AHRI Standard 1110-2024 (SI/I-P)

Performance Rating of Vapor Compression Transport Refrigeration Units

AIR-CONDITIONING, HEATING, & REFRIGERATION INSTITUTE

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ICS Code: 27.200

Note:

This standard supersedes ANSI/AHRI Standard 1110 (I-P)-2013 and ANSI/AHRI Standard 1111-2013 (SI)

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Intent

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

Review and Amendment

This standard is subject to review and amendment as technology advances.

2024 Edition

AHRI Standard 1110-2024 (SI/I-P), *Performance Rating of Vapor Compression Transport Refrigeration Units*, was prepared by Transportation Refrigeration Standards Technical Committee. The standard was approved by the Refrigeration Standards Subcommittee on 5 March 2024.

Origin and Development of AHRI Standard 1110

The initial publication was ARI 1110 – 1977, *Mechanical Transport Refrigeration Units*. Subsequent revisions include:

ARI 1110-1992, *Mechanical Transport Refrigeration Units*

ARI 1110-2001, *Mechanical Transport Refrigeration Units*

ARI 110-2001 with Addendum 1, *Mechanical Transport Refrigeration Units*

ARI 1110-2006, *Performance Rating of Mechanical Transport Refrigeration Units*

ANSI/AHRI Standard 1110-2013 (I-P), *Performance Rating of Mechanical Transport Refrigeration Units*

ANSI/AHRI Standard 1111-2013 (SI), *Performance Rating of Mechanical Transport Refrigeration Units*

Summary of Changes

AHRI Standard 1110-2024 (SI/I-P) contains the following updates to the previous edition:

- Title change
- Removal of ambient nominal and box nominal conditions
- Removal of split systems
- Removal of operating requirements section
- Changed to optional bulkhead testing equipment
- Consolidated AHRI Standard 1110 (I-P) and AHRI Standard 1111 (SI) into AHRI Standard 1110 (SI/I-P)

Committee Personnel

Transportation Refrigeration Standards Technical Committee

Company/Organization	Participant	Voting Role
Voting Organizations		
Trane Technologies & Thermo King Corporation	Gary McGinley, Chair	Alternate
	Chris Vath	Primary
	David Dykes	Alternate
	Mark Sagstetter	Alternate
Carrier Corporation	Chris Repice	Primary
	Richard Conway	Alternate
Copeland	Mark Gariety	Primary
	Shawn Vehr	Alternate
Nonvoting Organizations		
Heatcraft Worldwide Refrigeration LLC	Shreya Nair	Nonvoter
Honeywell Performance Materials & Technologies	Kaimi Gao	Nonvoter
	Patrick Birbarah	Nonvoter
Antonio Romeo		AHRI Staff Liaison

Transportation Refrigeration Technical Committee Scope:

The Transportation Refrigeration Standards Technical Committee (STC) is responsible for the development and maintenance of AHRI standards and guidelines pertaining to the performance ratings of Mechanical Transport Refrigeration units.

Refrigeration Standards Subcommittee

Company/Organization	Participant	Voting Role
Heat Transfer Products Group, LLC (HTPG)	Mike Straub, Chair	Primary
Everidge	Steve Combs	Primary
Heatcraft Worldwide Refrigeration LLC	Kunal Bansal	Primary
Hillphoenix	Scott Martin	Primary
Hussmann Corporation	Ron Shebik	Primary
KeepRite Refrigeration	Vince Zolli	Primary
Trane Technologies	Jennifer Kane	Primary
Zero Zone, Inc	Bruce Hierlmeier	Primary
Karl Best		AHRI Staff Liaison

Refrigeration Standards Subcommittee Scope:

The scope of the Refrigeration Standards Subcommittee is standards and guidelines related to the end products that are part of the AHRI Refrigeration Industry Sector. The definition of and list of products associated with each sector are found on the AHRI website.

These lists represent the membership at the time the Standards Technical Committee and Standards Subcommittee were balloted on the final text of this edition. Since that time, changes in the membership may have occurred. Membership on these committees shall not in and of itself constitute an endorsement by the committee members or their employers of any document developed by the committee on which the member serves.

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PERFORMANCE RATING OF VAPOR COMPRESSION TRANSPORT REFRIGERATION UNITS

Section 1. Purpose

This standard establishes definitions, test requirements, rating requirements, minimum data requirements for *published ratings*, operating requirements, marking and nameplate data, and conformance conditions for *vapor compression transport refrigeration units*.

Section 2. Scope

This standard applies to encased direct expansion vapor compression type *vapor compression transport refrigeration units* with the following components:

1) Compressor
2) Air-cooled condenser
3) Refrigerant flow control(s)
4) *Forced-circulation air-cooler*
5) Base or frame
6) *Prime mover* as described in the unit manufacturer's literature
7) *Power train* (including coupling, power take-off, transmission, and V-belt drive) connecting the unit to the *prime mover*

Section 3. Definitions

All terms in this document shall follow the standard industry definitions in the *ASHRAE Terminology* website unless otherwise defined in this section. These standard-specific defined terms are italicized throughout the standard.

3.1 Expressions of Provision

Terms that provide clear distinctions between requirements, recommendations, permissions, options, and capabilities.

3.1.1 "Can" or "cannot"

Express an option or capability.

3.1.2 "May"

Signifies a permission expressed by the document.

3.1.3 "Must"

Indication of unavoidable situations and does not mean that an external constraint referred to is a requirement of the document.

3.1.4 "Shall" or "shall not"

Indication of mandatory requirements to strictly conform to the standard and where deviation is not permitted.

3.1.5 "Should" or "should not"

Indication of recommendations rather than requirements. In the negative form, a recommendation is the expression of potential choices or courses of action that is not preferred but not prohibited.

3.2 Standard-specific Definitions

3.2.1 Ambient Air

Defined based off of the method of test:

1) The air in the test enclosure surrounding the *calibrated-box*, per the *calibrated-box* method of testing.
2) The air surrounding the engine-condenser side of a *vapor compression transport refrigeration unit*, per the *isothermal-box* method of testing.

3.2.2 Calorimeter

A test facility consisting of one or two rooms that can 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 *vapor compression transport refrigeration unit* under test.

3.2.2.1 Calibrated-box

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

3.2.2.2 Isothermal-box

A well-insulated enclosure with a known heat transfer rate determined through calibration, that is used for measuring the heat loss or gain between the enclosure's interior temperature and ambient temperature. The surrounding area 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.

3.2.3 Forced-circulation Air-cooler

A factory-made assembly including means for forcing air circulation and components where heat is transferred from air to refrigerant for the purpose of transferring heat from a refrigerated space, through the medium of air, to the refrigerant.

3.2.4 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. The net refrigerating effect provided for useful cooling.

3.2.5 Observation

A specific instance in time when measurements are recorded.

3.2.6 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.

3.2.7 Prime Mover

An engine, motor or same device that drives a refrigeration system.

3.2.8 Published Rating

A statement of the assigned values of those performance characteristics, under stated *rating conditions*, where a unit can be chosen to fit the application. These values apply to all units of the same nominal size and type (identification) produced by the same manufacturer. This 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*.

3.2.8.1 Application Rating

A rating based on tests performed at *rating conditions* other than *standard rating conditions*.

3.2.8.2 Standard Rating

A rating based on tests performed at *standard rating conditions*.

3.2.8.3 Standby Rating

A *published rating* based on using a standby power source and tests performed under *standard rating conditions* or application *rating conditions*.

3.2.9 Rating Conditions

Any set of operating conditions where a single level of performance results and causes only that level of performance to occur.

3.2.9.1 Standard Rating Conditions

Rating conditions used as the basis of comparison for performance characteristics.

3.2.10 Standby Drive

A device included in a *vapor compression transport refrigeration unit* that receives power from a source external to the vehicle served. The unit can operate to refrigerate the vehicle while stationary.

3.2.11 Surround Area

The enclosure about the *isothermal-box*.

3.2.12 Vapor Compression Transport Refrigeration Unit

A combination of one or more of the following factory-made assemblies:

1) A compressor, drive, and condenser combination
2) A *forced-circulation air-cooler*
3) All necessary refrigerant lines and electrical wiring
4) Means whereby the unit can be mounted and installed on a vehicle the unit 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.

Section 4. Test Requirements

4.1 Test Requirements

Vapor compression 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 where the engine-generator set is located shall be maintained at the same ambient condition as the condensing section of the *vapor compression 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	*Calibrated-box* and *Isothermal-box* Temperatures	*Ambient Air* Temperatures
	°F (°C)	°F (°C)	°F (°C)	°F (°C)
High temperature	35.0 (1.7)	100.0 (37.8)	35.0 (1.7)	100.0 (37.8)
Low temperature	0.0 (-17.8)	100.0 (37.8)	0.0 (-17.8)	100.0 (37.8)

Standard ratings at or below 10,000 Btu/h (2900 W) shall be *net refrigerating capacity* and shall be expressed only in terms of Btu/h (W) in multiples of 100 Btu/h (30 W). *Standard ratings* above 10,000 Btu/h (2900 W) shall be *net refrigerating capacity* and shall be expressed only in terms of Btu/h (W) in multiples of 500 Btu/h (150 W).

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, either mechanically or electrically driven, 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.

5.4.2 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 and 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 rated speed.

Section 6. 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 AHRI Standard 1110 (SI/I-P)”. All claims to ratings outside the scope of this standard shall include the statement “Outside the scope of AHRI Standard 1110 (SI/I-P)”. *Application ratings* within the scope of the standard shall include a statement of the conditions under which the ratings apply.

Each *published rating* of *vapor compression transport refrigeration units* shall include, or be accompanied by the following information:

1) Model number
2) *Net refrigerating capacity*, Btu/h (W)
3) Refrigerant designation(s) in accordance with ASHRAE 34.
4) Compressor speed, rpm

Section 7. Marking and Nameplate Data

As a minimum, the nameplate shall include:

1) Manufacturer's model designation
2) Manufacturer's serial number
3) Refrigerant designation(s) per ASHRAE 34 and operating charge, lb (kg)
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 AHRI 110. Nameplate voltages for 50 Hz systems shall include one or more of the utilization voltages shown in Table 1 of IEC 60038.

Section 8. Conformance Conditions

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

This appendix lists all standards, handbooks, and other publications essential to the development and implementation of the standard. All references in this appendix are part of the standard.

A.1. ANSI/AHRI Standard 110-2016, *Air-Conditioning, Heating, and Refrigerating Equipment Nameplate Voltages*, 2012, Air-Conditioning, Heating and Refrigeration Institute, 2311 Wilson Blvd, Suite 400, Arlington, VA 22201, USA.

A.2. ANSI/ASHRAE Standard 34-2022 with Addenda, De*signation and Safety Classification of Refrigerants*, 2022, ASHRAE, 180 Technology Parkway, Peachtree Corners, GA 30092, USA.

A.3. ANSI/ASHRAE Standard 41.1-2020, *Standard Method for Temperature Measurement*, 2020, ASHRAE, 180 Technology Parkway, Peachtree Corners, GA 30092, USA.

A.4. ANSI/ASHRAE Standard 41.3-2022, *Standard Method for Pressure Measurement*, 2022, ASHRAE, 180 Technology Parkway, Peachtree Corners, GA 30092, USA.

A.5. ASHRAE Terminology. ASHRAE. Accessed August 12, 2022. https://www.ashrae.org/technical-resources/free-resources/ashrae-terminology

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

A.7. *Agreement on the International Carriage of Perishable Foodstuffs and on the Special Equipment to be Used for such Carriage (ATP)*, June 2022, United Nations Economic Commission for Europe, Palais des Nations, CH-1211 Geneva 10, Switzerland.

APPENDIX B. REFERENCES – INFORMATIVE

This appendix lists standards, handbooks, and other publications that can provide useful information and background but are not essential for the use of this standard. All references in this appendix are not part of the standard.

None.

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

C.1. Purpose

This appendix provides a method of testing for *vapor compression transport refrigeration units* using the *calibrated-box* method.

C.2. Scope

C.2.1. In Scope

The test method provided in this appendix is for use with *vapor compression transport refrigeration units* and shall be used for both *standard ratings* and *application ratings.*

C.2.2. Exclusions

This appendix is not applicable to field tests.

C.3. Measuring Instrumentation Requirements

C.3.1. Temperature Measuring Instruments

Temperature measurements shall be made in accordance with ASHRAE 41.1.

C.3.2. Pressure Measuring Instruments

Pressure measurements shall be made in accordance with ASHRAE 41.3.

C.3.3. Electrical Measuring Instruments

Electrical measurements shall be made with integrating-type instruments.

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

C.3.4. Time Measurements

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

C.3.5. Revolution Measurements

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

C.4. General Test Data

The following data shall be recorded for each unit tested where applicable:

1) Manufacturer - name and address
2) Location of test facility - company name and address
3) Date of test run
4) Observers - responsible engineer and technicians
5) Designation of unit
    a) Model number
    b) Serial number
6) Refrigerant designation(s) per ASHRAE 34 with Addenda and operating charge, lb (kg)
7) *Prime mover* data
    a) Type (internal combustion, electric motor, other) and model designation
    b) *Prime mover* rotational speed, rpm; fuel

c) Voltage, V; current, A; frequency, Hz; phase

d) Fuel

8) Condensing unit data

a) Compressor make, model number and rotational speed, rpm

b) Type of fan drive

c) Fan-motor power, hp (W)

d) Fan-motor electrical data: voltage, V; current, A; frequency, Hz; phase

9) *Forced-circulation air-cooler* data

a) Type of fan drive

b) Fan-motor power, hp (W)

c) Fan-motor voltage, V; current, A; frequency, Hz; phase

C.5. Calibrated-box Method

This method determines the *net refrigerating capacity* of the *vapor compression transport refrigeration unit* by measuring the total heat input into the *calibrated-box* (Figure 1). This 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 C.5.2). The heat leakage into the *calibrated-box* shall not exceed 30.0% of the *net refrigerating capacity* of the unit being tested.

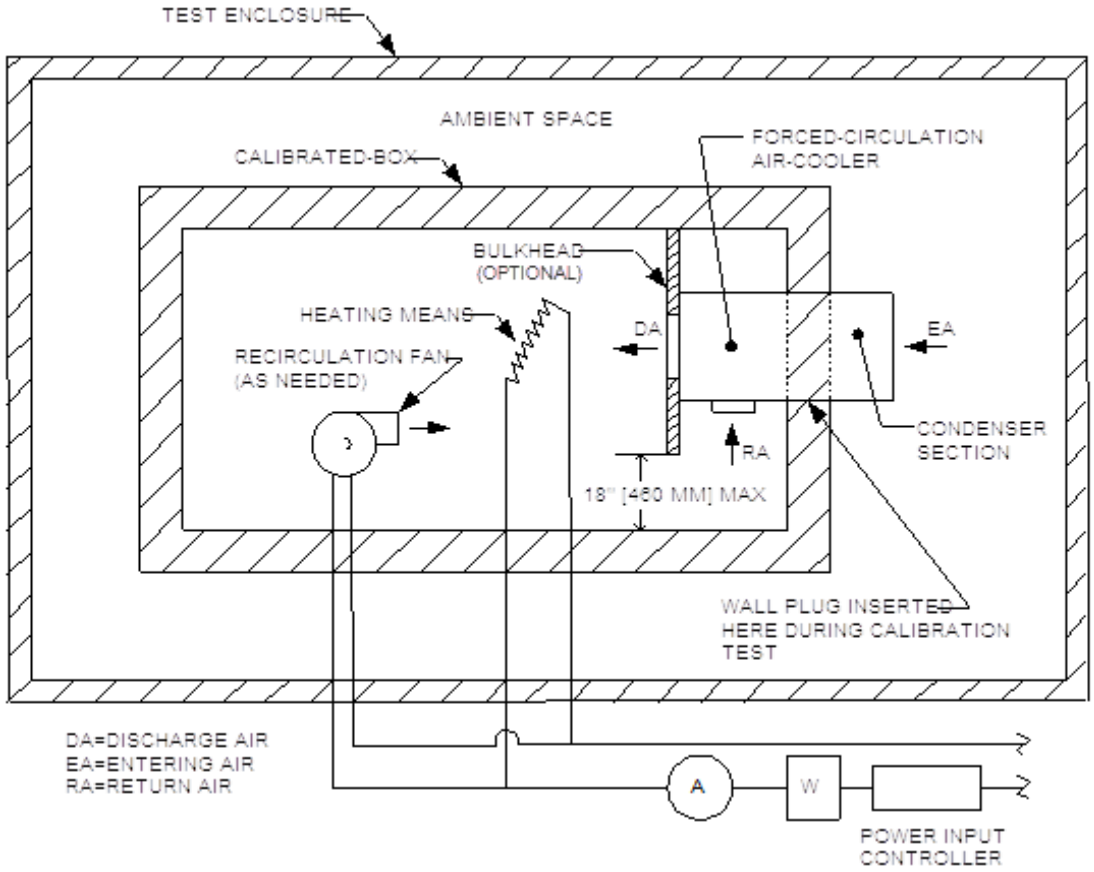

Figure 1 Calibrated -box Test Setup Schematic

C.5.1. Apparatus Setup for Calibration Test

1) The *calibrated-box* shall be installed in a test enclosure of a size that provides clearance at all sides, the top, and the bottom of the *calibrated-box* to confirm uniformity of the air temperature.
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 *vapor compression transport refrigeration unit* during the capacity test (Figure 1).
3) Sensors for measuring the controlled *ambient air* shall be located in the ambient space 6.0 in (150 mm) from the center of each surface of the *calibrated-box* (Figure 2). Temperature-sensing elements shall be shielded against radiation. The wind or airflow conditions shall not be simulated due to the motion of the vehicle for the intended equipment.
4) Means for circulating conditioned air throughout the ambient space to maintain steady-state conditions per Section C.5.2 shall be provided.
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 3).
6) An electric fan, if needed, shall be located within the *calibrated-box* to circulate air and maintain steady-state conditions per Section C.5.2 (Figure 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 3). This heating means shall be operated to establish and maintain steady-state conditions per Section C.5.2.

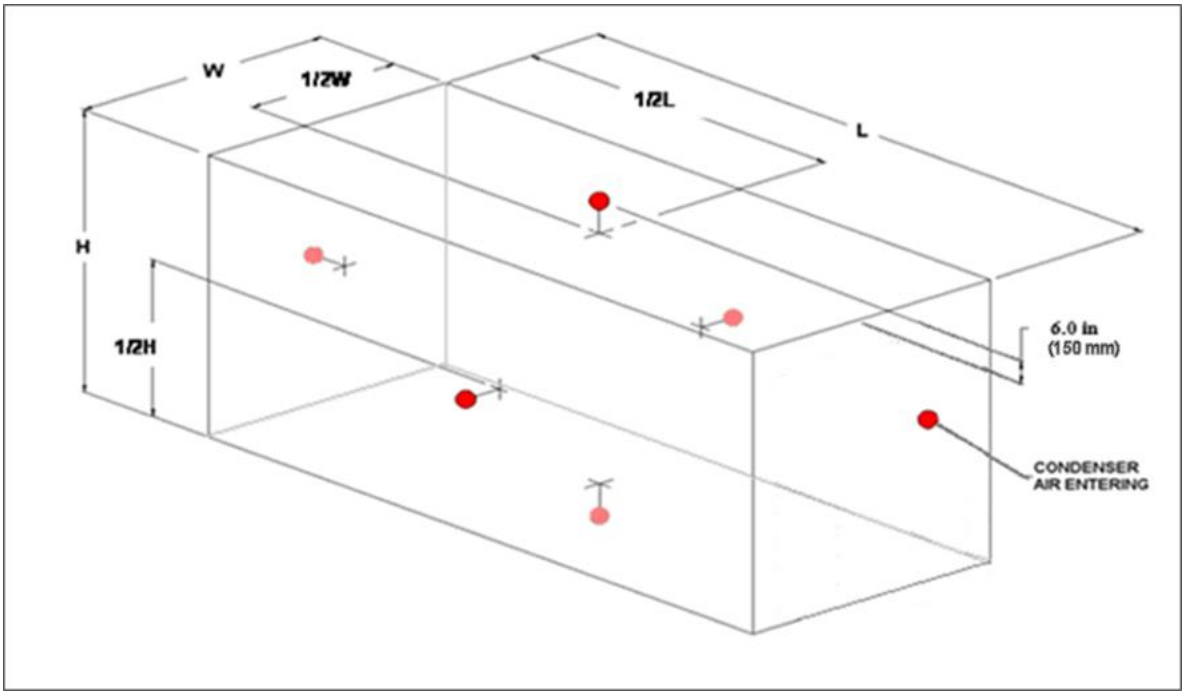

Figure 2 Ambient Area Temperature Measuring Station Location Diagram

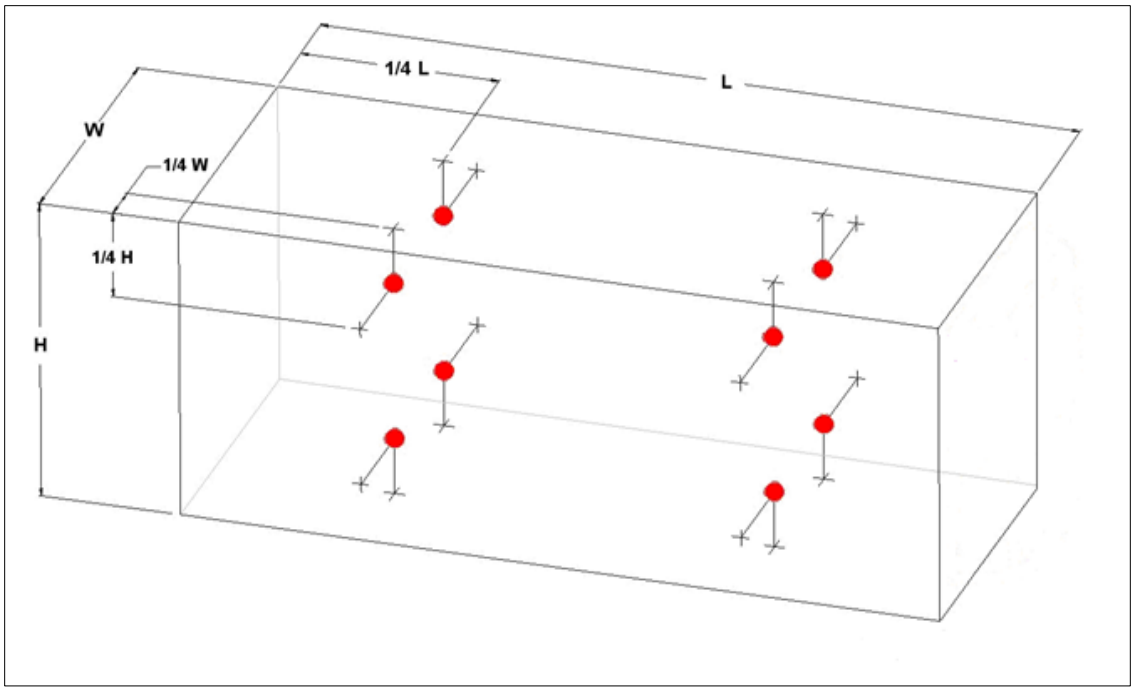

Figure 3 Calibrated-box Temperature Measuring Station Location Diagram

C.5.2. 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:

1) 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 (23.9°C). The system shall be operated and maintained at this condition for at least five hours.

2) After satisfying the requirements of Section C.5.3, temperature readings at the locations of Section C.5.1(3) and Section C.5.1(5) shall be taken at fifteen-minute intervals. Tests shall have nine consecutive *observations* over a two-hour period (per Section C.5.3).

3) 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 and all other data necessary shall be recorded to determine the heat leakage through the *calibrated-box* between the ambient space and *calibrated-box* per Section C.7.1. These readings shall be taken at the beginning and end of the two-hour period. These readings shall be taken simultaneously with the temperature readings.

4) Calculation of the heat transfer constant of the *calibrated-box* is determined from the steady-state data recorded per Section C.7.2.

C.5.3. Steady-state Conditions and Test Tolerances for Calibrated-box Calibration Test

Steady-state conditions for the calibration test shall be achieved when all the following conditions are satisfied (Table 2):

1) The average of the *ambient air* temperatures recorded at each *observation* shall be ± 2.0°F (1.1°C) of the *rating condition*.

2) The temperature difference between any two *ambient air* temperature measurement stations shall not exceed 4.0°F (2.2°C) at a specific *observation*.

3) The average of the *calibrated-box* temperatures recorded at each *observation* shall be ± 1.0°F (0.6°C) of the *rating condition*.

4) The temperature difference between any two temperature measurement stations within the *calibrated-box* shall not exceed 2.5°F (1.4°C) at a specific *observation*.

Table 2 Calibrated-box Test Tolerances

Readings	Calibration Test Tolerances °F (°C)	Capacity Test Tolerances °F (°C)
Ambient Air Temperatures		
Deviation of average from *rating condition*	± 2.0 (1.1)	± 2.0 (1.1)
Between any two stations (max-min)	4.0 (2.2)	6.0 (3.3)
Calibrated-box Temperatures		
Deviation of Average from *rating condition*	± 1.0 (0.6)	± 1.0 (0.6)
Between any two stations (max-min)	2.5 (1.4)	6.0 (3.3)
Forced-circulation Air-cooler Return Temperature		
Deviation of average from *rating condition*	—	± 1.0 (0.6)
Between any two stations (max-min)		3.0 (1.7)
Condenser Entering Air Temperature		
Deviation of average from *rating condition*	—	± 2.0 (1.1)

C.5.4. Vapor Compression Transport Refrigeration Unit Installation Setup for Capacity Test

The wall plug used during calibration shall be removed, and the *vapor compression transport refrigeration unit* shall be inserted into the *calibrated-box* (Figure 1). The *vapor compression transport refrigeration unit* shall be installed per the manufacturer's standard installation instructions.

C.5.5. Apparatus Setup for Capacity Test

In addition to the apparatus used in the calibration test (Section C.5.1), the following shall be required to perform the capacity test:

1) A minimum of eight individual temperature stations shall be equally spaced, by area, along the condenser air inlet of the *vapor compression transport refrigeration unit*. When using thermocouples for this purpose, a grid, meaning parallel wiring of the sensors, can be used.

2) The return air to the *forced-circulation air-cooler* shall be directed by a bulkhead (optional) 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. (460 mm) from the floor of the *calibrated-box* (Figure 1). 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.

C.5.6. Conducting Capacity Test by Calibrated-box Method of Test

The *vapor compression 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 C.5.6.1 at fifteen-minute intervals until nine consecutive sets of data (two-hour period) indicate that steady-state conditions have been achieved.

C.5.6.1. Data to Be Recorded

For each unit tested, complete data shall be recorded in accordance with Section C.4 and Section C.5.6:

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, Btu/h·°F (W/°C)

2) At the beginning of each capacity test, and at fifteen-minute intervals thereafter, the following shall be recorded:
    a) Time of *observation*
    b) *Ambient air* temperature, each station, °F (°C)
    c) *Calibrated-box* temperature, each station, °F (°C)
    d) Total energy input from variable electric heater; *calibrated-box* recirculation fan motor(s); miscellaneous devices, if used, W·h
    e) Compressor discharge pressure, psig or psia (kPa gage or kPa absolute)
    f) Compressor suction pressure, psig or psia (kPa gage or kPa absolute)
    g) Temperature of discharge gas leaving compressor, °F (°C)
    h) Temperature of liquid entering expansion device, °F (°C)
    i) Temperature of suction gas leaving evaporator coil, °F (°C)
    j) Temperature of suction gas entering compressor, °F (°C)
3) At the end of each capacity test cycle, record the following:
    a) For mechanically and electrically driven components, record measured speed, rpm, of:

    Forced-circulation air-cooler fan(s)

    Condenser fan(s)
    b) For mechanically driven components, record measured speed, rpm, of:

    Compressor

    Prime mover (internal combustion engine)
    c) For electrically driven components, record measured voltage, V; frequency, Hz input into:

    Compressor motor

    Prime mover (electric motor)

C.5.6.2. 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 2):

1) The average of the *ambient air* temperatures recorded at each *observation* shall be within ± 2.0°F (1.1°C) of the *rating condition.*
2) The temperature difference between any two *ambient air* temperature measurement stations shall not exceed 6.0°F (3.3°C) at a specific *observation*.
3) The average of the *calibrated-box* temperatures recorded at each *observation* shall be within ± 1.0°F (0.6°C) of the *rating condition.*
4) The temperature difference between any two temperature measurement stations within the *calibrated-box* shall not exceed 6.0°F (3.3°C) at a specific *observation*.
5) The average *forced-circulation air-cooler* return air temperatures recorded at a specific *observation* shall be within ± 1.0°F (0.6°C) of the *rating condition.*
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 (1.7°C) at a specific *observation*.
7) The average condenser entering air temperature recorded at a specific *observation* shall be within ± 2.0°F (1.1°C) of the *rating condition*.

C.6. Allowable Adjustments

C.6.1. Expansion Valve Adjustment

To change the super-heat setting of the expansion valve(s) as received from the manufacturer, adjustments can be made to the valve(s) as recommended by the manufacturer's printed instructions. Once adjusted, all tests shall be conducted at this setting.

C.6.2. Pressure Regulator

If suction pressure is not within the published range, the pressure regulator shall be adjusted per manufacturer's instructions. Once adjusted, all tests shall be conducted at this setting.

C.7. Calibrated-box Calorimeter Calculations

C.7.1. 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. See Equation 1.

$$Q_c = X \cdot (E/t) \quad \textbf{1}$$

Where:

c = Calibration

E = Electric energy input from heaters, fan motor(s), and miscellaneous devices, W·h

Q = Heat addition to the *calibrated-box*, Btu/h (W)

t = Time, h

X = A conversion constant

= 3.413 Btu/W·h (1 W/W)

C.7.2. 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. See Equation 2.

$$UA = \frac{Q_c}{(\overline{T}_i - \overline{T}_o)_c} \quad \textbf{2}$$

Where:

i = Inside of the *calibrated-box*

o = Outside of the *calibrated-box*, ambient

$\overline{T}$ = Time averaged air temperature, °F (°C)

UA = Heat transfer constant, Btu/h °F (W/°C)

C.7.3. 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. See Equation 3.

$$Q_s = X \cdot (E/t) \quad \textbf{3}$$

Where:

s = Steady-state

C.7.4. 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. See Equation 4.

$$Q_n = Q_s + UA(\overline{T}_o - \overline{T}_i)_s \quad \textbf{4}$$

Where:

n = Net

C.7.5. 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 VAPOR COMPRESSION TRANSPORT REFRIGERATION UNITS – NORMATIVE

D.1. Purpose

This appendix provides a method of testing for *vapor compression transport refrigeration units* using the *isothermal-box* method.

D.2. Scope

D.2.1. In Scope

The test method provided in this appendix is for use with *vapor compression transport refrigeration units* and shall be used for both *standard ratings* and *application ratings*.

D.2.2. Exclusions

This appendix is not applicable to field tests.

D.3. Measuring Instrumentation Requirements

D.3.1. Temperature Measuring Instruments

Temperature measurements shall be made in accordance with ASHRAE 41.1.

D.3.2. Pressure Measuring Instruments

Pressure measurements shall be made in accordance with ASHRAE 41.3.

D.3.3. Electrical Measuring Instruments.

Electrical measurements shall be made with integrating-type instruments.

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

D.3.4. Time Measurements

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

D.3.5. Revolution Measurements

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

D.4. General Test Data

The following data shall be recorded for each unit tested where applicable:

1) Manufacturer - name and address
2) Location of test facility - company name and address
3) Date of test run
4) Observers - responsible engineer and technicians
5) Designation of unit
    a) Model number
    b) Serial number
6) Refrigerant designation(s) in accordance with ASHRAE 34 and operating charge, lb (kg)
7) *Prime mover* data
    a) Type (internal combustion, electric motor, other) and model designation
    b) *Prime mover* rotational speed, rpm; fuel

c) Voltage, V; current, A; frequency, Hz; phase

d) Fuel

8) Condensing unit data

a) Compressor make, model number and rotational speed, rpm

b) Type of fan drive

c) Fan-motor power, hp (W)

d) Fan-motor electrical data: voltage, V; current, A; frequency, Hz, phase

9) *Forced-circulation air-cooler data*

a) Type of fan drive

b) Fan-motor power, hp (W)

c) Fan-motor voltage, V; current, A; frequency, Hz; phase

D.5. Isothermal-box Method

This method determines the *net refrigerating capacity* of the *vapor compression transport refrigeration unit* by measuring the total heat input into the *isothermal-box* (Figure 4). This 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 D.5.2). The heat leakage through the calibrated isothermal wall shall not exceed 5% of the *net refrigerating capacity* of the unit being tested.

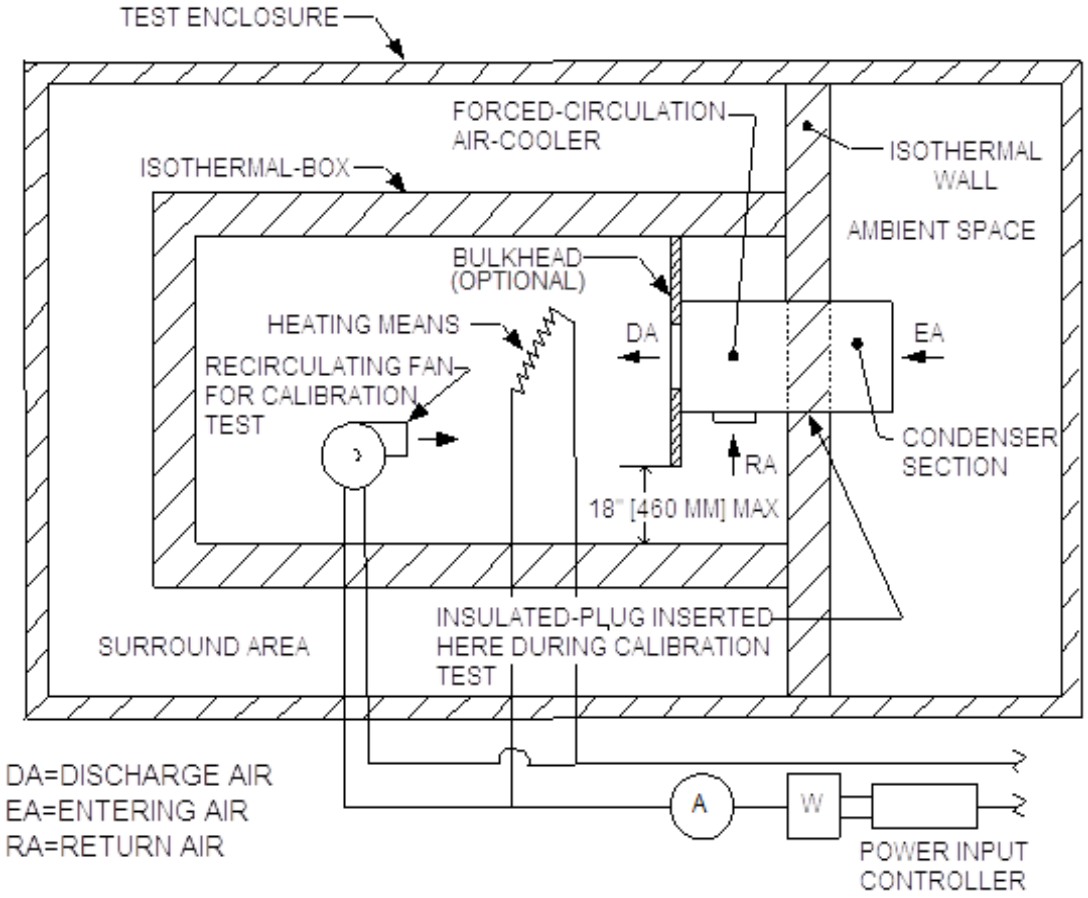

Figure 4 Isothermal-box Test Setup Schematic

D.5.1. Apparatus Setup for Calibration Test

1) The size of the *surround area* shall provide clearance on all sides of the *isothermal-box* for air circulation.

2) The size of the enclosure surrounding the engine-condenser side of the *vapor compression transport refrigeration unit* shall have 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.

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 *vapor compression transport refrigeration unit* during the capacity test (Figure 4).

4) Sensors for measuring the *surround area* air temperature shall be located within the *surround area* 6.0 in (150 mm) from the center of each surface of the *isothermal-box*, excluding the surface of the box that is touching the isothermal wall (Figure 5).

5) Sensors for measuring the *ambient air* temperature shall be located within the ambient space 6.0 in (150 mm) 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 (150 mm) from the center of the insulation plug.

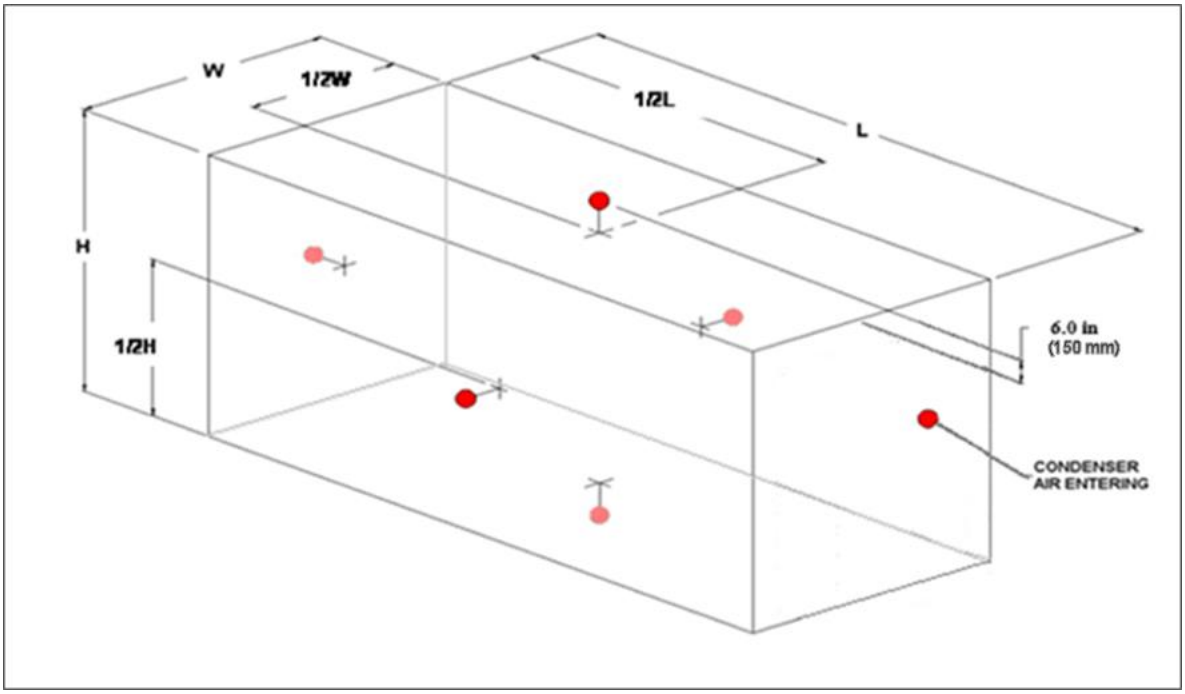

Figure 5 Surround Area Temperature Measuring Station Location Diagram

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 6).

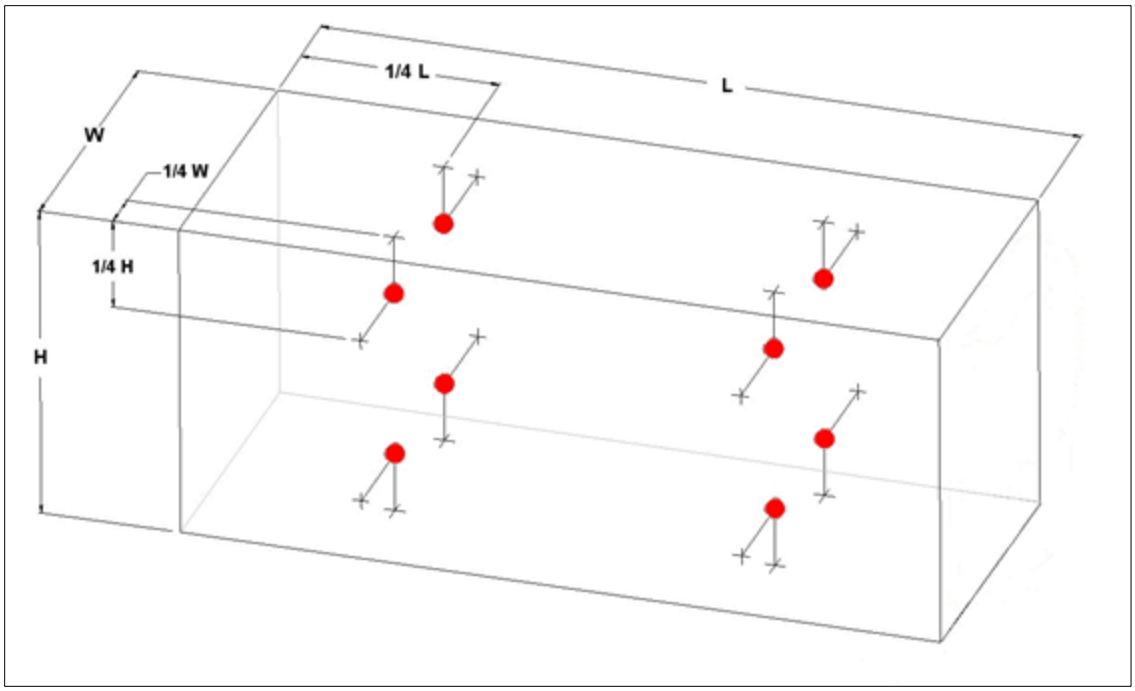

Figure 6 Isothermal-box Temperature Measuring Station Location Diagram

7) An electric fan, if needed, shall be located within the *isothermal-box* to circulate air and maintain steady-state conditions per Section D.5.2 (Figure 4).

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 6). This heating means shall be operated to establish and maintain steady-state conditions per Section D.5.2.

D.5.2. 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:

1) 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 (23.9 °C). The system shall be operated and maintained at this condition for at least five hours.

2) After satisfying the requirements of Section D.5.3, temperature readings at the locations of Section D.5.1(4), Section D.5.1(5) and Section D.5.1(6) shall be taken at fifteen-minute intervals. Tests shall complete nine consecutive *observations* over a two-hour period (per Section D.5.3).

3) During this two-hour period, the electrical input to the heater, fan motor(s), and other miscellaneous devices, if used, located 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* per Section D.7.1. These readings shall be taken at the beginning and the end of the two-hour period. These readings shall be taken simultaneously with the temperature readings.

4) Calculation of the heat transfer constant of the *isothermal-box* is determined from the steady-state data recorded per Section D.7.2.

D.5.3. Steady-state Conditions and Test Tolerances for Isothermal-box Calibration Test

Steady-state conditions for the calibration test shall be achieved when all the following conditions are satisfied (Table 3):

1) The average of the *ambient air* temperatures recorded at each *observation* shall be within ± 2.0°F (1.1°C) of the *rating condition*.

2) The temperature difference between any two *ambient air* temperature measurement stations shall not exceed 4.0°F (2.2°C) at a specific *observation*.

3) The average of the *isothermal-box* temperatures recorded at each *observation* shall be ± 1.0°F (0.6°C) of the *rating condition*.

4) The temperature difference between any two temperature measurement stations within the *isothermal-box* shall not exceed 2.5°F (1.4°C) at a specific *observation*.

5) The average of the *surround area* temperatures recorded at each *observation* shall be within ± 1.0°F (0.6°C) of the *rating condition*.

6) The temperature difference between any two temperature measurement stations in the *surround area* space shall not exceed 4.0°F (2.2°C) at a specific *observation*.

Table 3 Isothermal-box Test Tolerances

Readings	Calibration Test Tolerances °F (°C)	Capacity Test Tolerances °F (°C)
Ambient Air Temperatures		
Deviation of Average from *Rating Condition*	± 2.0 (1.1)	± 2.0 (1.1)
Between Any Two Stations (max-min)	4.0 (2.2)	6.0 (3.3)
Isothermal-box Temperatures		
Deviation of Average from *Rating Condition*	± 1.0 (0.6)	± 1.0 (0.6)
Between Any Two Stations (max-min)	2.5 (1.4)	6.0 (3.3)
Surround Area Temperatures		
Deviation of Average from *Rating Condition*	± 1.0 (0.6)	± 1.0 (0.6)
Between Any Two Stations (max-min)	4.0 (2.2)	2.5 (1.4)
Forced-circulation Air-cooler Return Temperature		
Deviation of Average from *Rating Condition*	—	± 1.0 (0.6)
Between Any Two Stations (max-min)		3.0 (1.7)
Condenser Entering Air Temperature		
Deviation of Average from *Rating Condition*	—	± 2.0 (1.1)

D.5.4. Vapor Compression Transport Refrigeration Unit Installation Setup for Capacity Test

The wall plug used during calibration shall be removed, and the *vapor compression transport refrigeration unit* shall be inserted into the *Isothermal-box* (Figure 4). The *vapor compression transport refrigeration unit* shall be installed per the manufacturer's standard installation instruction.

D.5.5. Apparatus Setup for Capacity Test

In addition to the apparatus used in the calibration test (Section D.5.2), the following shall be required to perform the capacity test:

1) A minimum of eight individual temperature stations shall be equally spaced, by area, along the condenser air inlet of the *vapor compression transport refrigeration unit*. When using thermocouples, a grid, or parallel sensor wiring, can be used.

2) The *forced-circulation air-cooler* return air shall be directed by a bulkhead (optional) separating discharge air from return air. This bulkhead shall frame the discharge air opening and 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. (460 mm) from the floor of the *isothermal-box* (Figure 4). 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.

D.5.6. Conducting Capacity Test by Isothermal-box Method

The *vapor compression 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 D.5.6.2, data shall be recorded, in accordance with Section D.5.6.1, at fifteen-minute intervals until nine consecutive sets of data (two-hour period) indicate that steady-state conditions have been achieved.

D.5.6.1. Data to be Recorded

For each test run of each unit tested, complete data shall be recorded in accordance with Section D.4and Section D.5.6:

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 (W/°C)
2) At the beginning of each capacity test, and at fifteen-minute intervals thereafter, the following shall be recorded:
   a) Time of *observation*
   b) Ambient space temperature, each station, °F (°C)
   c) *Isothermal-box* temperature, each station, °F (°C)
   d) *Surround area* temperature, each station, °F (°C)
   e) Total energy input from variable electric heater; *isothermal-box* recirculation fan motor(s); miscellaneous devices (such as separate fans, and lights), if used, W·h
   f) Compressor discharge pressure, psig or psia (kPa gage or kPa absolute)
   g) Compressor suction pressure, psig or psia (kPa gage or kPa absolute)
   h) Temperature of discharge gas leaving compressor, °F (°C)
   i) Temperature of liquid entering expansion device, °F (°C)
   j) Temperature of suction gas leaving evaporator coil, °F (°C)
   k) Temperature of suction gas entering compressor, °F (°C)
3) At the end of each capacity test cycle, record the following:
   a) For mechanically and electrically driven components, record measured speed, rpm, of:

      Forced-circulation air-cooler fan(s)

      Condenser fan(s)
   b) For mechanically driven components, record measured speed, rpm, of:

      Compressor

      Prime mover (internal combustion engine)
   c) For electrically driven components, record measured voltage, V; frequency, Hz input into:

      Compressor motor

      Prime mover (electric motor)

D.5.6.2. 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 3):

1) The average of the *ambient air* temperatures recorded at each *observation* shall be within ± 2.0°F (1.1°C) of the *rating condition*.
2) The temperature difference between any two *ambient air* temperature measurement stations shall not exceed 6.0°F (3.3°C) at a specific *observation*.
3) The average of the *isothermal-box* temperatures recorded at each *observation* shall be within ± 1.0°F (0.6°C) of the *rating condition*.
4) The temperature difference between any two temperature measurement stations within the *isothermal-box* shall not exceed 6.0°F (3.3°C) at a specific *observation*.
5) The average of the *surround area* temperatures recorded at each *observation* shall be within ± 1.0°F (0.6°C) of the *rating condition*.
6) The temperature difference between any two temperature measurement stations within the *surround area* shall not exceed 2.5°F (1.4°C) at a specific *observation*.
7) The average *forced-circulation air-cooler* return air temperature recorded at a specific *observation* shall be within ± 1.0°F (0.6°C) of the *rating conditions*.
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 (1.7°C) at a specific *observation*.
9) The average condenser entering air temperature recorded at a specific *observation* shall be within ± 2.0°F (1.1°C) of the *rating conditions*.

D.6. Adjustments

D.6.1. Expansion Valve Adjustment

To change the super-heat setting of the expansion valve(s) as received from the manufacturer, adjustments can be made to the valve(s) as recommended by the manufacturer's printed instructions. Once adjusted, all tests shall be conducted at this setting.

D.6.2. Pressure Regulator

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

D.7. Isothermal-box Calorimeter Calculations.

D.7.1. Heat Addition Calculation for Isothermal-box

The heat addition to the *isothermal-box* during the calibration test, Q_c, 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. See Equation 5.

$$Q_c = X \cdot (E/t) \quad \textbf{5}$$

Where:

c = Calibration
E = Electric energy input from heaters, fan motor(s), and miscellaneous devices, W·h
Q = Heat addition to the *isothermal-box*, Btu/h (W)
t = Time, h
X = A conversion constant
= 3.413 Btu/W·h (1 W/W)

D.7.2. 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. See Equation 6.

$$UA = \frac{Q_c}{(\overline{T}_i - \overline{T}_o)_c} \quad \textbf{6}$$

Where:

i = Inside of the *isothermal-box* & surround

o = Outside of the *isothermal-box*, ambient

$\overline{T}$ = Time averaged air temperature, °F (°C)

UA = Heat transfer constant, Btu/h · °F (W/°C)

D.7.3. 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. See Equation 7.

$$Q_s = X \cdot (E/t) \quad \textbf{7}$$

Where:

s = Steady-state

D.7.4. 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. See Equation 8.

$$Q_n = Q_s + UA(\overline{T}_o - \overline{T}_i)_s \quad \textbf{8}$$

Where:

n = Net

D.7.5. Calculation of Test Results

Calculations are based on the arithmetic mean values of readings recorded during tests under stable conditions.