WORLD METEOROLOGICAL ORGANIZATION

# Aircraft Meteorological
# Data Relay
# (AMDAR)
# Reference Manual

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# TABLE OF CONTENTS

Appendices

Knowledge is of two kinds.
We know a subject ourselves, or we know
where we can find information upon it

James Boswell Life of Samuel Johnson (1791)

# AIRCRAFT METEOROLOGICAL DATA RELAY (AMDAR) REFERENCE MANUAL

## 1. GENERAL

### 1.1 WHAT IS AMDAR?

The acronym for Aircraft Meteorological Data Relay is AMDAR. Modern commercial aircraft are equipped with meteorological sensors and associated sophisticated data aquisition and processing systems. These provide input in real time to the aircraft flight management, control and navigation systems and other on-board systems such as the environmental control system. Data are also recorded in the flight data recorder for off-line analysis and special (e.g. accident) investigations.

The aircraft computers may be programmed to make meteorological observations at predetermined times (or position) for automatic relay to the ground. This is usually accomplished through the Aircraft Communication and Reporting System (ACARS) and can provide worldwide data using either Very High Frequency (VHF) or satellite radio links. These links are two-way, so it is possible to modify the reporting programme in flight by uplink command. Ground processing and dissemination of data are accomplished through systems provided by the appropriate air-carrier, communication service provider and meteorological message processing centres.

### 1.2 HISTORICAL BACKGROUND

AMDAR was proposed for the First Global Atmospheric Research Programme (GARP) Global Experiment (FGGE) in the 1970s. Two systems were developed, one using communications facilities available on the meteorological geo-synchronous satellites – the geostationary operational environmental satellite (GOES), Meteosat and geostationary meteorological satellite (GMS); and one using a standard aircraft VHF communication system (ACARS) developed in the United States and rapidly gaining worldwide acceptance. The satellite system, Aircraft to Satellite Data Relay (ASDAR) was sponsored by a consortium of WMO Members and was developed into an operational system by 1991. ACARS-based systems require no additional specialized equipment to be fitted to the aircraft, whereas ASDAR uses a dedicated data processor and satellite transmitter. Experience with both systems has led to the conclusion that ACARS-based AMDAR systems are preferred, based on ease of implementation, worldwide applicability and overall cost. ASDAR operations reached a peak in the late 1990s with some 20 of 23 purchased systems still in service. It is anticipated that some of these systems will continue to provide useful data at least to 2003. No further ASDAR developments are envisaged, and consequently this manual does not give a technical description of ASDAR. Several new AMDAR systems are being developed using alternative methods for sensing and communications. New purpose-designed sensor modules are being developed and communications techniques are being built based on non-ACARS VHF communications and low Earth orbit (LEO) satellites. Global cooperation on AMDAR is facilitated by the WMO AMDAR Panel established in 1998 by a number of WMO Members operating or intending to operate AMDAR programmes. Further information on the AMDAR Panel is given in Appendix V.

### 1.3 PURPOSE OF THIS MANUAL

This manual is intended to provide a comprehensive technical description of AMDAR from sensor systems and their characteristics to the final output product. The detailed technical material is arranged in a series of self-contained appendices. It is envisaged that these appendices will be updated as the technology advances. Where appropriate, references are provided to WMO, International Civil Aviation Organization (ICAO) and Aeronautical Radio Incorporated (ARINC) documents that are subject to issue and review by the respective organizations. No recommendations or other information in this manual overrides or supersedes the requirements contained in referenced WMO, ICAO or ARINC documents. It is intended that the Manual will provide sufficient information to enable detailed technical specifications to be drawn up for individual AMDAR programmes with respect to observational data requirements and data management issues. In the implementation of an operational programme, these specifications would form part of a total package that would include (for example) contractual arrangements with the appropriate air carrier to provide the downlink data and the associated on-board data processing. The manual does not provide details of operational AMDAR programmes. For up-to-date information on AMDAR programmes, reference should be made to the AMDAR Panel.

## 2. SENSORS AND MEASUREMENTS

### 2.1 SENSORS FOR BASIC MEASUREMENTS

The basic meteorological measurements on board modern aircraft are made by:

*(a)* Pitot-static head for static and total air pressure;
*(b)* Immersion thermometer probe for total air temperature; and
*(c)* Inertial reference platform for normal, longitudinal and lateral acceleration of aircraft.

Other measurements include:

*(a)* Relative humidity, measured on some aircraft using a solid state sensor exposed in a standard temperature sensor housing;
*(b)* Aircraft pitch (angle of attack), measured by flow angle sensor and used to correct static pressure; and
*(c)* Sensors with which some aircraft are equipped to measure the presence of ice on the flying surfaces.

### 2.2 DERIVED VARIABLES

In a typical system, data from the sensor transducers are processed in the Air Data Computer (ADC) or Inertial Reference Unit (IRU) as appropriate. Some aircraft are equipped with Global Positioning System (GPS) navigation systems. A GPS system can provide position and wind vector information with greater precision than the typical IRU. It can also provide an independent, highly accurate time reference.

ADC outputs include:

*(a)* Pressure altitude derived from static pressure; and
*(b)* Static air temperature derived from total air temperature and Mach number, where the Mach number itself is computed using static and total pressure measurements;

IRU outputs include:

*(a)* Present position-latitude;
*(b)* Present position-longitude;
*(c)* Wind speed (derived from computed wind vectors using airspeed from the ADC corrected for Mach number and temperature);
*(d)* Wind direction (from computed wind vectors);
*(e)* Normal or vertical acceleration; and
*(f)* Roll angle.

### 2.3 OTHER DATA

Where relative humidity sensor data is available and/or turbulence reported, additional processing is required, usually carried out in the Aircraft Condition Monitoring System (ACMS).

Other data needed for attaching to the measured and processed meteorological data are available from other aircraft systems. These include:

*(a)* Time (UTC);
*(b)* Tail number; and
*(c)* Flight number.

### 2.4 DATA INTEGRATION

A typical system is illustrated in Figure 1. This shows schematically the principal data sources feeding into the ACMS. In this diagram (based on the configuration used by the KLM AMDAR/ACARS/ACMS system) the vertical acceleration is shown routed via the Flight Data Recorder.

### 2.5 MEASUREMENT ACCURACY

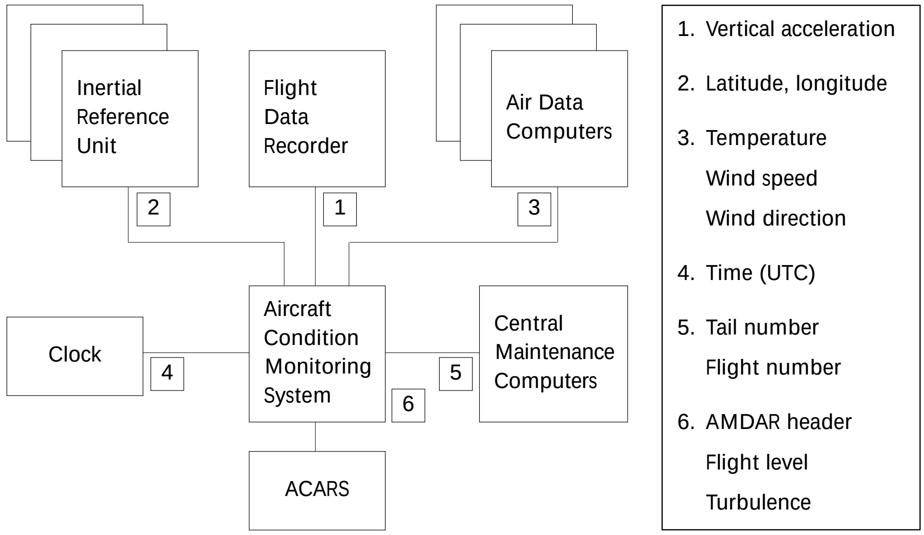
#### Pressure altitude

The aircraft altimeter is calibrated to indicate height according to the ICAO standard atmosphere model. The basic sensor (pitot-static head) provides static pressure as the fundamental measurement. Sources of error include:

*(a)* Calibration error;
*(b)* Short-term random instrument error;
*(c)* Calibration drift; and
*(d)* Exposure error or static source error.

Because aircraft safety separations are critical, these errors are corrected as much as possible in the ADC. Static source error which is a function of probe loca-

*Figure 1*
*Typical AMDAR System Schematic*



tion, Mach number and angle of attack is determined empirically during flight-testing.

Pressure altitude is resolved to the nearest foot and is often downlinked to a resolution of 10 feet; however when using WMO AMDAR code (FM 42-XI Ext) for data dissemination, heights are reported in hundreds of feet, leading to a resolution at cruise level of some 1.5 hPa. This represents roughly 0.1 per cent of the full-scale pressure measurement, and with instrumental accuracy at best of the order 0.05 per cent, the uncertainty in static pressure at cruise level derived from converting pressure altitude is about 2hPa. At zero reference level, the resolution is equivalent to about 3.5hPa, leading to an uncertainty of some 4.0 hPa.

### Static air temperature ($T_0$)

Static air temperature ($T_o$) is a function of probe temperature and Mach number. Mach number is derived from total pressure and static pressure, themselves independent measurements from the pitot-static head. The uncertainty of measurement is therefore a function of three error sources in addition to errors of calibration and correction for exposure and other effects (e.g. probe de-icing).

Taking these factors into account, the uncertainty of calculated $T_o$ is some 0.44° C at Mach 0.8 reducing to 0.3° C at low Mach numbers. Temperature data are typically stored as 11-bit binary words, thus the uncertainty of each stored value will increase by about 0.25° C.

### Wind speed and direction

Wind speed and direction are computed by resolution of the vectors:

$$V = Vg - Va$$

where V is the wind vector, Vg (ground velocity) is the velocity of the aircraft with respect to the Earth, and Va is the velocity of the air with respect to the aircraft. Va is calculated from true airspeed and heading. Heading and ground velocity are derived from the IRU.

True airspeed is a function of Mach number and static air temperature. Errors in Mach number are the most significant. For example, with a Mach number error of 0.5 per cent at cruise level, airspeed error is some 1.2 m/s. Thus, with zero error from the navigation system, wind vector errors up to 1.2 m/s are to be expected and are also dependent on the angle between the wind at flight level and the aircraft heading.

Errors in true airspeed combine with errors from the IRU. The basic calculations assume perfect alignment of the aircraft with the airstream and zero roll, pitch, yaw and perfect inertial platform alignment. At high pitch/roll angles, wind vector errors, which are proportional to true airspeed, can be significant. For example, at 150kt, airspeed with 5 degrees pitch and 10 degrees roll, a wind vector error of some 1 m/s can be expected regardless of the true wind vector.

At low wind speeds, vector errors can lead to large errors in wind direction. Thus, a more useful indication combining wind speed and direction error as vector error would suggest a typical uncertainty of 2 to 3 m/s.

### Relative humidity

Although various sensors have been used in research aircraft for the measurement of relative humidity (or a related variable), no suitable sensor was widely available for operational installation at the time this manual was prepared. A diode laser sensor under development in the United States, directly measuring water vapour mixing ratio , promises to measure to a few parts per million (ppm) by volume; however, when converting these measurements to relative humidity or dew point, accuracy is critically dependent on air temperature measurement.

### Turbulence

Turbulence is reported in one or more of three ways:

*(a)* As variation in vertical acceleration experienced by the aircraft;
*(b)* As ‘derived equivalent vertical gust’; and
*(c)* As an index related to eddy dissipation rate (EDR).

The accuracy of the finally reported variable depends on the output chosen and other assumptions. A discussion on the data processing methods and uncertainties involved is included in Appendix I.

### Icing

Several types of sensor may detect ice buildup on the flying surfaces.

Two types in use are:

*(a)* A thin film capacitive sensor attached to the airfoil; and
*(b)* A mechanical (vibrating transducer) sensor exposed to the airstream in a probe adjacent the relevant flying surface.

The output of either sensor is essentially an ice/no ice signal, and error would be described by a false alarm rate. At present, no data are available on false alarm rates for these sensors.

## 3.
## MESSAGE COMPILATION

### 3.1
### METEOROLOGICAL REQUIREMENTS

In order to meet, as far as possible, the requirements of WMO global and regional programmes, and allow for the more stringent requirements of national programmes, data requirements have been developed that define:

*(a)* The elements to be reported in a single observation, their ranges and resolution;
*(b)* The intervals in space and time between each observation;
*(c)* The recommended averaging times for specific elements reported according to operational environment (e.g. phase of flight);
*(d)* The recommended data compression schemes to be employed to minimize transmission time (and therefore cost);
*(e)* The recommended data selection options for space and time including route and airport selection; and
*(f)* The recommended output code formats for widespread data dissemination on the ground (e.g. Global Telecommunication System (GTS) distribution).

Elements to be reported in a single observation are summarized as follows:

*(a)* Latitude;
*(b)* Longitude;
*(c)* Time;
*(d)* Pressure altitude;
*(e)* Temperature;
*(f)* Wind direction;
*(g)* Wind speed;
*(h)* Turbulence ;
*(i)* Humidity;
*(j)* Icing;
*(k)* Phase of flight;
*(l)* Roll angle or roll and pitch angle; and
*(m)* Aircraft identifier.

Further details (including units, range, reported resolution and desired accuracy) are given in Appendix II.

### Observation intervals

AMDAR observation intervals are linked to aircraft flight phase. Three phases are recognized:

*(a)* Ascent;
*(b)* Level flight (or cruise or en-route); and
*(c)* Descent.

Observations made during ascent and descent are designed to meet meteorological requirements for profiles of temperature, humidity and wind. Intervals can be selected by time or, preferably, by pressure level above the terminal airfield.

Intervals between observations in level flight are determined mainly by requirements for synoptic meteorology and large-scale numerical models. Intervals are most conveniently selected by time interval and geographical position. Specifications recommended by the AMDAR Panel are given in Appendix II.

### Platform selection

At busy airfields it is possible to generate very large numbers of profiles, often very closely spaced or even overlapping in time. Some air routes are also congested and aircraft flying such routes might generate an excessive number of meteorological observations. It is desirable, therefore, to provide a means of platform selection according to airfield (profile selection) or geographical area (en-route report selection). Selection could be pre-programmed or established by uplink command. Recommended selection options are given in Appendix III.

## 3.2
## AERONAUTICAL REQUIREMENTS

To meet the needs of global Air Traffic Services (ATS) for the efficient operation and weather routing of modern commercial aircraft, and to meet aviation weather safety requirements, ICAO has drawn up requirements for in-flight weather observation reporting. Of particular relevance to AMDAR is the requirement related to the Automatic Dependent Surveillance (ADS) system, which concerns automatic reporting of aircraft meteorological measurements and their onward transmission to the World Area Forecast Centres (WAFCs). These requirements are published in ICAO documents and (where appropriate) in WMO *Technical Regulations* (WMO-No. 49). Relevant sections are discussed in Appendix II to this document.

# 4.
# DATA FORMATS FOR AIR-GROUND (DOWNLINK) COMMUNICATION

## 4.1
## ACARS BASED SYSTEMS

There are many downlink formats for transmitting meteorological reports from aircraft. In addition to many company-specific formats used mainly in North America, there are several formats in operational use specified by meteorological services. These include:

*(a)* Australian AMDAR, the earliest operational AMDAR format, in service since 1986;
*(b)* AAA (ACARS AMDAR ACMS) AMDAR version 1, developed by KLM for the Royal Netherlands Meteorological Institute (KNMI) using ASDAR specifications;
*(c)* AMDAR France, developed by Météo France in 1995 for operation on internal (domestic) flights;
*(d)* AAA AMDAR version 2, developed for the European AMDAR Programme under the European Meteorological Services Network (EUMETNET) umbrella; and
*(e)* ARINC 620, developed by ARINC to standardize formats for the United States Meteorological Data Collection and Reporting System (MDCRS).

Of the systems mentioned above, four are currently freely available for general use (*a, b, d* and *e*) and some newly delivered aircraft have ARINC 620 software loaded in the ACMS on delivery. In order to avoid the proliferation of future standards, this document will describe only two:

*(a)* AMDAR Panel Format (APF), a generic output format providing a framework for downlink encoding; and
*(b)* ARINC 620 (Now under revision, incorporating many AMDAR Panel recommendations).

Full details of APF and ARINC 620 are given in Appendix II.

### 4.2 AUTOMATIC DEPENDENT SURVEILLANCE (ADS)

ADS meteorological reporting formats are specified by the ICAO ADS Panel. The air-ground link is via the Aeronautical Telecommunications Network, an open, Wide Area Network (WAN) with data carried on various sub-networks, including VHF, ACARS, SATCOM and terrestrial networks. ADS data format specifications for the meteorological messages are included in Annex IV to Appendix II.

## 5. AMDAR DATA MANAGEMENT (AMDARDM)

### 5.1 GENERAL

AMDAR Data Management (AMDARDM) can be viewed within the context of the WMO World Weather Watch Data Management (WWWDM) programme. The goal of WWWDM is to carry out those activities required to optimize the integration of the Global Observing System (GOS), GTS and Global Data-processing System (GDPS). WWWDM functions include:

*(a)* Providing specifications for data representation, including codes and exchange formats, guidelines for the design of databases and storage of observational data and processed information;

*(b)* Defining and designing proper procedures and interfaces, particularly in the area of data processing and telecommunications, to allow Members to obtain the coherent and appropriate sets of data and products required, despite the disparity in the levels of sophistication of technology and techniques of various WWW centres; and

*(c)* Monitoring of AMDAR operations and the quality of basic data and output products.

### 5.2 GTS CODING

Data are circulated globally on the GTS. The GTS code forms in common use include:

*(a)* Alpha-numeric AMDAR code (WMO Code FM 42-XI Ext)

*(b)* Binary (BUFR) AMDAR code (WMO Code FM 94)

### 5.3 DATA DISSEMINATION

Downlinked data must be converted to one or both of the above formats before insertion into the GTS. AMDARDM is discussed in detail in Appendix IV.

## 6. QUALITY CONTROL (Q/C)

Quality Control (Q/C) is embodied within AMDARDM and applies to all stages of data production and dissemination. The main requirements are discussed below and dealt with in more detail in Appendix IV.

### 6.1 REAL-TIME Q/C

Real-time Q/C of AMDAR data is needed:

*(a)* At the measurement stage on board the aircraft;

*(b)* At the code conversion to GTS format stage; and

*(c)* At the data assimilation stage for real-time applications.

The first two stages are necessary to ensure an adequate quality of data is released for general user applications. The third stage is desirable to eliminate or flag erroneous data from model or analyzed fields, or for subsequent climate or archive purposes.

### 6.2 QUALITY EVALUATION (QEV)

QEV is a process carried out in near- or non-real time to apply statistical tests to individual or sets of AMDAR reports. This process will generally identify long-term sensor drift or constant measurement bias as well as highlighting platforms that are consistently transmitting poor quality data. The QEV process is an important link in the total AMDAR quality system and provides the most important feedback path for remedial action. Guidelines for an AMDAR quality system including Q/C, QEV and subsequent actions are given in Appendix IV.

## APPENDIX I

# AMDAR SENSOR DATA PROCESSING

### 1. MEASUREMENT OF PRESSURE ALTITUDE

Static (i.e. free airstream) pressure is measured directly by an electronic barometer connected to static pressure ports in the pitot-static probe (Figure 1).

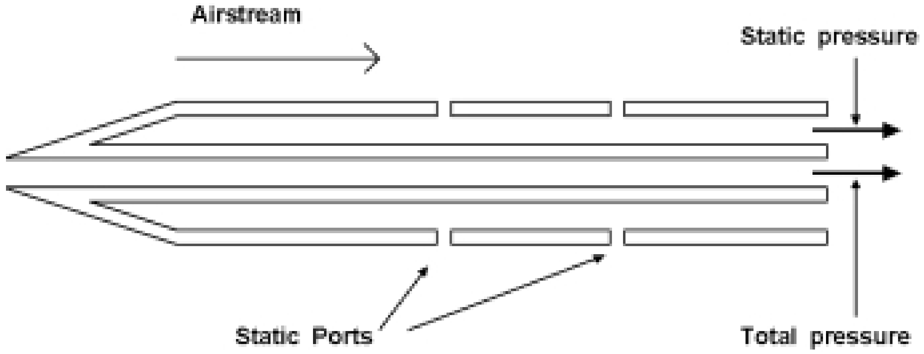


*Figure 1*
*Pitot-static probe*

The static pressure measurement is not normally reported in AMDAR but is converted in the ADC to the equivalent altitude – called ‘pressure altitude’ (PALT) or 'flight level' – based on the International Standard Atmosphere (ISA) (ICAO, 1964). The standard atmosphere (Figure 2) assumes a linear decrease in temperature with height of 6.5°C per kilometre up to 11 kilometres (36 089 ft), and a mean sea level temperature and pressure of 15°C and 1013.25hPa respectively. From 11 kilometres to 20 kilometres the temperature is assumed constant at -56.5°C.

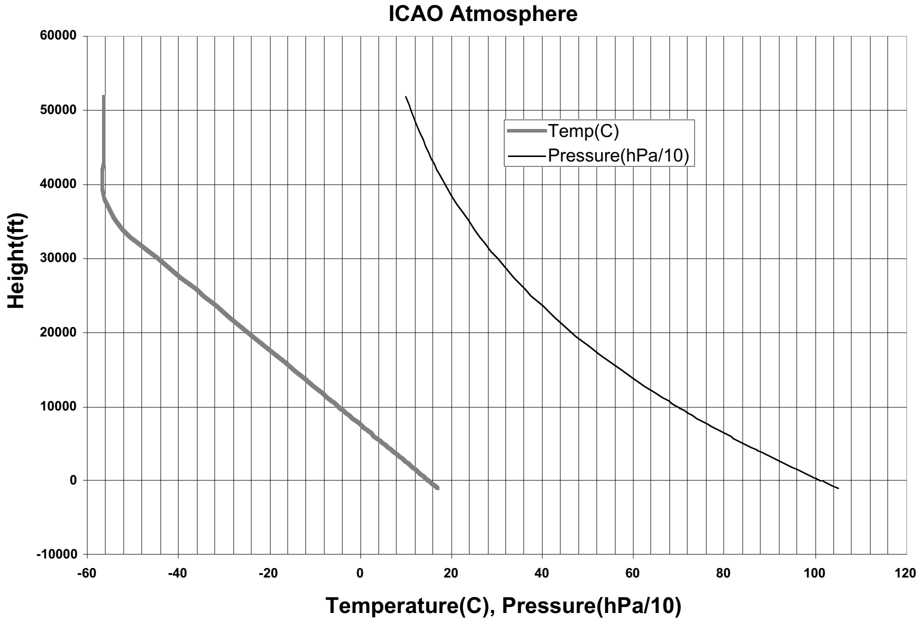


*Figure 2*
*ICAO International Standard Atmosphere*

For PALT equal to or less than 36 089 ft., static pressure (P) is related to PALT (ft) by the following expression:

$$P(hPa) = 10^{-2}P_o(1 - K_f\alpha(PALT)/T_o)^{\beta}$$

where $P_o = 1.01325\times10^5$ Pascals

$K_f = 0.3048$m/ft

$\alpha$ = lapse rate($6.5\times10^{-3}$Km$^{-1}$ when PALT < 36,089ft)

$g_o$ = Acceleration due to gravity at sea level = $9.80665 ms^{-2}$ at 45°N

$\rho_o$ = Density of dry air at sea level = $1.225 kgm^{-3}$

$T_o$ = 288.15K

And $\beta = g_o \rho_o T_o / \alpha P_o$

This reduces to:

$$P(hPa) = 1013.25(1 - 10^{-6} 6.8756(PALT))^{5.2559}$$

For example, if PALT is 30 000ft, P = 300.9hPa

The above expression can be used directly if the aircraft altimeter sub-scale (zero-reference) is set to standard pressure (1013.25hPa). In this case PALT is identical with indicated altitude. Navigational procedures also provide for altimeter sub-scale settings at other reference levels. For example, the setting can be aerodrome pressure ,'QFE' or 'QNH', which is a pressure reference on the standard atmosphere scale, such that aerodrome height is indicated at touchdown on a specific airfield. Thus, in general, PALT is given by the indicated altitude plus the altitude of the altimeter sub-scale reference on the standard atmosphere scale.

The general expression is:

$$PALT\ (ft) = Hi + Hr$$

where Hi is the indicated altitude and Hr is the height of the reference pressure.

$Hr = (1 - (Pr/1013.25)^{0.1903})10^6/6.8756$

where Pr(hPa) is the altimeter sub-scale setting.

(Note that Hr = 0 if Pr = 1013.25hPa.)

For example:

*(a)* If the sub-scale setting is a QNH value of 1000.0hPa and the indicated altitude is 9,335ft, PALT = 9335 + 364 = 9699ft and P = 705hPa.

*(b)* If the sub-scale setting is a QFE value 990hPa, the aerodrome height is 276 ft and the indicated altitude is 9058 ft, PALT = 9058 + 641 = 9699ft and the QNH value would be 1000hPa.

If PALT is greater than 36 089 ft static pressure is given by:

$$P(hPa) = 226.32exp-((PALT-36089)/20805)$$

For example, if PALT is 40 000ft, P = 187.5hPa

## 1.2 MEASUREMENT UNCERTAINTY

Sources of error include:

*(a)* Calibration error;

*(b)* Short-term random instrument error;

*(c)* Calibration drift; and

*(d)* Exposure error or static source error.

Because aircraft safety separations are critical, these errors are corrected as much as possible in the ADC. Static source error, which is a function of probe location, Mach number and angle of attack, is determined empirically during flight testing.

## 1.3 UNCERTAINTY OF PRESSURE INFERRED FROM REPORTED HEIGHTS

AMDAR heights as coded in WMO FM 42-XI Ext (WMO, 1995) are reported in hundreds of feet, equivalent at cruise level to some 1.5 hPa. This represents roughly 0.1 per cent of the full-scale pressure measurement. With instrumental accuracy at best of the order of 0.05 per cent, the uncertainty in static pressure at cruise level derived from converting pressure altitude is about 2hPa. At zero reference level, the resolution is equivalent to about 3.5hPa, leading to an uncertainty of some 4.0 hPa (Figure 3.).

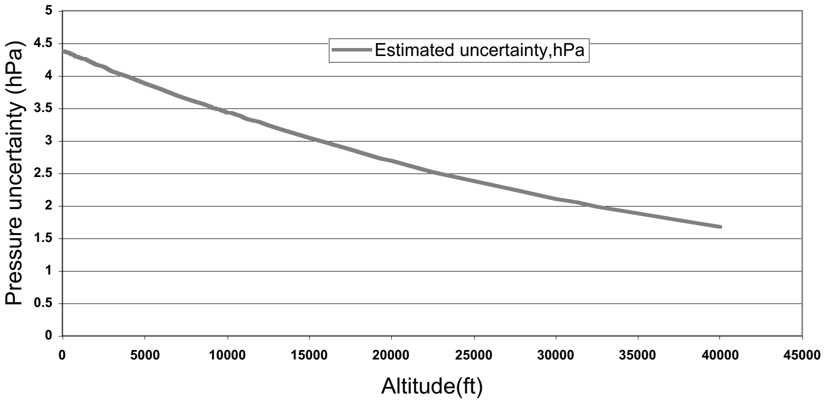


*Figure 3*
*Estimated uncertainty in derived pressure when altitude is reported in hundreds of feet*

## 2.
## MEASUREMENT OF AIR TEMPERATURE

Accurate measurement of air temperature is fundamental to the other derived meteorological elements. For example, it is used to correct indicated airspeed and thus impacts on calculation of the wind velocity components.

### 2.1
### SENSORS AND CALCULATION

Many commercial aircraft are equipped with temperature probes of the immersion thermometer type. Figure 4 shows a typical example. The sensing element is a platinum resistance thermometer. The housing is designed to divert cloud hydrometers from the sensing element, although it has been reported (Lawson and Cooper, 1990) that the sensing element becomes wet in cumulus clouds. The temperature ($T_1$) measured by the probe is close to the theoretical value of Total Air Temperature (TAT) that would occur with perfect adiabatic compression of the free airstream at the sensor probe. The static air temperature (SAT ($T_0$, in K)), the temperature of the free airstream, is related to the measured temperature by the expression:

$$T_0 = T_1 / \left( 1 + \lambda \frac{(\gamma - 1)}{2} M^2 \right)$$

where $\gamma$ is the ratio of specific heats of dry air (Cp and Cv);
M is the Mach number (true airspeed divided by the speed of sound in free air);
$\lambda$ is the probe recovery factor, which includes the effect of viscosity on the SAT, and the effect of incomplete stagnation of air at the sensor.
($T_1$ includes compensation for heat applied for de-icing if appropriate.)

For details see the standard texts on aircraft aerodynamics such as Abbott and von Doenhoff (1959) or Dommasch et al (1958). For the most common probe in service on commercial aircraft, $\lambda = 0.97$, and given $\gamma = 1.4$, the SAT becomes:

$$T_0 = T_1/(1 + 0.194M^2) \text{ K}.$$

Typical commercial jet aircraft cruise at a Mach number near 0.8, giving

$$T_0 \cong T_1/1.124$$

i.e. if $T_0$ = 223K (-50°C) then $T_1$ = 251K (-22°C)
Thus, a typical temperature correction at cruise level is -28°C.

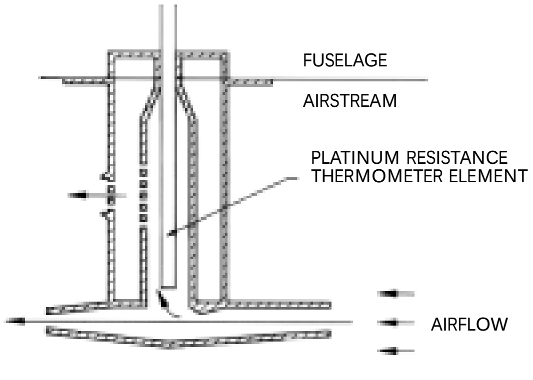


*Figure 4*
*Aircraft thermometer probe*

### 2.2
### MEASUREMENT UNCERTAINTY

Static air temperature is a function of probe temperature and Mach number. Mach number is derived from total pressure and static pressure, themselves independent measurements from the pitot-static head. The uncertainty of measurement is therefore a function of three error sources in addition to errors of calibration and correction for exposure and other effects (e.g. probe de-icing). Figure 5 shows the effect of errors of Mach number on Static air temperature where the temperature error ($\Delta T_o$) is related to Mach number error ($\Delta M$) by the expression:

$$\Delta T_o = 0.388MT_1(1 + 0.194M^2)^{-2}\Delta M$$

$$\text{or } \Delta T_0 = 0.388MT_0(1+0.194M^2)^{-1}\Delta M$$

Taking these various factors into account, the uncertainty of calculated Ts is some 0.4°C at Mach 0.8, reducing to 0.3°C at low Mach numbers. Temperature data are typically stored as 11-bit binary words, thus the uncertainty of each stored value will increase by about 0.25°C. In the event that the sensor is wetted in cloud, it will be cooled by evaporation leading to additional errors up to 3°C or so. At very low airspeed (for example prior to take-off) there may be insufficient airflow over the sensor to maintain accuracy of measurement. Some aircraft employ aspirated sensors to overcome this problem, but such measurements are usually outside the AMDAR observational envelope and may be neglected in AMDAR error considerations.

## 3.
## MACH NUMBER

### 3.1
### CALCULATION

Mach number (M) is calculated in order to correct air temperature measurements and airspeed measurements (indicated airspeed). In dry air, the speed of sound is proportional to the square root of absolute (static) temperature. However, static air temperature is not measured directly by the aircraft sensors, so an independent method of measuring Mach number is employed. The equation for $M$ is

$$M^2 = \frac{2}{\gamma - 1}\left[\left(\frac{p_s}{p_0}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

where $p_0$ is static pressure (in the undisturbed air stream) and $p_s$ is total pressure, both available from the pitot-static probe.

### 3.2
### MEASUREMENT UNCERTAINTY

The measurement accuracy is determined almost entirely by the accuracy of the fundamental measurements of pressure. In normal operation (with the pitot-static probe properly aligned and exposed to the free airstream) the derived Mach number should be accurate to better than 0.2 per cent.

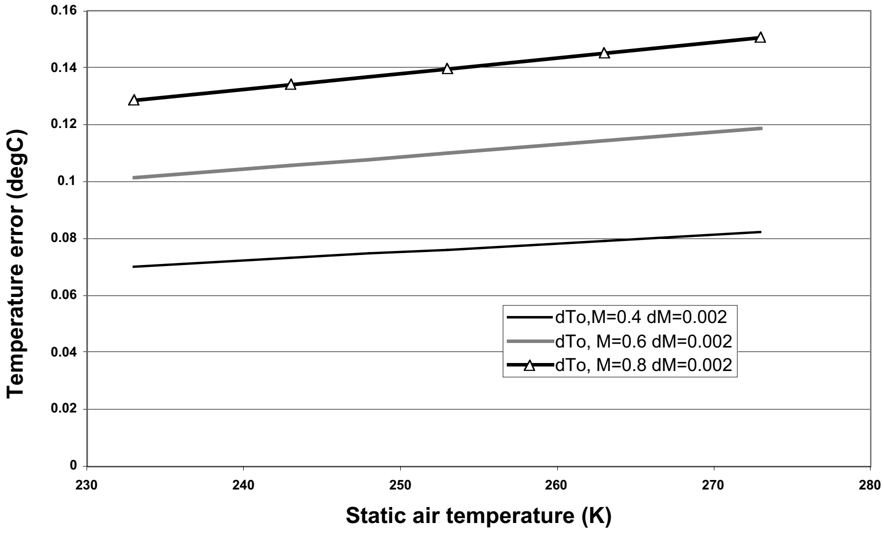


*Figure 5*
*Temperature error against Static Air Temperature for typical Mach numbers and Mach error of 0.002*

## 4.
## MEASUREMENT OF WIND SPEED AND DIRECTION

The measurement of the three-dimensional wind vector from an aircraft is a complicated problem. Using data from the aircraft navigation system (usually an inertial system) and the airspeed system (usually a pitot-static tube), together with data from the temperature sensors, it is possible to estimate to a high degree of accuracy the velocity ($V_g$) of the aircraft with respect to the Earth and the velocity of the air ($V_a$) with respect to the aircraft. The wind vector ($V$) is therefore given by

$$V = V_g - V_a$$

The vectors Vg and Va must be measured accurately since typical horizontal winds are small ($\cong 30\text{ms}^{-1}$) compared with aircraft groundspeed and true airspeed ($200$ to $300\text{ms}^{-1}$). The full resolution of the vectors requires measurements of aircraft pitch, roll and yaw and vertical angle of attack with respect to the airstream (Figure 6). In normal level flight, pitch, yaw and angle of attack are very small and can be neglected. However, errors during manoeuvres can be significant, but manoeuvres usually involve a substantial roll angle, so wind data are usually excluded when the roll angle is above a certain threshold.

For most applications, only the horizontal component of the wind is measured. The input data requirement therefore reduces to airspeed, heading and ground speed. Heading and ground speed are taken from the navigation system. True airspeed has to be calculated from the calibrated airspeed taken from the airspeed indicator. The components of the horizontal wind ($u$,$v$) are:

$$u = -\left| V_a \right| \sin\varphi + u_g$$

$$v = -\left| V_a \right| \cos\varphi + v_g$$

where $|V_a|$ is the magnitude of the true airspeed, $\varphi$ is the heading relative to true north and $u_g$ and $v_g$ are the components of ground speed.

## 4.1
## MEASUREMENT UNCERTAINTY

True airspeed is a function of Mach number and static air temperature:

$$V_a\,(\text{kt}) = 38.867 M T_o^{1/2}$$

$$= 38.867 T_1^{1/2} M/(1 + 0.194M^2)^{1/2}$$

If errors exist in both Mach number and static air temperature, the total error is given by:

$$\Delta V_a = 38.867 T_o^{1/2} \Delta M + 19.433 M T_o^{-1/2} \Delta T_o$$

where $\Delta V_a$ is wind error, $\Delta M$ is Mach error and $\Delta T_o$ is temperature error.

Unless gross temperature errors exist, Mach number uncertainty can be the most significant. For example, with a Mach number error of 0.2 per cent at cruise level, airspeed error is some 1kt (0.5m/s). Thus, with zero error from the navigation system, wind vector errors up to 0.5m/s are to be expected and are also dependent on the angle between the wind at flight level and the aircraft heading. Gross temperature errors will lead to gross wind errors. This is illustrated in Figure 7, which shows the extreme error in wind vector against temperature error for high Mach number at –50°C, and lower Mach number at 0°C.

Errors in true airspeed combine with errors from the IRU. The basic calculations assume perfect alignment of the aircraft with the airstream and zero roll, pitch, yaw and perfect inertial platform alignment. At high pitch/roll angles, wind vector errors, which are proportional to true airspeed, can be significant. Figure 8 shows the combined effect of pitch and roll at an airspeed of 150kt. Thus, with 5° pitch

*Figure 6*
*Aircraft reference axes and altitude angles*

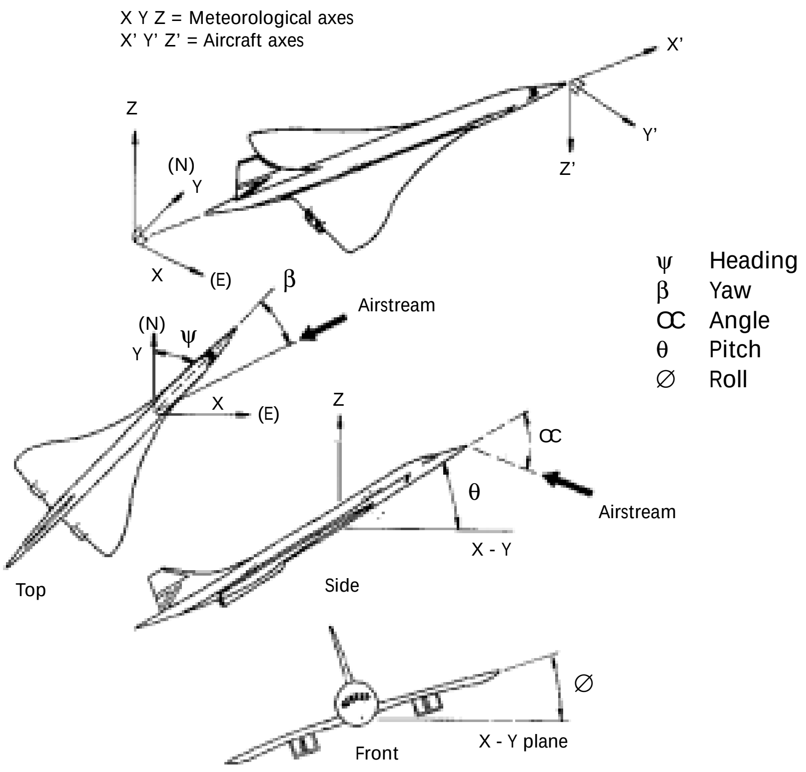
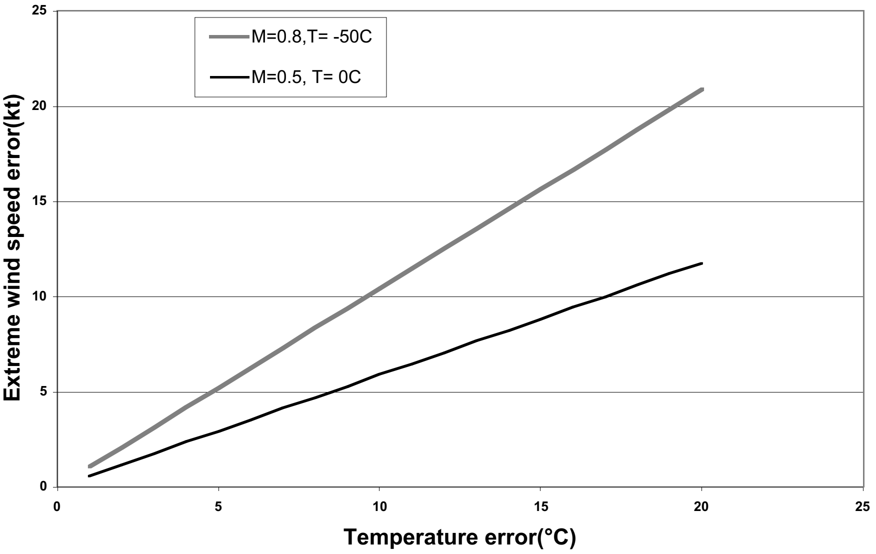


*Figure 7*
*Wind speed error v temperature error*



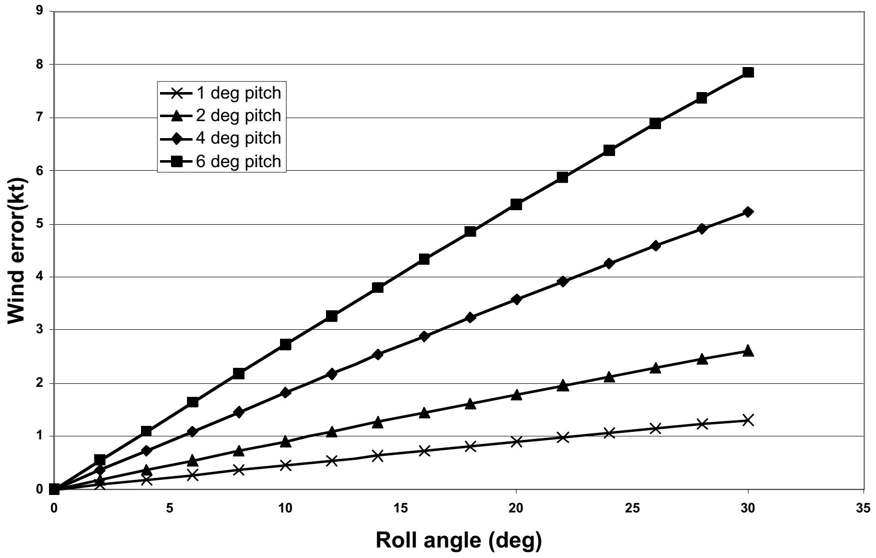
and 10° roll, wind vector error of some 2kt (1m/s) can be expected regardless of the true wind vector. At 300kt airspeed, the wind error doubles to 4kt (2m/s).

At low wind speeds, vector errors can lead to large errors in wind direction. Thus, a more useful indication, considering all the above error sources and combining wind speed and direction error as vector error, would suggest a typical uncertainty of 4 to 6kt (2-3m/s).

## 5.
## MEASUREMENT OF TURBULENCE

Atmospheric turbulence is not measured directly by aircraft instrumentation, however the vertical acceleration (normal to the aircraft horizontal reference plane) is measured in the inertial navigation system. The peak acceleration measured, referenced and scaled to the acceleration due to gravity, is commonly

*Figure 8*
*Effect of roll/pitch angle on wind speed*



categorized as shown in Table 1; however, the severity of turbulence affecting an aircraft depends principally on airspeed, the mass of the aircraft, altitude and the nature of the turbulence itself. Hence, reports of turbulence from an aircraft derived from peak acceleration according to the crude relationships given in Table 1 are of limited application and are aircraft-specific, so that a given gust will have different effects on different aircraft.

### Measurement uncertainty

There are two main sources of error in the aircraft instrumentation. They are the 'zero' (or reference) error and the output calibration (or measurement) error. For most aircraft, the reference value is nominally + 1g but this can vary by typically 3 per cent. This error can be virtually eliminated by correction when the aircraft is on the ground, leaving a residual (including measurement) error of around 3 per cent of measurement. (Sherman, 1985).

*Table 1*
*Scale of turbulence, defined by peak acceleration*

| *Turbulence category* | *Peak acceleration** |
|---|---|
| none | less than 0.15g |
| light | 0.15g to, but not including 0.5g |
| moderate | 0.5g to 1.0g |
| severe | greater than 1.0g |

* These accelerations, which may be positive or negative, are deviations from the normal acceleration of gravity (1.0g).

### 5.1
### DERIVED EQUIVALENT VERTICAL GUST VELOCITY (DEVG)

An alternative indicator of turbulence is the Derived Equivalent Vertical Gust Velocity (DEVG). This is defined as the instantaneous vertical gust velocity which, superimposed on a steady horizontal wind, would produce the measured acceleration of the aircraft. The effect of a gust on an aircraft depends on the mass and other characteristics, but these can be taken into account so that a gust velocity can be calculated which is independent of the aircraft.

The derived equivalent vertical gust is given (Sherman 1985) by:

$$U_{de} = \frac{A\,m\,\Delta n}{V_c}$$

where $U_{de}$ is the derived equivalent gust velocity;
$\Delta n$ is the modulus of the peak deviation of the aircraft vertical acceleration from 1g in units of g;
m is the total mass;

$V_c$ is the calibrated airspeed at the time of the acceleration peak occurrence; and $A$ is a parameter that depends on the aircraft type, and weakly on the mass, the altitude, and the Mach number.

### Measurement uncertainty

Errors in each of the elements contributing to $U_{de}$ have been estimated. These are typically less than 3 per cent maximum for each element in normal level flight and in the extreme could lead to a total error of 10 to 12 per cent. Assuming a random distribution of errors, a typical uncertainty would be 3 or 4 per cent of the final value of $U_{de}$. Aircraft manoeuvres can also lead to large vertical accelerations of an aircraft and, conversely, active control techniques can dampen the acceleration due to gusts leading to serious underestimation of vertical gust velocities.

## 5.2
## EDDY DISSIPATION RATE (EDR)

This method (Cornman et al, 1995) seeks to describe the vertical gust spectrum of the turbulent air around the aircraft by the single parameter ‘$\varepsilon^{1/3}$’, the EDR.

The input gust energy spectrum, at the frequencies of interest, is approximated by:

$$\varphi_i(\omega) = 0.7V^{2/3}\varepsilon^{2/3}\omega^{-5/3}$$

where V is the true airspeed and ω is the turbulent frequency relative to the aircraft. $\varepsilon^{1/3}$ is related to the total power in the gust spectrum ($\sigma^2$) divided by a length scale parameter ($L^{1/3}$) such that:

$$\varepsilon^{1/3} \equiv [\sigma^2/L^{1/3}]^{1/2}\ (m^{2/3}s^{-1})$$

Given the aircraft vertical acceleration response function to vertical gusts H (ω), the output vertical gust energy spectrum $\varphi_o$ (ω) is given by:

$$\varphi_o(\omega) = \left|H(\omega)\right|^2 0.7V^{2/3}\varepsilon^{2/3}\omega^{-5/3}$$

and the output vertical acceleration power $\sigma_o^2$ (ω) is given by:

$$\begin{aligned}\sigma_o^2(\omega) &= \int_{\omega 1}^{\omega 2} \varphi_o(\omega)\,d\omega \\ &= 0.7V^{2/3}\varepsilon^{2/3}\int \left|H(\omega)\right|^2 \omega^{-5/3}\,d\omega\end{aligned}$$

The limits of integration, $\omega_1$ and $\omega_2$, are chosen to remove the low frequency amplification of the gust spectral approximation, low frequencies due to aircraft manoeuvres, noise and high frequency aircraft response not modelled by H (ω).

Denoting the integral above I (ω1, ω2, ω) and rearranging, we have:

$$\varepsilon^{2/3}(\omega) = \sigma_o^2(\omega)/0.7V^{2/3}\,I(\omega_1, \omega_2, \omega)$$

The response integral can be determined for a particular aircraft and changes relatively slowly over time with changing aircraft weight and flight conditions.

As the EDR and output power will change with time as the aircraft encounters different turbulent conditions, and noting that for a given time interval (T) $\sigma_o^2(\omega) = \sigma_o^2(t)$, we can write:

$$\varepsilon^{2/3}(T) = \sigma_o^2(T)/0.7V^{2/3}\,I(\omega_1, \omega_2, T)$$

where T is the measurement interval for each estimation of EDR.

### Practical application

The output vertical accelerations are band pass filtered to match the response integral and $\sigma_o^2$ is estimated from the standard deviation of running 10-second samples of the filtered values. The pass band is currently set at 0.1 to 0.8Hz.

The aircraft response integral is evaluated for a range of flight conditions and stored in look-up tables, thus reducing and simplifying the on-board computation requirement.

For downlinking, the data can be reduced to a median and peak value over the reporting interval. The peak value usually chosen is the 90-percentile value in the reporting interval.

### Measurement uncertainty

As for DEVG, there is a potentially large number of error sources contributing to measurement uncertainty. Based on the error analysis for DEVG, one would expect an uncertainty of some 5 to 10 per cent in the calculation process. A further complication arises over the choices of sampling interval and averaging time. Examination of typical time series of vertical acceleration data often indicates high variability of statistical properties over short distances. Variation of airspeed for a single aircraft and between different aircraft types alter the sampling distances and vary the wavelengths filtered.

### Relationship between EDR and DEVG

Detailed field comparisons (Stickland, 1998) have been made between EDR and DEVG. These have shown a high correlation between peak EDR and DEVG for the same turbulence incidents.

This result should be expected since EDR is directly proportional to the standard deviation of vertical acceleration over the measurement interval chosen; hence, for a ‘normal’ distribution, the extreme value will correlate closely with the peak vertical gust (proportional to the peak deviation of vertical acceleration). Clearly, this relationship will not apply to a singular event falling outside the assumed distribution, and the EDR filter cut-off at 0.8 Hz might well unduly attenuate very sharp gust events.

## 6.
## RELATIVE HUMIDITY

Although various sensors have been used in research aircraft for the measurement of relative humidity (or a related variable) no suitable sensor was widely available at the time this Manual was prepared. A diode laser/solid state detector instrument under development in the United States (May, 1998) directly measuring water vapour mixing ratio, promises to measure to a few parts per million by volume.

The method is based on absorption of narrow band electromagnetic radiation by water vapour. The intensity of radiation at the detector is related to the emitted radiation by Beer’s law such that:

$$I = I_o exp(-kxp/p_o)$$

where:
$I$ = received signal;
$I_o$ = transmitted signal;
$k$ = absorption coefficient;
$x$ = path length;
$p$ = concentration of water in the sensing volume; and
$p_o$ = concentration of water vapour at standard temperature and pressure.

Since $I_o$, $k$, $x$ and $p_o$ are known properties of the system, the concentration of water in the sampling volume is measured and readily converted to water vapour mixing ratio (WVMR).

### 6.1
### PRACTICAL CONSIDERATIONS

By folding the path length, it has been possible to fit the complete sensor in a standard aircraft temperature probe. Differential measurement techniques are employed, largely overcoming drift in the measuring circuits.

As WVMR is conserved with adiabatic compression in the sensor probe, the measured value is suitable for direct downlinking without knowledge of static or total air temperature. This is also convenient in numerical atmospheric models using specific humidity (numerically almost indistinguishable from WVMR) as the input variable. Numerical analysis fields often require relative humidity as the moisture field variable. This is readily computed from WVMR if static air temperature and ambient pressure are known.

## 6.2 MEASUREMENT UNCERTAINTY

Accuracy claimed for the system is some 2 to 4 ppm by volume; however, for many meteorological applications, other psychometric variables such as dew point or relative humidity are required. The accuracy of these derived variables depends not only on the uncertainty of the basic measurement of WVMR, but also on uncertainty in static air temperature and to a lesser extent uncertainty in ambient pressure. An indication of this effect is seen in Figure 9, which shows the uncertainty of derived relative humidity (RH) with a temperature error of 1°C at a nominal 50 per cent RH and 90 per cent RH over the standard temperature and pressure range.

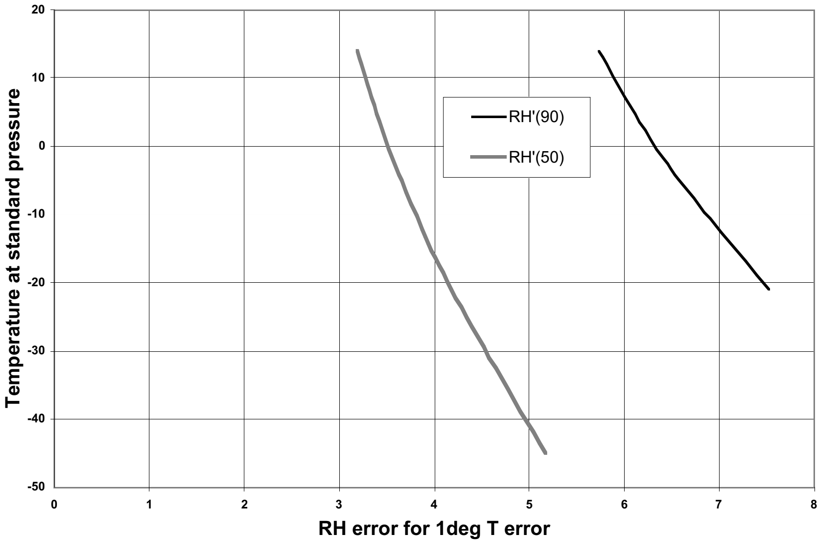


*Figure 9*
*Effect of error in static air temperature in derivation of relative humidity*

## 7. ICING SENSORS

Several types of sensors may detect ice build-up on the flying surfaces. Two types in use are:

*(a)* A thin film capacitive sensor attached to the airfoil; and

*(b)* A mechanical (vibrating transducer) sensor exposed to the airstream in a probe adjacent the relevant flying surface.

## 7.1 MEASUREMENT UNCERTAINTY

The output of either sensor is essentially an ice/no-ice signal, and error would be described by the false alarm rate. At present, no data are available on the false alarm rate for these sensors.

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APPENDIX II

# AMDAR DOWNLINK DATA SPECIFICATIONS

## 1. GENERAL

This document contains specifications, recommended by the AMDAR Panel, for meteorological and related data, measured on board commercial aircraft, to be relayed to the ground in the form of individual observations or batches of observations. The observation time and observation number uniquely identify each observation. The observation time is keyed to the basic measurements at a resolution of one second. Requirement specifications for basic and other measurements, observation intervals and on-board processing are given in the following sections. These requirements are intended to be compatible where possible with ASDAR, E-AMDAR, ARINC 620 and other operational AMDAR specifications .

## 2. DATA REQUIREMENTS

The following data are required to compile a meteorological report (observation) for automatic relay to a ground processing and data distribution network. The data are derived from the aircraft sensor and navigation data acquisition system, and further processed on board as appropriate.

| *Element number* | *Element* | *Note 1* | *Note 2* |
|---|---|---|---|
| 1 | Aircraft identifier | Section 3.1 | M |
| 2 | Observation number | Section 3.2 | O |
| 3 | Phase of flight | Section 3.3 | M |
| 4 | Latitude | Table 1 and 3.4 | M |
| 5 | Longitude | Table 1 and 3.5 | M |
| 6 | Day and time of observation | Table 1 and 3.6 | M |
| 7 | Pressure altitude | Table 1 and 3.7 | M |
| 8 | Static air temperature | Table 1 and 3.8 | M |
| 9 | Humidity | Table 2 and 3.9 | O |
| 10 | Wind direction | Table 1 and 3.10 | M |
| 11 | Wind speed | Table 1 and 3.11 | M |
| 11a | Maximum wind | Table 2 and 3.11 | M |
| 12 | Turbulence | Table 2 and 3.12 | O |
| 13 | Icing | Section 3.13 | O |

Note 1:
Further details of each element are given in the appropriate section or table referenced.
Table 1 comprises basic data (basic measurements) normally available without further processing from the aircraft systems.
Table 2 comprises data requiring additional on-board processing.

Note 2:
‘M’ denotes mandatory requirement.
‘O’ denotes optional requirement.

## 3. DETAILS OF ELEMENTS

3.1 Aircraft identifier shall comprise at least one of the following:
*(a)* Tail number (element 1.1); or
*(b)* Unique aircraft code (element 1.3).

Note: Flight number (element 1.2) can be used for real-time applications but is not suitable for data archiving or quality management.

3.2 Observation number (element 2), if included, shall be unique for an individual observation in any 24-hour period commencing at 00 UTC.

3.3 Phase of flight shall be identified as follows:

| *Phase of flight* | *Definition* | *Notes* |
|---|---|---|
| Unsteady | Roll or pitch/roll above threshold | 1, 2 |
| Ascent | Pressure Altitude >100ft higher than at previous observation and <20 000ft | 3 |
| Descent | Pressure Altitude >100ft below previous observation and <20,000ft | 3 |
| Level | Not in Ascent/Descent phase | |

Notes:
1. Phase of flight shall be assumed unsteady if roll angle exceeds 5° or roll and pitch both exceed 3°.
2. Unsteady and other flight phases may co-exist.
3. The value 20 000ft is the nominal value. This can be changed according to typical flight envelope (typically 15 000ft to 25 000ft). For simplicity, the nominal value is retained in this Appendix for describing reporting according to flight phase (Par. 4).

3.4 Latitude (element 4) shall be taken from the aircraft navigation system as specified in Table 1.

3.5 Longitude (element 5) shall be taken from the aircraft navigation system as specified in Table 1.

3.6 Day of month and time (element 6, UTC, as specified in Table 1), shall refer to the time of observation of the basic measurements.

3.7 Pressure altitude (element 7 and Table 1) is the indicated height with an altimeter setting of 1013.25 hPa (29.921 in Hg) according to the ICAO standard atmosphere. The standard atmosphere assumes a linear decrease in temperature with height of 6.5°C per kilometre up to 11 kilometres, and a mean sea level temperature and pressure of 15°C and 1013.25hPa, respectively. From 11 kilometres to 20 kilometres the temperature is assumed constant at -56.5°C.

3.8 Static air temperature (element 8) shall be taken from the aircraft data acquisition system as specified in Table 1.

3.9 Humidity (element 9), if available, shall be expressed as dewpoint, relative humidity or water vapour mixing ratio as specified in Table 2 according to the dowlink format chosen.

3.10 Wind direction (element 10) shall be taken from the aircraft data acquisition system as specified in Table 1.

3.11 Wind speed (element 11) shall be taken from the aircraft data acquisition system as specified in Table 1. Maximum wind (element 11a) is defined as the highest wind speed measured between routine observations and shall be reported only if the:

*(a)* Aircraft is in level flight (element 3, see section 3.3), above 600 hPa (14,000ft);

*(b)* Maximum wind exceeds 60kt;

*(c)* Maximum wind exceeds by at least 10kt the value of wind speed measured at the previous routine observation; and

*(d)* Maximum wind exceeds by at least 10kt the value of wind speed at the subsequent routine observation.

Routine observations are defined in section 4 below.

3.12 Turbulence (element 12) shall be computed from vertical (or normal) acceleration, specified as in Table 2 according to the downlink format chosen.

3.12.1 If turbulence is reported as vertical acceleration, the maximum departure from the reference level between routine observations shall be reported, provided aircraft is in level flight.

3.12.2 If turbulence is reported as DEVG, the value reported should be the highest gust measured between observations. DEVG shall be derived as specified in Annex 2.

3.12.3 If turbulence is reported as EDR, both mean and extreme values shall be computed in accordance with the requirements for ADS downlinked data. (See Annex 4.)

3.13 Icing information (element 13), if available from the aircraft data acquisition system, shall be defined as icing conditions present or not present.

*Table 1*
*Basic measurements*

| *Element* | *Unit* | *Range* | *Output resolution* | *Desired accuracy* |
|---|---|---|---|---|
| Pressure Altitude | Foot (ft) | -1000 to 50 000 | 10 | 100 (1) |
| Static Air Temperature | °C | -99 to 99 | 0.1 | 0.5(2) |
| Wind Direction | ° from true N | 1 to 360 | 1 | Note (2,3) |
| Wind Speed | Knot (kt) | 0 to 800 | 1 | Note (2,3) |
| Latitude | Degree: minute | 90:00S to 90:00N | 1.0min | Note (4) |
| Longitude | Degree: minute | 180:00E to 180:00W | 1.0min | Note (4) |
| Time (UTC) | Hour: Minute: Second | 00:00:00 to 23:59:59 | 1 min | 1s |

Notes:
(1) required to preserve temperature accuracy.
(2) WMO requirement for Numerical Weather Processing (NWP) in troposphere.
(3) $2ms^{-1}$ (4kt) vector error.
(4) 5Nm equivalent (specified for ASDAR).

*Table 2*
*Additional measurements and data requirements requiring on-board processing*

| *Element* | *Unit* | *Range* | *Output resolution* | *Desired accuracy* |
|---|---|---|---|---|
| Maximum wind | kt | 0 to 800 | 1 | 4 |
| Turbulence (g) | g (4) | -3 to 6 | 0.1 | 0.15 (1) |
| Turbulence (DEVG) | $ms^{-1}$ | 0 to 20 | 0.25 | 0.5 (1) |
| Turbulence (EDR) | $m^{2/3}s^{-1}$ | 0 to 1 | 0.05 | 0.1 (1) |
| Humidity (RH) | % | 0 to 100 | 1 | 5 (2) |
| Humidity (dew pt) | °C | -99 to +49 | 0.1 | Note (5) |
| Humidity (mixing ratio) | gram/kg | 0 to 100 | 0.001 | $1:10^3$ (measurement)(3) |

Notes:
(1) Determined by output categories required.
(2) WMO requirement for NWP in troposphere.
(3) To meet stratospheric humidity requirement.
(4) Acceleration due to gravity. ‘Zero’ reference on aircraft is usually +1.
(5) Equivalent to 5% RH error.

## 4. OBSERVATION INTERVALS

4.1 Observations intervals are determined according to flight phase as follows:

*(a)* Level Flight (en-route or cruise): Routine observations (see 4.2) shall be made. In addition, if a ‘maximum wind event’ has occurred, an observation containing all the elements of a routine observation shall be made at the time of occurrence of the maximum wind event. The first observation shall be made when the level flight phase is entered.

*(b)* Ascent: Observations at target pressures or target time intervals, according to height above the take-off aerodrome or time from take-off, as appropriate, shall be made. In addition, if not disabled, routine observations shall be made. Measurements shall commence at take-off or when the true airspeed exceeds 100kt.

(*i*) Pressure interval selection:
The take-off pressure ($P_{ref}$) shall be referenced to the pressure altitude at take-off and converted to hPa, according to the ICAO standard atmosphere. $P_{ref}$ is calculated from pressure altitude (h) as follows:

$$P_{ref} = 1.0133\times10^{3}(1-6.8756\times10^{-6}h)^{5.2559}$$

The target pressure intervals are as follows:
The first observation shall be made when calculated pressure ($P_1$) falls to the nearest multiple of 10hPa (or 5hPa if desired) below the reference pressure. For example, if $P_{ref}$ = 1002.5hPa, $P_1$ = 1000hPa.

The next nine observations are made at 10 hPa intervals (or 19 at 5hPa intervals if 5hPa intervals is selected). For example, as in the above example at 990, 980, 970, 960, 950, 940, 930, 920 and 910 hPa.

The next (11th) observation is made at the nearest multiple of 50hPa below the 10th target pressure. For example, at 900hPa (or 25hPa intervals after the 20th 5hPa sample if so selected).

Subsequent observations are made at 50hPa (or 25hPa) intervals until the top of the climb phase is reached (pressure altitude, element 7, exceeds 20 000ft (467.7hPa)). For example, at 850, 800, 750, 700, 650, 600, 550, 500 and 450hPa. A table giving the equivalent pressure altitudes for all relevant pressure levels is given in Annex 1.

(*ii*) Time interval selection:
If ascent observation intervals are selected by time (from take-off), it is desirable that two climb phases should apply, consisting of a first phase at high resolution and a second phase at lower resolution until level flight phase is reached. Intervals shall be preset or selected by uplink command. This method of selection applies to ARINC 620 format described in Annex 3.

*(c)* Descent: Observations shall be made at target pressures according to pressure altitude and height above the terminal aerodrome or at target time intervals. In addition, if not disabled, routine observations shall be made.

(*i*) Pressure interval selection:
The first observation shall be made when the aircraft passes through the 500hPa level. The second and subsequent observations shall be made at intervals of 50 hPa (or 25hPa) until the aircraft lands. On passing through the 700hPa level, additional observations shall be made at 10hPa intervals (or 5hPa intervals) until the aircraft lands. On landing, the 10 most recent 10hPa observations (or 20 most recent 5hPa observations) shall be retained and any duplicates eliminated. The descent profile shall thus contain, at least, a series of samples at 50 hPa (25hPa) intervals followed by 10 samples at 10hPa (5hPa) intervals representing the lowest 100hPa above the

terminal airfield. In the absence of an alternative indication, the aircraft will be assumed to have landed when the true airspeed falls below 100kt.

(*ii*) Time interval selection:
Observations shall be made at fixed time intervals, either preset or selectable by uplink command. This method of selection applies to ARINC 620 format described in Annex 3.

(Note: ARINC 620 format is in the process of being amended (November 2001) to allow pressure or time interval selection for profile data. Pressure intervals of 5 or 10hPa and 25 or 50 hPa will be selectable.)

4.2 When routine observations are selected, they shall be made at set intervals between three and 60 minutes. The interval chosen may be preset or adjustable by uplink command. The start of the time interval between successive routine observations shall be reset when observations are made for any reason, except maximum wind observations (e.g. during climb and descent phase). Thus, the maximum time between successive observations will be determined by the preset interval for routine observations. The contents of routine, ascent and descent observations are given in Tables 3a and 3b.

## 5.
## FORMING A MESSAGE

5.1 A message may consist of one or more observations according to a preset programme or by uplink command. A typical message will consist of at least 10 observations.

5.2 Each observation shall be formed as follows:

(*a*) Check for maximum wind conditions. Store maximum wind observation keyed to time of occurrence of maximum wind.

(*b*) At target time or when passing through a target height, read observational data keyed to time that target was reached:
  - (i) Establish flight phase;
  - (ii) Check maximum wind conditions and discard stored observation if wind speed is equal to or greater than stored value (Note: Observation is no longer ‘max wind’ observation);
  - (iii) Reset routine time interval;
  - (iv) Store observation; and
  - (v) Discard oldest 10hPa (5hPa if selected) descent phase observation if number stored is greater than 10 (20 if 5hPa intervals selected).

The above actions shall be taken at intervals not greater than one second.

5.3 Batching observations:

Observations are usually batched according to requirements for real-time applications. Thus, if feasible, profile observations (ascent and descent) are downlinked as single messages. (See, for example, ARINC 620 format). Limitations imposed by some communications management units can restrict the number of characters in a single message and in these cases more than one message may be necessary to downlink a single profile. En-route data are usually accumulated and transmitted to the ground at intervals not greater than one hour, however on long-haul flights over water, it is not unusual to be outside VHF ground station coverage. For most real-time applications, delays of up to three hours in data reception are acceptable, hence data to be transmitted by VHF data link can be stored on board for at least three hours before establishing a ground link and still be considered useful in real-time applications. Longer delays can be tolerated for non-real time use. These problems can be avoided by the use of satellite data link, but this incurs significantly higher communications charges than VHF data link.

## 6. DATA QUALITY CONTROL

6.1 In order to ensure, as far as possible, that observations consist of data of acceptable quality, it is desirable to carry out a simple set of checks on each element to be reported. The recommended minimal level of checking is as follows:

*(a)* Gross error check:
Data values falling outside the ‘range’ intervals given in Tables 1 and 2 or already flagged in the aircraft data acquisition system shall be replaced by values representing missing or erroneous data as specified in the downlink code form chosen.

*(b)* Sequential check:
On most modern aircraft, the data are updated several times per second and individual samples may be smoothed and/or subjected to quality checks in the avionics system. It is desirable that this process is standardized to ensure consistency between observations from different data acquisition and different on-board computing systems. The recommended procedures are outlined below:

- (i) To remove ‘spikes’ from noisy data, a sequential quality check can be employed. This check is especially important when a maximum value is to be observed (e.g. maximum wind). A suitable algorithm is given in Annex 5.
- (ii) Data should be smoothed as shown in the table below to reduce random error and standardize representativeness.

| | *Element* | *Averaging Time(s)* | |
|---|---|---|---|
| | | *Ascent/descent phase* | *Level flight phase,> 20 000ft* |
| 7 | Pressure altitude | 10s | 30s |
| 8 | Static air temperature | 10s | 30s |
| 9 | Humidity,RH | 10s | 30s |
| 10 | Wind direction | 10s | 30s |
| 11 | Wind speed | 10s | 30s |

Note: The smoothing time is the arithmetic averaging time to be applied. An alternative, continuous, exponential smoothing function with time constant 3s or10s respectively can be used. A suitable algorithm for this function is given in Annex 6.

### 6.2 Additional Quality Checks

6.2.1 Most aircraft carry multiple sensor arrays (e.g. up to four temperature probes and at least two pitot-static heads. Thus it is possible to make more sophisticated checks by comparing data with the alternative sensor or sensors.

6.2.2 Because the measured elements are highly interdependent, it is possible to flag doubtful data computed from two or more basic measurements. For example, if comparison checks show that static air temperature is doubtful, then wind speed and wind direction can be flagged as doubtful.

## 7. DOWNLINK FORMATS

### 7.1 AMDAR panel format (APF)

7.1.1 This format is designed to be compatible with WMO AMDAR character code (FM 42-XI Ext), ARINC 620 and ADS ‘met-info’ reports. APF as shown in Table 3a is a generic format intended to provide a basis for downlink encoding. Use of all the group identifiers would not be efficient for the air-ground link, however various methods for reducing message length can be utilized and examples are provided in paragraph 7.1.4 below. For cross-comparison purposes, the equivalent FM 42-XI Ext, ARINC 620 and ADS formats are shown for each element. For ARINC 620 and ADS, downlink codes refer to the appropriate detailed descriptions in Annex 3 and Annex 4 respectively.

| *Element number* | *Element* | *Generic format* | *Notes* | *FM 42-XI Ext* | *ARINC 620* | *ADS* |
|---|---|---|---|---|---|---|
| 1 | Aircraft identifier | **A**I….I | Up to 7 numeric characters unique to the aircraft | $I_A$.....$I_A$ | ICAO Airline code and flight no. | 24 bit ICAO airframe identifier |
| 2 | Observation number | **B**NNN | 0 to 999 | | | |
| 3 | Phase of flight | **C**$P_n$ | Table 4 | $i_pi_pi_p$ | Asc(A), Enroute(E)<br>Desc(D) | |
| 4 | Latitude | **D**LLLL or<br>**E**LLLL | Degrees and minutes N(D) or S(E) | $L_aL_aL_aL_aA$ | ADDMMT | Latitude |
| 5 | Longitude | **F**LLLLL or<br>**G**LLLLL | Degrees and minutes E(F) or W(G) | $L_oL_oL_oL_oL_oB$ | ADDDMMT | Longitude |
| 6 | Day and time of observation | **H**DDhhmmss | Day of month, Hour,minute,second UTC | YYGGgg | dd hhmm | DateTimeGroup |
| 7 | Pressure Altitude | **I**hhhh or<br>**J**hh | Tens of feet with sign, + = I, - = J | $S_hh_Ih_Ih_I$ | nnnn | Level |
| 8 | Static air temperature (SAT) | **K**TTT or<br>**L**TTT | Tenths of °C plus sign + = K, - = L | $SST_AT_AT_A$ | annn | temperature |
| 9 | Humidity | **M**UUU | 0-100% | UUU | | humidity |
| | | **N**TTT or<br>**O**TTT | Dew point, + = N, - = O | $SST_dT_dT_d$ | | |
| | | **P**RMMM | Mixing ratio x $10^{-R}$ in g/kg | | nnnQ | |
| 10 | Wind Direction | **Q**ddd | ° from north | ddd | nnn | wind direction |
| 11/11a | Wind speed/ Maximum wind | **R**fff or<br>**S**fff | kt (R)<br>m/s(S) | fff | nnn | wind speed |
| 12 | Turbulence | **T**B | Table 5 | $TBB_A$ | | |
| | | **U**fff | Vertical gust in tenths of m/s | $VGf_gf_gf_g$ | | |
| | | **V**BB | EDR (Table 6) | | Cnnnn | Turbulence, index |
| | | **W**mm | ‘age’ of peak EDR (Table 7) | | | Turbulence, time-of-occurrence |
| 13 | Icing | **X** or **Y** | No or Yes | | | |

Additional notes:

1. Roll angle flag (n) is included in ARINC 620 format.
2. Wind quality flag according to roll angle is included in ADS format.
3. First character (in bold) in generic code is unique element number.
4. Presence of ice and liquid water content is included in the ARINC 620 Icing Report (see Annex 3).

*Table 3a*
*AMDAR Panel format*

| *Element number* | *Element* | *Generic format* | *Notes* | *FM 42-XI Ext* | *ADS* |
|---|---|---|---|---|---|
| 3 | Phase of flight | **C**$P_n$ | Table 4 (‘1’ or ‘2’ only) | $i_pi_pi_p$ | |
| 4 | Latitude | **D**LL or<br>**E**LL | Minutes +(D) or -(E) from previous observation | $L_aL_aL_aL_aA$ | Latitude |
| 5 | Longitude | **F**LL or<br>**G**LL | Minutes +(D) or -(E) from previous observation | $L_oL_oL_oL_oL_oB$ | Longitude |
| 6 | Day and time of observation | **H**mmss | Minutes,seconds since previous observation | YYGGgg | DateTimeGroup |
| 7 | Pressure Altitude | **I**hh or **J**hh | Tens of feet with sign,<br>+ = I, - = J since last observation, | $S_hh_Ih_Ih_I$ | Level |
| 8 | Static air temperature (SAT) | **K**TTT or<br>**L**TTT | Tenths of °C plus sign<br>+ = K, - = L | $SST_AT_AT_A$ | temperature |
| 9 | Humidity | **M**UUU | 0-100% | UUU | humidity |
| | | **N**TTT or<br>**O**TTT | Dew point, + = N, - = O | $SST_dT_dT_d$ | |
| | | **P**RMMM | Mixing ratio x $10^{-R}$ in g/kg | | |
| 10 | Wind Direction | **Q**ddd | ° from north | ddd | wind direction |
| 11 | Wind speed | **R**fff | knots | fff | wind speed |
| 11a | Maximum wind | **S**fff | knots | fff | |
| 12 | Turbulence | **T**B | Table 5 | $TBB_A$ | |
| | | **U**fff | Vertical gust in tenths of m/s | $VGf_gf_gf_g$ | |
| | | **V**BB | EDR (Table 6) | | Turbulence, index |
| | | **W**mm | ‘age’ of peak EDR (Table 7) | | Turbulence, time-of-occurrence |
| 13 | Icing | **X** or **Y** | No or Yes | | |

*Table 3b*
*AMDAR Panel format*
*(Modified for data compression in ascent phase)*

7.1.2 Data Compression – APF is formulated such that each observation stands alone and can be decoded by a simple decoder, with knowledge of the group identifiers and associated content specification only. Where observations are grouped together, prior to downlinking, (e.g. a series of ascent observations), it is feasible to omit most identifiers and perhaps also redundant position and time data. It is also feasible to utilize a more efficient number base (e.g. base 40 would allow a single character to represent decimal numbers in the range –20 to +19, two characters could represent –800 to +799 and so on). It is important, however, that a single report, containing a group of observations, can be disassembled into individual observations without needing additional data that might vary with time. In addition, especially with regard to setting observation and report intervals, care should be taken to ensure that specifications for each element are consistent with specifications for all other elements reported; i.e. it should not be possible to specify characteristics to be reported for one element that preclude reporting the full range of characteristics specified for another element in a single report. Table 3b illustrates a possible APF ascent coding where time, position and altitude are truncated in order to shorten the downlink message.

7.1.3 Example of observation in generic code:

(a) A123456B001C6D5200F2015H01001015I3500L405M10Q310R065U010X
Decode: Aircraft number, 123456; observation number, 1; level flight; 52°00' north; 20°15'W; Day of month, 1; 0010.15UTC; Flight level,

35 000ft; SAT, -40.5°C; RH, 10%; Wind direction, 310°; Wind speed, 65kt; Equivalent vertical gust, 1.0m/s; no icing.

(*b*) Example of minimized ascent message coded as in table 3b, where data identifiers are omitted after first observation. For the first line, the observation number is replaced by the number of observations in the message, coded BNN where NN is 0 to 99:
A2123456B10C2D5145G0045H19073100I0000L013Q097R006
2 00 02 0015 10 L010 114 002
2 00 00 0015 20 L002 097 003
(For clarity, each observation here is allocated a new line and omitted indicators shown as spaces.)

(*c*) Example of ascent message with leading zeroes suppressed and all indicators included:
A2123456B10C2D5145G45H19073100I0L13Q97R6
C2D0G2H15I10L10Q114R2
C2D0G0H15I20L2 Q97R3

*Table 4*
*Phase of flight*

| *Flight phase* | | *APF code ($P_n$)* | *FM 42-XI Ext* |
|---|---|---|---|
| Ascent | Unsteady | 1 | UNS |
| Ascent | | 2 | ASC |
| Descent | Unsteady | 3 | UNS |
| Descent | | 4 | DES |
| Level Flight (en route) | Unsteady | 5 | UNS |
| Level flight (en route) | | 6 | LVR |
| Maximum wind | Unsteady | 7 | LVW |
| Maximum wind | | 8 | LVW |

*Table 5*
*Scale of turbulence, defined by peak acceleration*

| *Turbulence category* | *Peak acceleration** | *Code (B,BA)* |
|---|---|---|
| none | less than 0.15g | 0 |
| light | 0.15g to, but not including 0.5g | 1 |
| moderate | 0.5g to 1.0g | 2 |
| severe | greater than 1.0g | 3 |

* These accelerations, which may be positive or negative, are deviations from the normal acceleration of gravity (1.0g).

*Table 6*
*Turbulence (EDR) reporting scale*
(Classes corresponding to severe turbulence are shaded.)

| *PEAK VALUE OF TURBULENCE* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Average value of turbulence | EDR (m$^{2/3}$ s$^{-1}$) | | | | | | | Nil report |
| EDR (m$^{2/3}$ s$^{-1}$) | < 0.1 | 0.1-0.2 | 02.-0.3 | 0.3-0.4 | 0.4-0.5 | 0.5-0.8 | >0.8 | |
| < 0.1 | 0 | 1 | 3 | 6 | 10 | 15 | 21 | |
| 0.1 – 0.2 | | 2 | 4 | 7 | 11 | 16 | 22 | |
| 0.2 – 0.3 | | | 5 | 8 | 12 | 17 | 23 | |
| 0.3 – 0.4 | | | | 9 | 13 | 18 | 24 | |
| 0.4 – 0.5 | | | | | 14 | 19 | 25 | |
| 0.5 – 0.8 | | | | | | 20 | 26 | |
| > 0.8 | | | | | | | 27 | |
| Nil report | | | | | | | | 28 |

Note: This table is identical to the table used in ADS reports.

*Table 7*
*Time of occurrence of the peak value of turbulence index to be reported*

| *Peak value of turbulence occurring during the one-minute period; Minutes prior to the observation* | *Value to be reported* |
|---|---|
| 0 – 1 | 0 |
| 1 – 2 | 1 |
| 2 – 3 | 2 |
| . . . | . . . |
| 58-59 | 58 |
| 59-60 | 59 |
| No timing information available | 60 |

Note: This table is an extended form of the equivalent table for use with ADS reports.

## ANNEX I TO APPENDIX II

*Pressure altitude vs. target pressure*

| *Pressure (hPa)* | *Height (ft)* |
|---|---|
| 1050 | -989 |
| 1040 | -723 |
| 1030 | -454 |
| 1020 | -184 |
| 1013.25 | 0 |
| 1010 | 89 |
| 1000 | 364 |
| 990 | 641 |
| 980 | 920 |
| 970 | 1202 |
| 960 | 1486 |
| 950 | 1773 |
| 940 | 2062 |
| 930 | 2353 |
| 920 | 2647 |
| 910 | 2944 |
| 900 | 3243 |
| 890 | 3545 |
| 880 | 3850 |
| 870 | 4157 |
| 860 | 4468 |
| 850 | 4781 |
| 840 | 5097 |
| 830 | 5417 |
| 820 | 5739 |
| 810 | 6065 |
| 800 | 6394 |
| 790 | 6727 |
| 780 | 7062 |
| 770 | 7402 |
| 760 | 7745 |
| 750 | 8091 |
| 740 | 8442 |
| 730 | 8796 |
| 720 | 9154 |
| 710 | 9516 |
| 700 | 9882 |
| 650 | 11780 |
| 600 | 13801 |
| 550 | 15962 |
| 500 | 18289 |
| 450 | 20812 |
| 400 | 23574 |

# ANNEX II TO APPENDIX II

## DERIVED EQUIVALENT VERTICAL GUST (DEVG) CALCULATION.

1. The DEVG velocity is defined as the instantaneous vertical gust velocity which superimposed on a steady horizontal wind would produce the measured vertical acceleration of the aircraft.

The derived equivalent vertical gust (Sherman, 1985 and Sherman, 1997) is given by:

$$U_{de} = \frac{10 Am|\Delta n|}{V}$$

where

$|\Delta_n|$ = peak value of modulus of deviation of aircraft normal acceleration from 1g in units of g;

$m$ = total aircraft mass in (metric) tonnes;

$V$ = calibrated airspeed at the time of occurrence of the acceleration peak, in knots; and

$A$ = An aircraft specific parameter which varies with flight conditions, and may be approximated by the following formulae:

$$A = \bar{A} + c_4(\bar{A} - c_5)\left(\frac{m}{\bar{m}} - 1\right)$$

$$\bar{A} = c_1 + \frac{c_2}{c_3 + H}$$

where

$\bar{A}$ = Value of A when mass of aircraft equals reference mass;

H = altitude in thousands of feet; and

$\bar{m}$ Reference mass of aircraft in (metric) tonnes.

The parameters $c_1$, $c_2$, ..., $c_5$ depend on the aircraft's typical flight profile which may be expressed in the form:

Take-off at speed $V_1$, accelerate to calibrated airspeed $V_c$ by height $h_1$ and maintain the lesser of $V_c$ or Mach $M_c$ to cruise altitude $h_c$. Reverse the procedure during descent.

For various aircraft, the appropriate constants, based on the flight profiles indicated, are shown in Table 1.

## REFERENCES

Sherman, DJ, October 1985. The Australian Implementation of AMDAR/ACARS and the use of derived equivalent gust velocity as a turbulence indicator.
Aeronautical Research Laboratory Melbourne. Structures Report 418.
Sherman, DJ, July 1997. Updated values of curve fit parameters for derived equivalent vertical gust velocity.
Aeronautical Research Laboratories,
Defence Science and Technology Organisation,
506 Lorimer St, Fishermans Bend, Vic 3207 Australia.

| Aircraft | $V_1$ knot | $V_c$ knot | $M_c$ Mach | $h_1$ ft | $h_c$ ft | $\overline{m}$ Tonne | $c_1$ | $c_2$ | $c_3$ kft | $c_4$ | $c_5$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A300B4 | 130 | 300 | 0.78 | 5000 | 30000 | 120 | 0.971 | 2690 | 79 | 0.49 | 19.6 |
| A310 | 130 | 300 | 0.78 | 5000 | 35000 | 120 | 19.6 | 574 | 32 | 0.52 | 23.5 |
| A318 | 120 | 300 | 0.78 | 5000 | 35000 | 40 | 34.7 | 878 | 28 | 0.52 | 40.3 |
| A319 | 120 | 300 | 0.78 | 5000 | 35000 | 50 | 33.9 | 846 | 29 | 0.45 | 39.6 |
| A320-200 | 120 | 300 | 0.78 | 5000 | 35000 | 55 | 35.9 | 771 | 27 | 0.44 | 40.7 |
| A321 | 120 | 300 | 0.78 | 5000 | 35000 | 60 | 34.8 | 716 | 28 | 0.41 | 39.3 |
| A330-200 | 120 | 300 | 0.82 | 5000 | 35000 | 170 | 5.88 | 1010 | 55 | 0.44 | 13.7 |
| A330-300 | 120 | 300 | 0.82 | 5000 | 35000 | 170 | 5.89 | 1010 | 54 | 0.44 | 13.6 |
| A340-200 | 120 | 300 | 0.82 | 5000 | 35000 | 190 | 6.36 | 949 | 54 | 0.41 | 13.7 |
| A340-300 | 120 | 300 | 0.82 | 5000 | 35000 | 190 | 6.34 | 948 | 54 | 0.41 | 13.6 |
| B727 | 120 | 300 | 0.84 | 5000 | 30000 | 50 | 6.45 | 4580 | 83 | 0.54 | 37.3 |
| B737-200 | 120 | 300 | 0.73 | 3000 | 35000 | 30 | 62.0 | 351 | 14 | 0.64 | 59.4 |
| B737-300 | 120 | 300 | 0.73 | 3000 | 35000 | 40 | 56.4 | 328 | 15 | 0.56 | 54.7 |
| B737-400 | 120 | 300 | 0.73 | 3000 | 35000 | 40 | 56.3 | 329 | 15 | 0.56 | 54.5 |
| B737-500 | 120 | 300 | 0.75 | 3000 | 35000 | 40 | 56.4 | 303 | 14 | 0.57 | 54.3 |
| B737-600 | 120 | 300 | 0.78 | 3000 | 35000 | 40 | 45.4 | 420 | 18 | 0.57 | 45.3 |
| B737-700 | 120 | 300 | 0.78 | 3000 | 35000 | 50 | 42.4 | 374 | 19 | 0.54 | 42.4 |
| B737-800 | 120 | 300 | 0.78 | 3000 | 35000 | 50 | 42.2 | 350 | 18 | 0.57 | 41.9 |
| B747-200 | 140 | 300 | 0.85 | 5000 | 40000 | 250 | -2.41 | 2230 | 97 | 0.65 | 11.5 |
| B747-300 | 140 | 300 | 0.85 | 5000 | 40000 | 200 | 2.27 | 1630 | 81 | 0.69 | 13.3 |
| B747-400 | 140 | 300 | 0.85 | 5000 | 40000 | 250 | -7.78 | 3260 | 120 | 0.62 | 10.2 |
| B747SP | 140 | 300 | 0.85 | 5000 | 40000 | 250 | 7.44 | 644 | 48 | 0.74 | 12.4 |
| B757-200 | 140 | 300 | 0.8 | 3000 | 40000 | 100 | 29.2 | 298 | 22 | 0.55 | 30 |
| B757-300 | 140 | 300 | 0.8 | 3000 | 40000 | 100 | 28.9 | 292 | 21 | 0.55 | 29.7 |
| B767-200 | 140 | 300 | 0.8 | 3000 | 40000 | 110 | 12.8 | 918 | 46 | 0.65 | 19.8 |
| B767-300 | 140 | 300 | 0.8 | 3000 | 40000 | 100 | 13.1 | 821 | 42 | 0.69 | 19.4 |
| B767-400 | 140 | 300 | 0.8 | 3000 | 40000 | 150 | 12.9 | 701 | 45 | 0.54 | 18.3 |
| B777-200 | 140 | 300 | 0.82 | 3000 | 40000 | 170 | 12.6 | 198 | 21 | 0.72 | 13.0 |
| B777-300 | 140 | 300 | 0.82 | 3000 | 40000 | 210 | 13.1 | 147 | 19 | 0.65 | 12.9 |
| BAC111-200 | 120 | 280 | 0.7 | 3000 | 30000 | 30 | 55.8 | 924 | 27 | 0.54 | 60.1 |
| BAC111-475 | 120 | 280 | 0.7 | 3000 | 30000 | 30 | 50.6 | 930 | 28 | 0.54 | 55.3 |
| DC10-30 | 150 | 300 | 0.82 | 5000 | 30000 | 200 | -6.45 | 4080 | 130 | 0.56 | 15.0 |
| Electra | 100 | 350 | 0.7 | 5000 | 30000 | 30 | 48.9 | 220 | 9.1 | 0.57 | 41.2 |
| Fokker-100 | 130 | 280 | 0.7 | 3000 | 30000 | 35 | 52.9 | 917 | 27 | 0.52 | 57.2 |
| KingAir 100 | 110 | 200 | 0.6 | 9000 | 25000 | 3 | 70.6 | 2280 | 89 | 0.74 | 223. |
| L1011-500 | 120 | 300 | 0.83 | 5000 | 35000 | 150 | 11.7 | 712 | 47 | 0.59 | 17.1 |

*Table 1*
*Parameters used in the estimation of DEVG*

# ANNEX III TO APPENDIX II

# ARINC 620

## 1. GENERAL

ARINC Specification 620 describes, *inter-alia,* uplink and downlink message text formats to control and forward meteorological reports. Subsystems on board the host aircraft may be programmed to provide automatic downlinks of meteorological data at predetermined altitudes or at timed intervals as specified by the user. ARINC 620 defines three versions of meteorological reports, together with a special icing event report. Version 1 provides a unified format for all flight phases. Version 2 divides the report data and associated data sampling times into three flight regimes. Version 3 provides an alternative ascent format to the Version 2 ascent format. This Annex summarizes the meteorological uplink commands available and the data requirements and formats specified in the downlink meteorological report (Version 3 for ascent reports and version 2 for en-route and descent reports) and the data requirements for the icing report.

## 2. UPLINK COMMANDS

(See ARINC 620, para 4.3.9)

| *Character number* | *Data* | *Description* | *Units* | *Default value* |
|---|---|---|---|---|
| 1-3 | AWR | Fixed characters | | |
| 4-5 | 03-20 | Ascent series 1 intervals | Seconds | 06 |
| 6-8 | 030-200 | Ascent series 1 duration | Seconds | 90 |
| 9-10 | 180-300 | Ascent series 2 intervals | Seconds | 20 |
| 11-13 | 180-300 or 051-111 | Top of ascent (PALT) or duration | Hundreds of feet (PALT) or tens of Seconds | 051 |
| 14-15 | 01-60 | En-route intervals | Minutes | 03 |
| 16-18 | 180-300 | Top of descent (PALT) | Hundreds of feet | 250 |
| 19-21 | 020-300 | Descent intervals | Seconds | 060 |
| 22 | 0 or 1 | Ascent enable(1)/ Disable(0) | | |
| 23 | 0 or 1 | En-route enable(1)/ Disable(0) | | |
| 24 | 0 or 1 | Descent enable(1)/ Disable(0) | | |

## 3. DOWNLINK FORMAT

(See ARINC 620, para.5.3.13.2- 5.3.13.3)

### 3.1 ASCENT REPORTS

(See ARINC 620, Meteorological Report, Version 3)

An ascent report is a single message containing all the individual observations (data samples) from take-off to the top of the ascent. The message is compiled as a standard preamble, an initial observation at take-off, a set of observations at user-selected intervals for ‘Ascent Series#1’ and a set of observations at intervals and user-selected termination for ‘Ascent Series#2’. The contents of each message type (data sample) are tabulated below.

| *Number of characters* | *Data or data format* | *Units* | *Description* | *Notes* |
|---|---|---|---|---|
| | | *Message Preamble* | | |
| 10 | | | Standard message header | See ARINC Specification 618 |
| 2 | 02 | | Version number | Version 2 |
| 1 | A | | Type of Met format | Ascent |
| 2 | dd | Day | Date message assembled | Day of month |
| 4 | hhmm | Hour,minute | Time message assembled | |

| *Number of characters* | *Data or data format* | *Units* | *Description* | *Notes* |
|---|---|---|---|---|
| *Message Preamble (cont.)* | | | | |
| 4 | xxxx | | Departure station | 4-character code |
| 4 | xxxx | | Destination station | 4-character code |
| 2 | ss | Seconds | Series #1 time interval | |
| 2 | ss | Seconds | Series #2 time interval | |
| *Initial report* | | | | |
| 6 | ADDMMT | Degrees, minutes,tenths of minutes | Latitude | A=’N’ or’S’<br>DD=degrees<br>MM=minutes<br>T=tenths of minutes |
| 7 | ADDDMMT | Degrees, minutes,tenths of minutes | Longitude | A=’E’ or ‘W’<br>DDD=degrees<br>MM=minutes<br>T=tenths of minutes |
| 2 | dd | Day | Date of observation | Day of month |
| 4 | hhmm | Hour,minute | Time of observation | |
| 4 | nnnn | Tens of feet | Pressure altitude | |
| 4 | annn | Tenths of °C | Static air temperature | a=’P’ (plus) or<br>a=’M’ (minus) |
| 4 | $n_1n_2nQ$ | Gram/kg | WV mixing ratio | Value = $n_1n_2$ x $10^{-n}$ g/kg<br>Q=quality indicator (to be defined) |
| *Series#1*<br>(repeated as defined by uplink command or to default duration) | | | | |
| 4 | nnnn | Tens of feet | Pressure altitude | |
| 4 | annn | Tenths of °C | Static Air Temperature | a=’P’ (plus) or<br>a=’M’ (minus) |
| 3 | nnn | Degrees true | Wind Direction | |
| 3 | nnn | Knots | Wind Speed | |
| 1 | n | | Roll angle flag | ‘B’ if roll angle > 5° otherwise ‘G’ |
| 4 | $n_1n_2nQ$ | Gram/kg | WV mixing ratio | Value = $n_1n_2$ x $10^{-n}$ gram/kg<br>Q = quality indicator (to be defined) |
| *Delimiter* | | | | |
| 1 | / | | Slash | Character to indicate end of series#1 data and beginning of series#2 data |

| *Number of characters* | *Data or data format* | *Units* | *Description* | *Notes* |
|---|---|---|---|---|
| | | *Series#2*<br>(repeated as defined by uplink command or to default duration) | | |
| 6 | ADDMMT | Degrees, minutes, tenths of minutes | Latitude | A='N' or'S'<br>DD = degrees<br>MM = minutes<br>T = tenths of minutes |
| 7 | ADDDMMT | Degrees, minutes, tenths of minutes | Longitude | A='E' or 'W'<br>DDD = degrees<br>MM = minutes<br>T = tenths of minutes |
| 4 | nnnn | Tens of feet | Pressure altitude | |
| 4 | annn | Tenths of °C | Static air temperature | a = 'P' (plus) or<br>a = 'M' (minus) |
| 3 | nnn | Degrees true | Wind direction | |
| 3 | nnn | Knots | Wind speed | |
| 1 | n | | Roll angle flag | 'B' if roll angle > 5° otherwise 'G' |
| 4 | $n_1n_2nQ$ | Gram/kg | WV mixing ratio | Value = $n_1n_2$ x $10^{-n}$ gram/kg<br>Q = quality indicator (to be defined) |

## 3.2 ENROUTE REPORTS

(See ARINC 620, Meteorological Report, Version 2)

En-route data measurements commence at the conclusion of ascent data sampling and terminate when descent report measurements commence. Each report consists of a standard preamble plus six consecutive observations (data measurement samples) at user-defined intervals by uplink command or at the default intervals. If ascent and descent reports are inhibited by uplink command, en-route reports commence at take off and continue to touchdown unless modified by subsequent uplink command.

The contents of a single en-route report are tabulated below.

| *Number of characters* | *Data or data format* | *Units* | *Description* | *Notes* |
|---|---|---|---|---|
| | | *Message Preamble*<br>(repeated as defined by uplink command or to default duration) | | |
| 10 | | | Standard message header | See ARINC Specification 618 |
| 2 | 02 | | Version number | Version 2 |
| 1 | E | | Type of Met format | En-route |
| 2 | dd | Day | Date message Assembled | Day of month |
| 4 | xxxx | | Departure station | 4-character code |
| 5 | xxxx | | Destination station | 4-character code |

The preamble is followed by six observations (data samples) unless truncated by entering the descent phase. The format for each observation is shown below.

| *Number of characters* | *Data or data format* | *Units* | *Description* | *Notes* |
|---|---|---|---|---|
| *Series#1 (enroute)*<br>(six data samples to format below at user-defined intervals by uplink command or at default intervals) | | | | |
| 6 | ADDMMT | Degrees, minutes, tenths of minutes | Latitude | A=’N’ or’S’<br>DD = degrees<br>MM = minutes<br>T = tenths of minutes |
| 7 | ADDDMMT | Degrees, minutes, tenths of minutes | Longitude | A=’E’ or ‘W’<br>DDD = degrees<br>MM = minutes<br>T = tenths of minutes |
| 4 | hhmm | Hours,minutes | Time of observation | |
| 4 | nnnn | Tens of feet | Pressure altitude | |
| 4 | annn | Tenths of °C | Static Air Temperature | a = ’P’ (plus) or<br>a = ’M’ (minus) |
| 3 | nnn | Degrees true | Wind Direction | |
| 3 | nnn | Knots | Wind Speed | |
| 1 | n | | Roll angle flag | ‘B’ if roll angle > 5° otherwise ‘G’ |
| 4 | $n_1n_2Q$ | Gram/kg | WV mixing ratio | Value = $n_1n_2$ x $10^{-n}$ gram/kg<br>Q = quality indicator (to be defined) |
| 5 | Cnnnn | | Turbulence | See table below |

*Turbulence code*

| *Value of C* | *Meaning* | *Content of nnnn* | *Notes* |
|---|---|---|---|
| Z | Turbulence below minimum threshold | No data | |
| Q | Data error | No data | |
| n = 0 to 9 | 4n hex characters (nnnn) follow | $n_1n_2n_3n_4$ | $n_1n_2$ = average value of turbulence metric.<br>$n_3n_4$ = peak value of turbulence metric, both over one minute period. |

### 3.3
### DESCENT REPORTS

(See ARINC 620, Meteorological Report, Version 2)

During the descent phase, reports are assembled after every 10 observations (data samples). Descent sampling starts at the ‘top of the descent’ and at fixed intervals, both determined by uplink command or at the default values, and continues to touchdown. The final report is sent at touchdown and thus may contain less than 10 observations. As for ascent and en-route reports, each descent report contains a standard preamble. The contents of a single downlink report are identical to the en-route format except that the ‘type of met format’ in the preamble is coded ‘D’ and the turbulence report consists of one group ‘nnnn’ where the first two hexadecimal characters represent the average of the turbulence metric in the observation interval and the second two hexadecimal characters represent the peak turbulence in the observation interval.

## 4.
## ICING REPORTS
(See ARINC 620, para 5.3.52)

4.1 When programmed to provide automatic icing reports, the following report is transmitted every 5 minutes for the duration of icing conditions.

| *Number of characters* | *Data or data format* | *Units* | *Description* | *Notes* |
|---|---|---|---|---|
| *Icing Report* | | | | |
| 10 | | | Standard message header | See ARINC Specification 618 |
| 2 | 01 | | Version Number | Version 1 |
| 7 | XXXxxxx | | Flight identifier | Airline code and flight number |
| 7 | xxxxxxx | | Aircraft registration no | |
| 31 | | | Data Sample 1 | See table below |
| 31 | | | Data Sample 2 | See table below |
| 31 | | | Data Sample 3 | See table below |
| 31 | | | Data Sample 4 | See table below |
| 31 | | | Data Sample 5 | See table below |
| *Icing Report — Content of data samples 1-5* | | | | |
| 6 | ADDMMT | Degrees, minutes, tenths of minutes | Latitude | A='N' or'S'<br>DD = degrees<br>MM = minutes<br>T = tenths of minutes |
| 7 | ADDDMMT | Degrees, minutes, tenths of minutes | Longitude | A='E' or 'W'<br>DDD = degrees<br>MM = minutes<br>T = tenths of minutes |
| 6 | ddhhmm | Day, hours, minutes(UTC) | Date/time of observation | |
| 4 | Fnnn | Hundreds of feet | Flight level | F = fixed character |
| 4 | AAnn | °C | Static air temperature | AA = 'PS' (plus) or<br>AA = 'MS' (minus) |
| 1 | n | | Icing | '0' = no ice, '1' = icing conditions present |
| 2 | nn | 0.1gram/m$^3$ | Peak liquid water content | |
| 2 | nn | 0.1gram/m$^3$ | Average liquid water content | |
| 1 | n | | Supercooled large droplet (SLD) conditions | '0' = no SLD, '1' = SLD conditions present |

## ANNEX IV TO APPENDIX II

# AUTOMATIC REPORTING OF AIRCRAFT METEOROLOGICAL OBSERVATIONS AS A METEOROLOGICAL SERVICE FOR INTERNATIONAL AIR NAVIGATION.

## 1. INTRODUCTION

1.1 Standards and Recommended Practices Relating to Meteorological Service for International Air Navigation are published in ICAO - Annex 3 to the Convention on International Civil Aviation. Annex 3, Chapter 5 includes requirements for aircraft observations and reports both by voice and data link. The regulatory material contained in Annex 3 is, except for a few minor editorial differences, identical with that appearing in *Technical Regulations* (WMO-No. 49), [C.3.1], hereafter referred to as [C.3.1].

1.2 This Annex deals with data and reporting requirements using digital data link only. As appropriate, references are given to the relevant part, appendix and paragraph of [C.3.1]/Annex 3 and other related ICAO documents.

1.3 Meteorological reports by data link may be made as ‘routine air-reports’ at regular, pre-designated times or positions or as ‘special air-reports’ according to prescribed meteorological conditions encountered. Air-ground data link may be employed whether or not Automatic Dependent Surveillance (ADS) is being applied, however the precise data formats and downlink codes depend on the reporting mode in use. The standards and recommended practices relating to both modes of reporting are summarized in the following paragraphs.

## 2. GENERAL REQUIREMENTS

2.1 Each contracting State is obliged to arrange, according to the provisions of Annex 3, Chapter 5, for observations to be made by aircraft of its registry operating on international air routes as well as for the recording and reporting of these observations.
[C.3.1]/Annex 3, Part I, 5.1

2.2 Observations required are:
(*a*) Routine aircraft observations during en-route and climb-out phases of the flight; and
(*b*) Special and other non-routine aircraft observations during any phase of the flight.
[C.3.1]/Annex 3, Part I, 5.2

2.3 Observations are required to be reported during flight at the time the observation is made or as soon thereafter as is practicable.
[C.3.1]/Annex 3, Part I, 5.7.2

2.4 Selection of aircraft to make observations.
2.4.1 For air routes with high-density air traffic (e.g. organized tracks), routine observations are to be made by an aircraft from among the aircraft operating at each flight level. The designation of aircraft, at approximately hourly intervals, is subject to regional air navigation agreement.
[C.3.1]/Annex 3, Part I, 5.3.4

2.4.2 When routine observations are required during ascent, at each aerodrome, aircraft are required to be designated, at approximately hourly intervals, to make routine observations every 30 seconds for the first 10 minutes of the flight.
[C.3.1]/Annex 3, Part I, 5.3.5

2.5. Special air-reports.
2.5.1 All aircraft are required to make special observations whenever any of the following conditions are encountered or observed:
(*a*) Severe turbulence;

(*b*) Severe icing;
(*c*) Severe mountain wave;
(*d*) Thunderstorms, without hail, that are obscured, embedded, widespread or in squall lines;
(*e*) Thunderstorms, with hail, that are obscured, embedded, widespread or in squall lines;
(*f*) Heavy duststorm or heavy sandstorm;
(*g*) Volcanic ash cloud; or
(*h*) Pre-eruption volcanic activity or a volcanic eruption.

Note: Pre-eruption volcanic activity in this context means unusual and/or increasing volcanic activity which could presage a volcanic eruption.

In addition, in the case of transonic and supersonic flights:
(*a*) Moderate turbulence;
(*b*) Hail; or
(*c*) Cumulonimbus clouds.

[C.3.1]/Annex 3, Part I, 5.5

## 3.
## REPORTING OF AIR OBSERVATIONS BY AUTOMATIC DATA LINK WHEN ADS IS BEING APPLIED

3.1 ADS is a component of CNS/ATM systems of ICAO. ADS is a service for use by ATS in which aircraft automatically provide, via a data link, data derived from on-board navigation and position-fixing systems. As a minimum, the data include aircraft identification, time and position. Additional data may be provided as appropriate, including a meteorological information data block.

3.2 Observation interval for routine reports.

3.2.1. Annex 3 does not specify mandatory minimum requirements for routine observations. The recommended requirements are:

(*a*) en-route phase (cruise) – 15-minute intervals between observations; and
(*b*) Climb-out phase (ascent) – every 30 seconds for the first 10 minutes of the flight.

[C.3.1]/Annex 3, Part I, 5.3.1

Note: Annex 3 does not define ‘en-route’.

3.3 The contents of ADS routine meteorological reports are as follows:

| | *ADS element* | | *Units* | *Data range (notes)* |
|---|---|---|---|---|
| | Message type designator | | | |
| | aircraft-address | | | 24 bit ICAO airframe identifier |
| Data Block 1 | Position | Latitude | (Sign), | (Plus=’0’,minus=’1’), |
| | | | Degrees, | 0…90, |
| | | | Minutes, | 0…59, |
| | | | 0.1 seconds | 0…-599 |
| | | Longitude | (Sign), | (Plus=’0’,minus=’1’), |
| | | | Degrees, | 0…90, |
| | | | Minutes, | 0…59, |
| | | | 0.1 seconds | 0…599 |
| | | Level | 10 feet | -75…10000 |
| | Date time group | Year, month, day | Year, | 1996…2095, |
| | | | Month, | 1…12, |
| | | | Day | 1…31 |
| | | Hours, | Hours, | 0…23, |
| | | Minutes, | Minutes, | 0…59, |
| | | Seconds | Seconds | 0…59 |

| | *ADS element* | | *Units* | *Data range (notes)* |
|---|---|---|---|---|
| | Message type designator<br>aircraft-address | | | 24 bit ICAO airframe identifier |
| Data block 2 | Wind-speed | | Knots or km/h | 0…500 |
| | Wind-direction | | Degrees true north | 0…360 |
| | Wind-quality-flag | | (index) | (‘0’ if roll angle < 5 deg)<br>(‘1’ if roll angle ≥ 5 deg) |
| | Temperature | | 0.1 °C | -800…600 |
| | Turbulence (if available) | Time-of-occurrence, index | | 0..15,<br>0..28<br>(See Tables 1 and 2 below) |
| | Humidity (if available) | | Per cent (%) | 0…100 |

Note: When ADS is being applied, the requirements of routine air-reports may be met by the combination of the basic ADS data block (providing the information in data block 1) and the meteorological information data block (for data block 2), available from ADS reports.

The ADS message format is specified in the ICAO Procedures for Air Navigation Services - Rules of the Air and Air Traffic Services (PANS-RAC, Doc 4444), Part II, Section 14.4 and in Annex 10 – Aeronautical Telecommunications, Volume III – Communication Systems, Part I – Digital Data Communication Systems.

*Table 1*
*Turbulence (EDR) reporting scale*

| | *Peak value of turbulence* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Average value of turbulence | EDR ($m^{2/3}$ $s^{-1}$) | | | | | | | Nil report |
| EDR ($m^{2/3}$ $s^{-1}$) | < 0.1 | 0.1-0.2 | 02.-0.3 | 0.3-0.4 | 0.4-0.5 | 0.5-0.8 | >0.8 | |
| < 0.1 | 0 | 1 | 3 | 6 | 10 | 15 | 21 | |
| 0.1 – 0.2 | | 2 | 4 | 7 | 11 | 16 | 22 | |
| 0.2 – 0.3 | | | 5 | 8 | 12 | 17 | 23 | |
| 0.3 – 0.4 | | | | 9 | 13 | 18 | 24 | |
| 0.4 – 0.5 | | | | | 14 | 19 | 25 | |
| 0.5 – 0.8 | | | | | | 20 | 26 | |
| > 0.8 | | | | | | | 27 | |
| Nil report | | | | | | | | 28 |

*Table 2*
*Time of occurrence of the peak value of turbulence index to be reported*

| *Peak value of turbulence occurring during the one-minute period. Minutes prior to the observation* | *Value to be reported* |
|---|---|
| 0 – 1 | 0 |
| 1 – 2 | 1 |
| 2 – 3 | 2 |
| . . . | . . . |
| 13-14 | 13 |
| 14-15 | 14 |
| No timing information available | 15 |

## 4. REPORTING BY AIR-GROUND DATA LINK WHEN ADS IS NOT BEING APPLIED

4.1 Observation intervals for routine reports.

4.1.1 Annex 3 does not specify observation intervals for non-ADS data link applications. By inference the specifications for voice reporting might be assumed as follows:

> When voice communications are used, routine observations shall be made during the en-route phase in relation to those air traffic services reporting points or intervals:
>
> (*a*) At which the applicable air traffic services procedures require routine position reports; and
>
> (*b*) Which are separated by distances corresponding most closely to intervals of one hour of flying time.

[C.3.1]/Annex 3, Part I, 5.3.2

4.2 Content of routine reports.

4.2.1 When air-ground data link is used while ADS is not applied, the elements to be included in routine reports are as follows:

[C.3.1]/Annex 3, Part II, Appendix 4, 1.3/1.1.2

| | *Routine air-report*<br>*Message type designator* |
|---|---|
| Section 1<br>(Position information) | Aircraft identification<br>Position or latitude and longitude<br>Time<br>Flight level or altitude<br>Next position and time over ensuing significant point |
| Section 2<br>(Operational information) | Estimated time of arrival<br>Endurance |
| Section 3<br>(Meteorological information) | Air temperature<br>Wind direction<br>Wind speed<br>Turbulence<br>Aircraft icing<br>Humidity (if available) |

Note: When air-ground data link is used while ADS is not being applied, the requirements of routine air-reports may be met by the Controller Pilot Data Link Communication (CPDLC) application entitled ‘Position report’ The details of this data link application are specified in ICAO’s *Manual of Air Traffic Services (ATS) Data Link Applications* (Doc 9694) and in Annex 10 – Aeronautical Telecommunications, Volume III – Communication Systems, Part I – Digital Data Communication Systems.

## 5.
## CONTENT OF SPECIAL AIR-REPORTS

The elements contained in special air-reports are as follows:
[C.3.1]/Annex 3, Part II, Appendix 4, 1.2

| | *Routine air-report*<br>*Message type designator* |
|---|---|
| Data Block 1 | Latitude<br>Longitude<br>Level<br>Time |
| Data block 2 | Wind direction<br>Wind speed<br>Temperature<br>Turbulence (if available)<br>Humidity (if available) |
| Data Block 3 | Condition prompting the issuance of a special air-report (one condition to be selected from the list presented under [C.3.1]/Annex 3, Part I, 5.5 |

Note: Units,range and resolution are as for routine reports.

## 6.
## DISSEMINATION OF AIR-REPORTS TRANSMITTED BY DIGITAL DATA LINK

Annex 3 deals with the requirements for ground dissemination of air-reports. Data transmitted by digital data link are required to be forwarded to the WAFCs without delay in the form that they are received. (see [C.3.1]/Annex 3, Part I, 5.8). Air-reports received at WAFCs are required to be further disseminated as basic meteorological data, normally on the WMO GTS. This is complicated by the need to encode in standard international format. The only code capable of dealing with the full ADS ‘metinfo’ format is BUFR.

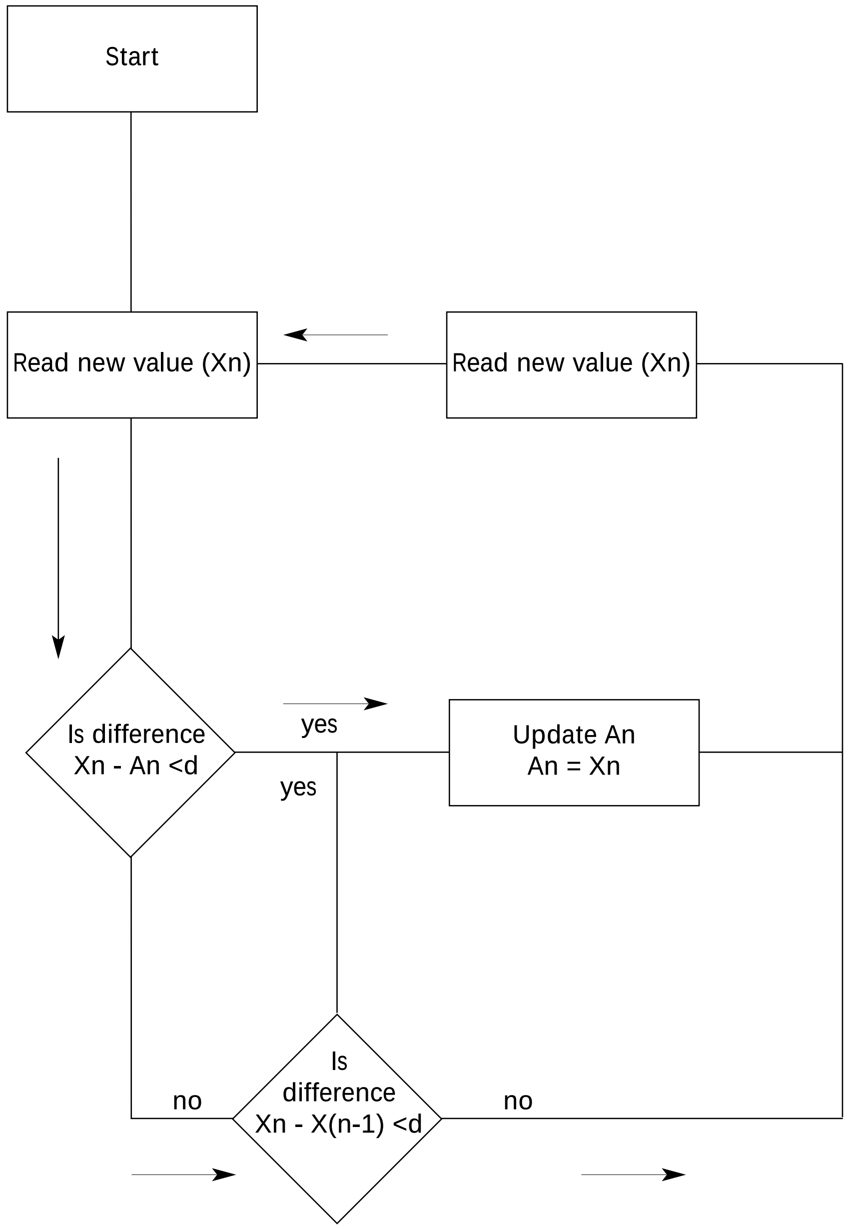
# ANNEX V TO APPENDIX II

# QUALITY CONTROL: SEQUENTIAL DATA CHECK

## 1. INTRODUCTION

1.1 Noise in high-speed data acquisition systems typically used in aircraft condition monitoring systems can lead to isolated errors (spikes) in the data stream. Such rare events can be unimportant as data are usually smoothed over several samples, however in the case that an extreme value is required or a small number of samples contribute to the value of a variable to be reported, it is useful to employ a sequential check of raw data designed to eliminate isolated erroneous samples. An example of a flow diagram for a suitable algorithm is given below.

Note: This algorithm rejects single values (Xn) equal or exceeding a designated difference (d) from the previous accepted value (An) and replaces it with the previous accepted value. If a step change occurs, the new level is accepted after one rejection.



Example: d = 5

Raw values and corresponding accepted values are in bold.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Xn | **6** | **7** | **4** | **10** | **6** | **3** | **10** | **8** | **9** | At start |
| An | | 6 | 7 | 4 | 4 | 6 | 3 | 3 | 8 | At start |
| X(n-1) | | 6 | 7 | 4 | 10 | 6 | 3 | 10 | 8 | At start |
| An | | **7** | **4** | **4** | **6** | **3** | **3** | **8** | **9** | Finish |
| X(n-1) | | 7 | 4 | 10 | 6 | 3 | 10 | 8 | 9 | Finish |

## ANNEX VI TO APPENDIX II

# DATA SMOOTHING

1.1 Raw data available from aircraft condition monitoring systems are sampled at various rates, principally to meet the operator's requirements. Data rates typically vary from one to 16 samples per second. Some data acquisition systems provide data smoothing, but standards vary widely with different avionics manufacturers. It is desirable, where feasible, to ensure that meteorological data are smoothed in a consistent way to ensure compatibility between measurements on individual and different aircraft. An example of a simple and efficient algorithm to be applied to raw data samples is shown below:

If $y_n$ is the nth raw data sample, t the sampling interval, T the averaging time and $Y_n$ the corresponding smoothed value, then:

$$Y_n = 3t(y_n - Y_{n-1})/\ T + Y_{n-1}$$

Note: It is assumed that T is much larger than t; e.g. $T=10s$, $t<1s$.

APPENDIX III

# AMDAR DOWNLINK DATA CONTROL SPECIFICATIONS

## 1. INTRODUCTION

1.1 The simplest AMDAR system on board an aircraft is configured with a fixed measurement and downlinking schedule, and the only options allowed are:

(a) AMDAR Programme enabled; and

*(b)* AMDAR Programme disabled.

ACARS systems can accept ground commands uplinked to the aircraft to apply the available options; thus, in its simplest form, the AMDAR equipment can be selectively enabled or disabled by ground command to improve the utility of the observing programme. For example, in data-rich areas, some AMDARs could be switched off through a ground monitoring and control system. Although such a system is feasible, it would require considerable ground processing and resources, and is relatively inflexible.

1.2 The next level of sophistication allows multiple pre-programmed configurations, updated off-line only. For this scheme, the AMDAR programme on board the host aircraft carries a configuration table that is fixed during flight and may only be amended on the ground. This scheme is attractive as, once set up, the ground system needs to respond only to a pre-determined observation programme. The disadvantage is that it could prove difficult to devise an optimum configuration for a particular AMDAR programme, and any changes necessitate physical access to the host aircraft.

1.3 The highest level of flexibility is achieved by allowing the programme configuration to be amended by uplink command. This Appendix gives recommendations for AMDAR configuration options to be programmed on board host aircraft to allow maximum flexibility in observation schemes, whatever the level of availability of ground processing and data control.

## 2. AMDAR ON-BOARD SYSTEM CONFIGURATION

2.1 The AMDAR on-board software should contain sufficient flexibility to allow selection of multiple data acquisition and reporting schemes. This is best achieved through a configuration table which can be modified off-line (i.e. by manually loading a new configuration on the ground) or in flight by ACARS data link. The recommended functions to be controlled are listed in the tables below. The functions are ordered as logical commands followed, as appropriate, with data fields.

2.2 The functions recommended in this Appendix are being implemented in a revised version of the airline industry standard ARINC 620 format that will become Version 4 following acceptance by the Airlines Electronics Engineering Committee.

*Table 1*
*Required functions*

| *Function* | *Command* | *Data table* | *Default* | *Remarks* |
|---|---|---|---|---|
| Enable AMDAR | On/off | | Off | |
| Inhibit reporting in selected time interval each day | On/off | 9 | Off | |
| Geographical region | On /off | 2 | Off | Report/inhibit report in selected region |
| Airport selection | On/Off | 3 | Off | Ascent/descent selection |
| Level flight observations | On/off | 4 | On | Interval selection |
| Ascent observations | On/off | 6,4,5,3,10 | On | Time and/or pressure level selection |
| Descent observations | On/off | 8,4,7,3,10 | On | Time and/or pressure level selection |

Notes: This is the basic configuration table. The data fields are logical switches to set up the detailed programme.

*Table 2*

| *Element* | *Data field* | *Data* | *Remarks* |
|---|---|---|---|
| Report in geographical region | 1 | $L_1L_1L_2L_2$N/S<br>$L_3L_3L_3L_4L_4L_4$E/W | $L_1L_1L_2L_2$ = latitude limits (degrees)<br>$L_3L_3L_3L_4L_4$ $L_4$= longitude limits (degrees) |
| | 2-16 | As field 1 | As field 1 |
| Inhibit reports in selected region | 17-32 | As field 1 | As field 1<br>Inhibit has priority over Report, if overlapping. |

Notes: This table can be used to designate up to 16 regions where AMDAR is enabled, that is required to make ascent and descent profiles and en-route reports. No AMDAR reports are required outside the specified regions, but profiles from individual airfields can be reported if specified in Table 3. If also required, regions where no reports are needed can be specified in fields 17-32. If fields 1-16 are empty, this is taken to mean AMDAR is enabled globally except in any regions specified in fields 17-32. If there are entries in both lists (1-16 and 17-32) and any of these overlap, ‘inhibit’ takes precedence over ‘report’.

*Table 3*

| *Element* | *Data field* | *Data* | *Remarks* |
|---|---|---|---|
| Airfield selected | 1-20 | AAAA | AAAA = airfield selected for ascent reporting |
| | 21-40 | DDDD | DDDD = airfield selected for descent reporting |
| | 41-60 | aaaa | aaaa = airfield inhibited from ascent reporting |
| | 61-80 | dddd | dddd = airfield inhibited from descent reporting |
| | 81 | On/Off | On = enable routine observations |

Notes: This table is used in conjunction with Table 2, which designates regions in which AMDAR is enabled. If, in a particular selected region, one or more airfields are selected for ascent and/or descent profile reporting, all other airfields in the region are inhibited from the relevant profile reporting. If, on the other hand, fields 1-20 are blank and fields 41-60 contain one or more airfield names, all ascents are reported in the region except the ones listed in fields 41-60. Where a designated ‘reporting’ airfield falls outside a ‘report’ and ‘inhibit’ area designated in Table 2, only profiles are to be reported. The final field allows routine reports to be made (reports at a fixed time interval regardless of flight phase) for all flights where profile reports are inhibited in designated reporting regions.

*Table 4*

| *Element* | *Data field* | *Data* | *Default value* | *Remarks* |
|---|---|---|---|---|
| Routine/level flight observing interval | 1 | Mm | 07 | Minutes |
| Maximum wind reporting | 2 | On/off | On | |

This table sets the routine (including en-route) observing interval. The second field allows maximum wind reporting to be disabled.

*Table 5*

| *Element* | *Data field* | *Data* | *Default value* | *Remarks* |
|---|---|---|---|---|
| Ascent enabled | 1 | n | 1 | Time intervals (n=1)<br>Pressure intervals (n=0) |
| | 2 | ss | 06 | Series 1 intervals(s) |
| | 3 | sss | 090 | Series 1 duration(s) |
| | 4 | ss | 20 | Series 2 intervals(s) |
| | 5 | SS | 51 | Total duration (sx10) |
| | 6 | hhh | 200 | Top of climb(ftx100) |
| | 7 | n | 2 | n = 1, use Table 10 List 1<br>n = 2, use Table 10 List 2 |
| | 8 | On/off | On | Enables timed level flight reports during ascent |

Notes: The first field determines if ascent profile reporting intervals are to be time-based or pressure-based. If a time-based system is required, the relevant data are in fields 2-6; if a pressure-based system is specified, field 7 designates one of two preset pressure altitude target lists to be used (Table 10, List 1 or 2). Reporting can be enabled to control observations when a temporary period of level flight occurs during the ascent phase using the level flight observing interval defined in Table 4.

*Table 6*

| *Element* | *Data field* | *Data* | *Default value* | *Remarks* |
|---|---|---|---|---|
| Ascent disabled | 1 | On/Off | On | On = routine observations enabled |

Note: This table allows routine reports to be made during ascent even if all ascent profiling is disabled through Table 1 command.

*Table 7*

| *Element* | *Data field* | *Data* | *Default value* | *Remarks* |
|---|---|---|---|---|
| Descent enabled | 1 | n | 1 | Time intervals (n=1)<br>pressure intervals (n=0) |
| | 2 | sss | 040 | Descent intervals(s) |
| | 3 | hhh | 200 | Top of Descent |
| | 4 | N | 2 | n = 1, use Table 10 List 1<br>n = 2, use Table 10 List 2 |
| | 5 | On/Off | On | Enables timed level flight reports during descent |

Notes: The first field determines if descent profile reporting intervals are to be time-based or pressure-based. If a time-based system is required, the relevant data is in field 2 and if a pressure-based system is specified, field 4 designates one of two preset pressure altitude target lists to be used (Table 10, List 1 or 2). Reporting can be enabled to control observations when a temporary period of level flight occurs during the descent phase using the level flight observing interval defined in Table 4.

*Table 8*

| *Element* | *Data field* | *Data* | *Default value* | *Remarks* |
|---|---|---|---|---|
| Descent disabled | 1 | On/Off | On | On = routine observations enabled |

Note: This table allows routine reports to be made during descent even if all ascent profiling is disabled though Table A command.

*Table 9*

| *Element* | *Data field* | *Data* | *Default value* | *Remarks* |
|---|---|---|---|---|
| Inhibit reporting in selected time interval each day | 1 | $H_1H_1H_2H_2$ | 0000 | $H_1H_1$ = start of inhibit period<br>$H_2H_2$ = end of inhibit period |

Note: This table is used if 'Inhibit reporting in selected time interval' is selected. It allows observations to be inhibited between selected hours UTC, each 24 hours it is enabled. The default value is interpreted as 'no interval selected'. The inhibit period starts at the first designated hour in the day and ends when the next designated hour is reached the same or next day. Thus '2301' means inhibit between 2300 hours and 0100 hours the next day, every day (two hours spanning midnight UTC). '0000' means 'report though all 24 hour periods'.

*Table 10*

*Preset Target Heights based on Pressure Level Selection*

| *Pressure (hPa)* | *Height (ft)* | *List 1* | *List 2* | *Height No. (nn)* |
|---|---|---|---|---|
| 1050 | -989 | 1 | 1 | 1 |
| 1045 | -856 | 2 | | 2 |
| 1040 | -723 | 3 | 2 | 3 |
| 1035 | -589 | 4 | | 4 |
| 1030 | -454 | 5 | 3 | 5 |
| 1025 | -319 | 6 | | 6 |
| 1020 | -184 | 7 | 4 | 7 |
| 1015 | -48 | 8 | | 8 |
| 1010 | 89 | 9 | 5 | 9 |
| 1005 | 226 | 10 | | 10 |
| 1000 | 364 | 11 | 6 | 11 |
| 995 | 502 | 12 | | 12 |
| 990 | 641 | 13 | 7 | 13 |
| 985 | 780 | 14 | | 14 |
| 980 | 920 | 15 | 8 | 15 |
| 975 | 1061 | 16 | | 16 |
| 970 | 1202 | 17 | 9 | 17 |
| 965 | 1344 | 18 | | 18 |
| 960 | 1486 | 19 | 10 | 19 |
| 955 | 1629 | 20 | | 20 |
| 950 | 1773 | 21 | 11 | 21 |
| 945 | 1917 | 22 | | 22 |
| 940 | 2062 | 23 | 12 | 23 |
| 935 | 2207 | 24 | | 24 |
| 930 | 2353 | 25 | 13 | 25 |
| 925 | 2500 | 26 | | 26 |
| 920 | 2647 | 27 | 14 | 27 |
| 915 | 2795 | 28 | | 28 |

*Table 10 Continued*

| Pressure (hPa) | Height (ft) | List 1 | List 2 | Height No. (nn) |
|---|---|---|---|---|
| 910 | 2944 | 29 | 15 | 29 |
| 905 | 3093 | 30 | | 30 |
| 900 | 3243 | 31 | 16 | 31 |
| 895 | 3394 | 32 | | 32 |
| 890 | 3545 | 33 | 17 | 33 |
| 885 | 3697 | 34 | | 34 |
| 880 | 3850 | 35 | 18 | 35 |
| 875 | 4003 | 36 | | 36 |
| 870 | 4157 | 37 | 19 | 37 |
| 865 | 4312 | 38 | | 38 |
| 860 | 4468 | 39 | 20 | 39 |
| 855 | 4624 | 40 | | 40 |
| 850 | 4781 | 41 | 21 | 41 |
| 845 | 4939 | 42 | | 42 |
| 840 | 5098 | 43 | 22 | 43 |
| 835 | 5257 | 44 | | 44 |
| 830 | 5417 | 45 | 23 | 45 |
| 825 | 5578 | 46 | | 46 |
| 820 | 5739 | 47 | 24 | 47 |
| 815 | 5902 | 48 | | 48 |
| 810 | 6065 | 49 | 25 | 49 |
| 805 | 6229 | 50 | | 50 |
| 800 | 6394 | 51 | 26 | 51 |
| 795 | 6560 | 52 | | 52 |
| 790 | 6727 | 53 | 27 | 53 |
| 785 | 6894 | 54 | | 54 |
| 780 | 7062 | 55 | 28 | 55 |
| 775 | 7232 | 56 | | 56 |
| 770 | 7402 | 57 | 29 | 57 |
| 765 | 7573 | 58 | | 58 |
| 760 | 7745 | 59 | 30 | 59 |
| 755 | 7917 | 60 | | 60 |
| 750 | 8091 | 61 | 31 | 61 |
| 745 | 8266 | 62 | | 62 |
| 740 | 8442 | 63 | 32 | 63 |
| 735 | 8618 | 64 | | 64 |
| 730 | 8796 | 65 | 33 | 65 |
| 725 | 8974 | 66 | | 66 |
| 720 | 9154 | 67 | 34 | 67 |
| 715 | 9334 | 68 | | 68 |
| 710 | 9516 | 69 | 35 | 69 |
| 705 | 9699 | 70 | | 70 |
| 700 | 9882 | 71 | 36 | 71 |
| 675 | 10817 | 72 | | 72 |
| 650 | 11780 | 73 | 37 | 73 |
| 625 | 12774 | 74 | | 74 |
| 600 | 13801 | 75 | 38 | 75 |
| 575 | 14862 | 76 | | 76 |
| 550 | 15962 | 77 | 39 | 77 |
| 525 | 17103 | 78 | | 78 |
| 500 | 18289 | 79 | 40 | 79 |
| 475 | 19524 | 80 | | 80 |
| 450 | 20812 | 81 | 41 | 81 |
| 425 | 22160 | 82 | | 82 |
| 400 | 23574 | 83 | 42 | 83 |
| 375 | 25061 | 84 | | 84 |

# APPENDIX IV

# AMDAR DATA MANAGEMENT

## 1. INTRODUCTION

1.1 AMDAR Data Management (AMDARDM) can be viewed within the context of the WMO World Weather Watch Data Management (WWWDM) programme. The concept of WWWDM is one of carrying out those activities required to optimize the integration of the Global Observing System (GOS), Global Telecommunications System (GTS) and Global Data Processing System (GDPS). WWWDM functions include:

*(a)* Providing specifications for data representation, including codes and exchange formats, guidelines for the design of databases and storage of observational data and processed information;

*(b)* Defining and designing proper procedures and interfaces, particularly in the area of data processing and telecommunications, to allow Members to obtain the coherent and appropriate sets of data and products required, despite the disparity in the levels of sophistication of technology and techniques of various WWW centres; and

*(c)* Monitoring AMDAR operations and the quality of basic data and output products.

1.2 AMDARDM applies to all the processes in the AMDAR operational system. This is shown schematically in Figure 1 below. It will be noted that the global system consists of several national or regional programmes with overall coordination facilitated by the WMO AMDAR Panel through its Technical Coordinator. In this appendix, each function is described with special attention given to quality management. In addition, detailed information is provided on recommended GTS codes that are subject to WMO Technical Regulations.

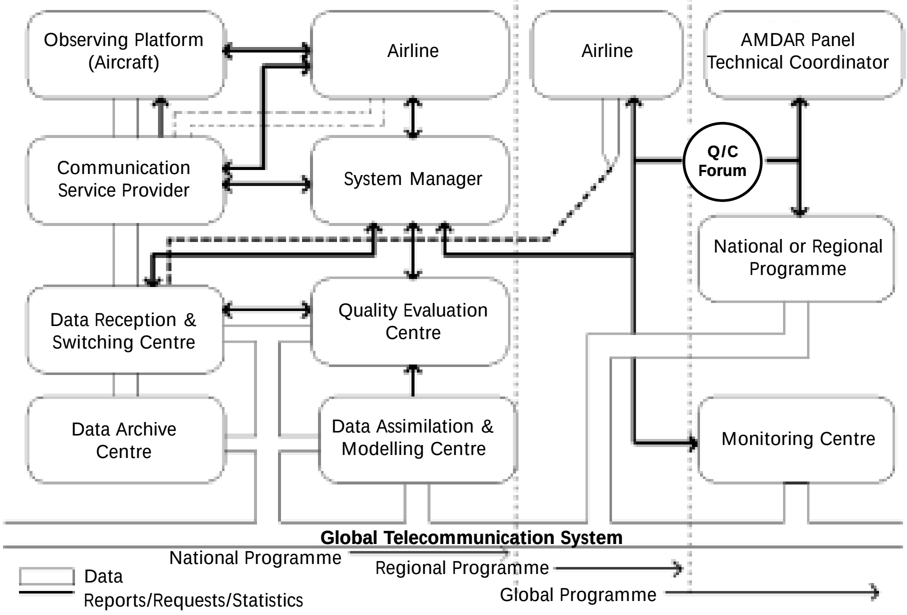
## 2. DATA MANAGEMENT FUNCTIONS

2.1 Observing platform:
*(a)* Compute and assemble observational data;
*(b)* Perform basic quality control (Q/C); and
*(c)* Transmit to ground in approved code.

2.2 Communications Service:
*(a)* Relay observations to ground network (to airline or data reception and switching centre (DRSC));
*(b)* Maintain error-free transmission;
*(c)* Process uplink commands; and
*(d)* Ensure timely delivery of data.

2.3 DRSC:
*(a)* Ingest real-time data, including data from cooperating programmes;
*(b)* Perform real-time Q/C;
*(c)* Assemble rejected data;
*(d)* Assemble bulletin;
*(e)* Eliminate duplicates;
*(f)* Pass all data (except duplicates) to QEV centre;
*(g)* Pass all data (except duplicates) to Archive centre;
*(h)* Eliminate additional rejects from QEV list;
*(i)* Pass accepted data bulletins to GTS and Numerical Processing Centre; and
*(j)* Assemble and forward reports to System manager.

*Figure 1*
*AMAR Data Management*



2.4 Data Assimilation and Numerical Modelling Centre:

*(a)* Assimilate data with other real-time information from numerical model and GTS;
*(b)* Send reject list and other monitoring information to QEV centre (including external data from GTS); and
*(c)* Put processed products on GTS.

2.5 Quality Evaluation (QEV) Centre:

*(a)* Perform near-real-time QEV on all data including rejects;
*(b)* Determine reasons for rejected data;
*(c)* Update reject list, pass to DRSC; and
*(d)* Report to System Manager.

2.6 System Manager:

*(a)* Serve as focal point for AMDAR programme;
*(b)* Analyze system status;
*(c)* Initiate Q/C actions internally through airline or communications service provider (as appropriate), notify appropriate airline of consistent bad data;
*(d)* Manage programme including data optimization and targeting schemes;
*(e)* Pass status reports, quality statistics and notifications to external parties; and
*(f)* Liaise with external programmes and monitoring centres.

2.7 Airline:

*(a)* Implement and manage on-board observing programme;
*(b)* Activate external commands, directly or through up-link control;
*(c)* Forward AMDAR messages to DRSC (as appropriate);
*(d)* Rectify problems with aircraft reporting bad data; and
*(e)* Report status to System Manager.

2.8 Regional programme participant:

*(a)* Pass data to DRSC;
*(b)* Activate Q/C reports from System Manager and external sources; and
*(c)* Provide status reports to System Manager.

2.9 External Programme:

*(a)* Insert data on GTS; and
*(b)* Disseminate Q/C reports and statistics.

2.10 Monitoring centres:

*(a)* Publish quality statistics; and

*(b)* Provide regular platform reject lists to interested parties.

2.11 AMDAR Panel Technical Coordinator:

*(a)* Maintain and publish contact list for AMDAR programmes;

*(b)* Monitor data flow statistics;

*(c)* Coordinate quality reporting activity;

*(d)* Advise programme managers and users on quality and data optimization issues; and

*(e)* Coordinate AMDARDM activity within the AMDAR Panel.

2.12 Data Archiving Centre:

*(a)* Access all AMDAR GTS data and rejects from the DRSC;

*(b)* Eliminate duplicates;

*(c)* Perform Q/C and flag data;

*(d)* Archive by individual aircraft (time series);

*(e)* Archive by month and area; and

*(f)* Publish data catalogue at regular intervals.

2.13 Q/C Forum:

*(a)* Provide network for interchange and discussion of data management issues, problems, reports, actions and initiatives.

## 3. DATA FORMATS AND CODING

3.1 Most AMDAR data are downlinked to specific addresses using ACARS standards. They are often embedded in airline messages and can be in unique, company-specific formats. Whatever the format, they must be converted into a recognized international format prior to worldwide distribution on the GTS. It is highly desirable that the processes carried out on the ground prior to dissemination are standardized so that users can be confident in the quality from any originator.

3.2 In some cases, AMDAR data are delivered to the responsible meteorological service in a recognised GTS code form. In these cases, either the airline or the communications provider has undertaken the necessary data processing. More generally, the task falls to the meteorological service designated in the particular AMDAR programme. The following steps can be identified:

| *Task No.* | *Task* | *Done by* | *Notes* |
|---|---|---|---|
| 1 | Strip AMDAR data from downlinked message | Airline | Can be done by service provider, e.g. ARINC in U.S. |
| 2 | Deliver to Met Service in standard form | Airline | Can be done by service provider |
| 3 | Perform initial Q/C | Met Service | Can be done by airline/ service provider in conjunction with Task 2 |
| 4 | Convert to WMO code | Met Service | Same as Task 3 |
| 5 | Update quality archive | Met Service | Advise Q/C Centre |
| 6 | Disseminate data through GTS bulletins | Met Service | Data selected according to established rules of programme |

### 3.3 GTS code conversion

3.3.1 There are four code forms available for the dissemination of AMDAR data:

*(a)* FM 42-XI Ext. AMDAR;
*(b)* FM 94 BUFR;
*(c)* FM 96-XI Ext. CREX; and
*(d)* AIREP.

3.3.2 FM 42 is an alphanumeric code in a series used for many years for the international exchange of meteorological data. The code consists of a series of symbolic words, letters, figures and groups. It is designed to be readily decoded manually with most data coded in easily recognized units. The code is relatively inflexible and not well suited to modern data-processing systems. Changes are difficult to accommodate and may take a long time to implement. At present, FM 42 cannot handle all the requirements of AMDAR. It is described in more detail in section 4.1.

3.3.3 FM 94 BUFR (Binary Universal Form for the Representation of meteorological data, WMO 1995) is a self-describing binary code designed to represent any meteorological data, employing a continuous binary stream. The code form may be applied to any numerical or qualitative data type. BUFR is ideally suited to the coding of AMDAR data and has the advantage of easily accommodating change or variations in observing practice. AMDAR coding in FM 94 BUFR is described in detail in section 4.2.

3.3.4 FM 96 CREX (Character form for the Representation and Exchange of data) is a self-describing code of similar design to BUFR. The essential feature of both BUFR and CREX is the use of a standard structure for each code with data descriptors provided in tabular form. The tables are easily expanded to accommodate code changes and new requirements without changing the basic code structure. New specially-adapted CREX AMDAR codes have been developed to provide AMDAR data in a form that makes it appear as a radiosonde sounding.

3.3.5 AIREP is a code designed originally for encoding manual (pilot) aircraft observations according to ICAO aviation meteorological requirements. It is not recommended for encoding AMDAR observations.

## 4. GTS CODE DESCRIPTIONS

### 4.1 FM 42-XI Ext. AMDAR - Aircraft report (aircraft meteorological data relay)

[This code is described in detail in the *Manual on Codes* (WMO-no 306). Sections of this document relevant to AMDAR data encoding are copied or summarized below.]

CODE FORM:

SECTION 1 AMDAR YYGG

SECTION 2 $i_pi_pi_p$ $I_A$. . . $I_A$ $L_aL_aL_aL_aA$ $L_oL_oL_oL_oL_oB$ YYGGgg
$S_hh_Ih_Ih_I$ $SST_AT_AT_A$ $\{SST_dT_dT_d$ or UUU$\}$ ddd/fff $TBB_A$ $Ss_1s_2s_3$

SECTION 3 333 $Fh_dh_dh_d$ $VGf_gf_gf_g$

Note: The WMO *Manual on Codes* contains 'regulations' concerning the reporting and definitions of the various code groups in FM 42; however FM 42 is commonly used for encoding aircraft reports that do not conform precisely to the written regulations. This practice is so common that the description following will designate certain rules as 'recommended'.

### 4.1.1 Specifications of code groups.

| *Group* | *Element(s)* | *Data* | *Notes* |
|---|---|---|---|
| YY GG | Time of bulletin | Day of month and hour UTC | See paragraph 4.1.2.1 below |
| $i_pi_pi_p$ | Phase of flight and observation type | Code | See paragraph 4.1.2.10 below |
| $I_A$. . . $I_A$ | Aircraft identifier | | See paragraph 4.1.2. 13 below |
| $L_aL_aL_aL_aA$ | Latitude | Deg and min | A='N' or 'S' |
| $L_oL_oL_oL_oL_oB$ | Longitude | Deg and min | B='E' or 'W' |
| YYGGgg | Time of observation | Day of month Hour and minute UTC | |
| $S_hh_Ih_Ih_I$ | Pressure altitude | Hundreds of feet with sign | $S_h$ ='F' when altitude is zero S or positive and 'A' when negative referred to 1013.2hPa |
| $SST_AT_AT_A$ | Static air temperature | Tenths °C with sign | SS = 'PS' when temperature is zero or positive and 'MS' when negative |
| $SST_dT_dT_d$ | Dew-point temperature | Tenths ° C with sign | As static air temperature |
| UUU | Relative humidity | Percent | |
| ddd | Wind direction | Degrees from true N | 001 to 360 |
| fff | Wind speed | Knots | |
| $TBB_A$ | Turbulence | Code table 0302 | 'TB' is indicator<br>See paragraph 4.1.2.14 |
| $Ss_1s_2s_3$ | Navigation system,<br>type of system,<br>Temperature precision | Code tables 3866,<br>3867,<br>3868 | 'S' is indicator<br>see paragraph 4.1.2.14 |
| 333 | Section 3 indicator | | |
| $Fh_dh_dh_d$ | Pressure altitude | Hundreds of feet | See paragraph 4.1.2.11 below |
| $VGf_gf_gf_g$ | Vertical gust | Tenths of metre/second | See paragraph 4.1.2.12 below |

Note: Leading zeroes are included, as appropriate.

### 4.1.2 Summary of regulations (rules) given in the *Manual on Codes.*

{Note: where a regulation is quoted, the WMO reference is given thus '[1-A-42.1]', meaning *Manual on Codes* Vol 1, Part A, Section A, Para 42.1}

#### 4.1.2.1 AMDAR bulletins:

'In a bulletin of AMDAR reports, the contents of Section 1 (the code name AMDAR and the group YYGG) shall be included only as the first line of the bulletin.' [1-A-42.1.1]

Note: YYGG is the day and time on which the first observation falls.

#### 4.1.2.2:

'Subject to Regulation 42.1.2.2, an AMDAR report shall include Section 2 containing at least the phase of flight indicator, the aircraft identifier, its geographical location and the time of observation, as well as the observed temperature and wind.' [1-A- 42.1.2.1]

4.1.2.3:
‘An AMDAR report from an ASDAR system shall include all data groups contained in Section 2 and shall not include Section 3.’ [1-A- 42.1.2.2]

4.1.2.4 [Recommendation]:
‘An AMDAR report from an ACARS system shall include Section 3.’ [1-A- 42.1.2.3]

4.1.2.5:
‘Use of solidi
Data shall be encoded as solidi when not available, when the data collection platform cannot acquire correct data, or in the event of parity errors.’ [1-A-42.1.2.4]

4.1.2.6:
‘Frequency of observations
The frequency of observations shall vary according to the phase of the flight (ascent, level flight or descent).’ [1-A- 42.1.3]

4.1.2.7 [Recommendation]:
‘Observations during ascent
During ascent, observations shall be made as the aircraft passes through certain pressure levels, as follows. The first level shall be the nearest multiple of 10 hPa less than pressure at take-off. The next nine observations shall be at intervals of 10 hPa. The 11th level shall be the first multiple of 50 hPa less than the 10th level. Observations shall continue at 50-hPa intervals until ascent is completed.
Note: For example, If the pressure at take-off was 1012 hPa, the first level to be reported would be 1010 hPa.’ [1-A-42.1.3.1]

4.1.2.8 [Recommendation]:
‘Routine observations
Routine observations during level flight shall be made at set intervals of time. The first observation shall be made at the first integral minute after the level flight phase has been continuously occupied for at least 15 seconds. Subsequent observations shall be made at seven-minute intervals. If level flight is interrupted by unsteady flight, the timing sequence shall begin again upon resumption of level flight.’ [1-A-42.1.3.2.1]

4.1.2.9 [Recommendation]:
‘Highest wind encountered
Highest wind encountered shall be reported when the aircraft is in level flight at a pressure level less than 600 hPa, according to the following scheme. Smoothed wind speed shall be sampled at one-second intervals, and a wind speed maximum shall be reported if and only if the wind speed:

(*a*) Is greater than 60 knots;
(*b*) Exceeds the observed wind speed at the previous routine observation by 10 knots or more; and
(*c*) Exceeds the observed wind speed at the subsequent routine observation by 10 knots or more.’ [1-A-42.1.3.2.2]

4.1.2.10 [Recommendation]:
‘Observations during descent
During descent, observations shall be made as the aircraft passes through certain pressure levels, as follows. The first level shall be the nearest multiple of 50 hPa greater than the pressure at the last observation before descent. Subsequent observations shall be at intervals of 50 hPa, until a pressure level of 700 hPa is reached. From that level, observations shall continue at 50-hPa intervals, but supplemented by observations at intervals of 10 hPa.’ [1-A-42.1.3.3]

4.1.2.11:
Phase of flight indicator $i_pi_pi_p$:

| Condition | Code | Notes |
|---|---|---|
| Unsteady | UNS | Roll angle >5° |
| Level flight | LVL | |
| Highest Wind Encountered | LVW | In level flight |
| Ascent | ASC | |
| Descent | DESC | |

Note: UNS takes precedence over all other codes.

4.1.2.12 [Recommendation]:
'Group $Fh_dh_dh_d$:
This group shall be used in an AMDAR report from an ACARS system to report the pressure altitude.
Note: Reports up to and including 700 hPa are considered to be above the aerodrome with height derived from the QNH value and the elevation of the aerodrome concerned. Heights above 700 hPa are included in accordance with the ICAO standard atmosphere. [1-A-42.3.1]
Additional Note: QNH is the value of altimeter setting which, when set on the sub-scale of an aircraft altimeter, will cause the altimeter to read the height of an airfield above mean sea level when the aircraft is at rest on the particular airfield.

4.1.2.13 [Recommendation]:
Group $VGf_gf_gf_g$:
'This group shall be used in an AMDAR report from an ACARS system to report the maximum derived equivalent vertical gust.

Notes:
(1) The qualitative severity of turbulence can be related approximately to values of derived equivalent gust velocity as follows:

| Ude | $<2 ms^{-1}$ | $2\text{-}4.5\ ms^{-1}$ | $4.5\text{-}9\ ms^{-1}$ | $>9\ ms^{-1}$ |
|---|---|---|---|---|
| Severity | Nil | Light | Heavy | Severe |

(2) The derived equivalent vertical gust, Ude is defined by aircraft design code such as the United States Federal Aviation Regulations - Part 25.341, or The Engineering Science Data Unit (London, United Kingdom) - Data Item 69023.' [1-A-42.3.2]

4.1.2.14:
Group $I_A . . . I_A$
(1) The aircraft identifier is an alphanumeric which includes, either directly or indirectly, the airline identifier and aircraft identifier and, in the case of an ASDAR report, the ASDAR flight unit identification.

(2) In an AMDAR report from an ASDAR aircraft, the aircraft identifier, by convention, ends with the letter Z. In the case of an AMDAR report from a non-ASDAR aircraft, the letter z is not appended.' [ 1-C-$I_A...I_A$]

4.1.2.15:
Code tables.
0302: $B_A$ – Turbulence

| Code figure | Meaning |
|---|---|
| 0 | None (acceleration less than 0.15g) |
| 1 | Light (acceleration from 0.15 up to but not including 0.5g) |
| 2 | Moderate (acceleration from 0.5 to 1.0g) |
| 3 | Severe (acceleration greater than 1.0g) |

Note: These accelerations, which may be positive or negative, are deviations from the normal acceleration due to gravity (1.0g).

3866: $s_1$ – Type of navigation system

| Code figure | Meaning |
|---|---|
| 0 | Inertial navigation system |
| 1 | OMEGA |

3867: $s_2$ – Type of system used

| Code figure | Meaning |
|---|---|
| 0 | ASDAR |
| 1 | ASDAR (ACARS also available but not operative) |
| 2 | ASDAR (ACARS also available and operative) |
| 3 | ACARS |
| 4 | ACARS (ASDAR also available but not operative) |
| 5 | ACARS (ASDAR also available and operative) |

3868: $s_3$ – Temperature precision

| Code figure | Meaning |
|---|---|
| 0 | Low (precision near 2.0°C) |
| 1 | High (precision near 1.0°C) |

4.2 FM 94 BUFR – A BUFR message is a continuous binary data stream. It is organized into six sections. Section 0 is 64 bits, fixed length and is used to indicate the type and length of the total message. Sections 2 to 4 are variable in length and contain data descriptors and data. Section 5 is 32 bits, fixed content to indicate the end of the BUFR message. The content of each section is best shown in tabular form. This mimics the BUFR encoding process. The contents of each section are organized into eight-bit bytes, called ‘octets’. A constraint placed on all sections is that they must contain an even number of complete octets.

*Table 1*
*Basic Structure*

| *Section Number* | *Name* | *Contents* | *Remarks* |
|---|---|---|---|
| 0 | Indicator section | Table 2 | |
| 1 | Identification | Table 3 | |
| 2 | Optional section | | Not required for AMDAR |
| 3 | Data description | Tables 4, 5 | |
| 4 | Data section | Table 6 | |
| 5 | End section | Table 7 | |

*Table 2*
*Section 0 - Indicator Section*

| *Octet Number* | *Contents* | *Fixed data bits* | *Remarks* |
|---|---|---|---|
| 1-4 | BUFR | 01000010<br>01010101<br>01000110<br>01010010 | CCITT International Alphabet No 5 |
| 5-7 | Length of message in octets | | Total length of message including Section 0 |
| 8 | BUFR edition no. | | Currently ‘2’ i.e. 00000010 |

*Table 3 (below)*
*Section 1 – Identification Section*

| *Octet Number* | *Contents* | *Fixed data bits* | *Remarks* | *Example* |
|---|---|---|---|---|
| 1-3 | Length of section, octets | | Must be even number | 00000000<br>00000000<br>00010010 = 18 |
| 4 | BUFR master table | 00000000 | WMO FM - 94 tables | 00000000 |
| 5-6 | Originating centre | | Code table 0 01 031 | 00000000<br>00000111 = 7 = NCEP |
| 7 | Update sequence number | | Zero for original BUFR messages; incremented for updates | 00000000 |
| 8 | Optional section indicator | 00000000 | Bit 1 (LHS) set to zero for AMDAR = no optional section | 00000000 |
| 9 | Data Category type | 00000100 | BUFR TABLE A | 00000100 = 4 = Single level upper-air data |
| 10 | Data Category sub-type | | Defined by local ADP centres | 00000000 |
| 11 | Version no. of master tables used | | Currently Version 2 | 00000010 = 2 |
| 12 | Version no. of local tables used | | Local use | 00000000 |
| 13 | Year of century | | | 00000001 = 1 = 2001 |
| 14 | Month | | | 00000010 = 2 = February |
| 15 | Day | | | 00010011 = 19 |
| 16 | Hour | | | 00010111 = 23 |
| 17 | Minute | | | 00111011 = 59 |
| 18- | Reserved | | Beginning here, a data processing centre may add additional information of any type for local use | 00000000 |

Note: Fixed data bits include those fixed for any AMDAR message. Other BUFR messages might differ.

*Table 4*
*Section 3 – Data description section*

| Octet number | Contents | Remarks |
|---|---|---|
| 1-3 | Length of section | Must be even |
| 4 | Set to zero | |
| 5-6 | Number of data subsets | |
| 7 | Bit 1 set = observed data<br>Bit 2 set = data compressed | |
| 8<br>9 | BUFR descriptor for Sequence of elements or single element in Aircraft report in F X Y format | First 2 bits = ‘F’<br>Second 6 bits = ‘X’<br>8 bits = ‘Y’<br>See Table 5 for relevant AMDAR descriptors. |
| 10<br>11 | BUFR descriptor for next sequence or element | Descriptors repeated as necessary |
| NN | Final octet set to zero | Needed to pad section to even number of octets |

Notes:
Octets 8 up to end of section contain descriptors for the data entries in Section 4.
For AMDAR reports these might take the form of single element descriptors (F = 0, BUFR Table B) or sequence descriptors (F = 3, BUFR Table D). For ACARS reports under 3-11-002 and related sequence 3-11-004, a special delayed replication descriptor is used, 1-01-000. This allows the number of repetitions for the particular element or elements to be entered in the data section. In Table 5 below, the entry 0-01-000 means that the following element , 0-11-034 (vertical gust velocity) is preceded in the data section by a replication count indicated by the replication factor described by 0-31-000, i.e. 0 or 1 (BUFR Table B).

*Table 5 (below)*
*Examples of AMDAR descriptors for section 3*

| Section 3 descriptor (BUFR table D) | | | Related sequence/ element descriptor (BUFR Table D/B) | | | Related sequence/ element descriptor (BUFR Table D/B) | | | Element descriptor for Section 4 (BUFR Table B) | | | Element |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F | X | Y | | | | | | | | | | |
| 3 | 11 | 001 | 3 | 01 | 051 | 0 | 01 | 006 | 0 | 01 | 006 | Aircraft identifier |
| | | | | | | 0 | 02 | 061 | 0 | 02 | 061 | Navigation System |
| | | | | | | 3 | 01 | 011 | 0 | 04 | 001 | Year |
| | | | | | | | | | 0 | 04 | 002 | Month |
| | | | | | | | | | 0 | 04 | 003 | Day |
| | | | | | | 3 | 01 | 012 | 0 | 04 | 004 | Hour |
| | | | | | | | | | 0 | 04 | 005 | Minute |
| | | | | | | 3 | 01 | 021 | 0 | 05 | 001 | Latitude |
| | | | | | | | | | 0 | 06 | 001 | Longitude |
| | | | | | | 0 | 08 | 004 | 0 | 08 | 004 | Phase of flight |
| | | | 0 | 07 | 002 | 0 | 07 | 002 | 0 | 07 | 002 | Altitude |
| | | | 0 | 12 | 001 | 0 | 12 | 001 | 0 | 12 | 001 | Temperature |
| | | | 0 | 11 | 001 | 0 | 11 | 001 | 0 | 11 | 001 | Wind Direction |
| | | | 0 | 11 | 002 | 0 | 11 | 002 | 0 | 11 | 002 | Wind speed |
| | | | 0 | 11 | 031 | 0 | 11 | 031 | 0 | 11 | 031 | Degree of turbulence |
| | | | 0 | 11 | 032 | 0 | 11 | 032 | 0 | 11 | 032 | Height of base of turbulence |
| | | | 0 | 11 | 033 | 0 | 11 | 033 | 0 | 11 | 033 | Height of top of turbulence |
| | | | 0 | 20 | 041 | 0 | 20 | 041 | 0 | 20 | 041 | Airframe icing |
| 3 | 11 | 002 | 3 | 01 | 065 | 0 | 01 | 006 | 0 | 01 | 006 | Flight number |
| | | | | | | 0 | 01 | 008 | 0 | 01 | 008 | Aircraft registration number |
| | | | | | | 0 | 02 | 001 | 0 | 02 | 001 | Type of station |

| Section 3 descriptor (BUFR table D) | | | Related sequence/ element descriptor (BUFR Table D/B) | | | Related sequence/ element descriptor (BUFR Table D/B) | | | Element descriptor for Section 4 (BUFR Table B) | | | Element |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F | X | Y | | | | | | | | | | |
| | | | | | | 0 | 02 | 002 | 0 | 02 | 002 | Type of instrument for wind measurement |
| | | | | | | 0 | 02 | 005 | 0 | 02 | 005 | Precision of temperature observation |
| | | | | | | 0 | 02 | 062 | 0 | 02 | 062 | Type of aircraft data relay system |
| | | | | | | 0 | 02 | 070 | 0 | 02 | 070 | Original specification of latitude/longitude |
| | | | | | | 0 | 02 | 065 | 0 | 02 | 065 | ACARS ground receiving station |
| 3 | 11 | 002 | 3 | 01 | 066 | 3 | 01 | 011 | 0 | 04 | 001 | Year |
| | | | | | | | | | 0 | 04 | 002 | Month |
| | | | | | | | | | 0 | 04 | 003 | Day |
| | | | | | | 3 | 01 | 013 | 0 | 04 | 004 | Hour |
| | | | | | | | | | 0 | 04 | 005 | Minute |
| | | | | | | | | | 0 | 04 | 006 | Second |
| | | | | | | 3 | 01 | 023 | 0 | 05 | 002 | Latitude |
| | | | | | | | | | 0 | 06 | 002 | Longitude |
| | | | | | | 0 | 07 | 004 | 0 | 07 | 004 | Pressure |
| | | | | | | 0 | 02 | 064 | 0 | 02 | 064 | Roll angle quality |
| | | | | | | 0 | 08 | 004 | 0 | 08 | 004 | Phase of flight |
| | | | 3 | 11 | 003 | 0 | 10 | 070 | 0 | 10 | 070 | Indicated aircraft altitude |
| | | | | | | 0 | 11 | 001 | 0 | 11 | 001 | Wind direction |
| | | | | | | 0 | 11 | 002 | 0 | 11 | 002 | Wind speed |
| | | | | | | 0 | 12 | 001 | 0 | 12 | 001 | Temperature/dry-bulb temperature |
| | | | | | | 0 | 13 | 002 | 0 | 13 | 002 | Mixing ratio |
| | | | 3 | 11 | 004 | 1 | 01 | 000 | 1 | 01 | 000 | Delayed replication of one descriptor |
| | | | | | | 0 | 31 | 000 | 0 | 31 | 000 | Replication count |
| | | | | | | 0 | 11 | 034 | 0 | 11 | 034 | Vertical gust velocity |
| | | | | | | 1 | 01 | 000 | 1 | 01 | 000 | |
| | | | | | | 0 | 31 | 000 | 0 | 31 | 000 | |
| | | | | | | 0 | 11 | 035 | 0 | 11 | 035 | Vertical gust acceleration |
| | | | | | | 1 | 01 | 000 | 1 | 01 | 000 | |
| | | | | | | 0 | 31 | 000 | 0 | 31 | 000 | |
| | | | | | | 0 | 11 | 075 | 0 | 11 | 035 | Mean turbulence intensity (EDR) |
| | | | | | | 1 | 01 | 000 | 1 | 01 | 000 | |
| | | | | | | 0 | 31 | 000 | 0 | 31 | 000 | |
| | | | | | | 0 | 11 | 076 | 0 | 11 | 076 | Peak turbulence intensity (EDR) |
| | | | | | | 1 | 01 | 000 | 1 | 01 | 000 | |
| | | | | | | 0 | 31 | 000 | 0 | 31 | 000 | |
| | | | | | | 0 | 33 | 025 | 0 | 33 | 025 | ACARS interpolated values |
| | | | | | | 1 | 01 | 000 | 1 | 01 | 000 | |
| | | | | | | 0 | 31 | 000 | 0 | 31 | 000 | |
| | | | | | | 0 | 33 | 026 | 0 | 33 | 026 | Mixing ratio quality |

*Table 6*
*Section 4 – Data Section*

| *Octet number* | *Contents* | *Remarks* |
|---|---|---|
| 1-3 | Length of section (octets) | |
| 4 | Set to zero | Reserved |
| 5- | Binary data | Defined by Section 3 descriptors |
| Final octet | | Padded as necessary with zeros |

*Table 6a (below)*
*Section 4 elements as described by descriptor examples of Table 5.*

| Section 3 element descriptor (BUFR table B) | | | Element | Unit[1] | No. of bits in Section 4 (Data width) | Scale[2] | Reference value[3] |
|---|---|---|---|---|---|---|---|
| 0 | 01 | 006 | Aircraft identifier | CCITT IA5 | 64 | 0 | 0 |
| 0 | 02 | 061 | Navigation System | Code Table[4] | 3 | 0 | 0 |
| 0 | 04 | 001 | Year | Year | 12 | 0 | 0 |
| 0 | 04 | 002 | Month | Month | 4 | 0 | 0 |
| 0 | 04 | 003 | Day | Day | 6 | 0 | 0 |
| 0 | 04 | 004 | Hour | Hour | 5 | 0 | 0 |
| 0 | 04 | 005 | Minute | Minute | 6 | 0 | 0 |
| 0 | 05 | 001 | Latitude (High accuracy) | Degree | 25 | 5 | -9000000 |
| 0 | 06 | 001 | Longitude (High accuracy) | Degree | 26 | 5 | -18000000 |
| 0 | 08 | 004 | Phase of flight | Code table | 3 | 0 | 0 |
| 0 | 07 | 002 | Altitude | m | 16 | -1 | -40 |
| 0 | 12 | 001 | Temperature | Kelvin | 12 | 1 | 0 |
| 0 | 11 | 001 | Wind Direction | Degree true | 9 | 0 | 0 |
| 0 | 11 | 002 | Wind speed | $ms^{-1}$ | 12 | 1 | 0 |
| 0 | 11 | 031 | Degree of turbulence | Code table | 4 | 0 | 0 |
| 0 | 11 | 032 | Height of base of turbulence[5] | m | 16 | -1 | -40 |
| 0 | 11 | 033 | Height of top of turbulence[5] | m | 16 | -1 | -40 |
| 0 | 20 | 041 | Airframe icing | Code table | 4 | 0 | 0 |
| 0 | 01 | 008 | Aircraft registration number | CCITT IA5 | 64 | 0 | 0 |
| 0 | 02 | 001 | Type of station | Code table | 2 | 0 | 0 |
| 0 | 02 | 002 | Type of instrument for wind measurement | Flag table[4] | 4 | 0 | 0 |
| 0 | 02 | 005 | Precision of temperature observation | Kelvin | 7 | 2 | 0 |
| 0 | 02 | 062 | Type of aircraft data relay system | Code table | 4 | 0 | 0 |
| 0 | 02 | 070 | Original specification of latitude/longitude | Code table | 4 | 0 | 0 |
| 0 | 02 | 065 | ACARS ground receiving station | CCITT IA5 | 40 | 0 | 0 |
| 0 | 04 | 006 | Second | Second | 6 | 0 | 0 |
| 0 | 05 | 002 | Latitude (coarse) | Degree | 15 | 2 | -9000 |
| 0 | 06 | 002 | Longitude (coarse) | Degree | 15 | 2 | -9000 |
| 0 | 07 | 004 | Pressure | Pascal | 14 | -1 | 0 |
| 0 | 02 | 063 | Roll angle | Degree | 15 | 2 | -18000 |
| 0 | 02 | 064 | Roll angle quality | Code table | 4 | 0 | 0 |
| 0 | 10 | 070 | Indicated aircraft altitude | m | 16 | 0 | -400 |
| 0 | 13 | 002 | Mixing ratio | $kgkg^{-1}$ | 14 | 5 | 0 |
| 0 | 11 | 034 | Vertical gust velocity | $ms^{-1}$ | 11 | 1 | -1024 |
| 0 | 11 | 035 | Vertical gust acceleration | $ms^{-2}$ | 14 | 2 | -8192 |
| 0 | 11 | 075 | Mean turbulence intensity(EDR) | $m^{2/3}s^{-1}$ | 8 | 2 | 0 |
| 0 | 11 | 076 | Peak turbulence intensity(EDR) | $m^{2/3}s^{-1}$ | 8 | 2 | 0 |

| Section 3 element descriptor (BUFR table B) | | | Element | Unit[1] | No. of bits in Section 4 (Data width) | Scale[2] | Reference value[3] |
|---|---|---|---|---|---|---|---|
| 0 | 33 | 025 | ACARS interpolated values | Code table | 3 | 0 | 0 |
| 0 | 33 | 026 | Mixing ratio quality | Code table | 6 | 0 | 0 |
| 0 | 11 | 037 | Turbulence (EDR) Index[6] | Code table | 6 | 0 | 0 |
| 0 | 11 | 038 | Time of occurrence of peak EDR[6] | Code table | 5 | 0 | 0 |

Notes:

General: Some new BUFR descriptors were adopted in November 2002.

1. Basic unit before scaling.
2. Power of 10 by which unit is multiplied to obtain desired resolution e.g. if wind speed is 3.2 m/s, data entry is 32 = binary 000000100000 (12 bit).
3. The reference value is the value that is to be subtracted from the source data after scaling; e.g. if latitude is 10N, the scaled value will be 10x105 = 1 000 000 and the data entry will be 1 000 000 + 9 000 000 = 10 000 000 = binary 0100110001001011010000000 (25 bit).
4. See tables below and code and flag tables associated with BUFR Table B.
5. Not reported in AMDAR.
6. 'Single element' descriptors not shown in Table 5.

AMDAR code and flag tables:

### 0 02 002
### Type of instrumentation for wind measurement

| Bit No. | Type of Instrumentation and original units for wind measurement |
|---|---|
| 0 | (measured in $ms^{-1}$ unless otherwise indicated) |
| 1 | Certified Instruments |
| 2 | Originally measured in knots |
| 3 | Originally measured in $kmh^{-1}$ |
| All 4 | Missing value |

Note: Bit is set to '1' = true, '0' = false. All 4 bits set to '1' indicates no information on wind instrumentation.

### 0 02 061
### Aircraft navigational system

| Code figure | |
|---|---|
| 0 | Inertial navigation system |
| 1 | OMEGA |
| 2-6 | Reserved |
| 7 | Missing value |

Note: Missing value (all code tables) is indicated by all bits set to '1'.

### 0 02 062
### Type of aircraft data relay system

| Code figure | |
|---|---|
| 0 | ASDAR |
| 1 | ASDAR (ACARS also available but not operative) |
| 2 | ASDAR (ACARS also available and operative) |
| 3 | ACARS |
| 4 | ACARS (ASDAR also available but not operative) |
| 5 | ACARS (ASDAR also available and operative) |
| 6-14 | Reserved |
| 15 | Missing value |

### 0 02 064

### Aircraft roll angle quality

| Code figure | Meaning |
|---|---|
| 0 | Good |
| 1 | Bad |
| 2 | Reserved |
| 3 | Missing value |

Note: Bad is currently defined as a roll angle >5 degrees from vertical.

### 0 02 070

### Original specification of latitude/longitude

| Code figure | |
|---|---|
| 0 | Actual location in seconds |
| 1 | Actual location in minutes |
| 2 | Actual location in degrees |
| 3 | Actual location in decidegrees |
| 4 | Actual location in centidegrees |
| 5 | Referenced to checkpoint in seconds |
| 6 | Referenced to checkpoint in minutes |
| 7 | Referenced to checkpoint in degrees |
| 8 | Referenced to checkpoint in decidegrees |
| 9 | Referenced to checkpoint in centidegrees |
| 10 | Actual location in tenths of a minute |
| 11 | Referenced to checkpoint in tenths of a minute |
| 12-14 | Reserved |
| 15 | Missing value |

### 0 08 004

### Phase of aircraft flight

| Code figure | |
|---|---|
| 0-1 | Reserved |
| 2 | Unsteady (UNS) |
| 3 | Level flight, routine observation (LVR) |
| 4 | Level flight, highest wind encountered (LVW) |
| 5 | Ascending (ASC) |
| 6 | Descending (DES) |
| 7 | Missing value |

### 0 11 031

### Degree of turbulence

| Code figure | | |
|---|---|---|
| 0 | Nil | In cloud |
| 1 | Light | |
| 2 | Moderate | |
| 3 | Severe | |
| 4 | Nil | In clear air |
| 5 | Light | |
| 6 | Moderate | |
| 7 | Severe | |
| 8 | Nil | Cloud/clear air not specified |
| 9 | Light | |
| 10 | Moderate | |
| 11 | Severe | |
| 12 | Extreme, in clear air | |
| 13 | Extreme, in cloud | |
| 14 | Extreme, cloud/clear air not specified | |
| 15 | Missing value | |

### 0 11 037
### Turbulence index

| Code figure | Average Value of Eddy Dissipation Rate (avg.) ($m^{2/3}s^{-1}$) | Peak Value of Eddy Dissipation Rate (peak) ($m^{2/3}s^{-1}$) |
|---|---|---|
| 0 | avg. <0.1 | peak <0.1 |
| 1 | avg. <0.1 | 0.1 <= peak <0.2 |
| 2 | 0.1 <= avg. <0.2 | 0.1 <= peak <0.2 |
| 3 | avg. <0.1 | 0.2 <= peak <0.3 |
| 4 | 0.1 <= avg. <0.2 | 0.2 <= peak <0.3 |
| 5 | 0.2 <= avg. <0.3 | 0.2 <= peak <0.3 |
| 6 | avg. <0.1 | 0.3 <= peak <0.4 |
| 7 | 0.1 <= avg. <0.2 | 0.3 <= peak <0.4 |
| 8 | 0.2 <= avg. <0.3 | 0.3 <= peak <0.4 |
| 9 | 0.3 <= avg. <0.4 | 0.3 <= peak <0.4 |
| 10 | avg. <0.1 | 0.4 <= peak <0.5 |
| 11 | 0.1 <= avg. <0.2 | 0.4 <= peak <0.5 |
| 12 | 0.2 <= avg. <0.3 | 0.4 <= peak <0.5 |
| 13 | 0.3 <= avg. <0.4 | 0.4 <= peak <0.5 |
| 14 | 0.4 <= avg. <0.5 | 0.4 <= peak <0.5 |
| 15 | avg. <0.1 | 0.5 <= peak <0.8 |
| 16 | 0.1 <= avg. <0.2 | 0.5 <= peak <0.8 |
| 17 | 0.2 <= avg. <0.3 | 0.5 <= peak <0.8 |
| 18 | 0.3 <= avg. <0.4 | 0.5 <= peak <0.8 |
| 19 | 0.4 <= avg. <0.5 | 0.5 <= peak <0.8 |
| 20 | 0.5 <= avg. <0.8 | 0.5 <= peak <0.8 |
| 21 | avg. <0.1 | 0.8 <= peak |
| 22 | 0.1 <= avg. <0.2 | 0.8 <= peak |
| 23 | 0.2 <= avg. <0.3 | 0.8 <= peak |
| 24 | 0.3 <= avg. <0.4 | 0.8 <= peak |
| 25 | 0.4 <= avg. <0.5 | 0.8 <= peak |
| 26 | 0.5 <= avg. <0.8 | 0.8 <= peak |
| 27 | 0.8 <= avg. | 0.8 <= peak |
| 28 | Nil | Nil |
| 29-62 | Reserved | Reserved |
| 63 | Missing value | Missing value |

### 0 11 038
### Time of Occurrence of Peak Eddy Dissipation Rate

| Code figure | Minutes prior to observation time (min) |
|---|---|
| 0 | min < 1 |
| 1 | 1 <= min < 2 |
| 2 | 2 <= min < 3 |
| 3 | 3 <= min < 4 |
| 4 | 4 <= min < 5 |
| 5 | 5 <= min < 6 |
| 6 | 6 <= min < 7 |
| 7 | 7 <= min < 8 |
| 8 | 8 <= min < 9 |
| 9 | 9 <= min < 10 |
| 10 | 10 <= min < 11 |
| 11 | 11 <= min < 12 |
| 12 | 12 <= min < 13 |
| 13 | 13 <= min < 14 |
| 14 | 14 <= min < 15 |
| 15 | No timing information available |
| 16-30 | Reserved |
| 31 | Missing value |

### 0 20 041
### Airframe Icing

| Code figure | |
|---|---|
| 0 | No icing |
| 1 | Light icing |
| 2 | Light icing In cloud |
| 3 | Light icing In precipitation |
| 4 | Moderate icing |
| 5 | Moderate icing in cloud |
| 6 | Moderate icing in precipitation |
| 7 | Severe icing |
| 8 | Severe icing in cloud |
| 9 | Severe icing in precipitation |
| 10 | Trace of icing |
| 11 | Trace of icing in cloud |
| 12 | Trace of icing in precipitation |
| 13-14 | Reserved |
| 15 | Missing value |

### 0 33 025
### ACARS interpolated values

| Code figure | |
|---|---|
| 0 | Time interpolated, latitude and longitude reported |
| 1 | Time reported, latitude and longitude interpolated |
| 2 | Time, latitude, and longitude interpolated |
| 3 | Time, latitude, and longitude reported |
| 4-6 | Reserved |
| 7 | Missing value |

### 0 33 026
### Moisture quality

| Code figure | |
|---|---|
| 0 | Normal operations, measurement mode |
| 1 | Normal operations, non-measurement mode |
| 2 | Small RH |
| 3 | Humidity element is wet |
| 4 | Humidity element contaminated |
| 5 | Heater fail |
| 6 | Heater fail and wet/contaminated humidity element |
| 7 | At least one of the input parameters used in the calculation of mixing ratio is invalid |
| 8 | Numeric error |
| 9 | Sensor not installed |
| 10-62 | Reserved |
| 63 | Missing value |

## 5. PRACTICAL APPLICATION OF WMO GTS CODE

5.1 FM 42-XI Ext is a traditional alphanumeric code. It is well suited to low volume or manual applications. It is unlikely to be extended to cater for all possible downlink formats.

5.2 FM 94 BUFR is ideally suited to high-volume numerical processing applications. It is readily expanded to allow for changes in downlink formats and elements measured. This is achieved by adding to existing tables or developing new ones. No fundamental changes are necessary in encoding or decoding software.

5.3 This Appendix to the *AMDAR Manual* provides a summary of the recommended GTS codes. For a complete description see WMO *Manual on Codes* (WMO-No. 306).

## 6. DATA DISSEMINATION

6.1 Once encoded in a suitable GTS code, AMDAR data are organized into ‘bulletins’ at the data reception centres. A bulletin might consist of a batch of observations from a single aircraft or observations from several aircraft. Bulletins are usually compiled at regular intervals such that delays in data reception are kept as far as possible within model cut-off times. As a further aid to data management, it is desirable to batch data in specific geographical regions. This will allow switching centres to direct data to appropriate users without the need to sort individual observations.

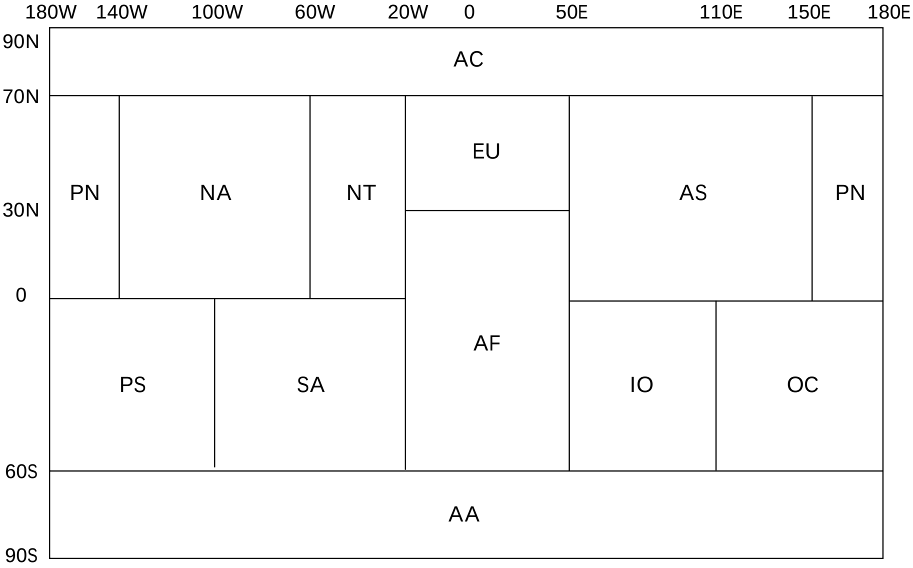
6.2 AMDAR GTS bulletin headers should take the form:

*(a)* For FM 42 data: UDAAII<<originating centre>>

where: UD signifies FM42 AMDAR; and

AA indicates geographical region appropriate for the first observation in the bulletin, according to the table below.

*(b)* For FM 94 BUFR data, the GTS bulletin headers should take the form: IUAX01 <<originating centre>>.

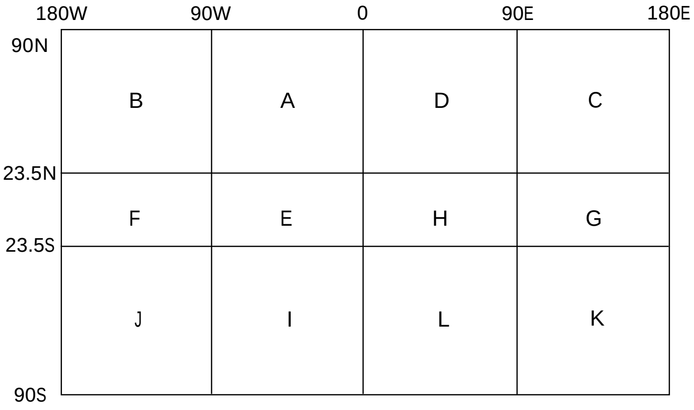


where: I signifies BUFR code;

U signifies upper air data;

A signifies single level AMDAR data; and

X signifies the geographical region, according to the following table:



Note: If the BUFR bulletin contains data from several aircraft flying in different sectors of the globe, X should be coded ‘X’.

## 7.
## DATA QUALITY CONTROL

7.1 An important element of AMDARDM is data quality control (Q/C). Q/C applies to all stages of the data management chain, from on-board data processing, message compilation, air-ground data link, coding, data dissemination, data assimilation and data archiving.

7.2 AMDAR Quality Management (AMDARQM) is a subset of AMDARDM and is designed as a closed feedback system. Q/C activities take place on various timescales according to data application. The basic building blocks are:
*(a)* On-board quality control;
*(b)* Real-time quality control prior to bulletin assembly and data dissemination;
*(c)* Real-time quality control for numerical model assimilation;
*(d)* Near real-time quality evaluation;
*(e)* Quality control for data archiving; and
*(f)* Quality feedback and reporting system.

The AMDAR Panel guidelines appropriate to each of the above elements are given in sections 7.3 to 7.8.

7.3 On-board quality control.
*(a)* Range or gross error check:

Data values falling outside the 'range' intervals given in the table below or already flagged in the aircraft data acquisition system shall be replaced by values representing missing or erroneous data.

| *Element* | *Unit* | *Range* |
|---|---|---|
| Pressure altitude | Foot (ft) | -1000 to 50 000 |
| Static air temperature | °C | -99 to 99 |
| Wind direction | ° from true N | 1 to 360 |
| Wind speed | Knot (kt) | 0 to 800 |
| Latitude | Degree: minute | 90:00S to 90:00N |
| Longitude | Degree: minute | 180:00E to 180:00W |
| Time (UTC) | Hour: Minute: Second | 00:00:00 to 23:59:59 |
| Turbulence (g) | g | -3 to 6 |
| Turbulence (DEVG) | $ms^{-1}$ | 0 to 20 |
| Turbulence (EDR) | $m^{2/3}s^{-1}$ | 0 to 1 |
| Humidity (RH) | % | 0 to 100 |
| Humidity (dew pt.) | °C | -99 to +49 |
| Humidity (mixing ratio) | gram/kg | 0 to 100 |

Note: Time (UTC) should be checked routinely against the aircraft master clock.

*(b)* Smoothing and sequential checks:
On most modern aircraft the data are updated several times per second and individual samples may have been smoothed and/or subjected to quality checks in the avionics system. It is desirable that this process is standardized to ensure consistency between observations from different data acquisition and on-board computing systems. The recommended procedures are outlined below.

(i) Data should be smoothed as shown in the table below to reduce random error and standardise representativeness;

| *Element* | | *Averaging Time(s)* | |
|---|---|---|---|
| | | *Ascent/descent phase* | *Level flight phase,>20 000ft* |
| 7 | Pressure altitude | 10s | 30s |
| 8 | Static air temperature | 10s | 30s |
| 9 | Humidity, RH | 10s | 30s |
| 10 | Wind direction | 10s | 30s |
| 11 | Wind speed | 10s | 30s |

Note: The smoothing time is the arithmetic averaging time to be applied.

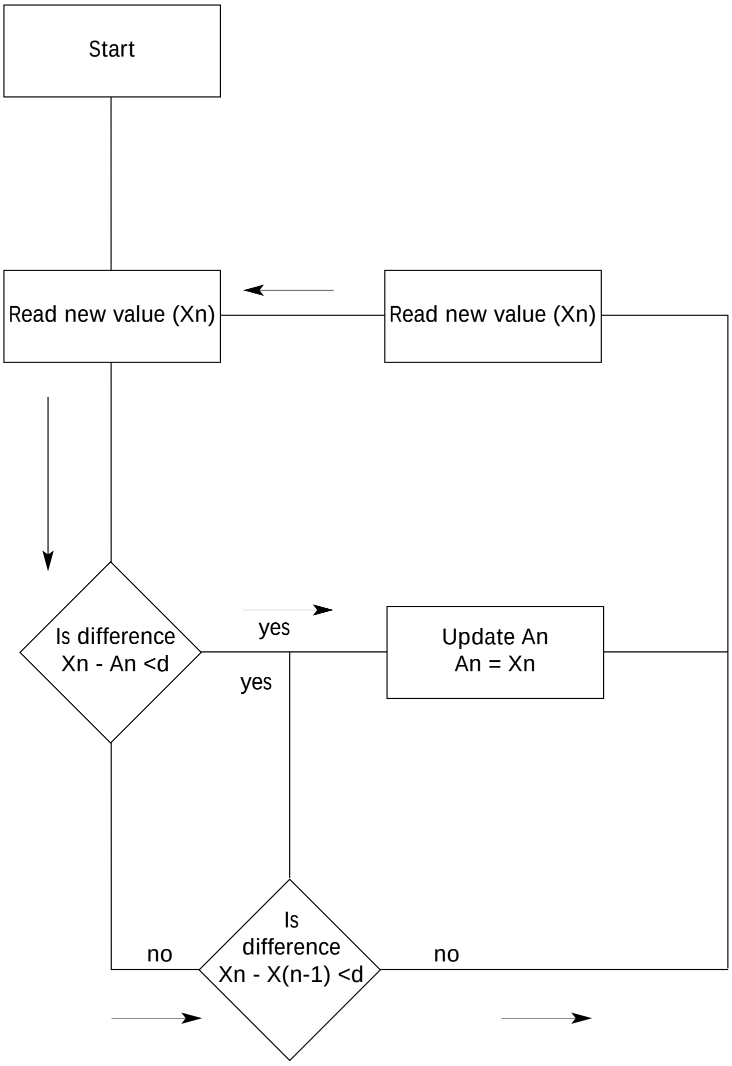
An alternative, efficient approach is to use a continuous exponential smoothing algorithm such as that given below:

If $y_n$ is the nth raw data sample, t the sampling interval, T the averaging time and $Y_n$ the corresponding smoothed value, then:

$$Y_n = 3t(y_n - Y_n\text{-}1)/\ T + Y_{n-1}$$

Note: It is assumed that T is much larger than t e.g. T=10s, t<1s.

(ii) To remove ‘spikes’ from noisy data, a sequential quality check can be employed. This check is especially important when a maximum value is to be observed (e.g. maximum wind). A suitable algorithm is given below:



Example: d = 5

Raw values and corresponding accepted values are in bold.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Xn | **6** | **7** | **4** | **10** | **6** | **3** | **10** | **8** | **9** | At start |
| An | | 6 | 7 | 4 | 4 | 6 | 3 | 3 | 8 | At start |
| X(n-1) | | 6 | 7 | 4 | 10 | 6 | 3 | 10 | 8 | At start |
| An | | **7** | **4** | **4** | **6** | **3** | **3** | **8** | **9** | Finish |
| X(n-1) | | 7 | 4 | 10 | 6 | 3 | 10 | 8 | 9 | Finish |

Note: This algorithm rejects single values (Xn) equal or exceeding a designated difference (d) from the previous accepted value (An) and replaces it with the previous accepted value. If a step change occurs, the new level is accepted after one rejection.

(iii) 'Buddy' checks:
Most aircraft carry multiple sensor arrays. For example, up to four temperature probes and at least two pitot-static heads might be installed, thus making it possible to make more sophisticated checks by comparing data with the alternative sensor or sensors.

(iv) Interdependence:
Because the measured elements are highly interdependent, it is possible to flag doubtful data computed from two or more basic measurements. For example, if comparison checks show that static air temperature is doubtful, then wind speed and wind direction can be flagged as doubtful.

## 7.4 Quality control prior to bulletin assembly and data dissemination.

7.4.1 This process should be carried out in real time. The principal objective is to pass high-quality data to the GTS and to the local data assimilation and numerical modelling centre with a minimum of delay.

The recommended Q/C checks to be applied are:
(*a*) Check for transmission errors;
(*b*) Check for duplicates;
(*c*) Range check (as given in 7.3 above);
(*d*) Sequential position and time check for time series data from single aircraft; and
(*e*) Check against QEV reject list.

7.4.2 Data passing these checks are inserted into the GTS and to any local numerical processing centre or operational centre as appropriate. All data (except duplicates) are passed to the QEV centre.

## 7.5 Quality Evaluation (QEV)

7.5.1 Here data are checked in near real time against forecast fields (typically the background field in a numerical model). Various reports and/or statistics are produced for each aircraft contributing data to specific internal programmes or perhaps to external programmes as resources allow. The variables subjected to the model comparisons are usually temperature and wind vector.

7.5.2 For those programmes for which the QEV centre has responsibility, the following actions are recommended:
(*a*) Data availability check;
(*b*) Data timeliness check;
(*c*) Gross error check; and
(*d*) Systematic error check.

7.5.3 For each aircraft, monthly or (preferably) weekly statistics are produced and regular reports provided to the System Manager and to other interested parties. (Daily reports of gross errors are highly desirable at the System Manager level.)

Notification of aircraft with unacceptable numbers of rejected data or mean ‘errors’ greater than predetermined levels are classified as rejects and this information, ideally, should be passed automatically to the real-time Q/C centre (see 7.4 above) to eliminate these data from GTS bulletins. The recommended criteria are given in the following table:

| *Element* | *Bias (mean difference)* | *RMS difference* | *Gross error* |
|---|---|---|---|
| Air temperature | 1.5°K | 2.0°K | 5.0°K |
| Wind speed | 1.8ms$^{-1}$ | 8.0ms$^{-1}$ | 10.0ms$^{-1}$ |
| Wind direction | 10° | 50° | 90° |
| Wind vector | | 7.0ms$^{-1}$ | 10.0ms$^{-1}$ |

Notes:

*(a)* The minimum number of observations contributing to mean differences is 20.

*(b)* The rejection level for gross error notification is recommended at 25 per cent. (This means that a variable with 25 per cent gross errors is considered unacceptable even if residual differences are within limits.)

7.6 Data assimilation.

7.6.1 This is a similar process to QEV except that rejection of data takes place on shorter timescales. ‘Blacklists’ of suspect platforms and reject data lists should be passed to the QEV centre, where they can be filtered to limit action to the local programme. Ideally, these reports are then passed to the System Manager for internal action or external notification as appropriate.

## 8.
## SYSTEM MANAGEMENT

8.1 The System Management function is central to AMDAR data management. The main components are:

*(a)* Quality management;
*(b)* Programme management;
*(c)* System control; and
*(d)* Internal and external liaison.

8.2 Quality management.
The main functions are:

*(a)* Monitoring quality reports and statistics provided from internal and external Q/C sources;
*(b)* Initiating remedial action for internal system elements; and
*(c)* Liaising with external agencies on quality matters.

8.3 Programme management.

8.3.1 Data optimization.
The aircraft supplying observations in AMDAR programmes fly on timetables and routes determined by factors outside the influence of the meteorological services receiving the data. Inevitably, this leads to the potential of generating excessive numbers of observations in the vicinity of busy airports and on congested air routes.

It is feasible to control individual aircraft observing schedules by uplinking commands. In principle, this can be done continuously, but in practice it is best achieved by selecting options pre-programmed on the aircraft and adjusting the related parameters on a daily basis according to airline schedules.

Clearly, such adjustments are only feasible through close cooperation with the appropriate airline. Suggested controllable functions are:

| *Function* | *Command* | *Default* | *Remarks* |
|---|---|---|---|
| Enable AMDAR | On/off | Off | |
| Geographical region | On /off | Off | Report in selected region |
| Airport selection | On/off | Off | Ascent/descent selection |
| Level flight observations | On/off | On | Interval selection |
| Ascent observations | On/off | On | Time and/or pressure level selection |
| Descent observations | On/off | On | Time and/or pressure level selection |

8.3.2 Data targeting.
This function is closely related to data optimization and is needed for the following purposes:

*(a)* To respond to specific meteorological events or set criteria;
*(b)* To provide data at specific data sparse locations; and
*(c)* To provide data for other programmes under special agreements.

8.4 System control.
This function involves day-to-day monitoring of the performance of the individual programme and adjusting system parameters as necessary, e.g. optimizing transmission schedules and content or adjusting real-time Q/C parameters. For regional programmes, it could involve adjusting national contributions in cooperation with partners to assist data optimization or improve cost efficiency.

8.5 The System Manager is the focal point for the individual AMDAR programme. The System Manager should have access to all functions and components of the individual programme and have efficient links to relevant external programmes and appropriate services and organizations.

## 9. DATA ARCHIVING

9.1 General principles.
AMDAR data are archived for a variety of purposes, for example:

*(a)* Raw downlinked data might be stored by the originating airline for their own meteorological or engineering purposes. These data are generally not in a form suitable for public dissemination (i.e. via the GTS) and are often treated as confidential to the originator;
*(b)* AMDAR data disseminated on the GTS may be archived along with other meteorological data for meteorological or climate applications;
*(c)* Data received in meteorological centres but not circulated on the GTS either through data selection or quality control rejection should also be archived locally for future investigations; and
*(d)* Long-term quality monitoring.

9.2 Archive formats.
As a first step, all AMDAR data archived should be ‘as received’. Duplicates (identical in all respects) should be eliminated. If received data are known to have been subjected to quality control prior to reception, this should be noted in the individual records. Ideally, two types of archive should be maintained:

*(a)* A time series of observations for each aircraft; and
*(b)* For suitable geographical regions, data sets of observations by calendar month and year.

9.3 Special data requirements.
Many AMDAR reports are identified by an aircraft code, withholding the originating aircraft registration number from public dissemination. In order that the

particular aircraft might be identified in the future (subject to owner agreement) it is desirable to store linking information to the data origins (e.g. programme name, contact organization, etc.) with each record.

## 10. GLOBAL COOPERATION

10.1 Q/C forum.
This is a loose network linking programmes, users and programme managers to information on AMDAR programmes and data. Central coordination is provided by the WMO AMDAR Panel mainly through its Technical Coordinator and facilitated though the AMDAR Panel Web Page on the WMO web server. This page will be developed to provide links to other sources of AMDAR Q/C data and provide contact lists for AMDAR programmes.

## REFERENCES

WMO, 1993. *Guide on World Weather Watch Data Management* (WMO-No. 788).

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APPENDIX V

# THE AMDAR PANEL

## 1. INTRODUCTION

1.1 Following on from the successful ASDAR programme, the AMDAR Panel was formally established in March 1998. At the inaugural meeting the goal, terms of reference, membership and operating procedures were agreed upon. (These are reproduced in full in Annex I and Annex II, respectively) The goal of the AMDAR Panel is to enhance the upper-air component of the Composite Observing System of the WWW. This is to be achieved through cooperation among Members in the acquisition, exchange and quality control of meteorological observations from aircraft using automated reporting systems.

1.2 The Panel recognized a fundamental principle of WMO to broaden and enhance the free and unrestricted international exchange of data, and noted the increasing availability of aircraft platforms with suitable sensors, avionics and communications systems. The Panel was established to take advantage of the opportunity to use these new cost-effective global data sources to better respond to the needs of WMO and WMO-sponsored programmes such as the WWW, World Climate Research Programme (WCRP), Global Climate Observing System (GCOS) and Global Ocean Observing System (GOOS), and to bring potential benefits to end-users in aviation and other communities. The Panel is considered necessary to ensure a coordinated approach to the development of AMDAR as an operational global programme with particular benefits in data-sparse areas of the world.

1.3 The Panel has held four annual meetings since the Inaugural meeting in March 1998. To help facilitate the work of the Panel, a Technical Coordinator (TC) was appointed in April 1999. An AMDAR Trust Fund was established to assist with the work of the Panel and is reliant on voluntary contributions from Panel members.

## 2. AMDAR PANEL – INFORMATION AND POINTS OF CONTACT

2.1 Chairperson:
The Panel is supported by an elected chairperson. The current (April 2003) chairperson is:

Mr A.T.F. Grooters
Royal Netherlands Meteorological Institute
Wilhelminalaan 10
P.O. Box 201
3730 AE De Bilt
The Netherlands
Tel: +31 302 206 691
Fax: +31 302 210 407
E-mail: frank.grooters@knmi.nl

2.2 Technical Coordinator:
The Panel is supported by a full-time TC, currently:

Mr. J.J. Stickland
Observations and Engineering Branch, Bureau of Meteorology
P.O. Box 1289K
GPO Melbourne 3001
Victoria
Australia
Tel: +613 9669 TBA
Fax: +613 9669 4168
E-mail: j.stickland@bom.gov.au

The TC is a central point of contact on AMDAR technical issues, especially those relating to data quality and availability. The TC assists AMDAR programme managers and developers on day-to-day operational matters and technical issues, and provides a link between users and AMDAR Panel facilities and activities.

2.3 WMO Secretariat support:
This is provided by the Aeronautical Meteorology Unit of the WMO World Weather Watch Applications Department. Currently, the designated officer is:

Mr N. T. Diallo
Chief, Aeronautical Meteorology
World Weather Watch Applications Department
World Meteorological Organization
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## ANNEX I TO APPENDIX V

# GOAL AND TERMS OF REFERENCE FOR THE PANEL ON AIRCRAFT METEOROLOGICAL DATA RELAY (AMDAR PANEL)

The goal of the Panel shall be to enhance the upper-air component of the Composite Observing System of the World Weather Watch through cooperation among Members in the acquisition, exchange and quality control of meteorological observations from aircraft using automated reporting systems.

Recognizing a fundamental principle of WMO to broaden and enhance the free and unrestricted international exchange of data, and noting the increasing availability of aircraft platforms with suitable sensors, avionics and communication systems, the Panel is established to take advantage of the opportunity to use these new cost-effective global data sources to better respond to the needs of WMO and WMO-sponsored programmes such as the WWW, WCRP, GCOS and GOOS, and to bring potential benefits to end-users in aviation and other communities. The Panel is considered necessary to ensure a coordinated approach to the development of AMDAR as an operational global programme with particular benefits in data-sparse areas of the world.

To achieve the goal, the AMDAR Panel shall:

1. Consider the expressed needs of the international meteorological and climatological communities for data from automated meteorological reports from aircraft and initiate action from its members, or others as appropriate, to meet these needs;

2. Facilitate the coordination of existing national and international programmes of automated meteorological reporting from aircraft so as to optimize the provision and timely exchange of high-quality data at minimum cost;

3. Propose, organize and implement, through the coordination of national and regional efforts, the expansion of the current and future AMDAR Programme, to obtain such data, particularly in data-sparse areas of the world;

4. Promote the exchange and dissemination of all appropriate automated meteorological reports from aircraft through the GTS and other systems as appropriate;

5. Promote the dissemination, exchange and use of information on AMDAR data availability and quality among Members and data providers, with a view to initiating appropriate corrective action;

6. Promote the exchange of information on AMDAR and encourage the development and transfer of appropriate technology;

7. Ensure that other bodies actively involved in automated meteorological reporting from aircraft are informed of the workings of the Panel and encourage, as appropriate, their participation in Panel deliberations;

8. Make and regularly review administrative arrangements as necessary, including securing the services of a Technical Coordinator when necessary;

9. Promote joint funding arrangements, as appropriate, for the development, implementation and operation of the AMDAR Programme;

10. Liaise and interact as appropriate with the relevant sections of the aviation community on issues of common concern, such as data acquisition, data management, communications and costs; and

11. Submit annual progress reports to WMO's Executive Council.

## ANNEX II TO APPENDIX V

# MEMBERSHIP AND OPERATING PROCEDURES FOR THE PANEL ON AIRCRAFT METEOROLOGICAL DATA RELAY (AMDAR PANEL)

The Panel is recognized as a body within the WMO structure, with the endorsement of the WMO Executive Council, fostering active cooperation among Members in the implementation and operation of AMDAR as a component of the WWW Composite Observing System.

Members:

Panel members shall be Members of WMO that operate or intend to operate AMDAR programmes and are willing to contribute to the Panel's activities.

Observers:

Representatives of any organization or programme actively involved in the use, development, collection or provision of automated meteorological reports from aircraft, or which specifically require such data, may be invited to participate as observers in meetings of the Panel.

Operating procedures of the Panel:

1. The Panel will normally meet annually. It will elect a chairperson and vice-chairperson from among the representatives of the Panel members, and will appoint working groups as necessary to carry out the agreed work programme of the Panel between sessions. The chairperson will prepare reports for WMO, as required;

2. The chairperson may call on representatives of individual Panel members for assistance in matters such as the representation of the Panel at meetings of other bodies, the preparation of reports on specific topics, etc.;

3. A Technical Coordinator may be appointed to support the work of the Panel. The costs associated with this position will be supported through contributions to a trust fund;

4. A biennial budget will be developed and approved by the Panel. This budget and associated income and expenditure will be reviewed at the annual meeting of the Panel;

5. The WMO Secretary-General will provide appropriate support to the Panel and manage any trust fund established;

6. The working language of the Panel shall be English;

7. The Panel's Terms of Reference, membership and operating procedures shall be reviewed and revised as necessary at the annual meeting. The chairperson shall prepare recommendations to be distributed before the meeting.

# APPENDIX VI

# ACRONYMS AND BIBLIOGRAPHY

## 1. LIST OF ACRONYMS

| | |
|---|---|
| ACARS | Aircraft Communication Addressing and Reporting System |
| ACMS | Aircraft Condition Monitoring System |
| ADC | Air Data Computer |
| ADS | Automatic Dependent Surveillance |
| AEEC | Airlines Electronic Engineering Committee |
| AIREP | air report |
| AMDAR | Aircraft Meteorological Data Relay |
| AMDARDM | AMDAR Data Management |
| APF | AMDAR Panel Format |
| ARINC | Aeronautical Radio, Incorporated |
| ASDAR | Aircraft to Satellite Data Relay |
| ATC | Air Traffic Control |
| ATM | Air Traffic Management |
| ATS | Air Traffic Services |
| CAeM | Commission for Aeronautical Meteorology |
| CAT | Clear Air Turbulence |
| CBS | Commission for Basic Systems |
| CIMO | Commission for Instruments and Methods of Observation |
| CMM | Commission for Marine Meteorology |
| COADS | Comprehensive Ocean-Atmosphere Data Set |
| CPDLC | Controller Pilot Data Link Communication |
| DEVG | Derived Equivalent Vertical Gust |
| DRSC | Data Reception and Switching Centre |
| EDR | Eddy Dissipation Rate |
| FGGE | First GARP Global Experiment |
| GARP | Global Atmospheric Research Programme |
| GCOS | Global Climate Observing System |
| GDPS | Global Data Processing System |
| GMS | Geostationary Meteorological Satellite (Japan) |
| GOES | Geostationary Operational Environmental Satellite (United States) |
| GOOS | Global Ocean Observing System |
| GOS | Global Observing System |
| GPS | Global Positioning System |
| GTS | Global Telecommunication System |
| IATA | International Air Transport Association |
| ICAO | International Civil Aviation Organization |
| IDCS | International Data Collection System |
| IRU | Inertial Reference Unit |
| KNMI | Royal Netherlands Meteorological Institute |
| MDCRS | Meteorological Data Collection and Reporting System |
| NASA | National Aeronautics and Space Administration (United States) |
| NOAA | National Oceanic and Atmospheric Administration (United States) |
| NWP | Numerical Weather Prediction |
| NWS | National Weather Service (United States) |
| OCAP | Operating Consortium of ASDAR Participants |
| OGP | Office of Global Programs (NOAA) |
| PIREP | Pilot Report |
| Q/C | Quality Control |
| QEV | Quality Evaluation |
| RAFC | Regional Area Forecast Centre |
| RMS | Root Mean Square |
| RTH | Regional Telecommunications Hub |

| | |
|---|---|
| SAT | Static Air Temperature |
| TAT | Total Air Temperature |
| UTC | Universal Time Coordinate |
| WAFC | World Area Forecast Centre |
| WMO | World Meteorological Organization |
| VHF | Very High Frequency |
| WCRP | World Climate Research Programme |
| WVMR | Water Vapour Mixing Ratio |
| WWW | World Weather Watch |
| WWWDM | WWW Data Management |

## 2. BIBLIOGRAPHY

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### 2.2 WMO TECHNICAL REPORTS

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