U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Use of Liquid Water Equivalent System to Determine Holdover Times or Check Times for Anti-Icing Fluids

Date: 7/14/15 **AC No:** 120-112
Initiated by: AFS-200 **Change:**

This advisory circular (AC) provides guidance for the Federal Aviation Administration's (FAA) standard for a Liquid Water Equivalent System (LWES). This AC applies to anyone proposing to design, procure, construct, install, activate, or maintain an LWES. An LWES is an automated weather measurement system that determines the Liquid Water Equivalent (LWE) rate in conditions of frozen or freezing precipitation. The LWE rate is used by the system with the appropriate endurance time (ET) regression equations and regression coefficients specified in an FAA-approved current database at http://66.46.192.186/RegressionInformation.html to determine the holdover time (HOT) or check time (CT) for an aircraft's applied anti-icing fluid (Society of Automotive Engineer (SAE) Types I, II, III, and IV). Thus, the LWES incorporates a Holdover Time Determination System (HOTDS) or Check Time Determination System (CTDS). The HOT is used to determine how long a fluid would provide protection assuming that the current conditions do not change. The CT is used to determine the fluid's current protection capability, while incorporating varying weather conditions.

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CHAPTER 1. INTRODUCTION

1-1. PURPOSE. This advisory circular (AC) provides guidance for the Federal Aviation Administration's (FAA) standard for a Liquid Water Equivalent System (LWES). This AC applies to anyone proposing to design, procure, construct, install, activate, or maintain an LWES. An LWES is an automated weather measurement system that determines the Liquid Water Equivalent (LWE) rate in conditions of frozen or freezing precipitation. The LWE rate is used by the system with the appropriate endurance time (ET) regression equations and regression coefficients specified in an FAA-approved current database at http://66.46.192.186/RegressionInformation.html to determine the holdover time (HOT) or check time (CT) for an aircraft's applied anti-icing fluid (Society of Automotive Engineer (SAE) Types I, II, III, and IV). Thus, the LWES incorporates a Holdover Time Determination System (HOTDS) or Check Time Determination System (CTDS). The HOT is used to determine how long a fluid would provide protection assuming that the current conditions do not change. The CT is used to determine the fluid's current protection capability, while incorporating varying weather conditions.

1-2. APPLICATION. The provisions of this AC are effective immediately for all systems, or portions thereof, that are submitted for consideration.

1-3. REQUEST FOR INFORMATION. Obtain further information concerning LWES standards and type certification approval process from:

Federal Aviation Administration
Air Transportation Division, AFS-200
800 Independence Ave. SW
Washington, DC 20591
Office phone: (202) 267-8166

1-4. WEATHER SENSORS. The LWES is typically a modular system utilizing a central processor that may receive input from several weather sensors. A minimum list of sensors used by the system should include a temperature sensor, precipitation type sensor, and LWE precipitation measurement device. A wind sensor may be included.

1-5. FAA'S RESPONSIBILITY. The FAA provides minimum acceptable standards and references for an LWES. Chapters 2 and 3 provide this information. The FAA does not certify or approve a specific LWES. However, the FAA Flight Standards Service (AFS) will authorize a specific air operator to use an LWES as part of the operator's ground deicing/anti-icing program, if required per Title 14 of the Code of Federal Regulations (14 CFR) part 121, § 121.629(c).

CHAPTER 2. AUTHORIZATION PROCESS

2-1. PROCESS OVERVIEW. The authorization process requires the manufacturer to produce and submit specific documents for review. The manufacturer must provide all documentation to the air operator, who will review and submit this documentation to the FAA office with direct oversight of the operator when applying to the FAA for authorization to use a LWES. The manufacturer must provide revisions to the air operator and make those revisions available to the FAA upon request. This chapter describes the following 11 documents. Item (1) below, the Performance Test Plan, should be submitted first, before any testing begins. Items (2) through (8) should be submitted after performance testing has been completed. Item (9), the Siting and Installation Report, should be submitted as sensor locations are determined and before installation begins. Item (10) should be submitted as described in subparagraph 2-8c.

(1) Performance test plan.

(2) Performance test report.

(3) Quality assurance (QA) documentation.

(4) System description.

(5) Verification report of HOT and/or CT determination.

(6) User's manual and training material.

(7) Technician's training manual.

(8) Maintenance manual.

(9) Siting and installation report.

(10) Maintenance log.

(11) System change proposal.

2-2. PERFORMANCE TESTING. Chapter 3 of this AC contains the minimum performance and testing standards that the LWES and its components must meet for the FAA AFS to authorize for use. Conformance with these standards must be demonstrated through performance testing by a third party acceptable to the FAA. The manufacturer bears all testing costs.

a. Performance Test Plan. A test plan must contain detailed procedures for conducting the tests as well as the name and location of the facility where the tests are to be conducted. The credentials of the third-party organization and qualifications of the personnel conducting the tests should be included in the plan. The rate pan collection times (refer to Society of Automotive Engineers (SAE) Aerospace Recommended Practices (ARP) 5485 and 5945) and the LWE sampling time, which the LWES uses to determine the HOT, should be made clear.

NOTE: Data used for development of the system must not also be used for evaluation of the performance of the system.

b. Performance Test Report. A test report from a third-party organization must be submitted directly to the air operator. The test report must evaluate the precipitation rate (in g/dm²/h) and precipitation type outputs in comparison to precipitation rate pan measurements and human observations. The operational stability of the LWES should also be evaluated. The report must include all data collected during a test; data must not be omitted because it falls outside of the acceptable limits of this AC. After completion of the tests, the data should be reduced to an easily understood format to demonstrate conformity with this AC. If third-party testing has previously been performed, the test procedures and data sheets from these tests may be submitted for consideration, along with supporting documentation conforming as fully as possible to that described in this paragraph. However, the FAA reserves the right to witness testing, request additional testing, and examine raw data.

2-3. QUALITY ASSURANCE. The manufacturer must ensure initial and ongoing QA of the computational software, hardware, and end-to-end data integrity as follows:

a. Design, develop, produce, and maintain the software in accordance with appropriate software assurance standards.

b. The manufacturer should design, develop, produce, and maintain the hardware in accordance with appropriate hardware assurance standards.

c. The system must include means of recognizing faulty data caused by all sources (e.g., corrupted ET regression equations/coefficients, corrupted data transmissions, etc.) through the use of comprehensive checks and safeguards. If the system identifies faulty data that would corrupt the determination of the HOT or CT, the system must issue an error code or statement indicating that it is not functioning properly and discontinue reporting HOT or CT information until the problem is resolved. The manufacturer must describe the QA of the LWE rate and HOT and/or CT determinations as appropriate.

2-4. SYSTEM DESCRIPTION. The system description document should identify and catalog the hardware components, software, and firmware. Include an equipment list and specification sheets. The manufacturer should describe the LWE rate and HOT and/or CT determinations using schematics, block diagrams, flow diagrams, and/or pseudo-code as appropriate.

2-5. VERIFICATION OF HOT AND/OR CT DETERMINATION. The manufacturer must verify HOT and/or CT determinations from the system for each Type II, III, and IV fluids and for Type I fluids for aluminum and composite surfaces, against known fluid dilution, precipitation type, precipitation rate, and temperature inputs to ensure that regression curves and associated coefficients have been correctly implemented within the system. The verification report must include, as a minimum:

a. Normal range test cases for which the system determines a HOT; and

b. Test cases outside the normal range, where the system is not to determine a HOT, to verify robustness. For these cases, the system should determine that no HOT is available;

(1) Including but not limited to cases that are included in the verification tables in an FAA-approved current database at http://66.46.192.186/RegressionInformation.html.

(2) Including LWE rates higher than the normal range and temperatures lower than the normal range.

c. For CT systems, in addition to verification of HOT as described in subparagraphs 3-5a and 3-5b, cases demonstrating CT determination by the system for minute-by-minute sequences of variable weather conditions. These sequences should also include conditions when permissible (determined by the system) gaps are found in the data. These gaps can be caused by events, such as data determined to be outside of the sensor thresholds, power outages, or data transmission errors.

2-6. USER'S MANUAL AND TRAINING MATERIAL.

a. The user's manual should provide all information the user needs for interacting with the system and interpreting the output.

b. Training material, either in written or electronic form, should be provided for system users.

c. Both the user's manual and the training material should emphasize that in the event that the user has reason to believe that the precipitation type, temperature, or HOT or CT information from the LWES is erroneous, the flightcrew should disregard it and resort back to the HOT tables for guidance. Details on how the information will be recognized as erroneous and how the process of switching back to the HOT tables will be accomplished should be provided in the operator's winter deicing plan under §121.629.

2-7. SITING AND INSTALLATION. Siting and installation of the LWES must be coordinated with the airport authority, air operator, and the FAA. Information and guidance on siting of meteorological sensors can be found in the current edition of FAA Order 6560.20, Siting Criteria for Automated Weather Observing Systems (AWOS), in FCM-S4-1994, Federal Standard for Siting Meteorological Sensors at Airports, published by the Office of the Federal Coordinator for Meteorology (OFCM), and in Airport Cooperative Research Program (ACRP) Report 45, Optimizing the Use of Aircraft Deicing and Anti-Icing Fluids, published in 2011 by the ACRP. The LWES input instruments should be sited in sufficient proximity of each other to provide coherent sampling of meteorological inputs for LWE rate determination in transitional weather conditions. A report must be provided to the air operator, describing the LWES siting. This report is supplemental to the filing of FAA Form 7460-1, Notice of Proposed Construction or Alteration. Its purpose is to relate the guidance and references stated in the previous paragraph to the siting of the LWES. This report must include each system installed at the airport.

2-8. MAINTENANCE. A manufacturer-trained technician must perform an annual onsite performance verification of the LWES prior to the winter season. A second onsite inspection should be performed mid-season during winter weather unless the manufacturer can demonstrate continuous sensor and system remote monitoring to ensure there are no sensor failures or sensor faults. Verification is the written assurance to the user that the system is providing the service

described in both this AC and in the manufacturer's manuals. System performance checks must identify and correct changes in performance and provide documented assurance to the user of the validity of the published information. The manufacturer's trained technician must document the results of these checks by making an appropriate entry in the manufacturer's maintenance log. If the checks are not satisfactory, the system, including individual sensors, must not be used until corrections are made.

a. Technician's Training Manual. The technician's training manual should include a summary of the knowledge and skills that a maintenance technician should possess to service the LWES. This document should also propose a program to familiarize maintenance technicians with the maintenance and operation of the LWES.

b. Maintenance Manual. The maintenance manual should include a complete description of the annual onsite verification of the LWES as well as all other maintenance information to be utilized to prevent system malfunctions and to remedy the system malfunctions that do occur.

c. Maintenance Log. The manufacturer must make the maintenance log accessible electronically to the FAA upon request. All site visits must be documented on this form. The log must provide a historical record of all maintenance and inspection actions accomplished on the LWES. Any damage must be logged (e.g., hole in vertical fin of the wind sensor, needs replacement), and any problem with the LWES must be noted (e.g., wind sensor disconnected, replacement required). When a system or component repair or adjustment has been accomplished, the maintenance technician must make a performance verification statement in the log. In all cases, the technician completing the action and making the entry must be identified in the log, as well as the date of the action, the facility name and location, and other identifying data.

CHAPTER 3. PERFORMANCE AND TESTING SPECIFICATIONS FOR LWES

3-1. GENERAL. This chapter contains the performance standards and testing specifications for LWES.

3-2. 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:

$$RMSE = \sqrt{\frac{\sum_{N=1}^{N}(T-M)^2}{N}}$$

Where
N = Number of independent comparisons
M = Measured value
T = True value

(RMSE is in the same units as the measured and true values).

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 that 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.

3-3. GENERAL POWER STANDARDS. This paragraph addresses aspects of power that are applicable to the LWES as a whole.

a. Input Power. LWES equipment should operate from a 120/240 volts (V) (±10 percent), 60 Hertz (Hz) ac (±5 Hz), 3-wire service.

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

3-4. OPERATING ENVIRONMENT. All LWES equipment and sensors should demonstrate that they meet all operating tolerances under the operational environmental conditions this AC describes.

a. Temperature. From -40°C to +3°C (-40°F to +37.4°F).

b. Wind. Up to 85 knots (kts).

3-5. MECHANICAL WIND SPEED AND DIRECTION SENSOR (If Included in System).

a. Performance Standard.

(1) Wind Speed Sensor.

(a) Range. The sensor should respond to a threshold of 2 kts and a maximum of at least 85 kts.

(b) Accuracy. The wind speed sensor should provide an accuracy of ± 2 kts up to 40 kts. Above 40 kts, RMSE should be within ± 5 percent.

(c) Resolution. The resolution should be 1 kt.

(d) Distance Constant. The distance constant should be less than 10 meters.

(e) Threshold. 2 kts.

(2) Wind Direction Sensor. This sensor should be aligned to true north.

(a) Range. 1° to 360° in azimuth.

(b) Threshold. 2 kts.

(c) Accuracy. Within ± 5° (RMSE).

(d) Resolution. To nearest 1°; dead band not to exceed 7° wide.

(e) Time Constant. Less than 2 seconds.

b. Performance Testing. If the manufacturer of the sensor has performed testing and it has been shown to meet the standards stated above, it is sufficient to submit documentation from the manufacturer establishing these facts, and further testing is not necessary. If testing is necessary, testing should be conducted in a calibrated wind tunnel, except for the wind direction accuracy test that is conducted on a bench test fixture. The wind speed sensor should be compared against a calibrated pitot-static tube or transfer reference standard traceable to the National Institute of Standards and Technology (NIST).

3-6. ULTRASONIC WIND SENSOR (If Included in System).

a. Performance Standard.

(1) Wind Speed.

(a) Range. The sensor should respond to a threshold of 1 kt and a maximum of at least 85 kts.

(b) Accuracy. The wind speed sensor should provide an accuracy of ±1 kt up to 40 kts. Above 40 kts, RMSE should be within ±3 percent.

(c) Resolution. The resolution should be 1 kt.

(d) Distance Constant. The distance constant should be less than 1 meter.

(e) Threshold. 1 kt.

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

(a) Range. 0º to 359º in azimuth.

(b) Threshold. 1 kt.

(c) Accuracy. Within ± 3º (RMSE).

(d) Resolution. To nearest 1º.

b. Performance Testing. If the manufacturer of the sensor has performed testing and it has been shown to meet the standards stated above, it is sufficient to submit documentation from the manufacturer establishing these facts, and further testing is not necessary. If testing is necessary, testing should be conducted in a calibrated wind tunnel. The ultrasonic sensor should be compared against a calibrated pitot-static tube or transfer reference standard traceable to the NIST.

3-7. TEMPERATURE SENSOR.

a. Performance Standards. The sensor should be thermally isolated to accurately measure environments below:

(1) Range. From -50ºC to +3ºC (-58ºF to +37.4ºF).

(2) Accuracy. 0.5ºC (1ºF) RMSE for entire range of the sensor, with maximum error of 1ºC (2 ºF).

(3) Resolution. Not greater than 0.5ºC (1ºF).

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

b. Performance Testing. If the manufacturer of the sensor has performed testing and it has been shown to meet the standards stated above, it is sufficient to submit documentation from the manufacturer establishing these facts, and further testing is not necessary. If testing is necessary, testing should be conducted in a temperature chamber.

3-8. PROVISIONS FOR LWES APPROVAL FOR SNOW.

a. Performance Standard for Identification of Snow. The following provision should be met if the system is to be approved for identification of snow: If precipitation of a LWE rate of at least 2.0 g/dm^2/h (as determined by SAE Aerospace Recommended Practices (ARP) 5485 and 5945, a glycol precipitation rate pan measurement for a LWE sampling time of at least 5

minutes) has been detected and identified as snow by a human observer with credentials the FAA finds acceptable, the system should identify it as snow at least 95 percent of the time.

b. Performance Tests for Identification of Snow. A detailed protocol for performance of the tests should be included in the test plan described in Chapter 2. A minimum of 100 data points for an LWE sampling time of at least 5 minutes in snow varying from very light to heavy, and documented as described in the test protocol, should be collected to demonstrate compliance with performance standard in subparagraph 3-8a. At least 10 data points of very light (0 to 4 g/dm^2/h), 15 data points of light (above 4 to 10 g/dm^2/h), 30 data points of moderate (above 10 to 25 g/dm^2/h) , and 15 data points of heavy (above 25 to 50 g/dm^2/h) should be included in the data set. The data set should include a range of temperatures and wind speeds representative of those in which the system may be used.

NOTE: Heavy snowfall HOTs may be reported for snowfall rates up to 50 g/dm^2/h. It is recommended that at least 15 data points during heavy conditions be submitted.

c. Performance Standards for Determination of LWE Rate for Snow. These provisions should be met if the system is to be approved for determination of LWE rate for snow:

(1) LWE rate measurements should be analyzed in reference to simultaneously recorded glycol precipitation rate pan measurements or in reference to simultaneously recorded measurements by another method the FAA finds acceptable. The testing period should be the same period used by the system operationally to determine HOT or CT, and cannot be less than 5 minutes.

(2) The LWES precipitation rate measurements should conform to the glycol precipitation rate pan measurements (refer to SAE ARPs 5485 and 5945) within the tolerances or alternate tolerance in Table 3-1 at a 95 percent confidence level:

TABLE 3-1. LWES SNOW RATE MEASUREMENT TOLERANCES

LWES Rate g/dm^2/h	Acceptance Tolerance g/dm^2/h	Alternate Acceptable Tolerance
From 2 to 10*	-3.0	-4.0 g/dm^2/h
Above 10 to 25	-6.0	-40%
Above 25 to 50	-14.0	

*** 0 g/dm^2/h may be used as the lower limit of this range at the discretion of the applicant.**

(3) If the system also meets the stated criteria in Table 3-1 when a minus (-) sign is replaced with a plus or minus (±) sign, then the system meets not only the stated (1-sided) criteria, but also a more stringent (2-sided) criteria. In its response to the report and data submission by the manufacturer, the FAA can provide a statement that this more stringent standard has been met.

d. Performance Tests for Determination of LWE Rate for Snow. A detailed protocol for performance of the tests should be included in the test plan required in paragraph 2-5. A minimum of 100 data points for the LWE sampling time in snow varying from very light to heavy, and documented as described in the test protocol, should be collected to demonstrate compliance with the performance standard in subparagraph 3-8c. At least 10 data points of very light (0 to 4 g/dm^2/h), 15 data points of light (above 4 to 10 g/dm^2/h), 30 data points of moderate (above 10 to 25 g/dm^2/h) , and 15 data points of heavy (above 25 to 50 g/dm^2/h) should be included in the data set. The data set should include a range of temperatures and wind speeds representative of those in which the system may be used.

NOTE: Heavy snowfall HOTs may be reported for snowfall rates up to 50 g/dm^2/h. It is recommended that at least 15 data points during heavy conditions be submitted.

e. Determination of HOT or CT Using LWE Rate and Temperature. These provisions should be met if the system is to be approved for determination of HOT or CT using LWE rates for snow:

(1) The LWE rate used by the system for the purpose of computing fluid HOT or CT should be the LWE rate determined by the system *plus* the tolerance (within a 95 percent confidence level) that has been demonstrated for each range. Notwithstanding, the precipitation rate used by the LWES for the purpose of computing fluid HOT or CT must not be less than 2.0 g/dm^2/h.

(2) The temperature used by the system for the purpose of computing fluid HOT or CT must be no higher than 0°C (32° F). Any temperatures reported by the system in excess of 0°C should be set to 0°C for the purpose of computing fluid HOT or CT.

(3) HOT or CT determinations must not be provided in snow conditions exceeding 50 g/dm^2/h. This threshold is to be compared to the LWE rate determined by the system *plus* the tolerance (within a 95 percent confidence level) that has been demonstrated for the appropriate range. In accordance with the currently accepted practice for HOT table development, HOT and CT determinations from the LWES for Type II and IV anti-icing fluids must be capped at 3 hours for snow.

(4) In accordance with the currently accepted practice for HOT table development, HOT and CT determinations from the LWES for Type II and IV anti-icing fluids must be capped at 3 hours for snow.

NOTE: If the accepted practice for HOT table development with respect to HOT caps is modified, these modifications should be applied to HOTDS and CTDS criteria.

3-9. PROVISIONS FOR LWES APPROVAL FOR FREEZING RAIN.

a. Performance Standards for Identification of Freezing Rain. The following provision should be met if the system is to be approved for identification of freezing rain. If precipitation of an LWE rate of at least 2.0 g/dm^2/h (as determined by SAE ARPs 5485 and 5945, a

precipitation rate pan measurement for an LWE sampling time of at least 5 minutes) has been detected and identified as freezing rain by a human observer with appropriate credentials, the system should identify it as freezing rain at least 95 percent of the time.

b. Performance Tests for Identification of Freezing Rain. A detailed protocol for performance of the tests should be included in the test plan described in Chapter 2. A minimum of 25 data points for an LWE sampling time of at least 5 minutes in freezing rain, where at least 20 data points are in the light range below 25 g/dm^2/h, and documented as described in the test protocol, should be collected to demonstrate compliance with the performance standard in subparagraph 3-9a. The data set should include a range of temperatures and wind speeds representative of those in which the system may be used.

c. Performance Standards for Determination of LWE Rate for Freezing Rain. These provisions should be met if the system is to be approved for determination of LWE rate for freezing rain:

(1) LWE rate measurements should be analyzed in reference to simultaneously recorded precipitation rate pan measurements or in reference to simultaneously recorded measurements by another method. The testing period should be the same period used by the system operationally to determine HOT or CT, and cannot be less than 5 minutes.

(2) The LWES precipitation rate measurements should conform to the precipitation rate pan measurements (ref.: SAE ARPs 5485 and 5945) or other measurements acceptable to the FAA, within the tolerances or alternate tolerances in Table 3-2 at a 95 percent confidence level:

TABLE 3-2. THE LWES FREEZING RAIN RATE MEASUREMENT TOLERANCES

LWES Rate g/dm^2/h	**Acceptable Tolerance g/dm^2/h**	**Alternate Acceptable Tolerance**
From 2 to 13*	-3.0	-4.0 g/dm2/h
Above 13 to 25	-6.0	-40%
Above 25	-14.0	

*** 0 g/dm^2/h may be used as the lower limit of this range at the discretion of the applicant.**

(3) If the system also meets the stated criteria in Table 3-2 when a minus (-) sign is replaced with a plus or minus (±) sign, then the system meets not only the stated (1-sided) criteria, but also a more stringent (2-sided) criteria. In its response to the report and data submission by the manufacturer, the FAA can provide a statement that this more stringent standard has been met.

d. Performance Tests for Determination of LWE Rate for Freezing Rain. A detailed protocol for performance of the tests should be included in the test plan required in paragraph 2-5. A minimum of 25 data points for the LWE sampling time in freezing rain, mainly in the light range, and documented as described in the test protocol, should be collected to demonstrate compliance with the performance standard in subparagraph 3-9c.

e. Determination of HOT or CT Using LWE Rate. These provisions should be met if the system is to be approved for determination of HOT or CT using LWE rates for freezing rain:

(1) The LWE rate used by the system for the purpose of computing fluid HOT or CT should be the LWE rate determined by the system *plus* the tolerance (within a 95 percent confidence level) that has been demonstrated for each range. Notwithstanding, the precipitation rate used by the LWES for the purpose of computing fluid HOT or CT must not be less than 2.0 $g/dm^2/h$.

(2) HOT or CT determinations must not be provided in freezing rain conditions exceeding 25 $g/dm^2/h$. This threshold is to be compared to the LWE rate determined by the system *plus* the tolerance (within a 95 percent confidence level) that has been demonstrated for the appropriate range.

(3) In accordance with the currently accepted practice for HOT table development, HOT and CT determinations from the LWES for Type II and IV anti-icing fluids must be capped at 3 hours for freezing rain.

NOTE: If the accepted practice for HOT table development with respect to HOT caps is modified, these modifications should be applied to HOTDS and CTDS criteria.

3-10. PROVISIONS FOR LWES APPROVAL FOR FREEZING DRIZZLE.

a. Performance Standard for Identification of Freezing Drizzle. The following provision should be met if the system is to be approved for identification of freezing drizzle. If precipitation of an LWE rate of at least 2.0 $g/dm^2/h$ (as determined by SAE ARPs 5485 and 5945, a precipitation rate pan measurement for an LWE sampling time of at least 5 minutes) has been detected and identified as freezing drizzle by a human observer with appropriate credentials, the system should identify it as freezing drizzle at least 80 percent of the time.

b. Performance Tests for Identification of Freezing Drizzle. A detailed protocol for performance of the tests should be included in the test plan described in Chapter 2. A minimum of 25 data points for an LWE sampling time of at least 5 minutes in freezing drizzle, distributed over the light, moderate, and heavy range, and documented as described in the test protocol, should be collected to demonstrate compliance with performance standard in subparagraph 3-10a. The data set should include a range of temperatures and wind speeds representative of those in which the system may be used.

c. Performance Standards for Determination of LWE Rate for Freezing Drizzle. These provisions should be met if the system is to be approved for determination of LWE rate for freezing drizzle:

(1) LWE rate measurements should be analyzed in reference to simultaneously recorded precipitation rate pan measurements or in reference to simultaneously recorded measurements by another method. The testing period should be the same period used by the system operationally to determine HOT or CT, and cannot be less than 5 minutes.

(2) The LWES precipitation rate measurements should conform to the precipitation rate pan measurements (refer to SAE ARPs 5485 and 5945) or other measurements acceptable to the FAA, within the tolerances or alternate tolerances in Table 3-3 at a 95 percent confidence level:

TABLE 3-3. THE LWES FREEZING DRIZZLE RATE MEASUREMENT TOLERANCES

LWES Rate $g/dm^2/h$	Acceptable Tolerance $g/dm^2/h$	Alternate Acceptable Tolerance
From 2 to 5*	-3.0	-4.0 g/dm2/h
Above 5 to 13	-6.0	-40%

*** (0 $g/dm^2/h$ may be used as the lower limit of this range at the discretion of the applicant.)**

(3) If the system also meets the stated criteria in Table 3-3 when a minus (-) sign is replaced with a plus or minus (±) sign, then the system meets not only the stated (1-sided) criteria, but also a more stringent (2-sided) criteria. In its response to the report and data submission by the manufacturer, the FAA can provide a statement that this more stringent standard has been met.

d. Performance Tests for Determination of LWE Rate for Freezing Drizzle. A detailed protocol for performance of the tests should be included in the test plan required in paragraph 2-5. A minimum of 25 data points for the LWE sampling time in freezing drizzle documented as described in the test protocol should be collected to demonstrate compliance with performance standard in subparagraph 3-10c.

e. Determination of HOT or CT Using LWE Rate. These provisions should be met if the system is to be approved for determination of HOT or CT using LWE rates for freezing drizzle:

(1) The LWE rate used by the system for the purpose of computing fluid HOT or CT should be the LWE rate determined by the system *plus* the tolerance (within a 95 percent confidence level) that has been demonstrated for each range. Notwithstanding, the precipitation rate used by the LWES for the purpose of computing fluid HOT or CT must not be less than 2.0 $g/dm^2/h$.

(2) HOT or CT determinations must not be provided in freezing drizzle conditions exceeding 13 $g/dm^2/h$. This threshold is to be compared to the LWE rate determined by the system *plus* the tolerance (within a 95 percent confidence level) that has been demonstrated for the appropriate range.

(3) In accordance with the currently accepted practice for HOT table development, HOT and CT determinations from the LWES for Type II and IV anti-icing fluids must be capped at 3 hours for freezing drizzle.

NOTE: If the accepted practice for HOT table development with respect to HOT caps is modified, these modifications should be applied to HOTDS and CTDS criteria.

3-11. PROVISIONS FOR LWES APPROVAL FOR SUPERCOOLED LARGE DROPS (SLD).

NOTE: These provisions pertain to a system that can identify Supercooled Large Drops (SLD) (i.e., freezing rain or freezing drizzle), but cannot distinguish between freezing rain and freezing drizzle.

a. Performance Standards for Identification of SLD. The following provision should be met if the system is to be approved for identification of SLD. If precipitation of an LWE rate of at least 2.0 $g/dm^2/h$ (as determined by a precipitation rate pan measurement for an LWE sampling time of at least 5 minutes) has been detected and identified as SLD by a human observer with credentials the FAA finds, the system should identify it as SLD at least 95 percent of the time.

b. Performance Tests for Identification of SLD. A detailed protocol for performance of the tests should be included in the test plan described in Chapter 2. A minimum of 25 data points for an LWE sampling time of at least 5 minutes in SLD, distributed over freezing drizzle and light freezing rain, and documented as described in the test protocol, should be collected to demonstrate compliance with performance standard in subparagraph 3-11a. The data set should include a range of temperatures and wind speeds representative of those in which the system may be used.

c. Performance Standards for Determination of LWE Rate for SLD. These provisions should be met if the system is to be approved for determination of LWE rate for SLD:

(1) LWE rate measurements should be analyzed in reference to simultaneously recorded precipitation rate pan measurements or in reference to simultaneously recorded measurements by another method acceptable to the FAA. The testing period should be the same period used by the system operationally to determine HOT or CT, and cannot be less than 5 minutes.

(2) The LWES precipitation rate measurements should conform to the precipitation rate pan measurements (refer to SAE ARPs 5485 and 5945) or other measurements the FAA finds acceptable, within the tolerances or alternate tolerances in Table 3-4 at a 95 percent confidence level:

TABLE 3-4. THE LWES SLD RATE MEASUREMENT TOLERANCES

LWES Rate $g/dm^2/h$	Acceptance Tolerance $g/dm^2/h$	Alternate Acceptance Tolerance
From 2 to 13*	-3.0	-4.0 g/dm2/h
Above 13 to 25	-6.0	-40%
Above 25	-14.0	

*** 0 $g/dm^2/h$ may be used as the lower limit of this range at the discretion of the applicant.**

(3) If the system also meets the stated criteria in Table 3-4 when a minus (-) sign is replaced with a plus or minus (±) sign, then the system meets not only the stated (1-sided) criteria, but also a more stringent (2-sided) criteria. In its response to the report and data submission by the manufacturer, the FAA can provide a statement that this more stringent standard has been met.

d. Performance Tests for Determination of LWE Rate for SLD. A detailed protocol for performance of the tests should be included in the test plan required in paragraph 2-5. A minimum of 25 data points for the LWE sampling time in SLD, distributed over freezing drizzle and light freezing rain, and documented as described in the test protocol, should be collected to demonstrate compliance with the performance standard in paragraph 3-11c.

e. Determination of HOT or CT Using LWE Rate. These provisions should be met if the system is to be approved for determination of HOT or CT using LWE rates for SLD:

(1) HOT or CT determinations for SLD should be based on computing the associated HOT or CT for freezing rain as specified in subparagraph 3-9e(1) and freezing drizzle as specified in subparagraph 3-10e(1) and using the resulting lower value.

(2) HOT or CT determinations must not be provided in SLD conditions exceeding 25 $g/dm^2/h$. This threshold is to be compared to the LWE rate determined by the system *plus* the tolerance (within a 95 percent confidence level) that has been demonstrated for the appropriate range.

(3) In accordance with the currently accepted practice for HOT table development, HOT and CT determinations from the LWES for Type II and IV anti-icing fluids must be capped at 3 hours for SLD.

NOTE: If the accepted practice for HOT table development with respect to HOT caps is modified, these modifications should be applied to HOTDS and CTDS criteria.

3-12. LWES LATENCY. The LWES should generate an updated HOT or CT every 10 minutes or less.

a. LWES Inputs. The inputs the system uses to generate a HOT/CT are Air Temperature, Precipitation Type, LWE, and Wind Speed (optional) and should not be more than 10 minutes old. These inputs should also be reported every 10 minutes along with the updated HOT/CT.

b. Onset of Winter Precipitation. The LWES should determine and report a HOT/CT within 10 minutes of the onset of a winter precipitation event as identified in paragraphs 3-8 through 3-11c.

APPENDIX 1. ACRONYMS USED IN THIS ADVISORY CIRCULAR

AC	Advisory Circular
AFS	Flight Standards Service
ARP	Aerospace Recommended Practice
AWOS	Automatic Weather Observation System
CFR	Code of Federal Regulations
CT	Check Time
CTDS	Check Time Determination System
FAA	Federal Aviation Administration
$g/dm^2/h$	Grams per Decimeter Squared per Hour
HOT	Holdover Time
HOTDS	Holdover Time Determination System
LWE	Liquid Water Equivalent
LWES	Liquid Water Equivalent System
RMSE	Root Mean Square Error
SAE	Society of Automotive Engineers
SLD	Supercooled Large Drops

APPENDIX 2. DEFINITIONS

a. Anti-Icing Fluid. A fluid applied to an aircraft as a precautionary procedure that provides protection against the formation of frost or ice and the accumulation of snow on treated surfaces of an aircraft for a period of time.

b. Check Time (CT). A time in the past that indicates whether an aircraft's anti-icing fluid is still providing protection in the given conditions. Incorporating real-time snowfall rates, the algorithm begins with the current time and integrates the fluid's loss in protection capacity rate backwards in time, minute by minute, until it determines sufficient precipitation has fallen for the protection capability to be exhausted. The time at which this occurs is displayed to the user as check time and is updated every minute. The check time is compared to the time the aircraft was anti-iced. As long as the time the aircraft was anti-iced remains more recent than the check time, the fluid is still providing protection.

c. Deicing Fluid. A fluid applied to an aircraft to remove contamination in the form of frost, ice, or snow.

d. Endurance Time. A time of protection determined from a test of a fluid of specified dilution at a given temperature for a given type of precipitation and LWE rate. (Based on the endurance time testing, estimated protection times for use in operations, called HOTs, are determined.)

e. Endurance Time Regression Analysis. A data analysis protocol used to analyze fluid endurance time data for the generation of HOTs for anti-icing fluids.

f. Glycol Pan Measurement. A process to determine precipitation rate by using a glycol-wetted pan that is weighed precisely before and after a timed exposure to precipitation. This methodology has been included in SAE Aerospace Recommended Practice (ARP) 5485 and 5945.

g. Holdover Time (HOT). The estimated time that deicing/anti-icing fluid will prevent the formation of frost or ice and the accumulation of snow on the critical surfaces of an aircraft. HOT begins when the final application of deicing/anti-icing fluid commences and expires when the deicing/anti-icing fluid loses its protection effectiveness.

h. Holdover Time Tables. Tables of HOTs for anti-icing fluids published as HOT guidelines by the FAA.

i. Liquid Water Equivalent (LWE) Rate. The rate of LWE accumulation of freezing or frozen precipitation in $g/dm^2/h$.

j. Liquid Water Equivalent System (LWES). A near-real-time system that in precipitation conditions determines precipitation type (if required) and LWE rate. The system can use the LWE rate to determine a HOT or CT.

k. Liquid Water Equivalent (LWE) Sampling Time. The period of LWE sampling used by the LWES to determine the LWE rate. This system sampling time must not be less than 5 minutes, and will ordinarily be 5 or 10 minutes.