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Amendment No. 3
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MANUAL ON VOLCANIC ASH, RADIOACTIVE MATERIAL AND TOXIC CHEMICAL CLOUDS

THIRD EDITION — 2015

AMENDMENT NO. 3

1. To incorporate this amendment, replace the following existing pages with the attached new pages dated 10/2/21:

- — Page (ix)
- — Page (xiii)
- — Pages I-3-19 and I-3-20
- — Pages I-5-7, I-5-8, I-5-12 and I-5-14
- — Pages I-6-1, I-6-6 and I-6-8
- — Page II-3-1
- — Page App H-2
- — Table of Contents
- — Glossary
- — Part I, Chapter 3
- — Part I, Chapter 5
- — Part I, Chapter 6
- — Part II, Chapter 3
- — Appendix H

2. Record the entry of this amendment on page (iii).

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GLOSSARY

ACC	area control centre
AFS	aeronautical fixed service
AIA	Aerospace Industries Association
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	Air Line 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 service
AVHRR	advanced 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
GML	geography markup language
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'Associations
IUGG	International Union of Geodesy and Geophysics
IWXXM	ICAO Meteorological Information Exchange Model
JMA	Japanese Meteorology Association
LIDAR	light detection and ranging
MODIS	moderate resolution imaging spectroradiometer
MSU	microwave sounding unit
MTSAT	multifunctional transport satellites
MWO	meteorological watch office
NASA	National Aeronautics and Space Administration
NESDIS	National Environmental Satellite, Data and Information Service

NOAA	National Oceanic and Atmospheric Administration
NOF	international NOTAM office
NOTAM	notice to airmen
PANS	Procedures for Air Navigation Services
RSMC	Regional specialized meteorological centre
SADIS	Secure Aviation Data Information Service
SAR	synthetic aperture radar
SBUV	solar back scattered ultra violet
SEVIRI	spinning enhanced visible and infrared imager
SIGMET	information concerning en-route weather and other phenomena in the atmosphere that 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 systemWIFS WAFS Internet file service
WMO	World Meteorological Organization
WOVO	World Organization of Volcano Observatories

3.4.7 One of the purposes of producing such volcanic ash trajectory forecasts is to provide advisory information to airlines to enable them to take this information into consideration during the planning stage of flights (especially long haul flights). These operational aspects are addressed in Chapter 5.

3.4.8 The advisory information is invariably disseminated in abbreviated plain language. The standardized volcanic ash advisory in abbreviated plain language, which has been agreed globally, is provided in Annex 3, Appendix 2, Table A2-1.

3.4.9 Volcanic ash advisory information is also to be disseminated in ICAO meteorological information exchange model (IWXXM) geography markup language (GML) form.

Note 1.— The technical specifications for IWXXM are contained in the Manual on Codes *(WMO – No. 306), Volume I.3, Part D* – Representations Derived from Data Models. *Guidance on the implementation of IWXXM is provided in the* Manual on the ICAO Meteorological Information Exchange Model *(Doc 10003).*

Note 2.— Geography markup language (GML) is an encoding standard of the Open Geospatial Consortium (OGC).

3.4.10 Some VAACs also disseminate volcanic ash advisory information in graphical format; such volcanic ash advisory information ought to be as specified in Annex 3, Appendix 1 and issued using the portable network graphics (PNG) format.

3.4.11 Verification of volcanic ash transport and dispersion models, as well as the underlying forecast meteorological models, is an ongoing task.

3.5 VISIBLE AND DISCERNIBLE ASH

3.5.1 As a result of the work of the International Volcanic Ash Task Force (IVATF, 2010-2012), the IAVWOPSG fine-tuned the concepts of *visible ash* and *discernible ash*.

3.5.2 The IAVWOPSG developed the following definitions based on the above-mentioned concepts:

a) *Visible ash:* volcanic ash observed by the human eye (not be defined quantitatively by the observer); and

b) *Discernible ash:* volcanic ash detected by defined impacts on/in aircraft or by agreed in situ and/or remote-sensing techniques.

In accordance with agreed VAAC best practices, the "*discernible ash*" definition should be applied to delineate volcanic ash clouds on volcanic ash forecasts (including volcanic ash advisories in graphical format); otherwise, the definition of visible ash would be tactically useful for the flight crew while en route.

3.6 AIRCRAFT INSTRUMENTATION FOR CONDUCTING VOLCANIC ASH SAMPLING

3.6.1 The following recommendations for airborne sampling of ash plumes result from experience with the Eyjafjallajökull eruption[18].

a) It is important to perform airborne measurements in the eruption plume as soon as possible after the eruption to get early information on the source term and ash properties. Therefore, research aircraft with suitable instrumentation should be available at short notice (within 1-2 days). The aircraft should be capable of making measurements in the entire range of flight levels used by commercial air traffic, i.e. at altitudes up to 40 000 ft. It is recommended that experienced pilots and instrument operators conduct the missions. The crew on sampling flights should also carefully document their visual observations. The planning of the flights should be based on all information available including data from satellites, ground-based observing systems, and predictions from dispersion models.

b) The recommended instrumentation of the aircraft includes a combination of remote-sensing (Lidar, IR radiometer, DOAS) and in situ measurement systems for particles and gas-phase plume tracer. The Lidar provides information on the horizontal and vertical extent of the ash plume with qualitative information on the ash concentration and serves as pathfinder for the in situ measurements. For the in situ sampling, the ash plume is best intercepted using a combination of stacked flight runs and vertical profiles covering the entire vertical extent of the plume, thereby data are obtained that are best suited for comparison with satellite observations and dispersion models. Table I-3-3 provides a list of recommended instrument types and measurements that are currently available.

c) The mass concentration of ash cannot be measured directly but is determined from the particle number size distribution measured with the wing-mounted optical particle counter for given refractive index and density of the particles. Therefore, it is important to cover the entire size range of ash particles in the plume. The resultant uncertainty in ash mass concentration is about a factor of 2 (Schumann et al., ACP, 2011).

18. Detailed scientific papers describing airborne sampling of the Eyjafjallajökull ash cloud include:
Schumann, U., et al. (2011) Airborne observations of the Eyjafjallajökull volcano ash cloud over Europe during airspace closure in April and May 2010, Atmos. Chem. Phys., 11, 2245-2279, doi: 10.5194/acp- 11 2245-2011. http://www.atmos-chem-phys.net/11/2245/2011/acp- 11 2245-2011.html
Johnson, B., et al. (2012) In situ observations of volcanic ash clouds from the FAAM aircraft during the eruption of Eyjafjallajökull in 2010, J. Geophys. Res., 117, D00U24, doi: 10.1029/2011JDO16760.
Turnbull, K., B. Johnson, F. Marenco, J. Haywood, A. Minikin, B. Weinzierl, H. Schlager, U. schumann, S. Leadbetter, and A. Woolley (2012). A case study of observations of volcanic ash from the Eyjafjallajökull eruption: 1. In situ airborne observations, J. Geophys. Res., 117, D00U12, https://www.agu.org/pubs/crossref/pip/2011JD016688.shtml

their users. Governments will respond quickly to protect the general life and property of the public, with aviation interests being only one special focus.

5.2.3.2 In order for the ACC/FIC to make informed decisions regarding the effect that the eruption/ash cloud could have on the airspace under its jurisdiction, and for the MWO to prepare the SIGMET for volcanic ash, access to advice from experts is necessary. As indicated elsewhere in this document, ICAO has designated nine volcanic ash advisory centres (VAACs) for this purpose. The VAAC issues volcanic ash advisory information on the trajectory of the ash cloud and the flight levels which are affected by the cloud, in accordance with Annex 3, Appendix 1 and Appendix 2, Table A2-1. The MWO's responsibility is to use this information and other sources of data for the issuance of a SIGMET for volcanic ash. The same information provided to the MWO by the VAAC is customarily sent to the ACC for transmission to aircraft in flight and for the initiation of a NOTAM. In addition to the information on the volcanic activity, the NOTAM contains information on air routes affected by volcanic ash and guidance on alternative routes. Volcanic ash SIGMETs are issued by the MWO in accordance with the Standards and Recommended Practices of Annex 3 (Appendix 6, Table A6-1A refers) and are usually issued after the meteorologist has verified the reported information. SIGMETs are used by supervisors in the ACC for managing airspace under their area of responsibility including the closing of airspace and the rerouting of aircraft. The information contained in the SIGMET is also passed on to pilots by ATS so the pilots can avoid the ash cloud. All decisions on rerouting aircraft are a coordinated effort between ATS, the pilot and the flight dispatcher.

5.2.4 Air traffic procedures for an ACC

5.2.4.1 If a volcanic ash cloud is reported or forecast in the flight information region for which the ACC is responsible, from any of the foregoing sources, the following procedures are 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 rerouting to avoid area of known or forecast ash clouds;

c) remind pilots that volcanic ash clouds are not detected by airborne or air traffic radar systems. The pilot should assume that radar will not give them advanced warning of the 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:

1) consider the aircraft to be in an emergency situation;

2) do not initiate any climb clearances to turbine-powered aircraft until the aircraft has exited the ash cloud; and

3) do not attempt to provide escape vectors without pilot concurrence.

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 responsibility for this decision, however, rests with the pilot.

5.2.4.2 Appendix B provides the U.S. Department of Transportation, Federal Aviation Administration, Anchorage Air Traffic Control Center Emergency Plan for Volcanic Eruptions in Alaska Airspace. The emergency plan is an example of the steps needed to be taken to provide a coordinated and controlled response for dealing with an event of this nature. Responsibilities are clearly denoted for the area manager in charge, area supervisor, traffic manager and controllers. The order also identifies the officials who need to be contacted, the type of messages that are to be created, and how to conduct business.

5.2.4.3 Appendix C provides the Australian Airservices Weather Deviation Procedures for Oceanic Controlled Airspace. These procedures provide an example of procedures to be followed for operations that require a deviation in the planned flight for avoiding severe weather, not unlike an event of encountering an ash cloud. These procedures are of particular use for areas outside the coverage of direct controller-pilot VHF communication. They describe actions to be followed by air traffic control and the responsibilities of pilots and pilot-controller communications.

5.2.4.4 Critical to the examples provided in Appendices B and C is the fact that each State needs to develop procedures that meet its circumstances and fulfil its obligations to ICAO to provide the necessary air traffic support to ensure safety of aircraft.

5.2.4.5 Controllers need to be trained and made aware that aircraft which encounter an ash cloud can suffer a complete loss of power to turbine engines and that extreme caution needs to be taken to avoid entering an ash cloud. Since there is no means to detect the density of the ash cloud and size distribution of the particles and their subsequent impact on engine performance and the integrity of the aircraft, controllers need to be aware of the serious consequences for an aircraft that may encounter an ash cloud. Chapters 4 and 5 of this document have described the damage that can result from ingesting volcanic ash in an engine and how ash can impair operations at an aerodrome. Some particular points of guidance are as follows:

a) ash clouds may extend for hundreds of miles horizontally and reach the stratosphere vertically, therefore pilots should not attempt to fly through or climb out of the cloud;

b) volcanic ash may block the pitot-static system of an aircraft, resulting in unreliable airspeed indications; and

c) braking conditions at airports where volcanic ash has recently been deposited on the runway will effect the braking ability of the aircraft. This is more pronounced on runways that have wet ash. Be aware of the consequences of ingesting the volcanic ash into the engines during landing and taxiing. When departing airports, it is recommenced that pilots avoid operating in visible airborne ash; instead they should allow sufficient time for the particles to settle before initiating a take-off roll, in order to avoid ingestion of ash particles into the engine.

5.2.5 Radio and ground notification

5.2.5.1 The ACC/FIC serves as the critical communication link between the pilot, dispatcher and meteorologists during a volcanic eruption. During episodes of volcanic ash clouds within their flight information region (FIR), the ACCs/FICs have two major communication roles. First and of greatest importance is their ability to communicate directly with aircraft en route which may encounter the ash cloud. Based on the information provided in the volcanic ash SIGMET and volcanic ash advisory and working with MWO meteorologists, the air traffic controllers should be able to provide the pilot with the flight levels that are affected by the ash cloud and the projected trajectory and drift of the cloud. Through the use of radio communication, ACCs/FICs have the capability to coordinate with the pilot alternative routes which would route the aircraft away from the volcanic ash cloud.

5.2.5.2 Similarly, the ACC through the issuance of a NOTAM for volcanic activity or an ASHTAM can disseminate information on the status and activity of a volcano even for pre-eruption increases in volcanic activity. NOTAM, ASHTAM and SIGMETs together with special air reports (AIREPs) are critical to dispatchers for flight planning purposes. Airlines need as much advance notification as possible on the status of a volcano for strategic planning of flights and the safety of the flying public. Dispatchers need to be in communication with their pilots en route so that a coordinated decision can be made between the pilot, the dispatcher and air traffic control regarding the alternative air routes that are available. It cannot be presumed, however, that an aircraft which is projected to encounter an ash cloud will be provided the most desirable air route to avoid the cloud. Other considerations have to be taken into account such as existing traffic levels on other air routes and the amount of fuel reserve available for flights which may have to be diverted to other routes to allow for the affected aircraft to divert to that air route.

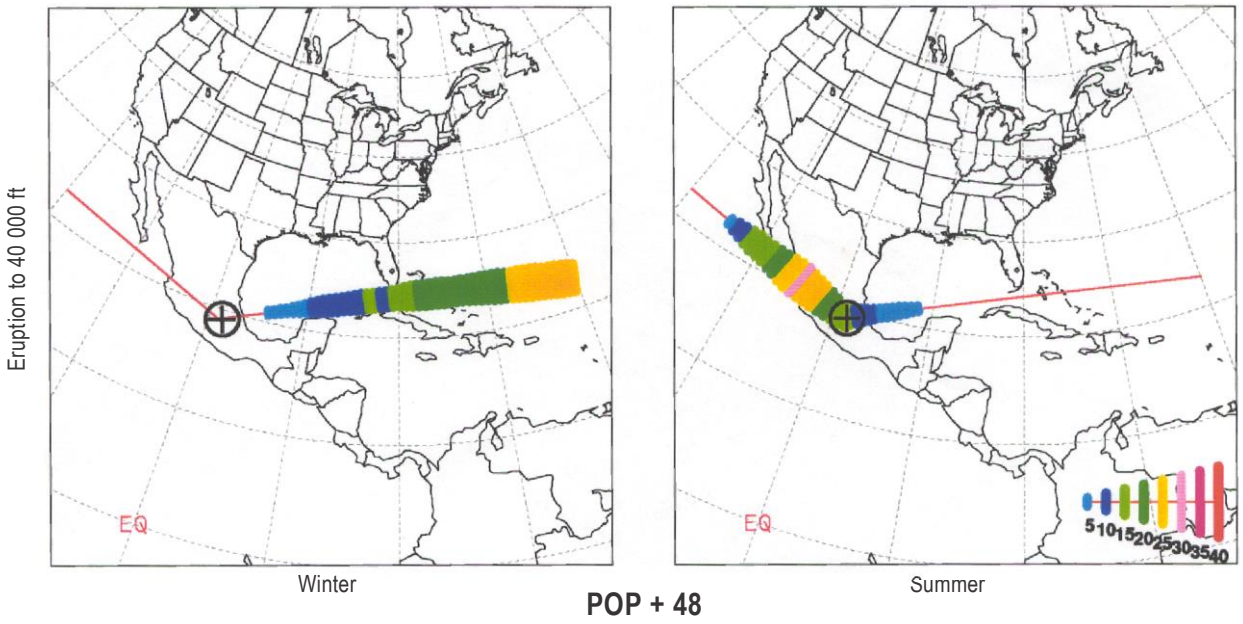

Figure I-5-3 b). Hypothetical AEP flight paths affected by volcanic ash from Popocatepetl, Mexico (+48 hours). (from Stunder and Heffter)

5.3.2 Observation of volcanic eruptions/ash cloud

Generally speaking, few aerodrome meteorological offices/stations are actually located within sight of an active volcano or groups of volcanoes. Nevertheless, those which are, e.g. Kagoshima airport near Mt. Sakurajima in Japan, and Anchorage within sight of a number of Alaskan volcanoes, are expected to issue volcanic activity reports in the event an eruption and/or ash cloud is observed. This information is passed up the chain of communications to the MWO which is responsible for maintaining a meteorological watch over the FIR concerned. If the volcanic ash in the atmosphere affects the visibility at the aerodrome, then it is also reported in METAR/SPECI. Although less likely, if volcanic ash is affecting an aerodrome, the associated visibility reduction could also be forecast, i.e. at least the visibility values, not the occurrence of volcanic ash, in the terminal aerodrome forecast (TAF) for the aerodrome.

5.3.3 Warnings for volcanic ash

5.3.3.1 The next higher link in the chain of communication and responsibility is the MWO. The responsibility at this level focuses on the transformation of received “observed” information from any source into a warning to aviation i.e. a SIGMET. The SIGMET for volcanic ash is valid for a maximum period of six hours. In principle, in order for an MWO to discharge this responsibility, its meteorologists would need access to:

a) geostationary and AVHRR data; and

b) a computer model capable of forecasting volcanic ash trajectories in real time.

As many MWOs do not have access to such support, it was necessary for ICAO to designate VAACs having this capability and able to provide the necessary advisory information to MWOs.

5.3.3.2 Nine such centres have been designated to assist MWOs in an agreed area of responsibility (see Chapter 6). On receipt of information from any source that a volcano has erupted and/or volcanic ash has been reported, the MWO immediately informs its associated ACC/FIC so that aircraft which could be affected may be warned and diverted. Next, the MWO notifies its associated VAAC by telephone or fax seeking confirmation of ash clouds from satellite data and requesting trajectory forecasts based on initial information provided by the MWO. The initial information may, or may not, include confirmation that volcanic ash in the atmosphere is involved and the height the ash column has reached. If the reports do indicate that ash has definitely been observed, or the eruption was of the explosive type and ash can be inferred, an initial SIGMET should be issued while a trajectory forecast is awaited from the VAAC. A second SIGMET will be issued as soon as further confirmation is received regarding the existence and extent of the ash cloud and/or the first trajectory forecast is received from the VAAC. The SIGMETs should be updated as necessary, but at least every six hours.

5.3.3.3 It is important that the MWO maintains constant contact with its associated ACC to ensure that the contents of SIGMET and NOTAM/ASHTAM are mutually consistent. Depending on the arrangements made in States, the ACC may receive information directly from the VAAC at the same time the MWO receives it. Where possible this is the preferred method as it saves valuable time. This VAAC/ACC contact must be confirmed, and if it is not the case, the MWO must ensure that all such information is passed to the ACC immediately. Care should be taken to cancel SIGMETs when volcanic ash no longer affects the FIR concerned. In principle, this will be when the VAAC confirms that ash is no longer detectable from satellite data, no further reports of volcanic ash in the atmosphere have been received and the volcano has reverted to its pre-eruption status on the basis of expert vulcanological advice. In the latter context, the ACC should have access to vulcanological advice, and coordination of the cancellation of SIGMETs should be based on this advice. It should be noted that the NOTAM/ASHTAM may be issued before an actual eruption, or may be maintained after an eruption has ceased temporarily, based on vulcanological advice. The SIGMET, however, is only issued when volcanic ash in the atmosphere is reported or expected to exist.

5.3.4 Volcanic ash advisory service

5.3.4.1 Eight States have accepted responsibility for providing nine VAACs as part of the IAVW on a 24-hour basis. Each MWO should be aware to which VAAC it is associated and have readily to hand the VAAC 24-hour telephone and fax contact numbers. The VAAC has to be in a position to react to the receipt of information from any source that a volcano has erupted and/or volcanic ash has been reported. If the VAAC receives this information from *any source* other than an ACC/FIC or MWO (i.e. when the MWO is providing initial notification and request for trajectory advice), such as direct from a vulcanological agency or from their own satellite data, the VAAC should *immediately* inform the MWO and then issue a volcanic ash advisory.

5.3.4.2 If the VAAC receives the initial information of an eruption and/or ash cloud from an ACC/FIC or MWO, the first step is to monitor available satellite data to confirm the existence and extent of the volcanic ash cloud. Next, based on all information available (which may involve consultation with vulcanologists) the volcanic ash forecast transport and deposition model is activated and the resulting trajectory forecasts compiled into volcanic ash advisory information in abbreviated plain language, in IWXXM GML form and in graphical format. The former is transmitted to ACCs/FICs, MWOs and the two WAFCs by aeronautical fixed service (AFS), global telecommunication system (GTS) or facsimile, as necessary. The graphical format advisory information is transmitted to the London and Washington WAFCs for distribution on the aeronautical fixed service (AFS) Internet-based services (i.e. Secure Aviation Data Information Service (SADIS) FTP and WAFS Internet file service (WIFS)). This graphical format may of course be used to provide individual MWOs with advisory information in response to specific requests.

5.3.4.3 The VAAC should continue to monitor the situation in consultation with vulcanologists and the ACC/FIC, MWOs concerned. Advisory information should be issued as necessary but at least every six hours to assist MWOs in updating their SIGMET information. Updated advisory information must continue to be issued until such time as:

a) the volcanic ash "cloud" is no longer identifiable from satellite data and, where available, ground-based and airborne data;

b) no further reports of volcanic ash are received from the area; and

c) no further eruptions of the volcano are reported.

5.3.4.4 The VAAC should maintain an awareness of the status of active and potentially explosive volcanoes in the FIRs which come under its area of responsibility. Assistance in this regard is provided in the monthly Scientific Event Alert Network Bulletin published by the U.S. Smithsonian Institution and sent free of charge to any ACC/FIC, MWO and VAAC requesting it.

5.3.5 World area forecast system (WAFS)

The two WAFCs in London and Washington have two responsibilities in respect of volcanic ash:

a) to include a reference to the occurrence of an eruption using the standard symbol on SIGWX forecast charts; together with a reminder to pilots to check SIGMETs for the area concerned;

b) to make available volcanic ash advisory information (in abbreviated plain language, IWXXM GML form and graphical format) on the AFS Internet-based services (i.e. SADIS FTP and WIFS).

The information provided in the SIGWX forecasts should be based on advice from the VAAC concerned, thereby ensuring consistency of information.

5.4 FLIGHT PLANNING, DISPATCH AND OPERATIONAL CONTROL

5.4.1 General

5.4.1.1 Volcanic ash cloud can cover a very wide area and move quickly from one region to another. Consequently, the accurate and timely availability of information is essential for safety of flight and to facilitate both the flight pre-planning stage as well as any consequential in-flight replanning. The options available include rerouting, unscheduled en-route technical stops, carriage of extra (contingency) fuel against possible en-route diversion or non-optimum flight altitudes, or cancellation. All of these materially affect load planning and crew preparation. All involve highly complex management decisions.

5.4.1.2 The overall situation can be further complicated when large numbers of passengers are involved. Carriage of additional fuel usually means loss of revenue payload. Offloading passengers or cargo close to departure time can bring additional complications. Technical stops are always costly and bring the additional risk of serious further delays due to flight crew duty time limitations being exceeded. Delayed or cancelled flights have a consequential effect on aircraft and crew availability for this and other sectors, beyond the immediate destination. For flights between Asia and Europe, curfews severely restrict the options to re-schedule flights. In fact, any interruption in the smooth and carefully planned operation of scheduled air services can lead to acute problems with serious financial penalties to the operator, and distress and frustration to the passenger.

5.4.1.3 The first consideration, however, must always be the safety of the aircraft and its occupants. The safety implications of an inadvertent ash encounter are already well documented and are addressed elsewhere in the manual. The aim is to avoid! Consequently, early knowledge of an event, however sketchy, will help airline operational staff make important planning decisions. Regular updates of information are essential.

5.4.2 Meteorological requirements

5.4.2.1 Annex 3

Specific user requirements for operational meteorological information (OPMET) are clearly stated in Annex 3.

5.4.2.2 Volcanic ash advisory information

5.4.2.2.1 Airlines have identified a need for volcanic ash advisories to be available through the ICAO AFS Internet-based services (i.e. SADIS FTP and WIFS) for immediate access. The advisories are also available through the International Society for Aeronautical Telecommunications (SITA) communications circuits and in the corresponding VAACs' websites. This information is required for flight planning, in particular for long-haul flights. It should be available at the flight planning stage as much as 15 hours before a possibly contaminated area is actually reached.

5.4.2.2.2 Additionally, airlines have identified a requirement for volcanic ash advisories in graphical format. The volcanic ash advisories are also to be provided in IWXXM GML form.

Note 1.— The technical specifications for IWXXM are contained in the Manual on Codes *(WMO – No. 306), Volume I.3, Part D* – Representations Derived from Data Models. *Guidance on the implementation of IWXXM is provided in the* Manual on the ICAO Meteorological Information Exchange Model *(Doc 10003).*

Note 2.— Geography markup language (GML) is an encoding standard of the Open Geospatial Consortium (OGC).

5.4.2.3 SIGMET and aerodrome warnings

5.4.2.3.1 SIGMET are to be valid for six hours. From a safety viewpoint, regular in-flight updates would be required, but important initial fuel and payload decisions would first need to have been taken. These include the availability of alternative routings and alternate en-route aerodromes as well as conditions at the destination. Dissemination of SIGMET to internationally agreed addresses well beyond the affected FIR is therefore an important factor. This will ensure the earliest possible notification of flights likely to be affected.

5.4.2.3.2 Unfortunately, the SIGMET is frequently the weakest link in the information chain. In the case of volcanic ash, forecasters at MWOs who issue SIGMET information are encouraged to consider the impact of such information on flight operations.

5.4.2.3.3 Meteorological and AIS staff should ensure the correct dissemination of SIGMET and NOTAM to internationally agreed addressees with particular attention to the ICAO four-letter FIR location indicator to ensure the longest possible warning and available preparatory time for airline operations staff and flight crews.

5.4.2.3.4 Aerodrome warnings for volcanic ash deposition have been identified as necessary by users. To that end, the meteorological office at the aerodrome is requested to issue such warnings if a forecast of impending ash deposition is available or as soon as the ash begins to accumulate at the aerodrome.

Chapter 6

THE INTERNATIONAL AIRWAYS VOLCANO WATCH (IAVW)

6.1 GENERAL

The definition of the IAVW given in Annex 3 is as follows:

International airways volcano watch (IAVW). International arrangements for monitoring and providing warnings to aircraft of volcanic ash in the atmosphere.

Note.— The IAVW is based on the cooperation of aviation and non-aviation operational units using information derived from observing sources and networks that are provided by States. The watch is coordinated by ICAO with the cooperation of other concerned international organizations.

Put in its simplest terms, the role of the IAVW is to keep aircraft in flight and volcanic ash in the atmosphere entirely separate. Nothing can be done to prevent volcanic ash erupting into the atmosphere and being carried by the upper winds across international air routes. The aviation community has the responsibility to ensure, as far as possible, that when this happens, the ash cloud is monitored, pilots concerned are advised and aircraft routed safely around it.

6.2 STRUCTURE OF THE IAVW

The IAVW consists of two parts, an observing part comprising observation sources, as follows:

a) observations from existing ground-based stations drawn from all known organized international observing networks regardless of their particular specialized function;

b) special air-reports; and

c) observations from satellites (meteorological and non-meteorological);

and an advisory warning part comprising advisory/ warning messages, as follows:

d) NOTAM or ASHTAM initiated by ACCs/FICs and issued by AIS units;

e) SIGMETs issued by MWOs; and

f) volcanic ash advisory information issued by VAACs.

The overall structure of the IAVW is shown diagrammatically in Figure I-6-1 and in terms of the relevant international regulatory provisions in Figure I-6-2.

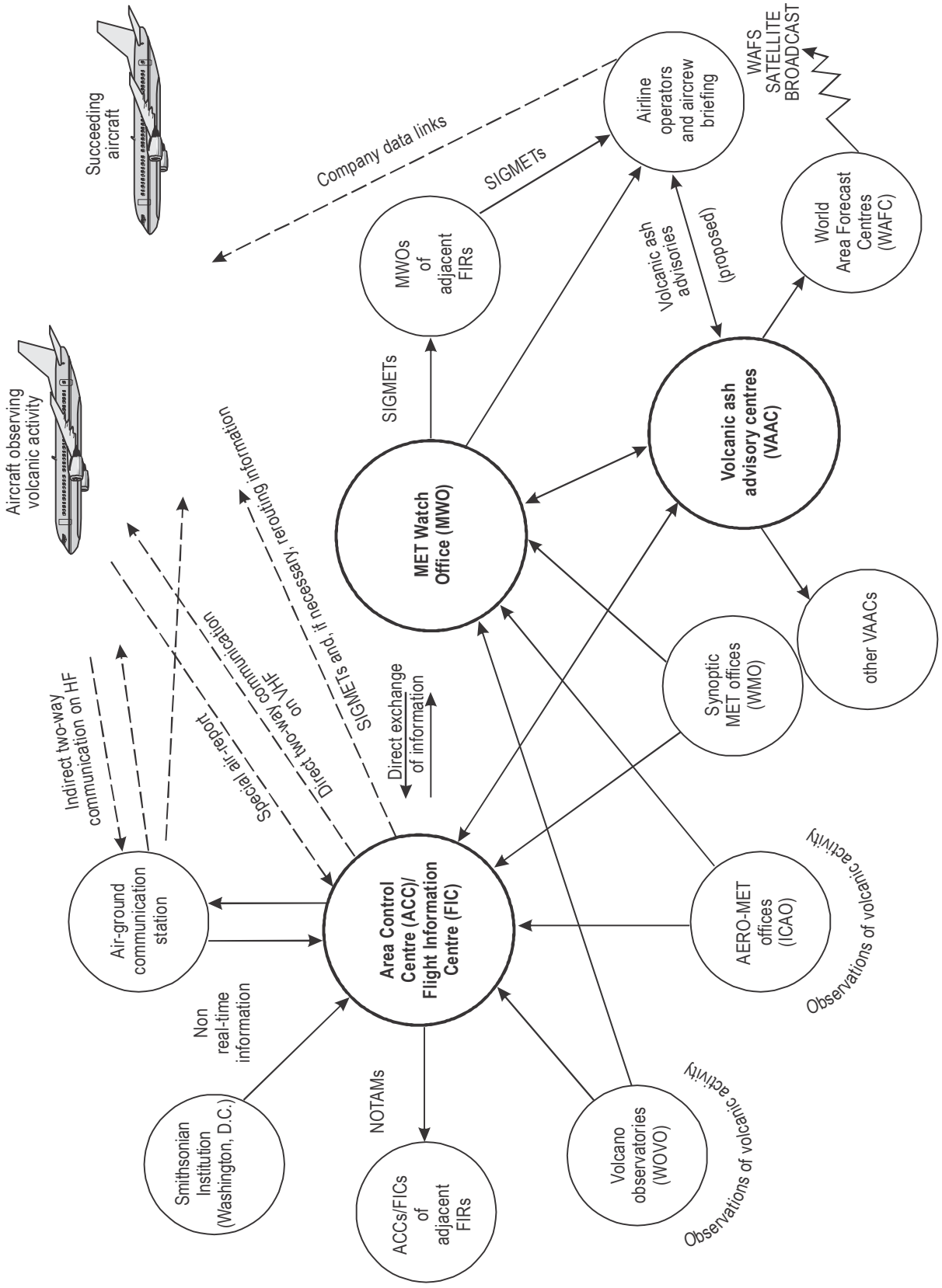

Figure I-6-1. Organization of the International Airways Volcano Watch

The relevant international regulatory and procedural documents which govern the work of the organized networks have been amended to indicate that, if their observing staff see or learn of a volcanic eruption or a volcanic ash cloud, the information must be sent immediately to the nearest area control centre or meteorological watch office through existing dedicated communications channels or by telephone, telex or facsimile.

6.3.2 Airborne observations

6.3.2.1 Mention was made in Chapter 1 that only a minority of active volcanoes is monitored on the ground, which means that pilots with their commanding view from the cockpit and regular travel over remote areas are often the first to observe a volcanic eruption or volcanic ash cloud, and therefore, may well be the first line of defence. In view of the danger volcanic ash presents to aircraft, however, it is appreciated that this is not an acceptable situation, and eventually must become the exception rather than the rule. Nevertheless, until such time as the world's active volcanoes are monitored more effectively, on many occasions pilots will continue to be the first to report volcanic activity.

6.3.2.2 In order to assist pilots in making these reports, volcanic activity, volcanic eruptions and volcanic ash clouds were included in the international regulatory documents as phenomena warranting the issuance of a special air-report. The international special air-report of volcanic activity reporting (VAR) format should be used. This format is given in Appendix 1 of the *Procedures for Air Navigation Services —Air Traffic Management* (PANS-ATM, Doc 4444) and its format was updated at the Third Meeting of the IAVWOPSG. A copy is provided in Figure I-6-3. The special air-report of volcanic activity (model VAR) is divided into two sections. Section 1 includes basic aircraft identification and position and the minimum information required immediately, i.e. the volcanic activity observed and wind/temperature at the flight level. This information is to be transmitted by radio to ATS units as soon as pilot workload permits. The wind/temperature information is included in the first section because it is of assistance to meteorologists in predicting the initial movement of the ash cloud at that flight level. When time permits, the pilot is encouraged to complete Section 2 of the message format giving additional details of the eruption, ash cloud and, if relevant, the effect on the aircraft. This information is handed in to ground personnel as a complete written post-flight special air-report at the next point of landing and is of assistance to vulcanologists in determining the type of eruption. The visual observation of pre-eruption volcanic activity and volcanic ash cloud by pilots is dealt with in 3.2.1 of this manual and the clues to warn the pilot that the aircraft has actually entered a volcanic ash cloud are discussed in 3.2.2. Aircraft engine and sensor anomalies which also assist the pilot in this latter regard are dealt with in 4.3. The requirements for pilots to report volcanic activity have been well publicized and supported throughout the aviation industry, due to the efforts of IATA and IFALPA, and there must be very few pilots by now who are unaware of these requirements.

6.3.3 Space-based observation

6.3.3.1 The final part of the IAVW observing triad comprises the observation of volcanic eruptions and ash cloud from satellites. The various satellites involved, the current data interpretation and analysis techniques used, and the expectations for future satellite sensors and systems are discussed in 3.3. For the most part, the satellites which are currently used for observing volcanic eruptions and volcanic ash cloud are polar-orbiting and geostationary meteorological satellites. These satellites form an integral part of the Global Observing System of the World Weather Watch which is coordinated and administered by WMO.

6.3.3.2 Other satellites and sensors which are of interest in the monitoring of volcanic eruptions and ash cloud, which are also discussed in Chapter 3, include environmental satellites, and sensors to detect stratospheric ozone which are currently operating on certain polar-orbiting meteorological satellites. These satellites and sensors also fall under the aegis of WMO in respect of their importance in environmental and climatological studies. It is the intention of WMO that the whole world will continue to be monitored by both polar-orbiting and geostationary meteorological satellites for the foreseeable future and, national budgets permitting, follow-on launches of replacement satellites for both series are planned at least through the current decade. WMO has committed itself to cooperating with ICAO in the development of satellite techniques in order to steadily improve the effectiveness of satellite data interpretation and analysis in

monitoring volcanic eruptions and ash cloud. The VOLCAM-dedicated UV/IR camera package proposed by NASA to monitor volcanic eruptions and ash cloud from geostationary satellites described in 3.3.4.4 would, if it came to fruition, provide a quantum leap in the efficacy of the IAVW and the protection of aircraft.

6.4 ADVISORY AND WARNING PART OF THE IAVW

6.4.1 Area control centres and flight information centres

6.4.1.1 Airspace around the world is divided by regional agreement into FIRs throughout which flight information and alerting service is provided. Within these regions various control areas and zones are designated in which air traffic control service is provided for flights conducted under instrument flight rules, such as around airports and along air routes. ACCs are units established by States to provide air traffic control service to controlled flights in control areas under their jurisdiction. FICs are units established by States to provide flight information service and alerting service. The ACC and FIC are in radio contact with all aircraft in flight operating within and through their FIR via the aeromobile communications service. These units are, therefore, the critical interface between ground units and aircraft in flight. In addition to the air-ground communications through air traffic services units, most of the larger airline companies also maintain data link communications between their centralized operational control units on the ground and the company fleet of aircraft. The airlines transmit available operational information, including relevant meteorological information to their aircraft fleet in addition to specific “company” information.

6.4.1.2 Among its responsibilities, the ACC/FIC has to keep aircraft advised of operational information which could affect them. Such information may be exchanged between ACCs/FICs in adjacent FIRs by radio, telephone and by NOTAM. The NOTAM is a message in a specified format containing information concerning, *inter alia*, hazards, the timely knowledge of which is essential to personnel concerned with flight operations. NOTAM may be initiated by ACCs/FICs, for example for volcanic ash affecting certain air routes, and are exchanged on the aeronautical fixed service (AFS) between AIS units. In the case of information of immediate concern to aircraft, again volcanic ash would be a good example, the information received by an ACC/FIC in a NOTAM is transmitted immediately by radio to aircraft in flight concerned. NOTAM also form part of the briefing documentation for aircrew prior to take-off and at the flight planning stage. In addition to information on the volcanic eruption and/or volcanic ash cloud, the NOTAM would normally include information on the air routes closed and alternative routing to avoid the ash cloud. It is essential that NOTAM for volcanic eruptions/ash cloud are cancelled as soon as it is considered that the volcano has reverted to its normal state and the airspace is no longer contaminated by volcanic ash, otherwise vast volumes of airspace may be unnecessarily denied to aircraft, thereby causing considerable extra costs to the airlines. A special series NOTAM called the ASHTAM has been introduced specifically for volcanic activity. States may choose to use either format, but are encouraged to use the ASHTAM because the name immediately denotes its content and facilitates the routing of the information to the aircraft quickly.

6.4.2 Meteorological watch offices

6.4.2.1 Once an ICAO Contracting State accepts responsibility for providing air traffic services within an FIR or control area, it also has to establish an MWO for that FIR or control area, or arrange for another State to undertake this responsibility. The MWO maintains a watch over the meteorological conditions in the FIR or control area and issues SIGMET and AIRMET information, as necessary, warning aircraft of specified observed or forecast en-route weather or other phenomena in the atmosphere that may affect the safety of aircraft operations. The AIRMET comprises information on weather phenomena of specific concern to low-level flights below flight level 100 (or 150 in mountainous areas) which has not already been included in the area forecasts provided for those low-level flights and/or a SIGMET (which may concern flights at any flight level). Volcanic ash is already included as a phenomenon which warrants issuance of a SIGMET (for whatever flight levels concerned) and, therefore, is not included in the list of phenomena warranting issuance of an AIRMET.

Special air-report of volcanic activity form (Model VAR)
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.

OPERATOR:			A/C IDENTIFICATION: (as indicated on flight plan)		
PILOT-IN-COMMAND:					
DEP FROM:	DATE:	TIME; UTC:	ARR AT:	DATE:	TIME; UTC:
ADDRESSEE			AIREP SPECIAL		
Items 1–8 are to be reported immediately to the ATS unit that you are in contact with.					
1) AIRCRAFT IDENTIFICATION			2) POSITION		
3) TIME			4) FLIGHT LEVEL OR ALTITUDE		
5) VOLCANIC ACTIVITY OBSERVED AT (position or bearing, estimated level of ash cloud and distance from aircraft)					
6) AIR TEMPERATURE			7) SPOT WIND		
8) SUPPLEMENTARY INFORMATION a) SO_2 detected Yes ☐ No ☐ b) Ash encountered Yes ☐ No ☐			Other _____ _____ _____ (Brief description of activity especially vertical and lateral extent of ash cloud and, where possible, horizontal movement, rate of growth, etc.)		
After landing complete items 9–16 then fax form to: (Fax number to be provided by the meteorological authority based on local arrangements between the meteorological authority and the operator concerned.)					
9) DENSITY OF ASH CLOUD	☐ (a) Wispy		☐ (b) Moderate dense	☐ (c) Very dense	
10) COLOUR OF ASH CLOUD	☐ (a) White ☐ (d) Black		☐ (b) Light grey ☐ (e) Other _____	☐ (c) Dark grey	
11) ERUPTION	☐ (a) Continuous		☐ (b) Intermittent	☐ (c) Not visible	
12) POSITION OF ACTIVITY	☐ (a) Summit ☐ (d) Multiple		☐ (b) Side ☐ (e) Not observed	☐ (c) Single	
13) OTHER OBSERVED FEATURES OF ERUPTION	☐ (a) Lightning ☐ (d) Ash fallout		☐ (b) Glow ☐ (e) Mushroom cloud	☐ (c) Large rocks ☐ (f) All	
14) EFFECT ON AIRCRAFT	☐ (a) Communication ☐ (d) Pitot static		☐ (b) Navigation systems ☐ (e) Windscreen	☐ (c) Engines ☐ (f) Windows	
15) OTHER EFFECTS	☐ (a) Turbulence		☐ (b) St. Elmo's Fire	☐ (c) Other fumes	
16) OTHER INFORMATION (Any information considered useful.)					

Figure I-6-3. VAR Model

6.4.2.2 The SIGMET is issued for a validity period of from four to six hours, but in the special case of volcanic ash and tropical cyclones the validity period should normally be for the maximum period of six hours. 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 PSN S1500 E07348 VA CLD OBS AT 1100Z APRX 50KM WID LINE BTN S1500 E07348 – S1530 E07642 FL310/450 INTSF FCST AT 1700Z APRX 50KM WID LINE BTN S1506 E07500 – S1518 E08112 – S1712 E08330

Meaning: The second SIGMET issued for the SHANLON* flight information region (identified by YUDD Shanlon area control centre) by the Shanlon/International* meteorological watch office (YUSO) since 0001 UTC; the SIGMET is valid from 1100 UTC to 1700 UTC on the 21st of the month; volcanic ash eruption of Mount Ashval* located at 15 degrees south and 73 degrees 48 minutes east; volcanic ash cloud observed at 1100 UTC in an approximately 50 km wide line between 15 degrees south and 73 degrees 48 minutes east, and 15 degrees 30 minutes south and 76 degrees 42 minutes east; between flight levels 310 and 450 intensifying; at 1700 UTC the volcanic ash cloud is forecast to be located in an approximately 50 km wide line between 15 degrees 6 minutes south and 75 degrees east, 15 degrees 18 minutes south and 81 degrees 12 minutes east, and 17 degrees 12 minutes south and 83 degrees 30 minutes east.

6.4.2.3 In the event that a volcanic eruption ejects volcanic ash into the atmosphere in a particular FIR, or volcanic ash is transported into the FIR from an adjacent FIR by the upper winds, the MWO responsible for that FIR is required to issue a SIGMET for volcanic ash. Issuance of the first SIGMET simply indicating the existence of a volcanic ash cloud (including volcano name, location, possible ash height and direction, if known) from a particular volcano is a straightforward matter for any MWO. Reference to Chapter 3, 3.3 and 3.4, however, indicates that substantial technical capabilities are required of an MWO in order to issue subsequent SIGMETs. As a minimum, the MWO should have reliable reception of polar-orbiting and geostationary satellites, including AVHRR satellite data and be in a position to manipulate, analyse and interpret the data in order to discriminate volcanic ash clouds from normal water/ice clouds. In addition, the MWO has to be able to forecast the trajectory of the volcanic ash cloud, which is a complex undertaking. It was appreciated from the beginning of the establishment of the IAVW that most MWOs do not have these capabilities. In view of this, ICAO has designated, on advice from WMO, nine VAACs whose responsibility is to provide advice to MWOs and ACCs/FICs in their area of responsibility of the extent and forecast movement of the volcanic ash.

6.4.3 Volcanic ash advisory centres

6.4.3.1 The role of a VAAC is to provide expert advice on a 24-hour watch to ACCs/FICs/MWOs in its area of responsibility (see Figure I-6-4) regarding the extent and forecast movement of a volcanic ash cloud. This information is required by the MWOs in order to issue SIGMETs for volcanic ash. The VAACs monitor the volcanic ash cloud using the data received from relevant geostationary and polar-orbiting meteorological satellites and, where available, from relevant ground-based and airborne sources, and forecast the movement of the ash cloud using volcanic ash transport and dispersion computer models. The techniques employed by the VAACs are described in detail in Chapter 3.

Note.— Relevant ground-based and airborne data includes data derived from Doppler weather radar, ceilometers, lidar and passive infrared sensors.

* Fictitious locations.

Chapter 3

NATIONAL AND INTERNATIONAL ARRANGEMENTS AND PROCEDURES TO DEAL WITH THE HAZARD TO AIRCRAFT

3.1 RELEASE OF RADIOACTIVE MATERIALS AND TOXIC CHEMICALS INTO THE ATMOSPHERE

3.1.1 The provision of national information on events in which radioactive materials or toxic chemicals are released into the atmosphere normally forms part of a State's emergency plan. On this assumption, appropriate provisions have been introduced into the relevant ICAO regulatory documents (Annex 3 — *Meteorological Service for International Air Navigation,* Annex 11 — *Air Traffic Services*, Annex 15 — *Aeronautical Information Services*, the *Procedures for Air Navigation Services — ICAO Abbreviations and Codes* (PANS-ABC, Doc 8400), the *Procedures for Air Navigation Services — Aeronautical Information Management* (PANS-AIM, Doc 10066) and the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444)) requiring that any information on such accidents available nationally should be provided by the responsible ACC to aircraft in flight likely to be affected in the FIR concerned. A specific designator "WR" is provided for in the NOTAM format used to disseminate information among aeronautical information services units, and then to air traffic services personnel, e.g. the ACC/FIC. Furthermore, a SIGMET for radioactive cloud is to be issued by the MWO concerned, in accordance with Annex 3, Appendix 6, Table A6-1 and Example A6-4.

3.1.2 The problem becomes more complex when a nuclear or chemical accident occurs in a neighbouring State. Such information should be passed by radio, telephone and NOTAM from the ACC/FIC responsible for the FIR in which the accident occurred to the ACCs/FICs of adjacent FIRs. This ensures that aircraft in flight or about to depart for the affected FIR are advised of the situation in time to take the necessary action.

3.1.3 The requirement for States to notify other States of a nuclear accident is derived from the United Nations *Convention on Early Notification of a Nuclear Accident*. A parallel instrument, the *Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency*, ensures that the State affected may seek and be provided with assistance from other States in order to minimize the consequences of the accident. Both of these conventions were adopted by the IAEA in 1986/1987 in the aftermath of the Chernobyl accident in April 1986.

3.1.4 In order to give practical effect to these conventions, the IAEA, together with other interested international organizations, have developed through the United Nations Inter-Agency Committee for Response to Nuclear Accidents, a set of internationally-agreed procedures (referred to as the "Convention Information Structure (CCI)"). Of particular interest to aviation is the specific set of procedures agreed between the IAEA and the WMO. The initial notification of the accident (an example is provided in Appendix G) comprises the following information:

— statement that an accident has occurred;

— nature of the accident;

— time of occurrence; and

— exact location of the accident.

Following notification, States which may be physically affected are provided by the IAEA with information regarding trajectory forecasts for the radioactive materials released into the atmosphere. In order to provide this, the WMO has designated a number of Regional Specialized Meteorological Centres (RSMCs) with the responsibility of providing forecast charts (output products) for the trajectory and deposition of radioactive material released into the atmosphere. The RSMCs designated are: Beijing, Exeter, Melbourne, Montréal, Obninsk, Tokyo, Toulouse and Washington. Examples of the output products from one RSMC for a hypothetical release of radioactive materials are given in Figures II-3-1 a) and b). Moreover, the inclusion of a symbol indicating "radioactive material in the atmosphere" on WAFS SIGWX charts in a similar manner to the inclusion of the "volcanic activity" symbol mentioned in 5.3.5 is intended to warn crew at a pre-flight stage. The ICAO regulatory provisions governing these procedures are shown diagrammatically in Figure II-3-2.

3.1.5 The foregoing paragraphs describe the internationally agreed procedures for notifying and exchanging information on the release of radioactive materials into the atmosphere. There are equivalent conventions and associated procedures governing the release of toxic chemicals. This is currently treated as a purely national matter and, as indicated above, from the aviation standpoint aircraft in flight are to be provided with information available nationally concerning the release into the atmosphere of toxic chemicals. The United Nations Department of Humanitarian Affairs in 1995 raised the issue of toxic chemical accidents and this has been addressed by ICAO with the assistance of WMO. Within WMO the work has been progressed with the assistance of the Emergency Response Activities (ERA) programme (in the non-nuclear area). The following WMO annexes contain relevant information and are under continuous update by the ERA programme.

— *Definition of Requirements Concerning Chemical Incidents*

ftp://ftp.wmo.int/Documents/PublicWeb/www/era/TD778_newSec5_Annex8(cbs-ext06).pdf

— *Role of National Meteorological Services (NMSs)*

ftp://ftp.wmo.int/Documents/PublicWeb/www/era/TD778_newSec5_Annex9(cbs-ext06).pdf

— *Guidance for Development of the Interface Between an NMS and Other Emergency Response Agencies in Case of Chemical Incidents*

ftp://ftp.wmo.int/Documents/PublicWeb/www/era/TD778_newSec5_Annex10(cbs-ext06).pdf

Basically, airborne "toxic chemicals" are highly localized effects, and the associated hazards are usually sudden onset and are short-lived in nature. The CBS ET has stated that such incidents have to be deal with efficiently, i.e. by the local authorities, and of course the emergency related decisions have to be consistent across the population and activities. Advice on meteorological aspects should come from the NMS. As a result of this work, it has been confirmed that the atmospheric dispersion of the release of chemicals into the atmosphere is largely a local problem since the material generally remains on the surface and near the location of release. Since the main potential impact would be at aerodromes if the source of the release is nearby, local arrangements within a State are considered as the most effective. Therefore, a requirement for aerodrome warnings for the release of toxic chemicals into the atmosphere has been included in Annex 3. This warning should be in accordance with the format provided in Annex 3, Appendix 5, Table A6-2 — *Template for aerodrome warnings*. Additionally, a NOTAM for toxic chemicals should be issued in accordance with Annex 15, 6.3.2.3 x) (3.1.1 above, refers).

Appendix H

TEMPLATE FOR NUCLEAR EMERGENCY MESSAGES

Element	*Detailed content*	*Template*	*Examples*
1. Identification of the type of message (M)	Type of message	NUCLEAR EMERG	NUCLEAR EMERG
2. Time of origin (M)	Year, month, day of month, time in UTC	DTG: nnnnnnnn/nnnnUTC	DTG: 20080317/1425UTC
3. Originator (M)	Name of VAAC	ORIGIN: VAAC LONDON	ORIGIN: VAAC LONDON
4. Information source (M)	Information source	INFO SOURCE: IAEA	INFO SOURCE: IAEA
5. Status (M)	Emergency or exercise	STATUS: nnnnnnnnnn	STATUS: EXER
6. Name of release site and country (M)	Site and country	SITE: nnnnnnnnnn	SITE: BILIBINO RUSSIA
7. Geographic location (M)	Location of release in decimal degrees	PSN: Nnnnn or Snnnn Wnnnnn or Ennnnn or UNKNOWN	PSN: N6805 E16645 N5100 W00130
8. Start of release (M)	Year, month, day of month, time in UTC	START OF RELEASE: nnnnnnnn/nnnnUTC	START OF RELEASE: 20080317/1300UTC
9. Duration or end of release (M)	Duration in days, hours and minutes or End date/time or not known.	DUR: n[nn] DAYS n[nn] HR n[nn] MIN or UNKNOWN or END OF RELEASE: nnnnnnnn/nnnnUTC or UNKNOWN	DUR: 0 DAYS 3 HR 30 MIN END OF RELEASE: 20080317/1800UTC UNKNOWN
10. FIR name(s) affected (M)	Name of FIR(S)	FIR NAME(S): nnnnnnnnnn	FIR NAME(S): PEVEK
11. FIR code(s) (M)	ICAO FIR code(S)	FIR CODE(S): nnnn nnnn nnnn	FIR CODE(S): UHMP
12. Additional information (O)	Additional information provided by IAEA using free text only (up to 256 characters)	ADDN INFO: nnnnnnnnnn	ADDN INFO: NOT AVBL NXT UPDATE EXP AT 17/1800UTC

M = inclusion mandatory
O = inclusion optional

Example of a nuclear emergency message for distribution via the AFS

GG UHMPZQZX
170425 EGRRYMYX
NNXX01 EGRR 170425

NUCLEAR EMERG

DTG: 20080317/1425UTC
ORIGIN: VAAC LONDON
INFO SOURCE: IAEA
STATUS: EXER
SITE: BILIBINO RUSSIA
PSN: N6805 E16645
START OF RELEASE: 20080317/1300UTC
END OF RELEASE: 20080317/1800UTC
FIR NAME(S): PEVEK
FIR CODE(S): UHMP
ADDN INFO: NXT UPDATE EXP AT 17/1800UTC

Note.— The highlighted items will change with each issuance. The other elements are fixed.

— END —