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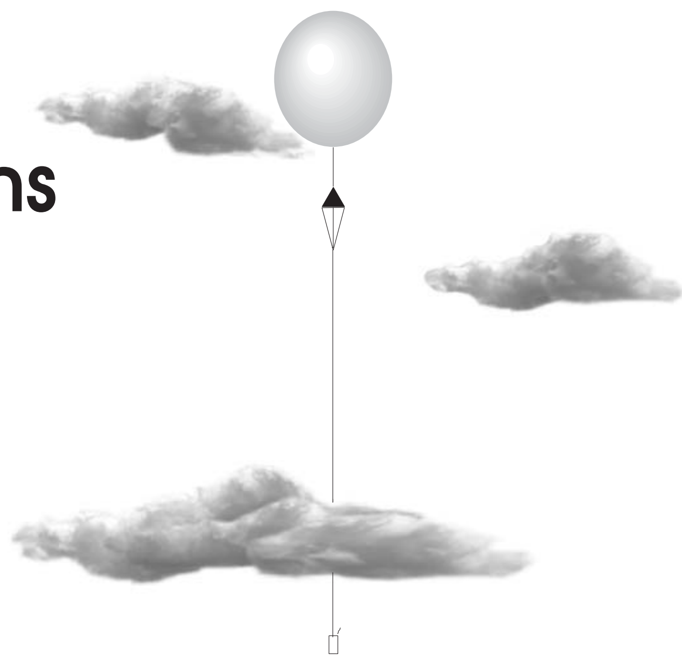
OFFICE OF THE FEDERAL COORDINATOR FOR
METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

Federal Meteorological Handbook No. 3

Rawinsonde and Pibal Observations



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CHANGE AND REVIEW LOG

Use this page to record changes and notices of reviews.

Change Number	Page Numbers	Date Posted	Initial
1	Page 6-2	Effective August 1st 2006	MMC
2			
3			
4			
5			
6			
7			
8			
9			
10			

Changes are indicated by a vertical line in the margin next to the change or by shading and strikeouts.

Review Date	Comments	Initial

FOREWORD

In 1987, the Office of the Federal Coordinator for Meteorology (OFCM) assumed responsibility for preparing and maintaining Federal Meteorological Handbooks. The task of accomplishing preparation and coordination of handbook No. 3 (FMH-3) — Radiosonde Observations and associated handbooks #4, 5, and 6, was assigned to the Ad Hoc Group for FMH-Upper Air (AHG/FMH-UA) through the Working Group for Upper Air Observations under the Committee for Basic Services (CBS).

This edition of FMH-3, "Rawinsonde and Pibal Observations," concludes a 5-year effort by the AHG/FMH-UA to meet the objectives outlined in guidance issued by CBS. Specifically, the CBS directed that the new FMH-3 should: (1) reflect our Nation's commitments to international organizations (i.e., WMO, ICAO); (2) integrate conventional and automatically observed data by adopting new standards for automated, augmented, and manual observations; (3) allow agencies to prepare and issue agency-specific procedures and instructions for taking and reporting upper air observations; and (4) combine FMHs 3, 4, 5, and 6 into a new FMH-3. In previous editions of the Federal Meteorological Handbooks, all procedures and internal agency instructions pertaining to upper air observations were described in FMHs 3 through 6. Beginning with this edition, FMH-3 will contain only Federal standards; it will not contain agency-specific procedures and practices.

I would like to acknowledge the efforts put forth by members of the AHG/FMH-UA, past as well as present, who diligently labored and persevered to produce this document. Interagency coordination, especially the establishment of new standards which have impacts on policies and procedures, is an extremely difficult task and worthy of special recognition. I commend the AHG/FMH-UA members for their efforts.

Julian M. Wright, Jr.
Federal Coordinator for Meteorological Services
and Supporting Research

FEDERAL METEOROLOGICAL HANDBOOK NO. 3
RAWINSONDE AND PIBAL OBSERVATIONS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Purpose and Scope. A radiosonde is a balloon-borne instrument used to simultaneously measure and transmit meteorological data while ascending through the atmosphere. The instrument consists of sensors for the measurement of pressure, temperature, and relative humidity. The sensors' information is transmitted in a predetermined sequence to the ground receiving station where that information is processed at some fixed time interval. When wind information is processed by tracking the balloon's movement the instrument package is termed a rawinsonde. Thus, rawinsonde observations of the atmosphere describe the vertical profile of temperature, humidity, and wind direction and speed as a function of pressure and height from the surface to the altitude where the sounding is terminated. Other derived parameters are also determined from a rawinsonde observation. The rawinsonde system consists of a balloon-borne radiosonde, receiving and tracking equipment, and computer systems for data processing. Pibal (pilot balloon) observations are soundings to delineate the vertical profile of wind direction and speed as a function of height. They are made by the tracking of a balloon by optical means or by radar equipment. In this Handbook only the optically-tracked balloon will be considered.

This Handbook prescribes federal standards for taking rawinsonde and pibal observations; for processing the observations; and for encoding, telecommunicating, and archiving the data. Also provided are procedures for quality control throughout the various phases of data acquisition, processing, and dissemination. All methodology contained in this Handbook is consistent with that stipulated by the World Meteorological Organization (WMO).

The standards defined in this Handbook apply to all U.S. government agencies or other U.S. facilities which take routine synoptic or unscheduled rawinsonde and pibal observations. The dissemination standards and requirements herein apply to all rawinsonde and pibal data transmitted over broadcast communication systems and/or use by the public or the government. Examples of such broadcast systems are satellites, the Automation of Field Operations and Services (AFOS) system, the Automated Weather Network (AWN) system, and the Global Telecommunications System (GTS). The standards and requirements also apply to all U.S. Agencies which provide rawinsonde and pibal data for archival at the World Data Center-A for Meteorology located at the National Climatic Data Center (NCDC), Asheville, North Carolina. Further, this Handbook is a reference and guide to the various users of upper-air data and to private enterprises engaged in the development of observational systems.

Throughout this manual, the following definitions apply:

- "***shall***" indicates that a procedure or practice is mandatory.
- "***should***" indicates that a procedure or practice is recommended.
- "*may*" indicates that a procedure or practice is optional.
- "will" indicates futurity, not a requirement to be applied to current practices.

1.2 Relation to Other Handbooks and Manuals. This version of FMH No. 3, Rawinsonde and Pibal Observations, supersedes and replaces the predecessor Federal Meteorological Handbooks:

- FMH No. 3
  - Radiosonde Observations
- FMH No.4
  - Radiosonde Code
- FMH No. 5
  - Winds Aloft Observations
- FMH No. 6
  - Winds Aloft Code

1.3 Changes and Revisions. Changes and revisions to this Handbook will be made under the direction of the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM). Agencies ***shall*** submit recommendations for changes through their representatives to the OFCM.

1.4 Agency Specific Procedures. Agencies *may* issue supplemental instructions, but such instructions are not to be identified as part of this Handbook. If agencies intend to enter data collected under the supplemental instructions into the GTS, the data ***shall*** meet or exceed the basic provisions of this Handbook.

1.5 Rawinsonde Program - General. The United States and other WMO member countries maintain, on a cooperative basis, observing locations that cumulatively form part of The Global Observing System of the World Weather Watch (WWW) network. The synoptic rawinsonde observing programs of the United States and the other WMO member countries are designed to meet real-time operational needs for weather analysis and forecasting. These observations also provide a national and international data base of upper-air observations for research and climatological purposes. Synoptic observations are defined as those that are being taken simultaneously at fixed, scheduled times at a large number of locations. Unscheduled observations are those taken in support of specific missions without regard to long-term continuing, fixed scheduled times.

1.6 History of U.S. Upper-air Observing Programs. Upper-air observations began in the United States as early as 1749 with experiments using large kites to carry aloft primitive instruments. Later in the eighteenth century, experiments were conducted using tethered balloons so that observations could be made on calm as well as windy days. The advent of the airplane provided a means to carry aloft and safely return recording instruments that were impractical for use with balloons. In 1920, the U.S. Weather Bureau and the Army Air Corps established a program of daily airplane upper-air observations at about 20 locations nationwide. These provided the first national coverage of upper-air data.

In 1921, the U.S. Weather Bureau established a kite network which remained in operation until 1933. In the meantime, free-flight pilot balloons, tracked visually with a theodolite, were being used to determine winds aloft.

Around 1930, radio telemetry was successfully incorporated with balloon-borne atmospheric sensing instrumentation, the forerunner of today's rawinsonde/radiosonde program. A radiosonde network in the coterminous U.S. was begun by the (then) Weather Bureau in 1937-38. World War II provided special impetus in development of the rawinsonde/radiosonde technology and fostered the growth of upper-air observing networks.

Before computerized processing of upper-air observation data became the norm, the process involved a significant amount of manual labor. The observation process was generally considered a two-person effort, with a third person frequently involved for quality control, general oversight of procedures, and assistance. All aspects of the observation, from preparation for the sounding release through subjective recorder record-trace evaluation to preparation of adiabatic charts and the coded message, were manually performed and labor intensive. The process of preparation, evaluation, and coded message generation typically took an additional period of time equal to or greater than the period of time required for the actual observation. U.S. agencies began experimenting with computerized reduction of rawinsonde data during the late 1960s and early 1970s.

In the 1980's, technological advances in telemetry and small computers made near-fully automated rawinsonde observations feasible. At U.S. locations, manual involvement in taking rawinsonde observations was significantly reduced. By the middle 1980s both the National Oceanic and Atmospheric Administration (NOAA) and the Department of Defense (DoD) had made significant progress in automation. The use of station minicomputers and interfaces to automatically acquire flight data meant that the data computations, coded message generation, data transfer, and data storage functions could all be performed with minimal human intervention. The rawinsonde observation had thus become an operation with improved data quality, even though the time required for preparing radiosonde data for transmission had been reduced to, typically, less than one staff hour.

Currently, the upper-air observing program of the U.S. comprises a network of rawinsonde stations together with a number of additional observing systems, including pibals, a network of ground-based remote-sensing wind profilers, en route commercial aircraft, and satellite-based temperature profile and cloud-motion wind capability. Together these systems provide upper-air measurements that are basic to meeting the needs of operational weather forecasting, climatological data bases, and meteorological research programs.

1.7 <u>Present Rawinsonde Program</u>. The U.S. participates in the WMO's World Weather Watch program by maintaining and operating the Washington D.C. World Meteorological Center (WMC); the WMO Region IV Regional Telecommunication Hub (RTH), which is responsible for North and Central America and adjacent ocean areas; and radiosonde facilities at a network of civilian and military sites on its major land masses and remote island locations. The Washington D.C. WMC comprises the NOAA National Weather Service Telecommunication Gateway (NWSTG) and the National Centers for Environmental Prediction (NCEP). Together they fulfill global and regional telecommunications, data processing, and data monitoring responsibilities for the WMO.

The U.S. program for rawinsonde and pibal observations assists in meeting the data requirements of the international, regional, national, state, and local forecast centers and offices. The basic requirements include station spacing and density, frequency of observations, precision and accuracy of data, and resolution of measurements. The requirements *may* be supplemented to meet special mission needs but ***shall not*** be diminished, except in emergencies, to less than the standards for routine scheduled operations. A list of the upper-air sites operated by the U.S. is given in Appendix C.

Pibal observations are taken mainly by Department of Defense operations in the field, and are used primarily for artillery support.

1.7.1 Network of U.S. Stations. The U.S. network of stations comprises more than ten percent of the global rawinsonde network. The primary responsibility for maintaining this network rests with NOAA's National Weather Service (NWS). The network is augmented by observations made at military, National Aeronautics and Space Administration (NASA), Department of Energy (DoE), and other installations. Regardless of the purpose for the observations, agencies that do acquire rawinsonde and pibal observations and communicate them for general use ***shall*** comply with the provisions of this Handbook.

1.7.2 Network Design and Configuration. The proper frequency and spacing of rawinsonde and pibal observations, together with other types of upper-air measurements (i. e. satellite, aircraft and ground-based remote-sensing systems), enable identification and prediction of meteorological phenomena to protect human life and promote economic interests.

Many factors influence the size of the U.S. network and the locations of stations. Operational requirements play a central role in determining the network of stations and types of observing systems needed to describe the state of the atmosphere. Budgetary realities, in terms of existing and planned appropriations, determine agencies' ability to establish and sustain operations over an extended period of time. Logistics determine the ability to supply and maintain each station on a continuing basis. Geography determines an optimum location for each station, taking into account terrain, climatology, urban development, and other physical considerations. Other important factors include national security requirements, special research studies (particularly of severe storms and in support of international programs), and needs for observations in support of special events.

The WMO recommends a minimum upper-air station spacing of about 250 km over large land areas and 1000 km over sparsely populated and oceanic regions and further recommends that observations be taken one-to-four times daily (Ref 12: II.2, II.3). The average continental U.S. rawinsonde station separation is presently about 315 km, and two observations daily (at 0000 and 1200 UTC) are scheduled.

1.7.3 Transmission of Observations. The coded report containing data from the observation, when presented to the telecommunication system for dissemination to the general public and government agencies, ***shall*** adhere to the standards set forth in Chapter 7 and Appendix E. Telecommunication systems are described in Chapter 7 and detailed description of the coding procedure is contained in Appendix E.

1.7.4 Recording and Preserving Observations. An archive record of all regular synoptic rawinsonde and pibal observations ***shall*** be made for presentation to NCDC. An archive record ***shall*** also be made of unscheduled observations that are transmitted over telecommunications for use by the public or the government. The requirements for recording and transmitting these records to the NCDC are described in Appendix F.

1.7.5 Data Applications. Rawinsonde observation data are applied to a broad spectrum of operational, climatological, and research efforts. Applications include: initialization for numerical weather prediction models; input for pollution/dispersion models; severe storm, general, aviation, and marine forecasts; climatology records and atlases; ground truth for satellite retrieval algorithm development and verification; support for DoD programs; climate studies; and general research.

CHAPTER 2

SYSTEMS AND EQUIPMENT

2.1 <u>Introduction</u>. This chapter describes the upper-air sounding systems and associated equipment used for fixed land-based, shipboard, and mobile rawinsonde observations taken by U.S. agencies. Upper-air systems are composed of a flight subsystem (inflated balloon, flight-train, radiosonde) and a ground-based subsystem (tracking, receiving, and signal- and data-processing equipment).

2.2 <u>Accuracy and Precision of the Measurements</u>. Table 2-1 presents accuracies and functional precisions of the measured variables: these ***shall*** be considered minimum standards. They are not to be interpreted as technical standards, but as quantities easily achievable with present (1997) technologies. Two important points about these specifications should be noted. The accuracy and precision of wind measurements depends upon the balloon-tracking system employed and the conditions under which the sounding is made. The geopotential height values are calculated and are a complicated function of the accuracy and precision of the individual pressure, temperature, and humidity variables. The values in the Table are based upon actual field tests (see Table 2-1 footnote #3).

2.3 <u>Flight Subsystem</u>. The flight subsystem is composed of a balloon, flight-train, and radiosonde. The free-flight meteorological sounding balloon is designed to lift the radiosonde to a desired height at a desired ascension rate. The flight-train connects the radiosonde to the balloon and *may* include a combination of parachute, train regulator, lights or radar reflector. The flight-train is designed to aid in radiosonde launching, flight, and descent. The radiosonde is composed of meteorological sensing instruments, telemetry encoders, and a radio-signal transmitter. The radiosonde is designed to make in-flight measurements and transmit them to the ground subsystem. The flight subsystem is designed to be expendable, although some radiosondes are recovered, reconditioned, and used again.

2.3.1 Balloons. Meteorological sounding balloons used for routine operational synoptic soundings are made of natural (latex) or synthetic (neoprene) rubber. The latex balloons tend to be more spherical when inflated and have a faster, more uniform ascension rate in the lower atmosphere. Comparatively, the neoprene balloons tend to be elongated vertically when inflated to the same lift and, because their tops tend to flatten when rising, have a slower, less uniform ascension rate. High wind launches are also more difficult with neoprene balloons. Severe weather and fast-rising balloons are also made, and are used for special conditions and purposes. Sounding balloons are made in a variety of sizes or weights. This variety allows for tailored performance in bursting height and ascent rates for combinations of gas type, lift, and payload weight. The inflation guidance and performance data of a specific balloon can be obtained from the balloon manufacturer. Typical lighter-than-air gasses used for upper-air soundings are hydrogen, helium, and natural gas. (See Chapter 3 and Appendix B for balloon preparation and inflation safety standards and guidelines.)

2.3.1.1 Inflation Gases. Hydrogen is used at most land stations because its price is only a fraction of the cost of helium. However, it is a highly combustible gas and can cause fires or explode. Hydrogen is either manufactured, compressed, and bottled by a gas distributor or produced locally at field sites by a hydrogen generator.

Table 2-1 Accuracy and Precision of the Variables

Variable being Sampled	Range Capability of Measurement	Accuracy of Measurement[1]	Precision of Measurement[2]	Resolution of Measurement
Air Temperature	+50 to -90°C	0.5°C	0.40°C for 1050 - 20 hPa 1.00°C for < 20 hPa	0.1°C
Relative Humidity	1 to 100%	5%	2.5% for 100 - 30% 3.5% for 29.9 - 1%	1%
Wind Speed	0 to 225 knots	3 knots 1.5 mps	6 knots 3 mps	1 knot 0.5 mps
Wind Direction	360 degrees	5 degrees	Varies with wind speed	1 degree
Atmospheric Pressure	1070 to 2 hPa	2.0 hPa for P > 300 hPa 1.5 hPa for 300 # P < 50 hPa 1.0 hPa for P # 50 hPa	1.5 hPa for 1050 - 100 hPa 1.5 hPa for 99.9 - 50 hPa 1.5 hPa for 49.9 - 2 hPa	0.1 hPa for P > 50 hPa 0.01 hPa for P # 50 hPa
Geopotential Height[3] of the Pressure Levels	1070-500 hPa 500-300 hPa 300-100 hPa 100-10 hPa 10-3 hPa	< 10 m < 15 m < 20 m < 30 m < 50 m	< 10 m < 15 m < 20 m < 30 m < 50 m	1 m

1- Sensor accuracy is defined as the closest whole or decimal value a given type of sensor is capable of measuring in the environment in which it is intended to operate and is expressed as the root mean square of differences between the sensor readings and the standard.
2- Sensor precision is defined as how closely randomly selected sensors of the same type may be expected to measure a quantity repeatedly. This type of precision is normally made by comparing in flight two or more sensors of a given type that are identical. When tested over the full range of measurement and environmental conditions, the precision of the sensor can be determined. The root mean square error of a large data sample may be considered its "precision", with respect to time.
3- Geopotential heights of the pressure surfaces as estimated from Ref. 3.

Helium is used for shipboard and mobile operations because it is an inert gas and does not pose as much of a safety hazard as hydrogen. It *may* also be used at fixed field sites owing to safety and supply considerations. Helium gas is normally compressed and bottled. Liquid helium is often used onboard ships owing to space constraints.

Natural gas is used in the Arctic because it is readily available and is more economical than hydrogen or helium in that remote region. It is a combustible gas and can cause fires or explode. While natural gas is usually cheaper than helium or hydrogen, its use is less desirable because it produces less lift per unit volume.

2.3.1.2 Safety Standards. Hydrogen and natural gas are extremely explosive. Extreme caution ***shall*** be taken when inflating sounding balloons with hydrogen or natural gas. The operator ***shall*** follow the hydrogen and natural gas safety regulations (refer to appendix B). Required safe practices ***shall*** be strictly adhered to when using hydrogen or natural gas. Proper caution ***shall*** be taken when handling bottles of compressed gas. Since the boiling-point of helium is -268°C (5.2°K), special care ***should*** be taken to prevent injury when handling it in its liquid form.

2.3.2 Flight-Train. The flight-train used for routine operational synoptic soundings typically consists of a parachute, a train-regulator, and a lighting unit attached at night, all connected and rigged with string of appropriate strength. The rigging between the radiosonde, balloon, and flight-train devices is illustrated in Figure 2-1 and discussed in Chapter 3.

2.3.2.1 Parachutes. Parachutes ***shall*** be used at all stations unless the parent agency issues specific instructions to the station to exclude them. Parachutes are optional in areas where risk of injury to people is essentially non-existent, (e.g., an island or at sea) and risk of property damage is negligible. The color of the parachute ***shall*** be orange or some other bright color that can be distinguished from the sky background.

2.3.2.2 Train Regulators. A train regulator (also termed dereeler or let-down) *may* be used when the release is made in high winds. Train regulators come in various designs. Train regulators *may* be provided by the radiosonde manufacturer as an add-on or incorporated into the radiosonde itself or *may* be acquired separately.

2.3.2.3 Shock Unit. A shock unit *may* be used in the flight train between train regulator and radiosonde if the vibration caused by the regulator tends to produce unstable signals.

2.3.2.4 Lighting Units. Tracking systems that require manual antenna positioning to track the radiosonde during the first few minutes of flight *may* use a lighting unit for nighttime releases to help in locking the tracking antenna on to the radiosonde's signal. The candlepower emitted from a lighting unit ***shall*** be sufficient that the position of the balloon flight-train can be distinguished from the background for at least five minutes after launch. Battery powered light bulbs or chemically activated light sticks are two commonly-used devices.

2.3.3 Radiosondes. The basic parts of the radiosonde are: the meteorological sensors, the data encoding electronics, and the telemetry transmitter. The traditional radiosonde measures atmospheric state properties of pressure (P), temperature (T), and relative humidity (U). This PTU or met (meteorological)

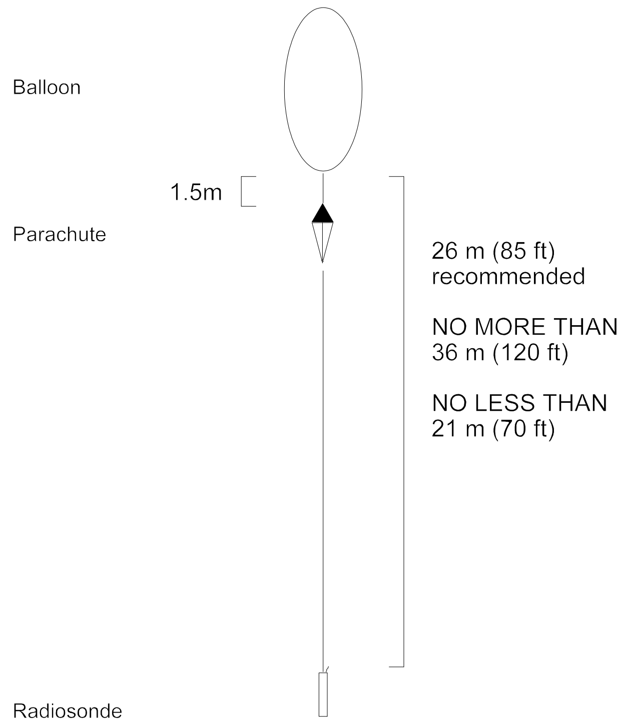

Figure 2-1. Schematic of a sonde with balloon, parachute, and train.

data is used to calculate derived variables such as geopotential height and dewpoint. With the wide-spread access to radio broadcasts of Navigational Aids (NAVAIDS) such as VLF and Loran-C systems, and Global Positioning System (GPS), a NAVAID translator or sensor has been incorporated into some radiosonde designs. These NAVAID sensors are used to determine upper-air winds represented by balloon movement. An alternative to using NAVAID sensors is to track the radiosonde with a precision radiotheodolite or a windfinding radar to determine the upper-air winds.

2.3.3.1 Meteorological Sensors. The meteorological sensors measure the bulk thermodynamic state properties of the atmosphere — specifically pressure, temperature, and relative humidity. Sensors are factory calibrated: the calibration ***shall*** be ground checked ("base lined") during preflight preparation (see Chapter 3). This process verifies that all radiosonde components are operating properly prior to release and that calibration values are appropriate. Descriptions of commonly employed sensors are given below.

The pressure sensor measures the ambient pressure over the whole range of flight conditions from launch to balloon burst. This sensor is usually an evacuated aneroid cell, a part of which flexes with variations in pressure. The flex is proportional to the absolute pressure. The flex is reported as a movement of a mechanical arm, as a capacitance, or as the amount of voltage required to balance a wheatstone bridge. The pressure cell is usually temperature-compensated to measure pressures at temperatures that range from +50°C to -90°C. A hypsometer can be also used to measure the ambient atmospheric pressure. The hypsometer bases its measurement on the known boiling-point of a fluid at a specific external pressure. By keeping the fluid at its boiling-point and measuring its temperature, the ambient air pressure can be calculated.

Some radiosondes do not use a pressure sensor. Instead, the pressure levels are computed from the hypsometric equation using height determined from radar together with the temperature and humidity measurements from the radiosonde (see Appendix D).

The temperature sensor measures the ambient temperature over the whole range of flight conditions from launch to balloon burst. This sensor is usually an electrical device whose resistance or capacitance varies proportionately with the change in temperature. The temperature sensor is exposed during flight to solar and infrared radiation which can introduce temperature measurement errors. Radiation, sensor lag, and other errors depend on the sensor coating, size, shape, mounting, and position in relation to the radiosonde and the balloon. Radiosonde manufacturers and various researchers have developed adjustment schemes to reduce biases in temperature measurements [e.g. Ref. 2].

All temperature sensors are affected to some extent by both solar short-wave and infrared long- wave radiation. The effect on the sensor is to cause it to report a temperature that differs from that of the ambient air. While the solar effect always causes warming, the long-wave effect may be either warming or cooling depending on the ambient air temperature and the temperature of bodies surrounding the temperature sensor. Because multiple long-wave sources exist (i.e., space, ground, clouds, atmosphere, radiosonde, balloon, etc.), determination of the net long-wave radiation effect is difficult. Radiation effects on temperature sensors also differ in the troposphere and stratosphere owing to the reversal of the thermal lapse rate. In general, radiation effects are larger in the stratosphere, where sensors read too warm in the daytime and usually too cold at night. The differences can be up to a few tenths C degrees in the troposphere and 1 C degree or more in the stratosphere.

The humidity sensor measures the ambient water vapor (humidity) over the whole range of flight conditions from launch to balloon burst. Physical sensors such as hair and goldbeaters skin, with poor measurement accuracy or precision, slow response times, or limited measurement range, are inadequate and ***shall not*** be used. Electrical sensors which have adequate accuracy, time response, and measurement range, such as the carbon element and the thin-film capacitance sensors, are recommended for use. Humidity sensors typically used on radiosondes measure relative humidity directly. The relative humidity is a function of the temperature, so any temperature errors will be reflected in the relative humidity measurements. The humidity sensor can also be affected by liquid and frozen precipitation encountered below and in precipitating clouds. Sensors have been typically placed in a duct within the radiosonde or otherwise protected to minimize this effect, but this placement can lead to inadequate ventilation.

Common limitations to sensors include sensor lag and hysteresis. Sensor lag mainly affects temperature and humidity sensors. A sensor's time constant is the time that the sensor takes to respond to some arbitrary quantitative change in the ambient environment. As the balloon rises, a sensor's value can lag significantly behind the actual values of the atmospheric environment. For temperature sensors, the lag is typically on the order of seconds. For the humidity sensor the lag may range from seconds to minutes. A carbon element sensor may require one minute or more to stabilize to the new conditions when passing through steep humidity gradients at temperatures lower than -40°C.

Hysteresis refers to the property of a sensor failing to reproduce the same values when cycling from an initial value to another value and then back again to the original value. For example, when a balloon enters and exits clouds, hysteresis of the carbon element sensor can cause a measurement error. Limiting the hysteresis effect in humidity sensors is important because of the highly variable nature of the vertical humidity profile in the atmosphere.

2.3.3.2 NAVAID Windfinding. Radiosondes that use NAVAID signals for windfinding contain electronics that receive the NAVAID signals from fixed transmitting stations on the ground (in the case of LORAN or VLF signals) or from moving satellites in space (in the case of GPS). The radiosonde then either retransmits the received signal to the ground subsystem or processes the received signals into Doppler-shift, velocity, or position information and then transmits. Balloon position and wind data are contained in or derived from this information. A description of the common NAVAID sensors flown on radiosondes follows:

2.3.3.2.1 GPS. Each one of the GPS satellites in the 24-satellite constellation transmits a very stable 1575.42 (L1) and 1227.60 (L2) MHZ frequency, precise time, and orbital almanac information. The L1 band is available for civilian use with a Selective Availability degradation of the positioning capability. The carrier is a spread-spectrum signal of about 2 MHZ bandwidth. Because of the large bandwidth, full signal translation is not desirable, so a number of alternatives have been used. They include velocity information extraction and retransmission, partial sampling of position information and retransmission, and full position processing onboard the radiosonde with digital position data transmitted to the ground system. GPS is a 24-hour, world-wide, all-weather navigational positioning system. GPS is capable of providing wind component accuracies of 0.5 m/s or better.

2.3.3.2.2 Loran-C. Each Loran-C station transmits a unique series of pulses on a 100 kHz carrier wave. The Loran-C sensor flown on Loran radiosondes receives the signals from all stations within reception range and retransmits them as a modulated signal on top of the radiosonde's carrier frequency. For this reason, it is commonly called a Loran translator. Loran-C coverage is not world-wide and the usefulness of regional chains is limited by transmitting power, skywave contamination, and geometry. Loran-C provides wind component accuracies of about 0.5 m/s.

2.3.3.2.3 VLF Systems. Currently radiosondes that use VLF translators for windfinding are in general use, and most use a hybrid of all available VLF system signals. VLF systems provide wind component accuracies of about 3 m/s.

2.3.3.3 Data Encoding Electronics. The data encoding electronics periodically sample the various sensors, encode the sensor signals, and modulate them on the radiosonde's carrier frequency. The sampling rate for each measurement ***shall*** be such that a representative profile of the atmosphere can be derived from the telemetered data. Present radiosonde sampling rates are in the 1- to 6- second range. The sensor data can be in digital or analog form and either amplitude modulated (AM) or frequency modulated (FM) on the radiosonde's carrier frequency. For the case of the digital radiosonde, the sensor's analog signal is digitized. For an analog AM radiosonde, the sensor's signal is Pulse Code Modulated on an AM carrier frequency. For a NAVAID radiosonde, the electronics also combine the NAVAID signal with the radiosonde's carrier frequency.

2.3.3.4 Telemetry Transmitter. A radiosonde can travel in excess of 200 km from its ground subsystem. The radiosonde ***shall*** transmit its carrier frequency at sufficient power, typically about 250 milliwatts, for the ground system to receive its signal at 250 km. The radiosonde ***shall*** transmit its carrier frequency within either of the two primary Meteorological Aids Service transmission bands. The carrier frequencies currently authorized are: 400.15 to 406.00 MHZ and 1668.4 to 1700 MHZ. Authorization for the 1680 MHZ band will decrease by 6.6 MHZ on January 1, 1999, to only allow use from 1675 to 1700 MHZ. Table 2-2 lists the applicable telemetry frequencies for the various types of radiosondes in use.

2.4 <u>The Surface Subsystem</u>. Several different systems located on the ground or aboard ship presently are used by U.S. agencies for rawinsonde observations. Specifics of engineering, design, configuration, and operation for these systems are addressed in agency manuals. The surface system typically fulfills the tracking, receiving, and signal- and data-processing functions.

2.4.1 The Antenna. The antenna for the ground subsystem detects the radiosonde's signal, provides signal amplification through its gain, and, if it is a directional antenna, allows for tracking the radiosonde. If the tracking is used for radio-direction-finding windfinding, the tracking control is a much more critical function of the antenna than signal strength. Otherwise, the critical function of the antenna is to pass a sufficiently strong signal to the receiver.

2.4.1.1 RDF Windfinding Antennae. A Radio Direction Finding (RDF) antenna is designed to track a radiosonde transmitting in the 1680 MHZ Meteorological Aids band. The antenna position information (i.e., azimuth and elevation) is combined with the height calculations from the radiosonde to determine the changes in position of the radiosonde during flight. These changes in position are taken as representative of the winds encountered during flight. A RDF antenna is also called a radiotheodolite. A parabolic dish antenna can resolve azimuth and elevation or azimuth angles to 0.05°. Newer phased-array RDF antennas resolve angles to about the same accuracy and have fewer moving parts. Both types of antennae suffer from multipath contamination when the elevation angle of the antenna to the radiosonde gets close to the horizon or any interposed obstruction. If it is expected that the flight will encounter elevation angles below those limited by multipath propagation, a radiosonde *may* be augmented with a transponder (i.e., a ranging adjunct) in order to measure its slant-range or distance to the radiosonde. Winds can then be determined using the azimuth, slant-range, and height of the radiosonde. With adequate antenna elevation angles, RDF systems provide wind component accuracies of about 1 m/s.

2.4.1.2 Other Antennae. Non-RDF windfinding antennae need only detect and amplify the radiosonde's telemetry signal. Current (1997) NAVAID processing units exist for Loran-C, VLF, and GPS systems.

2.4.2 The Receiver and Sensor Processing Units. The surface-based receiver filters, demodulates and outputs the various signals from the radiosonde. The receiver also tracks the telemetry signal to control the tuning circuits for optimum gain and frequency reception, and passes the meteorological signals to the signal processing units.

The signal processing units take these demodulated signals and convert them into values of pressure, temperature, and humidity. If appropriate, NAVAID signal processing units output times-of-arrival (TOAs) or pseudo-ranges from the various stations or satellites. The units may then process this

Table 2-2 Radiosonde Telemetry Frequencies

Ground System	Tracking/ Positioning	Nominal Frequency (MHZ)	Maximum Range* (MHZ)
RDF	Standard	1680±4	1668.4-1700
Ranging Adjunct	Transponder	1680±4 403 MHZ	1668.4-1700
NAVAID	Loran-C	403±1	400.15-406.00
NAVAID	VLF	403±1	400.15-406.00
NAVAID	GPS	403±1	400.15-406.00

***Refers to the maximum tuning range allocated for meteorological aids by the National Telecommunications and Information Administration Table of Frequency Allocations. Sondes must not be permitted to drift outside these ranges and cause interference with other frequencies.**

information into position and/or velocity information, or pass the information directly to the data processing unit that performs the actual windfinding computations.

The meteorological processing units are typically radiosonde-specific "blackboxes" that convert the demodulated radiosonde signal containing the sensor measurements into calibrated meteorological data expressed in the proper units. The output is typically a digitized signal to the data processing unit for storage, display, or further processing.

2.5 The Data Processing Subsystem. The data processing system ***shall*** have built-in capabilities for viewing, editing, and printing data. Systems ***shall*** have the capability to produce a hard copy of products that can be generated from the observation. Examples include: data versus time plots; quality control and system monitoring; time-tagged data files; coded messages for transmission (see Chapter 7 and Appendix E); and archiving file format (see Appendix F).

Graphical plotting of the meteorological variables serves to identify problems during the flight, providing the operator with an additional method for determining such things as sensor failures, unusual meteorological phenomena, and potential hardware problems. Data versus time plots are useful in identifying problems or phenomena that require observer editing, as are thermodynamic diagrams such as a Skew T-log P chart.

In addition, the data processing subsystem ***shall*** have the capability of performing signal processing, managing the meteorological information, and performing general file management and data-base tasks.

2.5.1 Recording Data. The release time of the radiosonde observation ***shall*** be determined and recorded and an elapsed time ***shall*** be assigned to in-flight data. The time of release may be determined externally by a release signal or internally by software detecting a decreasing trend in pressure.

The time-stamped in-flight data from the radiosonde ***shall*** be recorded electronically in a file consisting of the elapsed time in seconds, pressure in hPa, temperature in Celsius or Kelvin degrees, and relative humidity in percent of saturation with respect to water. The wind velocity data ***shall*** be recorded as vector wind components or as wind direction and speed.

2.5.2 Signal Processing. Before derived variables are calculated and subsequent processing is begun, the telemetered data ***should*** be analyzed to detect system noise and signal dropouts. The exact algorithm will depend upon the signal and noise properties of the radiosonde system used. The data telemetry will also depend upon the type and make of radiosonde: nominal procedure ***should*** maintain a high data-rate record of the telemetry for processing, thus allowing for maximum resolution in pressure (time). The intent of this requirement is to provide a time-tagged file of high quality basic variables for use in subsequent data manipulation. Similar signal processing ***shall*** be performed upon the balloon tracking data.

2.5.3 Data File Formats. A minimum of three files ***should*** be maintained during the processing described in this Chapter: a time-tagged file of the original, unedited values of pressure, temperature, and humidity; a time-tagged file of balloon position; and an edited, quality-controlled file of all variables and derived data.

CHAPTER 3

PREFLIGHT PROCEDURES AND SUCCESS CRITERIA

3.1. Introduction. This chapter describes standards and procedures for activities leading up to the release of the radiosonde and its train and for the determination of the end or completion of a valid sounding.

3.2 Safety Considerations. Safe practice procedures ***shall*** be followed for all pre-release and release activities. The following require special attention to safety guidance:

- location of any high tension electrical lines antennas, masts, etc. and procedures for removal of radiosondes and/or balloons which might become entangled during a release,
- movement of the assembled radiosonde train about, indoors and outdoors,
- exposure to potentially hazardous weather and terrain during the balloon release,
- employment of equipment such as weights, valves, and other hardware,
- operation of electrical and electronic equipment,
- use of hydrogen, helium, or natural gas, and
- clearance from FAA tower or ship's commanding officer.

3.3 Flight Equipment Prerelease Actions. Observers ***shall*** be cognizant of the wind and weather conditions and expected air traffic in the vicinity of the station prior to commencing an upper-air observation. For instance, the exposure and warm-up times required for the various types of equipment must be considered and the agency guidelines determining the order in which preliminary operations are to be performed must be followed. Expendables ***should*** be periodically checked to ensure an adequate supply to maintain observations without interruption. Batteries used with the various radiosondes ***should*** be prepared in accordance with the manufacturer’s instructions. In the event of a second or subsequent release, the radiosonde ***shall*** be tuned to a different frequency to avoid interference with previously released radiosonde(s).

3.3.1 Balloon Inflation and Performance. The burst altitude of a balloon is affected by:

- the free lift (number of grams of lift available over and above that required by a balloon to just support the weight of a complete flight-train and radiosonde),

- the air mass(es) through which the balloon ascends and the weather conditions to which it is exposed, and

- the thickness of the balloon skin and the size and shape of the balloon envelope.

Ascent rate is affected by free lift and drag. The amount of free lift required for producing optimum performance ***shall*** be determined before the balloon is inflated. Optimum performance is usually defined as the highest possible bursting altitude with an average ascension rate favorable for obtaining winds aloft data and for properly ventilating the radiosonde sensors (RH and temperature). The balloon must be sufficiently inflated to ensure successful release in the surface conditions which may exist at the time. These factors include, but are not limited to, the following considerations:

- During fair weather conditions, optimum performance and free lift will normally be achieved with 800-1300 grams of hydrogen or helium for 600-1200 gram balloons; 800-1000 grams of hydrogen or helium for 300 gram balloons; and 600-800 grams of hydrogen or helium for 100 gram balloons. The standard, average ascension rate ***should*** be 300 meters per minute. However, consideration should be given to how individual balloons produced by different manufacturers will perform based on their shape and thickness characteristics. Refer to manufacturer's instructions for recommended gas inflation amounts for specified ascension rates.

- The performance obtained by preceding flights ***should*** be considered in selecting a free lift value to be used.

- When precipitation, icing, or terrain turbulence is occurring, sufficient free lift ***shall*** be provided to ensure that the balloon will not descend or float. An increase of 100 grams free lift is typically sufficient to compensate for an increase in the weight of the train resulting from light precipitation. Under light or moderate icing conditions, moderate to heavy precipitation, or terrain turbulence induced by high surface winds, an increase in free lift of 200 to 300 grams will usually be sufficient. Under severe icing conditions, an increase of 500 grams or more *may* be required.

3.3.2 Balloon Inflation. Specific procedures for inflating balloons are contained in Appendix B.

3.3.3 Flight-Train Assembly. The train consists of the balloon, parachute, cord, regulator, and radiosonde plus lighting and shock units as appropriate. Assembly procedures ***shall*** be designed to minimize strain on the balloon neck, avoid entanglement of train components, reduce risk of collision with ground obstacles, and prevent unrepresentative atmospheric sensing.

Under normal conditions, a train length of about 26 meters (85 feet) ***should*** be used. Trains in excess of about 36 meters (120 feet) ***should not*** be used because they can induce excessive pendulum motion of the radiosonde and signal dropout leading to premature flight termination. Trains of less than about 21 meters (70 feet) in length ***should not*** be used. Short trains increase the risk of the radiosonde being too close to the radiation environment of the balloon or of encountering the balloon's wake as it ascends, thereby placing the radiosonde in disturbed and unnatural conditions. Longer train lengths *may* be used with radiosondes employing GPS technology. The length of line between the balloon and parachute ***should*** be 1.5 meters. (Refer to Figure 2-1).

3.4 <u>Preparing the Radiosonde for the Preflight Check.</u> The radiosonde ***should*** be physically inspected prior to being prepared for the preflight check. If the frequency check was done more than twelve hours prior to the sounding, the radiosonde frequency check ***shall*** be redone before the preflight check. The radio frequency of 1680 MHz radiosondes ***shall*** be adjusted to within ± 2 MHz of 1680 MHz or the 403 MHz radiosondes to within ± 1 MHz of 403 MHz.

3.4.1 Calibration of the Radiosonde Sensors. Preflight calibration of the sensors ***shall*** be performed to ensure that electronic signals from the radiosonde sensor circuits, with sensors in a controlled environment, are in agreement with data furnished with the radiosonde or with known surface conditions. This procedure is designed to ensure the radiosonde is functioning within acceptable tolerances prior to release and ***should*** be completed prior to entering administrative or surface data into the ground station computer. A check ***should*** be made of the accuracy of the temperature and relative humidity sensors. This can be done by comparing the radiosonde measurements with those taken by agency-approved instrumentation. The comparison may be done inside or outdoors. If the comparison is done outside, the radiosonde ***shall*** be acclimated to the ambient air before the comparison is made. The location of the instrumentation and radiosonde ***shall*** be as close as possible to each other. During this comparison the radiosonde ***should*** be suspended or placed on a non-conductive surface away from metallic or solid surfaces. If the comparison values are outside the range plus or minus 1°C for temperature and plus or minus 10% for relative humidity, the radiosonde ***shall*** be allowed to acclimate an additional 5 minutes. If the radiosonde fails this check a second time, it ***shall*** be rejected and another used.

3.4.2 The Surface Observation A surface observation as close as possible to the time and place of the release ***shall*** be made. Procedures for recording the observation are to be provided by the individual agencies. Station pressure ***shall*** be taken to the nearest tenth of a hectoPascal (hPa), and corrected for the appropriate pressure at the release point. A measurement of air temperature ***shall*** be taken and recorded to the nearest tenth of a degree Celsius. A measurement of humidity ***shall*** be taken and recorded such that the dew-point temperature is specified to the nearest tenth of a degree Celsius. Wind speed and direction appropriate to the release point ***shall*** be recorded to the nearest whole nautical mile per hour (knot) and 5 degrees for archival purposes. Clouds and weather ***shall*** be observed and reported as the "41414 $N_hC_LhC_MC_H$" group using 41414 and a five digit code to describe surface observed weather and cloud conditions at the time of the radiosonde observation. See Appendix E, E-II.2.8, for coding instructions. Note: the code to describe the state of the weather, wwww, is not required for international data exchange; it is required for archival purposes.

3.4.3 NAVAID Radiosonde. Observers using radiosondes that need navigational aid signals such as LORAN or VLF for computation of upper level wind data ***should*** follow manufacturer's instructions to prepare their system to properly receive the navigation signals. The latest information ***should*** be consulted regarding the availability of navigation stations, such as off-the-air, down for maintenance etc. Bulletins are routinely issued by responsible agencies (such as the U.S. Coast Guard.)

3.4.4 Release Notifications. Federal Aviation Regulations (FAR) Part 101, <u>Moored Balloons, Kites, Unmanned Rockets, and Unmanned Free Balloons</u> (Ref. 5), specifies notification requirements. Notification requirements for release near civilian airports or military airfields are as follows:

For Controlled airports with Air Traffic Control Tower (ATCT) in operation.

- ATCT ***shall*** be informed in accordance with agency procedures before the intended release time, and

- ATCT clearance ***shall*** be obtained prior to the actual time of release.

For Non-controlled Airports that do not have ATCT or whose ATCT is not in operation:

- a release notification broadcast on the local Flight Services Station and/or the local airport's UNICOM frequency ***shall*** be attempted.

For Military Activities:

- upper-air units operating within an eight km (five mile) radius of a military airfield ***shall*** provide the commander with a schedule of observations, and

- ATCT clearance at actual time of release ***shall*** be obtained.

- Upper-air units operating on a vessel underway ***shall*** notify the launch vessel's Tactical Action Office (TAO) or Officer of the Deck (OOD) of the intent to release, and, further, ***shall*** obtain release authority from either the TAO, OOD or both prior to release.

3.5 <u>**Notice to Airmen (NOTAM)**</u>. Routine rawinsonde/radiosonde observations are, in general, exempt from the provisions of FAR 101 (Ref. 5) relative to filing a NOTAM for the following reasons:

- radiosondes do not weigh more than four pounds or have a weight/size ratio of more than three ounces per square inch on any surface of the package,

- balloons do not carry a <u>total</u> payload package weighing more than six pounds,

- balloons do not transport two or more packages that weigh more than twelve pounds, and

- trains do not use a rope or other device for suspension of the payload that requires an impact force of more than fifty pounds to separate the suspended payload from the balloon.

Any station that launches a balloon, connecting train, or payload equaling or exceeding the limits shown in this paragraph ***shall*** comply with Subpart D of FAR 101. Agencies ***shall*** ensure that any of their stations which launch large observational packages have a current version of FAR 101 available for reference and compliance.

As with any other Federal Regulation, FAR 101 is subject to change from time to time.

3.6 <u>The Release</u>. Release ***shall*** be made immediately following completion of the release notification. Safety procedures relevant to the local site and weather conditions ***shall*** be followed. The radiosonde ***should*** be held at arms length and swung back and forth to force ambient air over the humidity sensors. The unit ***should not*** be placed on the ground at any time.

The actual release time expressed in terms of the 24-hour clock (UTC) ***shall*** be recorded to the nearest minute for use in the coded message. Midnight (UTC) ***shall*** be expressed as 0000 and regarded as the beginning of the day. Normally all rawinsonde stations operated in the coterminous U.S. take observations at 0000 and 1200 UTC. Stations in WMO Region IV that are unable to carry out the full upper-air program ***should*** give priority to the sounding scheduled for 1200 UTC (Ref. 12: II 3). (Stations in the Pacific Ocean sector *may* be exempted from this choice.) The actual release time of the regular radiosonde soundings ***shall*** fall within the time interval from 45 minutes before to the scheduled time of the observation (see para. 7.4 and Ref. 12:2.3.11.)

For all non-standard observation times the release window, in regard to the recorded time of the observation, is from 30 minutes before to 29 minutes after the hour of assigned observation time.

3.6.1. Release into Thunderstorms. For considerations of safety, a radiosonde ***shall not*** be released in or near thunderstorms. (An exception *may* be made, under agency control, because of research or other needs.) Thunderstorms can degrade the radiosonde signal, which results in early termination of the flight. Also, the resulting data provides profiles that are unrepresentative of the synoptic pattern. Chapter 4 describes how thunderstorms can affect the telemetered data quality.

3.6.2. Delayed Release. The radiosonde ***should*** be released within the officially prescribed time limits. If a release is delayed beyond the time limit, careful consideration ***should*** be given to replacing the battery to preclude battery failure during flight. Use the time limits set by the manufacturer in determining whether the battery be replaced. If a battery is replaced, preflight and exposure (see para. 3.4) procedures ***should*** be repeated.

3.7 <u>Termination of Radiosonde Observation</u>. The termination of a successful flight normally occurs when the balloon bursts or stops rising. However, some other occurrences could be cause for termination.

3.7.1 Due to Missing Data. Whenever a stratum of missing temperature data (see Chapter 4, Quality Control) is followed by a satisfactory record, the computations ***should*** be continued provided the stratum or strata of missing data do not exceed the limits given in Table 3-1. The flight ***should*** be terminated if at any time the limitations of missing temperature data are met or exceeded. The Table represents the maximum tolerable amount of missing data, expressed in both strata thickness and time interval. Agencies *may* enforce stricter limits.

Whenever a stratum of missing pressure is followed by a satisfactory record, the computations ***should*** be continued provided the stratum does not exceed a limit that causes the determination of geopotential heights to be unsatisfactory. (This limit is less restrictive than that of temperature because of the nature of the hypsometric equation, Appendix D, D.2.) Chapter 4, para. 4.2.1.2, contains the specification of this limit.

The occurrence of missing relative humidity data is not considered justification for termination of the sounding unless the responsible agency deems otherwise.

Whenever the limits are exceeded in one stratum of missing data, the computations ***should*** be terminated at the base of the stratum. Whenever the limits are exceeded in the summation of several strata of missing data, the observation ***should*** be terminated at the base of the stratum in which the limits are exceeded.

3.7.2 Due to Weak Signal. Weak or fading signals can result from a weak battery, a radiosonde moving too far away, or a ground tracking antenna that is not correctly locking onto the radiosonde signal (Chapter 4).

3.7.3 Other Causes for Termination. In the event that the quality of the telemetered data becomes questionable and the criteria covered above are not met, the ascent *may* be terminated. See Chapter 4 for details.

3.8. Successful/Unsuccessful Observation Criteria. All U.S. network (synoptic) radiosonde sites ***shall*** track the radiosonde to the natural termination of the observation and record and evaluate usable data to the highest altitude possible. A second release is required whenever the radiosonde terminates at a pressure greater than 400 hPa. Whenever necessary, a second radiosonde ***should*** be released as promptly as possible in order to stay within the time limits of scheduled observation (see para. 3.6.2 for instructions concerning delayed observations.) However, if, because of unfavorable atmospheric conditions or other reasons, it is apparent that a pressure equal to or less than 400 hPa cannot be attained in subsequent attempts, an additional release ***should not*** be made. If a second release is not made and the record from the first one is usable, even though it did not extend to a pressure equal to or less than 400 hPa, the record from the

Table 3-1 Termination Due to Missing Temperature Data: Maximum Tolerable Amounts

Pressure Range (hPa)	Strata Thickness (km)	Minutes of Missing Data
Surface to 700	1	3
Surface to 400	2	6, with above satisfied
Surface to 100	4	12, with above satisfied
1070 to termination	5 (less than 100 hPa)	16, with above satisfied

Note: The relation shown between strata thickness and time assumes a standard ascent rate of about 300 meters per minute: the maximum tolerable stratum thickness should be used.

first release ***should*** be evaluated and used for summary and transmission purposes. (When a second release is required but not made, the reasons for the omission ***should*** be stated fully in the "Remarks" section of the observational forms for the first release, if evaluated; otherwise, on the observational forms for the next succeeding radiosonde.) If a second and succeeding release does not reach the required minimum altitude, the ascension providing the greatest amount of data ***should*** be evaluated and used as the official observation.

3.9 Multiple Releases. A second or third release *may* be necessary when flight equipment or ground equipment fail, causing a premature termination of the observation. The limit for releases in attempting to complete a scheduled synoptic radiosonde observation is three. If a third release does not meet the criteria for a successful observation, further release attempts ***shall not*** be made and the data from the single most complete observation ***shall*** be disseminated unless missing data occurred in each of the observations that exceeded the tolerances in Table 3-1. In this case, ***no*** observation ***shall*** be reported.

3.10 Unscheduled or Special Observations. Special observations are those performed outside the standard times of scheduled synoptic observations (para. 3.6), and are generally under agency control. Special observations taken by designated network upper-air units ***shall*** adhere to all the basic requirements for the synoptic observations unless severe weather, equipment limitation, or other factors warrant early termination. Special observations ***shall*** be transmitted and archived in the same manner as scheduled synoptic observations.

CHAPTER 4

QUALITY CONTROL AT THE STATIONS

4.1 **Introduction**. Quality control of the sounding data at the observing site must be accomplished by an effective mix of automated and observer-initiated procedures. The data quality control information given herein is mostly appropriate for automated processing; however, observers must be capable of monitoring the automated processing and exercising final judgement of the quality of the sounding data before it is transmitted and archived.

Determining the quality of rawinsonde data can be a subjective process. In many cases it is a straightforward matter for an automated scheme to distinguish erroneous from satisfactory data. This Chapter provides guidelines for determining if the data are satisfactory, erroneous, or doubtful. These guidelines are based on research studies, known radiosonde sensor limitations, and what is physically possible to occur in the atmosphere.

This Chapter describes data anomalies that may be encountered when analyzing radiosonde pressure, temperature, humidity, and wind measurements. These data anomalies are defined as erroneous or doubtful data. Data determined to be erroneous ***shall*** be eliminated and considered as missing data. Data suspected to be erroneous, but not determined to be so, ***shall*** be reported as doubtful. (See Appendix E-II.2.9 and Table 0421.)

4.2 **Pressure Anomalies**. Because measurements of temperature, humidity, and wind are expressed in the coded message in terms of pressure, and because the relationship between pressure and geopotential height involves an integration with pressure (Appendix D), critical dependence is placed upon a satisfactory measurement of pressure.

The following sections describe the causes and identification of in-flight pressure profile distortions, and the procedures that ***shall*** be followed if these anomalies are observed. Radiosonde pressure data anomalies may be caused by ground system failure, a faulty pressure sensor, or atmospheric phenomena affecting the ascension rate of the flight train.

4.2.1 Anomalies Caused By Pressure Sensor or Radiosonde Failure.

4.2.1.1 Surface Pressure Discrepancy. It is important to determine if the pressure sensor is operating correctly as soon as possible after the balloon has been released. One method for checking this is to determine the discrepancy between the surface pressure observation (obtained from instrumentation other than the radiosonde) and the first few pressure readings from the radiosonde after release. Since the exact method is dependent on the radiosonde being used, agencies ***should*** develop specific techniques to check for surface discrepancies and the appropriate tolerances. Discrepancies that exceed the tolerance ***should*** result in a system message requesting the observer to verify that the surface pressure was entered correctly, since the discrepancy may be due to incorrect entry of observed surface pressure instead of an actual pressure sensor failure. If the observer determines that the radiosonde pressure sensor is at fault and the discrepancy exceeds agency tolerances, the flight ***shall*** be terminated.

4.2.1.2 Missing Pressure Data. Pressure sensor or ground system failures are to be suspected when there is loss of signal which causes a number of sampling points to be missing. If more than 10 minutes of contiguous pressure information is missing, a sufficient number of standard levels (Section 5.2) will be lost that the sounding will be without value and the sounding ***shall*** be terminated.

4.2.1.3 Constant Pressure Values. Pressure values that become constant with time are indicators of either sensor defects or balloon failure. The flight ***shall*** be terminated at the data point where the constant values began if, over a 5-minute period, the pressure does not change.

4.2.1.4 Rapidly-Changing or Biased Pressure Data. A faulty or leaking pressure cell causes the radiosonde to report pressures that are inconsistent or rapidly changing with time, rather than exhibiting a smooth and gradual minute-by-minute change. This problem may be especially apparent at pressures less than 100 hPa. Analysis or examination of a pressure-versus-time plot can help determine if this is occurring.

The observer should be aware that a leaking pressure cell is occurring if pressure levels are reached much earlier in the flight than is typical. For example, the 10 hPa level may be reached at 60 minutes instead of the usual 90 to 100 minutes (for nominal ascent rates). A serious effect of pressure-bias errors is that higher or lower (i.e. biased) temperatures are chosen along with the erroneous pressures, causing large changes (e.g. from previous soundings) in geopotential heights calculated for the pressure levels.

A pressure sensor that leaks slowly will cause erratic changes in ascension rate and height, resulting in a pressure versus time profile resembling a staircase. A pressure sensor that leaks abruptly will cause a rapid decrease in the reported pressures, resulting in a rapid, unrealistic increase in reported ascension rate and height.

Flights containing a leaking pressure sensor provide data that are no longer representative of the atmosphere and ***shall*** be terminated at the last usable pressure observation before the leakage began. When it cannot be exactly determined at what point the pressure cell began leaking, the flight ***shall*** be terminated at the last pressure where it is known the data are valid.

4.2.2 Anomalies Caused By Balloon.

4.2.2.1 Balloon Burst. Balloon burst is identified when the pressure changes from decreasing to increasing for at least two minutes at pressures less than 400 hPa and for five minutes at pressures greater than or equal to 400 hPa.

4.2.2.2 Floating Balloons. A balloon with a small hole or one weighed down by icing may stop rising and float. A floating balloon is identified by little or no change in pressure over time. The flight ***shall*** be terminated at the data point where the constant values began if over a 5-minute period the pressure stays constant or the ascent rate slows to 100 meters per minute or less.

4.2.3 Anomalies Caused by Atmospheric Events. Large changes in ascent rates may result from a variety of atmospheric events, including downdrafts or updrafts inside a thunderstorm and near strong winds aloft (such as the jet stream), icing on the balloon, or heavy rain.

Flights taken near or inside thunderstorms have a characteristic pressure -versus- time profile. The profiles are distorted, not because of a pressure sensor problem, but because of changes in the ascension rate of the balloon. The ascension rate-versus-time profile may show several periods of differing ascension rates. A reduced rate of pressure (height) change with time is likely due to the radiosonde being in a downdraft. On the other hand, an increased rate of pressure change with time likely reflects the influence of an updraft.

The cause of observed pressure anomalies ***should*** be determined. Other weather observations (e.g., surface, radar, pilot reports) can provide information to help. Erratic pressure profiles caused by weather conditions usually happen at pressures greater than 400 hPa, where ice accumulation on the flight train, strong updrafts/downdrafts, and heavy rain most likely occur.

If it is determined that the ascension rate changes are due to meteorological events, the flight ***shall not*** be terminated. However, if pressure sensor or general radiosonde failure is determined to be causing the anomaly the flight ***shall*** be terminated at the last satisfactory pressure observation.

4.3 Temperature Anomalies. Radiosonde temperature anomalies may be caused by ground system failure, radiosonde defects, or atmospheric events. The following sections describe typical temperature data anomalies and the procedures that ***shall*** be followed if they are observed. Whenever any portion of the temperature record is classified as doubtful, the flight ***shall*** continue provided that no more than three minutes of doubtful data occur at pressures greater than 700 hPa. If more than three minutes of data are doubtful, the flight ***shall*** be terminated and another flight made. Strata with doubtful data ***shall*** be encoded in the rawinsonde message in the proper group (see Appendix E-II.2.9 and Table 0421).

Since relative humidity calculations require temperature data, relative humidity data ***shall*** be defined as doubtful if the temperature data are doubtful.

4.3.1 Anomalies Caused By Temperature Sensor or Radiosonde Failure.

4.3.1.1 Missing Temperature Data. Ground system, temperature sensor, or radiosonde defects are to be suspected when there is loss of signal or sensor dropouts. Whenever a portion of missing data is followed by a satisfactory record, the computations ***shall*** be continued, provided the total amount of missing data does not exceed the limits provided in Table 3-1. If any of these limits are exceeded, the flight ***shall*** be terminated at the pressure value where the missing data began.

4.3.1.2 Constant Temperature Values. Constant temperature values with time (values changing by less than 0.5/C) can result immediately after release if the temperature sensor is damaged in some way. For instance, during release in high winds the radiosonde sometimes strikes the ground, damaging the temperature sensor. Radiosonde defects can also cause this effect to occur during later portions of the flight.

If temperature values change by less than 0.5/C over a 5-minute period from surface to 400 hPa the erroneous temperature data during the time period ***shall*** be deleted and the flight terminated. From 400 hPa to termination, temperatures changing less than 0.5/C over a 10-minute period ***shall*** necessitate the termination of the flight at the point where the constant temperatures began.

4.3.1.3 Erratic Temperatures. Abrupt shifts in the temperature data from one data point to the next can be caused by temperature sensor defects, radiosonde defects, or interference in the radiosonde signal and ***shall*** be deleted. The temperature profile may be abruptly shifted either toward higher or lower values from the normal trend, causing a shallow layer of superadiabatic lapse rates (see Section 4.3.2) and inversions to appear. Sometimes the shift may revert back to the original trend at a later point in the observation. Automated procedures for identifying erroneous data involve knowledge of the response time

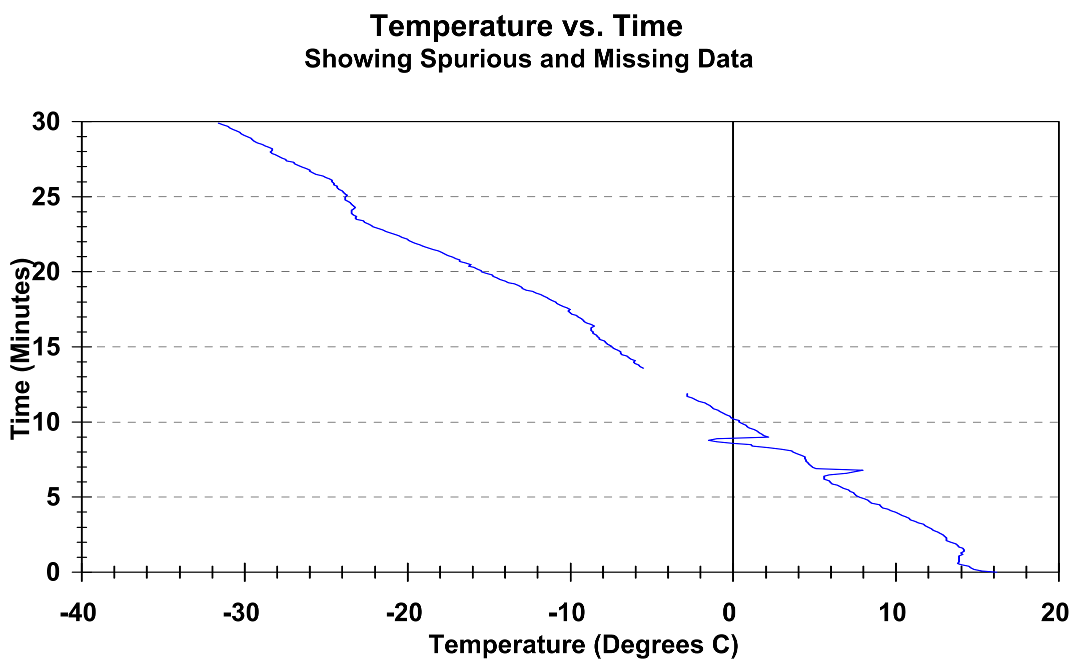

Figure 4-1. Plot of temperature -versus- time, showing incidents of missing and erroneous data.

of the temperature sensor. If the temperature change per unit of time is greater than the capabilities of the sensor, the data are erroneous and ***shall*** be deleted. Figure 4-1 illustrates some occurrences of some missing and erroneous temperatures.

4.3.1.4 Temperature Biases. Identifying temperature readings throughout a flight that are biased too high or low can be difficult. One way to check is for the observer to have knowledge of the temperature structure made throughout the previous sounding. If significant changes in this structure are observed that cannot be attributed to changes in atmospheric structure the sounding ***should*** be terminated.

4.3.2 Superadiabatic Lapse Rates. Superadiabatic lapse rates are defined as a temperature decrease with height greater than 9.77/C/km or any decrease in potential temperature with increasing height. Such indicated lapse rates might be associated with temperature sensor shifts, pressure sensor failures, or outliers resulting from signal noise. They may also occur naturally under certain atmospheric conditions. It is not uncommon for these lapse rates to occur in thin layers near the ground owing to surface heating from the sun; they are not typically found above the surface layer. Thunderstorms, atmospheric gravity waves, or upper-tropospheric fronts could, for example, be a cause of indicated super-adiabatic lapse rates.

Occasionally a thick layer exhibiting a superadiabatic lapse rate occurs when the sensor becomes covered with moisture. This is known as the "wet-bulb effect" and results when water or ice on the temperature sensor evaporates or sublimates, cooling the sensor. In general, high relative humidities occur with the wet-bulb effect, followed by a sharp drying trend. A characteristic temperature inversion also is present at the level of drying. The inversion is due to the sensor's recovery from the cooling of evaporation or sublimation.

Often a super-adiabatic lapse rate results at the beginning of the sounding because the surface temperature observation, taken with equipment other than the radiosonde, is significantly warmer than the first radiosonde temperature measurement a few seconds after release. The resulting profile may be real, owing to daytime heating from the sun; it may be erroneous, owing to radiosonde defects, poor siting of the surface observation equipment (e.g., too far from the release point) or differences in accuracy of both systems, since temperature sensors differ significantly. If strong near-surface profiles (more than 1/K decrease in potential temperature) frequently occur at a site, siting problems or problems with the observing equipment are likely the cause and ***should*** be corrected.

Layers of temperature data showing super-adiabatic lapse rates ***shall*** be categorized as valid if the decrease in potential temperature in the layer does not exceed 1.0/K. If the lapse rate exceeds this value, the temperature data in the layer are not realistic [Ref. 4.] Data ***shall*** be deleted if the potential temperature decreases by more than 1.0/K over any stratum or interval. If the temperature reverts back to the original trend, the data ***should*** be carefully examined to determine if the shift is real or erroneous. If the observer suspects it is erroneous those data ***shall*** be flagged as doubtful.

4.4 Relative Humidity Anomalies. The detection of relative humidity (RH) data anomalies is difficult since humidity data do not always decrease with height as does pressure. Some anomalies, caused by sensor failure, improper sensor acclimation to ambient conditions, or atmospheric events, can be readily identified and are described below. Even if any RH data are missing, geopotential height calculations ***shall*** be carried out.

4.4.1 Missing Relative Humidity Data. Ground system failure, RH sensor defects, or other radiosonde defects can cause missing RH data. Situations when doubtful data occur are described in the following sections. If the agency considers the RH data of decided importance, a stratum of missing or doubtful RH data exceeding the limits in Table 3-1 would require another release.

Since relative humidity sensor conversion algorithms require temperature data, relative humidity data ***shall*** be defined as doubtful if the temperature data are doubtful.

4.4.2 Erroneous RH Data. Erroneous RH data are much more difficult to spot than erroneous temperature data, although they may occur for the same reasons. However, if signal quality is marginal or better, the erroneous data may be identified if the relative humidity profile shows points that are significantly different (appear as a data "spike" in a RH versus time plot) from the data above and below them. This is easy to recognize if the suspect data points occur in a thick layer of humidities that are of equal value. Another method used by automated checking procedures for determining erroneous RH data is through knowledge of the response time of the humidity sensor: if the RH change per unit of time is greater than the capabilities of the sensor the data are erroneous.

4.4.3 RH Data Biased Too High or Too Low. Sometimes during a flight all or most of the RH values reported by the radiosonde may appear biased too high or low. This anomaly is likely caused by one or a combination of the following:

- Damaged sensor. A damaged sensor may occur during shipment from the factory, during observer prerelease procedures, or during release if the radiosonde strikes another object. Observers ***shall*** take extreme care not to damage the sensor during preflight procedures. Depending on the type of radiosonde used, a damaged sensor can cause the humidity to read too high or too low. For example, a scratch or fingerprint on a carbon element can cause RH profiles to be biased too high.

- Lack of a sensor. Some radiosonde types require the observer to place the humidity sensor (e.g., a carbon element) into the radiosonde. If the observer fails to do this, an "open circuit" results, causing the RH data to be near 100% throughout the flight.

- Sensor wetting or icing. A sensor that becomes wet from precipitation or from passing through a thick layer of cloud may not recover and will report RH values biased too high for the remainder of the flight.

- Incorrectly calibrated sensor.

- General radiosonde failure.

During the flight, identifying RH biases can be difficult. However, high biases are likely occurring if more than 30 minutes of RH data are greater than 90%, or at least 15 minutes are greater than 80% from 400 hPa to flight termination. If this occurs, all relative humidity data greater than 80% ***shall*** be designated as doubtful.

RH values that are biased low can sometimes be identified if a thick layer of clouds is observed covering the entire sky, but the RH profile at the height of the clouds is too dry (less than 50% RH). If this discrepancy is observed at pressures greater than 400 hPa (the region of the troposphere where most clouds occur), all RH data at and above the height of the cloud ceiling ***shall*** be deleted.

4.4.4 Rapid Change in RH Immediately After Release. Occasionally the RH profile just above the surface exhibits an abrupt shift from the surface observation. This anomaly usually occurs when an unventilated radiosonde is calibrated in a room where the temperature and RH are significantly different from what are observed at the release point. This effect is more likely to occur with radiosondes using carbon-element sensors positioned in a duct, and is caused by the RH sensors not being properly ventilated prior to release. This problem can be mitigated by having the observer hold the radiosonde outside and moving it up and down for 30 seconds so that air will pass through the duct and over the RH sensor.

Faulty or poor location of surface observing equipment can also cause this anomaly to occur. If this anomaly frequently occurs and inadequate radiosonde ventilation is not the cause, problems with the surface equipment accuracy or location with respect to the release point may be the cause and the equipment ***should*** be checked.

4.5 Wind Anomalies. Detecting wind data anomalies is difficult since wind speed and direction can change significantly with height and/or time. However, the following sections provide descriptions of how the ground tracking system and/or radiosonde can cause missing or erroneous winds. Guidelines for identifying and handling such data follow: additional instructive information on upper-air wind-finding can be found in Ref. 6, Chapter 12, and Ref. 8.

4.5.1 Anomalous Wind Data From Radio Direction Finding (RDF) Systems. Anomalous winds from RDF tracking systems result from incorrect determinations of the radiosonde's position that are due to errors in one or more of the positioning parameters: elevation angle, azimuth angle, and range. Factors affecting the accuracy of position determination are discussed below.

4.5.1.1 Tracking on Antenna Side Lobes. The RDF antenna receives radiosonde radio signals in two distinct patterns, one associated with the main lobe and the other the side lobes. If the radiotheodolite system locks onto a side lobe instead of the main lobe, the position data are incorrect and tend to be very erratic with time. Wind data determined to be derived from side lobe tracing are in error and ***shall*** be deleted.

4.5.1.2 Noisy or Weak Signal. Anomalous angular data may result from signal interference (i.e., noise), weak or fading signals, or faulty ground equipment. This situation is most prevalent when elevation angles are below 12 degrees, but can occur at other angles as well. Sudden, abrupt changes in the elevation or azimuth angles of the antenna from one data point to the next are not realistic and are caused by signals that are too weak to supply the ground receiver with an adequate reference or by the lack of tracking sensitivity in the ground equipment.

Another type of elevation angle anomaly occurs when the elevation angles are greater than 12 degrees and at least 15 minutes of the observation have elapsed. In this case, erratic angles can be caused by equipment which is not operating properly, is tracking on a secondary lobe, or has undergone a signal loss. The result will be tracking errors that are in excess of predetermined tolerances in azimuth or elevation angles.

Erratic angles or spikes in the data caused by noisy or weak signals or ground equipment problems ***shall*** be "smoothed" or removed in accordance with the manufacturer instructions or individual agency guidelines.

4.5.1.3 Multipath Propagation and Limiting Angles. Multipath propagation causes the antenna to stay in one position for a short time and recover when it gets an adequate signal. This will cause the antenna to "bounce" and plots of the elevation angles with time look like steps, or waves, on the plots. This situation is most prevalent when elevation angles below 12 degrees are encountered and becomes increasingly pronounced as the elevation angles near 0 degrees. If multipath propagation is determined to be occurring, the anomalous data ***shall*** be deleted.

The limiting angle is the elevation or azimuth angle of the RDF antenna above or along the horizon below which the antenna cannot successfully track the radiosonde owing to multipath propagation. Generally, limiting angles are no less than 6 degrees from the horizon or obstructions (e.g., mountains or buildings) along the horizon. All computer systems associated with RDF systems ***should*** contain a data file of the limiting angles to identify limiting angles for the antenna. Whenever the elevation and azimuth angles are equal to or less than the limiting angles, the data ***shall not*** be used to calculate winds.

4.5.1.4 Transponder-Related Problems. RDF systems that use transponder radiosondes for obtaining slant range of the flight train may encounter the following problems:

Slant Range Shift. Shifts in the slant ranges result from noise or momentary power interruptions. Abrupt differences in the slant range values from minute-to-minute may indicate where the failure has occurred. It is likely that the ground equipment did not receive one of the one-half wavelength cycles from the radiosonde. Errors of this type ***shall*** be corrected in the radiosonde position data file.

Transponder Failure. The following are guidelines to determine when the transponder sonde has failed:

- If the slant range stops increasing for a period of 5 minutes or increases at a rate of less than 500 meters/minute and the corresponding elevation angles continue to decrease, the ranging has failed or the balloon has burst.

- If the slant range increases at greater than 2000 meters/minute for at least 5 consecutive minutes without a decrease in the corresponding elevation angles, the ranging has failed.

- If the elevation angles are exceeding the limiting angle threshold and the change of slant range between consecutive minutes becomes less than 100 meters, the elevation angle must begin increasing; otherwise, it has failed.

- If the height in meters (MSL) is greater than the acquired slant range (after shift correction), that minute ***should*** be considered invalid. If five consecutive minutes have been designated invalid, the transponder has failed.

When the radiosonde transponder has failed and slant ranges cannot be used, elevation angles ***shall*** be used in the processing of the position data file if they are above the limiting angle threshold.

4.5.1.5 Balloon Overhead. Under light or calm wind conditions near the surface or with shifting winds aloft, the radiosonde may track directly over the RDF antenna (i.e., elevation angles approach 90 degrees) and the ground equipment antenna system may not be able to continue tracking. In such cases, the antenna drive mechanism "locks up," requiring operator intervention to regain antenna tracking. When the following conditions occur, the angular data may be in error and ***should*** be checked: the elevation angles are greater than 80 degrees within the first five minutes of the observation or the azimuth angles have changed by more than 100 degrees from one whole minute to the next for at least one of the elevation angles greater than 85 degrees.

In many instances, the RDF system software ***should*** detect this situation and automatically delete the wind data during the period of the lockup.

4.5.2 Anomalous Wind Data From NAVAID (LORAN or GPS) Systems. Unlike RDF systems, wind data obtained from LORAN or GPS tracking systems are not degraded by low elevation angle of the balloon flight train resulting from strong winds. Provided an adequate telemetry link is maintained between the balloon and the data processing ground station, NAVAID wind errors are not dependent on the distance between them. However, the availability and quality of LORAN and GPS wind data can be degraded by the following:

- poor maintenance of the ground equipment,
- strong electric fields in the vicinity of the radiosonde caused by thunderstorms or snowfall (this affects LORAN and VLF),
- radio interference, especially for radiosondes operating in the 400 MHz band,
- poor location of LORAN or VLF transmitters with respect to the release point (i.e., all transmitters are positioned within a limited azimuth angle or one transmitter located too close to the release point), or
- LORAN station or GPS satellite "signal" is lost immediately after balloon release.

4.5.3 Doubtful Wind Data. After the wind data have been processed from either the raw RDF or NAVAID data, a check ***shall*** be made to assess the validity of the data. Because of the variety of possible meteorological phenomena influencing the wind profile, it is difficult to determine if winds are erroneous or satisfactory. The following are some guidelines for identifying and handling doubtful wind data.

4.5.3.1 Missing Wind Data. The flight ***shall*** continue to termination regardless of the amount of missing, erroneous, or doubtful data. However, some agencies *may* set their own requirements for second releases.

4.5.3.2 Rapid Change in Winds Near the Surface. Immediately after release, a comparison ***should*** be made with the surface wind measuring equipment and the 300m wind measurement reported by the radiosonde. If the topography near the release point is generally flat and there is no low- level temperature inversion, surface winds at speeds over 15 knots are not expected to be significantly higher (10 knots or more) than the winds measured at 300m. If such a decrease is observed, the surface equipment may be out of calibration or the winds at 300m may be erroneous.

During a flight the winds may rapidly increase off surface. In many cases, this change in speed is real. However, wind speed increases of 40 knots or more between the surface and 300m are not likely to occur and such measurements may be erroneous.

Wind direction in the first 300m of the flight can shift through the layer more than 180 degrees. However, if the wind speed throughout the layer exceeds 20 knots and the wind direction shifts more than 90 degrees, the data may be in error.

4.5.3.3 Rapid Changes Above 300m. If rapid changes in wind speed or direction occur, the entire wind profile ***should*** be examined closely. The raw position data ***should*** be checked for validity and upper-air charts, aircraft observations, and/or wind forecasts ***should*** also be checked to determine if such winds are possible. Wind data determined to be erroneous ***shall*** be deleted.

Occasionally, the wind profile during the flight will show rapid changes in wind speed and direction over layers approximately 300 meters thick. If the winds are less than 20 knots in the layer, the rapid wind changes could be valid. However, if the wind speed changes more than 40 knots over a 300 meter layer the data may be in error, especially if the change occurred at altitudes where the jet stream winds are not located (generally below 8 km and above 15 km). Wind speeds that exceed 250 knots are not typical and may also be in error.

Wind profiles with wind speeds greater than 20 knots usually show a gradual change in wind direction at 300m increments. However, if the wind speed exceeds 20 knots in the layer and the wind direction changes more than 90 degrees, the wind data may be erroneous.

4.5.3.4 Flights Near and Into Thunderstorms. Thunderstorms may affect the validity of the flight position data. Typically, wind speed and direction change abruptly in and near thunderstorms, causing unusual wind profiles to appear. With RDF systems, erratic angles may also result from lightning causing radiosonde signals to drop out. High electric fields in and near the storms may cause NAVAID signals to drop out as well. If the observer determines that the flight train is in or near a thunderstorm, individual agency guidelines for processing the wind data ***shall*** be followed.

CHAPTER 5

PROCESSING SOUNDING DATA

5.1 <u>Introduction.</u> The processing of the high data-rate, time-tagged, and quality-controlled information includes not only the preparation of the information for the meteorological message, currently (1997) using the character-code format described fully in Appendix E, but also the preparation of the information for the data archive described in Appendix F. In the future, the full data record will be encoded in the binary, self-defining BUFR code both for transmission on the communication services and for archiving purposes.

This Chapter describes data processing for the creation of information to be included in the Rawinsonde and Upper-Air messages, as defined in Appendix E. A complete description of the material in this Chapter can be found in References 7, 9, and 12. An important part of this procedure is the selection of a limited number of or a subset of points or levels at which the atmospheric sounding is represented in the message form. The types of levels and the techniques used in making the selections are covered. Automated processing of the information, coupled with observer interaction, is assumed.

5.2 <u>Level Selection - Thermodynamic Variables</u>. The following procedures are used for selecting atmospheric levels for transmission and for archiving. Levels are selected at points in the time-tagged file which enable the definition of a representative profile of the temperature and humidity (and wind vectors) as a function of pressure or altitude. Levels are selected either when the flight reaches a predetermined specific pressure level or when a defined, significant change occurs in the temperature, humidity, or wind profiles. The following criteria for selecting the levels meet minimum standards. The criteria for selecting levels for the wind vector data are given in Section 5.3.

Levels pertaining to temperature and humidity information are classified into three main types: standard, mandatory significant, and additional levels. Standard and mandatory significant levels are pre-defined; additional levels (5.2.3) occur at any point in the sounding. [This WMO classification (and resulting definitions 5.2.1, 5.2.2, and 5.2.3) does not correspond to traditional U.S. meteorological usage that contained only 'mandatory' (= standard) and 'significant' (= mandatory significant and additional).]

Level selection ***shall*** occur by examining the time-tagged and signal-processed data values for pressure, temperature, and relative humidity. Calculated data values for geopotential height, dew point, and dew point depression ***shall*** be determined for each level. The height of the surface level in geopotential meters is set to that appropriate for the release point of the radiosonde (Chapter 3). Temperature and relative humidity values ***shall*** be interpolated for periods of missing data of less than one minute. Special procedures are applied to strata with missing relative humidity or temperature data and cases of abnormal balloon ascension. Appendix D provides formulas and information on geopotential height, geometric altitude, and dew point computations.

The standard levels are selected first, then the mandatory significant levels, followed by selection of the additional levels evaluated with temperature criteria; additional levels with respect to relative humidity criteria are selected last.

5.2.1 Standard Pressure Levels. The standard isobaric levels are selected at the specified pressure levels — namely 1000, 925, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10 hPa. These levels ***shall*** be reported in Part A and Part C of the coded message (refer to Appendix E-II.2.2.) In addition, the following levels ***should*** be considered as standard levels: 7, 5, 3, 2, and 1 hPa. Standard pressure levels ***shall*** be selected from the high data-rate time-tagged points closest to the specified pressures. Data are interpolated if a time-tagged point does not have a pressure exactly equal to the standard pressure.

5.2.2 Mandatory Significant Levels. The mandatory significant levels accommodate a number of important characteristics of the rawinsonde sounding which are included in the coded message. These levels are defined as:

- the surface;
- the highest level achieved (the termination level);
- one level between 110 and 100 hPa;
- the tropopause;
- the bases and tops of temperature inversions and isothermal layers greater than 20 hPa in thickness and at pressures greater than 300 hPa;
- the bases and tops of all inversion layers with temperature changes of 2.5°C or 20% relative humidity at pressures greater than 300 hPa; and
- levels delineating layers with missing or doubtful data.

In addition, WMO Regional and National Practice requirements define some supplemental mandatory significant levels. Mandatory significant levels ***shall*** be selected and reported according to the following:

5.2.2.1 Termination Level. The "termination level" ***shall*** be selected at the highest usable point of ascent. Listed below are the situations causing termination (Refer also to Chapter 3):

- Balloon Burst. When detected, the termination level ***shall*** be placed at the last identifiable pressure point.
- Floating Balloon. When a floating balloon has been detected, the termination level ***shall*** be placed at the last pressure point before the balloon began floating.
- Pressure Sensor Failure. When the pressure sensor fails the flight ***shall*** be terminated at the last pressure measurement before the failure. Pressure sensor failures are usually related to

a loss of signal or sensor dropouts causing a number of sampling points to be missing. Since the type of pressure sensor failure is dependent on the type of sensor used, requirements for this type of failure ***shall*** be stipulated by individual agencies.

- Temperature sensor failure or excessive missing temperature data (Table 3-1).

- Weak Signals. When the flight is terminated owing to weak signals, the termination level ***shall*** be placed at the last pressure point before the first weak signals were detected.

5.2.2.2 Descending and Reascending Levels. A "descending level" ***shall*** be selected when the balloon first descends. A "reascending level" ***shall*** be selected when the balloon reascends past the point of highest previous ascent. There are three cases where a reascending level ***shall not*** be selected following a descending level:

- If the balloon descends but never reascends past the highest ascent a reascending level ***shall not*** be assigned. In this case, the descending level ***shall*** be converted to a termination level.

- If the data become missing after the balloon descends and do not reappear until the balloon is above the prior highest ascent point, a reascending level cannot be selected since the data were missing where the balloon ascended past the prior highest point. Instead, an end missing data level ***shall*** be selected where the data reappeared.

- If the reascending level coincides with a standard pressure, the standard level ***shall*** be selected because these levels have higher priority.

5.2.2.3 Missing Temperature and End Missing Temperature Levels. If all data are missing at the point selected for the level, the level ***shall*** be classified as a "missing data level" rather than a "missing temperature level". The level at which the data return ***shall*** be classified as an "end missing temperature level". There are three cases where there will not be an end missing temperature level:

- If the data become missing and never return, an end missing temperature level ***shall not*** be assigned. The begin missing temperature level ***shall*** be converted to a termination level after the flight terminates.

- If the balloon descends after the data become missing and does not reascend until after the data return, an end missing temperature level ***should not*** be selected, since the balloon was not past the highest ascent when the data returned. Instead, a reascending level ***shall*** be selected where the balloon passed the highest ascent.

- If the end missing temperature level is the same point as a standard level, that level ***shall*** be selected because standard levels have higher priority.

If the flight has terminated before the return of temperature data the last level selected ***shall*** become the termination level.

5.2.2.4 Missing RH Levels. Missing relative humidity levels differ from missing temperature data levels in that the data for other variables between the begin missing relative humidity level and the end missing relative humidity level ***should*** still be checked against level criteria. Geopotential height calculations require pressure, temperature, and relative humidity for each incremental level, except when the relative humidity low value cutoff (dependent upon the humidity sensor used) has been reached or the relative humidity is missing.

5.2.2.5 Station Base Pressure Level. A level ***shall*** be selected at the station base pressure used for computation of the stability index. The station base level (the pressure at the release location of the sounding) ***should*** be determined in accordance with the criteria given in Table 5-1.

The base pressure level ***shall*** be selected from the high data-rate point closest to the release location pressure.

Table 5-1 Stability Index Station Base Levels

Station Elevation	Station Base Pressure Level
Less than 1000 gpm	850 hPa
1000 to 1400 gpm	800 hPa
1401 to 2000 gpm	750 hPa

5.2.2.6 Freezing Levels. For aviation purposes it is useful to know at what altitude(s) the sonde passes through the freezing level(s). Freezing levels are selected at zero degree (Celsius) temperatures. Two types of heights ***shall*** be assigned: the calculated heights computed for all levels and U. S. Standard Atmospheric heights rounded to the nearest 100 feet. Up to three crossings of 0°C ***shall*** be determined as follows:

- the one nearest the surface,
- the highest (lowest pressure) one, and
- the intermediate one between the above two with the highest relative humidity.

Additional freezing levels (more than three) ***shall not*** have Standard Atmospheric heights computed, but a count of the total number encountered maintained. Appendix E describes the coded message formats and Appendix D specifies the information for computing Standard Atmospheric heights.

5.2.2.7 Within 20 hPa of Surface Level. A level ***shall*** be selected within 20 hPa of the surface level if a level has not already been selected in this range for other reasons. This level is necessary to ensure that any significant lapse rate near the surface is properly identified. The point of maximum temperature deviation from a linear relation between time (or the logarithm of pressure) and the surface temperature and the temperature 20 hPa above the surface ***shall*** be selected. The level ***shall not*** be selected if temperature is missing.

5.2.2.8 Superadiabatic Lapse Rates. If a potential temperature lapse-rate between two consecutive levels exceeds 1.0°K, the level with the greater time ***shall not*** be selected provided:

- levels are less than or equal to 0.3 minutes apart,
- the level with the greater time is a temperature or relative humidity level, and
- it is not within 20 hPa of the surface.

5.2.2.9 Relative Humidity Cutoff. A level ***should*** be selected when the lower limit of the relative humidity sensor's measuring capacity is reached. This value will be sensor dependent.

5.2.3 Additional Level Selection. The data between standard and mandatory significant levels ***shall*** be examined for the additional levels and included in the coded message in Parts B and D. [E-II.1]. These levels are selected at points that are defined with respect to the temperature and relative humidity profiles based on the departure from linearity on a logarithmic pressure scale between two previously selected levels. Temperature levels ***shall*** be selected first, and relative humidity levels selected when no additional temperature levels can be identified.

5.2.3.1 Departure from Linearity. Temperature and relative humidity levels are selected at points of greatest departure from linearity (GDL). Departure from linearity is the absolute value of the difference between the measured temperature or relative humidity at each time-tagged point and the temperature or relative humidity at that point computed by linear interpolation, based on the logarithm of pressure, between the two nearest previously-selected levels on either side of the point. The point having the greatest absolute difference ***shall*** be selected as the point of GDL between the two levels. If two points have the same difference, the first point in time is selected. A level ***shall*** then be selected at the point of GDL if the data at that point meet certain criteria. The procedure ***shall*** then be repeated using the first point and the greatest departure point, then the greatest departure point and the second point, until no additional levels can be selected.

5.2.3.2 Selection Criteria. A temperature level ***shall*** be selected if the GDL exceeds ± 1.0°C for pressures from surface to 100 hPa and ±2.0°C for pressures from 100 hPa to termination.

A relative humidity level ***shall*** be selected if the GDL exceeds ± 10% for all pressures

5.3 <u>Wind Data</u>. After the thermodynamic level selection process is complete, wind levels are determined. Wind directions ***shall*** be reported in the rawinsonde messages with respect to true north to the nearest five degrees of the 360 degree compass. However, the processing and calculation of the winds and their use in the level selection ***shall*** be in whole degrees and in knots or tenths of meters per second.

The signal processing and creation of the time-tagged wind vector file will depend upon the type of wind-finding system employed. The procedures in this Section are given in terms of a nominal one-minute file structure. This does not necessarily mean that the wind-finding system is capable of accurate wind finding at one-minute intervals. It is suggested that such a structure or one similar to it ***should*** be employed.

Wind speeds and directions are derived for each level encoded in Parts A and C of the TEMP telecommunication message. In addition, wind speeds and directions ***shall*** be determined for the additional levels reported in Parts B and D. Winds are also reported in the PILOT message according to coding specifications given in E-I. The criteria for selecting and reporting fixed level and additional level winds are explained in the following subparagraphs.

- Standard Pressure Levels - The predefined pressure levels for which winds ***shall*** always be reported with accompanying thermodynamic data (see para. 5.2.1). (TEMP).

- Additional Levels - The levels chosen during the observation where either the wind direction or wind speed departs significantly from a linear change. As with the thermodynamic variables, the term is used with respect to the selection of the winds that will accurately replicate the wind profile of the observation. (TEMP and PILOT).

- Fixed Levels - These are predetermined altitude levels which are reported to supplement the winds provided with other data for the standard isobaric levels. Inclusion of winds for these fixed levels provides a more detailed profile of the vertical wind field than can be obtained from only the winds given for the standard and additional levels. (PILOT).

5.3.1 Fixed Levels for Reporting Purposes. Wind directions and speeds, when they are available, ***shall*** be selected on the basis of the altitudes of the fixed levels listed in Table 5-2. These levels have been defined by WMO Region IV as required levels for reporting wind measurements.

Table 5-2 Altitudes of the Fixed Wind Levels

Feet	Meters	Feet	Meters	Feet	Meters
1,000	300	12,000	3,600	70,000	21,000
2,000	600	14,000	4,200	80,000	24,000
3,000	900	16,000	4,800	90,000	27,000
4,000	1,200	20,000	6,000	100,000	30,000
6,000	1,800	25,000	7,500	110,000	33,000
7,000	2,100	30,000	9,000	*	**
8,000	2,400	50,000	15,000		
9,000	2,700	60,000	18,000		

* . . . and for every 10,000 feet upward.
* *. . . and for every 3,000 meters upward

5.3.2 Additional Winds. The criteria for determining the additional levels with respect to wind are based on the premise that these data alone would make it possible to reconstruct the wind speed and wind direction profiles within the limits of ten degrees for direction and five meters per second (ten knots) for speed. The number of additional levels ***should*** be kept to a minimum.

The additional level winds ***shall*** be selected without regard to the requirement for selecting fixed (regional) levels. In other words, an additional level wind could also be a fixed level wind.

5.3.2.1 Additional Level Selection Process. The additional wind levels for coding in the Part B and/or Part D of the coded message are selected in similar fashion to those for the thermodynamic variables. Levels are selected based on the departure of wind speed or direction from linearity when a function of the logarithm of pressure. To qualify, the wind speed must depart from such a linear interpolation by more than 10 knots or the wind direction must depart by more than 10 degrees. Winds whose speed is 10 knots or less are not considered at all in selecting additional wind levels. No additional wind levels occur within strata where the speed is 10 knots or less, regardless of the change in direction that may be occurring.

Some preference is given to speed over direction in selecting these levels. If the wind speed for a level exceeds the limit for departure from linearity and also is the greatest departure of wind speed from linearity, then the direction is not evaluated. If, however, the departure from linearity of wind speed is not sufficient to qualify a wind, then the direction is considered.

5.3.3 Terminating Wind. The terminating wind ***shall*** be selected if both of the following conditions are satisfied:

- the wind speed at the terminating level must exceed the speed of any other wind of the entire flight, and

- the wind speed at the terminating level must be greater than 60 knots.

5.3.4 Maximum Winds. Maximum winds are determined for Part A and/or Part C of the coded message (refer to Appendix E-II.2.4). Each maximum wind must satisfy <u>all</u> of the following criteria:

- the wind speed must be greater than 60 knots,

- it must occur at pressures less than 500 hPa, and

- a maximum wind level must be bounded by levels with winds of lower speeds than the maximum.

The following conditions disqualify a wind from being a maximum wind:

- a wind adjacent to a missing wind,

- a wind for a level whose pressure is equal to or less than 100 hPa (the dividing point for message Parts) if the adjacent wind at a level whose pressure is higher than 100 hPa is greater, or

- a wind for a level whose pressure is lower than 100 hPa if the adjacent wind below 100 hPa is larger.

Exception: The terminating wind qualifies as a level of maximum wind if it is the largest wind speed of the entire flight. It must be the largest wind speed in the range covered by a coded message Part (i.e., surface to 100 hPa or at pressures lower than 100 hPa).

5.3.5 Primary and Secondary Maximum Winds. If two winds with identical wind speeds satisfy the criteria for a maximum wind, the levels ***shall*** be encoded successively, beginning with the lowest altitude. The search for a secondary maximum does not start until a minimal wind is found. A minimal wind is identified when the previous trend is decreasing or missing and the current trend is increasing. When a minimal wind is identified, its speed is saved for further sequential analysis of candidate maximum winds.

A maximum wind is identified when the previous trend is increasing and the current trend is decreasing. When a maximum is found, it becomes a possible candidate for a secondary maximum wind if <u>all</u> of the following conditions are met:

- there has been no missing wind since the previous minimum wind,
- the speed of the maximum exceeds the speed of the two adjacent minima by at least ten meters per second (20 knots), and
- the speed of the maximum is greater than or equal to that of any candidate secondary maximum found.

The remaining winds are evaluated even after a secondary maximum is confirmed in case there is another wind with a higher speed, or the same speed but a higher altitude, that qualifies as another secondary maximum.

5.3.6 Wind Shear. The wind shear 915 meters (3000) ft above and 915 meters (3000 ft) below the maximum wind ***shall*** be computed and included in Part A and Part C of the coded messages. Refer to Appendices D and E for additional information on determining and coding wind shear.

5.3.7 Mean Winds. The mean wind direction and speed from the surface to 1525 meters (5000 ft) altitude and from 1525 to 3048 meters (5000 ft to 10,000 ft) ***shall*** be computed. The mean wind speed is a weighted average of wind vector components with respect to altitude. If the wind data are missing for 2500 ft altitude or more, then the mean wind is missing. Information for computing the mean wind is given in Appendix D.

5.3.8 Other Factors. In addition to the standard isobaric and fixed regional levels specified above, other factors are pertinent to the selection of wind levels.

- The surface level and the highest level of the wind sounding are specified as mandatory significant levels and they ***shall*** be recorded as the first and last additional levels.

- The highest level of the sounding is defined as the highest 1000 foot level for which observed data are available. For example, if the ascent ended at 94,900 feet, the 94,000 foot level is the highest level of the sounding because it is the highest 1000 foot level for which observed data are available.

- When two additional wind levels occur within the stratum from 150 meters (500 feet) below to 150 meters (499 feet) above a reportable altitude, the wind having the greater speed ***shall*** be recorded for that altitude. In the event that both the winds have the same speed, data for the one having the greater altitude ***shall*** be recorded. For example, if the two additional winds occurred within the 26,500 - 27,499 foot stratum, the altitude to be recorded would be the 27,000 foot level.

- When an additional wind level occurs within the stratum from 500 feet below to 499 feet above a fixed Regional level, the speed and direction of the wind ***shall*** be recorded for that fixed Regional level in lieu of the data observed at the fixed level. An exception to this rule is when this occurs just above the surface. In this case, the surface wind ***shall*** be the only one reported.

- When an additional level coincides with some other compulsory reporting level (standard isobaric, maximum wind, tropopause, etc.) the wind ***shall*** also be recorded as an additional wind level.

5.4 **<u>Selecting the Tropopause</u>**. The information required for selecting the tropopause(s) has been delayed to this Section because both thermodynamic and wind data are helpful in the determination; the tropopause is best determined by examining all the level data selected. The expected conditions at the tropopause, in simple terms, are an abrupt change in temperature lapse rate and a maximum in wind speed. There may be, however, more than one such occurrence.

5.4.1 **The First Tropopause**. The tropopause(s) ***shall not*** be selected if the radiosonde has not reached 200 hPa or if an adjacent stratum is missing temperature data. The criteria for selecting the first tropopause are:

A. At pressures from 500 to 30 hPa (all three must occur):

1) The first instance (i.e. pressure) where the temperature lapse rate becomes less than or equal to 2°C per kilometer.

2) The average lapse rate from the tropopause point (from A.1) to any point at a higher height, within the next 2 km, does not exceed 2°C.

3) The radiosonde ascends to 2 km or more above the tropopause point (from A.1).

No tropopause is reported at pressures less than 30 hPa.

B. At pressures greater than 500 hPa (and only if no tropopause is found in (A.)

1) The smallest pressure (greater than 500 hPa) where the temperature lapse rate becomes less than or equal to 2°C per kilometer.

C. Otherwise:

1) If the average lapse rate from the tropopause point (B.1) to any height within the next 1 km does not exceed 3°C, nor for any other subsequent 1 km layer at pressures greater than 100 hPa.

The results of the automated procedure for determining the tropopause ***shall*** be displayed for the observer to check. The purpose of such a display is to advise the observer that a possible tropopause was rejected and to allow an examination of the selected tropopause, if one was found, to ensure that it is correct.

5.4.2 Multiple Tropopause Levels. If more than one pressure level satisfies the criteria of para. 5.4.1, then an additional tropopause level(s) ***shall*** be selected and reported.

5.4.3 Reporting. The pressure, geopotential height, temperature, dew-point depression, and wind direction and speed ***shall*** be reported at the tropopause level(s) for the TEMP message, parts A or C. (Appendix E-II.2.3).

5.5 Coded Message Generation. Routinely, the processing of parts A and B of the coded messages ***should not*** begin until the observation has reached 70 hPa. The coded message sequence ***shall*** be processed as specified below.

The coded message generation sequence ***should*** be initiated in one of three ways: automatically (such as at 70 hPa), on flight termination, or when a command is invoked.

The ground-system computer ***shall*** alert the observer when the coded message generation is complete and ready for review.

Parts C and D of the message ***should*** be coded immediately upon termination of the sounding.

5.6 Additional Information. Additional information to be reported ***shall*** be logged. Included are the date and time, information about the tropopause and the computed stability index, a report of flight problems, type of sonde and ground equipment used, and actual release time. The requirements for these additional code groups are found in Appendix E and Table 0421.

The stability index (see definition, Appendix G) *may* be determined graphically on a thermodynamic diagram or calculated automatically. In the latter instance, a complicated algorithm must be constructed owing to the intractability of the moist adiabatic process; no specific algorithm is given in Appendix D.

CHAPTER 6

PILOT BALLOON OBSERVATIONS

6.1 **<u>Introduction</u>**. The methods available for tracking balloons in upper wind measurement can be divided into optical-theodolite and radio methods. The latter include radio direction finding, primary and secondary radar techniques and the use of stable radio transmissions (NAVAIDS). In radio-balloon observations (rabals), the balloon used for the radiosonde ascent is tracked with a theodolite in the same manner as that of a pilot balloon. Rabals differ from pibals in that the height data necessary to compute the position of the balloon at one-minute intervals are taken from the radiosonde observation. Double theodolite pibals are non-routine observations and are taken when there is a need for great accuracy for research or other purposes. **In this chapter however, only the single optical-theodolite method will be discussed.**

6.2 **<u>The Pibal Observation</u>**. In a pilot balloon observation (pibal), a balloon which is inflated with either hydrogen or helium to provide a fixed free lift is tracked visually with an optical theodolite. The height of the balloon at successive minutes is not measured, but is a pre-computed value based on the average of a large number of flights triangulated by two theodolites. These results are shown in Columns two and four of Table 6-1. In any individual observation, however, local turbulence may alter the ascension rate and the balloon may actually be higher or lower than the assumed altitude. At one-minute intervals during the ascent, the azimuth and elevation angles of the balloon with reference to the point of observation are read from the azimuth and elevation scales on the theodolite. Computations of the positions of the balloon at selected minutes and, consequently, computations of directions and speeds of movement of the balloon at selected intervals, are derived by trigonometry. The height to which the balloon can be tracked is governed by many factors, such as the speed of winds aloft, which might take it beyond the range of the theodolite; the intervention of an obscuring medium, such as cloud, between the balloon and the observer; and the bursting point of the balloon. Tracking the balloon during a night observation is accomplished by attaching a small, self-illuminating light stick or a small battery-powered lighting unit to the balloon. The single theodolite method ***should*** be used for taking all routine pibals.

6.3 **<u>Selecting the Site</u>**. The site of the observing equipment is regarded as the point of observation. The point of observation ***shall*** be selected with a view that reduces to a minimum the probability of loss of data due to interference by fixed obstructions such as buildings, trees, towers, etc. Angular elevations of obstructions around theodolite sites, with the exception of small pipes or masts, ***should not*** exceed 6° above the horizontal plane.

Table 6-1. Pibal Time vs. Height Table

MINUTE	Assumed HT ABOVE SFC (METERS) 30gram/100gram	SECONDS	ASSUMED HEIGHT(FT) 30g/100g
0			SURFACE
1	216/350	60	700/1150
2	414/670	120	1350/2200
3	612/980	180	2000/3200
4	801/1285	240	2630/4300
5	990/1585	300	3250/5400
6	1170/1880	360	3850/6200
7	1350/2170	420	4430/7100
8	1530/2455	480	5350/8050
9	1710/2740	540	5600/9000
10	1890/3020	600	6200/9900
11	2070/3300	660	6800/10800
12	2250/3580	720	7400/11750
13	2430/3855	780	8000/12650
14	2610/4130	840	8550/13550
15	2790/4405	900	9150/14450
16	2970/4675	960	9750/15300
17	3150/4945	1020	10300/16200
18	3330/5215	1080	10900/17100
19	3510/5485	1140	11500/18000
20	3690/5755	1200	12100/19000
21	3870/6025	1260	12700/19800
22	4050/6296	1320	13300/20650
23	4230/6565	1380	13900/21500
24	4410/6835	1440	14500/22400
25	4590/7105	1500	15000/23300
26	4770/7375	1560	16600/24200
27	4950/7645	1620	16200/25000
28	5130/7915	1680	16800/26000
29	5310/8186	1740	17400/26850
30	5490/8455	1800	18000/27800

Note: This Table is valid for an ascent rate of approximately 300 meters per minute. To achieve this the following Combined Inflation Nozzle and Counterweight free lift values are recommended.

		Helium	Hydrogen
30 Gram Balloons	Day	139 grams	125 grams
	Night	192 grams w/light	170 grams w/light
100 Gram Balloons	Day	515 grams	450 grams
	Night	552 grams w/light	482 grams w/light

6.4 <u>The Theodolite</u>. The type of theodolite used at either fixed or mobile land pibal stations is similar in many respects to a surveyor's transit telescope, with certain modifications made to adapt it to pibal work. A typical theodolite is shown in Figure 6-1a&b. The telescope, supported over the center of the upper plate by a yoke standard, is mounted in a manner that allows it to be rotated in both the vertical and horizontal planes; i.e., it can be turned on a horizontal axis passing through the center of the vertical circle and it can be revolved about a vertical axis passing through the center of the horizontal circle. The theodolite telescope differs from the transit telescope in that the line of sight in a theodolite is bent through an angle of 90°, which places the objective lens and the eyepiece at right angles to each other. A glass prism conveys the image from the objective lens to the eyepiece, which remains stationary in the vertical plane, as the objective lens is moved up and down while tracking the balloon. To avoid the use of two additional lenses, and a subsequent reduction in light, theodolites are equipped with non-erecting eyepieces; hence, the image appears inverted. By rotating an attached internal spiral cam the eyepiece is focused on crosshairs provided for use in centering the balloon in the field of the telescope. Measurement errors of the angles ***should not*** exceed +/-0.05°. Scale-reading errors become increasingly important at great distances and for low elevation angles and ***should not*** exceed 0.1°.

6.4.1 Optical features. Theodolites are classed as either fixed-focus or adjustable focus. The former is adjusted at the factory to focus on distant objects. The latter must be re-focused each time the theodolite is used, and usually several times during the course of an observation. In both types, the eyepiece must be focused on the crosshairs before the theodolite is used.

Some theodolites have a secondary wide-angle telescope of low magnification, which is often helpful in locating a balloon during the first few minutes of the observation. This telescope has a short-focus objective that is brought into view by means of a swinging mirror inside the unit. The focal planes of the two objectives coincide so that the same eyepiece is used, which eliminates the need to refocus. The change from one field to the other is made by means of a lever located on top of the telescope.

6.4.2 Angular Measurements. Vertical and horizontal circles, graduated in whole degrees, are provided for determining the bearing of the telescope. That is, the angles an elevated object makes with a plane tangent to the earth in a vertical plane, and with any reference point, such as true north in a horizontal plane, are read on the circles. Angles can be read to 0.1° by means of a micrometer-type tangent screw, and estimated to 0.01°. Backlash in the gearing of the circles ***should not*** exceed 0.025°. Errors in horizontal and vertical collimation ***should not*** exceed 0.1°.

Theodolites ***should*** be equipped with micrometer drums, integral with the tangent screws, for measuring angles to 0.1°. These drums ***should*** be graduated to 0.1°, and the graduations ***should*** be numbered from 0 to 9, inclusive. The reading ***should*** be taken in whole degrees if taken from the graduated circles, and to 0.1° from the micrometer drum.

6.4.3 Other Features. Gunsights ***should*** be mounted on each end of the telescope. They ***should*** be adjusted so that when the telescope is aimed correctly at a balloon it will be within the field of the theodolite and can be viewed by looking through the eyepiece. The gunsights ***should*** be a combination of short sights and folding sights.

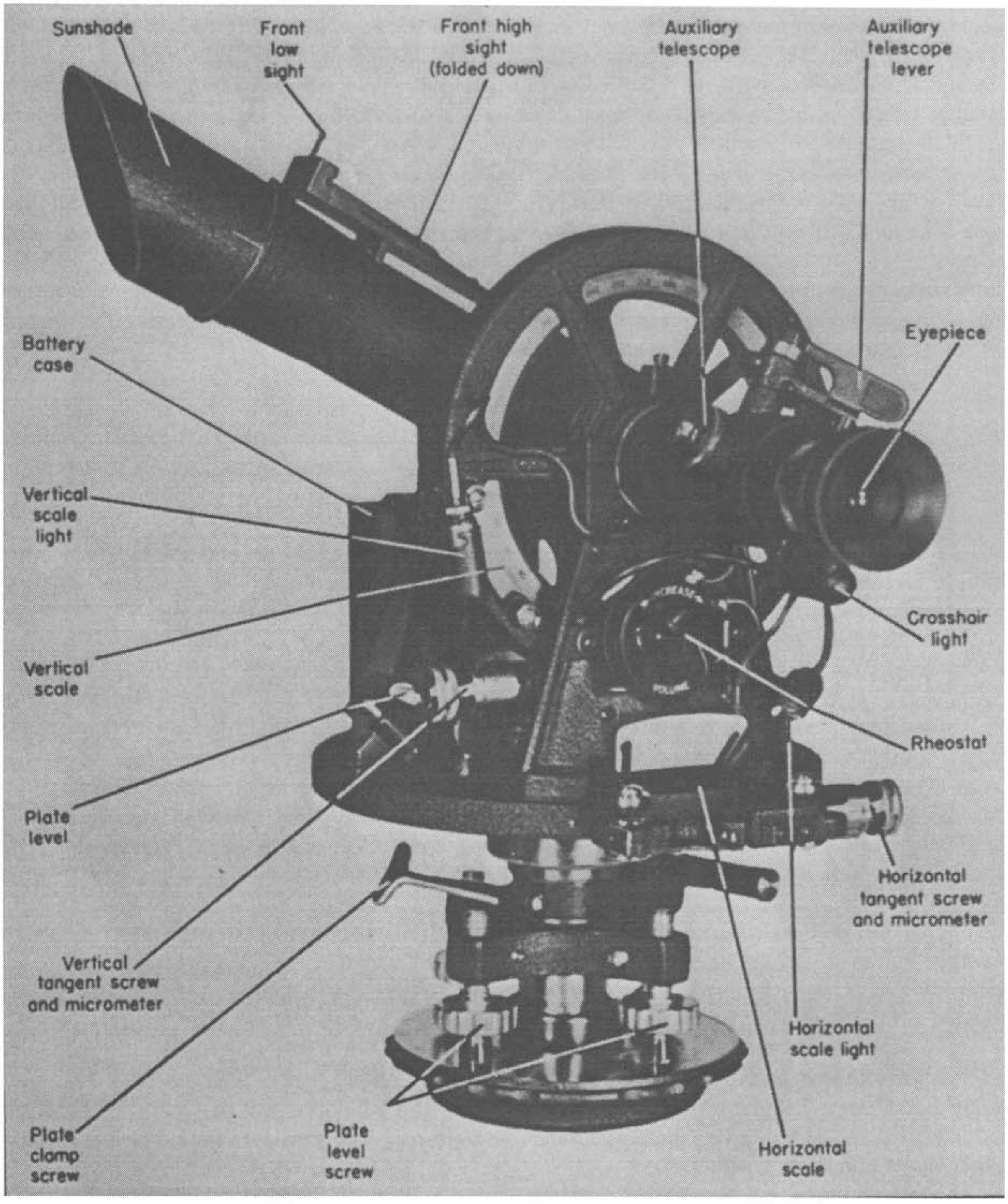

Figure 6-1a. Theodolite of the type used at land stations.

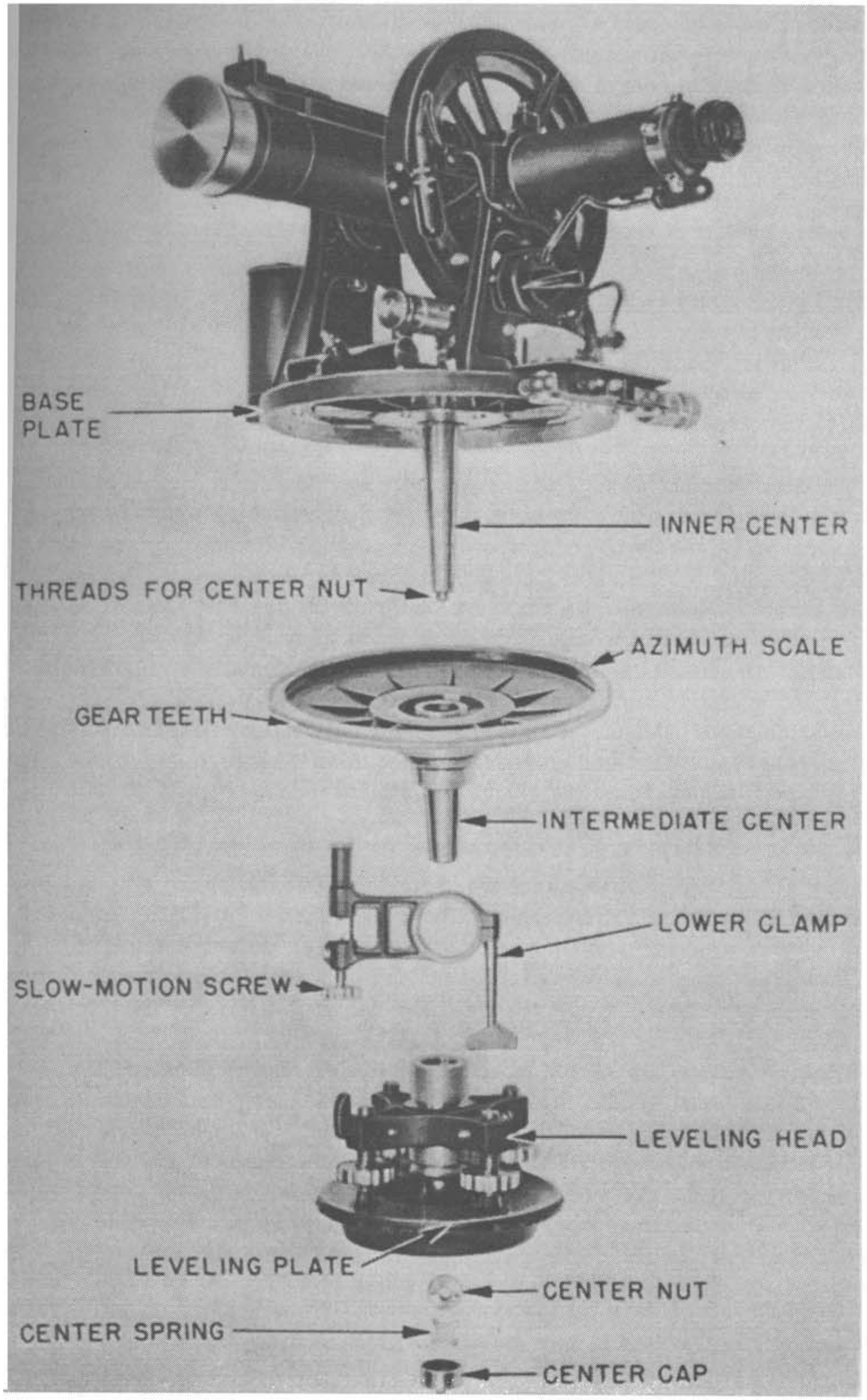

Figure 6-1b. Theodolite of the type used at land stations.

Theodolites ***should*** be equipped with lights to illuminate the crosshairs and micrometer drums when conducting night pibals. Power can be supplied by dry cells or a transformer. Theodolites ***should*** be equipped with a rheostat to control the intensity of the crosshair light, and with switches to turn off the crosshair and micrometer lights between readings. The intensity of the crosshair light ***should*** be adjusted to the lowest possible value consistent with accurate scalar readings. When there is danger of losing the balloon from the field of view, the crosshair and micrometer drum lights ***should*** be turned off between readings.

6.5 Theodolite Leveling and Orientation. When leveling the theodolite, the mount or tripod ***should*** be adjusted to a height convenient to the observer before the theodolite is leveled. The process of insuring that the base-plane of the theodolite is level involves a series of set screws controlling the orientation. Bubble levels are used to determine the orientation; when the theodolite has been leveled successfully the bubbles remain in the center of the levels as the theodolite is rotated about its vertical axis.

After the theodolite has been leveled, it ***should*** be oriented about its vertical axis by rotating it until the reading of the azimuth scale is the same as that of an orientation point with respect to true north. The azimuth tangent screw ***should*** be engaged with the base plate. Because the azimuth scale on some theodolites *may* be read at two positions, the theodolite ***shall*** be oriented with reference to the position to be used during the subsequent observations. The base-plate clamp screw ***should*** be loosened and the base plate turned about its vertical axis until the telescope is trained approximately upon the reference point of orientation. The base plate ***should*** be locked to the vertical axis by tightening the base-plate clamp screw. If the reference point is not at the intersection of the crosshairs, the necessary vertical adjustment ***should*** be made with the elevation tangent screw, and the azimuth adjustment with the slow-motion base-plate screw. This final azimuth adjustment ***should not*** be made with the azimuth tangent screw, because to do so would change the orientation of the theodolite.

6.6 Focusing the Theodolite. The theodolite eye-piece ***should*** be focused by turning the aperture disk to obtain maximum sharpness of the crosshairs. The telescope itself ***should*** be focused by use of the eyepiece sleeve-adjustment screw to obtain maximum sharpness of a distant object. The telescope ***should*** be re-focused during the observation whenever the balloon or lighting device appears blurred.

6.7 General Test. A general test ***should*** be conducted upon receipt of the theodolite and every three months thereafter to determine whether the theodolite requires adjusting by a laboratory technician. The test ***should*** determine if any alignment problems, such as confusion of horizontal and vertical angle change, exist. A satisfactory test involves sighting on a chosen object about 120 meters (400 feet) from the theodolite and recording the indicated angles. A change of both angles by 180 degrees and a re-reading of the indicated angles will normally produce identical readings. If the resulting difference is more than 0.2° in either azimuth or elevation individual agencies ***shall*** make the appropriate adjustments or corrections to insure that the theodolite is functioning within standards.

6.8 The Observation. Before starting a pibal observation, the observer ***shall*** become familiar with weather conditions prevailing at that time and those expected during the course of the observation. The type of observation, the time required for preparation of equipment, and station requirements ***should*** all be considered while preparing for the release.

6.8.1 Release Time. Insofar as possible, pilot balloon release times (actual times of observation) ***shall*** be scheduled as close as possible to H-30 minutes, where H is one of the standard times; eg: 0000, 0600, 1200, 1800 UTC. The release time of the pibal observation ***shall not*** fall outside of the time range from H-45 to H, a period known as the release window. For all non-standard observation times, the release window, in regard to the record time of the observation, is from 30 minutes before to 29 minutes after the assigned hour of observation.

6.8.2 Theodolite Preparation. The theodolite to be used in taking a pibal ***should*** be set up and adjusted in accordance with instructions outlined in para. 6.5. Particular attention ***shall*** be directed to the requirement for proper leveling and orientation of the theodolite with respect to established reference points before the observation is started. Accurate orientation of the theodolite with respect to true north is an essential preliminary to the observations of azimuth and elevation of the moving balloon. Lights for illuminating the crosshairs and micrometer drums ***shall*** be turned on and checked prior to night releases.

6.9 <u>**Balloons**</u>. All pilot balloons used in taking winds-aloft observations are spherical shaped films of natural (latex) or synthetic rubber (neoprene), which are inflated with a lighter-than-air gas (hydrogen, or helium.) The film thickness of the inflated balloons is extremely small, and the balloons are very delicate. The smallest cut, bruise, or scratch sustained during storage or preflight preparations will seriously affect the altitude at which the balloon will burst; therefore, the requirement for careful handling of the balloons cannot be overemphasized.

Balloons ***should*** be stored in their original sealed containers and, if possible, in a warm room at temperatures not exceeding 120°F (50°C). They ***should not*** be placed immediately adjacent to large electric generators or motors because these create ozone, which is detrimental to neoprene. Since balloons deteriorate with age, they ***should*** be used in the order of their production dates to avoid excessive aging. If balloons must be stored at below-freezing temperatures, they ***should*** be returned to a temperature of 18°C or higher for a period of 12 hours or more before removal from their containers. This practice will avoid any damage that they might receive when removed from containers and unfolded while cold. No part of the balloon except the neck ***should*** be touched with the bare hands. When it is necessary to handle any portion other than the neck, soft rubber gloves, soft cloth gloves, or some other non-abrasive material ***should*** be used.

Thirty-gram balloons ***should*** be used for land pibal observations that extend to 4600m (15,000 feet.) Hundred-gram balloons ***should*** be used for pibal requirements above 15,000 feet when a strong possibility exists that the 30-gram balloon would be lost before attaining that altitude. The balloon color is a matter for the observer to decide. In general though, a white balloon ***should*** be used with a clear sky, a black balloon with low or middle overcast, and a red balloon with high overcast or with a white or gray background. It will usually be found that when haze, dust, or smoke are present in a cloudless sky, a white balloon will remain visible longest because the sun shining upon it above a lower layer of haze creates scintillation that is absent when colored balloons are used. **Chapter 3 of this Handbook *should* be referred to for standards regarding balloon pre-release and release procedures.**

6.10 Night Pibal Lighting Units. Tracking a pibal at night can be made possible by attaching a lightweight, self-illuminating or battery-operated lighting unit to the balloon. No lighting unit ***should*** be used for a release more than 15 minutes after the unit has been activated. The lighting unit ***should*** be activated just prior to the release in accordance with accompanying manufacturer's instructions.

6.11 Train Assembly. Attachments ***should not*** be made to pilot balloons used in observations taken during daylight hours. At night, attach the lighting unit directly to the balloon with a length of cord. The length of the train ***should*** generally be limited to 2 meters (6 feet).

6.12 The Release. The timing device ***shall*** be started at the same instant as the balloon release. When the balloon is released 100 meters (300 feet) or more from the observation point, the azimuth bearing and distance from the point of release ***shall*** be noted.

A surface wind observation ***shall*** be taken at the release point no more than 5 minutes before the balloon is released.

Whenever the release point is below the level of the theodolite or whenever the released balloon is forced below the level of the theodolite by a downdraft, the time that the balloon re-ascends to the level of the theodolite ***shall*** be regarded as the time of release, and, if possible, the timing device ***should*** be reset accordingly. To minimize the error as much as possible in such instances, the time of release ***should*** be adjusted to the nearest whole minute. That is, if the balloon descends for less than one-half minute after the actual time of release, no adjustment in time ***should*** be made. If it descends for one-half minute or more, but less than a minute and a half, the time of release ***shall*** be regarded as the actual time of release plus 1 minute**.** In this case, angles read at the end of the second minute after the actual release of the balloon ***shall*** be ascribed to the first minute. The azimuth bearing of the theodolite ***should*** be read at this point and the distance between the balloon and the theodolite estimated. These values ***should*** be recorded when the distance is 100 meters or more. The speed of the surface wind should aid in making the estimation.

6.13 Errors Encountered in Tracking the Balloon. The time of any jar suffered by the theodolite ***should*** be noted since this is the most common cause for a shift in orientation. If the difference in orientation is less than 0.3°, the observation ***shall not*** be corrected. If difference is 0.3° or more, and the time of the shift is known, successive readings ***should*** be corrected by applying the amount of the difference and entering the corrected values above the original entries. If the time of the shift is not known, the observation ***shall*** be discarded and another started as soon as possible within the time constraints specified in para. 6.12.

6.13.1 Extraneous Light. The interference encountered in night pibals from extraneous light entering the objective lens ***should*** be reduced by using the theodolite sun shield. When light from an extraneous source enters the observer's eyes directly, a shield ***should*** be improvised from a piece of cardboard or other material cut with a U-shaped slot and mounted over the yoke standard. Authority ***should*** be obtained whenever possible to turn off all lights that are a persistent source of annoyance and that are not essential to local operations while a night pibal is being taken.

6.13.2 Sun in Field. **THE OBSERVER'S EYES WILL BE PERMANENTLY DAMAGED BY LOOKING DIRECTLY AT THE FOCUSED SUN IMAGE THROUGH THE THEODOLITE. THEREFORE, THE OBSERVER MUST USE EXTREME CAUTION FOLLOWING THE BALLOON WHILE IT IS NEAR THE SUN'S ANGULAR BEARING, AND NEVER TRACK THE BALLOON ACROSS THE SUN'S DISK.**

6.13.3 Confusion of Stars With the Lighting Device. When taking night observations, it is often possible to distinguish the lighting device from stars only by the relatively rapid movement of the former. When angular changes are small, the difficulty is correspondingly greater. If the light that is being tracked does not appear to diminish in brilliance with time, and if it moves from east to west with an angular change of about 1° in 4 minutes, it is probable that a star is being tracked.

6.14 Termination. Immediately upon the termination of a sounding, a preliminary accuracy check ***should*** be made of both the equipment and the observed data. A determination ***should*** be made as to whether the orientation of the theodolite has remained unchanged during the observation. Any reference point of known bearing ***should*** be sighted upon and the indicated azimuth angle read on the theodolite. If there is a difference between the indicated angle and the true bearing of the reference point, the difference is the amount that the theodolite has shifted during the observation.

6.15 Preliminary Inspection of Data. All pibal observations ***should*** be continued as long as possible up to 4600m (15,000 feet) above ground level, except when the agency specifically requests that an observation be continued to a higher level, when the pibal is taken in lieu of a scheduled rawinsonde observation, or when the official in charge of the station deems an extended observation desirable.

If the observed data are not known to be inaccurate but some reason exists for questioning their validity, the observation ***should*** be evaluated and filed for transmission. If severe or unusual weather exists in the vicinity of the station during the pibal observation, a verifying pibal ***should*** be taken as soon thereafter as possible, within the time limits specified in para. 6.12. Occasionally during a pibal, a balloon will develop a leak that markedly affects its ascension rate. This condition will usually be recognized by a sudden and rapid decrease in the elevation angle. Whenever a leaking balloon is suspected, a second release ***shall*** be made as soon as possible within the time constraints specified in para. 6.12.

The second pibal ***should*** be evaluated and, if necessary, a correction filed with the transmitted data. If a correction message is sent, the ascension number ***shall*** be assigned to the second pibal and the first discarded. If no correction message is sent, the verifying pibal ***shall*** be discarded.

6.16 Criteria for Satisfactory Observations. A pibal ***should not*** be taken whenever low clouds or other phenomena would prevent the observation from reaching 900m (3,000 feet) above the surface, unless specifically requested by the area or local forecaster, or whenever the station is within an area described in a severe weather warning or watch. Pilot balloon observations extending to less than 300m (1,000 feet) above the surface ***shall not*** be transmitted. Very light rain or very light rain showers, and occurrences of restrictions to vision that do not reduce the visibility to zero, are not in themselves regarded as sufficient justification for omission of a pibal observation. A pibal observation ***shall not*** contain more than 5 consecutive minutes of missing data. If this occurs and an observation is required, the flight shall be terminated and another pibal taken.

Whenever a pibal is lost from the field of the theodolite less than 10 minutes after release and the weather conditions or circumstances of the loss are such that a longer observation is possible, another pibal ***should*** be started immediately. The longer observation ***shall*** be used for all record and transmission purposes, and any record of the shorter observation ***should*** be discarded.

A loose base-plate clamp will necessitate a second observation if the duration of the flight prior to the loosening does not meet the requirements for a satisfactory observation unless the exact time of its loosening, and the amount of error, can be definitely determined and the observation corrected.

Another pibal ***shall not*** be required whenever the balloon is lost less than 10 minutes after release because of the following conditions:

- When the balloon entered the base of, or was obscured by, clouds and it seems unlikely that another pibal would extend to 10 minutes or more.
- Obstructions to vision, provided there is reasonable certainty that a longer observation could not be secured with a different color balloon.
- Obscuration by fixed obstruction, when the path of the balloon is so low as to render the success of another observation improbable.
- Disappearance at a horizontal distance of 10 kilometers or more in daytime and 7 kilometers or more at night, and the exact reason is not known (loss of the balloon will be ascribed to distance).

6.17 <u>Pibal Evaluation</u>. Evaluation of pibals taken at fixed or mobile land stations ***shall*** be accomplished by projecting the path of the balloon to a horizontal plane tangent to the surface of the earth through the observation point. The evaluation of wind speed and direction involves the trigonometric computation of the minute-to-minute changes in the plan position of the balloon. Computer software specifically designed for these computations is available and ***should*** be used in lieu of manual computation with plotting boards and graphs.

Wind direction and speed ***shall*** be evaluated for each minute for which actual or interpolated angular data are available using a 2-minute interval with a 1-minute overlap procedure.

6.17.1 Missing Data. At a minimum, when angular data are missing for 3 minutes or less and accurate data bound this stratum both above and below, interpolate for the missing angular data. If three minutes or less are missing or in error at the beginning of the pibal, a best estimate for the interpolated minutes ***should*** be used by using the reading changes of the following good minutes and the observed flight of the balloon after release.

6.17.2 Errors. For theodolite observations, the wind errors vary markedly with range, elevation and azimuth, even when the errors of these parameters remain constant.

In single-theodolite ascents the largest source of error is the uncertainty in the rate of ascent. This may be due partly to incorrect inflation and partly to vertical currents in the air. The proportional error of the assumed mean rate of ascent introduces a like proportional error in the height and, with modification by the elevation angle, a proportional error in wind speed.

Errors in the measurement of the mean wind in a shallow layer arise partly from errors in the assumed height of the layer. The latter errors result in the measured wind being attributed to the wrong level and are not usually serious unless the height is derived for an assumed rate of ascent. Height measurements are affected more by systematic errors, such as those arising from incorrect leveling of the equipment, than by random errors of observation.

When upper-wind data are required in mean layers up to one kilometer thick, corresponding to three or four minutes of the ascent, it is usual to smooth the reading over this period. This procedure reduces the errors to nearly one-half of those for pairs of observations at one minute intervals, provided the errors are perfectly random.

6.18 <u>The Pibal Message</u>. Instructions for coding the pibal message for transmission are found in Appendix E-I.

The height of the pibal balloon is assumed and given in Columns 2 or 4 of Table 6-1. However, WMO standards require that the coded message for a pibal observation include wind information at the height of standard isobaric surfaces (para 5.2.1). The height for these standard isobaric surfaces ***should*** be determined using the following methods:

- At stations taking rawinsonde observations in addition to pibal observations, use the pressure-altitude curve from a current rawinsonde observation to determine the heights of the constant pressure surfaces for the pibal observation.

- At stations taking pibal observations only, use tables of mean monthly heights of constant pressure surfaces. If mean monthly heights are not available, use U.S. Standard Atmosphere geopotential heights. (Ref. 15) (See Appendix D for method of computation.)

6.19 <u>Theodolite Care and Adjustments</u>. Special care ***should*** be taken to avoid any situation that might result in the theodolite being dropped or otherwise subjected to a severe jolt. In addition, theodolites ***should*** be cared for and adjusted by following the specific recommended guidelines that are listed in the following paragraphs:

- A clean cloth or lens tissue ***should*** be used to remove dust from the objective lens and the eyepiece. The lens ***should*** be kept covered when the theodolite is not in use. A sunshade ***should*** be used to protect the lens from the direct rays of the sun.

- In order to retard oxidation, the graduated circles and micrometer drums ***should*** be coated with a clear lacquer. A thin film of oil applied with a lint-free cloth may help keep the scale surfaces clean.

- The theodolite ***should*** be inspected frequently for loose screws or parts.

- The bearing surfaces on the theodolite ***should*** be lubricated occasionally with a small amount of anemometer or machine oil to keep them operating smoothly. Neither the worm gears nor any element of the optical system ***should*** be lubricated.

6.20 Storage Between Observations. If the theodolite is adequately covered and not accessible to unauthorized persons, it need not be taken indoors between observations, provided it is not exposed to the elements. If it is taken indoors between observations, care ***should*** be taken each time it is placed on its adjustable mount or tripod to ensure that the threads holding it to the mount are properly secured and engaged, and that the legs of the tripod are properly seated in their foot blocks.

Both tangent screws ***should*** be disengaged after the observation to avoid possible damage to the worm gears if the instrument is accidentally jarred. When moved about, the theodolite ***should*** be carried by the base plate rather than by the yoke assembly.

CHAPTER 7

DATA DISSEMINATION

7.1 <u>Introduction</u>. Radiosonde and pibal observations are disseminated for operational use by means of various communication services described below. In addition, these observations are archived for research and other use and disseminated by the archive centers. Under agency control, all observations ***shall*** be disseminated by means of one of the communication services and archived by one of the archival centers. This Handbook recognizes that some observations may be taken for local use only.

7.2 <u>Global, Regional, and National Telecommunications</u>. The GTS comprises the data collection systems of the World Weather Watch (WWW). The GTS ties together the three World Meteorological Centers (WMCs): Melbourne, Australia; Moscow, Russia; and Washington, DC; and their various supporting regional and national systems. The WMCs receive data from the various Regional Telecommunication Hubs (RTH) within their zone of responsibility. The systems for collection of data at the RTHs from the various National Meteorological Centers (NMCs) in each country comprise the Regional Telecommunications Network. Lastly, the individual national configurations for the collection of data within countries make up the National Telecommunications Systems for meteorological data.

7.2.1 The Regional Telecommunications System. WMO Regions IV and V, North America and Southwest Pacific Ocean, contain rawinsonde sites operated by the United States as part of the Global Observing (GOS) Network. Exceptions are the sites operated by the U.S. DoD at Diego Garcia located in the Indian Ocean, and Ascension Island in the Atlantic Ocean (both in Region I.) (See Appendix C - List of U.S. Rawinsonde Stations.)

7.2.2 National Telecommunications Systems. The principal systems for collecting and exchanging data among rawinsonde units and other facilities within the coterminous U.S. are NOAA's AFOS; Alaskanet, Pacific Communication Systems; and DoD's AWN.

The major hub for the AFOS is the NWSTG located in Silver Spring, Maryland, and for the AWN, Tinker AFB, Oklahoma. Each of these facilities is responsible for transferring data between one another and to and from all other national circuits. The NWSTG is the U.S. interface to the GTS and provides distribution to international users. Each system is designed to prevent system failure and data losses by having multiple data flow paths. If a failure occurs at a point that inhibits flow of data in one direction, data will continue to flow in the other direction. Reports from the DoD stations which form part of the GOS are entered onto the GTS through the NWSTG. Other DoD sites communicate their data only on the AWN or its branch circuits.

7.3 <u>WMO Index Numbers</u>. A station index number in the symbolic form IIiii is included in the reports of meteorological observations made at fixed land meteorological stations or aboard ships using land code forms. The station index number is composed of the WMO block number (II -representing Identification) and a three-digit national station number (iii). The two-digit block number defines the area in which the reporting station is located.

7.3.1 Assignment of International Station Index Numbers. Each station within the WWW Global Observing Network which communicates synoptic observations (surface and/or rawinsonde) or other specified types of data (e.g., CLIMAT, CLIMAT TEMP, etc.) has a five digit international station index number assigned to it. These numerical designations facilitate identifying, switching, and processing the bulletins and data that the individual stations provide. Quality control is imperative to ensure the accurate transmission of station numbers. An erroneous index number can cause either a loss of the report or assignment of the data to the wrong location if the erroneous number happens to be that of another station. Block number designation assignments are made by the WMO; station numbers assignments are delegated to member countries. If a station moves, even a short distance, a new index number may need to be assigned. Stations ***shall*** be responsible for obtaining a proper index number.

7.3.2 Obtaining Assignments of WMO Block/Station Numbers. Responsibility for the assignment of WMO Block/Station Numbers for U.S. rawinsonde stations rests exclusively with the Permanent Representative of the U.S. to the WMO. Agencies requiring assignments of WMO index numbers for any of their stations ***shall*** direct their requests to:

Headquarters, National Weather Service - NOAA
Attn: W/OSO242
Silver Spring Metro Center 2
Silver Spring, MD 20910

Requests for block/station number assignments must be made in writing and the following information about the station ***shall*** be provided:

- Name of the Station
- Latitude
- Longitude
- Date operations are to begin
- Synoptic programs to be carried out (i.e., synoptic, rawinsonde, CLIMAT, etc.)
- Schedule of planned synoptic times for data transmissions
- Station elevation information, in meters, including
    - H_P - the datum level to which barometric reports at the station refer (station pressure).
    - H - the elevation of the ground in the immediate vicinity of the station for stations not located on aerodromes
      or
      H_A - official height of the aerodrome for stations located on aerodromes.
    - Elevation of the release point (if different than station elevation).

7.4 Transmitting Rawinsonde Reports. The complete observation ***shall*** be transmitted not later than 30 minutes after termination of the ascent. The coded report containing data for pressures greater than 100hPa (Parts A & B, Appendix E) ***shall*** be transmitted no later than 45 minutes after the standard observation time (0000 or 1200 UTC). If, owing to unforeseen circumstances, less than a full data report can be provided, stations ***shall*** do the following:

- When no data are available, a report giving the coded reason ***shall*** be filed within the scheduled deadline.

- When some data are available but a full report cannot be filed, a partial report ***shall*** be transmitted within the time scheduled for a full report. In addition, the coded reason for providing only a partial report ***shall*** be included with the partial report.

The times shown in Table 7-1 are the maximum times allowable for transmissions. In the event a complete report is not ready at these times for any reason, rawinsonde sites ***shall*** communicate as much data as are available by the deadline and include in the message(s) the appropriate 101-- group explaining the reason for missing data (see Appendix E-II.2.9). As soon as the remaining data for the Part are available, a retransmission of the entire Part ***shall*** be made.

Table 7-1. Deadlines (in minutes after release time R) for Transmission of Scheduled Synoptic Rawinsonde Observations

CODE FORM: TEMP				CODE FORM: PILOT	
Part A	**Part B**	**Part C**	**Part D**	**Part B**	**Part D**
R* + 90 Minutes	R + 90 Minutes	R + 180 Minutes	R + 180 Minutes	R + 120 Minutes	R + 180 Minutes

* R is the balloon release time, **not the observation time**. [Ref 12, Part III]

7.4.1 RADAT. This coded report is composed of information concerning the freezing level and ***should*** be transmitted 15 minutes following the standard time of observation. Procedures for encoding RADAT reports are given in Appendix E, Table 0421.

7.5 Data Archiving. There are many critical non-real-time users of rawinsonde observations in climatology and research. In order to make rawinsonde observations available to retrospective users, all observations ***shall*** be sent to major data centers in compliance with the standards defined in Appendix F. Three major data centers maintain historical rawinsonde data: NOAA's NCDC; Operating Location-A (OL-A) of the U.S. Air Force's Combat Climatology Center (AFCCC); and Fleet Numerical Meteorology and Oceanography Detachment. These Centers are located in Asheville, NC. See Appendix F for details.

CHAPTER 8

QUALITY ASSURANCE

8.1 Introduction. Effective quality control (QC) requires actions on the part of observers; communicators; national analysis centers (the principal users of the data) and archival centers; and the upper-air program managers. The QC endeavors of these entities are so interrelated that their activities cannot be carried out independently. This Chapter describes an integrated system for coordination between these entities. Such a system provides Quality Assurance.

The purpose of Quality Assurance is to identify deficiencies in the rawinsonde data and to initiate swift and corrective actions. To identify deficiencies, an efficient monitoring program must be maintained. Subsequent to the detection of problems, procedures must exist to enable the problems to be corrected. Each of the entities listed above has a particular responsibility in the Quality Assurance program.

WMO recommendations and minimum standards for upper-air observations quality control are given in Reference 10.

8.2 Monitoring and Quality Control. Two types of quality control are imposed on U.S. upper-air observations. The primary type is referred to as Operational Quality Control (OQC). The second type is referred to as Administrative Quality Control (AQC). The basis for performing both types can be found in WMO Manuals and Guides for the Global Observing System, the Global Telecommunications System, and the Global Data Processing System. [Refs. 10-13] The requirements and methods for carrying out these two types of quality control are jointly agreed upon by the agencies involved and are specified in this Chapter.

8.2.1 Operational Quality Control. OQC is the term used to describe monitoring which is carried out in real-time to near-real-time (0 to 12 hours after observation). It is defined as the quality control performed in time to salvage missing, incomplete, or erroneous data for immediate use or to allow remedial actions to be taken in time to be of value before the next scheduled observation takes place. The following entities are involved: the observing station (OQC described in Chapter 4); the communication hubs (OQC described in this Chapter); and the national analysis centers (OQC covered in this Chapter).

Successful OQC monitoring includes checks of the following items: the quantity and regularity of observations, the quality of the data, the completeness and timeliness of the collection of observational data at the Center concerned, and adherence to standard codes and communications procedures.

Two very important keys to the success of quality control are awareness and timeliness. These include speed in detecting and correcting deficiencies and promptness in notifying data sources and parent units of deficiencies found in their data.

8.2.1.1 The Communications Centers. The Communications Centers are responsible for monitoring the regular flow of meteorological information. This first level of OQC, after the data leave the observing site, involves keeping a close watch on the receipt and transmission of information, generating requests for missing bulletins and reports, checking communications formats, and arranging for the rerouting of traffic in case of system difficulties.

Established procedures allow for verification of the successful transmission and reception of all parts of the rawinsonde message from each scheduled observation. Normally this verification takes place at a location other than the observing site, to assure that the data have successfully found their way through the telecommunications system, and may occur at a communication center or at an analysis center.

8.2.1.2 OQC at the National Analysis Centers. Procedures performed by the centers consist of a series of computerized and interactive examinations of the decoded upper-air messages. Each center makes a decision as to the quality of each report. Any change or rejection (deletion) of the entire report or a portion thereof is recorded.

8.2.1.3 Reporting Deficiencies. The centers have the authority for reporting suspected deficiencies to individual upper-air units within their purview. The National Centers for Environmental Prediction (NCEP) alert NWS upper-air units of problems with their observations. Air Force Global Weather Center (AFGWC) and Fleet Numerical Meteorology and Oceanography Center (FNMOC) perform a similar function for DoD installations. However, the centers ***should*** also exchange OQC information for stations of other agencies.

8.2.2 Administrative Quality Control. AQC is the term used to describe monitoring data after OQC has been completed. AQC includes monitoring data timeliness, quantity, and quality. It is intended to identify and correct chronic or persistent system problems which may not be readily identifiable by OQC. Its purpose is to review the general performance of the system and network and to identify shortcomings which may persist after real-time monitoring is completed. Non-real-time monitoring requires the preparation of summaries and various statistics. It *may* also include the more immediate record checking accomplished at the station by the following working shift.

AQC is performed at the centers by the upper-air program managers and at the Archival Centers. Most of the centers' programs assign probable values to questionable and erroneous data. This enables the centers to evaluate the magnitude of difference between reported and computed values - an essential tool in AQC. Daily statistics on the differences between the observed variables and the assimilating forecast are accumulated monthly. Also available are the records of the consistency-checking programs and the differences between the observed variables and the analysis in which they were used. Digital (by site) and graphical summaries of the mean difference to the forecast, the root-mean-square difference, and the number of rejections by the analysis (assimilation) scheme are produced. Monthly reports containing a brief summary of this information are prepared for the upper-air program managers.

8.2.3 WMO Reports. Under the World Weather Watch program, the WMO has requested that various WMCs and Regional Meteorological Centers (RMCs) assume the responsibility for global monitoring and quality control of specific types of data. The task of coordinating the monitoring of upper-air data has been undertaken by the European Center for Medium-Range Weather Forecasting (ECMWF), located near Reading, England. The ECMWF, along with the major numerical prediction centers throughout the world, monitors the reception and quality of upper-air data from every synoptic network upper-air station in the world. The ECMWF*s responsibility is to collect information from these prediction centers, identify sites whose data by consensus pose problems during the analysis and forecast procedure, and report its findings to the WMO Secretariat. NCEP (Washington D.C., WMC) compiles the U.S. AQC Monthly Quality

Monitoring report for the WMO which includes statistics for U.S. stations. The report is then distributed to other U.S. centers, ECMWF, and other WMCs and RMCs.

8.3 Coordination and Quality Assurance. The efficient exchange of information generated by AQC is essential for Quality Assurance. The entire atmospheric science community will have contact with upper-air observations at some time or other. In this Handbook, those units which perform regularly some kind of quality control are listed. Table 8-1 contains a list of the organizational units in the U.S. that have responsibility for some phase of the rawinsonde and pibal observations - either the taking of, the use of, or the management of the program. An alphabetic code is given for each as well as a location and telephone number. The purpose of this list is to enable them to contact one another and exchange information.

Table 8-1. Specific Components Involved in Upper-air Observations

Name	Location	Phone	OQC	AQC
National Centers for Environmental Prediction (DOC/NOAA/NWS/NCEP)	Camp Springs, MD	(301) 763-4408	X	X
Air Force Global Weather Center (DoD/USAF/AFGWC/SY)	Offutt AFB, NE	(402) 294-3947	X	
Fleet Numerical Meteorology and Oceanography Center (DoD/USN/NMOC/FNMOC)	Monterey, CA	(408) 656-4779	X	X
National Climatic Data Center (DOC/NOAA/NCDC)	Asheville, NC	(704) 271-4021		X
Air Force Combat Climatology Center (DoD/USAF/ACCC)	Asheville, NC	(704) 271-4202		X
Fleet Numerical Meteorology and Oceanography Detachment (DoD/USN/NMOC/FNMOC/FNMOD)	Asheville, NC	(704) 271-4852		X
Office of Systems Operations (DOC/NOAA/NWS/OSO)	Silver Spring, MD	(301) 713-0722		X

8.3.1 The National and Regional Headquarters. The Headquarters elements of the various agencies must be committed to and directly involved in the AQC aspect of the upper-air program. They ***should*** rely on the national centers and the communication centers to provide statistical information for evaluation and action. By assembling statistical data into useful formats, the various Headquarters can:

- identify repetitious occurrences of deficiencies in operational upper-air data,
- determine when and where system breakdowns and shortcomings are occurring,
- ascertain where additional training *may* be required,
- establish reasonable standards of performance for evaluating the observing and communicating networks as a function of geographic or management criteria, and
- use the objective standards for evaluating various segments of the upper-air network.

Initial corrective action ***should*** be taken as rapidly as possible by the observing sites' program manager. Follow-up action to remedy systematic deficiencies ***should*** be taken by the agency concerned in a timely fashion. Performance statistics and actions ***should*** be based on station groupings according to geographic and management criteria. Similarly, Regional Headquarters ***should*** establish standards for the observing sites under their management control.

8.3.2 Exchange of Information Notifying Individual Upper-air Units. The centers ***should*** provide the summary statistics to their upper-air program managers for further analysis, review, and action. Individual station supervisors ***should*** take action to correct deficiencies. The objective basis for actions ***should*** be predicated on the establishment of long term averages of the performance by individual observers. Based on these averages, attention ***should*** be focused on substandard performance.

The style and format for any published diagnostic information ***shall*** be coordinated among the centers and approved by the individual agencies. This will ensure consistency and compatibility among the methods and formats and will avoid misinterpretation of results. All diagnostics ***should*** be summarized, tabulated, printed, and distributed to interested offices within the agencies. They ***should*** also be exchanged among the centers for analysis and comparison.

8.4 <u>Documenting Quality Information for Archival Data</u>. The centers responsible for maintaining an archive of rawinsonde and pibal data collect reports that have been subjected to various levels of OQC and AQC. In addition, they perform some types of AQC independently of the centers responsible for forecasts. The results of all quality control activity ***should*** be archived as metadata in appropriate formats. Moreover, future users of archival information need to be aware of previously documented problems. Therefore, documentation related to data quality problems that may have been resolved but remain in the archived data ***should*** be maintained.

APPENDIX A

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APPENDIX B

OBSERVATION SITE SPECIFICATIONS

B.1 <u>Introduction</u>. This Appendix contains siting and equipment orientation standards for initiating a new fixed-location or mobile upper-air site. In addition, the standards required for operating a safe hydrogen program have been included.

B.2 <u>Site Standards</u>. The optimum location for an upper-air observing site would be on an immense flat plateau with no trees or buildings, far away from any population concentrations or industries, and with the surrounding land gently sloping away in all directions for a long distance. Since such locations are practically nonexistent, the alternative choice is a site as closely approximating the prime location as possible. There are three major factors to consider when selecting any site for radiosonde observations:

- The problem of terrain features or structures interfering with the tracking of the balloon/instrument.
- The suitability of the balloon release area to ensure safety of personnel.
- The absence of hazards which would interfere with the free flight of the balloon train, e.g. wires, trees, ship superstructure, etc.

The site of the observing equipment (tracking or receiving antenna) is regarded as the point of observation. The point of observation ***shall*** be selected to minimize the probability of data loss due to fixed obstructions such as buildings, trees, and towers. Obstructions around radiosonde sites may affect the ability of the antenna to track the instrument or receive the signal whenever the angular altitude and bearing of the obstruction is approached by that of the target. Therefore, insofar as possible, heights of obstructions ***should*** be less than that of the tracking antenna. The site for rawinsonde equipment ***should*** be on high ground with the horizon as free from obstructions as possible. In addition, the launching area terrain ***should*** be flat, smooth, well drained, and free of obstructions and vegetation that would constitute hazards to personnel during balloon launches. Since the flight-trains can range from 26 to 36 meters (85 to 120 feet) in length, the observer ***shall*** insure considerable maneuvering room, especially during strong surface wind releases. In the case of observations made aboard ships, releases ***should*** be made downwind from the superstructure even if it necessitates a brief alteration of the ship's course. There ***should*** be no extensive obstructions subtending an angle exceeding six degrees at the observation point. A symmetrical hill with a downward slope of about six degrees for a distance of 400 meters, in a hollow surrounded by hills rising to one or two degrees elevation, affords a good site because it would eliminate ground echoes beyond the short range. The site ***should*** be provided with a firm foundation on which the buildings and equipment can rest.

Mobile upper-air sites ***should*** follow the same guidelines that apply to fixed sites. In addition, the following general considerations ***should*** be taken: fixed man-made obstructions, dense trees, or other topographic features ***should not*** be less than 18 meters (60 feet) from the point of observation. Individual agencies ***should*** refer to manufacturer's instructions regarding detailed setup guidelines.

Requirements for equipment operating on low radio-frequencies (e.g. NAVAID systems) are more exacting since the effect of ground reflections is more pronounced. The site in such cases ***should*** be flat and have a largely obstruction-free horizon. There ***should*** be no conducting objects or irregularities, such as large machinery (i.e. electrical motors, farm implements, etc.), trees, hedges, or outlying buildings within a radius of about 500 meters in order to avoid reflections of the signal.

B.2.1. Surveying the Site. A complete survey of the site ***shall*** be performed to determine fixed compass points and landmarks in relation to the location of the ground tracking-antenna. The survey ***shall*** be performed in accordance with established surveying methods and the critical points ***shall*** be documented and made part of the station record. Stations using RDF systems ***should*** utilize the pertinent surveying points to orient the tracking antenna towards a known fixed point. If this equipment moves for any reason, a new survey ***shall*** be conducted.

B.2.2 Posting the Location of Wires Antennas, and Other Obstructions. The location of wires, antennas, buildings, and other critical obstructions throughout a 360 degree circle and within 1/4 mile of the launch site ***shall*** be charted and prominently posted by the upper-air unit. All observers ***shall*** be familiar with the meaning and importance of this chart. They ***shall*** be made aware that severe burns and possibly death could result from coming into contact with wires and antennas or from holding the radiosonde train if it comes into contact with them. The station manager ***shall*** advise all of the staff of the inherent dangers of trying to disentangle radiosonde equipment from wires of any kind that carry an electrical current.

B.2.3 Developing the RDF Limiting Angles Table. Limiting angles refer to angles either side of and above obstructions extending above the horizon which, when reached, would cause errors in the RDF antenna's position. Typical values are not less than six degrees. Equipment manufacturers ***should*** be consulted for specific system constraints. Errors are normally caused by radio interference and multipath propagation of the radiosonde's signal causing the position of the antenna to 'bounce" or be erratic. RDF systems require the generation of a limiting angles table for the purpose of determining the minimum elevation angle associated with every whole azimuth angle around the horizon. These angles are normally plotted to produce a Limiting Angles Plot diagram that ***should*** be posted conspicuously within the workplace. The limiting angles zone is, by definition, the area below each limiting angle in the plot. Angles in this zone are not representative of the radiosonde's true position and ***should***, therefore, be eliminated. Agencies ***should*** develop, maintain, and follow specific guidelines for the Limiting Angles Plot. (See para. 4.5.1.3.)

B.2.4 Developing the Surface Elevation/Launch Elevation Pressure Correction Table. When the release location and the location at which the surface pressure is determined are not collocated correction factors ***shall*** be applied to adjust pressure readings accordingly.

B.3 **Equipment Orientation Checks**. The orientation of the equipment in reference to true north ***should*** be checked at least every three months if wind data are obtained by RDF systems. This is done by either comparing RDF antenna readings with those taken simultaneously with an optical theodolite or by using a high resolution range/angle recorder.

RDF equipment ***should*** be checked daily by using a signal from a fixed distant object (if possible) whose location is accurately known. The range reading ***should*** be correct to within 20 meters and azimuth correct to within 0.05 degrees.

For meteorological purposes, all equipment used for determining direction is oriented with respect to true North. This includes orientation of Rawinsonde antennas, pibal theodolites, target antennas, and limiting angle diagrams required for radio direction finding systems. If using a compass to do this, care ***shall*** be taken to ensure the correct orientation by accounting for the local magnetic variation. To accomplish the correct orientation, knowing the current local magnetic variation, the following ***shall*** be performed:

1) The wind-finding antenna and theodolite ***shall*** be oriented such that a zero degree azimuth points to magnetic (compass) north.

2a) If the local variation angle is x degrees east, the antenna ***shall*** be rotated x degrees counter-clockwise, or

b) If the local declination angle is x degrees west, the antenna ***shall*** be rotated x degrees clockwise.

Figure B-1 presents an example of the large-scale magnetic variation (declination) for the coterminous U.S. Since the magnetic pole possesses a secular position drift, care ***should*** be taken to employ a current value for the local declination. Local magnetic variation can be obtained from current sectional aeronautical charts or USGS topographic maps.

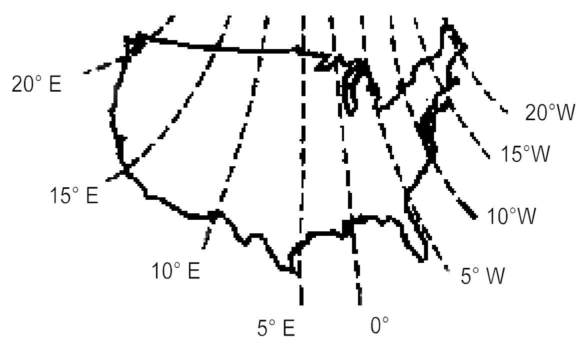


Figure B-1. Sample compass declination chart.

B.4 <u>Equipment and Shelter Considerations</u>. As long as VLF facilities continue to be maintained, some simplification in user equipment responsibilities can be expected to result from the choice of a NAVAID system. Although a stable platform is not required for such systems, it *may* be necessary to install a directional telemetry antenna to maintain a reliable radiosonde-to-ground station communication link. To allow rapid acquisition of phase differences after launch or to use the differential VLF technique, facilities ***should*** be equipped to receive the NAVAID signals locally at the ground station.

To allow for better signal reception and to maximize the field of view, RDF systems are normally located on top of a shelter inside of a fiberglass dome called a radome. The radome prevents the elements, such as salt air, from degrading the system and reduces maintenance problems.

NAVAID antennas are much smaller in size than RDF systems and can be situated anywhere that provides good reception.

B.5 <u>Inflation Gasses</u>. Hydrogen or helium gas ***should*** be used at all upper-air facilities, unless the use of hydrogen is determined to be unsafe or impractical by the agency. The determination of the source of hydrogen gas to use for balloon inflation ***shall*** be made on the basis of operational and economic feasibility. Helium gas ***shall*** be substituted for hydrogen gas at facilities determined to be impractical or unsafe for hydrogen.

B.5.1 Hydrogen Cylinders. When bottled gas is used, *only* commercial suppliers regulated by the U. S. Department of Transportation ***shall*** be used. Hydrogen cylinders ***shall*** be stored in nonmetallic racks and secured with cables with nonmetallic surfaces.

A manifold ***shall not*** be used on hydrogen cylinders under any circumstances. Further, only valving approved for hydrogen by the National Fire Protection Association (NFPA) or the American Gas Association ***shall*** be used. Such valves are normally a diaphragm type. Whenever possible, stainless steel tubing with stainless steel swagelock fittings ***should*** be used in hydrogen systems.

Cylinders ***shall*** be inspected upon arrival to assure that they have been pressure tested in accordance with the American Society of Mechanical Engineers pressure vessel codes. A pressure test is required every five to ten years depending upon the specific rating of the vessel and the supplier ***should*** know how often the vessels ***should*** be tested. The agency ***should not*** accept delivery of cylinders which have not been tested according to applicable Department of Transportation regulations. Cylinders which will require testing in the near future ***should*** be used first.

B.5.2 Pressure Regulation. Pressure regulators ***shall*** be the double-stage type and be approved by the Underwriters Laboratories (UL), Factory Mutual Insurance Company (FM or FMIC), or another testing company of comparable stature.

B.5.3 Heat/Leak Detectors. Heat detectors are required for all hydrogen cylinders and generators. Temperature sensitive tabs or crayons ***should*** be used to mark all hydrogen cylinders, and tabs ***should*** be used to mark all hydrogen generator cell head bolts to enable detection of hydrogen fires. Leak detecting fluids ***should*** be stored in the inflation building so that hydrogen gas leaks can be easily detected. Each agency ***shall*** determine the best gas heat/leak detectors for the type of generation method being used.

B.5.4 Inflation Equipment/Hydrogen Cylinders. Upper-air sites using hydrogen from cylinders ***shall*** inflate balloons using only one cylinder at a time. The cylinders ***shall never*** be moved during inflation and ***should*** be kept within the storage room. Cylinders ***shall*** be properly secured so that they won't fall over or generate sparks. A UL or FM approved multi-stage regulator ***should*** be attached to the cylinder in use and hydrogen ***should*** be routed to the balloon at low pressure via the special piping. Valves ***shall*** be kept closed on all cylinders not being used for inflation and the protective cap ***should*** be kept in place. If a cylinder's protective cap cannot be removed or the valve opened using normal hand exertion, mark the cylinder as defective and have the supplier pick it up. Use only approved spark-proof tools for cap removal.

Cylinder valves ***shall*** be kept closed while attaching or removing a regulator. Never let hydrogen escape into the free atmosphere. Improper practices which allow hydrogen to bleed from the cylinder are dangerous and could result in an unexpected ignition. Whenever a leak is suspected, test for escaping hydrogen gas by using a solution formulated for detecting leaks. Should a leak be discovered, mark the cylinder as defective and have the supplier pick it up immediately.

B.5.5 Inflation Equipment - Hydrogen Generators. The intelligent and safe use of the hydrogen generator requires special training. Operators of hydrogen generating equipment ***shall*** satisfactorily complete an upper-air operator's training course, or be certified by the station manager to have demonstrated proficiency. Hydrogen Generator Operating Instructions ***shall*** be posted in plain view in close proximity to the generator itself within the inflation building. Each agency ***shall*** ensure that all persons working with the hydrogen generator are familiar with the operating and safety instructions.

B.6 Safety Standards for Hydrogen Gas. Agency facilities ***shall*** comply with the National Fire Protection Association (NFPA) Codes and Standards. NFPA 50A is the Standard for Gaseous Hydrogen Systems at Consumer Sites and the NFPA 220 is the Standard on types of Building Construction. These two NFPA Standards along with the sections that follow describe the standards required for the construction of the inflation shelter and the proper and safe use of hydrogen gas. To reduce the risk of accidental death, personal injury, or property damage from accidental hydrogen ignitions and/or explosions, the guidelines and safety practices detailing the proper and safe use of hydrogen gas and related equipment outlined in this manual ***shall*** be strictly adhered to! Individual agencies ***should*** produce more specific standards for their unique situations, as required.

Agency facilities ***shall*** comply with the NFPA Codes and Standards. The minimum distance a facility ***should*** be in feet from a hydrogen system, in a separate building or in a special room which is part of or attached to a building, is specified in NFPA No. 50A, Table 2 (for a hydrogen system less than three thousand cubic feet, ten feet to a wood frame or a protected wood frame building or structure).

B.6.1 Grounding. The nozzle, weights, cutoff valve, regulator, and cylinder ***shall*** be connected to a common ground by a qualified person trained for this task. Grounding straps are required around the fill bench to assure passive grounding of the operator during filling operations. This requirement is particularly vital when the ambient relative humidity is below 50 percent. Grounding straps ***should*** also be provided for balloons during the fill operation and ***should*** remain connected to the balloon while it is secured to the fill bench awaiting release. A passive grounding strap arrangement is required around the drain port of the hydrogen storage tank on hydrogen generators.

The proper functioning of all grounds ***shall*** be ensured and documented by the agency every six months. The agency ***shall*** ensure that all grounds are inspected visually by the observer before each filling and that any defective ground is repaired immediately. The balloon fill nozzle ***shall*** be grounded to a common ground with the frame of the building and the remainder of the fill system. The grounding system ***should*** have a resistance of less than twenty-five ohms.

B.6.2 The Hydrogen Safety Switch. At stations where fill-line freeze-up is not a possibility, the hydrogen safety switch ***shall*** be used. Where line freeze-up is likely to occur, the switch ***should not*** be used; however, the inflation process ***should*** be closely monitored.

B.6.3 Electrical Components. All electrical equipment, except the hydrogen safety switch, ***shall*** have successfully met all Class I, Division 2, Group B specifications in the National Electrical Code (NEC), available from the NFPA, Battery Park, Quincy, MA, 02269.

Hydrogen systems ***shall*** be securely fastened, electrically grounded, and protected from damage due to falling objects. All interior wiring, receptacles, light switches, and light fixtures ***shall*** successfully meet all Class I, Division 2, Group B specifications in the NEC.

B.6.4 Hydrogen Housing. All buildings housing hydrogen cylinders or generators need to be well ventilated to take maximum advantage of hydrogen's most vital safety property, which is its ability to disperse to a non-flammable mixture in air in a matter of seconds. There ***should*** be at least four ventilation openings, having a minimum total area of one square foot per thousand cubic feet of room volume, for inflation buildings using hydrogen; the openings ***should*** be directed towards the open air. Ceilings of inflation buildings with radomes above the inflation building ***shall*** be gas-tight to prevent hydrogen from entering the radome.

B.6.5 Storage of Flammable Materials. Flammable materials ***shall not*** be stored in rooms where hydrogen gas is stored or used. A minimum distance of sixteen meters (fifty feet) is required between hydrogen and fast burning solids such as lumber, excelsior, or paper. Trash storage receptacles are not allowed inside an inflation building. The following are the standards for hydrogen systems and the shelter vents: a minimum distance of eight meters (25 feet) is required between hydrogen systems of less than 3,000 cubic feet and vent or fill openings of below ground flammable and combustible liquid storage tanks; a minimum distance of three meters (10 feet) is required between hydrogen systems of less than 3,000 cubic feet and up to 1000 gallons of flammable and combustible liquids in above-ground storage tanks or up to 15,000 cubic feet of flammable gas storage; and eight meters (25 feet) is required for larger flammable storage containers.

B.6.6 Fire Extinguishers. A twenty-pound or larger fire extinguisher ***shall*** be placed near an exit of the fill room. It ***shall*** be capable of extinguishing type A (ordinary combustibles that leave an ashen residue), type B (liquid/chemical), and type C (electrical fires). Fire extinguishers approved by the agency ***shall*** be placed in the radome room and in any other room with extensive electrical equipment. To prevent static electrical shock, plastic or fiber nozzles of extinguishers ***shall*** be grounded to the metal handle or body of the extinguisher. At stations where ambient temperature does not drop below -17.7° Celsius (0°F), approved extinguishers ***shall*** be used at locations with extensive electrical equipment. Hydrogen fires are not normally extinguished until the supply of hydrogen has been shut off. Re-ignition may occur if a metal surface adjacent to the flame is not cooled. The fire protection provided ***shall*** be determined by an analysis of local conditions. HYDROGEN FLAMES ARE PRACTICALLY INVISIBLE, so special care must he taken to assure that the fire is noticed and extinguished.

B.6.7 Additional Equipment. Only equipment, tools, and supplies required for balloon inflation ***should*** ever be stored in the inflation building and they ***should*** be placed in non-flammable storage cabinets when not in use. The use of the inflation building for storing extraneous materials and equipment can be a fire hazard and ***should*** be avoided.

B.6.7.1 Space Heaters. Any device used to heat the inflation building or the radome above the inflation building ***shall*** have met Class I, Division 2, Group B specifications in the NEC.

B.6.7.2 Spark-Proof Tools. Spark-proof tools ***should*** be used in making all repairs and adjustments near hydrogen tanks and generators. Insulated, spark-proof tools ***should*** be used when working on hydrogen generators when there is a danger of electrical shock. Even the so-called spark-proof tools, if used improperly, can provide an invisible spark sufficient to ignite hydrogen gas. Consequently, all repairs ***shall*** be carried out carefully and thoughtfully.

B.6.7.3 Radomes. Radomes ***should*** be vented at their apex, where feasible, as an added safety feature in the event of a failure of the gas tight seals between the fill room and the radome. Any device used to heat the radome ***shall*** have met Class I, Division 2, Group B specifications in the NEC.

B.7 <u>Procedure for Ground Equipment</u>. Only emergency maintenance ***should*** be performed on tracking equipment during balloon inflation periods. If an emergency repair becomes necessary while a balloon is being inflated, inflation ***shall*** stop, the hydrogen equipment ***shall*** be turned off, and the balloon ***shall*** be released without the radiosonde and parachute. The emergency maintenance ***shall*** be completed before any other filling operations are conducted. The presence of personnel in roof-top radomes or on the roof of the inflation building ***should*** be avoided during balloon inflation and release periods.

B.8 <u>Hydrogen Generator Maintenance</u>. Agencies ***shall*** establish and maintain records on maintenance and document the safe operation of the hydrogen generator unit. The procedures and format ***should*** be based on the experience gained within their respective agency. This allows each maintenance program to include characteristics unique to each agency. At a minimum, checklists ***should*** be established and the required safety check and maintenance thoroughly carried out by responsible people within the time limits established for the various elements of equipment. All procedures established ***shall*** be reviewed and approved prior to their implementation.

B.9 <u>General Safety</u>. Each agency ***shall*** continuously evaluate safety at upper-air facilities. The agency ***should*** designate a person who is responsible for all aspects of safety at their upper-air facilities, including carrying out recommended changes in procedure as well as any technical changes that can be handled locally. To assist in this safety task, the agency ***should*** designate a local safety representative to assure safe operation on a daily basis.

B.9.1 Smoking. Smoking or the lighting of flammable materials ***shall be*** absolutely prohibited within a distance of twenty-five (25) feet from buildings where hydrogen is stored or generated. "Hydrogen! No Smoking!" warning signs ***shall*** be posted on all exterior sides of the inflation shelter and at least one sign in all interior spaces.

B.9.2 Safety Instructions. Agencies ***shall*** provide General Rules for Hydrogen Fire Prevention posters to their upper-air units. Recommended emergency instructions are given in Exhibits B.1 through B.3 on the following four pages. They describe the general safety rules to be followed. Such rules ***shall*** be posted in plain view in the inflation building. The agency ***shall*** ensure that all persons involved in balloon inflation with hydrogen become familiar with these rules. Agencies ***should*** revise these guidelines to meet their particular safety requirements.

B.9.3 Inflation Building Safety Inspections. Agencies ***should*** establish and follow a daily routine of safety inspection prior to balloon inflation to minimize risks of hydrogen accidents. In addition, Agencies ***shall*** periodically inspect upper-air units to ensure that policies and standards are being followed.

B.9.4 Daily Inspections. No flammable materials ***shall*** be brought into or stored in the building other than those required for balloon inflation. All heat detectors ***shall*** be visually checked for indications of fire when entering the inflation room.

B.9.5 Annual Inspections of Inflation Facilities. Agencies ***shall*** develop a checklist that resembles the following recommended procedures. The check ***should*** be performed at least annually:

a. Check to see that all space heating devices have met Class I, Division 2, Group B specifications in the NEC. (Note: The same limitation applies to radomes above inflation buildings.)

b. Check to see that there are neither trash nor trash storage receptacles in the building.

c. Check to see that all wiring, receptacles, light switches, light fixtures, and electrical equipment other than the hydrogen safety switch are functioning properly and have met Class I, Division 2, Group B specifications in the NEC.

d. Check to see that only spark-proof tools are used and/or stored.

e. Check for adequate numbers and proper placement of heat detectors.

f. Check for presence of leak detector fluids.

g. Check for existence, proper placement, and proper connection to the common ground of passive grounding wires.

h. Check for proper grounding of the runners from the overhead door to the common ground.

i. Check for documentation stating that a semi-annual safety check conducted by an electronics technician has been done certifying that all grounds are functioning properly.

j. Check for use of a nonflammable cabinet for storing all equipment, tools, and supplies.

k. Check for posting of “ Hydrogen! No Smoking!” warning signs on all exterior sides and interior spaces.

l. Check for placement of a twenty pound or larger fire extinguisher near the exit of the building.

m. Check for proper grounding of the fire extinguisher nozzle to the fire extinguisher handle or body.

n. Check for posting of emergency instruction signs (see Exhibits B1 through B3).

o. Check for posting of general rules for hydrogen fire prevention (see Exhibit B3).

p. Verify that all upper-air operators have passed an operator qualification test.

q. When applicable, check for use of tested and approved two stage pressure regulators on all cylinders when being used for inflation.

r. When applicable, check for use of nonmetallic racks and securing cables with non-metallic surfaces.

s. When applicable, check for installation of venting hoods over cylinders (to catch and vent hydrogen gas) when there are less than four roof vents.

t. When applicable, check for posting of general safety rules for cylinders (see Exhibit B1).

u. When applicable, check for posting of generator operating instructions (see Exhibit B2).

v. When applicable, check for presence of salt or other chemicals to melt ice.

w. When applicable, check for a passive grounding strap around the drain port of the hydrogen storage tank on the hydrogen generator.

x. Check for smooth and proper operation of all doors.

y. Check for proper operation of the hydrogen safety switch.

z. Check the condition of all supply hoses and initiate action to replace those that have deteriorated.

EXHIBIT B.l

GENERAL SAFETY RULES FOR CYLINDERS

1. **NO SMOKING OR OPEN FLAME IS PERMITTED IN THE VICINITY OF HYDROGEN CYLINDERS.**

2. **MARK A CYLINDER AS DEFECTIVE IF THE HANDWHEEL CANNOT BE TURNED BY HAND TO OPEN THE VALVE.**

3. **MARK A CYLINDER AS DEFECTIVE IF THE CAP CANNOT BE REMOVED BY HAND. USE NO TOOL TO REMOVE THE CAP.**

4. **ONLY MOVE CYLINDERS WHEN ABSOLUTELY NECESSARY. ALWAYS HANDLE WITH CARE, NEVER DROPPING OR JARRING.**

5. **ALL CYLINDERS *SHOULD* BE STRAPPED, CHAINED, ETC... TO PREVENT ACCIDENTALLY KNOCKING OVER THE CYLINDER.**

6. **CAPS *SHOULD* BE LEFT ON CYLINDERS WHILE THEY ARE EITHER FULL OR EMPTY IF THEY ARE NOT CONNECTED TO THE SUPPLY HOSE.**

7. **NEVER OPEN A VALVE UNTIL THE BALLOON IS CONNECTED TO THE HOSE AND THE HOSE TO THE CYLINDER. NEVER "CRACK" THE VALVE, PERMITTING HYDROGEN TO ESCAPE INTO THE FREE ATMOSPHERE.**

8. **CHECK THE SUPPLY HOSE AND CORRECT TWISTS AND KINKS.**

9. **FULLY CLOSE THE VALVE AFTER A CYLINDER IS EXHAUSTED. MARK THE TANK AS EMPTY.**

10. **CYLINDERS THAT ARE DENTED, LEAKING, OR EXPOSED TO FIRE ARE CONSIDERED DEFECTIVE UNTIL RE-TESTED AND APPROVED FOR USE.**

EXHIBIT B.2

GENERAL RULES FOR HYDROGEN FIRE PREVENTION

1. **GROUND YOURSELF FREQUENTLY.**

2. **FILL THE BALLOON SLOWLY, USING APPROVED GAUGE ONLY.**

3. **ENFORCE NO SMOKING RULES.**

4. **USE ONLY HEATING DEVICES APPROVED FOR A CLASS I, GROUP B ENVIRONMENT.**

5. **DO NOT STORE ANY FLAMMABLE MATERIALS IN THE INFLATION BUILDING.**

6. **DO NOT USE POWER TOOLS INSIDE THE INFLATION BUILDING.**

7. **TURN OFF ELECTRICAL POWER AT THE MAIN BREAKER IF ELECTRICAL WORK MUST BE DONE, EVEN IF ONLY CHANGING A LIGHT BULB!**

8. **DO NOT PERMIT BATTERY-OPERATED DEVICES IN THE BUILDING UNLESS THEY HAVE BEEN APPROVED FOR CLASS I, GROUP B USE.**

HYDROGEN-FED FIRE

1. **IF POSSIBLE, TURN OFF THE SUPPLY OF HYDROGEN.**

2. **EVACUATE THE BUILDING IF THE FIRE CONTINUES AFTER TURNING OFF THE HYDROGEN OR IF YOU ARE UNABLE TO REACH THE CUTOFF.**

3. **NOTIFY:**

   B. FIRE DEPARTMENT ____________________

   B. STATION MANAGER____________________

   C. OTHER ________________________________

4. **TURN OFF ELECTRICAL POWER AT THE MAIN BREAKER IF POSSIBLE.**

5. **DO NOT ATTEMPT TO EXTINGUISH A HYDROGEN-FED FIRE WITH A FIRE EXTINGUISHER. THE RESULTING CHEMICAL INTERACTION COULD CAUSE UNBURNED HYDROGEN TO DISPERSE AND FORM AN EXPLOSIVE MIXTURE.**

EXHIBIT B.3

NON-HYDROGEN FIRE

1. **EXIT THE BUILDING.**

2. **NOTIFY:**

   A. FIRE DEPARTMENT ____________________

   B. STATION MANAGER ___________________

   C. OTHER ________________________________

   OR ACTIVATE THE FIRE ALARM.

3. **YOU MAY RETURN TO TRY TO EXTINGUISH THE FIRE, BUT IF YOU HAVE ANY DOUBT OF YOUR ABILITY TO DO SO, STAND CLEAR OF THE BUILDING.**

BALLOON RUPTURE

1. **TURN OFF THE SUPPLY OF HYDROGEN IF AUTOMATIC SHUT-OFF VALVE IS NOT IMPLEMENTED.**

2. **EXIT THE BUILDING.**

3. **NOTIFY:**

   A. STATION MANAGER ________

   B. OTHER _________________

   FOR ASSISTANCE IF NECESSARY.

4. **ALLOW ADEQUATE VENTING AND FOLLOW AGENCY GUIDELINES BEFORE RE-ENTERING THE INFLATION BUILDING .**

APPENDIX C

U.S. LAND-BASED RAWINSONDE STATIONS

STATION NAME AND LOCATION	RSPNSBL AGENCY	STN ID	WBAN NUMBER	INT'L INDEX	SONDE TYPE	GROUND EQUIP	LAT/LONG (DEGS/MINS)	ELEVATION (METERS)
WMO REGION I, BLOCK 61								
DIEGO GARCIA IS.	NAVY	FJDG	70701	61967	VSL	MARWIN	07/18S 72/24E	3
WIDE AWAKE FIELD	USAF	FHAW	50101	61902	V/11	GMD-5	07/58S 14/24W	79
WMO REGION IV, BLOCK 01								
THULE AB, GREENLAND	USAF	BGTL	17605	04202	V/11	GMD-5	76/32N 68/45W	77
WMO REGION IV, BLOCK 70								
ANCHORAGE, AK	NWS	PAFC	26409	70273	V/51	ART-2	61/09N 149/59W	50
ANNETTE, AK	NWS	PANT	25308	70398	V/51	ART-2	55/02N 131/34W	37
BARROW, AK	NWS	PABR	27502	70026	V/51	ART-2	71/18N 156/47W	12
BETHEL, AK	NWS	PABE	26615	70219	VSL/52	ART-2	60/47N 161/48W	36
COLD BAY, AK	NWS	PACD	25624	70316	VSL/52	ART-2	55/12N 162/43W	30
FAIRBANKS, AK	NWS	PAFA	26411	70261	VSL/52	ART-2	64/49N 147/52W	135
KING SALMON, AK	NWS	PAKN	25503	70326	VSL/52	ART-2	58/41N 156/39W	15
KODIAK, AK	NWS	PADQ	25501	70350	VSL/52	ART-2	57/45N 152/29W	4
KOTZEBUE, AK	NWS	PAOT	26616	70133	VSL/52	ART-2	66/52N 162/38W	5
MCGRATH, AK	NWS	PAMC	26510	70231	VSL/52	ART-2	62/58N 155/37W	103
NOME, AK	NWS	PAOM	26617	70200	VSL/52	ART-2	64/30N 165/26W	5
ST. PAUL ISLAND, AK	NWS	PASN	25713	70308	V/51	ART-2	57/09N 170/13W	10
SHEMYA AFB, AK	USAF	PASY	45715	70414	V/11	GMD-5	52/43N 174/06W	31
YAKUTAT, AK	NWS	PAYA	25339	70361	VSL/52	ART-1	59/31N 139/40W	12

STATION NAME AND LOCATION	RSPNSBL AGENCY	STN ID	WBAN NUMBER	INT'L INDEX	SONDE TYPE	GROUND EQUIP	LAT/LONG (DEGS/MINS)	ELEVATION (METERS)

WMO REGION IV, BLOCK 72

STATION NAME AND LOCATION	RSPNSBL AGENCY	STN ID	WBAN NUMBER	INT'L INDEX	SONDE TYPE	GROUND EQUIP	LAT/LONG (DEGS/MINS)	ELEVATION (METERS)
ABERDEEN, SD	NWS	KABR	14929	72659	V/51	ART-2	45/27N 98/25W	397
ALBANY, NY	NWS	KALB	14735	72518	V/51	ART-1	42/45N 73/48W	86
ALBUQUERQUE, NM	NWS	KABQ	23050	72365	V/51/65	ART-2R	35/02N 106/37W	1615
ALPENA, MI	NWS	KAPX	04837	72634	V/51	ART-2	44/55N 84/43W	1465
AMARILLO, TX	NWS	KAMA	23047	72363	VSL/52	ART-1	35/14N 101/42W	1094
ATLANTA, GA	NWS	KFFC	53819	72215	V/51	ART-2	33/22N 84/34W	246
BIRMINGHAM, AL	NWS	KBMX	53823	72230	V/51	ART-2	33/10N 86/46W	178
BISMARCK, ND	NWS	KBIS	24011	72764	V/51/65	ART-2R	46/46N 100/45W	505
BOISE, ID	NWS	KBOI	24131	72681	VSL/52	ART-2	43/34N 116/13W	871
BROWNSVILLE, TX	NWS	KBRO	12919	72250	V/51	ART-2	25/54N 97/26W	7
BUFFALO, NY	NWS	KBUF	14733	72528	V/51	ART-1	42/56N 78/44W	218
CARIBOU, ME	NWS	KCAR	14607	72712	V/51/65	ART-2R	46/52N 68/01W	191
CHARLESTON, SC	NWS	KCHS	13880	72208	V/51	ART-2	32/54N 80/02W	15
CINCINNATI, OH	NWS	KILN	13841	72426	V/51	ART-2	39/25N 83/49W	323
CORPUS CHRISTI, TX	NWS	KCRP	12924	72251	V/51	ART-2	27/46N 97/30W	14
DEL RIO, TX	NWS	KDRT	22010	72261	V/51	ART-2	29/22N 100/55W	314
DENVER INT APT, CO	NWS	KDNR	23062	72469	VSL/52	ART-2	39/46N 104/52W	1611
DESERT ROCK, NV	DOE	KDRA	03160	72387	V/51	ART-1	36/37N 116/01W	1007
DETROIT, MI	NWS	KDTX	04830	72632	V/51	ART-2	42/42N 83/28W	329
DODGE CITY, KS	NWS	KDDC	13985	72451	V/51	ART-2	37/46N 99/58W	790
EDWARDS AFB, CA	USAF	KEDW	23114	72381	V/11	GMD-5	34/54N 117/55W	724
EGLIN AFB, FL	USAF	KVPS	13858	72221	V/61	DIGICORA	30/29N 86/31W	20
ELKO, NV	NWS	KLKN	04105	72582	V/51	ART-2R	40/52N 115/44W	1607
EL PASO, TX	NWS	KEPZ	03020	72364	VSL/52	ART-2	31/52N 106/42W	1257
FLAGSTAFF, AZ	NWS	KFGZ	53103	72376	V/51	ART-2	35/14N 111/49W	2180
FORT HOOD, TX	ARMY	KHLR	03033	72257	V/10	RDF	31/06N 97/20W	270
FORT HUACHUCA, AZ	ARMY	KFHU	03188	72273	VSL/61	DIGICORA	31/34N 110/21W	1439*
FORT WORTH, TX	NWS	KFWD	03990	72249	V/51/65	ART-2R	32/08N 97/03W	198
GLASGOW, MT	NWS	KGGW	94008	72768	V/51	ART-1	48/13N 106/37W	696
GRAND JUNCTION, CO	NWS	KGJT	23066	72476	V/51/65	ART-2R	39/07N 108/32W	1475
GREAT FALLS, MT	NWS	KTFX	04102	72776	V/51	ART-2	47/27N 111/23W	1132

STATION NAME AND LOCATION	RSPNSBL AGENCY	STN ID	WBAN NUMBER	INT'L INDEX	SONDE TYPE	GROUND EQUIP	LAT/LONG (DEGS/MINS)	ELEVATION (METERS)

WMO REGION IV, BLOCK 72

GREEN BAY, WI	NWS	KGRB	14898	72645	V/51	ART-2	44/29N 88/08W	2 1 4
GREENSBORO, NC	NWS	KGSO	13723	72317	V/51	ART-2	36/05N 79/57W	277
INTERNATIONAL FALLS, MN	NWS	KINL	14918	72747	V/51	ART-2	48/34N 93/23W	361
JACKSON, MS	NWS	KJAN	03940	72235	V/51	ART-1	32/19N 90/05W	91
JACKSONVILLE, FL	NWS	KJAX	13889	72206	V/51	ART-2	30/29N 81/42W	11
KEY WEST, FL	NWS	KEYW	12850	72201	V/51	ART-1	24/33N 81/45W	2
LAKE CHARLES, LA	NWS	KLCH	03937	72240	V/51	ART-2	30/07N 93/13W	5
LITTLE ROCK, AR	NWS	KLZK	03952	72340	V/51/65	ART-2R	34/50N 92/16W	172
MEDFORD, OR	NWS	KMFR	24225	72597	V/51	ART-2	42/23N 122/53W	397
MIAMI, FL	NWS	KMFL	92830	72202	V/51	ART-2	24/45N 80/23W	5
MIDLAND, TX	NWS	KMAF	23023	72265	VSL/52	ART-1	31/57N 102/11W	873
MINNEAPOLIS, MN	NWS	KMPX	94938	72649	V/51	ART-2	44/51N 93/54W	288
MOREHEAD CITY, NC	NWS	KMHX	93768	72305	V/51	ART-2	34/47N 76/53W	11
NASHVILLE, TN	NWS	KOHX	13897	72327	V/51	ART-2	36/15N 86/34W	180
NEW ORLEANS, LA	NWS	KLIX	53813	72233	V/51	ART-1	30/20N 89/50W	10
NEW YORK CITY, NY	NWS	KOKX	94703	72501	V/51	ART-2	40/52N 72/52W	20
NORMAN, OK	NWS	KOUN	03948	72357	V/51	ART-1	35/14N 97/27W	357
NORTH PLATTE, NE	NWS	KLBF	24023	72562	V/51	ART-2	41/08N 100/41W	847
OAKLAND, CA	NWS	KOAK	23230	72493	V/51	ART-2	37/45N 122/13W	6
OMAHA, NE	NWS	KOAX	94980	72558	V/51	ART-2	41/19N 96/22W	350
PITTSBURGH, PA	NWS	KPBZ	94823	72520	V/51	ART-2	40/32N 80/14W	360
PT. MUGU, CA	NAVY	KNTD	93111	72391	VSL	MARWIN	34/07N 119/07W	14
QUILLAYUTE, WA	NWS	KUIL	94240	72797	V/51	ART-2	47/47N 124/33W	56
RAPID CITY, SD	NWS	KUNR	24090	72662	V/51	ART-2	44/03N 103/04W	966
RENO, NV	NWS	KREV	03198	72489	V/51	ART-2	39/34N 119/48W	1516
RIVERTON, WY	NWS	KRIW	24061	72672	VSL/52	ART-2	43/04N 108/29W	1700
ROANOKE, VA	NWS	KRNK	53829	72318	V/51	ART-2	37/12N 80/25W	648
SALEM, OR	NWS	KSLE	24232	72694	V/51	ART-2	44/55N 123/01W	61
SALT LAKE CITY, UT	NWS	KSLC	24127	72572	V/51/65	ART-2R	40/47N 111/57W	1288
SAN DIEGO, CA	NWS	KSGX	03190	72293	V/51	ART-1	32/50N 117/07W	134
SAN NICOLAS IS., CA	NAVY	KNSI	93116	72291	VSL	MARWIN	33/14N 119/28W	14
SHREVEPORT,LA	NWS	KSHV	13957	72248	V/51	ART-1	32/27N 93/50W	85

STATION NAME AND LOCATION	RSPNSBL AGENCY	STN ID	WBAN NUMBER	INT'L INDEX	SONDE TYPE	GROUND EQUIP	LAT/LONG (DEGS/MINS)	ELEVATION (METERS)

WMO REGION IV, BLOCK 72

STATION NAME AND LOCATION	RSPNSBL AGENCY	STN ID	WBAN NUMBER	INT'L INDEX	SONDE TYPE	GROUND EQUIP	LAT/LONG (DEGS/MINS)	ELEVATION (METERS)
SPOKANE, WA	NWS	KOTX	24157	72785	V/51/65	ART-1R	47/38N 117/32W	720
SPRINGFIELD, MO	NWS	KSGF	13995	72440	V/51	ART-2	37/14N 93/24W	390
TALLAHASSEE, FL	NWS	KTLH	93805	72214	V/51	ART-1	30/23N 84/21W	18
TAMPA BAY AREA, FL	NWS	KTBW	12842	72210	V/51	ART-1	27/42N 82/24W	13
TOPEKA, KS	NWS	KTOP	13996	72456	V/51	ART-2	39/04N 95/38W	270
TUCSON, AZ	NWS	KTUS	23160	72274	VSL/52	ART-1	32/07N 110/56W	7 8 7
VANDENBERG AFB, CA	USAF	KVBG	93214	72393	OSC/	MSS	34/44N 120/33W	100
WALLOPS ISLAND, VA	NWS	KWAL	93739	72402	V/49	WL9000	37/56N 75/29W	13
WASHINGTON D.C.	NWS	KLWX	93734	72403	VSL/52	ART-2	38/59N 77/28W	85

WMO REGION IV, BLOCK 74

STATION NAME AND LOCATION	RSPNSBL AGENCY	STN ID	WBAN NUMBER	INT'L INDEX	SONDE TYPE	GROUND EQUIP	LAT/LONG (DEGS/MINS)	ELEVATION (METERS)
ABERDEEN PROVING, MD	ARMY	KAPG	93763	74002	VSL/61	DIGICORA	39/28N 76/04W	5*
CAPE CANAVERAL, FL	USAF	KXMR	12868	74794	V/11	GMD-5	28/29N 80/33W	5
CENTRAL ILLINOIS, IL	NWS	KILX	04833	74560	V/51	ART-2	40/09N 89/20W	178
CHATHAM, MA	NWS	KCHH	14684	74494	V/51/65	ART-2R	41/40N 69/58W	16
DUGWAY PROVING, UT	ARMY	KDPG	24103	74003	V/49	WL9000	40/01N 112/32W	1325*
PORTLAND, ME	NWS	KGYX	54762	74389	VSL/52	ART-2	43/54N 70/15W	125
QUAD CITY, IA	NWS	KDVN	94985	74455	V/51/65	ART-2R	41/37N 90/35W	229
REDSTONE ARSENAL, AL	ARMY	KRSA	53815	74001	VSL/61	DIGICORA	34/36N 86/38W	175*
S. VANDENBERG AFB, CA	USAF	KVBG	93220	74606	V/45	MSS	34/39N 120/34W	112
WHITE SANDS, NM	ARMY	KWSD	93098	74690	VSL/61	DIGICORA	32/13N 106/13W	1224*
YUMA, AZ	ARMY	K1Y7	03125	74004	VSL/61	DIGICORA	32/33N 113/29W	145*

WMO REGION IV, BLOCK 78

STATION NAME AND LOCATION	RSPNSBL AGENCY	STN ID	WBAN NUMBER	INT'L INDEX	SONDE TYPE	GROUND EQUIP	LAT/LONG (DEGS/MINS)	ELEVATION (METERS)
GUANTANAMO, CUBA	NAVY	MUGM	11706	78367	VSL	MARWIN	19/54N 75/13W	56
HOWARD AFB, C.Z.	USAF	MPHO	10705	78806	V/11	GMD-1	08/59N 79/33W	69
SAN JUAN, PR	NWS	KSJU	11641	78526	V/51	ART-2	18/26N 66/00W	3

STATION NAME AND LOCATION	RSPNSBL AGENCY	STN ID	WBAN NUMBER	INT'L INDEX	SONDE TYPE	GROUND EQUIP	LAT/LONG (DEGS/MINS)	ELEVATION (METERS)
				WMO REGION V, BLOCK 91				
CHUUK, ECI	TRUST	PTKK	40505	91334	VSL/52	ART-1	07/27N 151/50E	3
GUAM	NWS	PGUM	41406	91212	V/49	WO9000	13/29N 144/48E	78
HILO, HI	NWS	PHTO	21504	91285	V/51	ART-1	19/43N 155/04W	10
KOROR, PALAU WCI	TRUST	PTRO	40309	91408	VSL/52	ART-1	07/20N 134/29E	30
KWAJALEIN ATOLL	ARMY	PKWA	40604	91366	V/45	MSS	08/44N 167/44E	8
LIHUE, HI	NWS	PHLI	22536	91165	VSL/52	ART-1	21/59N 159/21W	32
MAJURO, MARSHALL IS	TRUST	PMKJ	40710	91376	V/51	ART-1	07/05N 171/23E	3
PAGO PAGO, AM SAMOA	NWS	NSTU	61705	91765	VSL/52	ART-1	14/20S 170/43W	5
PONAPE, ECI	TRUST	PTPN	40504	91348	VSL/52	ART-1	06/58N 158/13E	39
WAKE ISLAND	NWS	PWAK	41606	91245	V/51	ART-1	19/17N 166/39E	5
YAP, WCI	TRUST	PTYA	40308	91413	VSL/52	ART-1	09/29N 138/05E	14

LEGEND:

1. **"STN ID"** column - The three or four letter group is the station identifier.
2. **"WBAN NUMBER"** column - used to by NCDC to identify the station.
3. **"INT'L INDEX"** column - is the International Index Number issued by the WMO and is used to identify each station's meteorological data transmissions.
4. **"SONDE TYPE"** column -

   V - VIZ | VSL - Vaisala
   10 - Type A Pressure-Commutated | 11 - Type B Time-Commutated
   49 - Microsonde (Omega/Loran) | OSC - Orbital Sciences Corporation
   51 - Type B2 Time-Commutated | 52 - Time-Commutated
   65 - Type B Transponder

5. **"GROUND EQUIP"** column -

   ART-1 is a GMD-1 with an automatic radiotheodolite modification
   ART-2 is a WBRT-57 with an automatic radiotheodolite modification
   R - designates ranging capability
   GMD-5 - RDF Ground System
   W9000 - VIZ Ground System (WO9000 - Omega WL9000 - Loran)
   MARWIN - Vaisala Ground System

APPENDIX D

COMPUTATIONAL FORMULAE AND CONSTANTS

D.1 Radiosonde Sensors and Data Reduction. Pressure - the conversion from the engineering units to meteorological units will be specific to the radiosonde and its manufacturer. Values ***shall*** be converted to and reported in hectoPascals (hPa). The hectoPascal is equivalent to the previously used millibar.

Temperature - as with pressure, the conversion will be specific to the radiosonde. Temperatures ***shall*** be recorded in degrees Kelvin or degrees Celsius.

Relative Humidity - the same applies. Relative Humidity ***shall*** be recorded in per cent.

Wind - NAVAID-derived winds will be under the control of the manufacturer and may not be the same for the same radiosonde type. Wind information ***shall*** be recorded in polar form, in degrees from true north and in knots. A secondary form may be in vector form and in meters per second. Winds ***shall*** be computed using earth spherical geometry, insuring that accurate determinations result in the cases of high mean wind.

D.2 Geopotential Height. The altitude of the radiosonde is reported in units of scaled geopotential (geopotential height) above mean sea level (MSL). The elevation of the release point (typically the station elevation) ***should*** be a surveyed geometric position, and ***shall*** be converted to geopotential height. The strata or layers (in pressure) resulting from the radiosonde telemetry rate ***shall*** be employed to calculate the geopotential height of the instrument. The time increments are usually the points sampled, but the values of the variables ***should*** be the result of the signal processing algorithm (Chapter 2) in order to achieve a balance between vertical resolution and the quality of the variables. Layer thicknesses ***shall*** be calculated from the measured pressures at the bounds of each layer and the mean virtual temperature within the layer.

The definition of geopotential is the potential energy due to gravity of a unit mass of air at some point above a standard position (i.e. zero energy), usually mean sea-level, and is measured in a positive sense vertically upward. Geopotential is:

$$\Phi = \int_0^Z g dZ \ .$$

The geopotential meter (gpm) is defined as a rescaled geopotential, and is given by:

$$h_n = \frac{1}{9.80665} \int_0^n g(z)\, dz \ .$$

Thus, a discrete version of the hypsometric equation is

$$\ln \frac{p_{i+1}}{p_i} = -\frac{g\,\delta h}{R^* Tv}$$

where;

p = pressure in hPa
g = acceleration of gravity (standard) = 9.80665 according to WMO Technical Regulations
R* = gas constant for dry air = 287.04 $m^2 s^{-2} K^{-1}$
Tv = mean virtual temperature for the layer = [Tv(i+1) + Tv(i)]/2 in degrees K
*h = layer thickness (meters)
i refers to lower boundary.

For simplicity, the equation above can also be expressed as:

$$\Delta h_i = -14.6355\,(T_{i-1} + T_i)\ln(\frac{p_{i-1}}{p_i})$$

Finally, the thickness) h_i of each pressure layer above the surface in geopotential meters may be summed to give the height h_n of any pressure surface. Thus,

$$h_n = \sum_i^n \Delta h_i$$

Occasionally it is necessary to convert from geopotential to geometric height. The conversion algorithm is:

$$z_n = \frac{h_n R_e}{Gr - h_n}$$

where

Gr = the gravity ratio = [g_N Re/9.80665]
Re = radius of the earth at latitude N , and
g_N = gravity at N = 9.80616[1-0.002637(cos(2N)) + 0.0000059($\cos^2$(2N))]

For constructing the Standard Atmosphere pressure-altitude (pressure-height) relationship, the following parameters are defined; they are identical for the ICAO and U.S. Standard Atmospheres (Ref. 15):

The pressure at zero altitude is 1013.250 hPa.
The Temperature at zero pressure-altitude is 288.16°K.
The lapse rate of temperature to 11.0km is -6.5°C per kilometer.
The lapse rate of temperature from 11.0 to 25km is 0.0°C per kilometer.
The lapse rate of temperature from 25.0 to 47km is +3.0°C per kilometer.

In using the hypsometric equation to construct the pressure-altitude relation, the following constants shall be used:

The acceleration of gravity is 9.80665 meters per second.
The gas constant R=R* (the atmosphere is assumed to be dry) is 287.04 $m^2s^{-2}K^{-1}$.

D.3 <u>Thermodynamic Relationships</u>. The basic moisture variable sensed by a radiosonde is the relative humidity. Other variables are calculated from this and the sensed air temperature. Relative humidity ***shall*** be defined as the ratio of the existing vapor pressure, e, to that at saturation, e_s, at temperature, T. If expressed in percent, the notation U is used; if in fractional form, u, thus

$$u = e/e_s .$$

The following expressions ***shall*** be used:

D.3.1 Vapor Pressure. The pressure due to the presence of water substance in gaseous form is given by

$$e_s = 6.1121 \exp[(17.502\,T)\,(240.97 + T)^{-1}]$$

where e_s = saturation vapor pressure in hectoPascals at temperature, T, in degrees Celsius. This approximation is valid for vapor pressure over water to -50° Celsius.

D.3.2 Virtual Temperature. Virtual temperature is derived from temperature and relative humidity, thus:

$$T_v = T_p[p - (0.37821\,e)]^{-1}$$

where, e = vapor pressure , a function of temperature only
p = measured ambient air pressure.

D.3.3 Dew Point and Dew Point Depression. The dew point temperature in degrees Celsius is approximated by

$$T_d = \frac{b(b+T)\ln u + aT}{ab - (b+T)\ln u}$$

where u is the fractional relative humidity at temperature T (degrees Celsius) and constants a = 17.502 and b = 240.97. This expression is consistent with D3, and has the advantage that u can be easily recovered if desired. The dew point depression is $T - T_d$, a positive definite quantity.

D.4 Mixing Ratio. Mixing ratio, r, in parts per thousand, is derived from the measured air pressure and the vapor pressure, thus

$$r = 0.622\,[e/(p-e)]\ .$$

D.5 Potential Temperature. The potential temperature is useful in checking and characterizing super-adiabatic lapse rates. It is defined as a reference temperature obtained by changing an air parcel's temperature adiabatically to a pressure of 1000hPa. Thus:

$$\theta = T\left(\frac{1000}{P}\right)^{\frac{R^*}{C_p}}$$

where R* is the gas constant for air and c_p is the specific heat of air at constant pressure. The quantity R^*/c_p is equal to 2/7 exactly.

D.6 Wind Variables. The calculation of wind from the position of the balloon ***shall*** be made using earth spherical coordinates. The position of the balloon ***should*** also be used for establishing the position of the information at the levels selected for the rawinsonde message (Chapter 5).

D.6.1 Wind Speed and Direction. Meteorological convention specifies wind direction as that FROM which the wind blows. A 360 degree compass oriented clockwise from north is used; thus, a wind blowing from the west is given a 270 degree direction, and from the south a 180 degree direction. This convention is in contra-distinction to Oceanographic convention, in which currents are labelled with the direction TOWARD which the current is flowing.

In meteorological usage the Cartesian velocity component values are calculated from the wind speed and direction. The u-component (east-west) of the wind is given by

$$u = \text{speed}[\ -\sin(\text{direction})]$$

and the v- component (north-south) by

$$v = \text{speed}[\ -\cos(\text{direction})].$$

In the inverse case, correct determination of the proper quadrant for the wind direction can be obtained by using the ATAN2 subroutine available in system software, or

if u = 0 and v < 0, direction = 360°
if u = 0 and v > 0, direction = 180°, otherwise

$$D_c = 57.29578 \cdot [\arctan(\frac{v}{u})]$$

and, if u < 0 then Direction = 270 - D_c,
if u > 0 then Direction = 90 - D_c.

Wind speed can be determined from position components by

$$Speed = (u^2 + v^2)^{\frac{1}{2}}.$$

D.6.2 Wind Shear. The magnitude of the wind shear between any level and the level immediately below it is given by:

$$Wind\ shear = [(u - u_{-1})^2 + (v - v_{-1})^2]^{\frac{1}{2}} \cdot (\Delta z)^{-1}.$$

D.6.3 Mean Wind. The mean wind (5.3.7) included in the coded message is calculated by averaging separately the u- and v-components obtained from the high-data-rate and time-tagged data file between the surface and the 1525m (5000 ft) level and between the 1525m and the 2048m (10,000 ft) levels. D.6.1 is used to convert to direction and speed.

D.7 <u>Location of the Balloon</u>. Earth spherical geometry ***shall*** be used for the location of the balloon relative to the launch site. When the height of the balloon has been calculated from integration of the hypsometric equation (Section D.2) independently from the measurement of the elevation angle of the ground tracking antenna (e.g. RDF systems):

$$d(km) = 6371(\frac{\pi}{2} - \beta - \sin^{-1}\left\{\frac{R_e}{(R_e + h)}\cos(\beta)\right\})$$

where d is the distance from the launch point, $ is the measured elevation angle (rad), Re is the radius of the earth (km), and h the height of the balloon (km).

D.8 <u>Three-Dimensional Balloon Location</u>. In the event that the radiosonde does not carry a pressure sensor and that the height of the balloon is established by NAVAID positioning, the balloon position in two dimensions can be obtained from the system itself.

D.9 Logarithmic Pressure Ratio (for Interpolation to Selected Pressure). The logarithmic pressure ratio is used to interpolate pressure between levels:

$$P_r = \frac{\log(P_i) - \log(P_s)}{\log(P_i) - \log(P_{i+1})}$$

where, P_r = pressure ratio,
P_i = pressure of the lower bounding level,
P_{i+1} = pressure of the upper bounding level, and
P_s = pressure of the constant pressure surface being selected.

Interpolation of any parameter (height, temperature, relative humidity, etc) is carried out using:

$$X_{im} = P_r \cdot (X_{i+1} - X_i) + X_i$$

where, X_{im} = parameter value at interpolated level,
P_r = pressure ratio,
X_i = parameter value at lower bounding level, and
X_{i+1} = parameter value of the upper bounding level.

APPENDIX E

PILOT BALLOON AND RAWINSONDE OBSERVATION ENCODING AND DECODING

APPENDIX E
TABLE OF CONENTS

Page

APPENDIX E

RAWINSONDE AND PILOT BALLOON OBSERVATION ENCODING AND DECODING

E.1 **Introduction**. Coded messages are used for the international exchange of meteorological information comprising observational data provided by the World Weather Watch (WWW) Global Observing System and processed data provided by the WWW Global Data-processing System. Coded messages are also used for the international exchange of observed and processed data.

The WMO, through its Commission for Basic Systems (CBS), prescribes standard formats for the exchange of meteorological information. These formats (codes) are described in the WMO Manuals on Codes Volumes I and II (WMO No. 306) [Ref. 9]. The United States, as a member of the WMO, uses these codes for the exchange of upper-air data.

Rules concerning the selection of code forms to be exchanged for international purposes, and the selection of their symbolic words, figure groups and letters, are contained in Volume I of the Manual on Codes (issued with separate covers as Volume I.1 -- Part A, and Volume I.2 -- Part B and Part C.)

Apart from the international codes, several sets of regional codes exist which are intended for exchanges only within a specific WMO Region. These codes are contained in Volume II of the Manual on Codes. Volume II also contains descriptions of:

-- Regional procedures for the use of international code forms;
-- National coding practices in the use of international or regional codes of which the WMO Secretariat has been informed;
-- National code forms.

E.2 **WMO Code Forms**. Each WMO code form is identified by the letters FM followed by a complex term composed of an Arabic numeral followed by a Roman numeral and a short descriptor. The Arabic numeral assigns classes to the various code forms. In general the 10-series pertains to codes related to surface observations. The 20-series pertains to radar observations. The 30-series pertains to upper-air observations involving the tracking of a balloon or sounding device. However, this convention does not continue through the rest of the code-series so should not be relied upon as a hard and fast rule. The sub-classes in each series pertain to specific types of observations within those classes such as 32-PILOT (an upper wind observation); 35-TEMP (a rawinsonde observation from a fixed land station); 36-TEMP SHIP (a rawinsonde observation from a ship; 37-TEMP DROP (a dropsonde observation from an aircraft); and 38-TEMP MOBIL (a rawinsonde observation from a mobile land station). The Roman numeral indicates at which session of the WMO Commission the code was either adopted or last revised. The principal function of the Roman numeral is to enable users to determine if they have the most recently published version of the code.

E.3 **Symbolic Forms for Data Groups**. The codes are composed of a set of CODE FORMS and BINARY CODES made up of SYMBOLIC LETTERS (or groups of letters) representing meteorological or, as the case may be, other geophysical elements. In messages, these symbolic letters (or groups of letters) are transcribed into figures indicating the value or the state of the elements described. SPECIFICATIONS have been defined for the various symbolic letters to permit their transcription into figures. In some cases, the specification of the symbolic letter is sufficient to permit a direct transcription into figures. In other cases, it requires the use of CODE FIGURES, the specifications of which are given in CODE TABLES. Furthermore, a certain number of SYMBOLIC WORDS and SYMBOLIC FIGURE GROUPS have been developed for use as code names, code words, symbolic prefixes or indicator groups. The number of letters used in the symbolic form (exclusive of subscripts or superscripts) always equals the number of digits that will appear in the numeric form of an actual coded message.

Parts and sections of code forms may have been built up from a number of well-defined components, each comprising a different type of coded information. Components which can be transmitted as termed a separate report are 'parts' and carry special identification groups. Code forms, or their parts, can be divided into sections which may be omitted from the report under certain conditions and therefore carry a symbolic indicator figure or group.

Code form groups in round brackets are drop-out items and may or may not be included, depending on specified conditions. The absence of round brackets means that the group concerned is always included, as determined by international decision; these decisions are indicated in the regulations appearing under each code form.

Unless indicated otherwise, specifications apply to all forms of the Pilot Balloon and Rawinsonde codes. Code Tables, if needed, are referenced at the end of the specification.

E.4 <u>**References To Level Coding**</u>. The following code forms and tables contain both explicit and implicit references to the three types of levels: standard, mandatory significant, and additional. Standard levels are covered explicitly in paragraphs E-I.2.2 and E-II.2.2. Additional levels are covered explicitly in paragraphs E-I.2.4 and E-II.2.5 and .6. Some of the mandatory significant levels. such as the surface and tropopause, are dealt with explicitly, while the remainder are referred to implicitly in the paragraphs on Additional Levels.

E.5 <u>Basic Code Construction for Formatted Messages</u>

E.5.1 Versions of the PILOT Messages. Messages from fixed land stations which contain only wind data are called PILOT messages. Those transmitted from ships are labelled PILOT SHIP. Those from mobile land stations are PILOT MOBIL. The three versions of the PILOT code are:

- FM 32-IX PILOT, an upper wind report from a land station;
- FM 33-IX PILOT SHIP, an upper wind report from a ship;
- FM 34-IX PILOT MOBIL, an upper wind report from a mobile land station.

A report from a fixed land station which has been assigned a WMO location index number ***shall*** report in FM 32 PILOT. Temporary land stations, tasked and equipped to take and transmit upper level wind observations, ***shall*** use FM 34 PILOT MOBIL. There is no provision in any of the upper-level wind codes for reports from an instrument released from an aircraft.

E.5.1.1 PILOT Observations. The relationship of the four parts of the code form and component sections that can be a part of a given part follow:

The code form consists of the following four parts:

Part	Identifier Letters (M_jM_j)	Isobaric surfaces
A	AA	} Up to and including the 100-hPa surface
B	BB	
C	CC	} Above the 100-hPa surface
D	DD	

(Each part can be transmitted separately.)

The code form is divided into the following sections and indicated Parts:

Section number	Indicator figures or symbolic figure groups	Contents	Parts A	B	C	D
1	--	Identification and position data	X	X	X	X
2	44 or 55	Data for standard isobaric surfaces	X		X	
3	6,7,66,or 77	Data for maximum wind level(s), with altitudes given in pressure units or tens of geopotential meters, and data for vertical wind shear	X		X	
4	8,9(or 1) or 21212	Data for fixed regional levels and/or additional levels, altitudes given either in geopotential units or in pressure units	X		X	
5	51515 52525 59595	Code groups to be developed regionally	X		X	
6	61616 62626 69696	Code groups developed nationally	X		X	

E.5.1.2 The full Code Form for PILOT Observations is contained in APPENDIX E-I. Where possible, sections and parts are combined in the APPENDIX E-1 to minimize largely redundant symbolic letters, definitions, and regulations.

E.5.2 Versions of the TEMP Messages. Each code form is further specified by a character string that describes the code form more succinctly. For example, the rawinsonde coded messages are described as TEMP messages. The three versions of the TEMP code described in this Handbook are:

- FM 35-X Ext. TEMP, an upper level pressure, temperature, humidity and wind report from a land station;
- FM 36-X Ext. TEMP SHIP, an upper level pressure, temperature, humidity and wind report from a sea station;
- FM 38-X Ext. TEMP MOBIL, an upper level pressure, temperature, humidity, and wind report from a mobile land station.

Temporary land stations are established to support special studies or other short-term activities. Short-term activities are usually less than six months in duration.

E.5.2.1 The relationship of the four parts of the code form and component sections that can be a part of a given TEMP message are outlined in the succeeding paragraphs.

The code form consists of the four parts as follows:

Part	Identifier letters (M_jM_j)	Isobaric surfaces
A	AA	Up to and including the 100-hPa surface
B	BB	
C	CC	Above the 100-hPa surface
D	DD	

The code form is further divided into the following sections and their associated parts:

Section number	Indicator figures or symbolic figure groups	Contents	Parts A	Parts B	Parts C	Parts D
1	--	Identification and position data	X	X	X	X
2	--	Data for standard isobaric surfaces	X		X	
3	88	Data for tropopause level(s)	X		X	
4	66 or 77	Data for maximum wind level(s) and data for vertical wind shear	X		X	
5	--	Data for additional levels, with respect to temperature and/or relative humidity		X		X
6	21212	Data for additional levels, with respect to wind		X		X
7	31313	Data on sea-surface temperature and sounding system		X		
8	41414	Cloud data		X		
9	51515 52525 59595	Code groups developed regionally		X		X
10	61616 62626 69696	Code groups developed regionally		X		X

E.5.2.2 The full Code Form for TEMP Observations is contained in Appendix E-II. Where possible, sections and parts are combined to minimize largely redundant symbolic letters, definitions, and regulations.

E.6 Numbering System of International Code Tables. When coding a report, symbolic letters or groups are replaced by figures, which specify the value or the state of the corresponding element. In some cases the specification of the symbolic letter (or group of letters) is sufficient to permit a direct transcription into figures, e.g. GG or PPP. In other cases, these figures are obtained by means of special Code Table for each element.

The Code Tables are also used for decoding incoming reports thus making available the information contained therein.

The Code Tables are numbered, each bearing a number consisting of four figures from 0100 up to 5299 and allotted in the alphabetical order of the symbols to which the Code Tables correspond. The attribution of the numbers is done in accordance with the following system:

(1) The first two figures represent the number of the main letter of the symbol in alphabetical order. Capital letters are given an odd number, and small letters an even number: 01 for A, 02 for a, 03 for B, 04 for b.....51 for Z and 52 for z.

(2) The last two figures are allocated in accordance with the following scheme:

00 to 01 — are reserved for Code Tables corresponding to a symbol composed of one letter only (X or x, for instance);

02 to 30 — are reserved for Code Tables corresponding to symbols of the forms X_A to X_Z, x_A to x_Z and derived symbols such as X_{AO} or x_{AO};

31 to 60 — are reserved for Code Tables corresponding to symbols of the forms X_a to X_z, x_a to x_z and derived symbols such as X_{aO} or x_{AO}

61 to 70 — are reserved for Code Tables corresponding to symbols of the forms X_0 to X_n, or x_0 to x_n, n being any number;

71 to 99 — are reserved for Code Tables corresponding to symbols of the forms X', XX, XXX, x', xx, xxx or any similar forms such as X_bX_b, $X_0X_0X_0$, x_bx_b, $x_0x_ox_o$.

The numbers attributed to the Code Tables for the different elements specific to upper-air observations for PILOT and TEMP observations are provided in Appendix E-III.

Besides the specifications given by the Code Tables in worldwide use, other sets are established for regional use, which are numbered with a three-figure number ranging from 120 to 800, and are given in Ref. 9: Volume II.

APPENDIX E-I

CODE FORM FOR PILOT OBSERVATIONS

E-I.1 CODE FORM: PILOT Parts A, B, C, and D by SECTION NUMBER

Parts A, B, C, and D: SECTION 1 (E-I.2.1)

$M_iM_iM_jM_j$ D....D** YYGGa_4

{ IIiii*

{ or 99$L_aL_aL_a$ $Q_cL_oL_oL_oL_o$ MMM$U_{La}U_{Lo}$** $h_0h_0h_0h_0i_m$***

Parts A and C: SECTION 2 (E-I.2.2)

44nP_1P_1
or } ddfff ddfff ..... etc.
55nP_1P_1

Part A and C: SECTION 3 (E-I.2.3)

77$P_mP_mP_m$
or } $d_md_mf_mf_mf_m$ (4$v_bv_bv_av_a$)
66$P_mP_mP_m$

or
7$H_mH_mH_mH_m$ } $d_md_mf_mf_mf_m$ (4$v_bv_bv_av_a$)
or
6$H_mH_mH_mH_m$
or
77999

Parts B and D: SECTION 4 (E-I.2.4)

9 or 8 }	$t_n u_1 u_2 u_3$ ddfff ddfff ddfff
.....	....
9 or 8 }	$t_n u_1 u_2 u_3$ ddfff ddfff ddfff

or

21212

$n_0 n_0 P_0 P_0 P_0$ $d_0 d_0 f_0 f_0 f_0$
$n_1 n_1 P_1 P_1 P_1$ $d_1 d_1 f_1 f_1 f_1$
....
$n_n n_n P_n P_n P_n$ $d_n d_n f_n f_n f_n$

Parts B and D: SECTION 5 (E-I.2.5)

51515
52525
.....
59595 } Code groups developed regionally

Parts B and D: SECTION 6 (E-I.2.6)

61616
62626
.....
69696 } Code groups developed nationally.

E-I.2 PILOT Upper Wind Report Code Forms. Requirements for international exchange require Parts A, B, C, and D for the Upper Winds.

NOTE: For exchange within Region IV and inclusion in subregional and regional broadcasts, Parts A and B may be transmitted together or separately, as may Parts C and D.

CODE FORM: Parts A and B Up to and including the 100-hPa surface
Parts C and D above the 100-hPa surface

E-I.2.1 SECTION 1 Identification and position data

$M_iM_iM_jM_j$ { D....D** or IIiii* } $YYGGa_4$
or
$99L_aL_aL_a$ $Q_cL_oL_oL_oL_o$ $MMMU_{La}U_{Lo}$** $h_0h_0h_0h_0i_m$***

Symbolic letters and definitions

M_iM_i Type of report
- PP = PILOT (FM 32)
- QQ = PILOT SHIP (FM 33)
- EE = PILOT MOBIL (FM 34)

M_jM_j Part of report transmitted
- AA = Part A
- BB = Part B
- CC = Part C
- DD = Part D

* Used in FM 32 only.
** Used in FM 33 and FM 34 only.
*** Used in FM 34 only.

D....D ship or mobile land station--for ship use ships call sign (three or more alphanumeric characters or the identifier SHIP. In the case of mobile land station, the group ***shall*** be either the radio call-sign of the station if assigned or an identification group assigned for the duration of the activity which the station is supporting. If possible, the mobile station ***should*** maintain the same identification for the duration.

YY Day of the month (UTC), (01 equals the first day, 02 the second day, etc.) on which the actual time of observation falls. YY ***shall*** also be used to indicate the unit of wind speed in addition to indicating the day of the month. When wind speeds are given in knots, 50 ***shall*** be added to YY. When the speed is given in meters per second, YY ***shall*** not be modified.

E-I.2.1 SECTION 1 Identification and position data (Continued)

Symbolic letters and definitions

GG Actual time of observation to the nearest whole hour UTC. In the case of a PIBAL observation, the actual time of observation is the time at which the balloon is actually released.

a_4 Type of measuring equipment used (Code Table 0265)

IIiii WMO index number assigned to a fixed land station

$99L_aL_aL_a\ Q_cL_oL_oL_oL_o\ MMMU_{La}U_{Lo}$ replacement group for IIIiii of the report for a sea station, aircraft, a carrier balloon, or a mobile land station.

99 data on position to follow

$L_aL_aL_a$ latitude in tenths of a degree

Q_c quadrant of the globe (Code Table 3333)

$L_oL_oL_oL_o$ longitude in tenths of a degree

MMM Marsden square number in which station is located at observation time. (Code Table 2590)

U_{La} unit digit of reported latitude

U_{Lo} unit digit of reported longitude

$h_0h_0h_0h_0i_m$ elevation of mobile land station, units of elevation, and elevation accuracy

$h_0h_oh_0h_0$ elevation if meters or feet as indicated by i_m

i_m indicator for units of elevation and confidence factor of accuracy (Code Table 1845) assigned or an identification group assigned for the duration of the activity which the station is supporting. If possible, the mobile station ***should*** maintain the same identification for the duration.

APPENDIX E-I.2: PILOT Upper Wind Report Code Forms

CODE FORM: Part A Up to and including the 100-hPa surface and C above the 100-hPa surface

E-I.2.2 SECTION 2 Data for standard isobaric surfaces

$44nP_1P_1$
or } ddfff ddfff.....etc.
$55nP_1P_1$

Regulations:
Section 2 ***shall*** contain data, in ascending order with respect to altitude, for the standard isobaric surfaces of 850, 700, 500, 400, 300, 250, 200, 150, and 100 hPa in Part A and for the standard isobaric surfaces of 70, 50, 30, 20, and 10 hPa in Part C.

When pressure measurements are not available, wind data ***shall*** be reported using geopotential approximations to the standard isobaric surfaces.

All standard isobaric surfaces within the sounding ***shall*** be represented in Section 2 of the report by either a data group or a group of solidi (/////).

Indicator figures 44 ***shall*** be used when the standard isobaric isobaric surfaces are located by means of pressure equipment. Indicator figures 55 ***shall*** be used for the reporting of winds at altitudes approximating the standard isobaric surfaces. If the pressure element failed during the ascent, indicator figures 55 ***shall*** replace the indicator figures 44 for the remaining standard isobaric surfaces to be reported.

In the report, no more than three wind groups ***shall*** follow a $44nP_1P_1$ or $55nP_1P_1$ group. The latter groups ***shall*** therefore be repeated as often as necessary.

Symbolic letters and coding remarks

44 Standard isobaric surfaces located by radiosonde.

55 Winds reported at altitudes approximating the standard isobaric surfaces (Code Table 5300).

n Number of consecutive isobaric surfaces for which wind data are reported, starting with the surface specified by P_1P_1.

P_1P_1 Pressure of the lowest standard isobaric surface, with respect to altitude, for which wind data are reported. The pressure of surfaces up to and including the 100-hPa surface ***shall*** be reported in tens of hectopascals. Above the 100-hPa surface, pressure ***shall*** be reported in whole hectopascals.

dd True direction (rounded off to the nearest 5^O), in tens of degrees, from which wind is blowing.

fff Wind speed in, in meters per second or knots. When encoding wind direction that has been rounded off to the nearest 5^O, the hundreds and tens figures of this rounded direction ***shall*** be reported by dd and the units figure ***shall*** be added to the hundreds figure of the wind speed. When wind speeds are in knots, 50 ***shall*** be added to YY. When speed is given in meters per second, YY ***shall*** not be modified.

E-I.2.3 SECTION 3 Data for maximum wind level(s), with altitudes given in pressure units or tens of geopotential meters, and data for vertical wind shear.

$77P_mP_mP_m$
or
$66P_mP_mP_m$ } $d_md_mf_mf_mf_m$ $(4v_bv_bv_av_a)$
or
$7H_mH_mH_mH_m$
or } $d_md_mf_mf_mf_m$ $(4v_bv_bv_av_a)$
$6H_mH_mH_mH_m$
or
77999

Regulations:

For coding purposes, a maximum wind level:

(a) ***Shall*** be determined by consideration of the list of significant levels for wind speed, as obtained by means of the relevant recommended or equivalent national method and not by consideration of the original wind-speed curve;

(b) ***Shall*** be located above the 500-hPa isobaric surface and ***shall*** correspond to a speed of more than 30 meters per second.

NOTE: A maximum wind level is defined as a level at which the wind speed is greater than that observed immediately above and below that level.

Symbolic letters and coding remarks

77 When a maximum wind occurred within the sounding and its level was determined by means of pressure, this indicator ***shall*** be used in the first group of Section 3, i.e. $77P_mP_mP_m$.

7 When a maximum wind occurred within the sounding and its altitude was expressed in tens of standard geopotential meters, the indicator figure 7 ***shall*** be used in the first group of Section 3, i.e. $7H_mH_mH_mH_m$.

66 When the greatest wind speed observed throughout the sounding occurred at the top of the sounding and the level of the greatest wind was determined by means of pressure, the indicator figures 66 ***shall*** be used in the first group of Section 3, i.e. $66P_mP_mP_m$.

6 When the greatest wind speed observed throughout the sounding occurred at the top of the sounding and the altitude of the greatest wind was expressed in tens of standard geopotential meters, the indicator figure 6 ***shall*** be used in the first group of Section 3, i.e. $66H_mH_mH_m$.

77999 When a maximum wind is not observed or not reported, group 77999 ***shall*** be reported in lieu of he maximum wind section, i.e. Section 3.

$P_mP_mP_m$ Pressure at the maximum wind level. (1) The pressure of surfaces up to and including the 100-hPa surface ***shall*** be reported in whole hPas. Above the 100-hPa surface, pressure ***shall*** be reported in tenths of a hectopascal.

d_md_m True direction (rounded off to the nearest 5^O), in tens of degrees, from which maximum wind is blowing.

CODE FORM: Part A Up to and including the 100-hPa surface and Part C above the 100-hPa surface(Continued)

E-I.2.3 SECTION 3 Data for maximum wind level(s), with altitudes given in pressure units or tens of geopotential meters, and data for vertical wind shear (Continued)

Whenever more than one maximum wind level exists, these levels ***shall*** be reported as follows:

(a) The level of greatest maximum wind speed ***shall*** be transmitted first;

(b) The other levels ***shall*** be classified in descending order of speed, and be transmitted only if their speed exceeds those of the two adjacent minimals by at least ten meters per second;

(c) The levels of maximum wind with the same speed ***shall*** be encoded successively, beginning with the lowest ones;

(d) Furthermore, the highest level attained by the sounding ***shall*** be transmitted, provided:
   (i) It satisfies the criteria set forth in the Regulation 32.2.3.1 above;

   (ii) It constitutes the level of the greatest speed of the whole sounding.

When more than one level of maximum wind is observed, data for each level ***shall*** be reported by repeating Section 3.

<u>Symbolic letters and coding remarks (Continued)</u>

$f_mf_mf_m$ Maximum wind speed in meters per second or knots. (1) When encoding wind direction that has been rounded off to the nearest 5^O, the hundreds and tens figures of this rounded direction ***shall*** be reported by dd and the units figure ***shall*** be added to the hundreds figure of the wind speed. (2) The day of the month (UTC) ***shall*** be used to indicate the unit of wind speed in addition to indicating the day of the month. When wind speeds are given in knots, 50 ***shall*** be added to YY. When wind speed is given in meters per second, YY ***shall*** not be modified.

$(4v_bv_bv_av_a)$ Section containing wind shear. This group ***shall*** be included only if data for vertical wind shear are computed and required.

v_bv_b Absolute value of the vector difference between the maximum wind and the wind blowing at 1 km above the level of maximum wind, in units indicated by YY.

v_av_a Absolute value of the vector difference between the maximum wind and the wind blowing at 1 km above the level of maximum wind, in units indicated by YY.

$H_mH_mH_mH_m$ Altitude of the level of maximum wind, in tens of standard geopotential meters.

E-I.2.4 SECTION 4 Data for fixed-additional levels and/or additional levels, with altitudes given either in geopotential units or in pressure units.

9
or } $t_n u_1 u_2 u_3$ ddfff ddfff ddfff
8
....
9
or } $t_n u_1 u_2 u_3$ ddfff ddfff ddfff
8
or
21212 $n_0 n_0 P_0 P_0 P_0$ $d_0 d_0 f_0 f_0 f_0$
$n_1 n_1 P_1 P_1 P_1$ $d_1 d_1 f_1 f_1 f_1$
....
$n_n n_n P_n P_n P_n$ $d_n d_n f_n f_n f_n$

Regulations:

Additional levels

The reported additional data alone ***shall*** make it possible to reconstruct the wind profile with sufficient accuracy for practical use. Care ***shall*** be taken that:

(a) The direction and speed curves (in function of the log of pressure or altitude) can be reproduced with their prominent characteristics;

(b) These curves can be reproduced with an accuracy of at least 10^{O} for direction and five meters per second for speed;

(c) The number of additional levels is kept strictly to a necessary minimum.

NOTE: To satisfy these criteria, the following method of successive approximations is recommended, but other methods of attaining equivalent results may suit some national practices better and may be used:

Symbolic letters and coding remarks

Indicator figures

9 The indicator figure 9 ***shall*** be used when the altitudes of fixed-additional levels and/or additional level are given in units of 300 meters. The figure 9 ***shall*** be used in Section 4 up to and including the height of 29 700 meters. Above that level, the indicator figure 1 ***shall*** be used to specify that 30 000 meters be added to the heights indicated by $t_n u_1 u_2 u_3$

8 The indicator figure 8 ***shall*** be used in Section 4 when the altitudes of fixed-additional levels and/or additional levels are given in units of 500 meters.

t_n Tens digit of the altitude, expressed in units of 300 meters or 500 meters, which applies to the following data groups

u_1 Units digit of the altitude, expressed in units of 300 meters or 500 meters, for the first data group following.

u_2 Units digit of the altitude, expressed in units of 300 meters or 500 meters, for the second data group following.

u_3 Units digit of the altitude, expressed in units of 300 meters or 500 meters, for the third data group following.

dd True direction, (rounded off to the nearest 5^{O}), in tens of degrees, from which wind is blowing.

(1) When encoding wind direction that has been rounded off to the nearest 5^{O}, the hundreds and tens figures of this rounded direction ***shall*** be reported by dd and the units figure ***shall*** be added to the hundreds figure of the wind speed.

APPENDIX E-I.2: PILOT Upper Wind Report Code Forms

CODE FORM: Part B up to and including the 100-hPa surface
Part D above the 100-hPa surface

E-I.2.4 SECTION 4 Data for fixed-additional levels and/or additional levels, with altitudes given either in geopotential units or in pressure units (Continued).

(1) The surface level and the highest level attained by the sounding constitute the first and the last mandatory significant levels. The deviation from the linearly interpolated values between these two levels is then considered. If no direction deviates by more than 10^{O} and no speed by more than five meters per second, no other significant level need be reported. Whenever one parameter deviates by more than the limit specified in paragraph (b) above, the level of greatest deviation becomes a supplementary significant level for both parameters.

(2) The additional levels so introduced divide the sounding into two layers. In each separate layer, the deviation from the linearly interpolated values between the base and the top are then considered. The process used in paragraph (1) above is repeated and yields other significant levels. These additional levels in turn modify the layer distribution, and the method is applied again until any level is approximated to the above-mentioned specified values. For the purpose of computational work, it ***should*** be noted that the values derived from a PILOT report present two different resolutions:

- (a) Winds at all levels are reported to the resolution of 5^{O} in direction and one meter per second in speed;
- (b) Any interpolated wind at a level between two levels is implicitly reported to the resolution of $\pm 10^{O}$ in direction and ± 5 meters per second in speed.

In addition to wind data at other levels, altitudes of which ***shall*** be reported in geopotential units, data at the following levels ***shall*** be included:

300 m	1200 m	2400 m	3600 m	7500 m
600 m	1800 m	2700 m	4800 m	9000 m
900 m	2100 m	3200 m	6000 m	15000 m

fff Wind speed in meters per second or knots.

(1) YY ***shall*** be used to indicate the unit of wind speed in addition to indicating the day of the month. When wind speeds are given in knots, 50 ***shall*** be added to YY. When the speed is given in meters per second, YY ***shall*** not be modified.

21212 $n_0n_0P_0P_0P_1$ $d_0d_0f_0f_0f_0$
$n_1n_1P_1P_1P_1$ $d_1d_1f_1f_1f_1$
... ...
$n_nn_nP_nP_nP_n$ $d_nd_nf_nf_nf_n$

21212 Data for significant levels

n_0n_0, n_1n_1, ..., n_nn_n — Number of level, starting with station level. Station level ***shall*** be coded n_0n_0.

$P_0P_0P_0$, $P_1P_1P_1$, ..., $P_nP_nP_n$ — Pressure at specified levels. The pressure of the surfaces up to and including the 100-hPa surface ***shall*** be reported in whole hectopascals. Above the 100-hPa surface, pressure ***shall*** be reported in tenths of a hectopascal.

d_0d_0, d_1d_1, ..., d_nd_n — True direction (rounded off to the nearest 5^{O}), in tens of degrees, from which wind is blowing at specified levels starting with surface level. (1) When encoding wind direction that has been rounded off to the nearest 5^{O}, the hundreds and tens figures of this rounded direction ***shall*** be reported by dd and the units figure ***shall*** be added to the hundreds figure of the wind speed.

E-I.2.4 SECTION 4 Data for fixed-additional levels and/or additional levels, with altitudes given either in geopotential units or in pressure units. (Continued)

Fixed Levels reported in Section 4 ***shall*** be determined by regional decision.

In Section 4, the data groups for the fixed- and additional levels within the sounding ***shall*** appear in ascending order with respect to altitude.

To indicate that the first wind group refers to station level, u_1 ***shall*** be coded/ (solidus), and appropriate values ***shall*** be reported for t_n, u_2 and u_3.

Altitudes: The altitudes of fixed- and additional levels ***shall*** be reported either in geopotential units or in pressure units. Only one of the units ***shall*** be used in a coded report.

In addition to wind data at significant levels, altitudes of which ***shall*** be reported in geopotential units, data at the following fixed levels ***shall*** be included: 18000, 21000, 24000, 27000, 30000, 33000 m and all successive levels at 3000 m, provided they do not coincide with one of the included significant levels.

The altitudes of 30000 m and above ***shall*** be encoded using units of 500 m, i.e. the altitudes 30000 m and 33000 m shall be included as 8606/, at the altitudes 36000 m and 39000 m as 8728/, etc.

Symbolic letters and coding remarks

$f_0f_0f_0$
$f_1f_1f_1$
...
$f_nf_nf_n$

Wind speed in meters per second or knots, at specified levels starting with station level.

(1) When encoding wind direction that has been rounded off to the nearest 5°, the hundreds and tens figures of this rounded direction ***shall*** be reported by dd and the units figure ***shall*** be added to the hundreds figure of the wind speed. (2) YY ***shall*** be used to indicate the unit of wind speed in addition to indicating the day of the month. When wind speeds are given in knots, 50 ***shall*** be added to YY. When the speed is given in meters per second, YY ***shall*** not be modified.

APPENDIX E-I.2: PILOT Upper Wind Report Code Forms

CODE FORM: Part B Up to and including the 100-hPa surface and
Part D above the 100-hPa surface (Continued)

E-I.2.5 SECTION 5 Code groups developed regionally

51515	}	Code groups developed regionally
52525		
.....		
59595		

E-I.2.6 SECTION 6 Code groups developed nationally

61616	}	Code groups to be developed nationally
62626		
.....		
69696		

APPENDIX E-II

CODE FORM FOR TEMP RAWINSONDE OBSERVATIONS

E-II.1 CODE FORM: TEMP Parts A and B Up to and including the 100-hPa Surface and Parts C and D Above the 100-hPa Surface

SECTION 1: Parts A, B, C, and D

$\underline{M_iM_iM_jM_j}$ D....D** $YYGGI_d$
IIiii*
or
$99L_aL_aL_a$ $Q_cL_oL_oL_oL_o$ $MMMU_{La}U_{Lo}$*** $h_0h_0h_0h_0i_m$

SECTION 2: Parts A and C

$\underline{99P_0P_0P_0}$ $T_0T_0T_{a0}D_0D_0$ $d_0d_0f_0f_0f_0$
$\underline{P_1P_1h_1h_1h_1}$ $T_1T_1T_{a1}D_nD_n$ $d_1d_1f_1f_1f_1$
....
$\underline{P_nP_nh_nh_nh_n}$ $T_nT_nT_{an}D_nD_n$ $d_nd_nf_nf_nf_n$

SECTION 3: Parts A and C

$\underline{88P_tP_tP_t}$ $T_tT_tT_{ar}D_tD_t$ $d_td_tf_tf_tf_t$
or
88999

SECTION 4: Parts A and C

$\underline{77P_mP_mP_m}$ $d_md_mf_mf_mf_m$ $(4v_bv_bv_av_a)$
or
$\underline{66P_mP_mP_m}$
or
77999

SECTION 5: Parts B and D

$n_0n_0P_0P_0P_0$ $T_0T_0T_{a0}D_0D_0$
$n_1n_1P_1P_1P_1$ $T_1T_1T_{a1}D_1D_1$
....
$n_nn_nP_nP_nP_n$ $T_nT_nT_{an}D_nD_n$

APPENDIX E-II.1 CODE FORM: TEMP Parts A and B Up to and including the 100-hPa Surface and Parts C and D Above the 100-hPa Surface

CODE FORM: TEMP Parts A and B Up to and including the 100-hPa surface and Parts C and D above the 100-hPa surface

SECTION 6: Part B

21212	$n_0n_0P_0P_0P_0$	$d_0d_0f_0f_0f_0$
	$n_1n_1P_1P_1P_1$	$d_1d_1f_1f_1f_1$
	.....	.....
	$n_nn_nP_nP_nP_n$	$d_nd_nf_nf_nf_n$

SECTION 7: Part B

31313 $s_rr_ar_as_as_a$ 8GGgg ($9s_nT_wT_wT_w$)

SECTION 8: Parts B and D

41414 $N_hC_LhC_MC_H$

SECTION 9: Parts B and D

51515
52525 } Code groups developed regionally
.....
59595

SECTION 10: Parts B and D

61616
62626 } Code groups developed nationally
.....
69696

APPENDIX E-II.2: TEMP Upper-level Pressure, Temperature, Humidity, and Wind Report Code Forms

CODE FORM: Parts A and B Up to and including the 100-hPa surface
Parts C and D above the 100-hPa surface

E-II.2.1 SECTION 1 Identification and Position Data

$\underline{M_iM_iM_jM_j}$ D....D** YYGGI$_d$
IIiii*
or
{ 99$L_aL_aL_a$ $Q_cL_oL_oL_oL_o$ MMM$U_{La}U_{Lo}$*** $h_0h_0h_0h_0i_m$

NOTES: Relative to I_d indicator

(1) When wind data are missing for one or more isobaric surfaces but are available for other isobaric surfaces below and above, a group (or groups) of solidi ***shall*** be included for the missing data.

(2) The wind group ***shall*** be omitted in the case of those isobaric surfaces for which no data are available, provided wind data are not available for any still higher surface.

(3) Code figure I_d = 0 ***shall*** refer to the 1000-hPa level.

(4) When wind data are not available for any standard isobaric surfaces (either in Part A or in Part C), I_d ***shall*** be reported by means of a solidus (/).

(5) When the wind group relating to the surface level ***shall*** be included in the report; when the corresponding wind data are not available, this group ***shall*** be coded /////.

<u>Symbolic letters and definition</u>

M_iM_i type of report
TT = TEMP REPORT (FM 35)
UU = TEMP SHIP (FM 36)
XX = TEMP DROP (FM 37)
II = TEMP MOBIL (FM 38)

M_jM_j part or report transmitted
AA = Part A
BB = Part B
CC = Part C
DD = Part D

* Used in FM 35 only
** Used in FM 36 and FM 38 only
*** Used in FM 36, FM 37, and FM 38 only
**** Used in FM 38 only

D....D ship or mobile land station call sign consisting of three or more alphanumeric characters--includes mobile land station observations or issuance of a radiological report on a routine basis and/ or in case of accident. It is recommended that this group be encoded in the form A_1A_2DDD, where A_1A_2 are the two-letter geographical designators related to countries or territories as specified in of the Manual on the Global Telecommunications System (Volume 1, Table C1, Part 1, Attachment II-5). DDD are location designators comprising the first three letters of the name of the town or commune where the mobile land station carries out upper-air reporting.

APPENDIX E-II-2: TEMP Upper-level Pressure, Temperature, Humidity, and Wind Report Code Forms

CODE FORM: Parts A and B Up to and including the 100-hPa surface
Parts C and D above the 100-hPa surface (Continued)

E-II.2.1 SECTION 1 Identification and position data

NOTES: (Continued)

(6) If wind data are available up to and including the 250-hPa level, the wind group relating to the 200 hPa ***shall*** also be included in the report and codes as ///// except when the 250-hPa level is the highest standard isobaric surface reached by the sounding. The same rule ***shall*** apply to the 150-hPa level with regard to the 100-hPa level.

Symbolic letters and definitions (Continued)

IIiii WMO index number assigned to a fixed land station

$99L_aL_aL_a$ $Q_cL_oL_oL_oL_o$ $MMMU_{La}U_{Lo}$ replacement group for IIIiii of the report for a sea station, aircraft or a carrier balloon, or a mobile land station.

99 data on position to follow

$L_aL_aL_a$ latitude in tenths of a degree

Q_c quadrant of the globe (Code Table 3333, WMO No. 306)

$L_oL_oL_oL_o$ longitude in tenths of a degree

MMM Marsden square number in which station is located at observation time (Code Table 2590)

U_{La} unit digit of reported latitude

U_{Lo} unit digit of reported longitude

$h_0h_0h_0h_0i_m$ elevation of mobile land station, units of elevation, and elevation accuracy

$h_0h_oh_0h_0$ elevation in meters or feet as indicated by i_m

i_m indicator for units of elevation and confidence factor of accuracy (Code Table 1845) assigned or an identification group assigned for the duration of the activity which the station is supporting. If possible, the mobile station ***should*** maintain the same identification for the duration.

E-II.2.1 SECTION 1 Identification and position data (Continued)

Symbolic letters and definitions (Continued)

YY Day of the month (UTC), (01 indicating the 1st day, 02 the 2nd day, etc.) on which the actual time of observation falls. YY ***shall*** also be used to indicate the unit of wind speed in addition to indicating the day of the month. When wind speeds are given in knots, 50 ***shall*** be added to YY. When the speed is given in meters per second, YY ***shall*** not be modified.

GG Actual time of observation to the nearest whole hour UTC. In the case of upper-air observations, the actual time of observation is the time at which the balloon is actually released.

I_d Indicator used to specify the hundreds of hectopascals figure (in Part A of TEMP, TEMP SHIP, and TEMP MOBIL reports) or tens of hectopascals figure (in Part C of TEMP, TEMP SHIP, TEMP DROP and Temp MOBIL reports) of the pressure relative to the last standard isobaric surface for which the wind is reported

APPENDIX E-II-2: TEMP Upper-level Pressure, Temperature, Humidity, and Wind Report Code Forms

CODE FORM: Part A Up to and including the 100-hPa surface
Part C above the 100-hPa surface (Continued)

E-II.2.2 SECTION 2 Data for standard isobaric surfaces

$99P_0P_0P_0$	$T_0T_0T_{a0}D_0D_0$	$d_0d_0f_0f_0f_0$
$P_1P_1h_1h_1h_1$	$T_1T_1T_{a1}D_nD_n$	$d_1d_1f_1f_1f_1$
.....	.....	.....
$P_nP_nh_nh_nh_n$	$T_nT_nT_{an}D_nD_n$	$d_nd_nf_nf_nf_n$

Regulations:
The data groups for the surface level and the standard isobaric surfaces of 1000, 925, 850, 700, 500, 400, 300, 250, 200, and 100 hPa ***shall*** appear in Part A in ascending order with respect to altitude.

For Part C the standard isobaric surfaces are 70, 50, 30, 20, 10, 7, 5, 2, and 1 hPa.

When the geopotential of a standard isobaric surface is lower than the altitude of the reporting station, the air temperature-humidity group for that surface ***shall*** be included. Solidi (/////) ***shall*** be reported for these groups. The wind groups for these levels ***shall*** be included as specified by the value reported for symbol I_d.

When wind data are available for all levels, the wind group ***shall*** be included for each level as indicated in the symbolic code form. If wind data are not available for all levels, the procedures given below ***shall*** be followed:

<u>Symbolic letters and definitions</u>

$99P_0P_0P_0$ $T_0T_0T_{a0}D_0D_0$ $d_0d_0f_0f_0f$

99 data for the surface level follows

$P_0P_0P_0$ Pressure from the surface through 100 hPa ***shall*** be reported to whole hPa. Pressures < 100 hPa, report to tenths of a hPa.

T_0T_0 Tenths and units digits of air temperature not rounded off, in ^{O}C at the specified levels starting with station level.

T_{a0} Tenths of degrees temperature ***shall*** be indicated by means of T_{a0}, T_{a1},..., T_{an}

D_0D_0 Dewpoint depression at standard isobaric surfaces or at D_1D_1 significant levels, starting with station level (use WMO Code Table 0777)

I_d Indicator used to specify the pressure relative to the last standard isobaric surface for which a wind is reported (WMO Code Table 1734).

E-II.2.2 SECTION 2 Data for standard isobaric surfaces (Continued)

Regulations: (Continued)

(a) When wind data are missing for one or more standard isobaric surfaces but are available for other standard isobaric surfaces below and above the level of missing wind data, the wind group(s), i.e. $d_nd_nf_nf_nf_n$, ***shall*** be coded by means of solidi (/////).

(b) When wind data are missing for a standard isobaric surface and are also missing for all succeeding standard isobaric surfaces up to the termination of the ascent, the wind group ***shall*** be omitted for all these levels and the symbol I_d reported accordingly.

Whenever it is desired to extrapolate a sounding for the computation of the geopotential at a standard isobaric surface, the following rules ***shall*** apply:

(a) Extrapolation is permissible if, and only if, the pressure difference between the minimum pressure of the sounding and the isobaric surface for which the extrapolated value is being computed does not exceed one quarter of the pressure at which the extrapolated value is desired, provided the extrapolation does not extend through a pressure interval exceeding 25 hPa;

(b) For the purposes of geopotential calculation, and for this purpose only, the sounding will be extrapolated, using two points only of the sounding curve on a T-log p diagram, namely that at the minimum pressure reached by the sounding and that at the pressure given by the sum of this minimum pressure and the pressure differences, mentioned in (a) above.

Symbolic letters and definitions

d_0d_0 True direction (rounded off to the nearest 5^O), in tens of degrees from which the wind is blowing at specified levels starting with surface level

$f_0f_0f_0$ Wind speed in knots (or meters per second depending on YY) starting with station level

CODE FORM: Part A Up to and including the 100-hPa surface
Part C above the 100-hPa surface (Continued)

E-II.2.3 SECTION 3 Data for tropopause level(s)

$88P_tP_tP_t$ $T_tT_tT_{at}D_tD_t$ $d_td_tf_tf_tf_t$
or
88999

Regulations:

When more than one tropopause is observed, each ***shall*** be reported by repeating Section 3.

When no tropopause data are observed, the group 88999 ***shall*** be reported for Section 3.

$88P_tP_tP_t$ $T_tT_tT_{at}D_tD_t$ Data for tropopause levels
or
88999

<u>Symbolic letters and definitions</u>

$P_tP_tP_t$ Pressure at the tropopause levels. The pressures of the level(s) greater than and including the 30 hPa surface ***shall*** be reported in whole hectopascals.

T_tT_t Air temperature in whole degrees Celsius at the tropopause level. This temperature, measured in degrees and tenths, is not rounded off to the next whole degree; only the whole degrees are indicated by T_tT_t. The tenths of this temperature ***shall*** be indicated by means of T_{at}.

T_{at} Approximate tenths value and sign (plus or minus) of the air temperature at the tropopause level (Code Table 3931).

88999 When no tropopause data are observed, 88999 ***shall*** be used for Section 3.

CODE FORM: Part A Up to and including the 100-hPa surface
Part C above the 100-hPa surface (Continued)

E-II.2.4 SECTION 4 Data for maximum wind level(s) and data for vertical wind shear

$77P_mP_mP_m$
or
$66P_mP_mP_m$ } $d_md_mf_mf_mf_m$ $(4v_bv_bv_av_a)$
or
77999

Regulations:

When more than one maximum wind level is observed, each ***shall*** be reported by repeating Section 4.

When no maximum wind level is observed, the group 77999 ***shall*** be reported by for Section 4.

Indicator figures 77 ***shall*** be used when the level(s) for which maximum wind data are reported does not coincide with the top of the wind sounding corresponds to the highest wind speed observed throughout the ascent. For the purpose of the above regulation, the "top of the wind sounding" is to be understood as the highest altitude level for which wind data are available.

Group $(4v_bv_bv_av_a)$ ***shall*** be included only if data for vertical wind shear are computed and required.

Symbolic letters and definitions

77 or 66 Indicator for maximum wind level(s) and wind shear. Indicator figure 77 ***shall*** be used when the level(s) for which maximum wind data are reported does (do) not coincide with the top of the wind sounding. Indicator figures 66 ***shall*** be used in the opposite case, i.e. whenever the top of the wind sounding corresponds to the highest wind speed observed throughout the ascent. The top of the wind sounding is to be understood as the highest level for which wind data are available.

$P_mP_mP_m$ Pressure at the maximum wind level. (1) The pressures from the surface including the 100-hPa surface ***shall*** be reported in whole hPas. For a pressure level less than 100-hPa surface, pressure ***shall*** be reported in tenths of a hectopascal.

d_md_m True direction (rounded off to the nearest 5^O), in tens of degrees, from which maximum wind is blowing.

$f_mf_mf_m$ Maximum wind speed in meters per second or knots. (1) When encoding wind direction that has been rounded off to the nearest 5^O, the hundreds and tens figures of this rounded direction ***shall*** be reported by dd and the units figure ***shall*** be added to the hundreds figure of the wind speed. (2) The day of the month (UTC) ***shall*** be used to indicate the unit of wind speed in addition to indicating the day of the month. When wind speeds are given in knots, 50 ***shall*** be added to YY. When wind speed is given in meters per second, YY ***shall*** not be modified.

E-II.2.4 SECTION 4 Data for maximum wind level(s)and data and data for vertical wind shear (Continued)

Symbolic letters and definitions (Continued)

($4v_bv_bv_av_a$) Section containing wind shear.

v_bv_b Absolute value of the vector difference between the maximum wind and the wind 1 km above the level of maximum wind, in units indicated by YY.

v_av_a Absolute value of the vector difference between the maximum wind and the wind 1 km above the level of maximum wind, in units indicated by YY.

77999 When no maximum wind level is observed, the group 77999 ***shall*** be reported for Section 4.

CODE FORM: Part B Isobaric surfaces up to and including the 100-hPa surface Part D above the 100-hPa surface (Continued)

E-II.2.5 SECTION 5 Data for additional levels, with respect to temperature and/or relative humidity

$n_0n_0P_0P_0P_0$ $T_0T_0T_{a0}D_0D_0$
$n_1n_1P_1P_1P_1$ $T_1T_1T_{a1}D_1D_1$
....
$n_nn_nP_nP_nP_n$ $T_nT_nT_{an}D_nD_n$

Regulations:
If, in the determination of additional levels with respect to specified criteria for changes in air temperature and/or relative humidity, the criteria for either variable are satisfied at a particular point in altitude, data for both variables (as available) ***shall*** be reported for that level.

Dew-point data ***shall*** be derived using the function (or near equivalent) for the relationship between saturation vapor pressure over water and air temperature (Appendix D, Section D.5.) Dew-point data ***shall*** not be reported when the air temperature is outside the range stated by WMO for the application of the function; a lesser range may be used as a national practice.

The highest level for which a dew point is reported ***shall*** be one of the levels selected.

The reported additional levels alone ***shall*** make it possible to reconstruct the air temperature and humidity profiles within the limits of the criteria specified.

Symbolic letters and definitions

$n_0n_0P_0P_0P_0$ $T_0T_0T_{a0}D_0D_0$ Data for significant levels, with respect to
$n_1n_1P_1P_1P_1$ $T_1T_1T_{a1}D_1D_1$ temperature and/or relative humidity.
....
$n_nn_nP_nP_nP_n$ $T_nT_nT_{an}D_nD_n$

n_0n_0, n_1n_1, ..., n_nn_n — Number of level, starting with station level. Station level ***shall*** be coded n_0n_0=0

$P_0P_0P_0$, $P_1P_1P_1$, ..., $P_nP_nP_n$ — Pressure at specified levels. The pressure of the surfaces up to and including the 100-hPa surface ***shall*** be reported in whole hectopascals. Above the 100-hPa surface, pressure ***shall*** be reported in tenths of a hectopascal.

T_0T_0, T_1T_1, ..., T_nT_n — Tens and units digits of air temperature not rounded off, in degrees Celsius, at specified levels starting with station level.

T_{a0}, T_{a1}, ..., T_{an} — Approximate tenths value and sign (plus or minus) of the air temperature at specified levels starting with station level (Code Table 3931).

E-II.2.5 SECTION 5 Data for mandatory significant levels, with respect to temperature and/or relative humidity

Regulations: (Continued)

The following ***shall*** be included as "mandatory significant levels":

(a) Surface level and the highest level of the sounding, or aircraft reference level and termination level for descent soundings.

(b) A level between 110 and 100 hPa;

(c) Bases and tops of inversions and isothermal layers which are at least 20 hPa thick, provided that the base of the layer occurs below the 300-hPa level or the first tropopause, whichever is the higher;

(d) Bases and tops of inversion layers which are characterized by a change in temperature of at least 2.5^{O}C or a change in relative humidity of at least 20 percent, provided that the base of the layer occurs below the 300-hPa level or the first tropopause, whichever is the higher;

Note:
The inversion layers of (c) and (d) may be comprised of several thinner inversion layers separated by thin layers of temperature lapse. To allow for this situation, the tops of the inversion layers or (c) and (d) ***shall*** each be at a level such that no further inversion layers, whether thick or thin, ***shall*** occur for at least 20 hPa above the level.

The following ***shall*** be included as additional levels. They ***shall*** be selected in the order given, thereby giving priority to representing the temperature profile. As far as possible, these additional levels ***shall*** be the actual levels at which prominent changes in the lapse rate of air temperature occur:

(a) Levels which are necessary to ensure that the temperature obtained by linear interpolation (on a T-log P or essentially similar diagram) between adjacent levels ***shall*** not depart from the observed temperature by more than 1^{O}C below the first level reported above the 300-hPa level or the first tropopause, whichever is the lower, or by more than 2^{O}C thereafter;

(b) Levels which are necessary to ensure that the relative humidity obtained by linear interpolation between adjacent additional levels ***shall*** not depart by more than 15 percent from the observed values. (The criterion of 15 percent refers to an amount of relative humidity and not to the percentage of the observed value, e.g. if an observed value is 50 percent, the interpolated value ***shall*** lie between 35 percent and 65 percent.)

Symbolic letters and definitions (Continued)

D_0D_0 D_1D_1 ... D_nD_n Dew-point depression at standard isobaric surfaces or at significant levels, starting with station level. (Code table 0777)

E-II.2.5 SECTION 5 Data for additional levels, with respect to temperature and/or relative humidity (Continued)

Regulations: (Continued)

(c) Levels which are necessary to limit the interpolation error on diagrams other than T-log P. These levels ***shall*** be such that the pressure at one significant level divided by the pressure of the preceding significant level ***shall*** exceed 0.6 for levels up to the first tropopause and ***shall*** be determined by use of the method for selecting additional levels but with application of tighter criteria.

When an additional level (with respect to air temperature and/or relative humidity) and a standard isobaric surface coincide, data for that level ***shall*** be reported in Parts A and B (or C and D, as appropriate).

In Part B and D, a layer for which data are missing ***shall*** be indicated by reporting the boundary levels of the layer and a level of solidi (/////) to indicate the layer of missing data, provided that the layer is at least 20 hPa thick. The boundary levels are the levels closest to the bottom and top of the layer for which the observed data are missing. The boundary levels are not required to meet the additional level criteria. The boundary levels and the missing data level groups will be identified by appropriate nn numbers. For example:

$33P_3P_3P_3T_3T_3T_{a3}D_3D_3$
44////////
$55P_5P_5P_5T_5T_5T_{a5}D_5D_5$

where the levels 33 and 55 are the boundary levels and 44 indicates the layer for which data are missing.

CODE FORM: **Part B Isobaric surfaces up to and including the 100-hPa surface**
Part D above the 100-hPa surface

E-II.2.6 SECTION 6 Data for additional levels, with respect to winds

21212 $n_0n_0P_0P_0P_0$ $d_0d_0f_0f_0f_0$
$n_1n_1P_1P_1P_1$ $d_1d_1f_1f_1f_1$
....
$n_nn_nP_nP_nP_n$ $d_nd_nf_nf_nf_n$

Regulation:

Additional levels ***shall*** be chosen so that the data from them alone ***shall*** make it possible to reconstruct the wind profile with sufficient accuracy for practical use.

Note: Criteria for determining additional levels with respect to changes in wind speed and direction are given in Regulation 32.3.1.

<u>Symbolic letters and definitions</u>

21212 $n_0n_0P_0P_0P_1$ $d_0d_0f_0f_0f_0$
$n_1n_1P_1P_1P_1$ $d_1d_1f_1f_1f_1$
... ...
$n_nn_nP_nP_nP_n$ $d_nd_nf_nf_nf_n$

n_0n_0, n_1n_1, ..., n_nn_n — Number of level, starting with station level. Station level ***shall*** be coded n_0n_0.

$P_0P_0P_0$, $P_1P_1P_1$, ... — Pressure at specified levels. Pressure levels from the surface up to and including the 100-hPa $P_nP_nP_n$ surface ***shall*** be reported in whole hectopascals. For pressures less than 100-hPa surface, pressure ***shall*** be reported in tenths of a hectopascal.

d_0d_0, d_1d_1, ..., d_nd_n — True direction (rounded off to the nearest 5^{O}), in tens of degrees, from which wind is blowing at specified levels starting with surface level. (1) When encoding wind direction that has been rounded off to the nearest 5^{O}, the hundreds and tens figures of this rounded direction ***shall*** be reported by dd and the units figure ***shall*** be added to the hundreds figure of the wind speed.

E-II.2.6 SECTION 6 Data for additional levels, with respect to winds (Continued)

Symbolic letters and definitions

$f_0f_0f_0$ Wind speed in meters per second or knots,
$f_1f_1f_1$ at specified levels starting with station level
$f_nf_nf_n$

(1) When encoding wind direction that has been rounded off to the nearest 5^O, the hundreds and tens figures of this rounded direction ***shall*** be reported by dd and the units figure ***shall*** be added to the hundreds figure of the wind speed. (2) YY ***shall*** be used to indicate the unit of wind speed in addition to indicating the day of the month. When wind speeds are given in knots, 50 ***shall*** be added to YY. When the speed is given im meters per second, YY ***shall*** not be modified.

E-II.2.7 SECTION 7 Data on sea-surface temperature and sounding system

31313 $s_rr_ar_as_as_a$ 8GGgg ($9s_nT_wT_wT_w$)

Regulation:

Section 7 is a mandatory section and ***shall*** always be reported. The group $s_rr_ar_as_as_a$ and 8GGgg are mandatory for all TEMP, TEMP SHIP, and TEMP MOBIL. In TEMP SHIP reports, the group $9s_nT_WT_WT_W$ ***shall*** also be included.

Symbolic letters and definitions

31313 $s_rr_ar_as_as_a$ 8GGgg ($9s_nT_wT_wT_w$)

- s_r Solar and infrared radiation correction (Code Table 3849).
- r_ar_a Radiosonde/sounding system used. (Code Table 3685)
- s_as_a Tracking technique/status of system used. (Code Table 3872)
- 8 Indicator for Greenwich time

CODE FORM: Part B Isobaric surfaces up to and including the 100-hPa surface
Part D above the 100-hPa surface

E-II.2.7 SECTION 7 Data on sea-surface temperature and sounding system (Continued)

Symbolic letters and definitions (Continued)

GGgg Time of observation, in hours and minutes UTC, the actual time of radiosonde release.

9 Indicator for

s_n Sign of data, and relative humidity indicator (Code Table 3845)

$T_WT_WT_W$ Sea-surface temperature, in tenths of a degree Celsius, its sign being given by s_n.

E-II.2.8 SECTION 8 Cloud data Symbolic letters and definitions

41414 $N_hC_LhC_MC_H$

Regulation:

In TEMP, TEMP SHIP, and TEMP MOBIL reports, this section ***shall*** be used to report cloud data. N_h, h, C_L, C_M, and C_H ***shall*** be coded in accordance with the regulations in FM 12 SYNOP.

Symbolic letters and definitions

41414 $N_hC_LhC_MC_H$ Section 8 Cloud Data

N_h Amount of all the C_L present or, if no C_L is present, the amount of all the C_M cloud present. (WMO Code Table 2700)

C_L Clouds of the genera Stratocumulus, Stratus, Cumulus and Cumulonimbus. (WMO Code Table 0513)

.

Symbolic letters and definitions (Continued)

h Height above surface of the base of the lowest cloud seen. (Code Table 1600) (1) the term "height above surface" ***shall*** be considered as being the height above the official aerodrome elevation or above station level at a non-aerodrome station, or above the surface of the water in reports from ships

C_M Clouds of the genera Altocumulus, Altostratus, and Nimbostratus. (Code Table 0515) (1) The figure to be reported for C_M ***shall*** be determined on the basis of the detailed description of C_M clouds and illustrations of them in the International Cloud Atlas in conjunction with specifications in Code Table 0515.

C_H Clouds of the genera Cirrus, Cirrocumulus and Cirrostratus. (Code Table 0509) (1) The figure to be reported for C_H ***shall*** be determined on the basis of the detailed description of C_H clouds and illustrations of them in the International Cloud Atlas in conjunction with specifications in Code Table 0509. (2) The figure $C_H = 9$ ***shall*** be used when the predominant C_H clouds are Cirrocumulus although small amounts of Cirrocumulus may be present in the C_H cloud system reported under $C_H = 1$ to 8.

APPENDIX E-II: TEMP Upper-level Pressure, Temperature, Humidity, and Wind Report Code Forms

CODE FORM: Part B Isobaric surfaces up to and including the 100-hPa surface Part D above the 100-hPa surface (Continued)

E-II.2.9 SECTION 9 Code groups developed regionally

Symbolic letters and definitions

WMO Region IV practice calls for additional information for pressure from the surface levels to and including the 100 hPa level ***shall*** be reported in this section by including supplementary groups.

51515	101$A_{df}A_{df}$	$A_{df}A_{df}$	Form of additional data reported (Code Table 421)
52525			
.....			
59595			

E-II.2.10 SECTION 10 Code groups developed nationally

Symbolic letters and definitions

61616		Place holder for Section 10
62626	Code groups developed nationally	
.....		
69696		

APPENDIX E-III

REQUIRED CODE TABLES FOR PILOT AND TEMP CODE FORMS

Code Table	Page Number	Indicator	Descriptor
0265	E-38	a_4	Type of measuring equipment used
0421	E-39	$101A_{df}A_{df}$	Form of Additional Regional Data
0509	E-43	C_H	Clouds of the genera Cirrus, Cirrocumulus and Cirrostratus
0513	E-44	C_L	Clouds of the genera Stratocumulus, Stratus, Cumulus, and Cumulonimbus
0515	E-45	C_M	Clouds of the genera Altocumulus, Altostratus, and Nimbostratus
0777	E-46	D_tD_t--D_nD_n	Dew-point depression in two figures
1600	E-47	h	Height above the surface at the base of the lowest cloud
1734	E-48	I_d	Indicator used to specify the hundreds of hectopascals figure
1845	E-49	i_m	Indicator for units of elevation, and confidence factor for accuracy of elevation
2582	E-49	M_iM_i M_jM_j	Identification letters of the report; identification letters of the part of the report or the version of the code form
2590	E-50	MMM	Number of Marsden square in which the station is situated at the time of observation
2700	E-54	N	Total cloud cover
3333	E-55	Q_c	Quadrant of the globe
3685	E-56	r_ar_a	Radiosonde/sounding system used
3845	E-58	S_n	Sign of the data, exponent, and reference value
3849	E-58	s_r	Solar and infrared radiation correction
3872	E-59	s_as_a	Tracking technique/status of system used
3931	E-61	T_a-T_c	Encoding/Decoding the sign and Tenths value of the air temperature
5300	E-62	$P_nP_nh_nh_nh_n$	Standard heights of isobaric surfaces

Table 0265 (WMO-No. 306, Vol I.1)
a_4 Type of measuring equipment used

Code Figure

Code Figure	
0	Pressure instrument associated with wind-measuring equipment
1	Optical theodolite
2	Radiotheodolite
3	Radar
4	Pressure instrument associated with wind-measuring equipment but pressure element failed during ascent
5	VLF-Omega
6	Loran-C
7	Wind profiler
8	Satellite navigation
9	Reserved

Table 0421 (WMO-No. 306, Vol II)
$101A_{df}A_{df}$ - Form of Additional Regional Data Reported

Code Figure	Definition
00-31	
00	Not to be allocated
01	First day of month (UTC)
02	Second day of month (UTC)
03	Third day of month (UTC)
04	Fourth day of month (UTC)
05	Fifth day of month (UTC)
06	Sixth day of month (UTC)
07	Seventh day of month (UTC)
08	Eighth day of month (UTC)
09	Ninth day of month (UTC)
10	Tenth day of month (UTC)
11	Eleventh day of month (UTC)
12	Twelfth day of month (UTC)
13	Thirteenth day of month (UTC)
14	Fourteenth day of month (UTC)
15	Fifteenth day of month (UTC)
16	Sixteenth day of month (UTC)
17	Seventeenth day of month (UTC)
18	Eighteenth day of month (UTC)
19	Nineteenth day of month (UTC)
20	Twentieth day of month (UTC)
21	Twenty-first day of month (UTC)
22	Twenty-second day of month (UTC)
23	Twenty-third day of month (UTC)
24	Twenty-fourth day of month (UTC)
25	Twenty-fifth day of month (UTC)
26	Twenty-sixth day of month (UTC)
27	Twenty-seventh day of month (UTC)
28	Twenty-eighth day of month (UTC)
29	Twenty-ninth day of month (UTC)
30	Thirtieth day of month (UTC)
31	Thirty-first day of month (UTC)
32-39	**Not allocated**
40-59	**Reason for no report or an incomplete report**
40	Report not filed
41	Incomplete report; full report to follow
42	Ground equipment failure
43	Observation delayed
44	Power failure

Code Figure	Definition
45	Unfavorable weather conditions
46	Low maximum altitude (less than 1500 ft above ground)
47	Leaking balloon
48	Ascent not authorized for this period
49	Alert
50	Ascent did not extend above 400 hPa level
51	Balloon forced down by icing conditions
52	Balloon forced down by precipitation
53	Atmospheric interference
54	Local interference
55	Fading signal*
56	Weak signal*
57	Preventive maintenance
58	Flight equipment failure (transmitter, balloon, attachments, etc.)
59	Any reason not listed above

* Fading signals differ from weak signals in that "fading signals" are first received satisfactorily, then become increasingly weaker, and finally become too weak for reception, while "weak signals" are weak from the beginning of the ascent.

60-64: Miscellaneous

60	Unassigned
61	Unassigned
62	Radiosonde report precedes
63	Unassigned
64	Unassigned

65-69: Doubtful Data

65	Geopotential and temperature data are doubtful between following levels: $0P_nP_nP'_nP'_n$
66	Geopotential data are doubtful between the following levels: $0P_nP_nP'_nP'_n$
67	Temperature data are doubtful between the following levels: $0P_nP_nP'_nP'_n$
68	Dew point depression is missing for reasons other than "motor-boating" between the following levels: $0P_nP_nP'_nP'_n$ (not used when T_nT_n is also missing)
69	Unassigned

70-74 Not allocated

101$A_{df}A_{df}$ - Form of Additional Regional Data Reported

Code Figure	Definition
75 - 89	**Corrected Data**
75	Unassigned
76	Unassigned
77	Unassigned
78	Corrected tropopause data section follows
79	Corrected maximum wind section follows
80	Corrected report for the entire report (first* and second* transmissions) precedes
81	Corrected report of the entire first transmission precedes
82	Corrected report of the entire second transmission precedes
83	Corrected data for mandatory levels** follow
84	Corrected data for significant levels** follow
85	Minor error(s) in this report; correction follows
86	Significant level(s) not included in original report follow: //$P_nP_nP_n$ $T_nT_nT_{an}D_nD_n$ or $P_nP_nP_nT_nT_n$
87	Corrected data for surface follow
88	Corrected additional data groups follow: 101$A_{df}A_{df}$ .... etc.
89	Unassigned
90-99	
90	Extrapolated geopotential data follow: $P_nP_nh_nh_nh_n$ ($d_nd_nd_nf_nf_n$)
91	Extrapolated data precede *
92	Unassigned
93	Unassigned
94	Averaged wind for the surface to 5000 foot MSL layer and the 5000 to 10000 foot MSL layer follow: ddfff ddfff (can be used in the PART A message)
95	Early transmission of 850 and 500 hPa data and stability index follows: 85hhh TTT_aDD ddfff 50hhh TTT_aDD ddfff i_si_s
96	Early transmission of 850, 700, and 500 hPa data and stability index follow: 85hhh TTT_aDD ddfff 70hhh TTT_aDD ddfff 50hhh TTT_aDD ddfff i_si_s

Code Figure	Definition
97	Early transmission of 500 hPa data and stability index follows: 50hhh TTT_aDD ddfff i_si_s
98	Early transmission of 700 hPa data and stability index follows: 70hhh TTT_aDD ddfff i_si_s
99	Not to be allocated

* Code figure 91 is used only in reports of dropsonde observations.

Unless both the stability index and the mean winds are missing, the Part A message always contains two special 101 groups as follows:

10164	Group that identifies stability index.
10194	Group that identifies the mean winds.

A 5-character group follows the 10164 which contains the encoded stability index. The value that appears in the coded message for the stability index is interpreted as follows:

Coding Stability Index

Code Value	Meaning
00 to 40	Stability index is 0 to 40
51 to 90	Stability index is -1 to -40
91	RH < 20% at either base or 500 hPa level or calculation failed.
92	RH is missing at the base level.

Table 0509 (WMO-No. 306, Vol I.1)
C_H Clouds of the genera Cirrus, Cirrocumulus and Cirrostratus

Code figure	Technical specifications	Code figure	Non technical specifications
0	No C_H clouds	0	No Cirrus, Cirrocumulus or Cirrostratus
1	Cirrus fibratus, sometimes uncinus, not progressively invading the sky	1	Cirrus in the form of filaments, strands or hooks, not progressively invading the sky
2	Cirrus spissatus, in patches or entangled sheaves, which usually do not increase and sometimes seem to be the remains of the upper part of a Cumulonimbus; or Cirrus castellanus or floccus	2	Dense Cirrus, in patches or entangled sheaves, which usually do not increase and sometimes seem to be the remains of the upper part of a Cumulonimbus; or Cirrus with sproutings in the form of small turrets or battlements, or Cirrus having the appearance of cumuliform tufts
3	Cirrus spissatus cumulonimbogenitus	3	Dense Cirrus, often in the form of an anvil, being the remains of the upper parts of Cumulonimbus
4	Cirrus uncinus or fibratus, or both, progressively invading the sky; they generally thicken as a whole	4	Cirrus in the form of hooks or of filaments, or both, progressively invading the sky; they generally become denser as a whole
5	Cirrus (often in bands) and Cirrostratus, or Cirrostratus alone, progressively invading the sky; they generally thicken as a whole, but the continuous veil does not reach 45 degrees above the horizon	5	Cirrus (often in bands converging towards one point or two opposite points of the horizon) and Cirrostratus, or Cirrostratus alone; in either case, they are progressively invading the sky, and generally growing denser as a whole, but the continuous veil does not reach 45 degrees above the horizon
6	Cirrus (often in bands) and Cirrostratus, or Cirrostratus alone, progressively invading the sky; they generally thicken as a whole; the continuous veil extends more than 45 degrees above the horizon, without the sky being totally covered	6	Cirrus (often in bands converging towards one point or two opposite points of the horizon) and Cirrostratus, or Cirrostratus alone; in either case, they are progressively invading the sky, and generally growing denser as a whole; the continuous veil extends more than 45 degrees above the horizon, without the sky being totally covered
7	Cirrostratus covering the whole sky	7	Veil of Cirrostratus covering the celestial dome
8	Cirrostratus not progressively invading the sky and not entirely covering it	8	Cirrostratus not progressively invading the sky and not completely covering the celestial dome
9	Cirrocumulus alone, or Cirrocumulus pre-dominant among the CH clouds	9	Cirrocumulus alone, or Cirrocumulus ac-companied by Cirrus or Cirrostratus, or both, but Cirrocumulus is predominant
/	CH clouds invisible owing to darkness, fog, blowing dust or sand, or other similar phenomena, or because of a continuous layer of lower clouds	/	Cirrus, Cirrocumulus and Cirrostratus invisible owing to darkness, fog, blowing dust or sand, or other similar phenomena, or more often because of the presence of a continuous layer of lower clouds

Table 0513 (WMO-No. 306, Vol I.1)
C_L Clouds of the genera Stratocumulus, Stratus, Cumulus and Cumulonimbus

Code figure	Technical specifications	Code figure	Non-technical specifications
0	No C_L clouds	0	No Stratocumulus, Stratus, Cumulus or Cumulonimbus
1	Cumulus humilis or Cumulus fractus other than of bad weather,* or both	1	Cumulus with little vertical extent and seemingly flattened, or ragged Cumulus other than of bad weather,* or both
2	Cumulus mediocris or congestus, with or without Cumulus of species fractus or humilis or Stratocumulus, all having their bases at the same level	2	Cumulus of moderate or strong vertical extent, generally with protuberances in the form of domes or towers, either accompanied or not by other Cumulus or by Stratocumulus, all having their bases at the same level
3	Cumulonimbus calvus, with or without Cumulus. Stratocumulus or Stratus	3	Cumulonimbus the summits of which, at least partially, lack sharp outlines, but are neither clearly fibrous (cirriform) nor in the form of an anvil; Cumulus, Stratocumulus or Stratus may also be present
4	Stratocumulus cumulogenitus	4	Stratocumulus formed by the spreading out of Cumulus; Cumulus may also be present
5	Stratocumulus other than Stratocumulus cumulogenitus	5	Stratocumulus not resulting from the spreading out of Cumulus
6	Stratus nebulosus or Stratus fractus other than of bad weather,* or both	6	Stratus in a more or less continuous sheet or layer, or in ragged shreds, or both, but no Stratus fractus of bad weather*
7	Stratus fractus or Cumulus fractus of bad weather,* or both (pannus), usually below Altostratus or Nimbostratus	7	Stratus fractus of bad weather* or Cumulus fractus of bad weather,* or both (pannus), usually below Altostratus or Nimbostratus
8	Cumulus and Stratocumulus other than Stratocumulus cumulogenitus, with bases at different levels	8	Cumulus and Stratocumulus other than that formed from the spreading out of Cumulus; the base of the Cumulus is at a different level from that of the Stratocumulus
9	Cumulonimbus capillatus (often with an anvil), with or without Cumulonimbus calvus, Cumulus, Stratocumulus, Stratus or pannus	9	Cumulonimbus, the upper part of which is clearly fibrous (cirriform), often in the form of an anvil; either accompanied or not by Cumulonimbus without anvil or fibrous upper part, by Cumulus, Stratocumulus, Stratus or pannus
/	CL clouds invisible owing to darkness, fog, blowing dust or sand, or other similar phenomena	/	Stratocumulus, Stratus, Cumulus and Cumulo-nimbus invisible owing to darkness, fog, blowing dust or sand, or other similar phenomena

* 'Bad weather' denotes the conditions which generally exist during precipitation and a short time before and after.

Table 0515 (WMO-No. 306, Vol I.1)
C_M Clouds of the genera Altocumulus, Altostratus and Nimbostratus

Code figure	Technical specifications	Code figure	Non-technical specifications
0	No C_M clouds	0	No Altocumulus, Altostratus or Nimbostratus
1	Altostratus translucidus	1	Altostratus, the greater part of which is semi-transparent; through this part the sun or moon may be weakly visible, as through ground glass
2	Altostratus opacus or Nimbostratus	2	Altostratus, the greater part of which is sufficiently dense to hide the sun or moon, or Nimbostratus
3	Altocumulus translucidus at a single level	3	Altocumulus, the greater part of which is semi-transparent; the various elements of the cloud change only slowly and are all at a single level
4	Patches (often lenticular) of Altocumulus translucidus, continually changing and occurring at one or more levels	4	Patches (often in the form of almonds or fish) of Altocumulus, the greater part of which is semitransparent; the clouds occur at one or more levels and the elements are continually changing in appearance
5	Altocumulus translucidus in bands, or one or more layers of Altocumulus translucidus or opacus, progressively invading the sky; these Altocumulus clouds generally thicken as a whole	5	Semi-transparent Altocumulus in bands, or Altocumulus, in one or more fairly continuous layer (semi-transparent or opaque), progressively invading the sky; these Altocumulus clouds generally thicken as a whole
6	Altocumulus cumulogenitus (or cumulonimbogenitus)	6	Altocumulus resulting from the spreading out of Cumulus (or Cumulonimbus)
7	Altocumulus translucidus or opacus in two or more layers, or Altocumulus opacus in a single layer, not progressively invading the sky, or Altocumulus with Altostratus or Nimbostratus	7	Altocumulus in two or more layers, usually opaque in places, and not progressively invading the sky; or opaque layer of Aftocumulus, not progressively invading the sky; or Altocumulus together with Altostratus or Nimbostratus
8	Altocumulus castellanus or floccus	8	Altocumulus with sproutings in the form of small towers or battlements, or Altocumulus having the appearance of cumuliform tufts
9	Altocumulus of a chaotic sky, generally at several levels	9	Altocumulus of a chaotic sky, generally at several levels
/	Cm clouds invisible owing to darkness, fog, blowing dust or sand, or other similar phenomena, or because of continuous layer of lower clouds	/	Altocumulus, Altostratus and Nimbostratus invisible owing to darkness, fog, blowing dust or sand, or other similar phenomena, or more often because of the presence of a continuous layer of lower clouds

Table 0777 (WMO-No. 306, Vol I.1)
D_tD_t--D_nD_n Dew-point depression in two figures

D_tD_t Dew-point depression at the tropopause level
D_0D_0
D_1D_1 Dew-point depression at standard isobaric surfaces or at significant **...** levels, starting with station level
D_nD_n

Code figure	Degrees Celsius	Code figure	Degrees Celsius	Code figure	Degrees Celsius	Code figure	Degrees Celsius
00	0.0	25	2.5	50	5	75	25
01	0.1	26	2.6	51	not used	76	26
02	0.2	27	2.7	52	not used	77	27
03	0.3	28	2.8	53	not used	78	28
04	0.4	29	2.9	54	not used	79	29
05	0.5	30	3.0	55	not used	80	30
06	0.6	31	3.1	56	6	81	31
07	0.7	32	3.2	57	7	82	32
08	0.8	33	3.3	58	8	83	33
09	0.9	34	3.4	59	9	84	34
10	1.0	35	3.5	60	10	85	35
11	1.1	36	3.6	61	11	86	36
12	1.2	37	3.7	62	12	87	37
13	1.3	38	3.8	63	13	88	38
14	1.4	39	3.9	64	14	89	39
15	1.5	40	4.0	65	15	90	40
16	1.6	41	4.1	66	16	91	41
17	1.7	42	4.2	67	17	92	42
18	1.8	43	4.3	68	18	93	43
19	1.9	44	4.4	69	19	94	44
20	2.0	45	4.5	70	20	95	45
21	2.1	46	4.6	71	21	96	46
22	2.2	47	4.7	72	22	97	47
23	2.3	48	4.8	73	23	98	48
24	2.4	49	4.9	74	24	99	49

// No humidity data available

Table 1600 (WMO-No. 306, Vol I.1)
h - Height above surface of the base of the lowest cloud seen

Code Figure	
0	0 to 50 m
1	50 to 100 m
2	100 to 200 m
3	200 to 300 m
4	300 to 600 m
5	600 to 1000 m
6	1000 to 1500 m
7	1500 to 2000 m
8	2000 to 2500 m
9	2500 m or more, or no clouds
/	Height of base of cloud not known or base of clouds at a level lower and tops at a level higher than that of the station.

Notes:

(1) A height of exactly equal to one of the values at the ends of the ranges shall be coded in the higher range, e.g., a height of 600 m shall be reported by code Figure 5.

(2) Due to the limitation in range of the cloud-sensing equipment used by an automatic station, the code figures reported for h could have one of the three following meanings:

(a) The actual height of the base of the cloud is within the range indicated by the code figure; or
(b) the height of the base of the cloud is greater than the range indicated by the code figure but cannot be determined due to instrumental limitations; or
(c) There are no clouds vertically above the station.

Table 1734 (WMO-No. 306, Vol I.1)
I_d -Indicator used to specify the hundreds of hectopascals figure (in Part A of TEMP, TEMP SHIP, TEMP DROP and TEMP MOBIL reports) or tens of hectopascals figure (in Part C of TEMP, TEMP SHIP, and TEMP MOBIL reports) of the pressure relative to the last standard isobaric surface for which the wind is reported.

Code Figure — Wind group included up to and including the following standard isobaric surfaces:

Code Figure	Part A	Part C
1	100 hPa or 150 hPa*	10 hPa
2	200 hPa or 250 hPa**	20 hPa
3	300 hPa	30 hPa
4	400 hPa	---
5	500 hPa	50 hPa
6	---	---
7	700 hPa	70 hPa
8	850 hPa	---
9	925 hPa	---
0	1000 hPa	---
/	No wind group is included for any standard	isobaric surface

* In this case (150 hPa), the wind group relating to the 100-hPa level shall also be included and coded as ///// except when 150 hPa is the highest standard isobaric surface reached by the sounding.

** In this case (250 hPa), the wind group relating to the 200 hPa level shall also be included and coded as ///// except when 250 hPa is the highest standard isobaric surface reached by the sounding.

Table 1845 (WMO-No. 306, Vol I.1

i_m - **Indicator for Units of Elevation and Confidence Factor for Accuracy of Elevation**

Code Figure	Units	Confidence Factor
0	Not Used	
1	Meters	Excellent (within 3 meters)
2	Meters	Good (within 10 meters)
3	Meters	Fair (within 20 meters)
4	Meters	Poor (more than 20 meters)
5	Feet	Excellent (within 10 feet)
6	Feet	Good (within 30 feet)
7	Feet	Fair (within 60 feet)
8	Feet	Poor (more than 60 feet)
9	Not Used	

Table 2582 (WMO-No. 306, Vol I.1)

M_iM_i --M_jM_j

M_iM_i Identification letters of the report

M_jM_j Identification letters of the part of the report or the version of the code form

Literal (M_iM_i/M_jM_j) Designators for Data Type and Message Part

Code Type	PART A	PART B	PART C	PART D	RADAT
PILOT	PP	PPAA	PPBB	PPCC	PPDD
PILOT SHIP	QQ	QQAA	QQBB	QQCC	QQDD
PILOT MOBIL	EE	EEAA	EEBB	EECC	EEDD
TEMP	TT TTXX	TTAA	TTBB	TTCC	TTDD
TEMP SHIP	UU UUXX	UUAA	UUBB	UUCC	UUDD
TEMP MOBIL	II IIXX	IIAA	IIBB	IICC	IIDD

Table 2590 (WMO number 306, Vol I.1)

MMM - Number of marsden square in which the station is situated at the time of observation.

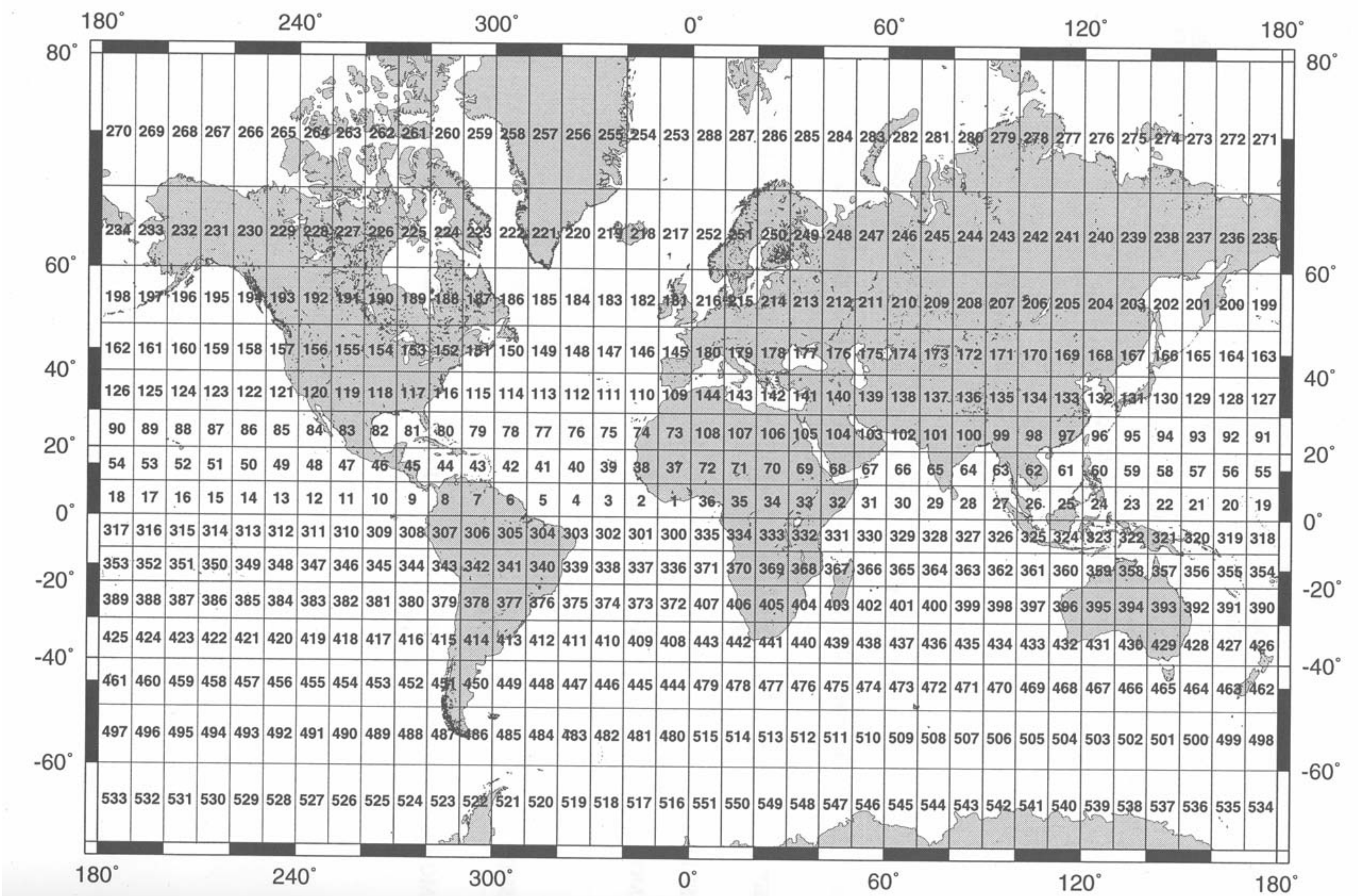


Figure E-1: Assignment of Marsden square numbers

Polar Zones

North of 80°N	918	917	916	915	914	913	912	911	910	909	908	907	906	905	904	903	902	901	936	935	934	933	932	931	930	929	928	927	926	925	924	923	922	921	920	919
70°-80° South	569	568	567	566	565	562	563	562	561	560	559	558	557	556	555	554	553	552	587	586	585	584	583	582	581	580	579	578	577	576	575	574	573	572	571	570
South of 80°S	605	604	603	602	601	600	599	598	597	596	595	594	593	592	591	590	589	588	623	622	621	620	619	618	617	616	615	614	613	612	611	610	609	608	607	606

West longitudes | East longitudes

180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180

Figure E-2: Assignment of Marsden Square numbers for polar zones.

WEST

99	98	97	96	95	94	93	92	91	90
89									80
79									70
69									60
59									50
49									40
39									30
29									20
19									10
09	08	07	06	05	04	03	02	01	00

Q_C = 7

EAST

90	91	92	93	94	95	96	97	98	99
80									89
70									79
60									69
50									59
40									49
30									39
20									29
10									19
00	01	02	03	04	05	06	07	08	09

Q_C = 1

NORTH

09	08	07	06	05	04	03	02	01	00
19									10
29									20
39									30
49									40
59									50
69									60
79									70
89									80
99	98	97	96	95	94	93	92	91	90

Q_C = 5

00	01	02	03	04	05	06	07	08	09
10									19
20									29
30									39
40									49
50									59
60									69
70									79
80									89
90	91	92	93	94	95	96	97	98	99

Q_C = 3

SOUTH

Figure E-3: Subdivisions of the Marsden 10-degree squares into one-degree squares for the eight octants (Q) of the globe.

Note: The number to be coded for $U_{LA}U_{LO}$ in the position verifying group $MMMU_{LA}U_{LO}$ is obtained by combining the second figure for L_a and the third figure for L_o in the reported position ($L_aL_aL_aQ_CL_oL_oL_oL_o$) This number $U_{LA}U_{LO}$ is the number of the one-degree subdivision of the Marsden 10-degree square in which the ship is located at the time of observation.

When the ship is on the boundary between two (or four) 10-degree Marsden squares, the number to be coded for MMM is that of the Marsden 10-degree square for which the one-degree subdivision whose number is $U_{LA}U_{LO}$, as defined above, corresponds to the ship's position.

When the ship is on the meridian 0° or 180°, as well as on the Equator, the number used for reporting Q_C shall be taken into account for determining the relevant number of the Marsden 10-degree square.

Examples:

(1) For a ship located at 42.3°N and 30.0°W, the position is coded as follows:

$$Q_C = 7,\ L_aL_aL_a = 4\mathbf{2}3,\ \ L_oL_oL_oL_o = 03\mathbf{0}0$$

$U_{LA}U_{LO}$ is therefore **20**. The ship is on the boundary between Marsden squares 147 and 148. The relevant scheme of the annex (Q_C = 7) shows that the one-degree subdivision corresponding to the ship's position would be numbered 29 in Marsden square 147 and **20** in Marsden square 148. MMM is therefore to be coded 148.

(2) For a ship located at 40.0°S and 120.0°E, the position is coded as follows:

$$Q_C = 3,\ L_aL_aL_a = 4\mathbf{0}0,\ L_oL_oL_oL_o = 12\mathbf{0}0$$

$U_{LA}U_{LO}$ is therefore **00**. The ship is on the boundary point between Marsden squares 431, 432, 467, and 468. The relevant scheme of the annex (Q_C = 3) shows that the one-degree subdivision corresponding to the ship's position would be 90 in Marsden square 431, 99 in Marsden square 432, **00** in Marsden square 467, and 09 in Marsden square 468. MMM is therefore coded 467.

Table 2700 (WMO-No. 306, Vol I.1)

N **Total cloud cover**

N_h **Amount of all the C_L cloud present or, if no C_L cloud is present, the amount of all the C_M cloud present**

N_s **Amount of individual cloud layer or mass whose genus is indicated by C**

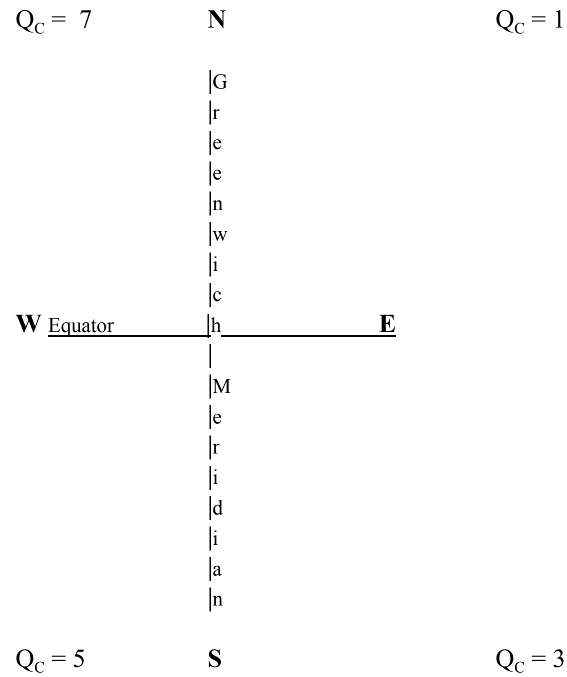
N' **Amount of cloud whose base is below the level of the station**

Code figure		
0	0	0
1	1 okta or less, but not zero	1/10 or less, but not zero
2	2 oktas	2/10 - 3/10
3	3 oktas	4/10
4	4 oktas	5/10
5	5 oktas	6/10
6	6 oktas	7/10 - 8/10
7	7 oktas or more, but not 8 oktas	9/10 or more, but not 10/10
8	8 oktas	10/10
9	Sky obscured by fog and/or other meteorological phenomena	
/	Cloud cover is indiscernible for reasons other than fog or other meteorological phenomena, or observation is not made	

Note: For use of (/), see WMO Regulation 12.1.4, Ref. 7.

Table 3333 (WMO-No. 306, Vol I.1)
Qc   Quadrant of the globe

Code figure	Latitude	Longitude
1	North	East
3	South	East
5	South	West
7	North	West



Note : The choice is left to the observer in the following cases:

-- When the ship is on the Greenwich meridian or the 180th meridian ($L_OL_OL_OL_O$ = 0000 or 1800 respectively):

Q_C = 1 or 7 (northern hemisphere) or

Q_C = 3 or 5 (southern hemisphere);

-- When the ship is on the Equator ($L_aL_aL_a$., = 000):

Qc = 1 or 3 (eastern longitude) or
Qc = 5 or 7 (western longitude)

Table 3685 (WMO-No. 306, Vol I.1)
(Table 0 02 011 WMO-No. 306, Vol I Part B)
r_ar_a - Radiosonde/sounding system used

Code Figure	Meaning
00	Reserved
01	Reserved
02	No radiosonde/Passive target (e.g. reflector)
03	No radiosonde/Active target (e.g. transponder)
04	No radiosonde/Passive temperature-humidity profiler
05	No radiosonde/Active temperature-humidity profiler
06	No radiosonde/Radio-acoustic sounder
07	No radiosonde/...)reserved
08	No radiosonde/...)reserved
09	No radiosonde/Sounding system unknown or not specified
10	RS VIZ type A pressure-commutated (USA)
11	RS VIZ type B time-commutated
12	RS SDC (Space Data Corporation - USA)
13	Astor (no longer made - Australia)
14	VIZ MARK I MICROSONDE (USA)
15	EEC Company Type 23 (USA)
16	Elin (Austria)
17	Graw G. (Germany)
18	Reserved for allocation of radiosondes
19	Graw M60 (Germany)
20	Indian Meteorological Service MK3 (India)
21	VIZ/Jin Yang Mark I MICROSONDE (South Korea)
22	Meisei RS2-80 (Japan)
23	Mesural FMO 1950A (France)
24	Mesural FMO 1945A (France)
25	Mesural MH73A (France)
26	Meteolabor Basora (Switzerland)
27	AVK-MRZ (Russian Federation)
28	Meteorite Marz2-1 (Russian Federation)
29	Meteorite Marz2-2 (Russian Federation)
30	Oki RS2-80 (Japan)
31	VIZ/Valcom type A pressure-commutated (Canada)Sangamo
32	Shanghai Radio (China)
33	UK Met Office MK3 (UK)
34	Vinohrady (Czechoslovakia)
35	Vaisala RS18 (Finland)
36	Vaisala RS21 (Finland)
37	Vaisala RS80 (Finland)
38	VIZ LOCATE Loran-C (USA)
39	Sprenger E076 (Germany)
40	Sprenger E084 (Germany)
41	Sprenger E085 (Germany)
42	Sprenger E086 (Germany)
43	AIR IS-4A-1680 (USA)
44	AIR IS-4A-1680 X (USA)
45	RS MSS (USA)

46	Air IS-4A-403 (USA)	
47	Meisei RS2-91 (Japan)	
48	VALCOM (Canada)	
49	VIZ MARK II (USA)	
50	GRAW DFM-90 (Germany)	
51	VIZ B2	
52	Vaisala RS80-57	
53	Reserved for allocation of radiosondes	
54	Reserved for allocation of radiosondes	
55	Reserved for allocation of radiosondes	
56	Reserved for allocation of radiosondes	
57	Reserved for allocation of radiosondes	
58	Reserved for allocation of radiosondes	
59	Reserved for allocation of radiosondes	
60	Vaisala RS80/MicroCora (Finland)	
61	Vaisala RS80/DigiCora or Marwin (Finland)	
62	Vaisala RS80/PCCora (Finland)	
63	Vaisala RS80/Star (Finland)	
64	Orbital Sciences Corporation, Space Data Division, transponder radiosonde, type 909-11-XX, where XX correspondes to the model of the instrument (USA)	
65	VIZ transponder radiosonde, model number 1499-520 (USA)	
66-89	Reserved for additional automated soundings systems	
90	Radiosonde not specified or unknown	
91	Pressure-only radiosonde	
92	Pressure-only radiosonde plus transponder	
93	Pressure-only radiosonde plus radar reflector	
94	No-pressure radiosonde plus transponder	
95	No-pressure radiosonde plus radar reflector	
96	Descending radiosonde	
97-99	**Reserved for allocation of sounding systems with incomplete sondes**	
100 254	Reserved	BUFR Table 002011 only
255	Missing value	

NOTES:
(1) References to countries in brackets indicate the manufacturing location rather than the country using the instrument.

(2) Some of the radiosondes listed are no longer in use but are retained for archiving purposes.

Table 3845 (WMO-No. 306 Vol I.1)

sn	**Sign of the data, and relative humidity indicator**
sn	**Sign of the exponent**
sn	**Sign of the reference value indicated by rrrrrrr**

Code figure	
0	Positive or zero
1	Negative
2	Relative humidity follows

Notes:
(1) Code figures 3 to 8 are not used.
(2) See WMO Regulation 12.2.3.3.1 for the use of code figure 9.

Table 3849 (WMO-No. 306, Vol I.1)
(Table 0 02 013 WMO-No. 306, Vol I Part B)

s_r - Solar and Infrared Radiation Correction

Code Figure	Meaning
0	No correction
1	CIMO solar corrected and CIMO infrared corrected
2	CIMO solar corrected and infrared corrected
3	CIMO solar corrected only
4	Solar and infrared corrected automatically by radiosonde system
5	Solar corrected automatically by radiosonde system
6	Solar and infrared corrected as specified by country
7	Solar corrected as specified by country
8-14*	Reserved
15*	Missing value

* BUFR Table 0 02 012 only

Table 3872 (WMO-No. 306, Vol I.1)
(Table 0 02 014 WMO-No. 306, Vol I Part B)
$s_a s_a$ - Tracking Technique/Status of System Used

Code Figure	Meaning
00	No windfinding
01	Automatic with auxiliary optical direction finding
02	Automatic with auxiliary radio direction finding
03	Automatic with auxiliary ranging
04	Not used
05	Automatic with multiple VLF-Omega frequencies
06	Automatic cross chain Loran-C
07	Automatic with auxiliary wind profiler
08	Automatic satellite navigation
09-18	Reserved
19	Tracking technique not specified

Tracking Technique/Status of ASAP System

Status of Ship System

20	Vessel stopped
21	Vessel diverted from original destination
22	Vessel's arrival delayed
23	Container damaged
24	Power failure to container
25-28	Reserved for future use
29	Other problems

Sounding System

30	Major power problems
31	UPS inoperative
32	Receiver hardware problems
33	Receiver software problems
34	Processor hardware problems
35	Processor software problems
36	NAVAID system damaged
37	Shortage of lifting gas
38	Reserved
39	Other problems

Launch Facilities

40	Mechanical defect
41	Material defect (Hand launcher)
42	Power failure
43	Control failure
44	Pneumatic/hydraulic failure
45	Other problems
46	Compressor problems
47	Balloon problems
48	Balloon release problems
49	Launcher damaged

Table 3872 (WMO-No. 306, Vol I.1) (Continued)
(Table 0 02 014 WMO-No. 306, Vol I Part B)
$s_a s_a$ - Tracking Technique/Status of System Used

Code Figure	Meaning
	Data Acquisition Systems
50	R/S receiver antenna defect
51	NAVAID antenna defect
52	R/S receiver cabling (antenna) defect
53	NAVAID antenna cabling defect
54-58	Reserved
59	Other problems
	Communications
60	ASAP communications defect
61	Communications facility rejected data
62	No power at transmitting antenna
63	Antenna cable broken
64	Antenna cable defect
65	Message transmitted power below normal
66-68	Reserved
69	Other problems
70	All systems in normal operation
71-98	Reserved
99	Status of system and its components not specified
100-126	Reserved
127	Missing value

Table 3931 (WMO-No. 306, Vol I.1)
T_a -- T_c Encoding/Decoding the Sign and Tenths Value of the Air Temperature in Radiosonde Reports

Code Figures

Tenths Figure of Observed Air Temperature	Positive Temperature	Negative Temperature
0, 1	0	1
2, 3	2	3
4, 5	4	5
6, 7	6	7
8, 9	8	9

Table 5300 (WMO-No. 306, Vol. I.1)

Standard Heights of Isobaric Surfaces
(Based on U.S. Standard Atmosphere - 1976)

Standard Surface (hPa)	P_nP_n Coded as	Approximate Height m)	$h_nh_nh_n$ Coded as
1000	00	100	100
925	92	750	750
850	85	1500	500
700	70	3000	000
500	50	5600	560
400	40	7200	720
300	30	9200	920
250	25	10400	040
200	20	11800	180
150	15	13600	360
100	10	16200	620
70	70	18500	850
50	50	20600	060
30	30	23900	390
20	20	26500	650
10	10	31100	110
7	07	33400	340
5	05	35800	580
3	03	39400	940
2	02	42400	240
1	01	47800	780

APPENDIX F

ARCHIVING

F.1 Introduction. There are many critical non-real-time users of rawinsonde observations in climatology and research. In order to make rawinsonde observations available to retrospective users, observations ***shall*** be sent to major data centers in compliance with the standards defined in this chapter. Three data centers maintain historical rawinsonde data: NOAA's NCDC, OL-A of the AFCCC, and the U.S. Navy's Fleet Numerical Meteorology and Oceanography Detachment (FNMOD). All three centers are collocated in Asheville, NC.

F.2 Data Centers. NCDC is a designated Department of Commerce Agency Records Center operating under the federal regulations issued by the National Archives and Records Administration. NCDC is the official repository for meteorological records collected by NOAA observing systems and for other agencies where there is an agreement between NOAA and the agency(s). NCDC currently has such an agreement with the U.S. Navy and the U.S. Marine Corps. NCDC also serves as the archive for data collected from the GTS by the NCEP. Navy's FNMOD Asheville processes and stores rawinsonde data from Navy ships and upper reporting stations as received by FNMOC Monterey, CA. Following quality control, these observations are submitted to NCDC. Information about NCDC may be obtained from:

Data Administrator
National Climatic Data Center
151 Patton Avenue
Asheville, NC 28801-5001
704-271-4384

AFCCC processes and stores rawinsonde observations from worldwide locations as received by the AFGWC. AFCCC also receives original records from U.S. Air Force and U.S. Army sites and submits these records to NCDC for archiving. Information about AFCCC may be obtained from:

Data Administration
OL-A, AFCCC
151 Patton Avenue
Asheville, NC 28801-5002
DSN 266-3100
704-271-4299

F.3 Data Transfer to the Data Centers. NCDC, AFCCC, and FNMOD Asheville all receive and archive data from the GTS system as collected by NCEP, AFGWC, and FNMOC. In addition, agencies ***shall*** submit the highest resolution upper-air data directly to NCDC, AFCCC, or FNMOD Asheville. In order for the data to be processed at NCDC, the observation ***shall*** be sent in the NCDC Standard Nonreal-Time Transfer Format. The format contains two types of records; an identification record and data records. Each balloon flight must contain one identification record which contains fields for the location and time of the observation along with metadata information. The data records contain the actual data and are unlimited in number. Archival requirements changes to accept BUFR code, position information for GPS flights, and fields for corrected and uncorrected data will require format revision or a new format. If the current format does not provide fields for required information contained from flights or is anticipated to not meet next-generation system requirements, contact NCDC, AFCCC, or FNMOD Asheville for guidance. The format and the field descriptions follow:

Identification Record

FIELD	1	2	3	4	5	6	7	8
ELEMENT	STN IND	STN NUM	LAT	LONG	ELEV	YEAR	MONTH	DAY
#CHARS.	X	X..X	XXXXA	XXXXXA	XXXX	XXXX	XX	XX
REC POS	1	2-9	10-14	15-20	21-24	25-28	29-30	31-32

FIELD	9	10	11	12	13	14	15	16
ELEMENT	HOUR	REL TIME	ASCN NUM	OBSVR INIT	DATA RDC	SONDE MAN	SONDE TYPE	SON/BAR IND
#CHARS.	XX	XXXX	XXXX	XXXX	XXX	XXX	XXX	X
REC POS	33-34	35-38	39-42	43-46	47-49	50-52	53-55	56

FIELD	17	18	19	20	21	22	23	24
ELEMENT	SON/BAR NUMBER	HUM TYPE	TEMP TYPE	PRESS TYPE	TRACK TYPE	TRNSP	BAL MAN	BAL WGT
#CHARS	X....X	XXX	XXX	XXX	XXX	X	XX	XXXX
REC POS	57-76	77-79	80-82	83-85	86-88	89	90-92	93-96

FIELD	25	26	27	28	29	30	31	32
ELEMENT	BAL AGE	TRN REG	PBL LGT	PBL TYPE	REASON TERM	NUM RCP	CLOUDS AND WX	SFCWND DIR
#CHARS	XX	X	X	X	XX	X	XXXXXXXXX	XXX
REC POS	97-98	99	100	101	102-103	104	105-113	114-116

FIELD	33	34	35	36	37
ELEMENT	SFCWND SPD	WND AVE INT	TYPE OFCORRECTION P Z T H TD W	SOFTWARE VERSION	RESERVE FIELD
#CHARS	XXX	XXX	XX XX XX XX XX XX	X...X	X...X
REC POS	117-119	120-122	123-134	135-144	145-160

Data Record

FIELD	1	2	3	4	5	6	7	8	9
ELEMENT	ASC NUM	ELP TME	PRESS	HGT	TEMP	REL HUM	DPDP	WND DIR	WND SPD
#CHARS	X.X	X.X	X...X	XXXXX	XXXX	XXXX	XXX	XXX	X..X
REC POS	1-4	5-9	10-15	16-20	21-24	25-28	29-31	32-34	35-38

FIELD	10	11	12	13
ELEMENT	TYPE LVL	SIGNAL QUALITY QP QT QU QD	ELEMENT QUALITY ET P H T U D WD WS	RES FLD
#CHARS	XX	XXX XXX XXX XXX	XX XX XX XX XX XX XX XX	X..X
REC POS	39-40	41-52	53-68	69-80

Identification Record

RECORD POSITION	ELEMENT NAME	CODE DEFINITIONS AND REMARKS
1	STN IND	STATION NUMBER INDICATOR -- This field contains an indicator specifying the type of station number in the next field: 0 = WBAN NUMBER 1 = WMO NUMBER 2 = AIR FORCE AUGMENTED WMO NUMBER 3 = SHIP CALL SIGN 4 = MOBILE UNIT CALL SIGN
2-9	STN NUM	STATION NUMBER -- The number assigned to the station according to the numbering system specified in record position 1. Numbers ***should*** be right-justified with leading blanks, ship CALL signs left justified with trailing blanks. NWS stations must enter WBAN number. If the number is missing, enter "00000000".
10-14	LAT	LATITUDE -- The station latitude in degrees and minutes. The last character is "N" or "S" as appropriate. When unknown, this field contains "9999N".
15-20	LONG	LONGITUDE -- The station longitude in degrees and minutes. The last character is "E" or "W" as appropriate. When unknown, this field contains "99999E".
21-24	ELEV	ELEVATION -- The height of the launch site in whole meters.

Identification Record

RECORD POSITION	ELEMENT NAME	CODE DEFINITIONS AND REMARKS
25-28	YEAR	YEAR -- The 4-digit year expressed at the hour of observation (UTC).
29-30	MONTH	MONTH -- The numeric month expressed at the hour of observation (UTC).
31-32	DAY	DAY -- The numeric day expressed at the hour of observation (UTC).
33-34	HOUR	HOUR -- The hour (24-hour clock) of observation (UTC). The hour of observation will be the nearest whole hour, H-30 to H+29 (e.g. the hour is entered as 10 when release is 0930 to 1029 UTC).
35-38	REL TIME	TIME OF ACTUAL RELEASE -- The hour and minute UTC (24-hour clock) of the actual release time.
39-42	ASCN NUM	ASCENSION NUMBER -- The ascension number for the year. The first release on or after Jan 1 will be numbered 0001. Ascension numbers are right-justified with leading zeros.
43-46	OBSVR INIT	OBSERVER INITIALS -- The initials of the first and last name of the observer.
47-49	DATA RDC	DATA REDUCTION SYSTEM -- The type of data reduction system used at the site. 001 = MANUAL 002 = TIME-SHARE 003 = NOVA MINI COMPUTER 004 = MINI-ART 005 = MICRO-ART 007 = MARWIN, MRS 008 = MSS 009 = LAM 010 = ASAP 011 = MV 7800 012 = AIR MET RESEARCH RAWIN SYSTEM 013 = VIZ WO-9000 Meteorological Processing System

Identification Record

RECORD POSITION	ELEMENT NAME	CODE DEFINITIONS AND REMARKS
50-52	SONDE MAN	SONDE MANUFACTURER -- The manufacturer of the Sonde in use. 001 = VIZ 002 = VAISALA 003 = SPACEDATA 004 = AIR 005 = ATEAR
53-55	SONDE TYP	SONDE TYPE -- The type of Sonde used at the station. 001 = VIZ J031 002 = VIZ ACCU-LOC 003 = VIZ A 004 = VIZ B 005 = VIZ MSS 006 = SPACEDATA-TRANSPONDER 007 = SPACEDATA-ARTSONDE 008 = SPACEDATA-MSS 009 = VAISALA 010 = VIZ B - TRANSPONDER 011 = AIR INTELLISONDE 012 = VIZ Mark II MICROSONDE
56	SON/BAR IND	SONDE/BAROSWITCH NUMBER INDICATOR -- An indicator specifying the type of number in the next field. 0 = SONDE SERIAL NUMBER 1 = BAROSWITCH NUMBER
57-76	SON/BAR NUM	SONDE/BAROSWITCH -- The Sonde serial number or the Baroswitch number right-justified in the field, with leading blanks. This "number" probably will include non-numeric characters.

Identification Record

RECORD POSITION	ELEMENT NAME	CODE DEFINITIONS AND REMARKS
77-79	HUM TYPE	HUMIDITY TYPE -- Type of humidity element used in the system. 001 = Lithium Chloride Hygristor 002 = 1960's Carbon Hygristor 003 = 1980's Carbon Hygristor 004 = Humicap 005 = H-Humicap 006 = VIZ Mark II carbon hygristor
80-82	TEMP TYPE	TEMPERATURE TYPE -- Type of temperature element used in the system. 001 = Rod Thermistor 002 = Bead Thermistor 003 = Chip Thermistor 004 = Capacitive Bead
83-85	PRESS TYPE	PRESSURE TYPE -- Type of pressure element used in the system. 001 = Baroswitch 002 = Transducer - oven controlled 003 = Transducer - non-oven controlled 004 = Derived (Transponder) 005 = Capacitive aneriod
86-88	TRACK TYPE	TRACKING TYPE -- The type of tracking system. 001 = 72-2 002 = SCR-658 003 = WBRT-57 004 = WBRT-60 005 = GMD-1 006 = GMD-1A 007 = GMD-1B 008 = GMD-5 009 = OMEGA 010 = LORAN 011 = ART-1 012 = ART-1R 013 = ART-2 014 = ART-2R 015 = MDS 016 = MSS RANGING 017 = RADIO THEODOLITE
89	TRNSP	TRANSPONDER -- Is a transponder used? 0 = No 1 = Yes

Identification Record

RECORD POSITION	ELEMENT NAME	CODE DEFINITIONS AND REMARKS
90-92	BAL MAN	BALLOON MANUFACTURER -- The manufacturer of the balloon. 001 = KAYSAM 002 = WEATHERTRONICS
93-96	BAL WGT	BALLOON WEIGHT -- Nominal weight of the balloon in grams.
97-98	BAL AGE	BALLOON AGE -- Age of the balloon in months.
99	TRN REG 4	TRAIN REGULATOR -- Was a train regulator used N = No Y = Yes
100	PBL LGT	PIBAL LIGHT -- Was a PIBAL light used N = No Y = Yes
101	PBL TYPE	PIBAL TYPE -- PIBAL wind equipment type according to WMO Code Table 0265. 0 = Pressure instrument associated with wind-measuring equipment 1 = Optical Theodolite 2 = Radio Theodolite 3 = Radar
102-103	REASON TERM	REASON FOR TERMINATION of the flight: 01 = Balloon burst 02 = Balloon forced down by icing 03 = Leaking or floating balloon 04 = Weak or fading signal 05 = Battery failure 06 = Ground equipment failure 07 = Switching failure 08 = Radiosonde failure 09 = Other
104	NUM RCP	RECOMPUTES -- The number of times this flight has been recomputed.

Identification Record

RECORD POSITION	ELEMENT NAME	CODE DEFINITIONS AND REMARKS
105-113	CLOUDS AND WX	CLOUDS AND WEATHER -- The observation of the clouds and weather at the time of release. The field is of the form NhCLhCMCHWWWW, where: Nh=The amount of low or mid-level clouds present according to WMO Code Table 2700. See Appendix E. 0 = 0 okta (tenths) 1 = 1 okta (1/10) or less, but not zero 2 = 2 oktas (2/10-3/10) 3 = 3 oktas (4/10) 4 = 4 oktas (5/10) 5 = 5 oktas (6/10) 6 = 6 oktas (7/10-8/10) 7 = 7 oktas (9/10) or more, but not overcast 8 = 8 oktas (10/10) 9 = Sky is obscured by fog and/or other meteorological phenomena - = Cloud cover is indiscernible for reason other than "9" or observation not made. The WMO code figure "/" must be converted to "-". CL,CM,CH = The cloud type according to WMO Code Tables 0509, 0513, and 0515. Code figure "/" must be converted to "-". H = WMO Code Table 1600 for the height above ground of the base of the lowest cloud seen. Code figure "/" must be converted to "-". WW = Present weather according to WMO Code Table 4677. Up to two types of present weather or obscurations *may* be entered. If present weather is not observed, enter "////" in this field (WWWW). See Appendix E.
114-116	SFCWND DIR	SURFACE WIND DIRECTION -- The direction of the surface wind at time of release in whole degrees.
117-119	SFCWND SPD	SURFACE WIND SPEED -- The speed of the surface wind at time of release in meters per second to the nearest 0.1 meter per second. Do not enter the decimal point; 12.3 meters per second = 123.

RECORD POSITION	ELEMENT NAME	CODE DEFINITIONS AND REMARKS
120-122	WIND AVE INT	WIND AVERAGING INTERVAL -- The interval of time or height over which the wind is derived. 000 = None (instantaneous) 001 = Two mins. to 14km (MSL), four mins. above 14km (MSL). (Pre-1990 FMH Standard, NWS) 002 = Post-1989 FMH Standard 003 = 20 seconds to 15K ft.,60 seconds above 15K ft. 004 = 30 seconds up to 2500m AGL, 45 seconds up to 5000m AGL, 60 seconds up to 7500m AGL, 75 seconds up to 10 km AGL, 90 seconds up to 15 km AGL, 105 seconds up to 20 km AGL, 120 seconds above 20 km AGL. 005 = Four mins. for the entire flight
123-134	CORTYP	TYPE OF CORRECTION -- The type of correction applied to individual data elements by automated systems or observers.
123-124	*CORTYP-P*	*PRESSURE CORRECTIONS* 00 = No correction applied 01 = NASA temperature correction 02 = ECMWF temperature correction . . . 99 = Unknown
125-126	*CORTYP-Z*	*HEIGHT CORRECTIONS* 00 = No correction applied 01 = Local gravity correction 02 = Standard gravity correction . . . 99 = Unknown

Identification Record

RECORD POSITION	ELEMENT NAME	CODE DEFINITIONS AND REMARKS	
127-128	*CORTYP-T*		*TEMPERATURE CORRECTIONS*
		00 =	No correction applied
		01 =	NASA radiation correction
		02 =	ECMWF radiation correction
		03 =	NCEP radiation correction
		04 =	Vaisala RSN-93 solar and infrared radiation correction
		.	
		.	
		.	
		11 =	NASA lag correction
		12 =	ECMWF lag correction
		13 =	NMC lag correction
		.	
		.	
		.	
		21 =	NASA radiation and lag correction
		22 =	ECMWF radiation and lag correction
		23 =	NMC radiation and lag correction
		.	
		.	
		.	
		99 =	Unknown
129-130	*CORTYP-H*		*HUMIDITY CORRECTIONS*
		00 =	No corrections applied
		01 =	NASA lag correction
		02 =	ECMWF lag correction
		03 =	NMC lag correction
		.	
		.	
		.	
		99 =	Unknown
131-132	*CORTYP-TD*		*DEW POINT CORRECTIONS*
		00 =	No corrections applied
		01 =	NASA lag correction
		02 =	ECMWF lag correction
		03 =	NMC lag correction
		.	
		.	
		.	
		99 =	Unknown

Identification Record

RECORD POSITION	**ELEMENT NAME**	**CODE DEFINITIONS AND REMARKS**
133-134	*CORTYP-W*	*WIND CORRECTIONS* 00 = No corrections applied 01 = Elevation angle correction 02 = Ranging correction . . . 99 = Unknown
135-144	SOFT VER	SOFTWARE VERSION -- The version of software in use with the specified recording system. Enter the software version left-justified with trailing blanks.
145-160	RES FLD	RESERVED FIELD -- Leave blank

Data Record

RECORD POSITION	ELEMENT NAME	CODE DEFINITIONS AND REMARKS
1-4	ASCN NUM	ASCENSION NUMBER -- The ascension number for the year. The first release on or after Jan 1 will be numbered 0001.
5-9	ELPSD TIME	ELAPSED TIME -- The time in minutes and seconds (mmmss) since the actual release time.
10-15	PRESS	PRESSURE -- Atmospheric pressure at the current level in hundredths of hectopascals (0.01 millibars).
16-20	HGT	HEIGHT -- Geopotential height of the pressure level in whole geopotential meters (MSL).
21-24	TEMP	TEMPERATURE -- Dry-bulb temperature to the nearest 0.1 Celsius degree.
25-28	REL HUM	RELATIVE HUMIDITY -- The relative humidity to the nearest 0.1 percent.
29-31	DPDP	DEW POINT DEPRESSION -- The dew point depression to the nearest 0.1 Celsius degree.
32-34	WIND DIR	WIND DIRECTION -- The wind direction to the nearest whole degree.
35-38	WND SPD	WIND SPEED -- Wind speed to the nearest 0.1 meter per second.

Data Record

RECORD POSITION	ELEMENT NAME	CODE DEFINITIONS AND REMARKS
39-40	TYPE LVL	TYPE OF LEVEL -- The reason for selection of the level: 00 = High resolution data sample 01 = Within 20 hectopascals (mb) of the surface 02 = Pressure less than 10 hectopascals (mb) 03 = Base pressure level for stability index 04 = Begin doubtful temperature, altitude data 05 = Begin missing data (all elements) 06 = Begin missing relative humidity data 07 = Begin missing temperature data 08 = Highest level reached before balloon descent because of icing or turbulence. 09 = End doubtful temperature, altitude data 10 = End missing data (all elements) 11 = End missing relative humidity data 12 = End missing temperature data 13 = Zero degree crossing for the RADAT 14 = Mandatory pressure level 15 = Operator added level 16 = Operator deleted level 17 = Balloon re-ascended beyond previous highest level 18 = Significant relative humidity level 19 = Relative humidity level selection terminated 20 = Surface level 21 = Significant temperature level 22 = Mandatory temperature level 23 = Flight termination level 24 = Tropopause 25 = Aircraft report 26 = Interpolated (generated) level 27 = Mandatory wind level 28 = Significant wind level 29 = Maximum wind level 30 = Incremental wind level (e.g., 1-minute, fixed regional) 31 = Incremental height level (generated) 40 = Significant thermo level (reason for selection unknown)

Data Record

RECORD POSITION	ELEMENT NAME	CODE DEFINITIONS AND REMARKS
41-43	SQP (Pressure)	SIGNAL QUALITY -- Signal quality for the element expressed as a percentage of individual samples accepted
44-46	SQT (Temperature)	
47-49	SQU (Humidity)	
50-52	SQD (Dew point temperature)	
53-54	EQET	ELEMENT QUALITY FLAGS -- These fields contain the results (Elapsed Time) of any quality control procedures for identifying suspect and doubtful individual elements:
55-56	EQP (Pressure/Ranging)	00 = Element is correct 01 = Element is suspect
57-58	EQH (Height)	02 = Element is doubtful 03 = Element failed QC checks 04 = Replacement value (correction)
59-60	EQT (Temperature)	05 = Estimated value 06 = Observer edited value 09 = Element not checked
61-62	EQU (Humidity)	
63-64	EQD (Dew point depression)	
65-66	EQWD (Wind direction)	
67-68	EQWS (Wind speed)	
69-80	RES FLD	RESERVED FIELD Leave Blank

The data records are repeated as many times as necessary to record all levels of the flight.

All fields must be right-justified (least significant digit in the rightmost position) unless specified otherwise.

All missing fields must be 9 filled unless specified otherwise.

Do not enter decimal points. The decimal point is implied by the field position.

F.4 <u>Station Information</u>. Station information contains details about the operational status of rawinsonde observing stations to include observational site characteristics, the type of equipment in use, and the date of a station's establishment, re-establishment, or closure. Station information ***shall*** be forwarded to NCDC, AFCCC, or FNMOD Asheville for placement in the station's Information File. Also, any changes involving the site or the equipment at the site ***shall*** be submitted to NCDC, AFCCC, or FNMOD Asheville. The information ***shall*** include the item changed and the date of the change. The following are items that ***shall*** be contained in a Station Information File.

<u>Physical Characteristics</u>

Station Name
Type of Station
Airport Name
Description of Significant Topography
Station Identifier/Ship Call Sign
WMO or WBAN Index Number
Time Zone
Latitude/Longitude (release site)
Release Elevation (release site)
Date of establishment, re-establishment, closure

<u>Observation Schedule</u>

Types of Observations
Schedule for Observations

<u>Observation Program</u>

Processing Algorithms
Corrections Made to Data

<u>Sensor Data</u>

Type/Model of Sonde
Type of Sensors
Receiving Equipment
Length of Train
Balloon Make/Model Number/Size
Wind Finding Method

APPENDIX G
GLOSSARY

-A-

Adiabatic process. A thermodynamic change of state of a system in which there is no transfer of heat or mass across the boundaries of the system. In an adiabatic process, compression always results in warming and expansion in cooling.

Adiabatic chart. A graphical representation of the quantitative relationships between the thermodynamically active constituents of the atmosphere. Generally arranged such that graph area is proportional to energy. See Skew-T diagram.

Accuracy. The extent to which a measurement of a quantity agrees with its true value.

ADWS. Automated Digital Weather Switch, the DoD weather communications system.

AFCCC. U.S. Air Force Combat Climatology Center.

AFGWC. Air Force Global Weather Center.

AFOS. Automation of Field Operations and Services.

AGL. Above ground level.

Air mass. A wide-spread body of air that is approximately homogeneous in horizontal extent, particularly with reference to vertical temperature and moisture distribution.

Altitude. The vertical distance of a level, a point, or an object considered as a point, measured from a reference point, usually taken to be mean sea-level.

Amplitude. The magnitude of the displacement of a wave from a mean value.

Aneroid. Literally, "not wet," containing no liquid; applied to a kind of barometer which contains no liquid, an aneroid barometer.

Anomalous. Not encompassed by rules governing the majority of cases; distinguished from abnormal by implying a difference of kind rather than a difference merely of degree.

Assimilating forecast. The numerical, computer-generated forecast of the principal meteorological variables used as the basis for objectively incorporating the updated, current observations.

ATCT. Air Traffic Control Tower.

AQC. Administrative quality control; applied once a report has reached a processing or archiving center.

AWN. Automated Weather Net. The meteorological communications system of the Department of Defense.

Azimuth (azimuth angle). The length of the arc of the horizon (in degrees) intercepted between a given point and an adopted reference direction, usually true north, and measured clockwise from the reference direction.

-B-

Baselining. Meteorological jargon; a term for the initial, preflight preparation and calibration of a radiosonde.

BUFR. Binary Universal Form for the Representation of data, a self-defining binary code for geophysical data.

-C-

CBS. WMO Commission for Basic Systems.

CLIMAT. A series of messages containing climate-related data sent over the GTS by WMO members.

Climatology. The scientific study of climate.

-D-

Dew point temperature. The temperature to which a given parcel of air must be cooled at constant pressure and constant water-vapor content in order for saturation to occur. In this handbook, the dew point temperature is defined with respect to liquid water.

Dew point depression. The difference between the ambient air temperature and the dew point temperature.

DoD. Department of Defense.

DoE. Department of Energy.

Dropsonde (dropwindsonde). (Also called parachute radiosonde.) A radiosonde which is dropped by parachute from an aircraft for the purpose of obtaining soundings of the atmosphere below.

Dry-adiabatic lapse rate. The decrease of temperature with height in a completely mixed, dry, atmosphere having no external energy sources. Quantitatively equal to 9.77°C/km.

-E-

ECMWF. European Center for Medium-range Weather Forecasting.

Elevation. The vertical distance of a point or level affixed to the surface of the earth, measured from mean sea-level.

Elevation angle. The angle between the local horizon and an object in the sky, measured positively from the horizon upwards.

-F-

FAR. Federal Aviation Regulation(s).

FNMOC. US Navy Fleet Numerical Meteorology and Oceanography Center.

FNMOD. US Navy Fleet Numerical Meteorology and Oceanography Detachment

-G-

GDL. Greatest departure from linearity; used to locate additional levels in a radiosonde report.

Geopotential. A measure of potential energy, given by the integral with height (altitude) of the local acceleration of gravity. See Appendix D.

Geopotential height. The height of a given point relative to sea-level, obtained by dividing the geopotential by a constant. See Appendix D.

Gpm. Geopotential meter (See D.2).

Global Data Processing System (GDPS). The coordinated global system of meteorological centers and arrangements for the processing, storage, and retrieval of meteorological information within the framework of the World Weather Watch.

Global Observing System (GOS). The coordinated systems of methods and facilities for making meteorological and other environmental observations on a global scale within the framework of the World Weather Watch.

Global Positioning System (GPS). The satellite-based location system.

Global Telecommunications System (GTS). The coordinated global system of telecommunication facilities and arrangements for the rapid collection, exchange, and distribution of observational and processed information within the framework of the World Weather Watch.

Gravity wave. A form of atmospheric wave motion in which the principal restoring force is that of gravity.

-H-

HectoPascal (hPa). A unit of pressure (SI) equivalent to 100 Pascals. One hectoPascal is numerically equal to one millibar.

Height. 1) The vertical distance of a level, point, or object considered as a point, measured from a specific datum. 2) The vertical dimension of an object.

Hygristor. A humidity sensor used in radiosonde equipment.

Hygrometer. An instrument which measures the water vapor content of the atmosphere.

Hygrothermograph. A recording instrument combining, on one record, the variation of atmospheric temperature and humidity content as a function of time. The most common hygrothermograph is a hair hygrograph combined with a thermograph.

-I-

ICAO. International Civil Aeronautical Organization; the international body governing the operation of commercial aircraft.

Interpolated (interpolation). The estimation of unknown intermediate values from known discrete values of a dependent variable.

Ionosphere. The atmospheric shell characterized by a high ion density. Its base is at about 70 or 80 km and it extends to an indefinite height.

Isobaric. Of equal or constant pressure, with respect to either space or time.

Isotherm. A line of equal or constant temperature.

-J-

Jet stream. The term applied to a more-or-less spatially continuous maxima of wind speed located in the upper troposphere, usually at the tropopause.

-L-

Lapse rate. The decrease of temperature with height, considered positive when temperature decreases with height.

Linear. Confined to first-degree algebraic terms in the dependent variables.

LORAN. Long Range Navigation (System); the U.S. operated off-shore navigation system.

-M-

Mandatory significant level. A set of WMO-defined pressure values for which the values of temperature, humidity, and wind are reported.

Mesoscale. A generic term for describing the spatial extent of a meteorological phenomenon, generally encompassing the range 100 to 1000 km.

Metadata. Information about data or a data set; usually, but not restricted to, details of access, quality, ownership, and history.

MHz or megaHertz. The SI unit of radio frequency, expressed in cycles/sec.

Meteorological Aids Service. A radio communication service used for meteorological and hydrological observations and investigations.

Meteorological Bulletin. An electronic, coded message comprising meteorological information and a header required for identification and transmission purposes.

Millibar (mb). A pressure unit of 1000 dynes per cm, convenient for reporting atmospheric pressure. Not an SI unit (see hectoPascal).

Moist adiabatic process. A quasi-adiabatic thermodynamic process which assumes that the latent heat of condensation is entirely used to maintain the liquid water at the same temperature as the (surrounding) dry air.

-N-

NASA. The National Aeronautics and Space Administration.

National analysis centers. The complex of organizational units within NOAA and DoD which make operational use of rawinsonde data. They include the National Centers for Environmental Prediction of NOAA; the Air Force Global Weather Center; and the Navy's Fleet Numerical Meteorological and Oceanography Center.

National Meteorological Center (NMC). Any center responsible for carrying out a nation's meteorological functions, including those of the World Weather Watch.

NAVAID. Navigational aid, implied usage of radio frequency signals.

NCDC. National Climatic Data Center, Asheville, NC.

NCEP. The National Centers for Environmental Prediction and part of the Washington D.C. WMC. The six centers of the National Weather Service which perform the forecast function. All NWS forecasts originate from one of these Centers.

NEC. National Electrical Code.

NFPA. National Fire Protection Association.

NOAA. National Oceanic and Atmospheric Administration.

NOTAM. Notice to Airmen. Issued in the U.S. by the Federal Aviation Administration.

NWS. The National Weather Service, part of NOAA.

NWSTG. National Weather Service Telecommunications Gateway; part of the Washington D.C. WMC, and the Region IV RTH.

-O-

OFCM. Office of the Federal Coordinator for Meteorological Services and Supporting Research.

OIC. Officer-in-charge.

Oktas. Literally, eights. Used to measure cloud cover as a portion of the sky.

OL-A. Operating Location-A of the AFCCC.

Omnidirectional. All directions.

OQC. Operational quality control, applied in real-time or near-real-time.

Orthogonal. Originally, at right angles; later generalized to mean the vanishing of a sum (or integral) of products.

-P-

PCA. Polar cap absorption.

PCM. Pulse code modulation.

Pibal. Meteorological jargon for a Pilot-balloon. Also used to denote the determination of upper winds by the tracking of a free balloon.

Potential temperature. The temperature of a parcel of dry air brought adiabatically from its initial state to 1000hPa (an arbitrary pressure).

Precision. The closeness of agreement between independent measurements of a single quality obtained by applying a stated measurement procedure several times under prescribed conditions.

Pressure-altitude curve. A functional relation, usually in tabular form, between pressure and geopotential height. More correctly termed a pressure-height curve.

-Q-

QC. Quality Control.

-R-

Radio direction-finder. An instrument for determining the direction from which radio waves (RDF) approach a receiver. A device which can "home" or "lock onto" a transmitted radio signal and determine the location of the source.

Radiotheodolite. Same as radio direction-finder.

Radome. A structure, made of material capable of passing radio-frequency signals, used to shelter antennae and other electronic equipment.

Rawinsonde. A type of upper-air observation for determining the wind speed and direction, pressure, temperature, and relative humidity aloft by means of a balloon-borne radiosonde tracked by a radar, a radio direction-finder, or by NAVAID.

RDF. Radio direction-finder.

Regulator (flight-train regulator). A device sometimes incorporated into a radiosonde flight-train to store and pay out gradually the length of line between the parachute and the radiosonde.

Relative humidity. The ratio of the ambient vapor pressure of water to the saturated vapor pressure at the particular temperature. It is usually calculated with respect to liquid water even when the temperature is below the melting point.

RMC. Regional Meteorological Centers of the WMO.

RTH. Regional Telecommunication Hub of the WMO.

-S-

Shock unit. A device sometimes incorporated into the radiosonde flight-train to minimize transient line shock between units of the train.

Significant level. In general, a pressure value in an atmospheric sounding deemed to be of importance in any reconstruction of that sounding with a limited amount of information. Present WMO nomenclature does not use this term - see mandatory significant and additional level.

Skew-T log P diagram. A graphical representation of pressure, temperature, and humidity made in a vertical sounding based upon thermodynamic laws. The coordinates are temperature and the logarithm of pressure, with the temperature isotherms rotated 45 degrees. The graphical representation is such that an area on the diagram is proportional to energy.

Slant range. The distance between a point on the earth's surface and an elevated object, taken to be a geodesic straight line.

Sling psychrometer. Coupled wet and dry-bulb mercury-in-glass thermometers arranged with a handle so that it can be whirled about an observer. Used to measure humidity.

Stability index. A defined, quantitative measure of the potential energy existing in the atmosphere. It is found by determining the temperature a parcel of air, initially at a selected level, would have if brought from its condensation level to the 500hPa surface by a moist adiabatic process, and then subtracting that temperature from the ambient air temperature at 500hPa.

Standard atmosphere (U. S. Standard Atmosphere). A hypothetical vertical distribution of temperature, humidity, and pressure taken to be representative. Used for aircraft altimetry, engineering design, etc. The particular standard atmosphere used is the U. S. S. A., equivalent to the ICAO standard atmosphere (Reference 15).

Station index. A 5-digit identifier for observing stations used in coded messages.

Strata (stratum). Synonymous with layer; here, a vertical portion of the atmosphere sampled by a radiosonde.

Stratosphere. The region of the atmosphere above the tropopause and below, approximately, 50 km in which temperature increases with height.

Superadiabatic lapse rate. An environmental lapse rate greater than the dry-adiabatic lapse rate (which see), such that potential temperature decreases with height.

Synoptic. In general, pertaining to or affording an overall view. In meteorology, this term has become somewhat specialized in referring to the use of meteorological data obtained simultaneously over a wide area for the purpose of presenting a comprehensive and nearly instantaneous picture of the state of the atmosphere.

-T-

Telemetry. The electronic transmission of information from a distant source.

Telemetering (telemeter). The measuring, transmitting, receiving, and indicating apparatus for obtaining the value of a quantity at a distance.

Thermodynamic diagram. A graphical representation of the thermodynamic laws of the atmosphere, generally arranged such that area on the diagram is proportional to energy. See skew-T log P entry as an example.

Thermistor. A device for measuring temperature whose electrical resistance varies markedly and monotonically with varying temperature and which possesses a negative temperature coefficient of resistivity.

TOA. Time-of-arrival.

Transponder. A transmitter-receiver arrangement so designed that the receiver generates a new signal which is then retransmitted. Used to measure linear distance or changes therein.

Tropopause. The boundary between the troposphere and stratosphere, usually characterized by an abrupt change of lapse rate. The change is in the direction of increased atmospheric stability from regions below to the regions above the tropopause.

Troposphere. That portion of the atmosphere from the earth's surface to the tropopause (approximately 8 to 16 km) characterized by a general decrease of temperature with height.

-U-

UL. Underwriters Laboratory**.**

UTC. Universal Time Coordinated- after the French equivalent.

-V-

Virtual temperature. The temperature that a volume of dry air must have in order to have the same density as an equal volume of moist air at the same pressure. (Since moist air is always less dense than dry air, the virtual temperature is always greater than the moist air temperature.)

-W-

WBAN. Outmoded meteorological jargon for Weather Bureau, Air Force, Navy.

Wet-bulb temperature. The temperature an air parcel would have if cooled adiabatically to saturation at constant pressure by evaporation of water into it, all latent heat being supplied by the parcel.

Wind shear. The variation of the wind vector along any direction, usually vertically.

WMC. World Meteorological Centers (Melbourne, Australia; Moscow, Russia; and Washington, DC, USA).

WMO. World Meteorological Organization. The United Nations body of meteorological agencies and interests.

WMO Region. Areas of the globe defined by the WMO

Region I - Africa
Region II - Asia
Region III - S. America
Region IV - N. America
Region V - S-W Pacific
Region VI - Europe
Antarctica

World Weather Watch (WWW). The world-wide, coordinated, developing system of meteorological facilities and services provided by member countries for the purpose of ensuring that all members obtain the environmental information they require.

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