AHRI Standard 1110-2013 (I-P)

2013 Standard for

Performance Rating of Mechanical Transport Refrigeration Units

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2311 Wilson Boulevard, Suite 400
Arlington, VA 22201, USA
www.ahrinet.org
PH 703.524.8800
FX 703.562.1942

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Note:

This standard supersedes AHRI Standard 1110-2006.
Approved as an American National Standard (ANS) on 1 October 2013.
AHRI withdrew support of ANS on 23 November 2022.

For SI ratings, see AHRI Standard 1111-2013 (SI).

The AHRI Mechanical Transport Refrigeration (TR) Certification Program will certify only to AHRI Standard 1110 (I-P)-2013. AHRI Standard 1111 (SI)-2013 will not be used for the TR Certification Program.

AHRI CERTIFICATION PROGRAM PROVISIONS

Refer to the Mechanical Transport Refrigeration Unit Certification Program Operational Manual, OM-1110, for the governing policies of the Certification Program.

Certified Ratings

The following certification program ratings are verified by test:

1. High Temperature Cooling Capacity, Btuh
2. Low Temperature Cooling Capacity, Btuh
3. Electric Standby High Temperature Cooling Capacity, Btuh
4. Electric Standby Low Temperature Cooling Capacity, Btuh

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PERFORMANCE RATING OF MECHANICAL TRANSPORT REFRIGERATION UNITS

Section 1. Purpose

1.1 *Purpose*. The purpose of this standard is to establish for Mechanical Transport Refrigeration Units: definitions; test requirements; rating requirements; minimum data requirements for Published Ratings; operating requirements; marking and nameplate data; and conformance conditions.

1.1.1 *Intent.* This standard is intended for the guidance of the industry, including manufacturers, engineers, installers, contractors and users.

1.1.2 *Review and Amendment*. This standard is subject to review and amendment as technology advances.

Section 2. Scope

2.1 *Scope*. This standard applies to encased direct expansion vapor compression type Mechanical Transport Refrigeration Units with the following components:

2.1.1 Compressor
2.1.2 Air-cooled condenser
2.1.3 Refrigerant flow control(s)
2.1.4 Forced-Circulation Air-Cooler
2.1.5 Base or frame
2.1.6 Prime Mover as described in the unit manufacturer's literature
2.1.7 Power Train (coupling, power take-off, transmission, V-belt drive, etc.) connecting the unit to the Prime Mover

Section 3. Definitions

All terms in this document will follow the standard industry definitions in the ASHRAE Wikipedia website (http://wiki.ashrae.org/index.php/ASHRAEwiki) unless otherwise defined in this section.

3.1 *Ambient Air*.

3.1.1 The air surrounding the vehicle served by the Mechanical Transport Refrigeration Unit.
3.1.2 The air in the test enclosure surrounding the Calibrated-Box, per the calibrated-box method of testing.
3.1.3 The air surrounding the engine-condenser side of a Mechanical Transport Refrigeration Unit, per the isothermal-box method of testing.

3.2 *Calorimeter*. A test facility consisting of one or two rooms, which may have an annular space(s); each equipped with instrumented reconditioning equipment. The output of this equipment is measured and controlled to counterbalance the Net Refrigerating Capacity of the Mechanical Transport Refrigeration Unit under test.

3.2.1 *Calibrated-Box.* A well-insulated enclosure, with a known heat transfer rate determined through calibration, which is used for measuring the heat loss or gain between the enclosure's interior temperature and ambient temperature. The area surrounding the entire exterior of the Calibrated-Box is maintained at the rated ambient air temperature.

3.2.2 *Isothermal-Box*. A well-insulated enclosure, with a known heat transfer rate determined through calibration, which is used for measuring the heat loss or gain between the enclosure's interior temperature and ambient temperature. The area surrounding the Isothermal-Box is divided into a Surround Area and an ambient space. The Surround Area is maintained at the rated return air temperature to the Forced-Circulation Air-Cooler, while the ambient space is maintained at the rated ambient air temperature.

3.3 *Forced-Circulation Air-Cooler*. A factory-made assembly including means for forcing air circulation and components where heat is transferred from air to refrigerant. The purpose of this unit is to transfer heat from a refrigerated space, through

the medium of air, to the refrigerant.

3.4 *High-Temperature Service*. Service requiring the maintenance of air temperature at a value of 25°F or above in the refrigerated compartment of the vehicle typically transporting non-frozen product.

3.5 *Low-Temperature Service*. Service requiring the maintenance of air temperature at a value below 25°F in the refrigerated compartment of the vehicle typically transporting frozen product.

3.6 *Mechanical Transport Refrigeration Unit*. A combination of one or more of the following factory-made assemblies:

3.6.1 A compressor, drive, and condenser combination
3.6.2 A Forced-Circulation Air-Cooler
3.6.3 All necessary refrigerant lines and electrical wiring
3.6.4 Means whereby the unit can be suitably mounted and installed on a vehicle which it is intended to serve.

Where such equipment is used in more than one assembly, the individual assemblies are designed to be used together, and the requirements of rating outlined in this standard are based on the use of matched assemblies.

3.7 *Net Refrigerating Capacity*. The rate of heat transferred from the air in the refrigerated space to the refrigerant circulated through the Forced-Circulation Air-Cooler, less heat added by the fan and drive, and other sources, in operation under specified conditions. It is the net refrigerating effect available for useful cooling.

3.8 *Observation*. A specific instance in time where measurements are recorded.

3.9 *Power Train*. A mechanical device whereby power received from a primary source of power at a given rotating speed is transferred to a driven device at the same or a different rotating speed.

3.9.1 *Power Train Ratio*. The ratio of the rotating speed at which power is delivered to the driven device, to the rotating speed at which power is received from the primary source.

3.10 *Prime Mover*. An engine, motor or similar device that drives a refrigeration system at a known speed.

3.11 *Published Rating*. A statement of the assigned values of those performance characteristics, under stated Rating Conditions, by which a unit may be chosen to fit its application. These values apply to all units of like nominal size and type (identification) produced by the same manufacturer. The term Published Rating includes the rating of all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated Rating Conditions.

3.11.1 *Application Rating.* A rating based on tests performed at application Rating Conditions (other than Standard Rating Conditions).

3.11.2 *Standard Rating.* A rating based on tests performed at Standard Rating Conditions.

3.11.3 *Standby Rating*. A Published Rating based on using a standby power source and tests performed under Standard Rating Conditions or application Rating Conditions.

3.12 *Rating Conditions*. Any set of operating conditions under which a single level of performance results and which causes only that level of performance to occur.

3.12.1 *Standard Rating Conditions*. Rating Conditions used as the basis of comparison for performance characteristics.

3.13 "*Shall*" *or* "*Should.*" "Shall" or "should" shall be interpreted as follows:

3.13.1 *Shall*. Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

3.13.2 *Should.* "Should" is used to indicate provisions which are not mandatory but are desirable as good practice.

3.14 *Standby Drive*. A device included in a Mechanical Transport Refrigeration Unit, which receives power from a source external to the vehicle served. The unit may operate to refrigerate the vehicle while it is at rest.

3.15 *Surround Area.* The enclosure about the Isothermal-Box.

3.16 *Test Nominal Condition.* The reading that is taken at the initial Observation of the test and is used as a basis of reference for all subsequent observations.

3.16.1 *Ambient Nominal Condition.* The reference temperature for the ambient space of the Calibrated-Box or Isothermal-Box. It is taken as the arithmetic average of the individual temperature measurement stations within the ambient space at the initial Observation of the test.

3.16.2 *Box Nominal Condition.* The reference temperature for the interior of the Calibrated-Box or Isothermal-Box. It is taken as the arithmetic average of the individual temperature measurement stations within the Calibrated-Box or Isothermal-Box at the initial Observation of the test.

3.17 *Unit-Mounting*. Types of mountings for Mechanical Transport Refrigeration Units are:

3.17.1 *Nose-Mounted.* A Mechanical Transport Refrigeration Unit in which the condensing unit is mounted on the external front wall of the refrigerated compartment.

3.17.2 *Under-Mounted.* A Mechanical Transport Refrigeration Unit in which the condensing unit is mounted externally on the bottom of the refrigerated compartment.

Section 4. Test Requirements

4.1 *Test Requirements*. Mechanical Transport Refrigeration Units shall be tested for the rated Net Refrigerating Capacity in accordance with one of the two methods set forth in Appendix C and Appendix D.

4.2 *All-Electric Unit*. When the unit being tested includes an engine-generator set in conjunction with an electric drive, the space in which the engine-generator set is located shall be maintained at the same ambient condition as the condensing section of the Mechanical Transport Refrigeration Unit.

Section 5. Rating Requirements

5.1 *Standard Ratings*. Standard Ratings shall be published for the Standard Rating Conditions specified in Table 1. All Standard Ratings shall be verified by tests conducted in accordance with one of the two test methods described in Appendix C and Appendix D.

Table 1. Standard Rating Conditions

Standard Rating	Return Air Temperature to Forced-Circulation Air-Cooler	Entering Air Temperature to Condenser
	°F	°F
High Temperature	35.0	100.0
Low Temperature	0.0	100.0
NOTE: The unit shall be rated at a compressor driven speed in accordance with manufacturer's recommended high speed setting ± 50 rpm.		

5.1.1 *Values of Standard Ratings*. Standard Ratings at or below 10,000 Btuh shall be Net Refrigerating Capacity and shall be expressed only in terms of Btuh in multiples of 100 Btuh. Standard ratings above 10,000 Btuh shall be Net Refrigerating Capacity and shall be expressed only in terms of Btuh in multiples of 500 Btuh.

5.2 *Application Ratings*. Application Ratings shall be expressed in the same terms as Standard Ratings and shall be accompanied by pertinent conditions.

5.3 *Standby Ratings*. When an electric Standby Drive is provided, the unit shall be rated in accordance with this standard. The nameplate voltage and frequency of the standby drive motor is measured at the unit's service connection and under Standard Rating Conditions.

5.4 *System Requirements.*

5.4.1 *Compressor*. For all tests, the compressor shall be operated at a rotating speed in accordance with the manufacturer's recommended high speed operational setting. During the test, operating speed shall not vary by more than ± 50 rpm.

5.4.1.1 For an electrically driven compressor, the frequency tolerance shall be in compliance with the rotational tolerance in Section 5.4.1

5.4.2 *Condensing Unit*. Any engine or motor hoods, cabinets, louvers, wind deflectors, dampers, fan guards, coil guards, and other furnished components and equipment specified by the manufacturer shall be used during the test. These components shall be installed in accordance with the manufacturer's instructions.

5.4.3 *Refrigerant*. The unit shall be charged with the refrigerant type and the charge amount as shown on the unit's nameplate. The unit shall be charged in accordance with the manufacturer's published instructions.

5.4.4 *Refrigerant Flow Control(s)*. Refrigerant flow control(s) used during the test shall be the same as that furnished by the manufacturer. It shall be operated at the manufacturer's specified setting.

5.4.5 *Forced-Circulation Air-Cooler*. Any nozzles, diffusers, cowls, deflecting vanes and other furnished components and equipment shall be used during the test. These components shall be installed in accordance with the manufacturer's published installation instructions. Under zero external static pressure, tests shall be on completely assembled units with fans operating at normal speed.

5.4.6 *Split Systems*. For testing purposes, split systems shall be connected by the following minimum lengths of refrigerant tubing and fittings of a type and size furnished or recommended for installation:

5.4.6.1 Under-Mounted:25 ft
5.4.6.2 Nose-Mounted: 7 ft

5.5 *Tolerance*. To comply with this standard, measured Net Refrigerating Capacity at rating conditions shall not be less than 95% of published capacity ratings.

Section 6. Minimum Data Requirements for Published Ratings

6.1 *Minimum Data Requirements for Published Ratings.* As a minimum, Published Ratings shall include all Standard Ratings. All claims to ratings within the scope of this standard shall include the statement "Rated in accordance with ANSI/AHRI Standard 1110 (I-P)." All claims to ratings outside the scope of this standard shall include the statement "Outside the scope of ANSI/AHRI Standard 1110 (I-P)." Wherever Application Ratings are published or printed, they shall include a statement of the conditions at which the ratings apply.

6.2 Each Published Rating of Mechanical Transport Refrigeration Units shall include, or be accompanied by the following information:

6.2.1 Model number
6.2.2 Net Refrigerating Capacity, Btuh
6.2.3 Refrigerant designation(s) in accordance with ANSI/ASHRAE Standard 34 with Addenda
6.2.4 Compressor speed, rpm

Section 7. Operating Requirements

7.1 *Start Test.* This test shall be performed using the components furnished by the manufacturer. The Mechanical Transport Refrigeration Unit shall operate in its normal mode throughout the test. All system components shall be soaked at an ambient of 100.0 ± 2.0°F for a period of not less than two hours. The unit shall be operated for a period of one hour, after which the unit shall be interrupted for five minutes and then restarted. During the test, the condenser entering air temperature shall be maintained at 100.0 ± 2.0°F. The air temperature entering the Forced-Circulation Air-Cooler shall be maintained within the temperature range of 100.0°F to 80.0°F while the unit is in operation, and shall not be less than 80.0°F for the restart. Upon restart, the unit shall be operated for an additional hour, interrupted for five minutes, and a second restart shall be attempted. If the unit successfully restarts for a second time, the unit has passed the requirement of the test.

7.1.1 *Electric Standby Drives and All-Electric Units.* On electric Standby Drives and all-electric Mechanical Transport Refrigeration Units, the entire start test shall be conducted at 90% of unit nameplate voltage as measured at the unit's service connection.

7.2 *Continuous Operation*. Under prime mover and standby drive operation, the unit shall be capable of one hour of continuous refrigeration with the return air temperature to the Forced-Circulation Air-Cooler maintained at 70.0°F ± 1.0°F. The Ambient Air entering the condenser shall be maintained at 120.0°F ± 2.0°F. Automatic methods of limiting power input are permissible under this requirement.

Section 8. Marking and Nameplate Data

8.1 *Marking and Nameplate Data.* As a minimum, the nameplate shall include:

8.1.1 Manufacturer's model designation
8.1.2 Manufacturer's serial number
8.1.3 Refrigerant designation(s) per ANSI/ASHRAE Standard 34 with Addenda and operating charge, lb
8.1.4 Standby drive electrical data, if applicable: voltage, V; current, A; frequency, Hz; phase.

Nameplate voltages for 60 Hz systems shall include one or more of the equipment nameplate voltage ratings shown in Table 1 of ANSI/AHRI Standard 110. Nameplate voltages for 50 Hz systems shall include one or more of the utilization voltages shown in Table 1 of IEC Standard 60038.

Section 9. Conformance Conditions

9.1 *Conformance.* While conformance with this standard is voluntary, conformance shall not be claimed or implied for products or equipment within the standard's *Purpose* (Section 1) and *Scope* (Section 2) unless such product claims meet all of the requirements of the standard, and all of the testing and rating requirements are measured and reported in complete compliance with the standard. Any product that has not met all the requirements of the standard shall not reference, state, or acknowledge the standard in any written, oral, or electronic communication.

APPENDIX A. REFERENCES - NORMATIVE

A1 Listed here are all standards, handbooks and other publications essential to the formation and implementation of this standard. All references in this appendix are considered as part of the standard.

A1.1 ANSI/AHRI Standard 110-2012, *Air-Conditioning, Heating and Refrigerating Equipment Nameplate Voltages*, 2012, Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Blvd., Suite 500, Arlington, VA 22201, U.S.A.

A1.2 ANSI/ASHRAE Standard 34-2010 with Addenda, *Designation and Safety Classification of Refrigerants*, 2010, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

A1.3 ANSI/ASHRAE Standard 41.1-2006, *Standard Method for Temperature Measurement*, 2006, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

A1.4 ANSI/ASHRAE Standard 41.3-1989, *Standard Method for Pressure Measurement*, 1989, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

A1.5 *ASHRAEwiki, Terminology*. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc, Web. 21 Sept. 2012 <http://wiki.ashrae.org/>

A1.6 IEC Standard 60038, *IEC Standard Voltages*, 2009, International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

APPENDIX B. REFERENCES - INFORMATIVE

None.

APPENDIX C. CALIBRATED-BOX METHOD OF TESTING FOR RATING MECHANICAL TRANSPORT REFRIGERATION UNITS – NORMATIVE

C1 *Purpose.* The purpose of this appendix is to provide a method of testing for Mechanical Transport Refrigeration Units using the calibrated-box method**.**

C2 *Scope.* The test method provided in this appendix is for use with Mechanical Transport Refrigeration Units. It shall be used for both Standard and Application Ratings.

C2.1 *Exclusions.* This appendix is not applicable to field tests.

C3 *Measuring Instrumentation Requirements.*

C3.1 *Temperature Measuring Instruments*. Temperature measurements shall be made in accordance with ANSI/ASHRAE Standard 41.1.

C3.2 *Pressure Measuring Instruments*. Pressure measurements shall be made in accordance with ANSI/ASHRAE Standard 41.3.

C3.3 *Electrical Measuring Instruments*. Electrical measurements shall be made with integrating-type instruments.

C3.3.1 *Accuracy*. Instruments measuring the electrical input to heater, fan motors, and miscellaneous devices, if used, shall be accurate within 1.0% of the reading.

C3.4 *Time Measurements*. Time measurements shall be made with apparatus whose accuracy is within 0.2 % of the time interval being measured.

C3.5 *Revolution Measurements*. Revolution measurements shall be made with apparatus whose accuracy is within 1.0% of the measured speed.

C4 *General Test Data*. The following data shall be recorded for each unit tested where applicable:

- **C4.1** Manufacturer - name and address
- **C4.2** Location of test facility - company name and address
- **C4.3** Date of test run
- **C4.4** Observers - responsible engineer and technicians
- **C4.5** Designation of unit
  - **C4.5.1** Model number
  - **C4.5.2** Serial number
- **C4.6** Refrigerant designation(s) per ANSI/ASHRAE Standard 34 with Addenda and operating charge, lb
- **C4.7** Prime mover data
  - **C4.7.1** Type (internal combustion, electric motor, other) and model designation
  - **C4.7.2** Prime mover rotational speed, rpm
  - **C4.7.3** Voltage, V; current, A; frequency, Hz; phase
  - **C4.7.4** Fuel
- **C4.8** Condensing unit data
  - **C4.8.1** Compressor make, model number and rotational speed, rpm
  - **C4.8.2** Type of fan drive
  - **C4.8.3** Fan-motor power, hp
  - **C4.8.4** Fan-motor electrical data: voltage, V; current, A; frequency, Hz; phase
- **C4.9** Forced-circulation air-cooler data
  - **C4.9.1** Type of fan drive
  - **C4.9.2** Fan-motor power, hp
  - **C4.9.3** Fan-motor voltage, V; current, A; frequency, Hz; phase

C5 *Calibrated-Box Method*. This method determines the Net Refrigerating Capacity of the Mechanical Transport Refrigeration Unit by measuring the total heat input into the Calibrated-Box (Figure C1) which is the sum of the electrical heat added to the box, and the heat leakage into the box from the ambient space. The calibrated-box heat transfer constant is determined in the calibration test (Section C5.2). In no case, shall the heat leakage into the Calibrated-Box exceed 30.0 % of the Net Refrigerating Capacity of the unit being tested.

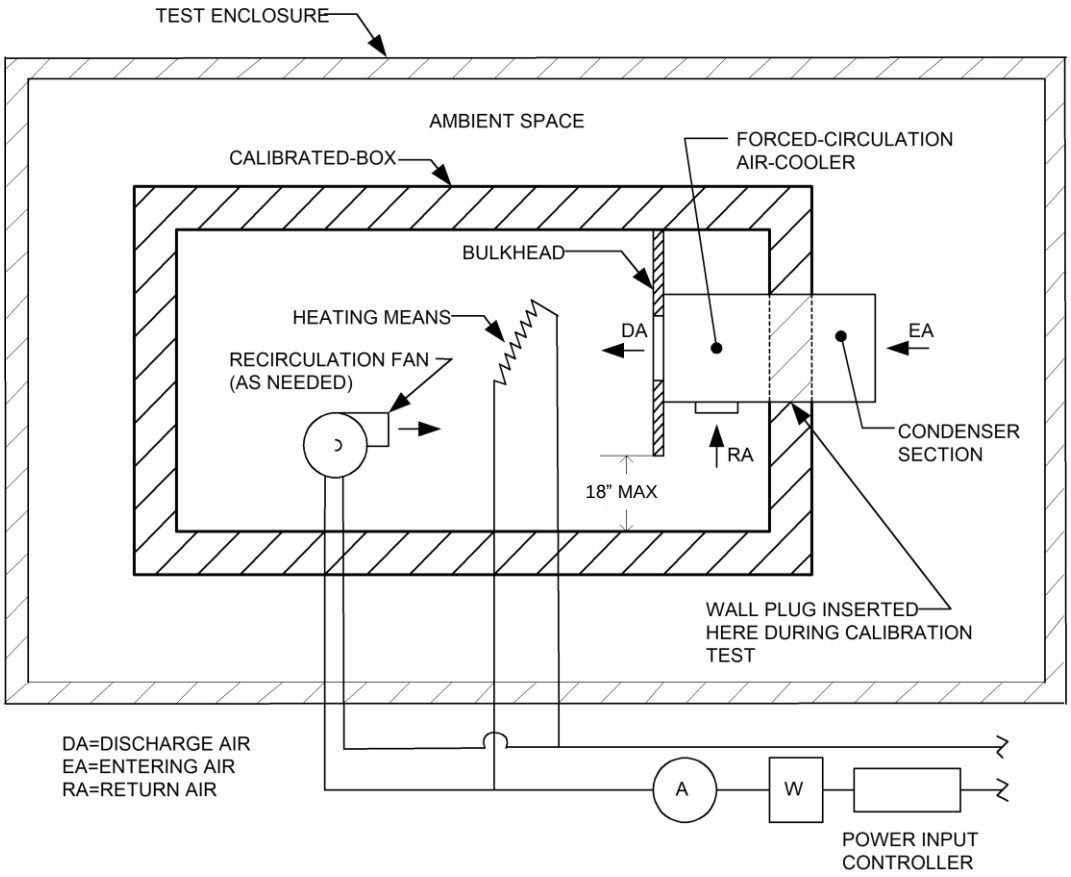

Figure C1. Calibrated Box Test Setup Schematic

C5.1 *Apparatus Setup for Calibration Test.*

C5.1.1 The Calibrated-Box shall be installed in a test enclosure of a size that will provide adequate clearance at all sides, the top, and the bottom of the Calibrated-Box to ensure uniformity of the air temperature.

C5.1.2 A wall plug of equal insulating value to the Calibrated-Box shall fill the opening in the box provided for the insertion of the Mechanical Transport Refrigeration Unit during the capacity test (Figure C1).

C5.1.3 Sensors for measuring the controlled Ambient Air shall be located in the ambient space 6.0 in from the center of each surface of the Calibrated-Box (Figure C2). Temperature-sensing elements shall be shielded against radiation. No attempt is to be made to simulate wind or airflow conditions due to the motion of the vehicle for which the equipment is intended.

C5.1.4 Means for circulating conditioned air throughout the ambient space to maintain steady-state conditions per Section C5.2 shall be provided.

C5.1.5 Sensors for measuring the air temperature within the Calibrated-Box shall be located at eight stations one-fourth of the length, one-fourth of the width, and one-fourth of the height of the box from each side of the box (Figure C3).

C5.1.6 An electric fan, if needed, shall be located within the Calibrated-Box to circulate air and maintain steady-state conditions per Section C5.2 (Figure C1).

C5.1.7 A heating means shall be provided within the Calibrated-Box in a manner to prevent radiation to the calibrated-box walls or to any of the temperature measuring sensors (Figure C3). This heating means shall be operated to establish and maintain steady-state conditions per Section C5.2.

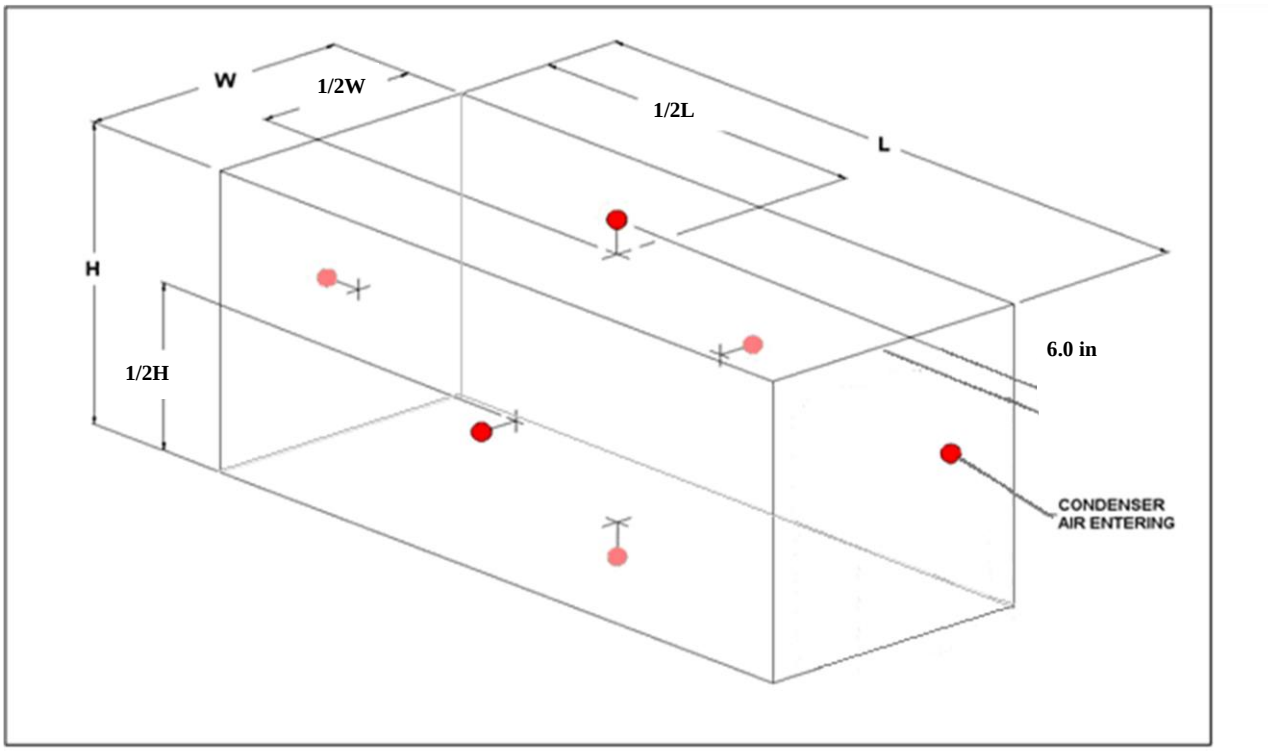

Figure C2. Ambient Area Temperature Measuring Station Location Diagram

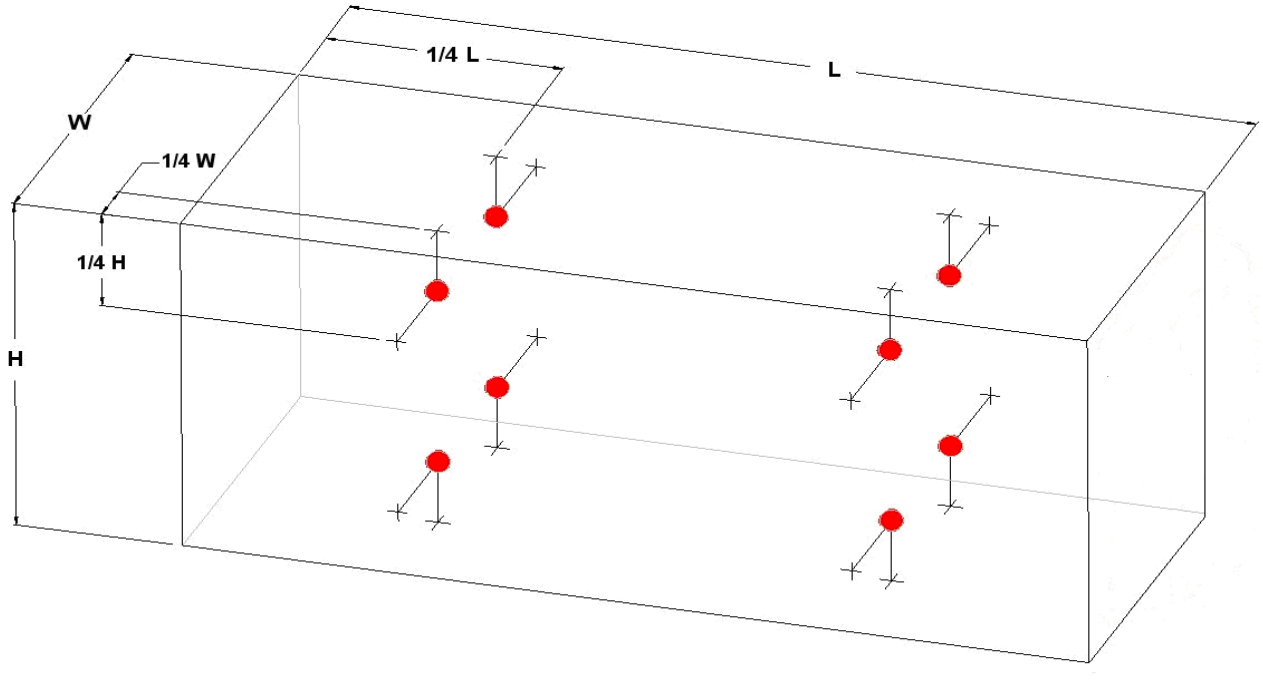

Figure C3. Calibrated-Box Temperature Measuring Station Location Diagram

C5.2 *Calibration of Calibrated-Box Calorimeter*. The calibration of the Calibrated-Box consists of obtaining the heat transfer constant through the walls between the Calibrated-Box and the ambient space. At least one calibration test shall be performed annually using the following procedure:

a. The test facility shall be operated such that the Ambient Air is cooled relative to the interior of the Calibrated-Box. The calculated temperature difference between the average internal calibrated-box temperature and the average ambient air temperature shall not be less than 75.0°F. The system shall be operated and maintained at this condition for at least 5 hours.
b. After satisfying the requirements of Section C5.2.1, temperature readings at the locations of Section C5.1.3 and Section C5.1.5 shall be taken at 15-minute intervals. Nine consecutive observations over a two-hour period (per Section C5.2.1) shall be considered a sufficient test.
c. Also during this two-hour period, the electric power input to the heating means, fan motor(s), and other miscellaneous devices, if used, located within the Calibrated-Box shall be measured. These readings should be taken simultaneously with the temperature readings but shall be taken at the beginning and end of the two-hour period.
d. Calculation of the heat transfer constant of the Calibrated-Box is determined from the steady-state data recorded per Section C7.1.

C5.2.1 *Steady-State Conditions and Test Tolerances for Calibrated-Box Calibration Test.* Steady-state conditions for the calibration test shall be achieved when all of the following conditions are satisfied (Table C1):

C5.2.1.1 The average of the ambient air temperatures recorded at each Observation shall be ± 2.0°F of the Ambient Nominal Condition.
C5.2.1.2 The temperature difference between any two ambient air temperature measurement stations shall not exceed 4.0°F at a specific Observation.
C5.2.1.3 The average of the calibrated-box temperatures recorded at each Observation shall be ± 1.0°F of the Box Nominal Condition.
C5.2.1.4 The temperature difference between any two temperature measurement stations within the Calibrated-Box shall not exceed 2.5°F at a specific Observation.

Table C1. Calibrated-Box Test Tolerances

Readings	Calibration Test Tolerances	Capacity Test Tolerances
	°F	°F
Ambient Temperatures		
Deviation of Average from Ambient Nominal Condition	±2.0	±2.0
Between Any Two Stations (max-min)	4.0	6.0
Calibrated-Box Temperatures		
Deviation of Average from Box Nominal Condition	±1.0	±1.0
Between Any Two Stations (max-min)	2.5	6.0
Air-Cooler Return Temperature		
Deviation of Average from Rated Condition		±1.0
Between Any Two Stations (max-min)		3.0
Condenser Entering Air Temperature		
Deviation of Average from Rated Condition		±2.0

C5.3 *Mechanical Transport Refrigeration Unit Installation Setup for Capacity Test*. The wall plug used during calibration shall be removed, and the Mechanical Transport Refrigeration Unit shall be inserted into the Calibrated-Box (Figure C1). The Mechanical Transport Refrigeration Unit shall be installed per the manufacturer's standard installation instructions.

C5.4 *Apparatus Setup for Capacity Test.* In addition to the apparatus used in the calibration test (Section C5.1), the following shall be required to perform the capacity test:

C5.4.1 A minimum of eight individual temperature stations shall be equally spaced, by area, along the condenser air inlet of the Mechanical Transport Refrigeration Unit. When using thermocouples for this purpose, a "grid" i.e., parallel wiring of the sensors is acceptable.

C5.4.1.1 For Nose-Mounted, the average temperature of these stations shall denote the ambient air temperature for that surface of the Calibrated-Box.

C5.4.1.2 For Under-Mounted and split systems, the average temperature of the six stations (Section C5.1.3) located about the surface of the Calibrated-Box shall denote the ambient air temperature.

C5.4.2 The return air to the Forced-Circulation Air-Cooler shall be directed by a bulkhead separating discharge air from return air. This bulkhead shall frame the discharge air opening, extend from side to side of the Calibrated-Box, and extend from the ceiling of the Calibrated-Box to not more than 18 in from the floor of the Calibrated-Box (Figure C1). Sensors for measuring the forced-circulation air-cooler return air temperature shall be located at not less than eight individual stations at the return air opening and equally spaced by area. These temperature sensors shall be shielded against moisture and radiation.

C5.5 *Conducting Capacity Test by Calibrated-Box Method of Test.* The Mechanical Transport Refrigeration Unit shall be started. The average forced-circulation air-cooler return air temperature and average condenser entering air temperature shall be maintained at the Standard Rating Conditions. Data shall be recorded per Section C5.5.1 at 15-minute intervals until nine consecutive sets of data (2-hour period) indicate that steady-state conditions have been achieved.

C5.5.1 *Data to Be Recorded*. For each unit tested, complete data shall be recorded in accordance with Section C4 and Section C5.5:

C5.5.1.1 At the beginning of each capacity test cycle, the following shall be recorded:

a. Date of most recent calibration test
b. Heat transfer constant of Calibrated-Box determined by most recent calibration test, Btuh·°F

C5.5.1.2 At the beginning of each capacity test, and at 15-minute intervals thereafter, the following shall be recorded:

a. Time of Observation
b. Ambient air temperature, each station, °F
c. Calibrated-box temperature, each station, °F
d. Total energy input from variable electric heater; calibrated-box recirculation fan motor(s); miscellaneous devices, if used, W-hr
e. Compressor discharge pressure, psig or psia
f. Compressor suction pressure, psig or psia
g. Temperature of discharge gas leaving compressor, °F
h. Temperature of liquid entering expansion device, °F
i. Temperature of suction gas leaving evaporator coil, °F
j. Temperature of suction gas entering compressor, °F

C5.5.1.3 At the end of each capacity test cycle, record the following:

a. Speed of air-cooler fan(s), rpm
b. Speed of condenser fan(s), rpm
c. Compressor rotational speed, rpm
d. Prime mover rotational speed, rpm

C5.5.2 *Steady-State Conditions and Test Tolerances for Calibrated-Box Capacity Test.* Steady-state conditions for the capacity test shall be achieved when all of the following conditions are satisfied (Table C1):

C5.5.2.1 The average of the ambient air temperatures recorded at each Observation shall be within ± 2.0°F of the Ambient Nominal Condition.

C5.5.2.2 The temperature difference between any two ambient air temperature measurement stations shall not exceed 6.0°F at a specific Observation.

C5.5.2.3 The average of the calibrated-box temperatures recorded at each Observation shall be within ±1.0°F of the Box Nominal Condition.

C5.5.2.4 The temperature difference between any two temperature measurement stations within the Calibrated-Box shall not exceed 6.0°F at a specific Observation.
C5.5.2.5 The average forced-circulation air-cooler return air temperatures recorded at a specific Observation shall be within ± 1.0°F of the Rating Condition.
C5.5.2.6 The temperature difference between any two temperature measurement stations of the forced-circulation air-cooler return air temperature shall not exceed 3.0°F at a specific Observation.
C5.5.2.7 The average condenser entering air temperature recorded at a specific Observation shall be within ± 2.0°F of the Rating Condition.

C6 *Allowable Adjustments*.

C6.1 *Expansion Valve Adjustment*. In the event that it is desired to change the super-heat setting of the expansion valve(s) as received from the manufacturer, it shall be permissible to make an adjustment to the valve(s) as recommended by the manufacturer's printed instructions. Once properly adjusted, all tests shall be conducted at this setting.
C6.2 *Pressure Regulator*. If suction pressure is not within the published range, the pressure regulator shall be adjusted per manufacturer's instructions. Once properly adjusted, all tests shall be conducted at this setting.

C7 *Calibrated-Box Calorimeter Calculations.*

C7.1 *Heat Addition Calculation for Calibrated-Box.* The heat addition to the Calibrated-Box during the calibration test, Q, is equal to the electrical energy consumed by the variable electric heater(s), recirculation fan motor(s), and miscellaneous devices in operation during the calibration test.

$$Q_c = X \cdot (E/t) \qquad \text{C1}$$

Where:
c = Calibration
E = Electric energy input from heaters, fan motor(s), and miscellaneous devices, W·h
Q = Heat addition to the Calibrated-Box, Btuh
t = Time, h
X = A conversion constant
= 3.413 Btu/W·h

C7.2 *Calibration Calculation for Calibrated-Box.* The heat transfer constant of the Calibrated-Box, UA, is the heat addition divided by the time averaged temperature difference between the interior and exterior conditions.

$$UA = \frac{Q_c}{(\overline{T}_i - \overline{T}_o)_c} \qquad \text{C2}$$

Where:
i = Inside of the Calibrated-Box
o = Outside of the Calibrated-Box, ambient
$\overline{T}$ = Time averaged air temperature, °F
UA = Heat transfer constant, Btu/ h · °F

C7.3 *Heat Addition Calculation for Steady-State Conditions.* The heat addition to the Calibrated-Box during steady-state conditions, Q_s, is equal to the electric energy consumed by the variable electric heaters(s), recirculation fan motor(s), and miscellaneous devices in operation during the test.

$$Q_s = X \cdot (E/t) \qquad \text{C3}$$

Where:
s = Steady-state

C7.4 *Net Refrigeration Capacity Calculation.* When steady-state conditions have been achieved, the Net

Refrigeration Capacity, Q_n, is equal to the sum of the heat addition to the Calibrated-Box and the heat transfer constant multiplied by the time averaged temperature difference between the interior and exterior conditions.

$$Q_n = Q_s + UA(\overline{T}_o - \overline{T}_i)_s \quad \text{C4}$$

Where:
n = Net

C7.5 *Calculation of Test Results*. Calculations are based on the arithmetic mean values of readings recorded during tests under stable conditions.

APPENDIX D. ISOTHERMAL-BOX METHOD OF TESTING FOR RATING MECHANICAL TRANSPORT REFRIGERATION UNITS - NORMATIVE

D1 *Purpose.* The purpose of this appendix is to provide a method of testing for Mechanical Transport Refrigeration Units using the isothermal-box method**.**

D2 *Scope.* The test method provided in this appendix is for use with Mechanical Transport Refrigeration Units. It shall be used for both Standard and Application Ratings.

D2.1 *Exclusions.* This appendix is not applicable to field tests.

D3 *Measuring Instrumentation Requirements.*

D3.1 *Temperature Measuring Instruments*. Temperature measurements shall be made in accordance with ANSI/ASHRAE Standard 41.1.

D3.2 *Pressure Measuring Instruments*. Pressure measurements shall be made in accordance with ANSI/ASHRAE Standard 41.3.

D3.3 *Electrical Measuring Instruments*. Electrical measurements shall be made with integrating-type instruments.

D3.3.1 *Accuracy*. Instruments measuring the electrical input to heating means, fan motors, and miscellaneous devices, if used, shall be accurate within 1.0% of the reading.

D3.4 *Time Measurements*. Time measurements shall be made with apparatus whose accuracy is within 0.2% of the time interval being measured.

D3.5 *Revolution Measurements*. Revolution measurements shall be made with apparatus whose accuracy is within 1.0% of the measured speed.

D4 *General Test Data*. The following data shall be recorded for each unit tested where applicable:

- **D.4.1** Manufacturer - name and address
- **D.4.2** Location of test facility - company name and address
- **D.4.3** Date of test run
- **D.4.4** Observers - responsible engineer and technicians
- **D.4.5** Designation of unit
  - **D.4.5.1** Model number
  - **D.4.5.2** Serial number
- **D.4.6** Refrigerant designation(s) per ANSI/ASHRAE Standard 34 with Addenda and operating charge, lb
- **D.4.7** Prime mover data
  - **D.4.7.1** Type (internal combustion, electric motor, other) and model designation
  - **D.4.7.2** Prime mover rotational speed, rpm
  - **D.4.7.3** Voltage, V; current, A; frequency, Hz; phase
  - **D.4.7.4** Fuel
- **D.4.8** Condensing unit data
  - **D.4.8.1** Compressor make, model number and rotational speed, rpm
  - **D.4.8.2** Type of fan drive
  - **D.4.8.3** Fan-motor power, hp
  - **D.4.8.4** Fan-motor electrical data: voltage, V; current, A; frequency, Hz, phase
- **D.4.9** Forced-circulation air-cooler data
  - **D4.9.1** Type of fan drive
  - **D4.9.2** Fan-motor power, hp
  - **D4.9.3** Fan-motor voltage, V; current, A; frequency, Hz; phase

D5 *Isothermal-Box Method*. This method determines the Net Refrigerating Capacity of the Mechanical Transport

Refrigeration Unit by measuring the total heat input into the Isothermal-Box (Figure D1), which is the sum of the electrical heat added to the box, plus the heat leakage in the box from the ambient space. The isothermal-box heat transfer constant is determined in the calibration test (Section D5.2). In no case shall the heat leakage through the calibrated isothermal wall exceed 5% of the Net Refrigerating Capacity of the unit being tested.

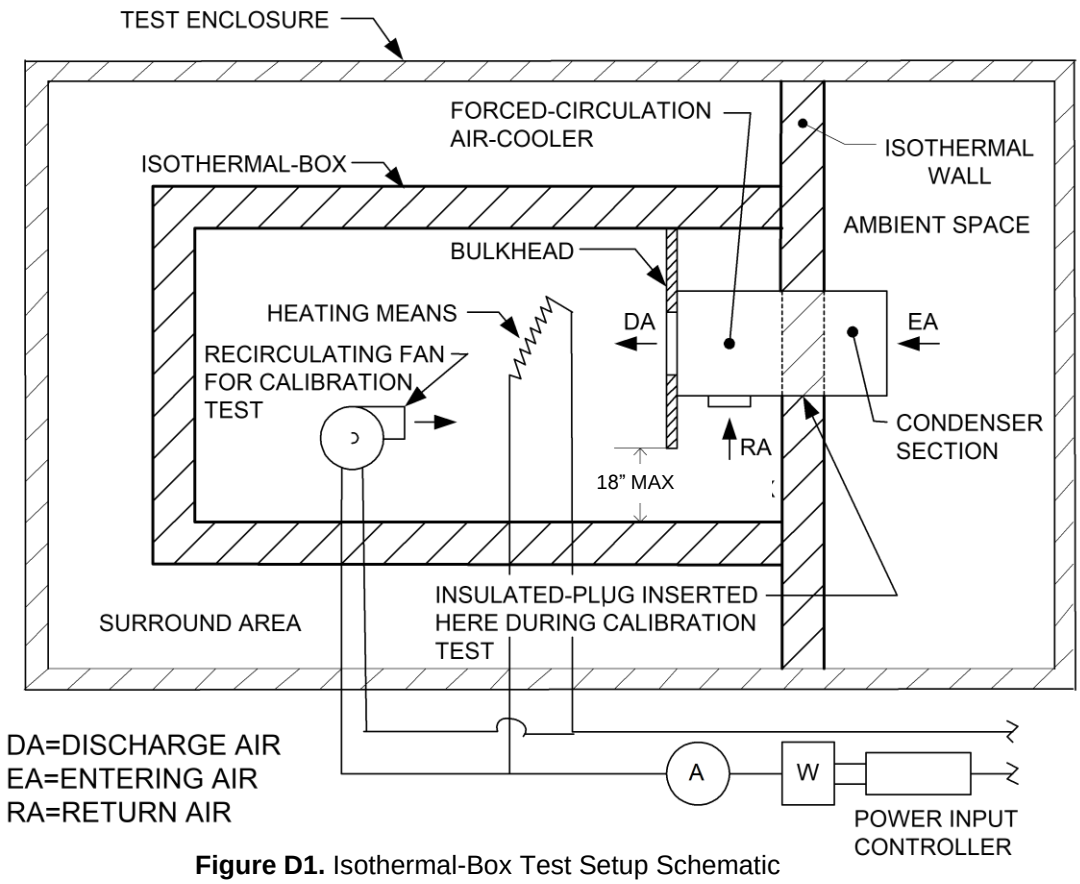

Figure D1. Isothermal-Box Test Setup Schematic

D5.1 *Apparatus Setup for Calibration Test.*

D5.1.1 The Surround Area shall be of sufficient size to provide adequate clearance on all sides of the Isothermal-Box to allow adequate air circulation.

D5.1.2 The enclosure surrounding the engine-condenser side of the Mechanical Transport Refrigeration Unit shall be of sufficient size to allow clearance around the unit for air circulation and temperature measurement. The area surrounding the engine-condenser section of the unit shall be called the ambient space.

D5.1.3 A wall plug of equal insulating value to the isothermal wall shall fill the opening in the isothermal wall provided for the insertion of the Mechanical Transport Refrigeration Unit during the capacity test (Figure D1).

D5.1.4 Sensors for measuring the surround area air temperature shall be located within the Surround Area 6.0 in from the center of each surface of the Isothermal-Box, excluding the surface of the box that is touching the isothermal wall (Figure D2).

D5.1.5 Sensors for measuring the ambient air temperature shall be located within the ambient space 6.0 in from the isothermal wall at points that are equidistant from each side of the insulation plug and each side of the ambient space enclosure. At least one temperature measuring station shall be located at a point in the ambient space that is 6.0 in from the center of the insulation plug.

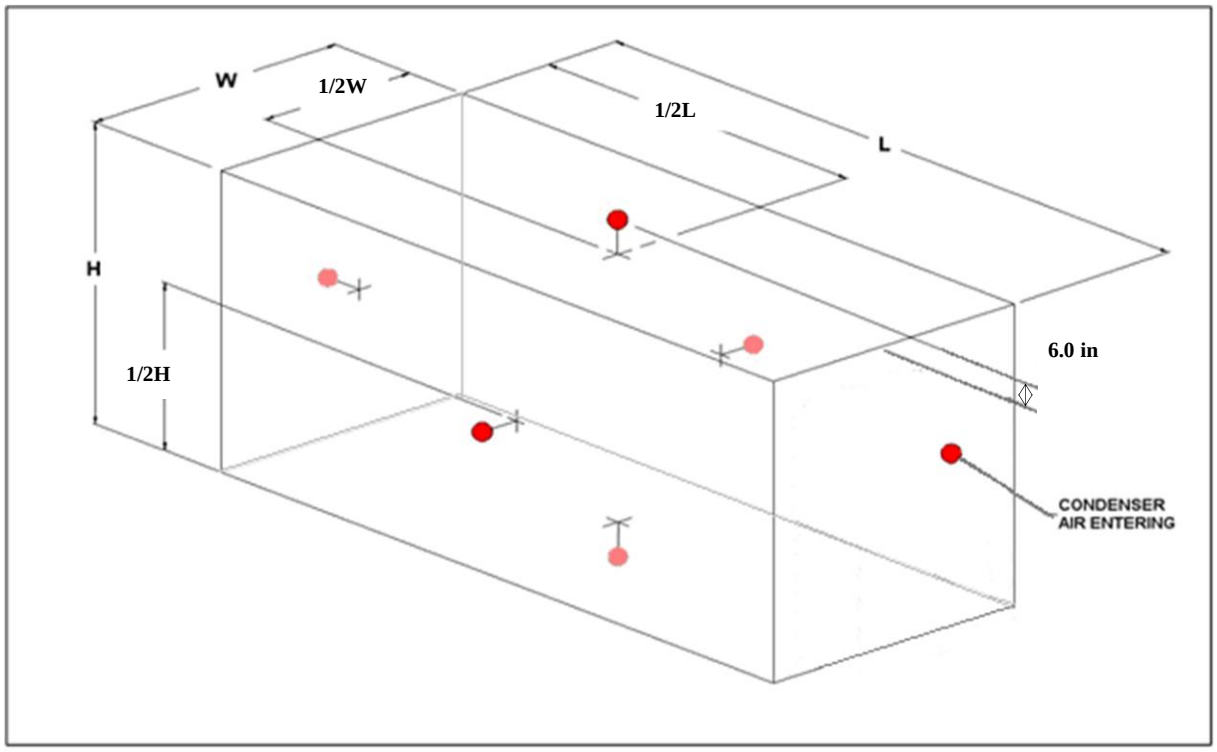

Figure D2. Surround Area Temperature Measuring Station Location Diagram

D5.1.6 Sensors for measuring the air temperature within the Isothermal-Box shall be located at eight stations one-fourth of the length, one-fourth of the width, and one-fourth of the height of the Isothermal-Box (Figure D3).

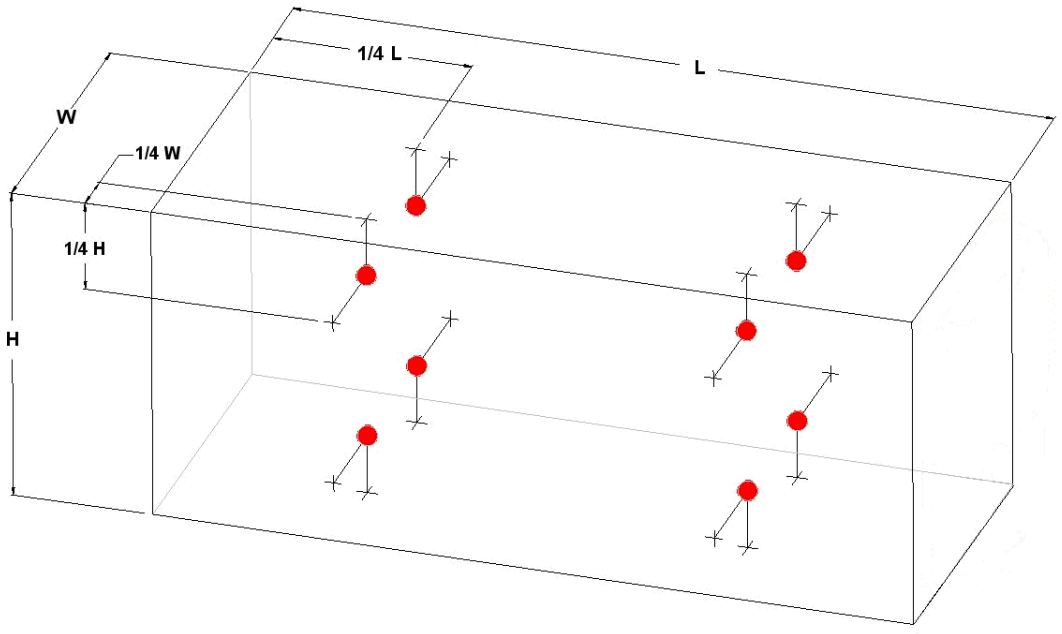

Figure D3. Isothermal-Box Temperature Measuring Station Location Diagram

D5.1.7 An electric fan, if needed, shall be located within the Isothermal-Box to circulate air and maintain steady-state conditions per Section D5.2 (Figure D1).

D5.1.8 A heating means shall be provided within the Isothermal-Box in a manner to prevent radiation to the isothermal-box walls or to any of the temperature measuring sensors (Figure D3). This heating means shall be operated to establish and maintain steady-state conditions per Section D5.2.

D5.2 *Calibration of Isothermal-Box Calorimeter*. The calibration of the Isothermal-Box consists of obtaining the heat transfer constant for the common isothermal wall between the Isothermal-Box and the ambient space. At least one calibration test shall be performed annually using the following procedure:

a. The test facility shall be operated such that the Ambient Air is being cooled relative to the interior of the Isothermal-Box. The calculated temperature difference between the average internal isothermal-box temperature and the average ambient air temperature shall not be less than 75.0°F. The system shall be operated and maintained at this condition for at least 5 hours.

b. After satisfying the requirements of Section D5.2.1, temperature readings at the locations of Section D5.1.4, Section D5.1.5, and Section D5.1.6 shall be taken at 15-minute intervals. Nine consecutive observations over a two-hour period (per Section D5.2.1) shall be considered a sufficient test.

c. Also during this two-hour period, the electrical input to the heater, fan motor(s), lights, and other electrical devices within the Isothermal-Box, shall be measured and all other data necessary shall be recorded to determine the heat leakage through the common isothermal wall between the ambient space and Isothermal-Box (Section D7.1.1). These readings should be taken simultaneously with the temperature readings but shall be taken at the beginning and the end of the two-hour period.

d. Calculation of the heat transfer constant of the Isothermal-Box is determined from the steady-state data recorded per Section D7.1.

D5.2.1 *Steady-State Conditions and Test Tolerances for Isothermal-Box Calibration Test.* Steady-state conditions for the calibration test shall be achieved when all of the following conditions are satisfied (Table D1):

D5.2.1.1 The average of the ambient air temperatures recorded at each Observation shall be within ± 2.0°F of the Ambient Nominal Condition.

D5.2.1.2 The temperature difference between any two ambient air temperature measurement stations shall not exceed 4.0°F at a specific Observation.

D5.2.1.3 The average of the isothermal-box temperatures recorded at each Observation shall be ± 1.0°F of the Box Nominal Condition.

D5.2.1.4 The temperature difference between any two temperature measurement stations within the Isothermal-Box shall not exceed 2.5 F at a specific Observation.

D5.2.1.5 The average of the surround area temperatures recorded at each Observation shall be within ±1.0°F of the Box Nominal Condition.

D5.2.1.6 The temperature difference between any two temperature measurement stations in the surround area space shall not exceed 4.0°F at a specific Observation.

Table D1. Isothermal-Box Test Tolerances		
Readings	Calibration Test Tolerances	Capacity Test Tolerances
	°F	°F
Ambient Temperatures		
Deviation of Average from Ambient Nominal Condition	±2.0	±2.0
Between Any Two Stations (max-min)	4.0	6.0
Isothermal-Box Temperatures		
Deviation of Average from Box Nominal Condition	±1.0	±1.0
Between Any Two Stations (max-min)	2.5	6.0
Surround Area Temperatures		
Deviation of Average from Box Nominal Condition	±1.0	±1.0
Between Any Two Stations (max-min)	4.0	2.5
Air-Cooler Return Temperature		
Deviation of Average from Rated Condition		±1.0
Between Any Two Stations (max-min)		3.0
Condenser Entering Air Temperature		
Deviation of Average from Rated Condition		±2.0

D5.3 *Mechanical Transport Refrigeration Unit Installation Setup for Capacity Test*. The wall plug used during calibration shall be removed, and the Mechanical Transport Refrigeration Unit shall be inserted into the Isothermal-Box (Figure D1). The Mechanical Transport Refrigeration Unit shall be installed per the manufacturer's standard installation instruction.

D5.4 *Apparatus Setup for Capacity Test.* In addition to the apparatus used in the calibration test (Section D5.2), the following shall be required to perform the capacity test:

D5.4.1 A minimum of eight individual temperature stations shall be equally spaced, by area, along the condenser air inlet of the Mechanical Transport Refrigeration Unit. When using thermocouples a "grid" or parallel sensor wiring is acceptable.

D5.4.1.1 For Nose-Mounted, the average temperature of these stations shall denote the ambient air temperature for that surface of the Isothermal-Box.

D5.4.1.2 For Under-Mounted and split systems, the average temperature of the five stations (Section D5.1.5) located about the surface of the isothermal-box wall shall denote the ambient air temperature.

D5.4.2 The forced-circulation air-cooler return air shall be directed by a bulkhead separating discharge air from return air. This bulkhead shall frame the discharge air opening; shall extend from side to side of the Isothermal-Box and extend from the ceiling of the Isothermal-Box to not more than 18 in from the floor of the Isothermal-Box (Figure D1). Sensors for measuring the forced-circulation air-cooler return air temperature shall be located at not less than eight individual stations, located at the return air opening and equally spaced by area. These sensors shall be shielded against moisture and radiation.

D5.5 *Conducting Capacity Test by Isothermal-Box Method*. The Mechanical Transport Refrigeration Unit shall be started. The average isothermal-box temperature and average ambient air temperature shall be brought to the Standard Rating Conditions. The heater in the Isothermal-Box shall be operated to maintain the forced-circulation air-cooler return air temperature at the Standard Rating Conditions. The average surround area temperature shall be controlled within the allowable temperature limit of the average isothermal-box temperature. After satisfying the requirements of Section D5.5.2, data shall be recorded, per Section D5.5.1, at 15-minute intervals until nine consecutive sets of data (2-hour period) indicate that steady-state conditions have been achieved.

D5.5.1 *Data to be Recorded*. For each test run of each unit tested, complete data shall be recorded in accordance with Section D4 and Section D5.5:

D5.5.1.1 At the beginning and end of each capacity test cycle, the following shall be recorded:

a. Date of most recent calibration test
b. Heat transfer constant of Isothermal-Box determined by most recent calibration test, Btu/ h · ºF

D5.5.1.2 At the beginning of each capacity test, and at 15-minute intervals thereafter, the following shall be recorded:

a. Time of Observation
b. Ambient space temperature, each station, °F
c. Isothermal-box temperature, each station, °F
d. Surround area temperature, each station, °F
e. Total power input from variable electric heater; isothermal-box recirculation fan motor(s); miscellaneous devices (such as separate fans, lights, etc.), if used, W
f. Compressor discharge pressure, psig or psia
g. Compressor suction pressure, psig or psia
h. Temperature of discharge gas leaving compressor, °F
i. Temperature of liquid entering expansion device, °F
j. Temperature of suction gas leaving evaporator coil, °F
k. Temperature of suction gas entering compressor, °F

D5.5.1.3 At the end of each capacity test cycle, record the following:

a. Speed of air-cooler fan(s), rpm
b. Speed of condenser fan(s), rpm
c. Compressor rotational speed, rpm
d. Prime mover rotational speed, rpm

D5.5.2 *Steady-State Conditions and Test Tolerances for Isothermal-Box Capacity Test.* Steady state conditions for the capacity test shall be achieved when all of the following conditions are satisfied (Table D1):

D5.5.2.1 The average of the ambient air temperatures recorded at each Observation shall be within ±2.0°F of the Ambient Nominal Condition.

D5.5.2.2 The temperature difference between any two ambient air temperature measurement stations shall not exceed 6.0°F at a specific Observation.

D5.5.2.3 The average of the isothermal-box temperatures recorded at each Observation shall be within ±1.0°F of the Box Nominal Condition.

D5.5.2.4 The temperature difference between any two temperature measurement stations within the Isothermal-Box shall not exceed 6.0°F at a specific Observation.

D5.5.2.5 The average of the surround area temperatures recorded at each Observation shall be within ±1.0°F of the Box Nominal Condition.

D5.5.2.6 The temperature difference between any two temperature measurement stations within the Surround Area shall not exceed 2.5°F at a specific Observation.

D5.5.2.7 The average forced-circulation air-cooler return air temperature recorded at a specific Observation shall be within ±1.0°F of the Rating Conditions.

D5.5.2.8 The temperature difference between any two temperature measurement stations of the forced-circulation air-cooler return air temperature shall not exceed 3.0°F at a specific Observation.

D5.5.2.9 The average condenser entering air temperature recorded at a specific Observation shall be within ±2.0°F of the Rating Conditions.

D6 *Allowable Adjustments*.

D6.1 *Expansion Valve Adjustment*. In the event that it is desired to change the super-heat setting of the expansion valve(s) as received from the manufacturer, it shall be permissible to make an adjustment to the valve(s) as recommended by the manufacturer's printed instructions. Once properly adjusted, all tests shall be conducted at this setting.

D6.2 *Pressure Regulator*. If suction pressure is not within the published range, adjust the pressure regulator per manufacturer's installation or operating instructions. Once properly adjusted, all tests shall be conducted at this setting.

D7 *Isothermal-Box Calorimeter Calculations.*

D7.1 *Heat Addition Calculation for Isothermal-Box.* The heat addition to the Isothermal-Box during the calibration test, Q, is equal to the total electrical power supplied to the variable electric heater(s), recirculation fan motor(s), and miscellaneous devices in operation during the calibration test.

$$Q_c = X \cdot (E/t) \quad \text{D1}$$

Where:

c = Calibration
E = Electric energy input from heaters, fan motor(s), and miscellaneous devices, W·h
Q = Heat addition to the Calibrated-Box, Btuh
t = Time, h
X = A conversion constant
= 3.413 Btu/W·h

D7.2 *Calibration Calculation for Isothermal-Box.* The heat transfer constant of the Isothermal-Box, UA, is the heat addition divided by the time averaged temperature difference between the interior and exterior conditions.

$$UA = \frac{Q_c}{(\overline{T}_i - \overline{T}_o)_c} \quad \text{D2}$$

Where:

i = Inside of the Calibrated-Box
o = Outside of the Calibrated-Box, ambient
$\overline{T}$ = Time averaged air temperature, °F
UA = Heat transfer constant, Btu/ h · °F

D7.3 *Heat Addition Calculation for Steady-State Conditions.* The heat addition to the Isothermal-Box during steady-state conditions, Q_s, is equal to the electric energy consumed by the variable electric heater(s), recirculation fan motor(s), and miscellaneous devices in operation during the test.

$$Q_s = X \cdot (E/t) \quad \text{D3}$$

Where:

s = Steady-state

D7.4 *Net Refrigeration Capacity Calculation.* When steady-state conditions have been achieved, the Net Refrigeration Capacity, Q_n, is equal to the sum of the heat addition to the Isothermal-Box and the heat transfer constant multiplied by the time averaged temperature difference between the interior and exterior conditions.

$$Q_n = Q_s + UA(\overline{T}_o - \overline{T}_i)_s \quad \text{D4}$$

Where:

n = Net

D7.3 *Calculation of Test Results*. Calculations are based on the arithmetic mean values of readings recorded during tests under stable conditions.