, unloading and transfer of fuel. If vents are plugged with ash, or if sealed, the tank could collapse. A 4-5 Psi vacuum is sufficient to cause collapse.

RUNWAYS

3.1 If aircraft operations are not suspended, runways must be continually cleaned as ash is resuspended by wind, aircraft take-off and ground vehicle movement. There is some disagreement on the proper use of water in cleaning runways. Some sources felt that water turns the ash to sludge (or causes it to harden), whereas others found it impossible to control the ash without wetting it first. Open-graded (popcorn surface) runways are to some extent self-cleaning because the engine blast on take-off will blow ash out of crevices. Basic techniques include:

a) Wet ash with water trucks;

b) Blade into windrows;

c) Pick up with belt or front-end loaders;

d) Haul to dump areas;

e) Sweep and flush residue;

f) Sweep/vacuum ash first, then flush with water (best for ramps, etc.);

g) Push ash to runway edge and plow under or cover with binder such as Coherex or liquid lignin;

h) Install sprinklers along edges of runway to control resuspension of ash from aircraft engine blast or wing-tip vortices; and

i)Keep residue wet on taxiways and ramps.

Note.— The slippery nature of wet ash should be taken into account by pilots manoeuvring aircraft on the ground and during landing and take-off.

LANDING AIDS AND AIR TRAFFIC CONTROL

4.1 Protection of landing aids and air traffic control systems will require periodic cleaning, maintenance and monitoring. Also, turning off unnecessary equipment will reduce exposure. Exposed light and indicator systems, radar antennas and any equipment that requires cooling air are especially vulnerable to ash contamination and damage. Interruption of commercial power supplies will require backup generators, which are also vulnerable to ash damage. Techniques include:

a) Replace antennas that have Teflon insulators. Because ash is hard to remove and will cause shorting, ceramic insulators should be used;

b) Seal relay boxes and remove indicator units and light systems to prevent ash entry;

c) Increase cleaning and maintenance of systems that cannot be sealed or that require cooling air;

d) Vacuum or blow ash out and clean relays with contact cleaner;

e) Use high-pressure water wash on exposed antenna rotor bearings and then relubricate;

f) Cover exposed joints, seams and bearings;

g) Seal buildings, control access, vacuum shoes and clothes; and

h) Reduce operating levels: shut down unused equipment, reduce broadband displays to a minimum, and reduce cooling and power consumption.

GROUND SUPPORT EQUIPMENT

5.1 The consensus is that ground support equipment is the key to flight operations. If ground support equipment is unserviceable because of ash, aircraft cannot be operated. Unfortunately, there are more problems than solutions in the ash contamination of ground equipment.

5.2 Gas turbines, air compressors and air conditioners operate by ingesting large volumes of air. This equipment has only coarse filtration (or none at all), and extra filtration cannot be added without affecting operation. Using air conditioners to pressurize aircraft compartments would only blow ash into the aircraft and ruin the air conditioners in the process. Techniques include:

a) Constant cleaning and maintenance;

b) Do not wash equipment, because water turns ash to sludge and washes it into the equipment;

c) Vacuum equipment;

d) Change oil and filters more often; and

e) Change design to include better filtration.

6. COMPUTER SYSTEMS

6.1 The most widely advised damage-prevention tactic is to shut down all computer and electronic systems until the ash has been completely removed from the area and from the equipment. Computer heads and disks, and any high-voltage circuits, are especially vulnerable to ash upset and damage. Ash on digital circuits will not cause much of a problem because of the low voltages involved. High-voltage or high- impedance circuits are very vulnerable to leakage caused by semi-conductive ash. Ash that is acidic is conductive as well as corrosive. Continual cleaning and aggressive protection of computer systems should allow for continued operation in all but the heaviest ash fallout. Techniques include:

a) Clean and condition surrounding air to keep ash out of equipment;

b) Cotton mat filters used in clean rooms were found to be best for filtering particles, but they reduce air flow. A solution is to use larger fans to maintain required air flow. Rack-mounted equipment can be modified to add a larger fan, but smaller instruments or components with a built-in fan would require a design change to increase fan capacity;

c) Use fluted filters as a compromise; this increases surface area but reduces air flow by only about 20 per cent;

d) humidifying ambient air (e.g. wetting carpets) will help to control ash re-entrainment;

e) Ash on equipment can be blown out with compressed air. If the air is too dry, static discharge could damage sensitive components (e.g. integrated circuits). If the air is too damp, the ash will stick. Relative humidity of 25-30 per cent is best for compressed air;

f)Cleaning with a pressurized mixture of water and detergent and using a hot-water rinse is quite effective, however, this process requires at least partial disassembly;

g) Ash may have a high static charge and be hard to dislodge, thus requiring brushing to dislodge particles;

h) Accelerate filter change, use prefilters;

i)Change to absolute filters, these will keep out particles down to 1 µm and smaller;

j) Keep computer power on for filtration, but do not operate, especially disk drives;

k) Maintain room-within-a-room configuration, restrict access, re-circulate air and accelerate cleaning of the critical area.

7. RADAR AND OPTICAL SYSTEMS

7.1 Most radar equipment in the heaviest ash-fall areas has to be shut down for the duration of severe ash contamination. Thus, few problems are likely aside from clean-up and control of residual ash. The simplest mitigation tactic is to cease operations. Clean-up techniques include:

a) Repair and clean high-voltage circuits

b) Wash antenna rotor bearings, re-lubricate, and cover exposed bearings;

c) Ash on optical components should be blown away or washed with copious amounts of water. Do not wipe, brush or nib, as this will abrade the optics;

d) Take care not to wash ash into optical-instrument mounts on aircraft (e.g. sextant);

e) Turn off non-essential radar equipment to reduce cooling load and power requirements;

f) Transfer radar coverage to other facilities, combine sectors;

g) Remove and replace camera bearings and clean gear drives; and

h) Protect video tape from ash because it will cause “drop-outs” and scratches.

8. PLANNING FOR ASH MITIGATION

8.1 Techniques for reducing the impacts of volcanic ash are basically “low tech” and depend more on procedural approaches than on technical fixes. Also, they are quite labour and resource intensive. Normal stock of daily-use items such as filters, lubricants, spare parts, cleaning supplies, etc., may be expended much faster than they can be replaced through the normal reordering process. Prior planning is necessary to reduce the severity of ash effects. Planning actions include:

a) Conduct a vulnerability analysis of equipment and facilities to determine which would be most impacted by ash, which are adequately protected, and which need long-term or expedient modification;

b) Develop a priority list of facilities that must be kept in operation versus those that can be closed or shut down for the duration of ash fall;

c) Ensure hazard-alert and information channels are properly maintained with the vulcanological/ geological agencies, and the meteorological service, local news media, and State and local governments;

d) Establish plans and procedures for alerting and notification, reduced operations, accelerated maintenance, protection of critical facilities, and clean-up and disposal;

e) Alert air traffic controllers and airport operations personnel to notify aircraft as soon as volcano "watch" and "warning" notices are received. Normal air traffic and weather radars cannot detect volcanic ash; therefore, relatively large "keep-out zones" should be established at night or during bad weather once the warning notice is issued. Personnel should also be alerted to the existence of fall-out beneath the clouds and lightning conditions, etc.

f) Stockpile spare parts for critical equipment, filters, sealing, cleaning and disposal equipment;

g) plan for extended clean-up and maintenance activities including 24-hour operations, augmentation of the work force, and training of clean-up crews; and

h) Ensure that sufficient water and back-up power is available to support clean-up operations, should normal supply sources fail.

Ash clean-up operations may continue for weeks or months if multiple eruptions occur. Effective mitigation of volcanic ash effects depends on prior planning and preparation, mobilization of resources, and persistence.

APPENDIX B

RECOMMENDED GENERAL PROCEDURES TO MITIGATE THE EFFECT OF VOLCANIC ASH ON AIRCRAFT

Volcanic eruptions and subsequent ash drift/fallout have previously caused delays and damage to aircraft and equipment.

The following general procedures have been recommended for use by pilots whose aircraft inadvertently encounter a volcanic ash cloud:

i) Immediately reduce thrust to idle. This will lower the exhaust-gas temperature(EGT),which in turn will reduce the fused ash build-up on the turbine blades and hot-section components. Volcanic ash can also cause rapid erosion and damage to the internal components of the engines;

ii)Turn auto throttles off (if engaged).The auto throttles should be turned off to prevent the system from increasing thrust above idle. Due to the reduced surge margins, limit the number of thrust adjustments and make changes with slow and smooth thrust-lever movements;

iii) Exit volcanic ash cloud as quickly as possible. Volcanic ash may extend for several hundred miles. The shortest distance/time out of the ash may require an immediate, descending 180- degree turn, terrain permitting. Setting climb thrust and attempting to climb above the volcanic ash cloud is not recommended due to accelerated engine damage/flame-out at high thrust settings;

iv) Turn engine and wing anti-ice on. All air conditioning packs on. Turn on the engine and wing anti-ice systems and place all air conditioning packs to “on”, in order to further improve the engine stall margin by increasing the bleed-air flow. It may be possible to stabilize one or more engines at the idle thrust setting where the EGT will remain within limits. An attempt should be made to keep at least one engine operating at idle and within limits to provide electrical power and bleed air for cabin pressurization until clear of the volcanic ash;

v) Start the auxiliary power unit (APU), if available. The APU can be used to power the electrical system in the event of a multiple-engine power loss. The APU may also provide a pneumatic air source for improved engine starting, depending on the aircraft model; and

vi) Put oxygen mask on at 100 percent, if required. If a significant amount of volcanic ash fills the cockpit or if there is a strong smell of sulphur, don an oxygen mask and select 100 per cent. Manual deployment of passenger oxygen masks is not recommended if cabin pressure is normal because the passenger oxygen supply will be diluted with volcanic ash-filled cabin air. If the cabin altitude exceeds 4 250 m (14 000 ft), the passenger oxygen masks will deploy automatically.

b) In the event of engine flame-out:

i) Turn ignition on. Place ignition switches to "on" as appropriate for the engine model (position normally used for in-flight engine start). Cycling of fuel levers (switches) is not required. For aircraft equipped with auto start systems, the auto start select or should be in the "on" position. The auto start system as designed and certified with a "hands-off" philosophy for emergency air starts in recognition of crew workload during this type of event;

ii) Monitor EGT. If necessary, shut down and then restart engines to keep from exceeding EGT limits;

iii)Close the outflow valves, if not already closed;

iv) Do not pull the fire switches;

v) Leave fuel boost pump switches "on" and open crossfeed valves;

vi) Do not use fuel heat — this would be undesirable if on suction fuel feed;

vii) Restart engine. If an engine fails to start, try again immediately. Successful engine start may not be possible until airspeed and altitude are within the air-start envelope. Monitor EGT carefully. If a hung start occurs, the EGT will increase rapidly. If the engine is just slow in accelerating, the EGT will increase slowly. Engines are very slow to accelerate to idle at high altitude, especially in volcanic ash—this may be interpreted as a failure to start or as a failure of the engine to accelerate to idle or as an engine malfunction;

viii) Monitor airspeed and pitch attitude. If unreliable, or if a complete loss of airspeed indication occurs (volcanic ash may block the pitot system), establish the appropriate pitch attitude dictated by the operations manual for "flight with unreliable airspeed."If airspeed indicators are unreliable, or if loss of airspeed indication occurs simultaneously with an all-engine thrust loss, shutdown or flame-out, use the attitude indicator to establish a minus-one degree pitch attitude. Inertial ground speed may be used for reference if the indicated airspeed is unreliable or lost. Ground speed may also be available from approach control during landing;

ix) Land at the nearest suitable airport. A precautionary landing should be made at the nearest suitable airport if aircraft damage or abnormal engine operation occurs due to volcanic ash penetration; and

x) Because of the abrasive effects of volcanic ash on windshields and landing lights, visibility for approach and landing may be markedly reduced. Forward visibility may be limited to that which is available through the side windows. Should this condition occur, and if the autopilot system is operating satisfactorily, a diversion to an airport where an auto landing can be accomplished should be considered. After landing, if forward visibility is restricted, consider having the aircraft towed to the parking gate.

NOTE** The foregoing general procedures should be supplemented by specific procedures in the aircraft operations manual—developed by aircraft operators for each aircraft type in their fleet—dealing with the particular aircraft engine combination concerned. Guidance on this is provided in the ICAO document Preparation of an Operations Manual (Doc 9376), Chapter 8 and Attachment K, and in aircraft manufacturers' flight manual procedures for each of their aircraft types.

Guidance should also be included in aircraft maintenance manuals regarding the necessary maintenance and/or inspections to be undertaken on an aircraft following an encounter with volcanic ash. Mention has already been made in Chapter 2 that for those airlines which operate aircraft regularly through regions of the world subject to frequent volcanic eruptions, the long-term consequences of frequent flights through even very low concentrations of volcanic ash may be increased maintenance costs. Certainly a number of airlines have found that cockpit and passenger windows needed to be re-polished or replaced rather more frequently than expected for the flight hours involved. At this stage it is not clear, however, if this is due more to newer types of plastic window materials used for passenger outer windows or if low concentrations of volcanic ash/acid droplets in the atmosphere are contributing to the problem.

Given that the most serious threat to an aircraft from volcanic ash is the risk of multiple-engine flame-out, it is extremely important to consider the ways and means of improving the success of engine restarts in air contaminated by volcanic ash. To this end, it is recommended that:

1)Aircraft manufacturers, with assistance from the engine manufacturers, should define maximum engine power levels (expressed in engine pressure ratio (EPR), fanspeed (N1), and (or) exhaust-gas temperature (EGT) levels) that will minimize buildup of melted and re-solidified ash on HPT nozzle guide vanes. These values should be added to flight-manual procedures and should be used only when the recommended flight idle power will not assure adequate terrain clearance.

2)Aircraft manufacturers, with assistance from engine manufacturers, should consider addition of a time-delay circuit to allow an air-started engine to reach stabilized idle speed before the electrical or generator load is applied. This would facilitate engine restarts under less-than-ideal conditions.

3)States should require that air crews practice engine air-restart procedures in a simulator on recurring basis. Norma land deteriorated engine start characteristics should be simulated."

The prime importance of the last recommendation cannot be overestimated. Engine shut-downs or flame-outs in-flight are rare events which many pilots will never be called upon to deal with in their whole careers. This is further complicated by the different procedures used for air-start as compared to normal ground-start. The only solution is for pilots to be provided with a set of air-start procedures which also cover procedures in volcanic ash contaminated air and for simulator air-starts to be part of basic and recurrent pilot training.

APPENDIX C

Special air-report of volcanic activity form (Model VAR)
(to be used for post-flight reporting)

VOLCANIC ACTIVITY REPORT

Air-reports are critically important in assessing the hazards which volcanic ash cloud presents to aircraft operations.

ERATOR:			IDENTIFICATION: (as indicated on flight plan)		
OT-IN-COMMAND:					
P FROM:	TE:	IE; UTC:	R AT:	TE:	IE; UTC:
DRESSEE			EP SPECIAL		
ns 1–8 are to be reported immediately to the ATS unit that you are in contact with.					
AIRCRAFT IDENTIFICATION			POSITION		
TIME			FLIGHT LEVEL OR ALTITUDE		
VOLCANIC ACTIVITY OBSERVED AT sition or bearing, estimated level of ash cloud and distance from aircraft)					
AIR TEMPERATURE			SPOT WIND		
SUPPLEMENTARY INFORMATION SO_2 detected Yes ☐ No ☐ Ash encountered Yes ☐ No ☐ ief description of activity especially vertical and lateral extent of ash cloud and, where possible, horizontal movement, rate of growth, etc.)			Other__________		
er landing complete items 9–16 then fax form to: (Fax number to be provided by the meteorological authority based on local arrangements ween the meteorological authority and the operator concerned.)					

DENSITY OF ASH CLOUD	☐ (a) Wispy	☐ (b) Moderate dense	☐ (c) Very dense
COLOUR OF ASH CLOUD (d) Black	☐ (a) White	☐ (b) Light grey ☐ (e) Other ________	☐ (c) Dark grey
ERUPTION	☐ (a) Continuous	☐ (b) Intermittent	☐ (c) Not visible
POSITION OF ACTIVITY (d) Multiple	☐ (a) Summit	☐ (b) Side ☐ (e) Not observed	☐ (c) Single
OTHER OBSERVED ATURES OF ERUPTION	☐ (a) Lightning ☐ (d) Ash fallout	☐ (b) Glow ☐ (e) Mushroom cloud	☐ (c) Large rocks ☐ (f) All
EFFECT ON AIRCRAFT (d) Pitot static	☐ (a) Communication	☐ (b) Navigation systems ☐ (e) Windscreen	☐ (c) Engines ☐ (f) Windows
OTHER EFFECTS	☐ (a) Turbulence	☐ (b) St. Elmo's Fire	☐ (c) Other fumes
OTHER INFORMATION y information considered useful.)			

Figure 6-3. VAR Model.

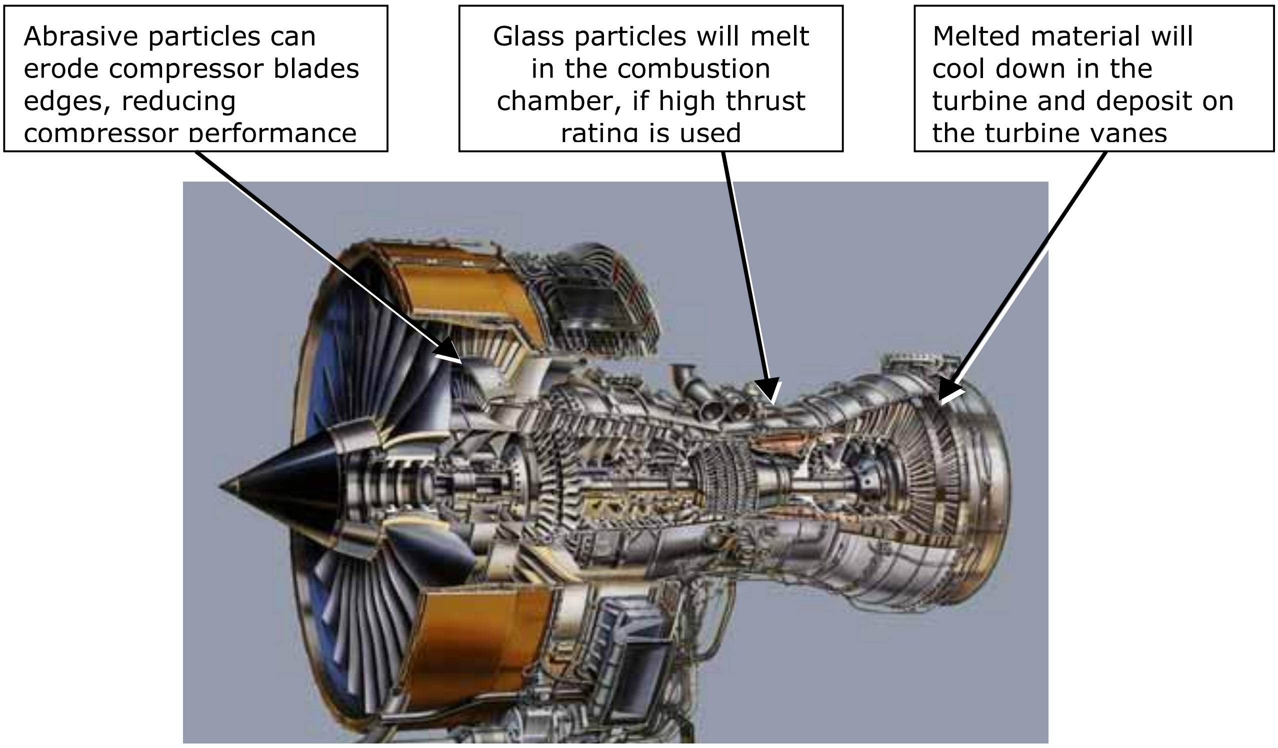
An example of such a SIGMET is as follows:

SIGMET FOR VA YUDD SIGMET 2 VALID 211100/211700

YUSO-
YUDD SHANLON FIR/UIR VA ERUPTION MT ASHVAL LOC S1500 E07348 VA CLD OBS AT 1100Z
FL310/450 APRX 220KM BY 35KM S1500 E07348 – S1530 E07642 MOV SE 65KMH FCST 1700Z VA CLD APRX S1506 E07500 – S1518 E08112 – S1712 E08330 – S1824 E07836

APPENDIX D

EFFECT OF VOLCANIC ASH ON ENGINE



APPENDIX E

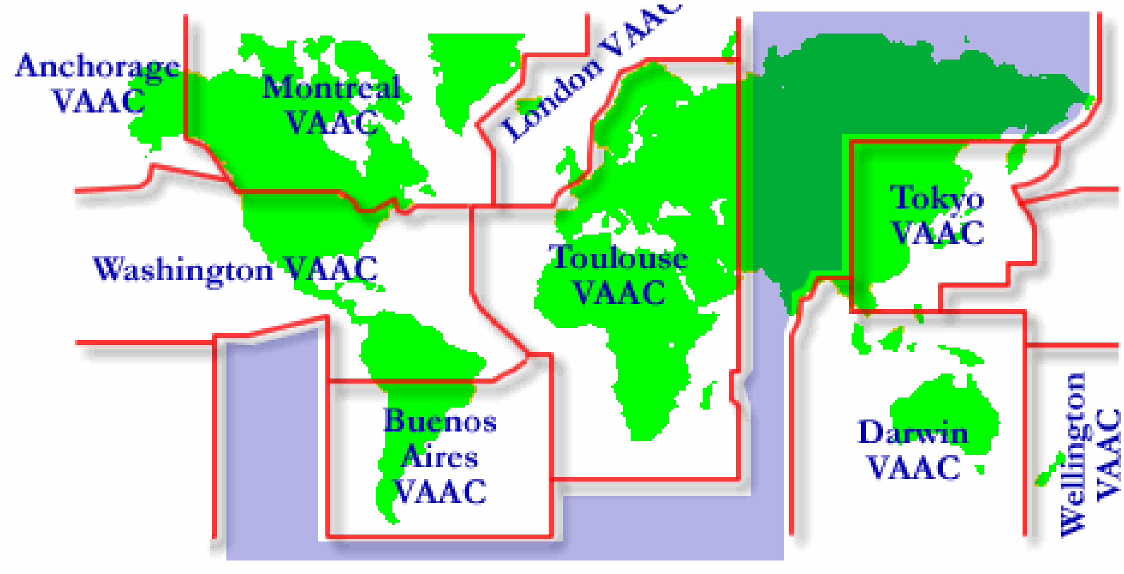
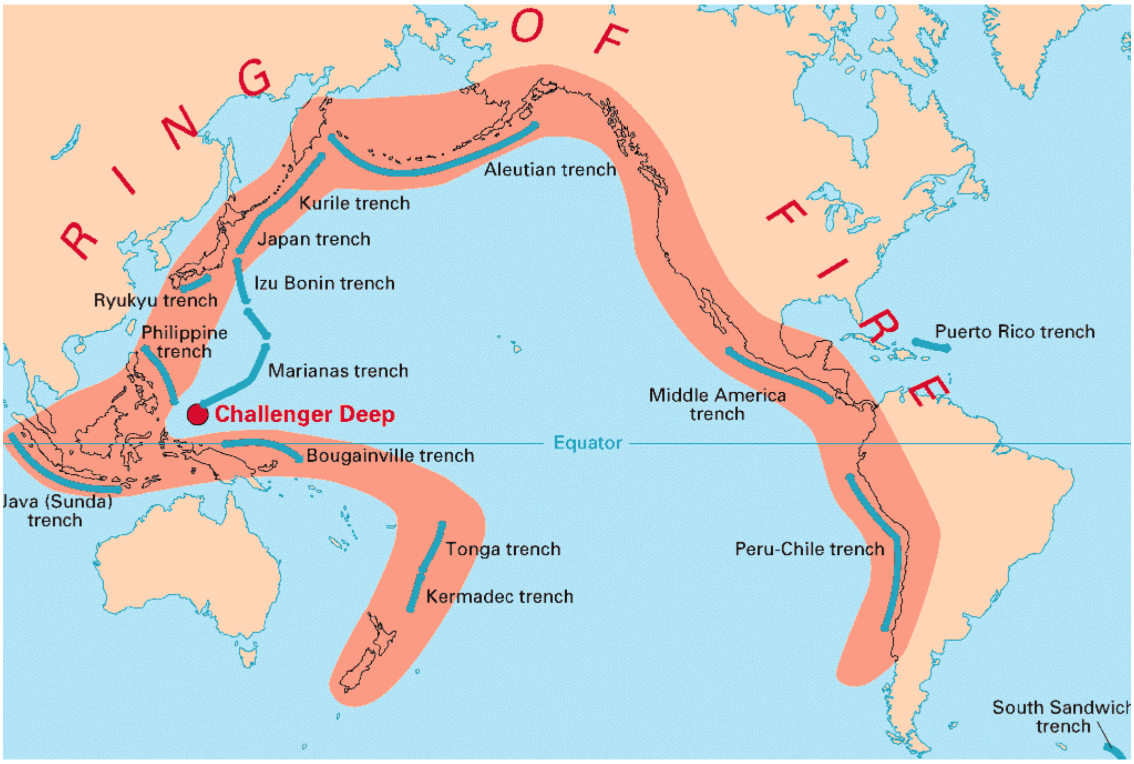


Figure 2 (Credit: Alaska Aviation Weather Unit) *Volcanic Ash Advisory Centers area of responsibility*

APPENDIX F *ACTIVE VOLCANOES IN PACIFIC AREA*



APPENNDIX G

Cleveland volcano, Alaska 23 May 2006 (Photo: Courtesy NASA)