U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Obsolete

Subject: AUTOMATED WEATHER OBSERVING SYSTEMS (AWOS) FOR NON-FEDERAL APPLICATIONS

Date: 6/12/90
Initiated by: ANW-140

AC No: 150/5220-16A
Change:

1. PURPOSE. This advisory circular (AC) contains the Federal Aviation Administration (FAA) standard for non-Federal Automated Weather Observing Systems.

2. CANCELLATION. AC 150/5220-16, Automated Weather Observing Systems (AWOS) for Non-Federal Applications, dated 4/11/86, is canceled.

3. DEFINITION. An AWOS is a computerized system that automatically measures one or more weather parameters, analyzes the data, prepares a weather observation that consists of the parameter(s) measured, and broadcasts the observation to the pilot using an integral VHF radio or an existing navigational aid.

4. APPLICATION. The provisions of this AC are effective immediately for all systems, or portions thereof, that are submitted for type certification, or for previously type certified systems that are submitted for modification of their type certification certificate. An AWOS that has been manufactured, installed, and maintained according to the criteria in this AC is approvable as a source of weather information that partially satisfies Federal Aviation Regulations (FAR); it may be eligible to receive a broadcast frequency assignment or to broadcast over a NAVAID; its weather may be eligible to be distributed over the national weather network; and it may be eligible for funding under Federal grant programs.

5. REQUESTS FOR INFORMATION. Further information concerning AWOS standards and the FAA type approval process may be obtained from the AWOS program office at the Federal Aviation Administration, Attention: Program Director for Weather and Flight Service Systems, Engineering Division, ANW-100, Washington, D.C. 20591, telephone (202) 267-8676.

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CHAPTER 1. INTRODUCTION

1. FUNCTIONAL DESCRIPTION. An AWOS automatically measures meteorological parameters, reduces and analyzes the data via computer, and broadcasts weather reports which can be received on aircraft radios. Pilots may use weather information provided by the AWOS to partially fulfill the requirements of various Federal Aviation Regulations (FAR). For example, at airports with instrument approaches, an AWOS weather report eliminates the remote altimeter penalty and thereby allows use of the published minimum descent altitude.

2. WEATHER SENSORS. The AWOS is a modular system utilizing a central processor which may receive input from several sensors. Five standard groups of sensors are defined in subparagraphs a-e; however, an AWOS may be certified with any combination of sensors. Depending upon system design, additional sensors may be certified to any AWOS configuration.

a. AWOS A. The AWOS A system contains only dual pressure sensors that measure pressure and report altimeter setting to the pilot.

b. AWOS I. The AWOS I system contains the AWOS A sensors, plus sensors to measure wind data (speed, direction, and gusts), temperature, dewpoint, and to report density altitude.

c. AWOS II. The AWOS II system contains the AWOS I sensors plus a visibility sensor.

d. AWOS III. The AWOS III system contains all the AWOS II sensors plus a cloud-height sensor.

e. AWOS IV. The AWOS IV system contains all the AWOS III sensors, plus precipitation occurrence, type and accumulation; freezing rain; thunderstorm; and runway surface condition.

3. OUTPUT MEDIA FOR AWOS WEATHER INFORMATION.

a. The output of the AWOS is reported by a computer-generated voice, which is transmitted to pilots over the voice output of a navigational aid (NAVAID) or via a discrete very high frequency (VHF) transmitter. The transmission may be continuous, or may be a 3-minute broadcast triggered by three clicks of a pilot's microphone on the AWOS broadcast frequency (if the AWOS broadcasts over a VHF discrete frequency radio). System design may permit the transmission of the identification of a NAVAID by using the AWOS voice capability. In all cases where the voice output of a navigational aid is used, provision must be made so that the failure of an AWOS will in no way result in any failure of the NAVAID being used.

b. AWOS messages may be offered via other formats which the owner chooses to provide, including a telephone dial-up service. An option allows an AWOS III (or greater capability) to be linked to the national weather network so that the weather information is available nationally for forecasting and flight planning purposes. To contribute to this network, the AWOS must have an interface module which puts the data into a format which is compatible with the planned, centrally located AWOS Data Acquisition System (ADAS). The ADAS will be located in each Air Route Traffic Control Center (ARTCC), and will collect and consolidate AWOS reports for input to the national network. The data communications protocol and other details of the interface between the AWOS and the ADAS may be obtained from the office listed on the front of this AC. Options to provide AWOS data directly into the Weather Message Switching Center (WMSC) using the National Airspace Data Interchange Network (NADIN) may be approved by the FAA. The sponsor of an AWOS that has been linked to the national weather network via either ADAS or NADIN will be required to sign a Memorandum of Agreement with the FAA Air Traffic Division in the applicable FAA region that commits them to:

(1) In the case of an ADAS interface, convert the AWOS data to the current or future ADAS format. In the case of a NADIN interface, to the current or future Surface Aviation Observation format (SAO), to include a possible change from the SAO to the Meteorological Aeronautical Report (METAR) format.

(2) In the case of a NADIN interface, a reporting frequency (e.g., number of reports per hour) and in accordance with criteria directed by the FAA.

(3) Bear all communications, quality assurance, troubleshooting and administrative costs to interconnect their AWOS to the ADAS or NADIN.

(4) Provide a focal point for use by the FAA and others to report problems with the AWOS or with the communications link to the ADAS or NADIN. The focal point must be available by telephone and responsive on a 24-hour/day basis.

c. The output of the AWOS weather observation is controlled by one of four modes of operation. Mode 1 is applicable to all systems; modes 2,3, and 4 are applicable only to systems configured with an operator terminal (OT). Modes 3 and 4 require an agreement with the National Weather Service (NWS) to maintain a Supplementary Aviation Weather Reporting Station (SAWRS) capability for augmentation and backup.

(1) Mode 1, Full-time Automated Operation. In this mode, the AWOS operates 24 hours/day without any manual input. The automated weather observations are updated on a minute-by-minute basis. There is no weather observer input to the AWOS. However, a manual observing capability may be maintained as backup provided that an agreement with the NWS to maintain a manual observing capability exists.

(2) Mode 2. Full-time Automated Operation with Local Notice to Airmen (NOTAM). Operation in this mode is the same as Mode 1, with the addition of the capability to append a manually recorded NOTAM to the automated voice reports. The airport manager is responsible for the NOTAM information. The NOTAM information is heard on the local voice broadcast; it is not transmitted longline. There is no weather observer input.

(3) Mode 3. Full-time Automated Operation with Manual Weather Augmentation and Local NOTAM Option. Operation in this mode provides the capability for a weather observer to manually augment the automated observation by appending a weather entry to the observation during the published weather observer duty hours. The observer duty hours should be published in the Airport/Facility Directory. The addition of a local NOTAM per subparagraph (2), above, is also permitted in this mode of operation, provided there is no interference with the observer augmentation. The weather observer is responsible for the accuracy and timeliness of the added weather information. The weather to be added is limited to thunderstorms, all types of precipitation, and obstructions to vision. [Note: Tornadoes, waterspouts, and funnel clouds are reported as urgent specials (USP) using Mode 4]. The weather added by the observer is to be manually recorded and appended to the automated voice reports using the OT microphone, and, as applicable, entered manually (using the AWOS keyboard) into the system for transmission over the Service A teletype network. The procedures in Federal Meteorological Handbook No. 1 (FMH-1) or, as applicable, Federal Meteorological Handbook No. 9 (FMH-9), apply to the thunderstorm, precipitation, and obstruction to vision entries, except:

(i) The manual entries are to be included in the "remarks" portion of the observation prefaced with the phrase "OBSERVER WEA:".

(ii) The precipitation entries are limited to type and intensity, e.g., "OBSERVER WEA: R-S-."

(iii) The thunderstorm entries are limited to intensity (if appropriate), and direction (OVHD, NE, etc.), e.g., "OBSERVER WEA: TRW+ T OVHD."

(iv) Obstructions to vision (alone or in combination with precipitation) are to be included when the visibility is 3 miles or less, e.g., "OBSERVER WEA: F."

(4) Mode 4. Part-time Manual Operation. Operation in this mode is normally used for backup and, as applicable, dissemination of USP over the Service A teletype network. Operation in this mode permits a weather observer to enter a complete manual observation into the system. The procedures in FMH-1 (or -9) apply to the recording and formatting of these manual observations. As applicable, the manual observations are transmitted over the Service A teletype network. Voice dissemination of the observations must be done manually using the OT microphone. The manual observations include input from the automated AWOS outputs available to the weather observer on the OT display, to be modified to

FMH-1 (or -9) requirements. For example, the manual observation includes manually derived ceiling/sky condition and visibility using FMH-1 (or -9) definitions, which differ somewhat from the AWOS algorithms. Temperature, dewpoint, wind direction/speed and altimeter setting are the same and should be used exactly as presented on the AWOS OT display. Sea level pressure, if required to be included in the observation, must be computed manually since it is not an output included in the AWOS automated output.

CHAPTER 2. CERTIFICATION AND COMMISSIONING PROCESS

4. PROCESS OVERVIEW. In order to provide confidence in the quality of the meteorological data which the AWOS provides to users in the aviation community, the FAA has initiated a three-part AWOS certification and commissioning process.

a. The manufacturer will provide the FAA with the test data and other documentation to demonstrate that the AWOS system meets the criteria of this AC (par 5, type approval). Upon completion of all the requirements set forth herein, the FAA grants type approval to the specific system that was documented in the request.

b. Prospective users should closely coordinate their plans with the regional non-Federal system coordinator. After the AWOS is installed onsite, the FAA will conduct an inspection to verify that the system is installed and operating correctly and that the owner has the resources to maintain the system in proper operating condition (par 11, facility commissioning). This process must be successfully completed for the AWOS to be commissioned by the FAA, and thus to be authorized to operate as part of the National Airspace System (NAS).

c. Finally, there may be visits to the operating AWOS by the FAA and other technical representatives to verify that the system continues to operate correctly (par 14, ongoing system validation).

5. SUBMITTALS BY MANUFACTURER FOR TYPE APPROVAL. The FAA will grant approval to an AWOS design after review and approval of three submittals from the manufacturer. The first submittal consists of test procedures and data sheets which demonstrate that the proposed AWOS configuration meets the hardware and software criteria of this AC. This submittal for type approval shall include a single matrix showing each specific requirement from this AC, cross referenced to the specific location (paragraph, page, etc.) within the manufacturer's submittal where the requirement has been addressed. The second submittal consists of warranty, training, and maintenance documents intended to support the AWOS system owner. The third submittal consists of a configuration control plan which identifies the components and options approved for use with the system. Requests for type approval should be sent to the AWOS program office at the address listed on the front of this AC. Product approval may be revoked (or an individual site may be removed from service) if:

a. The equipment has an unacceptable failure rate or outputs weather data that is not representative of actual weather conditions.

b. There is a deficiency that adversely affects safety of flight.

c. Changes are made in the equipment without FAA approval.

d. The manufacturer fails to honor the warranty.

6. UNACCEPTABLE FAILURE RATE. Since reliable equipment is of prime importance to safety of aircraft operations, equipment which proves unreliable in use must be removed from the approval listing. The determination of unreliability must be based on judgment and experience with equipment of a like nature. Where any such equipment is deemed to have an unsatisfactory failure rate or is deficient in workmanship or materials, the manufacturer will be notified in writing as to the basis for this determination. The manufacturer shall then notify the FAA in writing as to its plan of action for correcting the problem. If the manufacturer does not resolve the problem within a reasonable time (the timeframe will, of necessity, be based on safety considerations and/or the nature of the problem), the equipment will be removed from the approval listing. The FAA reserves the right to require the equipment to be resubjected to any or all qualification tests when the equipment has been deemed unreliable or deficient in design, materials or workmanship. Owners of similar AWOS's will be notified of any problems uncovered during this retesting through the configuration control procedure discussed in paragraphs 9 and 14c.

7. TEST PROGRAM. Chapter 3 contains the performance and testing standards for each component of the AWOS. The manufacturer shall demonstrate compliance with these standards through performance testing (where a test is specified) or by analysis and inspection. The manufacturer provides all necessary equipment and bears all testing costs. It is recommended that the manufacturer propose a test plan to the FAA containing detailed procedures for conducting the tests as well as the name and location of the facility where the tests will be conducted. Prior FAA review of the test plan will minimize the likelihood of improper test procedures which will result in rejection of the data. It is the responsibility of the manufacturer to provide test data to the FAA that is credible, factual, and representative of the equipment being certified. Submissions shall include all data collected during a test; data shall not be omitted because it falls outside of the acceptable limits of this AC. After completion of the tests, the manufacturer must reduce the data to an easily understood format to demonstrate compliance with this AC. If the manufacturer has previously performed testing, the test procedures and data sheets from these tests may be submitted for FAA approval. However, the FAA reserves the right to witness testing and to examine raw data.

8. SYSTEM DOCUMENTATION. The documentation described in this paragraph should be submitted by the manufacturer to the FAA for review and approval. After the FAA has approved the (a) system description, (b) maintenance manual, (c) installation and checkout manual, (d) operating instructions, and (e) annual system revalidation plan, 12 copies of these approved documents shall be submitted to the AWOS program office before type approval of any system (or any system modification requiring a change in any of these documents) shall be granted. These documents are intended to assist the AWOS owner in installing, operating, and maintaining the system. They shall be provided as separate manuals. The items may be cross-referenced to avoid duplication, but the elements of each portion of each document should be clear. (For example, the maintenance procedures which are performed during the annual system revalidation must be explicitly referenced.) If the manufacturer wishes to modify the

initially approved configuration, then the supporting documentation must be revised to reflect the approved change (and 12 copies of the approved documents shall be submitted to the program office) before type approval is granted and the system is offered for sale.

a. System Description. The system description identifies and catalogs the hardware components to the level of the smallest field-replaceable module and describes computer software. The principles of system operation are described using schematics, block diagrams, and flow diagrams. For peripheral devices, the performance parameters are included along with the name and address of the original manufacturer.

b. Manufacturer's Maintenance Manual. The manufacturer's maintenance manual shall contain a comprehensive maintenance program to be implemented by the owner to ensure reliable and accurate performance over the life of the system. As a minimum, the program will define all maintenance activities which are required within a period of 5 years and a recommended frequency (e.g., quarterly, annually) for each operation. The following topics should be addressed in the maintenance manual.

(1) Maintenance Procedures. The manual shall contain a step-by-step procedure for each scheduled (i.e., periodic) and unscheduled (i.e., repair) maintenance operation. It shall discuss calibration methods, troubleshooting procedures, suggested spare parts, and shall identify all test equipment required. This document shall also include the detailed procedures (e.g., the keystrokes) followed by the maintenance technician when using the Operator Terminal to perform maintenance on the system.

(2) System Performance Parameters. The manual shall contain a complete listing of the test points, sensor outputs, waveforms, and other parameters which indicate system performance and that may be measured in the field. If these quantities are field-adjustable, then an initial value (for use during initial certification) and an operating tolerance (for use during the annual verification) shall be given. The key system parameters shall also be identified, i.e., those values which best indicate system performance and that therefore should be checked most frequently. The frequency of scheduled maintenance actions (e.g., monthly, quarterly, annually) shall also be given.

(3) Data Recording Forms. The manual contains two forms designed to aid the system owner in recording the system performance data described in subparagraph (2). The Comprehensive Facility Performance and Adjustment Data form is to be completed at system commissioning, after major repair work, and during the annual system revalidation. The form contains space to record the performance of all significant system parameters with additional space to detail any repair work completed. The Technical Performance Record contains space for the key parameters only and is intended for use after a scheduled maintenance visit to the facility. Both forms contain the date of the action, the facility name and location, and other identifying data. These forms shall be maintained in the Facility Reference Data File (FRDF, paragraph 12).

c. Installation, Checkout Manual. This document shall thoroughly describe the installation and checkout procedures to be followed by the technician at the installation site.

d. Operating Instructions. Provides detailed instructions to a weather observer on operation of the system. This document will provide guidance for the certification of weather observers; describe and provide instructions for operation in each of the four modes (par 3c); it will explain the procedures when using the Operator Terminal to augment or to back up the AWOS, or to disseminate NOTAM information.

e. Training Program. The training program shall consist of a summary of the knowledge and skills which a technician must possess to operate an AWOS. This document shall also propose a program to familiarize maintenance technicians with the maintenance and operation of the AWOS system. The instruction program may be conducted onsite, at the factory, via home study, or by other means suggested by the manufacturer. The training program shall also contain standards for establishing the proficiency of and certifying potential maintenance technicians. These standards shall contain a minimum of 100 questions (with answers) that may be used to test the competence of the maintenance technician on the specific system being submitted to the FAA for approval.

f. Annual System Revalidation Plan. This plan shall contain the manufacturer's recommended procedures to conduct an annual inspection of the facility in order to verify that it is operating within tolerance.

g. Warranty. The manufacturer will submit a statement certifying that the following minimum warranty will be provided for the equipment:

> "This equipment has been manufactured and will perform in accordance with requirements of FAA Advisory Circular 150/5220-16A. Any defect in design, materials, or workmanship which may occur during proper and normal use during a period of 1 year from date of installation or a maximum of 2 years from shipment will be corrected by repair or replacement by the manufacturer f.o.b. factory."

9. CONFIGURATION CONTROL PLAN. Due to the modular nature of the AWOS, many system components such as sensors and peripheral devices may be interchangeable. Since type approval is given only to specific combinations of components, the manufacturer must establish a configuration control mechanism which will uniquely identify each FAA-approved system and the components which comprise them. Before type approval will be granted, the manufacturer must submit a configuration control plan. The manufacturer's configuration control system shall be explained, and shall include the procedures for configuration control of all system documentation. The identifying information for each system shall be permanently inscribed on a system nameplate. Changes to an approved configuration shall be submitted for FAA approval to the AWOS program office at the address listed on the front of this AC. Minor product improvement changes

may be incorporated by the manufacturer after notifying and obtaining approval from the FAA. Major changes, such as a sensor or a major software change, must be fully supported by documentation and appropriate test data. Significant changes, such as a sensor or major software changes, will be fully supported by documentation and appropriate test data. (Major changes will normally require the assignment of a new configuration number.) Every change to an approved AWOS will be supported by revised (configuration controlled) documentation. The plan shall also address:

a. Explanation of the manufacturer's arrangement for assigning a configuration identification number/symbol/etc., and the means used to identify which system components are included in a particular system configuration.

b. Procedures for notifying system owners of changes in the approved configuration of their AWOS.

c. Procedures for identifying and maintaining a record of the configuration of each operational systems that have been sold and installed by the manufacturer.

d. A definition of major and minor product improvement changes.

e. Procedures for the configuration control of documentation, to include procedures for issuing changes, numbering, and dating pages.

10. PLANNING THE AWOS INSTALLATION.

a. All airport owners, sponsors, or other parties contemplating purchase and installation of a non-Federal AWOS should coordinate with the FAA in the planning stages of the project before the equipment is ordered. The regional FAA non-Federal coordinator is the official FAA point of contact and is responsible for the overall project coordination with the sponsor and other elements in the FAA. Airport sponsors obtaining a grant under the Airport Improvement Program (AIP) should also coordinate, in concert with the non-Federal coordinator, with the FAA Airport District Office or Field Office that has jurisdiction over their specific geographical area. The FAA non-Federal coordinator will coordinate the proposal with the FAA regional Flight Standards division, Air Traffic division, and the regional Frequency Management Officer.

b. The selection of a voice outlet frequency for the AWOS is a critical issue which is advisable to be coordinated with regional Frequency Management Officer in the early planning stages of the facility, since there are a limited number of frequencies available for this purpose. FAA policy is to use an existing NAVAID [VHF omnidirectional range (VOR) or nondirectional radio beacon (NDB)] voice outlet for the AWOS whenever practical. If there is no NAVAID facility that satisfies the coverage requirements, or if the facility is being used for Automatic Terminal Information Service (ATIS), Transcribed Weather Broadcast (TWEB), or Hazardous In-Flight Weather Advisory Service, the regional Frequency Management Officer will recommend the use of a dedicated transmitter operating on a discrete frequency. If the AWOS system proposed for installation does not meet the requirements of this AC, the FAA will not assign the system a broadcast frequency.

c. After an AWOS III has been certified and commissioned by the FAA, it becomes the official airport weather observation. Any existing manual weather observation program whose hours conflict with the AWOS III should be terminated. However, as specified in paragraph 3c, the AWOS owner may elect to maintain a manual observation capability to back up the AWOS in the event the system, or any critical parameter (wind speed/direction, ceiling/sky condition, visibility, altimeter setting), fails. In addition, the AWOS owner may elect to augment the AWOS output with specified parameters (e.g., thunderstorms or precipitation) that are not within the capability of the AWOS. In these cases, the SAWRS agreement with the National Weather Service should be amended accordingly.

11. FACILITY COMMISSIONING. The AWOS facility will be formally commissioned by the FAA before it becomes part of the National Airspace System. After receiving approval of a broadcast frequency, the owner may procure and install the AWOS facility. At least 120 days prior to the anticipated commissioning date, the owner should notify the FAA regional Flight Standards division so that routine revisions may be made to the instrument approach procedures. As the system approaches operational readiness, the owner will request a commissioning ground inspection, which will be conducted by regional Airway Facilities (AF) personnel. This inspection requires participation of the owner or owner's maintenance representative. The commissioning inspection consists of the tests and checks in subparagraphs a-e, a review of the operations and maintenance documents on file at the facility, and recording of facility performance data which will be retained as commissioning documentation in the FRDF.

a. Siting and Installation. The AWOS is a permanent facility and is located, constructed, and installed in accordance with applicable code requirements. It shall be installed by a technician who is fully qualified in electronic applications who has a knowledge of the operations, testing and maintenance of the AWOS, and is either a maintenance technician employed at the manufacturer's factory, or has been certified by the FAA. The procedures in the FAA approved Installation, Checkout Manual shall be performed (par 8c). An FAA AF representative will verify that the AWOS equipment was installed in accordance with the siting criteria contained in the current version of Order 6560.20, Siting Criteria for Automated Weather Observing Systems (AWOS), and that the checkout procedures have been performed. Any discrepancies found during this inspection must be rectified before the facility will be commissioned.

b. Performance Test. The AWOS owner or maintenance representative will operate the system and will measure all system performance parameters described in the maintenance manual. These parameters are recorded on a Facility Equipment Data and Adjustment Form and retained at the facility as commissioning documentation.

c. Flight Inspection. All AWOS facilities utilizing a NAVAID (e.g., VOR, NDB) for a voice outlet to broadcast weather information shall be flight inspected to assure that operation of the NAVAID has not been derogated. If, during flight inspection, it is determined that performance of the NAVAID has been affected, the AWOS shall not be activated until the malfunction has been corrected (e.g., through modification, or by employing a separate discrete frequency transmitter to broadcast the weather). An AWOS utilizing a discrete frequency transmitter is not required to undergo a flight inspection.

d. Notification of the AWOS Program Office. Following successful completion of the commissioning inspection, the FAA regional non-Federal AWOS coordinator shall notify the FAA program office of the commissioning date, broadcast frequency, voice access telephone number, system owner, and maintenance arrangements.

e. Relocation of an AWOS. In the event that an AWOS is removed from service in order to be relocated, a "Decommissioning" NOTAM shall be issued, instead of a "Facility out-of-service NOTAM." After relocation, a facility commissioning inspection shall be performed.

12. ONSITE DOCUMENTATION. The following documentation will comprise the FRDF. It will contain all pertinent onsite documentation, and is to be maintained and kept at the facility. It will be reviewed at the commissioning inspection.

a. Type Approval. A copy of the FAA letter to the manufacturer granting type approval for the AWOS system design. The subsystems will be inspected to verify that the installed AWOS is exactly the configuration for which the type approval was given.

b. Frequency Allocation Approval. The documentation from the Federal Communications Commission (FCC) assigning the approved operating frequencies (if appropriate).

c. Manufacturer's Documentation. Copies of the AWOS operating instructions (par 8d), manufacturer's maintenance manual (par 8b), and system description (par 8a).

d. Operational Procedures. Site-specific operational procedures which set forth mandatory site procedures for both routine and nonscheduled situations. These procedures may incorporate appropriate sections of the manufacturer's manuals and will be available for inspection at the time of the commissioning inspection. The following items will be covered:

(1) Physical security of the facility.

(2) Maintenance and operations by authorized persons.

(3) Posting of licenses and signs.

(4) Notice to the FAA when any AWOS service has been suspended.

(5) Keeping of station logs and other technical reports.

(6) Names, addresses, and telephone numbers of persons to be notified in the event of system failure.

(7) Procedures for shutdown for periodic scheduled maintenance, including the office to be notified to generate a NOTAM for routine or nonscheduled shutdowns. Also, an explanation of the kinds of activities (such as construction or grading) in the vicinity of the AWOS facility that may require shutdown or reverification of the AWOS.

(8) Procedures for amending or revising the instructions.

(9) Procedures to be followed to freeze the AWOS data in the archive file in the data processor for a specified period before and after the time of an aircraft accident or incident, and the procedures to be followed to retrieve this data. These procedures shall assign the responsibility for accomplishing those actions. They shall be automatically accomplished in the event of an accident or an incident, or upon the request of a member of the FAA.

(10) Locations of AWOS components on the airport. This includes the result of the survey to establish the elevation of the barometric pressure sensors.

(11) A Memorandum of Understanding signed by the owner and the FAA regional Airway Facilities and Logistics division managers. This memorandum will state that the owner agrees to maintain, repair, and modify the AWOS in accordance with the requirements, standards, or criteria governing AWOS, particularly those contained in the operation instructions and maintenance manuals. The owner understands that noncompliance with the requirements of this AC may result in removal from service or decommissioning of the AWOS.

(12) A copy of any agreement with the NWS to maintain a SAWRS capability to augment or back up the AWOS.

e. Commissioning Documentation. The Facility Equipment Data and Adjustment Form, completed during commissioning.

13. MAINTENANCE PROGRAM. At the time of facility commissioning, the owner will show that a maintenance program has been established. The maintenance program shall cover a minimum period of 5 years (as established in par 8b) and shall consist of properly trained personnel, adequate test equipment, and resources to fulfill the manufacturer's recommended scheduled maintenance and calibration procedures defined in the manufacturer's maintenance manual. The maintenance program is the responsibility of the owner, but may be performed by the owner, the manufacturer, or a qualified third party.

a. Maintenance Personnel. The owner will show that the maintenance program adopted has qualified personnel available to maintain the AWOS system. Each AWOS maintenance technician who is responsible for repair and adjustments leading to verification of the system [routine preventative (i.e., periodic) maintenance excluded] will have the special knowledge and skills needed to maintain the AWOS facility, and shall have completed the manufacturer's training program (par 8d). They shall be proficient in maintenance procedures and the use of specialized test equipment, and shall be certified by the FAA.

b. Test Equipment. The owner will have available at the facility at the time of commissioning all test equipment required by the approved maintenance plan for maintenance and calibration of the facility. Test equipment shall be calibrated in accordance with the schedule submitted to (and approved by) the FAA during Type Acceptance. Test equipment calibration shall be traceable to National Standards, and proof of calibration (e.g., a current calibration sticker) shall accompany each piece of test equipment when it is being used. After commissioning, the test equipment will be available when required for scheduled system maintenance and calibration or for repairs after system failure.

c. Performance/Configuration Revalidation. The owner shall show provisions for complying with the manufacturer's recommended procedure for system revalidation (par 8e). This plan shall include a list of the procedures to be followed during the revalidation and the source of the qualified person who will conduct the inspection.

14. ONGOING SYSTEM VALIDATION. To verify that the system is being properly maintained and that the system retains an approved configuration, the following ongoing validation program will be conducted. Failure to meet the criteria of this program will result in decommissioning the AWOS facility (i.e., withdrawal of the broadcast frequency authorization).

a. Performance/Configuration Revalidation. Each AWOS will be annually inspected by a qualified technical representative in accordance with the manufacturer's approved Annual System Revalidation Plan. This inspection will include the items in subparagraphs (1) through (4), and the results shall be recorded on a Facility Performance and Adjustment Data form and retained on file in the FRDF at the facility.

(1) Verify that the maintenance program is being followed and properly documented.

(2) Perform a comprehensive check and calibration to verify that system performance is within the limits specified by the manufacturer's documentation, and to ensure that every component of the system is operating properly.

(3) Verify that the AWOS configuration is the same as approved at the time of commissioning, or as formally modified in accordance with approved configuration control procedures. Additionally, it shall be determined that all

mandatory configuration changes approved by the FAA have been accomplished and documented.

(4) A summary of all maintenance (hardware and software) performed since the last report is on file at the facility.

b. FAA Site Visits. The FAA will visit certificated non-Federal AWOS facilities. Through a review of the documentation at the AWOS site, the FAA representative will verify that the system operates within tolerance, that all maintenance tasks have been properly performed and documented, and that the AWOS configuration has been approved by the FAA. Scheduled (periodic) and unscheduled maintenance, and the documentation of these activities, shall have been accomplished in accordance with the approved manufacturer's maintenance manual and the annual system revalidation plan provided to and approved by the FAA during the type approval process. The owner will provide the FAA representative with access to the sites in order to perform this inspection.

c. Mandatory Configuration Changes. If the FAA determines that an AWOS system, or any element of the system, is providing data which could be in error, the FAA may direct the system manufacturer to issue a mandatory configuration change order to the owners of similar systems. The system owner will disable the appropriate part of the system and will issue a NOTAM describing the missing parameter and giving an estimate of the time for which it will be disabled.

CHAPTER 3. PERFORMANCE AND TESTING SPECIFICATIONS FOR AWOS

15. GENERAL. This chapter contains the performance standards and testing specifications for components of the AWOS. Equipment will comply with the these standards in order to constitute a source of weather information to be used to satisfy the FAR's. However, the following tests are intended to be performed in a laboratory environment, and are not intended to be duplicated in the field. Field measurements (i.e., standards and tolerances during certification and annual verification) are detailed in the FAA approved maintenance manual for each type certified AWOS.

16. DEFINITIONS.

a. Root Mean Square Error (RMSE). RMSE is determined by comparing the output value with the true value of a parameter according to the following equation:

$$RMSE = \left[\frac{1}{N} \sum_{N=1}^{N} (T-M)^2\right]^{\frac{1}{2}}$$

Where

N = Number of independent comparisons

M = Measured value

T = True value

b. Time Constant. After a step change in the value of a parameter measured by a sensor, the time constant is the length of time it takes the sensor to register a given percentage (63 percent unless otherwise specified) of the change.

c. Resolution. The resolution of a sensor is the value of the least significant digit which is given as sensor output.

d. Variance. For the purposes of this AC, variance is defined as the difference between the value of the reference sensor and the sensor under test.

e. Thunderstorm. For purposes of this AC, a "thunderstorm" is a storm produced by a single cumulonimbus cloud (i.e., a cell), and includes one or more forms of lightning. At any one time, a period of storm activity may consist of a number of thunderstorms (i.e., cells) within the area surrounding the reference point.

17. GENERAL PERFORMANCE STANDARDS. This paragraph addresses aspects of performance which are applicable to the AWOS as a whole. The electromagnetic interference, transient, and lighting protection standards are also applicable to the entire system and are addressed in paragraphs 30 and 31.

a. Input Power. AWOS equipment operates from a 120/240 V (±10 percent), 60 Hz ac (±5 Hz), 3-wire single phase service.

b. Loss of Power. The AWOS system will return to normal operation without human intervention after a power outage. When power is restored, the system will not output erroneous data.

c. Wind Sensor Tower. If a separate tower is used for the wind sensor, daytime marking and nighttime lighting shall be provided in accordance with AC 70/7460-1G.

(1) It shall be lighted with a dual L-810 fixture placed within 5 feet (1.5m) of the top of the tower. The two lamps on the L-810 shall be wired in parallel. The standards for the L-810 fixtures may be found in AC 150/5345-43, Specification for Obstruction Lighting Equipment, which may be ordered from the Department of Transportation, Utilization and Storage, M-443.2, Washington, D.C. 20590.

(2) Since the nominal height for this tower is 30 to 33 feet, and since most towers are manufactured in 10 foot sections, a waiver to AC 70/7460-1G has been granted to permit a six-band marking, with the bands alternating between aviation orange (the top band) and aviation white. This pattern will permit dip painting the tower at the factory without sacrificing the level of safety provided by the standard tower.

d. VHF Transmitter. It is FAA policy that the output of the AWOS will be transmitted on an existing navigational aid voice outlet whenever practical. When the AWOS is broadcast over a NAVAID, that NAVAID shall be given a flight check during the initial commissioning procedure, and shall be given an annual flight check in conjunction with the annual AWOS verification. If there is no NAVAID available, then the output will be broadcast via a separate VHF transmitter which will be licensed by the FCC. The transmitter operates in the 118-137 MHz band on a frequency assigned by the FAA. The transmitter will have an FCC type acceptance, and shall have the following operational parameters:

Channel Spacing: 25 KHz

RF Power Output: nominal 5 watts, at the transmitter
10 watts maximum (under unusual circumstances, only with FAA approval)
NOTE: No compensation should be necessary to allow for antenna feed line losses.

Frequency Stability: ±0.001% (-30 to +60° C)

Emission Type: 6A3

Spurious and harmonic emissions: 80 db minimum up to 90% modulation

e. Generation of the NAVAID Identifier by the AWOS. The AWOS may be designed to provide both the NAVAID tone identifier and the AWOS weather data over the NAVAID frequency. The tone shall be generated only between the AWOS voiced weather messages. This design will eliminate the interference between the AWOS voice and the NAVAID generated tone identifier, and provides for better identification of the NAVAID in marginal conditions. If this design is adopted, it is imperative that the NAVAID automatically return to using its internal tone generator to provide the identifier if the AWOS capability to provide the NAVAID identifier has been lost.

f. VHF/UHF Data Link Radio Transmitter. When a VHF or UHF radio is used to transfer data between components of the system, the transmitter shall have FCC type acceptance, and the power output shall be limited to the minimum necessary to accomplish the job, and shall not exceed one watt. The FCC will license the use of the facility and shall assign the frequency. Frequency stability, deviation/percent modulation, Voltage Standing Wave Ratio (VSWR) and initial/operating power output shall be in accordance with FCC regulations, and shall be clearly defined in the manufacturer's maintenance manual.

18. OPERATING ENVIRONMENT. AWOS equipment will operate under the environmental conditions described in this AC. Equipment that cannot satisfy the full range of conditions may be waivered for operation in locales where those conditions do not occur.

a. Site Elevation. From 100 feet below sea level to 10,000 feet above sea level.

b. Equipment Installed Indoors in a Conditioned Space.

(1) Temperature. From +40 to +105° F (+5 to +40° C).

(2) Relative Humidity. 5 percent to 90 percent (noncondensing).

c. Equipment Installed Outdoors.

(1) Temperature.

Class 1: -30 to +130° F (-35 to +55° C)
Class 2: -65 to +130° F (-55 to +55° C)

(2) Relative Humidity. 5 percent to 100 percent.

(3) Wind. Up to 85 knots.

(4) Hail. Up to 1/2 inch in diameter.

(5) Ice Build-up. Freezing rain rate equivalent to a buildup of 1/2 inch per hour, lasting for a period of one hour. The accuracy of the wind sensors is permitted to deteriorate during icing conditions.

(6) Rain. Up to 3 inches per hour with 40 knot wind.

19. WIND SPEED AND DIRECTION SENSOR.

a. Performance Standard.

(1) Wind Speed Sensor.

(i) Range. The sensor shall respond to a threshold of 2 knots and a maximum of at least 85 knots.

(ii) Accuracy. The wind speed sensor shall provide an accuracy of 2 knots or 10 percent RMSE, whichever is greater, with a maximum error of 15 percent at any speed.

(iii) Resolution. The resolution shall be one knot.

(iv) Distance Constant. The distance constant shall be less than 10 meters. The method for calculation is given in subparagraph b(1)(ii).

(v) Threshold. Two knots.

(2) Wind Direction Sensor. This sensor shall be aligned to true north and shall withstand a wind speed of 85 knots without damage.

(i) Range. 1° to 360° in azimuth.

(ii) Threshold. 2 knots.

(iii) Accuracy. Within 5° (RMSE), with a maximum error of 10° on any direction.

(iv) Resolution. To nearest 1°; dead band not to exceed 10°.

(v) Time constant. Less than 2 seconds.

b. Performance Testing. Testing shall be conducted in a calibrated wind tunnel, except for the wind direction accuracy test which is conducted on a bench test fixture. The wind speed sensor shall be compared against a calibrated pitot-static tube or transfer reference standard traceable to the National Bureau of Standards. The test procedure in subparagraphs (1) and (2) will be used:

(1) Wind Speed.

(i) Accuracy and Resolution. The test is conducted under "no rain" conditions. Four full test cycles (2 - 85 knots) shall be conducted in increments of 2 knots between 2 and 10 knots, in increments of 10 knots between 10 and 80 knots, and at 85 knots. During these test runs, data shall be gathered to demonstrate compliance with the requirements for accuracy and resolution.

(ii) Distance Constant. The distance constant shall be computed according to the following formula.

$$D = T \times W$$

Where:

D = Distant Constant (in meters).
T = Time constant.
W = Wind speed (meters per second) in the wind tunnel.

The distance constant will be determined from an average of 10 runs (5 runs each with the tunnel wind speed at 10 knots (5 meter/sec.) and at 20 knots (10 meter/sec) with the sensor propeller speed at the zero at time zero). The distance constant must be less than 10 meters for the sensor to pass this test. If the sensor is of a type with no moving parts (i.e., no propeller), the manufacturer shall develop a test for FAA approval to demonstrate compliance with the distance constant requirement.

(2) Wind Direction.

(i) Accuracy. This test will be conducted on a bench test fixture under "no rain" conditions. The accuracy of the sensor shall be checked at each 15° increment. The accuracy shall be checked in 2° increments between 350° and 010° (a dead band of up to 10° is permissible). Two complete test cycles shall be conducted, and RMSE accuracy shall be within specified limits.

(ii) Time Constant. The time constant will be determined from an average 10 runs (5 runs each with the tunnel speed at 10 knots and at 20 knots). The vane shall be displaced 10° from the indicated wind direction and released. The time constant shall be less than 2 seconds to reach within 5° of the indicated wind direction.

20. AMBIENT TEMPERATURE SENSOR.

a. Performance Standards. The sensor shall be thermally isolated to accurately measure the environments below.

(1) Range. From -35° to +55°C (-30° to +130°F) for Class 1 systems.

From -55° to +55°C (-65° to +130°F) for Class 2 systems.

(2) Accuracy. 1°F RMSE for the entire range of the sensor, with a maximum error of 2°F.

(3) Resolution. Not greater than 1°F.

(4) Time Constant. Not greater than 2 minutes.

b. Performance Testing.

(1) Accuracy. Temperature accuracy will be verified using a calibrated reference instrument traceable to the National Bureau of Standards. The temperature sensor shall be exercised through the full range of the device in 20°F increments. This 20° change in chamber temperature must be accomplished within 5 minutes, and the sensor reading will be taken 5 minutes after the chamber temperature is stable. This test cycle shall be performed a total of eight times (or four times with two sensors in the chamber). These cycles shall include two increasing and two decreasing temperature cycles without radiation heating; and two increasing and two decreasing temperature cycles, with radiation heating on the aspirated enclosure of 1.6 gram-calories per square centimeter per minute. The accuracy of the sensor shall be within 1°F (RMSE) for each test cycle (a total of 9 data points for each Class 1 system cycle; 11 data points for each Class II system cycle.)

(2) Time Constant. The sensor shall be placed in a chamber and stabilized at 85°F. The temperature shall be rapidly raised (within one minute) 5° (to 90°F); the time constant shall be 2 minutes or less. The same test shall be repeated with a 5° decrease in temperature within one minute. The time constant shall be 2 minutes or less.

21. DEWPOINT SENSOR. A single thermal shield and aspirator unit may include both the dewpoint and temperature sensors.

a. Performance Standards.

(1) Operating Range. From -30° to +90°F

(2) Dewcell Protection. If the dewpoint sensor is a dewcell, it shall not be damaged if the sensor becomes excessively wet (e.g., from precipitation or from absorption of moisture after a loss of power). The dewcell probe will return to normal operation, without damage, within 30 minutes after the abnormal, excessively wet condition is alleviated (i.e., after precipitation ends), or after restoration of power.

(3) Resolution. Not greater than 1°F.

(4) Time constant. Less than 2 minutes.

(5) Accuracy. The accuracy shall be as follows (all errors are RMSE):

(i) 2°F dewpoint for dry bulb temperatures of +30° to +90°F (80 to 100 percent relative humidity), with a maximum error of 3°F at any dry bulb temperature.

(ii) 3°F dewpoint for dry bulb temperature of +30° to +120°F (15 to 75 percent relative humidity) with a maximum error of 4°F at any dry bulb temperature.

(iv) 4°F dewpoint for dry bulb temperatures of -20° to +20°F (25 to 95 percent relative humidity) with a maximum error of 5° at any dry bulb temperature. The minimum dewpoint required is -30°F.

b. Performance Testing.

(1) Accuracy. All tests shall be performed with the sensor in the aspirated enclosure supplied with the sensor. Temperature and dewpoint accuracy will be verified using calibrated reference instruments traceable to the National Bureau of Standards. The data points given in subparagraphs (i) through (iii) will be taken during four test runs (two with increasing humidity and two with decreasing humidity.) This may be reduced to two test runs if two sensors are placed in the chamber. During the test run, the change in temperature and/or relative humidity will be accomplished within 5 minutes, and the sensor reading will be taken 5 minutes after the temperature and humidity have stabilized. The following data points will be demonstrated and the RMSE calculated to demonstrate the error in each category.

(i) With an error not to exceed 2°F (RMSE) dewpoint,
30°F temperature; 80, 90, 100 percent relative humidity
60°F temperature; 80, 90, 100 percent relative humidity
90°F temperature; 80, 90, 100 percent relative humidity

(ii) With an error not to exceed 3°F (RMSE) dewpoint,
30°F temperature; 15, 45, 75 percent relative humidity
60°F temperature; 15, 45, 75 percent relative humidity
90°F temperature; 15, 45, 75 percent relative humidity
120°F temperature; 15, 40 percent relative humidity

(iii) With an error not to exceed 4°F (RMSE) dewpoint,
-20°F temperature; between 65 and 95 percent relative humidity
0°F temperature; 25, 60, 95 percent relative humidity
+20°F temperature; 25, 60, 95 percent relative humidity

(2) Time Constant. At ambient temperature and 50 percent relative humidity, change the dewpoint +5°F (within one minute), and then -5°F (within one minute). In each case, the time constant shall be less than 2 minutes.

(3) Power Interruption. At ambient temperature and 90 percent relative humidity with the sensor operating normally, disconnect the power from the sensor for a period of one hour. Power shall then be reapplied, and the sensor shall return to normal operation and accuracy within 30 minutes.

22. PRESSURE SENSOR.

a. Design. Two pressure sensors shall be provided for each AWOS system. The pressure sensors shall have provisions for venting to the outside of the building where required. Pressure variations due to airflow over the venting interface shall be avoided. The venting interface shall be designed to avoid and damp pressure variation and oscillation due to "pumping" or "breathing" of the pressure sensor, venting, and porting equipment. Each sensor shall have an independent venting interface (from separate outside vents through dedicated piping to the sensors). Means shall be provided to avoid insect nesting and moisture entrapment in the venting interface.

b. Performance Standards.

(1) Altitude Ranges. High pressure shall be standard atmospheric pressure at -100 feet plus 1.5 inHg (30.65 + 1.5 = 31.565 inHg). Low pressure shall be standard atmospheric pressure at +10,000 feet minus 3.0 inHg (20.58 - 3.00 = 17.58 inHg).

(2) Pressure Range. The sensor shall be capable of measuring a pressure range at any fixed location (station) of +1.5 to -3.0 inHg from the standard atmospheric pressure at that location. Pressure sensors shall have a provision for setting the sensor to the station elevation to the nearest 1 foot over the range of -100 feet to +10,000 feet.

(3) Accuracy. The accuracy shall be 0.01 inHg RMSE at all altitudes from -100 to +10,000 feet mean sea level (MSL), maximum error 0.02 inHg at any one pressure.

(4) Resolution. The resolution shall not be greater than 0.005 inHg.

(5) Differential Accuracy. The sensor shall exhibit an average differential accuracy of 0.01 inHg or less between a series of two pressure measurements taken from the same sensor 3 hours apart. Ambient temperature over this 3-hour period shall not change more than 5°F; ambient pressure shall not vary more than 0.1 inHg (RMSE) over the 3-hour period.

(6) Maximum Drift With Time. Each sensor shall be stable and continuously accurate within 0.01 inHg RMSE for a period of not less than 6 months. The maximum error shall be 0.02 inHg.

c. Performance Tests.

(1) Accuracy. Both pressure sensors shall successfully complete the following accuracy test. A calibrated barometer or transfer standard with an accuracy of at least 0.003 inHg that is traceable to the National Bureau of Standards shall be used as a standard during testing. Two test cycles shall be performed on each pressure sensor. One test cycle consists of running the sensor through the full pressure range at each of the three ambient temperatures. Before taking measurements, allow sufficient time for the sensor to achieve steady state at each data point (not to exceed 5 minutes). The RMSE shall be within the specified limits.

(i) Pressure Range. The pressure sensors shall be tested through the full range of performance (normally 17.5 to 32.0 inHg) in 1 inHg increments of both increasing and decreasing pressure. Partial range (4.5 inHg) pressure sensors shall be tested by setting the sensor to a pressure altitude from zero to 10,000 feet in 500 foot increments. The sensor will be tested from minus 3.0 inHg to +1.5 inHg at 0.5 inHg increments at each pressure altitude.

(ii) Temperature Range. The sensor shall be tested at ambient (approximately +85°F), and at the hot and cold extremes called for in the environmental requirements.

(2) Differential Accuracy. Differential accuracy (change in accuracy) of the pressure sensor shall be tested at ambient temperature (approximately 85°F) and ambient barometric pressure.

(i) Take 14 measurements of pressure on the pressure sensor under test and 14 measurements of pressure on the reference barometer. These measurements should be taken about 5 seconds apart, and all 14 measurements shall be completed within 90 seconds. This time shall be called t=0.

(ii) Repeat the 14 measurements on the pressure sensor under test and 14 measurements of pressure on the reference barometer after an elapsed time of 3 hours. The ambient temperature shall have changed less than 5°F, and the ambient pressure shall have changed not more than 0.1 inHg. This time shall be called t=3.

(iii) Compute the average reading of the reference barometer at t=0. Compute the average reading of the reference barometer at t=3. Determine the difference in the two averages. If the difference is greater than 0.1 inHg, or if the average difference between the reference and the test barometer at either t=0 or t=3 is greater than 0.02 inHg, repeat steps (i) and (ii).

(iv) Compute the 14 errors in reading between the sensor and reference barometer at t=0.

(v) Compute the 14 errors in reading between the sensor and reference barometer at t=3.

(vi) Subtract the 14 t=0 errors from the 14 t=3 errors determined in steps (iv) and (v). Preserve the order of subtraction such that the first t-0 error is subtracted from the first t-3 error. These differences are the changes in accuracy (the differential accuracy).

(vii) Compute the average and standard deviation of the 14 changes in accuracy determined in step (vi). The average differential accuracy shall be no greater than 0.010 inHg. The standard deviation shall be less than 0.003 inHg.

(3) Resolution. The manufacturer shall demonstrate that the resolution is not greater than ±0.005 inHg.

(4) Drift Over Time. Testing shall be done to determine maximum drift [paragraph 22b(6)] over a 6-month period.

23. CLOUD HEIGHT SENSOR.

a. General. The cloud height sensor shall have a design range of 12,500 feet, or greater. The sensor shall provide an output representative of the sky conditions when surface visibilities are equal to or greater than ¼ mile. Sensors shall comply with the performance standards throughout their design range.

b. Performance Standards. The sensor shall detect the height of atmospheric phenomena (i.e., clouds and obscuring phenomena aloft) or, in the event the phenomena are surface based (e.g., fog), provide an estimate of the contact height (CH) or vertical visibility (VV). CH is defined as the vertical height above ground at which visual reference to recognized lights or objects on the surface can be established sufficiently to permit visual determination of the ground plane and position. VV is defined as the vertical distance that an observer can see vertically into surface-based obscuring phenomena (e.g., dust, fog, sand, etc.), or the height corresponding to the upper limit of the return of the ceilometer signal, or the height corresponding to the height at which a balloon would completely disappear during the presence of surface-based phenomena (i.e., an obscured sky). The sensor shall have the capability of discriminating between a negative response (i.e., no hit), resulting from no phenomena within the sensor's design range, and a sensor error/fault. The sensor shall not indicate a response (i.e., hit) that is not the result of the detection of atmospheric phenomena.

(1) Range. The sensor shall measure cloud heights and the heights of obscuring phenomena aloft to a minimum of 12,500 feet.

(2) Accuracy. Under laboratory conditions, the sensor shall provide an accuracy of 100 feet or five percent, whichever is greater.

(3) Resolution. Not greater than: 50 feet surface to 5,500 feet; 250 feet from 5,501 to 10,000 feet; 500 feet above 10,000 feet.

(4) Detection Performance. The sensor shall perform within the limits specified in paragraphs 23c(2) and 23c(3).

(5) Sampling. The sensor shall provide an output at least once every 30 seconds. However, to extend sensor life, this sampling rate may be reduced to provide at least one sample every 3 minutes when no cloud, obscuring phenomena aloft, or CH/VV values (i.e., hits) are detected for the preceding 15 minutes.

(6) Eye Safety. The cloud height sensor shall be designed to conform to ANSI-Z 136.1, Accessible Emission Limits for Laser Radiation, with Class 3b maximum accessible emission level applied to direct viewing without optical instruments (excluding ordinary eye glasses). This document may be obtained from the American National Standards Institute, 1430 Broadway, New York, New York, 10018. (An) interlock device(s) in the laser power circuit shall be provided to disable the laser when any doors are open or the cover is removed to prevent inadvertent exposure of the laser emission to the eyes of the technician or others. The interlock(s) may have a manual override in order that power can be purposely restored during maintenance.

(7) Laser Power Stability. The sensor shall contain a self-check, self adjusting feature that will maintain laser output power at the level necessary to sustain sensor detection and accuracy. When this adjustment can no longer provide the compensation necessary to maintain the sensor within specified operational limits, sensor operation shall be terminated.

(8) Optics Contamination. An air blower or other device shall be used to reduce the contamination of the sensor optics. A signal shall be generated to indicate the amount of optics contamination, thereby indicating the need for optics cleaning.

(i) Snow. The ceilometer window shall demonstrate an ability to remain clear of snow under the condition of snow accumulating at a rate of 2 inches per hour for one hour at a temperature of 20°F.

(ii) Ice. The window shall remain clear of ice for 60 minutes under conditions of freezing rain with a maximum accretion rate of 1/2 inch per hour radial thickness of clear ice.

c. Performance Testing.

(1) Accuracy Test. The signal shall be projected horizontally to a target at known distances (two distances, separated by at least 1,000 feet, from 100 to 5,500 feet, two distances, separated by at least 1,000 feet, from 5,600 to 10,000 feet, and one distance beyond 10,000 feet). All range points

will be within the accuracies specified in paragraph 23b(2). This test is a laboratory test, conducted at full rated power output. It is not intended to be duplicated when the AWOS is installed in the field.

(2) Detection Tests Under Uniform Sky Conditions.

(i) Test Conditions. The sensor shall be tested under the following conditions:

Group A. Visibility greater than 3 miles, with a minimum of 10 percent of the data sets in each subgroup (table 1) collected with light precipitation (rain and snow) occurring, and a minimum of 10 percent with moderate precipitation (rain and snow) occurring.

Table 1. Group A Test Conditions

Subgroup	Cloud Height (feet)
1	100-700
2	800-1500
3	1600-3000
4	3100-5500
5	5600-12500

Group B. Visibility equal to or less than 3 miles, but equal to or greater than 1 mile, with a minimum of 10 percent of the data sets in each subgroup (table 2) with light precipitation (rain and snow) occurring, and a minimum of 10 percent with moderate precipitation (rain and snow) occurring.

Table 2. Group B Test Conditions

Subgroup	Cloud Height (feet)
1	100-700
2	800-1500
3	1600-3000
4	3100-5500
5	5600-12500

Group C. Visibility equal to or greater than 1/4, but less than 1 mile, with a minimum of 10 percent of the data sets in each subgroup (table 3) collected with light precipitation (rain and snow) occurring, and a minimum of 10 percent with moderate precipitation (rain and snow) occurring.

Table 3. Group C Test Conditions

Subgroup	Cloud Height (feet)
1	100-700
2	800-1500
3	1600-3000
4	3100-5500
5	5600-12500

Group D. Not more than 3/10 total sky coverage with the lowest cloud layer at 20,000 feet or higher under the visibility conditions in table 4, with a maximum of 80 percent of the data in each subgroup collected under daytime conditions.

Table 4. Group D Test Conditions

Subgroup	Visibility (miles)
1	Equal to or greater than 1, but less than 3
2	Equal to or greater than 3, but less than 7
3	Equal to or greater than 7

(ii) Collection of Test Data.

A. A minimum of 25 data sets shall be collected for each subgroup in Groups A through C (i.e., a minimum of 125 data sets shall be collected under each group). However, if weather conditions at the test site over a period of one year make collection of at least 25 data sets in every subgroup impossible, the FAA will consider approval of a lesser number of data sets in the affected subgroups, after analysis of available data. Further, for test data to be acceptable, a continuous test period shall be selected to allow for collection of representative data.

Also, it must be clear that all data collected during the test period were considered. Any data not used shall be explained. For example, if data analysis in a subgroup is truncated after 25 data sets are analyzed, this fact shall be documented and explained.

One data set is defined as the second 10-minute period during which a uniform cloud or obscuration is detected by a rotating beam ceilometer (RBC) or is determined by a qualified weather observer. In order to be classified as a uniform cloud or obscuration, the RBC must continuously measure, or a qualified weather observer shall determine, a cloud, obscuration aloft or vertical visibility height (for a 30-minute period) that does not vary from its mean height more than the variance shown in table 5 more than 5 percent of the time.

B. A minimum of 25 data sets shall be collected for each subgroup under Group D. One data set is defined as the second 10-minute period of any consecutive 30-minute period during which the cloud/sky coverage/visibility conditions specified for group D are met.

Table 5. Criteria for Determining Uniform Cloud Layers

Mean Height (as determined by observer or as measured by RBC)	Variance (feet)
Equal to or less than 1,000 ft.	200
Greater than 1,000 ft., but equal to or less than 2,000 ft.	300
Greater than 2,000 ft., but equal to or less than 3,000 ft.	400
Greater than 3,000 ft., but equal to or less than 5,000 ft.	500
Greater than 5,000 ft., but equal to or less than 7,000 ft.	600
Greater than 7,000 ft., but equal to or less than 9,000 ft.	700
Greater than 9,000 ft., but equal to or less than 12,500 ft.	800

(iii) Test Standards.

A. An FAA-approved cloud height indicator whose accuracy is traceable to a National Weather Service approved and calibrated RBC, or observations taken by a qualified weather observer, shall be the standard for determining heights and sky conditions.

B. An FAA-approved visibility sensor whose accuracy is traceable to an FAA standard shall be the standard for determining visibilities.

C. Liquid precipitation measurements shall be made using an FAA-approved 0.01 inch per tip tipping bucket precipitation gage. Light precipitation is defined as one, but not more than two buckets tips in a 10-minute period. Moderate precipitation is defined as more than two, but not more than five tips in a 10-minute period. Heavy precipitation is defined as more than five tips in a 10-minute period. The intensity of frozen precipitation shall be determined by a qualified weather observer.

(iv) Criteria for Acceptance Under Uniform Sky Conditions.

A. Groups A, B, and C conditions. The mean height of the cloud, obscuration aloft, or vertical visibility (measured by the RBC or determined by a qualified weather observer) shall be determined for each data set. The variance for each cloud, obscuration aloft, and CH/VV height (i.e., hit) detected by the candidate sensor in each data set shall be computed. Eighty-eight percent of the data sets within a subgroup (e.g., 22 out of 25 minimum) shall satisfy the following condition: 90 percent of the heights determined by the candidate sensor in each data set shall agree with the mean height measured by the RBC or determined by a qualified weather observer within the variance limits as shown in table 6. Negative responses, i.e., no hits by the candidate sensor, shall be included as data points and considered to be outside the variance limits. Also, the no-hit percentage in each subgroup shall not exceed 5 percent. The candidate sensor will successfully demonstrate the conditions in table 6 for each subgroup to pass this test. Failure of any subgroup constitutes failure of the test.

B. Group D conditions. Not more than one false hit per data set in each subgroup. More than one false hit per data set shall constitute failure of the test.

(3) Detection Tests Under Ragged Overcast or Obscured Sky Conditions.

(a) Heights (cloud/obscuration aloft or CH/VV) measured by the candidate sensor shall be compared with heights measured by the RBC or determined by a qualified weather observer during ragged overcast or obscured sky conditions. Valid data shall be that collected during overcast or obscured sky conditions below 12,500 feet as verified by an RBC hit percentage of 95 percent or more, or as determined by a qualified weather observer, during a 20-minute period. Negative responses, i.e., no hits, shall be included as data points and considered to be outside the variance limits. Calculate the percent of heights (i.e., hits) by the candidate sensor falling within the ranges in subparagraph (ii), under each of the conditions specified in subparagraph (iv), with allowable height variances as specified as in subparagraph 23c(2)(iv)(A). Data shall be collected under as many of the conditions as possible; however the FAA may accept less than the specified requirement after evaluation of the available data. For test data to be accepted, a continuous test period shall be selected to allow for

Table 6. Criteria To Satisfy Groups A, B, and C Conditions

Mean Height (as determined by observer, or as measured by RBC)	Variance (feet), for cloud and obscuration aloft heights (feet)	Variance for CH/VV values(feet)
Equal to or less than 1,000 ft.	200	400
Greater than 1,000 ft., but equal to or less than 2,000 ft.	300	600
Greater than 2,000 ft., but equal to or less than 3,000 ft.	400	800
Greater than 3,000 ft., but equal to or less than 5,000 ft.	500	1000
Greater than 5,000 ft., but equal to or less than 7,000 ft.	600	1200
Greater than 7,000 ft., but equal to or less than 9,000 ft.	700	1400
Greater than 9,000 ft., but equal to or less than 12,500 ft.	800	1600

representative data collection. It will also be clear that all data collected during the test period were considered. Any data not used shall be explained.

(ii) Height ranges (as determined by RBC or qualified observer)

A. 100- 700 feet

B. 800-1,500 feet

C. 1,600-3,000 feet

D. 3,100-5,500 feet

E. 5,600-12,500 feet

(iii) Conditions:

A. No precipitation. Visibilities ¼ to 1 mile, 1 to 3 miles, and greater than 3 miles.

B. Light or moderate precipitation (rain and snow). Visibilities ¼ to 1 mile, 1 to 3 miles, and greater than 3 miles.

C. Heavy precipitation (rain and snow). Visibilities ¼ to 1 mile, 1 to 3 miles, and greater than 3 miles.

(iv) A minimum of 90 percent weighted average of the hits by the candidate sensor shall fall within the range of the RBC or within the height range determined by a qualified weather observer. Also, the weighted negative response, (i.e., no hit) percentage shall not exceed 5 percent.

24. VISIBILITY SENSOR.

a. Performance Standards.

(1) Range. The visibility sensor shall be capable of determining visibilities from less than ¼ mile to 10 miles. A method of calibration traceable to the FAA approved standards in paragraph 24b shall be provided.

(2) Resolution. In terms of equivalent visibility, the sensor shall provide data to report visibility values as follows (in statute miles): less than ¼, ¼, ½, 3/4, 1, 1-¼, 1-½, 2, 2-½, 3, 3-½, 4, 5, 7, and 10 miles.

(3) Time Constant. The time constant shall not exceed 3 minutes.

(4) Accuracy. The sensor shall agree with the transmissometer standards as follows:

Table 7. Visibility Sensor Accuracy Requirement.
(All values in statute miles)

Reference Transmissometer Reading	Acceptable Sensor Variance
¼ through 1-¼	± ¼
1-½ through 1-3/4	+ ¼, -½
2 through 2-½	± ½
3 through 3-½	+ ½, -1
4, and greater than 4	± 1

(5) Ambient Light Sensor. The visibility sensor shall contain an ambient light sensor (i.e., a photocell) to measure the ambient luminance within its field of view, and to generate a signal to the visibility sensor to indicate whether the ambient light level is day or night. It shall indicate day for increasing illumination between 0.5 and 3 footcandles (FC), and night for decreasing illumination between 3 and 0.5 FC. This sensor may be exposed to ambient light levels as high as 50 FC.

b. FAA Approved Visibility Standards. The high visibility reference standard shall be a visible light transmissometer(s) that uses a narrow band of light centered at 0.55 microns (95 percent of the response within ±3 microns of 0.55 microns) for visibility ranges to an extinction coefficient of 1 $mile^{-1}$. At higher extinction coefficients, an FAA approved transmissometer(s) that radiates in the infrared spectrum shall be used as a standard. Comparisons with scatter-type instruments (different from those being tested) may be used to correct for small drifts in reference standard calibration.

c. Performance Tests. The visibility sensor shall be tested using FAA approved transmissometers as the reference standard.

(1) Accuracy Testing.

(i) At least 2 months of accuracy test data shall be accumulated, assuring that a representative number of valid test points are experienced at each of the reporting increments [par 24a(2)] and under conditions of both with and without precipitation. All data collected during the test shall be included in the test report. Any samples not included in determining the candidate sensor's accuracy shall be fully explained. The test data shall consist of a number of independent samples of 10 minutes each, with at least 5 minutes between each sample. Samples shall consist of visibilities from less than ¼ mile to greater than 10 miles, and shall be weighted in the following ratio:

70 percent without precipitation (i.e, with fog; under clear conditions; and with approximately 5 percent of the data points collected under summer haze conditions)

30 percent with precipitation (e.g., 15 percent with rain, 15 percent with snow)

(ii) Eighty percent (overall weighted average) of the total of all sensor test data points shall agree with the transmissometer standard within the allowed variances from less than ¼ through 5 miles.

(iii) Eighty percent of the sensor test samples that are obtained when the transmissometer reads greater than 5 miles shall be 5 miles or greater.

(2) Time Constant Demonstration. Under conditions of 10-mile visibility, a technique shall be used to reduce the sensor detector output to one mile or less. After the restriction is applied, the time constant shall be measured to reflect the reduction of visibility. After a period of 10 minutes, the artificial restriction to visibility shall be removed, and the sensor time constant shall be measured to reflect the increase in visibility. The time constant shall be equal to or less than 3 minutes.

(3) Ambient Light Sensor Testing. The manufacturer shall demonstrate that the ambient light sensor complies with paragraph 24a(5).

25. PRECIPITATION OCCURRENCE AND ACCUMULATION SENSOR(S). The term "precipitation" is defined as including all forms, i.e., liquid, freezing, frozen, or combinations thereof. The term "precipitation amount" is the liquid or liquid equivalent amount. The precipitation sensor provides an indication of precipitation occurrence and measures the precipitation amount. The sensor(s) may be designed as a single or separate unit.

a. Performance Standards.

(1) Precipitation Occurrence Sensor. The sensor shall detect the occurrence of precipitation as specified. It shall not "false alarm" on other moisture sources such as dew and frost.

(i) Precipitation Onset. The sensor shall detect the onset of precipitation 95 percent of the time as follows:

A. With the precipitation rate of 0.11 inches per hour or more, the sensor shall detect the onset of precipitation within one minute.

B. With precipitation rates of 0.05 to 0.10 inches per hour, the sensor shall detect the onset of precipitation within 2 minutes.

C. With precipitation rates of 0.01 to 0.04 inches per hour, the sensor shall detect the onset of precipitation within 5 minutes.

D. With a precipitation rate of less than 0.01, but equal to or greater than 0.0005 inches per hour, the goal shall be the detection of the onset of precipitation within 10 minutes.

(ii) Precipitation Cessation. The sensor shall detect the cessation of precipitation within 5 minutes 95 percent of the time.

(2) Precipitation (Liquid Equivalent) Accumulation. The sensor shall be capable of measuring the precipitation amount with a range of 0.01 to 5 inches per hour, with a resolution of 0.01 inches and an accuracy of 0.02 inches per hour (RMSE) or 4 percent of actual (which ever is greater).

b. Performance Testing. The manufacturer shall conduct a test program to demonstrate that the precipitation occurrence and accumulation sensor(s) meet the performance requirements under the environmental conditions found in paragraph 18.

26. Precipitation Type Sensor. The term "precipitation type" as used herein includes the following: rain, drizzle, snow, ice pellets, and hail. The precipitation type sensor shall provide an indication of the type of precipitation occurring, or shall output "precipitation" for any precipitation (liquid, freezing, frozen, or combinations thereof) when a type cannot be identified. However, recognizing that the sensor technology is not yet available to identify ice pellets and hail, a precipitation type sensor may qualify by identifying only rain, drizzle and snow, while outputting "precipitation" for those types not identified. The sensor unit may be designed as a separate unit, or may be combined with the requirements of other parts of this AC (e.g., paragraph 24) so that one unit fulfills the requirements of two or more paragraphs.

a. The sensor shall identify the type of precipitation when the rate of precipitation equals or exceeds 0.01 inch per hour, with the goals for accuracy as follows:

(1) Within the temperature range of:

(i) +28°F to +38°F, identify precipitation type correctly as:

A. Rain: 90 percent of the cases.

B. Drizzle: 80 percent of the cases.

C. Snow: 90 percent of the cases.

D. Ice pellets (optional): 50 percent of the cases.

(ii) Less than +28°F. Identify precipitation type correctly as snow in 99 percent of the cases.

(iii) Greater than +38°F, identify precipitation type correctly as:

A. Rain: 99 percent of the cases.

B. Drizzle: 90 percent of the cases.

C. Hail (optional): 90 percent of the cases.

(2) Priority: Only one precipitation type shall be reported, with a the reporting priority established in subparagraphs A through F.

A. Hail.

B. Ice pellets.

C. Snow.

D. Rain.

E. Drizzle.

F. Precipitation, no type defined.

b. <u>Performance Tests</u>. The manufacturer shall conduct a test program to demonstrate that the sensor satisfies the performance standards, under the environmental conditions in paragraph 18. As a minimum, the following test conditions shall be satisfied:

(1) Prior to testing, the AWOS manufacturer shall develop and submit a test plan to the FAA for approval to the address shown at the front of this AC. The test plan shall clearly outline the tests to be performed; it shall define the capabilities of the sensor to be tested, and shall include a detailed description of the test procedures. It shall contain a clear statement of pass/fail criteria. The test plan shall identify the location(s) and the proposed time planned for the tests. All data collected during the test shall be incorporated into the test report. Any data not included in determining the candidate sensor's compliance with the requirements of this circular shall be fully explained.

(2) The test shall be conducted in two phases. One phase shall be conducted in a test chamber with varying conditions simulated to generate drizzle, rain, snow, hail, and ice pellets. At least 15 events (at various rates of accumulation) shall be simulated for each of these conditions to demonstrate the above requirements, and the results shall be included in the test report.

(3) The second phase of the test shall be conducted at a location(s) and during the times when there is a propensity for drizzle, rain, snow, hail, and ice pellets, and where there is a qualified weather observer on duty. The test report shall compare the performance of the sensor under test with the log maintained by the official observer at the test location.

27. <u>Thunderstorm Detection Sensor or Network</u>. This stand-alone sensor or thunderstorm detection network shall detect the presence of a thunderstorm in the vicinity of an airport, shall locate the thunderstorm, and shall provide this data in such a form that the information can be incorporated into the AWOS voice and data weather message.

a. Performance Standards.

(1) Range. Thunderstorms within 30 nautical miles (nm) of the reference point on the airport shall be reported.

(2) Resolution. The thunderstorm location shall be defined within:

(i) One nm of the location defined by the latitude and longitude (to the nearest minute) of the actual location of the thunderstorm; or

(ii) From the reference point, one nm range and one degree in bearing of the actual location of the thunderstorm.

(3) Accuracy.

(i) The standard detects strikes within 10 nm of the reference point:

A. Detection Accuracy. Ninety percent of all thunderstorms identified and located within this area by the thunderstorm sensor/network standards shall have been detected by the thunderstorm sensor/network under test.

B. Location Accuracy. The distance from each thunderstorm located by the sensor standard within 10 nm of the reference point, and the corresponding thunderstorm located by the sensor/network under test, shall be computed. The RMSE of these distances accumulated during the test period shall not exceed 3 nm (5 km).

(ii) The standard detects strikes between 10 nm and 30 nm of the reference point:

A. Detection Accuracy. Eighty percent of all thunderstorms identified and located within this area by the thunderstorm sensor/network standards shall have been detected by the thunderstorm sensor/network under test.

B. Location Accuracy. The distance from each thunderstorm located by the sensor standard between 10 nm and 30 nm of the reference point, and the corresponding thunderstorm located by the sensor/network under test, shall be computed. The RMSE of these distances accumulated during the test period shall not exceed 6 nm (10 km).

(4) False Reports. Not more than two percent of all thunderstorms reported by the sensor under test shall have been caused by sources other than a naturally occurring thunderstorm.

(5) Sensor/System Reporting to the AWOS.

(i) The thunderstorm sensor/network shall provide an updated output to the AWOS at least every minute.

(ii) The thunderstorm sensor/network shall update the AWOS once each minute.

c. Performance Tests. The manufacturer shall conduct a test program to demonstrate that the thunderstorm sensor/network meets the performance standards under the environmental conditions identified in paragraph 18.

(1) Prior to Testing. The AWOS manufacturer shall develop and submit a test plan to the FAA for approval at the address shown at the front of this AC. The test plan shall outline the tests to be performed; it shall clearly define the capabilities of the sensor/network to be tested, and shall include a detailed description of, and the capabilities of, the method that will be used to prove that the sensor is performing in accordance with the performance standards (par 27a). It shall define the criteria necessary for the standard(s), as well as the sensor/network under test, to recognize a thunderstorm. A clear statement of pass/fail criteria shall be included. If the sensor/network proposed will only detect cloud-to-ground lightning, or if it will detect other evidence of a thunderstorm, this fact will be clearly identified. The test plan shall identify the locations and the proposed time planned for the tests.

(2) Duration of the Test. The test shall be conducted in at least two locations (i.e., reference points) where there is a propensity for thunderstorms. It shall encompass a sufficient period of time to accomplish the following minimum detection/location events to prove that the sensor/network under test conforms with the requirements of this circular. A thunderstorm day is a day during which thunderstorm data are accumulated from the standard(s) and the sensor/network under test.

(i) Summer Environment. Thunderstorms shall have been detected during at least 25 thunderstorm days during the summer months at a location where there is a high level of thunderstorms generated by summertime convection activity. It is desirable that at least 100 thunderstorms (i.e., cells) shall have been detected and located by the standard(s) during the summer test.

(ii) Winter Environment. Thunderstorms shall have been detected during at least 10 thunderstorm days during the months of November through February at a cold weather location where there is a propensity for thunderstorms associated with mid-latitude winter storms. It is desirable that at least 20 thunderstorms (i.e., cells) shall have been detected and located by the standard(s) during the winter test.

(3) Thunderstorm Detection Standards. All means available within the test area to identify and locate thunderstorms shall be used. These "standards" shall include:

(i) Qualified Weather Observer(s). Qualified weather observers shall be used to identify and locate thunderstorms within the vicinity of the reference point. The observer shall identify a thunderstorm in accordance with the criteria in FMH-1. The time and the estimated location (bearing and distance) shall be logged when identifying the existence (beginning time) of a thunderstorm. Once a thunderstorm has been identified, observations shall be recorded every 10 minutes. The ending time of the thunderstorm shall be identified. The results of these observations shall be plotted on a grid of approximately 3 nm squares, with the reference point in the center, and an area encompassing a circle with a radius of 10 nm. The scale of this plot shall be the same as the scale of the radar echo plot. A plot shall be made every 10 minutes. All plots for these tests (e.g., observer, radar, network, system/network under test) shall be based upon the same time periods (e.g., beginning on the same minute).

(ii) Weather Radar. Weather radar may be used to identify and locate thunderstorms within the area under test. The radar antenna shall be located within 30 miles of the reference point. Level three and greater intensity radar echoes shall, by themselves, constitute the detection of a thunderstorm. Level two radar echoes, when correlated with another standard observation of a thunderstorm, or with a report from the sensor/network under test, shall constitute detection of a thunderstorm. However, if the sensor/network under test does not recognize a level two radar echo as a thunderstorm, and the level two echo is the only evidence of a thunderstorm, a thunderstorm shall not be assumed to be present. Plots of the area under test from the radar screen shall be made every 10 minutes, and shall depict levels two through six radar echoes. Plots shall be made on a grid of approximately 3 nm squares, with the reference point as the center. The highest intensity level shall be marked in each grid square.

(iii) Thunderstorm Network(s) as a Reference Standard. Network(s) may be used to identify and locate thunderstorms. Thunderstorms identified and located by a thunderstorm sensor network shall be plotted on a grid identical to the grid used for the radar echo plot (i.e., approximately 3 nm squares on a 30 nm radius circle, with the reference point as the center). Plots shall be made of the area under test every 10 minutes.

(iv) Secondary Reference Systems. The use of secondary reference systems shall be fully defined in the test plan.

(4) Execution of the Test. After the FAA has approved the test plan, the manufacturer shall perform the test in accordance with the test plan. All data collected during the test shall be included in the test results. Any data omitted from the results shall be fully explained. Thunderstorms identified and located by the thunderstorm sensor/network under test shall be

plotted on a grid identical to the grid used for the radar echo plot (i.e., approximately 3 nm squares on a 30 nm radius circle, with the reference point as the center). Plots shall be made of the area under test every 10 minutes. The test plan shall establish the criteria for the system under test, as well as all of the sensor/network standards, to be operational. As a minimum, in order for a thunderstorm day to be counted in the test results, a qualified weather observer must take observations, and the weather radar must be operational when testing.

(5) Test Report. A report shall be prepared and submitted to the FAA by the AWOS manufacturer in accordance with the requirements of this AC in order to obtain certification of their AWOS with a thunderstorm detection, location and reporting capability. Data obtained during this test shall be analyzed as follows:

(i) Within 10 nm of the reference point. The grid plots obtained from the sensor under test shall be matched with the grid plots obtained from the standards (qualified weather observer, the weather radar, thunderstorm sensor network, etc.), for each 10 minute increment. Thunderstorm occurrences shall be matched as previously described (e.g., paragraphs 27c(3)(ii) and 27c(4)), and anomalies explained.

A. The number of test sensor/network identifications shall be compared with the number of thunderstorms identified by the standards. The percentage detection accuracy shall be computed and compared with the requirement in paragraph 27b(3)(i)A.

B. The number of test sensor/network identifications that are in the same or an adjacent 3 nm grid square as the thunderstorm identified by the observer/sensor/network standard shall compared with the number of thunderstorms identified by the standards. The percentage location accuracy shall be computed and compared with the requirement in paragraph 27b(3)(i)B.

(ii) Between 10 nm and 30 nm of the reference point. The grid plots obtained from the sensor under test shall be matched with the grid plots obtained from the standards (qualified weather observer, the weather radar, thunderstorm sensor network, etc.), for each 10-minute increment. Thunderstorm occurrences shall be matched and anomalies explained.

A. The number of test sensor/network identifications shall be compared with the number of thunderstorms identified by the standards. The percentage detection accuracy shall be computed and compared with the requirement in paragraph 27b(3)(ii)A.

B. The number of test sensor/network thunderstorm identifications shall be counted that are in the same, an adjacent, or in a grid square separated by one square from the 3 nm grid square where an observer/sensor/network standard located a thunderstorm. This number shall be compared with the number of thunderstorms identified by the standards. The percentage location accuracy shall be computed and compared with the requirement in paragraph 27b(3)(ii)B.

(iii) The number of thunderstorms identified by the sensor/network under test that cannot be matched with a thunderstorm identified by the standards (i.e., false signals) shall be counted and compared with the total number of thunderstorms identified by the standards. The percentage of false signals shall not be greater than the percentage identified in paragraph 27b(4).

(6) Basis of the reporting algorithm. The AWOS sensor/system shall locate and report a thunderstorm within one of ten areas of a circle with the reference point as the center and a radius of 30 nm, as follows:

Within a circle with a radius of 5 nm, with the reference point at the center.

Within the circular area between 5 nm and 10 nm from the reference point.

Within one of eight 45 degree clockwise sectors of the circular area between 10 nm and 30 nm from the reference point, beginning with the 22.5 degree radial from the reference point.

(7) AWOS Report of a Thunderstorm. The AWOS voice and data report shall be in accordance with the latest Government furnished algorithm. This algorithm processes lightning strike data through a 15-minute moving window, i.e., each strike is expired 15 minutes after it is received. With certain exceptions, the algorithm will report a thunderstorm when two lightning strikes have been received within the 30 mile radius circle within 15 minutes.

Within the 5 nm radius, the report is "at the airport."

Between 5 and 10 nm of the airport, the report is "in the vicinity of the airport."

Between 10 and 30 nm of the airport, the thunderstorm is reported using the appropriate sector designation. For example, "THUNDERSTORM NORTHEAST"; "THUNDERSTORM SOUTHWEST AND NORTH"; THUNDERSTORM EAST THROUGH SOUTH"; or "THUNDERSTORM ALL QUADRANTS."

When no activity is detected within the area, no report will be voiced.

If the thunderstorm sensor/system is inoperative, the message shall be "THUNDERSTORM DETECTION INOPERATIVE."

28. Freezing Rain Occurrence Sensor. This sensor shall be capable of detecting the occurrence of freezing rain.

a. Performance Standards. Freezing rain shall be reported when a minimum 0.01 inch radial thickness freezing rain has accumulated.

b. Accuracy.

(1) The sensor shall correctly detect the occurrence of freezing rain 95 percent of the time.

(2) The sensor shall not false alarm on frost. The sensor false alarm rate shall not exceed 0.1 percent when there is rain at temperatures above 40°F, or when there is no precipitation. During snow, the false alarm rate shall not exceed 1 percent.

c. Performance Tests. The manufacturer shall conduct a test program to demonstrate that the sensor meets the performance standards under the environmental conditions identified in paragraph 18. As a minimum, the following test conditions shall be satisfied:

(1) Prior to testing, the AWOS manufacturer shall develop and submit a test plan for approval to the FAA at the address shown at the front of this AC. The test plan should clearly outline the tests to be performed; it should define the capabilities of the sensor to be tested, and should include a detailed description of the test procedures. It should contain a clear statement of pass/fail criteria. The test plan should identify the location(s) and the proposed time planned for the tests. All data collected during the test should be incorporated into the test report. Any data not included in determining the candidate sensor's compliance with the requirements of this circular shall be fully explained.

(2) The test shall be conducted in two phases. One phase shall be conducted in a test chamber with varying conditions simulated to generate freezing rain. At least 25 freezing rain events, at various accumulation rates beginning at 0.01 inch per hour, shall be simulated to demonstrate the requirements in paragraph 28b(1), and the results shall be included in the test report. Additionally, at least 10 snow events (at temperatures of 28°F or less) and 10 rain events (at temperatures of 40°F) shall be conducted (at various accumulation rates) to demonstrate that the sensor does not provide false reports. (If false reports are generated during the tests, additional testing shall be accomplished to demonstrate the requirements in paragraph 28b(2)).

(3) The second phase of the test shall be conducted during the months of November through February at a location where there is a propensity for freezing rain and where there is a qualified weather observer on duty. The test report shall compare the performance of the sensor under test with the log maintained by the official observer at the test location.

29. RUNWAY SURFACE CONDITION SENSOR. This sensor provides real-time information on runway conditions to alert the pilot if the runway is wet or if there are possible icing conditions.

a. Performance Standards. The sensor shall meet the requirements found in chapter 2, paragraph 8a of AC 150/5220-13, Runway Surface Condition Sensor Specification Guide. This AC may be ordered from the Department of Transportation, Utilization and Storage, M443.2, Washington, D.C. 20591. The sensor shall be capable of detecting three runway conditions: dry runway (no perceptible moisture), wet runway (visible moisture on the surface), and possible freezing conditions (pavement temperature below freezing and moisture present on the surface).

b. Performance Testing.

(1) The testing shall be performed on a sensor installed in a runway or other suitable pavement section which is free from chemicals, rubber build-up, or other contamination. The pavement temperature shall be measured with an infra-red thermometer or other approved method. The sensor shall be accurate within ± 1°F within the temperature band of 25 to 35°F. At least 10 observations shall be made under each of the conditions in subparagraphs (i) through (iii).

(i) Dry Runway. No visible moisture is present on the sensor.

(ii) Wet Runway. The sensor is damp, wet, or flooded, and the temperature is above 32°F.

(iii) Possible Freezing Conditions. The sensor is damp, wet, flooded, covered with ice, or packed snow, while the surface temperature is at or below 32°F.

(2) The sensor shall be operationally tested during an entire winter season. The sensor reports shall be visually verified (with consideration of the effects of wind and any chemicals on the surface) and shall be accurate at least 80 percent of the time in each of the three conditions (i.e., dry, wet, and possible freezing).

30. AWOS DATA PROCESSOR. The four principle functions of the processor are data acceptance, data reduction, data processing, and product dissemination (digital and voice). The processor typically accepts data inputs, performs various data reduction functions, implements the AWOS algorithms, and prepares weather observation reports. The processor shall have the ability to provide a computer generated voice weather observation to a ground-to-air radio (VOR, NDB, VHF discrete, etc.) for transmission to pilots. As an option, this voice message may also be provided to users via an integral automatic telephone answering device.

a. Performance Standards.

(1) Data Reduction. The data reduction function consists of the processing of information prior to the actual algorithm processing. The AWOS data reduction software shall include quality control checks to ensure that the data received is accurate and complete, and that the associated equipment is working properly before the weather algorithms are performed. If data from any sensor is erroneous or missing (e.g., the sensor loses power, etc.), that parameter shall be reported "missing" in the weather observation. The processor shall continue to sample the data, and if the error condition is corrected, the weather parameter shall be reinserted in the AWOS report. As an optional feature, an error indication light may be provided which will be located in an attended location and will be energized when a parameter is reported "missing" by the AWOS. If the examples of data reduction checks given in subparagraphs (i) through (v) are not applicable to a sensor's output, the manufacturer shall propose suitable criteria. Additional criteria are encouraged.

(i) The processor shall periodically check reference or calibration points within the system (e.g., reference voltage; aspirator airflow; sensor heater current, etc.) to monitor system operation.

(ii) The processor may set upper and lower limits on the sensor output which correspond to the normal operating limits of the sensor or to the real-world limits of the site. For example, the temperature sensor may have upper and lower limits of +130°F and -60°F. This is a gross error check that will prevent reporting clouds below ground level, negative wind speeds, etc.

(iii) The processor may set rate-of-change limits on the sensor's output. A rate-of-change limit might be set by determining the maximum acceptable change in temperature or signal characteristics allowable over a given period of time.

(iv) The processor may examine the history of the sensor output to detect sensor problems. As an example, the mean and standard deviation of a sensor measurement may be calculated every hour and compared to established upper and lower limits. If the wind speed sensor has a mean greater than 3 knots but a standard deviation less than 0.5 knot, the sensor has probably malfunctioned. Likewise, the wind direction sensor is probably inoperative if the wind speed is above 5 knots and the standard deviation is less than 1 degree. Other examples of data checks include consistently low wind speeds, unvarying wind speed or direction, lack of visibility of more than 5 miles for long periods, a consistent cloud layer or a lack of clouds for long periods, and so forth.

(v) The processor shall recognize continued static data output, which usually indicates a malfunction. If the sensor output is static for a sustained period of time, the parameter shall be reported as missing. For example, if the anemometer output does not vary for 15 minutes, it would be assumed frozen or otherwise inoperative and wind "missing" would be reported.

(2) Weather Algorithms. The system processor shall implement algorithms provided by the FAA to generate the elements of the weather observation. If the output is to be supplied to the National Weather Network, it shall be in accordance with the appropriate Interface Control Document (ICD) (e.g., AWOS/ADAS ICD). Copies of the ICD's may be obtained from the AWOS program office at the address given in the front of the AC. An observation shall be generated each minute containing the current weather information for all the valid parameters observed by the AWOS.

(3) System Output. The system shall generate the output listed in subparagraph (i), with the other output formats being provided at the manufacturer's option.

(i) Computer generated voice transmitted to pilots over radio (VOR, NDB, discrete frequency, etc.).

(ii) Optional telephone port for dial-up service.

(iii) Optional output port for a video display.

(iv) Optional input/output port for an operator terminal.

(v) Optional output port to the national weather network.

(4) Remote Maintenance Monitoring (RMM). All systems shall include a dial-up input/output port that provides remote access to archived and real time operational (i.e., weather reports) and maintenance data. This port should be used to remotely enable or disable the system, or a specific sensor(s), or to set the clock, etc. The maintenance program should be designed to utilize this RMM capability to effectively and efficiently maintain the proper operation of the AWOS. Monitoring of the system should be performed by a responsible office to regularly review and analyze the archived operational and maintenance data. The monitor shall determine that all system parameters are being correctly reported, and that the real time clock is within the specified tolerance.

(5) Real-Time Clock. Coordinated Universal Time (UTC) shall be a product of the processor. Typically, days, hours, minutes, and seconds are provided as a system output for use in system displays, computer-generated voice output, etc. The day shall be expressed in the Gregorian Calendar. Hours and minutes shall be indicated numerically from 0000 to 2359. The clock function shall be accurate with 15 seconds each month.

(6) Power Outage. The system shall return to normal operation without human intervention after a power outage. The system shall not output erroneous data when power is restored.

(7) Data Archiving. The processor shall retain a record of the automated weather reports, as well as the data entered through the keyboard, for use by accident investigators. The interval between archived reports shall not be more than 20 minutes, and the report shall be retained for at least 96 hours (4 days). A method shall be provided for the retrieval of archived reports using a floppy disk or other permanent record (e.g., a hard copy print out), and the operator shall be able to suspend the updates of the archived weather reports to freeze the data until retrieval may be accomplished.

(8) System Constants. The following system constants shall be either permanently installed in the processor at the factory or placed in a tamper-proof enclosure so that they may not be changed after initial adjustment at the site.

(i). Elevation of the pressure sensors at the installation site MSL.

(ii) Magnetic variation of the intended installation site to the nearest degree.

(iii) AWOS facility identification.

(iv) Algorithm constants to include the pressure reduction ratio or pressure reduction constant.

(v) Alert criteria, including site unique criteria.

b. Performance Testing. System processing validation tests shall be performed in three stages.

(1) A listing of digital data sets will be supplied by the FAA. This data shall be input into the system processor to verify proper operation of the algorithms. Fixed and variable data sets will be provided to exercise the processor over the full range of possible sensor inputs and will include various over-range and abruptly changing data to check the data reduction quality control routines. Smaller data subsets shall be run with the processing unit operating in extreme environmental conditions.

(2) Analog data sets (or digital data sets, if sensor output is digital) corresponding to the digital data in subparagraph (1) shall be input at the sensor input ports to verify accurate and correct operation of the data acquisition process.

(3) Finally, a full complement of actual sensor devices shall be connected to the processor (through the data collection unit if part of the design) and driven by actual or simulated weather conditions to verify accurate and correct operation of the entire AWOS unit. The sensors shall

have passed their individual performance/acceptance tests. Data outputs from the processor shall meet the same standards of accuracy as have been established for the sensors in their individual parts of this document.

31. OPERATOR TERMINAL (OT). The OT is an optional component of the AWOS. It is normally a part of an AWOS installed at a facility with a qualified weather observer. It includes a video display terminal and keyboard as well as a microphone that will permit the manual addition of a voice message to the end of the computer generated voice message.

a. Performance Standards.

(1) Product Augmentation. The product augmentation function allows an authorized observer to initiate or change any observation product. A specific "editing" password shall control access to this function. Manual entries of weather phenomena not automatically observed shall be placed in the remarks section of the observation. In the case of a sensor failure or an incorrect AWOS output, an operator shall have the capability to replace the incorrect parameter value with a missing symbol. An authorized observer shall have the capability to:

(i) Prepare a current observation using the latest updated parameters.

(ii) Prepare corrected observation products, either from scratch or by editing a previously disseminated product still accessible in memory.

(iii) Edit any observation product (before release for dissemination) by override of AWOS parameters, cancellation of AWOS parameters, addition of new data, or cancellation of the entire product.

(iv) Add to the voice message. Typically, the OT should have the capability to manually input a voice message (30 seconds maximum) to the end of the computer-generated voice message when the AWOS is installed at a non-towered airport. However, when installed at a towered airport, the AWOS shall have the capability to manually input a voice message of at least 90 seconds duration to the end of the computer generated message.

(2) Security. If an OT is a part of the AWOS system, it shall be designed to prevent unauthorized persons from entering data into the system. The system shall require the operator to enter a successive series of codes in response to system queries prior to allowing him/her to proceed with the entry of data.

(3) Periodic Data Validation. Where an OT is used to modify the report, all manually entered data shall be automatically time tagged by the system. The data shall be valid until the next hourly or manually input observation. In order to retain the manually entered data in the system, the operator shall be required to revalidate his/her "on-the-hour" observation,

when it must be revalidated. If no data is to be changed, the operator shall be able to accomplish the revalidation using a simple procedure. The data shall then be tagged with a new one-hour limit.

b. Performance Testing. The AWOS manufacturer shall test the OT to demonstrate that the unit performs as follows:

(1) Displays the most current AWOS observation.

(2) Retrieves archived data.

(3) Editing capability, to include rejection of erroneous inputs.

(4) When called for in the system design, provide maintenance diagnostics data and perform maintenance diagnostics.

(5) Adequate AWOS/OT communications security.

(6) Manual voice entry capability.

32. VOICE SUBSYSTEM. The voice subsystem shall provide high quality computer-generated speech for output of the AWOS observation. A high-level error-checking scheme shall be incorporated to prevent erroneous outputs. The voice subsystem will also provide the speech for the local ground-air radio broadcast and for telephone dial-up users. An optional feature is the capability for the addition of a manually input (analog) voice message from the OT at the end of the computer-generated voice message [par 31a(1)(iv)].

a. Performance Standards. The voice subsystem shall have the following features:

(1) The voice output shall be a balanced, low-impedance driver providing a minimum of one milliwatt of power into a 600-ohm line. The output amplitude shall be adjustable to a nominal 0 db output, or a nominal -13 db output.

(2) The voice message shall be output continuously with approximately a 5-second delay between the completion of one message and the beginning of the next.

(3) If the voice message is in process of output when the new AWOS observation is received, the output message will be completed without interruption; voice transmission of the new AWOS observation will begin upon completion of the next delay time.

(4) The quality (clarity and phrasing) of the automated speech shall provide high intelligibility from telephone and ground-air radio transmitters. As a guideline, the FAA Interim Voice Response System (IVRS) provides the quality of synthesized voice acceptable for the AWOS. Information on the IVRS

may be found in Notices to Airmen (Class II), and Airman's Information Manual, Basic Flight Information and ATC Procedures. These documents may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Information may also be obtained by telephoning the IVRS Project Office at (202) 267-8383.

(5) The format and sequence of the voice message shall be in accordance with Order 7110.10, Flight Services Handbook. The document may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. When any weather parameter is reported "MSG" (missing) due to a disabled or inoperative sensor, as determined by internal AWOS checks, the voice report shall be "(parameter) MISSING", e.g., "WIND SPEED MISSING", "CLOUD HEIGHT MISSING," etc. The UTC time of the observation will be given after the location identification.

(6) If the valid data update is not received prior to the start of the next voice transmission, the last valid data set received shall be used to compose the voice message. Failure to receive a data update for more than 5 minutes shall result in the termination of the voice output and generation of a failure message. In this event, the AWOS shall output the message "(station identification) automated weather observing system temporarily inoperative."

(7) As an option, the voice system may contain an automatic telephone answering device that will permit user access to the voice message via the public telephone system. The incoming call shall be answered prior to completion of the second ring, and the audio signal in progress at the time the call is received shall be placed on line. The voice subsystem shall automatically disconnect when the weather observation has been completely transmitted twice. Typically, the telephone answering device should have the capability to answer five calls at a time with no loss of audio signal strength or intelligibility. The minimum requirement is that the system answer a single call.

(8) The voice system shall contain a headset/speaker jack for monitoring the voice output.

(9) The voice quality shall not be degraded when output on a VOR, NDB, or other NAVAID.

b. Performance Testing. As a minimum, the manufacturer shall demonstrate the following voice unit capabilities:

(1) Capability to generate all combinations of words corresponding to possible AWOS output reports.

(2) Detection of communication transmission errors, data loss, and cessation of voice transmission after loss of updates.

(3) Response to dial-up requests for voice data.

(4) If the Operator Terminal is offered as an option, demonstrate the transmission of the manually input voice messages at the end of the AWOS observation.

(5) The frequency response of the computer-generated speech (i.e., voice quality) is compatible with the frequency of the intended transmission medium (i.e., VOR, NDB, VHF radio or telephone).

(6) Tests shall be performed to demonstrate that the quality of the AWOS computer-generated voice is equal to or greater than the IVRS.

33. ELECTROMAGNETIC INTERFERENCE (EMI) PROTECTION. The AWOS is to be designed to minimize susceptibility to EMI and to operate successfully in the complex electromagnetic environment of an airport.

34. TRANSIENT AND LIGHTING PROTECTION. AWOS equipment shall be protected against damage or operational upset due to lighting-induced surges on all sensor input lines, sensor supply lines, and incoming power and data communications lines. Equipment (including electrical circuits of fiber optics modems) and personnel shall be protected from lighting currents and voltages, from power line transients and surges, and from other electromagnetic fields and charges. Lighting protection systems shall be designed and installed in accordance with this AC and the Lighting Protection Code, NFPA 78, for all equipment and structures. This publication may be obtained from the National Fire Protection Association, Inc., 470 Atlantic Avenue, Boston, MA 02210.

a. General.

(1) Cone of Protection. All equipments, including antennas, sensors, and obstruction lights that are tower mounted, shall be within a maximum 45 degrees cone of protection provided by an air terminal. The air terminal shall be connected to the earth electrode grounding system. The structure of steel towers may serve the function of down conductors, provided the air terminal and grounding cable connections are made as defined herein.

(2) Materials. All materials shall be Underwriters Laboratory (UL) approved for the purpose used except where specific requirements or exceptions given herein apply. Down conductors shall be a soft-drawn, stranded, bare copper cable weighing approximately 215 pounds per 1,000 feet. Down conductors shall always be routed in a downward direction and bends shall have an 8 inch or greater radius. Down conductors shall be attached to the tower at approximately 3-foot intervals. Substantial electrical and mechanical connections are required between air terminals and down conductors, and between down conductors and the below grade earth electrode grounding system.

b. Earth Electrode Grounding System. New earth grounding systems shall be provided and installed, or existing earth grounding systems shall be upgraded as necessary. These grounding systems shall consist of driven ground rods or buried plates, and buried interconnecting cables. All site grounding conductors shall terminate or directly connect to the earth ground system. Adjacent earth grounding systems within 30 feet of each other shall be interconnected by buried cables. The earth electrode grounding system configurations shall depend upon the geological conditions at the site, with very extensive systems justifiable in areas with high soil resistivity and frequent lighting damage. Ground rods shall be copper clad steel, UL approved, 10-foot minimum length, 3/4-inch minimum diameter, pointed end or coupling type, as necessary. Tops of driven rods shall be at least 18 inches below grade level. Separation between rods at a site shall be at least equal to their driven depth and preferably at twice their depth where space permits. Grounding plates shall be 20-gauge minimum sheet copper and at least 2 feet by 2 feet in size. Grounding cables used to interconnect ground rods or plates shall be bare copper of the same size as the largest down conductor required for the site. Grounding cables shall be installed a minimum of 18 inches below grade level. All steel materials used to anchor guy wires shall be interconnected using split bolt connectors and No. 6 AWG bare copper grounding wire. Similar bonding jumpers shall be connected around guy wire couplings and fittings. Where driven poles or foundations piers are required to support towers, earth grounding cables shall be installed.

c. <u>Grounding</u>. Grounding shall be provided to conduct lightning charges, power faults, and unbalanced currents; to eliminate static and electromagnetic charges; and to provide an equal potential reference for the operation of equipments. All metallic structures, enclosures, conduit, cable armor, and conductor shielding shall have a direct, identified path to the earth electrode grounding system. The grounding path shall be provided by a separate grounding conductor or by bonding metallic structures or enclosures with a separate conductor to the earth electrode grounding system. All grounding conductors shall be routed as directly as possible without loops, excess length, or sharp (less than 8-inch radius) bends. All equipment enclosures, housings, cases, cabinets, and racks shall be grounded by an equipment grounding conductor provided and installed in accordance with the National Electric Code (NFPA-70); except that conduit and other power circuit enclosures shall not be used to serve the purpose. A separate equipment grounding conductor shall be provided and installed with each power circuit. The neutral conductors for power circuits shall not be grounded in or by any equipment or at any point in the system except at service entrances as defined by the National Electrical Code (NEC). At service entrances and at main disconnect circuit breaker boxes serving this purpose, the power neutral conductor and the equipment grounding conductor shall be common and connected directly to the earth electrode grounding system. The grounding electrode conductor shall be unspliced and routed separately without loops, excess length, or sharp (i.e., less than 8-inch radius) bends. All signals transmitted by interface lines or landlines shall be balanced two-wire signal lines, or an individual ground return conductor shall be routed with each signal line. A third wire may be routed with two-wire signal lines to serve as ground return or reference. The outer conductors for all coaxial, twinaxial, and triaxial cable shall be grounded at equipments, antennas, and bulkheads, and not isolated at any point.

d. Bonding. Bonding is the mechanical and electrical connection of metal materials, wires, and cables for the low impedance conduction of currents and electromagnetic energy. The effectiveness of lightning protection, transient protection, grounding and shielding depends upon the quality of bonding connections. Therefore, high quality bonding shall be designed and implemented into the AWOS and its installations.

e. Shielding. Shielding shall be provided to protect equipment and interface lines (all signal data, control, monitoring, power lines, and cables) from lightning currents and discharges. Shielding shall also provide for the containment of interference and signals produced by equipments and to protect susceptible equipments from related environmental signals and interference.

f. Conductor Segregation, Separation, and Routing. The segregation, separation, and routing of all lines, cables, and conductors shall be designed by the installer to minimize the coupling of lightning currents, transients, surges, and interference. AC power lines, signal lines, and grounding cables shall be segregated and routed separately and not installed in the same trench or conduit. The parallel routing of these types of cables shall be avoided, and, where necessary, shall conform to NFPA-78 code. To the extent feasible, all crosses shall be at right angles.

g. Transient and Surge Suppression. All transients and surge arrestors, suppressors, circuits, suppressors required at service entrances to existing buildings and shelters, and components required for the system and equipments shall be furnished and installed by the manufacturer.