AHRI Standard 540

# 2015 Standard for

# Performance Rating Of Positive Displacement Refrigerant Compressors and Compressor Units

AIR-CONDITIONING, HEATING, & REFRIGERATION INSTITUTE

we make life better™

2111 Wilson Boulevard, Suite 500
Arlington, VA 22201, USA
www.ahrinet.org
PH 703.524.8800
FX 703.562.1942

## IMPORTANT

## *SAFETY RECOMMENDATIONS*

AHRI does not set safety standards and does not certify or guarantee the safety of any products, components or systems designed, tested, rated, installed or operated in accordance with this standard/guideline. It is strongly recommended that products be designed, constructed, assembled, installed and operated in accordance with nationally recognized safety standards and code requirements appropriate for products covered by this standard/guideline.

AHRI uses its best efforts to develop standards/guidelines employing state-of-the-art and accepted industry practices. AHRI does not certify or guarantee that any tests conducted under its standards/guidelines will be non-hazardous or free from risk.

Notes:

This standard supersedes AHRI Standard 540-2004.

It is the responsibility of the user to select its preferred units of measure.

Foreword

The following are significant changes made in this update:

1) Move away from standard ratings and work primarily with published ratings
    a. Ratings from coefficients are primary source
    b. Old tables of standard rating conditions would be included in appendix for reference
    c. Manufacturers can continue to publish information at specific points of interest
2) Different uncertainties for different parts of the Application Envelope
    a. High Temperature
    b. Medium Temperature
    c. Low Temperature
3) More specific information to help with the development of ratings and the verification of the ratings
    a. Adding statistical aspect to uncertainties
    b. Incorporation of more specific information on uncertainty
4) Specific guidelines for initial estimates of performance at different superheat values

Price $10.00 (M) $20.00 (NM)
Printed in U.S.A.

## TABLE OF CONTENTS

## APPENDICES



## FIGURES FOR APPENDICES



## TABLES FOR APPENDICES

# PERFORMANCE RATING OF POSITIVE DISPLACEMENT REFRIGERANT COMPRESSORS AND COMPRESSOR UNITS

## Section 1. Purpose

**1.1** Purpose. The purpose of this standard is to establish, for Compressors: 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. The standard defines the minimum amount of information, in a standard form to enable the evaluation and comparison of different Compressors for use in a particular application.

**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 positive displacement refrigerant Compressors operating in subcritical applications at a fixed displacement. This standard also applies to the presentation of performance data for Compressors for air-cooled, evaporative-cooled or water-cooled air-conditioning, heat pump and refrigeration applications. The manufacturer is solely responsible for the determination of values to be used in published product information. This standard stipulates the minimum amount of information to be provided and suggests a method to be used to verify the accuracy of that information.

**2.2** *Exclusions*.

**2.2.1** This standard does not apply to Compressors employing ammonia, as covered in ANSI/AHRI Standard 510 or carbon dioxide in subcritical and transcritical applications, as covered in ANSI/AHRI Standard 570 (I-P) and ANSI/AHRI Standard 571 (SI).

**2.2.2** This standard does not apply to modulated refrigerant mass flow Compressors or Compressors utilizing vapor injection for the purpose of subcooling to gain capacity.

**2.2.3** This standard does not apply to Compressors intended for use in:

**2.2.3.1** Household refrigerators and freezers

**2.2.3.2** Automotive air-conditioners

**2.2.3.3** Dehumidifiers

**2.2.3.4** Industrial products other than heating and cooling

## Section 3. Definitions

All terms in this document will follow the standard industry definitions in the *ASHRAE Terminology* website (https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology) unless otherwise defined in this section.

**3.1** *Batch of Equipment*. A number of Compressors intended to perform the same function, produced in quantity, manufactured to the same technical specifications and characterized by the same Published Rating.

**3.2** *Compressor*. A positive displacement machine in which an increase in refrigerant vapor pressure is attained by changing the internal volume of the compression chamber through work applied to the compressor's mechanism. This may or may not include other accessories required to sustain operation of the Compressor at the rating conditions. Types of Compressors include Hermetic Refrigerant Compressors, Semi-hermetic Refrigerant Compressors, and Open Type Refrigerant Compressors.

Note: Accessories might include fans, liquid receivers, desuperheaters, strainers, service valves, check valves, suction filters, lubricant separators, motor starters, and unloaders, as supplied or specified by the compressor manufacturer.

**3.2.1** *Hermetic Refrigerant Compressor*. A Compressor and motor assembly, both of which are contained within a gas tight housing that is permanently sealed by welding, or brazing with no access for servicing internal parts in the field.

**3.2.2** *Open Type Refrigerant Compressor*. A Compressor with a shaft or other moving part extending through its casing to be driven by an outside source of power thus requiring a shaft seal or equivalent rubbing contact between fixed and moving parts.

**3.2.3** *Semi-hermetic Refrigerant Compressor*. A Compressor and motor assembly contained within a gas-tight housing that is sealed by gasketed joints to provide access for servicing internal parts.

**3.3** *Performance Factor*. Performance factor shall be computed as a ratio of capacity to power input at specified operating conditions. The potential forms of the performance factor include, but are not limited to, the energy efficiency ratio (EER) in Btu/h·W, coefficient of performance (COP) in W/W, and ratio of power input to capacity in bhp/ton.

**3.4** *Power Input*. The time rate of energy usage of the Compressor (compressor power) plus any accessories required to sustain operation of the compressor at the Reference Rating Condition. If accessories are not included it shall be explicitly stated.

**3.5** *Published Operating Envelope.* The applicable operating envelope for which Equation 1 is valid shall be stated. Equation 1 shall not be used to extrapolate beyond the Published Operating Envelope.

**3.6** *Published Rating*. A statement of the assigned values of those performance characteristics, under stated operating 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. For a Batch of Equipment, the Published Rating shall represent the expected average value for the batch. 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 Reference Rating Condition.

**3.7** *Rating Uncertainty*. The limit within which the measured performance of an individual Compressor or a specified large portion of a batch of Compressors can be expected to fall relative to the Published Rating.

**3.8** *Reference Rating Conditions*. A specific condition selected from Table 1 for quick reference or comparison.

**3.9** *Refrigerant Mass Flow Rate*. The mass flow rate of the volatile refrigerant, which is potentially mixed with lubricant.

**3.10** *Refrigerating Capacity*. The capacity associated with the increase in total enthalpy between the refrigerant entering the evaporator and the superheated return gas entering the Compressor. Parasitic heat transfer effects shall not be included in the calculation of Refrigerating Capacity, Btu/h, W.

**3.11** "*Shall*" or "*Should,*" *shall be interpreted as follows:*

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

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

## Section 4. Test Requirements

**4.1** *Test Requirements*. All Published Ratings shall be verified by tests conducted in accordance with ANSI/ASHRAE Standard 23.1.

**4.2** *Ambient Temperature.* Published Ratings shall be established with an ambient temperature around the Compressor of 95.0°F, 35.0°C. If Published Ratings are established at ambient temperatures other than 95.0°F, 35.0°C, the actual ambient temperature used to establish the Published Ratings shall be stated by the manufacturer.

**4.3** *Airflow.* Published Ratings shall be established with no airflow across the Compressor. If Published Ratings are established with airflow across the compressor, the details of the airflow over the Compressor used to establish Published Ratings shall be stated by the manufacturer.

**4.4** *Nameplate Voltages for Rating*. Published Ratings shall be established using the nameplate rated voltage and frequency. For dual nameplate voltage ratings, Published Ratings shall be established using both voltages, or using the higher of the two voltages, if only a single rating is to be published.

## Section 5. Rating Requirements

**5.1** *Published Ratings*. The Published Rating of the Compressor shall consist of the following individual ratings which are established through coefficients provided by the manufacturer that are to be used in Equation 1 and tested as specified in Section 4 meeting the uncertainty in Section 5.4.

**5.1.1** Power Input, W, W
**5.1.2** Refrigerant Mass Flow Rate, lbm./h, kg/s
**5.1.3** Refrigerating Capacity, Btu/h, W

**5.2** *Polynomial Equation.* The polynomial equation that shall be used to present the Published Ratings is a third degree equation of ten coefficients in the form of:

$$X = C_1 + C_2 \cdot (t_S) + C_3 \cdot t_D + C_4 \cdot (t_S^2) + C_5 \cdot (t_S \cdot t_D) + C_6 \cdot (t_D^2) + C_7 \cdot (t_S^3) + C_8 \cdot (t_D \cdot t_S^2) + C_9 \cdot (t_S \cdot t_D^2) + C_{10} \cdot (t_D^3) \qquad 1$$

Where:

$C_1$ through $C_{10}$ = Regression coefficients provided by the manufacturer
$t_D$ = Discharge dew point temperature, °F, °C
$t_S$ = Suction dew point temperature, °F, °C
X = Individual Published Ratings shown in Sections 5.1

**5.2.1** *Least Squares Method.* The coefficients to be used in Equation 1 shall be established using the method of "Least Squares."

**5.2.2** *Superheat and Return Gas Temperatures*. The coefficients to be used in Equation 1 shall be established using the superheat and/or return gas temperature conditions specified in Tables 1 and 2. The same superheat or return gas temperature shall be used over the entire Published Operating Envelope. The manufacturer will clearly state the superheat and/or return gas temperature conditions at which the Published Ratings apply.

**5.2.3** *Subcooling*. The coefficients to be used in Equation 1 shall be established using the subcooling specified in Tables 1 and 2. The manufacturer will clearly state the subcooling at which the Published Ratings apply.

**5.3** *Reference Rating Conditions (I-P).* Reference Rating Conditions are specified in Table 1 (I-P).

**Table 1 (I-P). Reference Rating Conditions[2]**

| Temperature Points | Air Conditioning and Heat Pump | | Refrigeration | | |
|---|---|---|---|---|---|
| | Heating | Cooling | Low[1] | Medium[1] | High |
| Suction Dew Point, °F | 5.0 | 50.0 | -25.0 | 20.0 | 45.0 |
| Discharge Dew Point, °F | 95.0 | 115.0 | 105.0 | 110.0 | 130.0 |
| Suction Return Gas Temperature, °F or | 25.0 | 70.0 | 40.0 | 65.0 | 65.0 |
| Superheat[4], R | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| Subcooling[3], R | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Notes:
1) The manufacturer shall clearly state which superheat is published.
2) Refer to Figure 1 (I-P) graphical representation of the Reference Rating Conditions.
3) Refer to Appendix C for subcooling calculation for capacity.
4) Refer to Appendix D for superheat correction for capacity.

**5.4** *Uncertainties of Published Ratings (I-P).* When Published Ratings fall within the Application Envelope specified in Table 2 (I-P) and Figure 1 (I-P), they shall comply with the uncertainties stated in Table 3.

**Table 2 (I-P). Application Envelope for the Rating Uncertainties**

| Temperature Points | Region 1 | Region 2 | Region 3 |
|---|---|---|---|
| Suction Dew Point, °F | ≥-40.0 and <0.0 | ≥0.0 and <30.0 | ≥30.0 and ≤55.0 |
| Discharge Dew Point, °F | ≥-5.0 and ≤140.0 | ≥20.0 and ≤140.0 | ≥50.0 and ≤140.0 |
| Suction Return Gas Temperature, °F | 30.0 | 65.0 | 65.0 |
| or Superheat[1], R | 20.0 | 20.0 | 20.0 |
| Subcooling, R | 0.0 | 0.0 | 0.0 |

Notes:
1) The manufacturer shall clearly state which superheat is published.
2) Refer to Figure 1 (I-P) for a graphical representation of the Application Envelope over which the Rating Uncertainties apply.

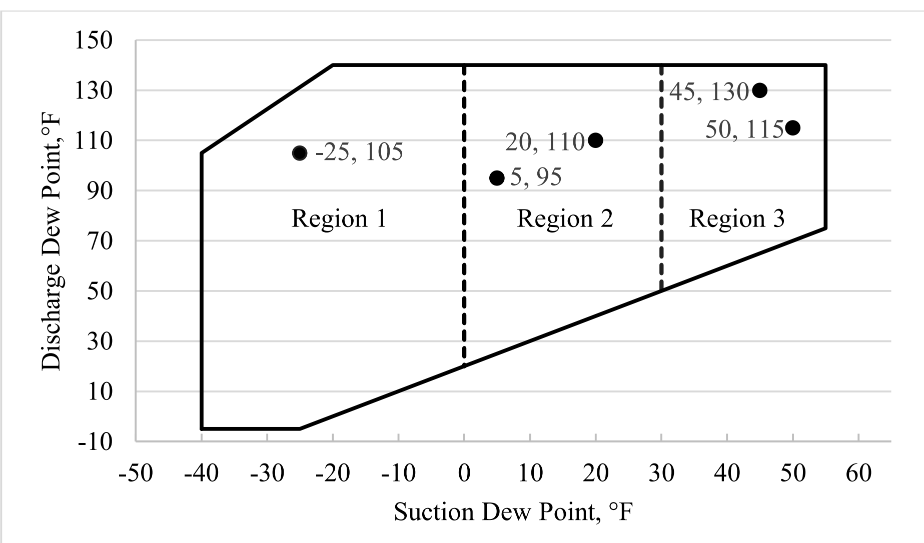


**Figure 1 (I-P). Application Envelope for the Rating Uncertainties, with Reference Rating Conditions Shown (Table 1 (I-P))**

**5.5** *Reference Rating Conditions (SI).* Reference Rating Conditions are specified in Table 1 (SI).

**Table 1 (SI). Reference Rating Conditions[2]**

| Temperature Points | Air Conditioning and Heat Pump | | Refrigeration | | |
|---|---|---|---|---|---|
| | Heating | Cooling | Low[1] | Medium[1] | High |
| Suction Dew Point, °C | -15.0 | 10.0 | -31.5 | -6.5 | 7.0 |
| Discharge Dew Point, °C | 35.0 | 46.0 | 40.5 | 43.5 | 54.5 |
| Suction Return Gas Temperature, °C | -4.0 | 21.0 | 4.5 | 18.5 | 18.5 |
| or Superheat[4], K | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 |
| Subcooling[3], K | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Notes:
1) The manufacturer shall clearly state which superheat is published.
2) Refer to Figure 1 (SI) graphical representation of the Reference Rating Conditions.
3) Refer to Appendix C for subcooling calculation for capacity.
4) Refer to Appendix D for superheat correction for capacity.

**5.6** *Uncertainties of Published Ratings (SI).* When Published Ratings fall within the Application Envelope specified in Table 2 (SI) and Figure 1 (SI), they shall comply with the uncertainties stated in Table 3.

**Table 2 (SI). Application Envelope for the Rating Uncertainties [2]**

| Temperature Points | Region 1 | Region 2 | Region 3 |
|---|---|---|---|
| Suction Dew Point, °C | ≥-40.0 and <-18.0 | ≥-18.0 and <-1.0 | ≥-1.0 and ≤13.0 |
| Discharge Dew Point, °C | ≥-20.5 and ≤60.0 | ≥-6.5 and ≤60.0 | ≥10.0 and ≤60.0 |
| Suction Return Gas Temperature, °C | -1.0 | 18.5 | 18.5 |
| or Superheat[1], K | 11.0 | 11.0 | 11.0 |
| Subcooling, K | 0.0 | 0.0 | 0.0 |

Notes:
1)The manufacturer shall clearly state which superheat is published.
2)Refer to Figure 1 (SI) for a graphical representation of the Application Envelope over which the Rating Uncertainties apply.

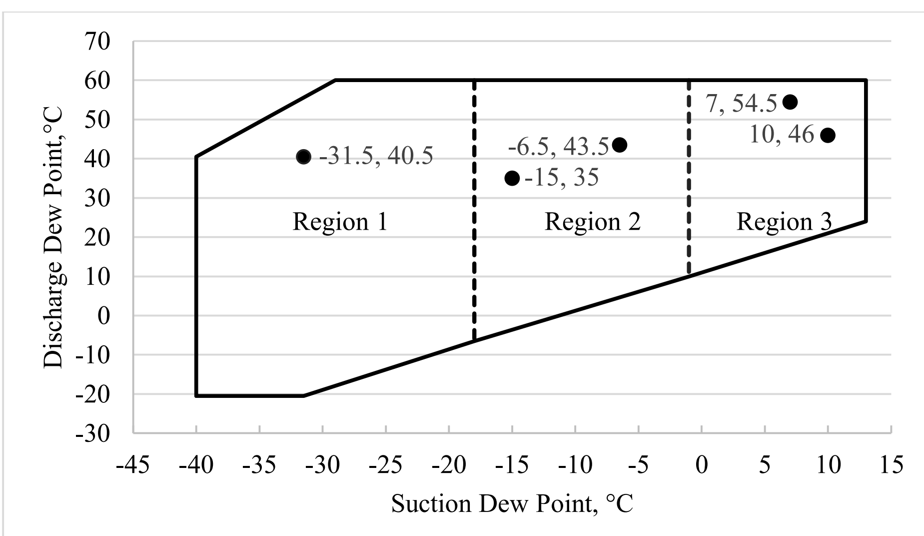


**Figure 1 (SI). Application Envelope for the Rating Uncertainties, with Reference Rating Conditions Shown (Table 1 (SI))**

**5.7** *Rating Uncertainty Limits for the Verification of Published Ratings*. Published Ratings shall fall within the Application Envelope specified in Table 2 (I-P) and Figure 1 (I-P) or Table 2 (SI) and Figure 1 (SI).

**Table 3. Rating Uncertainty Limits for the Verification of Published Ratings**

| Published Rating | Region 1 | Region 2 | Region 3 |
|---|---|---|---|
| Minimum Refrigerant Mass Flow, lbm/hr, kg/s | 90.0% | 92.5% | 95.0% |
| Minimum Refrigerating Capacity, Btu/h, W | 90.0% | 92.5% | 95.0% |
| Maximum Power Input, W, W | 110.0% | 107.5% | 105.0% |

## Section 6. Minimum Data Requirements for Published Ratings

**6.1** *Minimum Data Requirements for Published Ratings.* As a minimum, Published Ratings shall include the following:

**6.1.1** Range for suction dew point temperature ratings, °F, °C
**6.1.2** Range for discharge dew point temperature ratings, °F, °C
**6.1.3** Suction return gas temperature, °F, °C or superheat, R, K
**6.1.4** Liquid temperature, °F, °C or subcooling, R, K
**6.1.5** Coefficients for Power Input, W, W
**6.1.6** Coefficients for Refrigerant Mass Flow Rate, lbm/h, kg/s
**6.1.7** Coefficients for Refrigerating Capacity, Btu/h, W
**6.1.8** Refrigerant designation per ANSI/ASHRAE Standard 34
**6.1.9** Electrical Information
**6.1.9.1** Input voltage, V
**6.1.9.2** Phase
**6.1.9.3** Frequency, Hz
**6.1.9.4** Capacitor size for single phase

**6.2** *Tabular Data*. Tabular data is generated from Equation 1 and shall be used to present the published data in 5°F or 3°C increments for suction dew point temperatures and 10°F or 5.6°C increments for discharge dew point temperatures.

Values of the same performance characteristics calculated from Equation 1 shall be rounded to 4 significant digits so that the values agree with the tabular values within ± 1%.

The published data shall include the following values:
**6.2.1** Suction dew point temperature, °F, °C
**6.2.2** Discharge dew point temperature, °F, °C
**6.2.3** Suction return gas temperature, °F, °C or superheat, R, K
**6.2.4** Liquid temperature, °F, °C or subcooling, R, K
**6.2.5** Power Input, W, W
**6.2.6** Current, A
**6.2.7** Refrigerant mass flow rate, lbm/h, kg/s
**6.2.8** Refrigerating Capacity, Btu/h, W
**6.2.9** Refrigerant designation per ANSI/ASHRAE Standard 34
**6.2.10** Electrical Information
**6.2.10.1** Input voltage, V
**6.2.10.2** Phase
**6.2.10.3** Frequency, Hz
**6.2.10.4** Capacitor size for single phase
**6.2.11** Performance Factor, EER, COP, or bhp/ton

**6.3** *Reference Rating Condition*. At least one of the Reference Rating Conditions specified in both versions of Table 1 shall be included in the tabular data defined by Section 6.2.

**6.4** *Superheat Corrections.* Refer to Appendix D for suggested superheat correction methodology.

**6.5** *Claims to Ratings*. All claims to ratings within the scope of this standard shall include the statement "Rated in accordance with AHRI Standard 540". All claims to ratings outside the scope of this standard shall include the statement "Outside the scope of AHRI Standard 540". Wherever ratings are published or printed, they shall include a statement of the conditions at which the ratings apply.

## Section 7. Operating Requirements

**7.1** *Loading Requirements*. The Compressor shall be capable of operating continuously at all operating points in the Published Operating Envelope for a minimum period of two hours at the minimum and maximum utilization voltage as described in ANSI/AHRI Standard 110, Table 1.

## Section 8. Marking and Nameplate Data

**8.1** *Compressor Nameplate Marking*. As a minimum, each Compressor shall have a nameplate, affixed on which the following information shall be marked:

- **8.1.1** Compressor manufacturer's name and/or symbol
- **8.1.2** Compressor model number
- **8.1.3** Electrical Information
  - **8.1.3.1** Input voltage, V
  - **8.1.3.2** Phase
  - **8.1.3.3** Frequency, Hz

Nameplate voltages for 60 Hertz systems shall include one or more of the utilization voltages specified in Table 1 of ANSI/AHRI Standard 110. Nameplate voltages for 50 Hertz systems shall include one or more of the equipment nameplate voltages specified 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 the 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 Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

**A1.2** ANSI/AHRI Standard 510-2006, *Performance Rating of Positive Displacement Ammonia Compressors and Compressor Units*, 2006, Air- Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

**A1.3** ANSI/AHRI Standard 570 (I-P)-2012, *Performance Rating of Positive Displacement Carbon Dioxide Refrigerant Compressors and Compressor Units*, 2012, Air- Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

**A1.4** ANSI/AHRI Standard 571 (SI)-2012, *Performance Rating of Positive Displacement Carbon Dioxide Refrigerant Compressors and Compressor Units*, 2012, Air- Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Boulevard, Suite 500, Arlington, VA 22201, U.S.A.

**A1.5** ANSI/ASHRAE Standard 23.1-2010, *Methods of Testing for Rating the Performance of Positive Displacement Refrigerant Compressors and Condensing Units That Operate at Subcritical Temperatures*, 2010, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

**A1.6** ANSI/ASHRAE Standard 34-2013 with Addenda, *Number Designation and Safety Classification of Refrigerants,* 2013, American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers, 11 West 42nd Street, New York, NY 10036, U.S.A./1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

**A1.7** ASHRAE *Terminology,* https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology, 2015, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A

**A1.8** IEC Standard Publication 60038, 2009, *IEC Standard Voltages,* International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

# APPENDIX B. REFERENCES – INFORMATIVE

**B1** Listed here are all standards, handbooks, and other publications not essential to the formation and implementation of the standard and intended for referenced only.


**B1.1** A. E. Dabiri and C. K. Rice, 1981. "A Compressor Simulation Model with Corrections for the Level of Suction Gas Superheat," *ASHRAE Transactions*, Vol. 87, Part 2, pp.771-782. http://www.ornl.gov/~webworks/cppr/y2003/jrnl/111018.pdf

**B1.2** B. Shen, J. E. Braun, and E. A. Groll, 2009. "Improved Methodologies for Simulating Unitary Air Conditioners at Off-Design Conditions", *International Journal of Refrigeration*, Volume 32.

**B1.3** ISO 3951: 2013, *Sampling procedures for inspection by variables,* International Organization for Standardization, Case Postale 56, CH-1211, Geneva 21 Switzerland.

**B1.3** ISO 3534 Parts 1-4: 2006, *Statistics — Vocabulary and symbols,* International Organization for Standardization, Case Postale 56, CH-1211, Geneva 21 Switzerland.

**B1.4** ISO 7574: 1985, *Statistical methods for determining and verifying stated noise emission values of machinery and equipment,* International Organization for Standardization, Case Postale 56, CH-1211, Geneva 21 Switzerland.

# APPENDIX C. METHOD TO HANDLE ZEOTROPIC MIXTURES – INFORMATIVE

**C1** *Cycle Process.*

**C1.1** *Cycle Process for Single Component Refrigerants and Azeotropic Mixtures*. Figure C1 shows a typical single stage cycle for single component refrigerants and azeotropic mixtures. As shown, the evaporating and condensing processes occur at fixed temperatures $t_o$ and $t_c$.

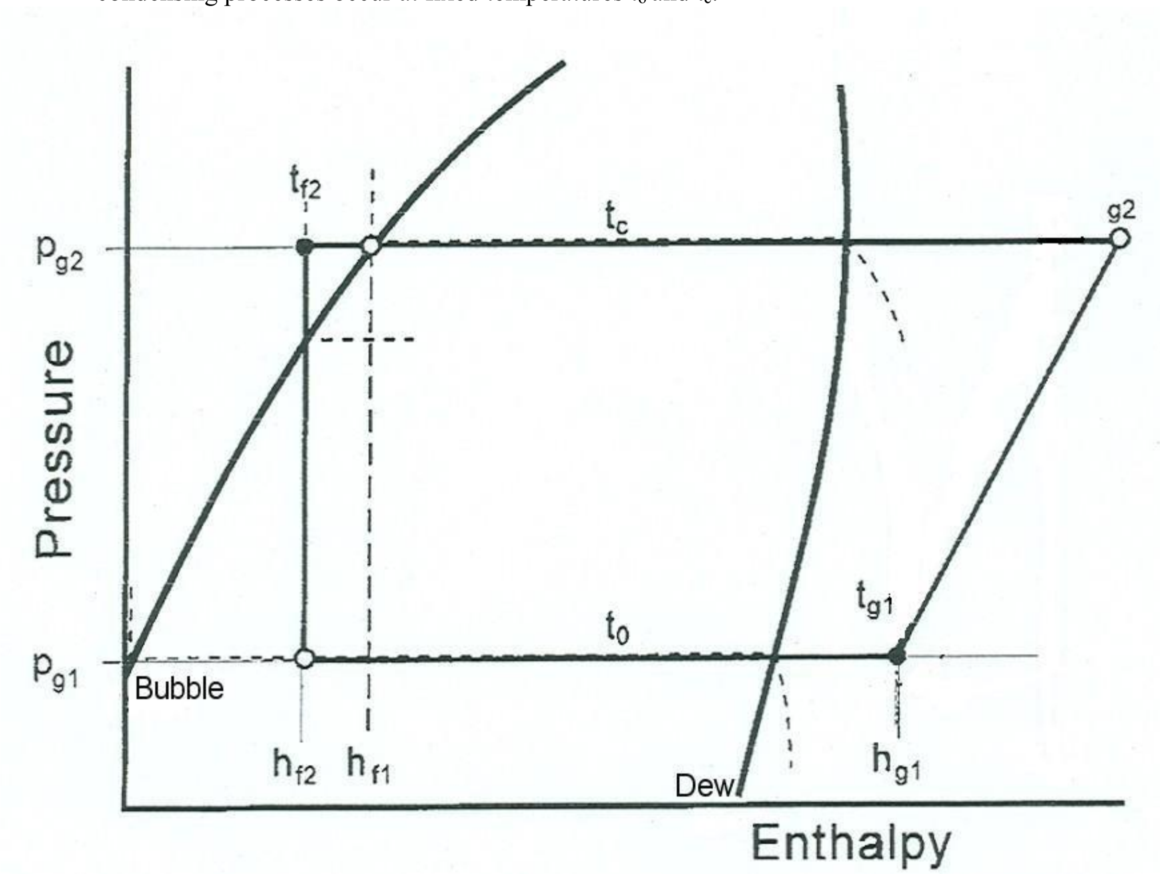


**Figure C1. Cycle Process for Single Component Refrigerants and Azeotropic Mixtures**

**C1.2** *Cycle Process for Zeotropic Refrigerant Mixtures*. Figure C2 shows "temperature glide" for zeotropic refrigerant mixtures at the evaporation and condensation processes. Standard reference temperatures are the dew-point temperatures $t_o''$ at the evaporating pressure $p_{g1}$ and $t_c''$ at the condensing pressure $p_{g2}$.

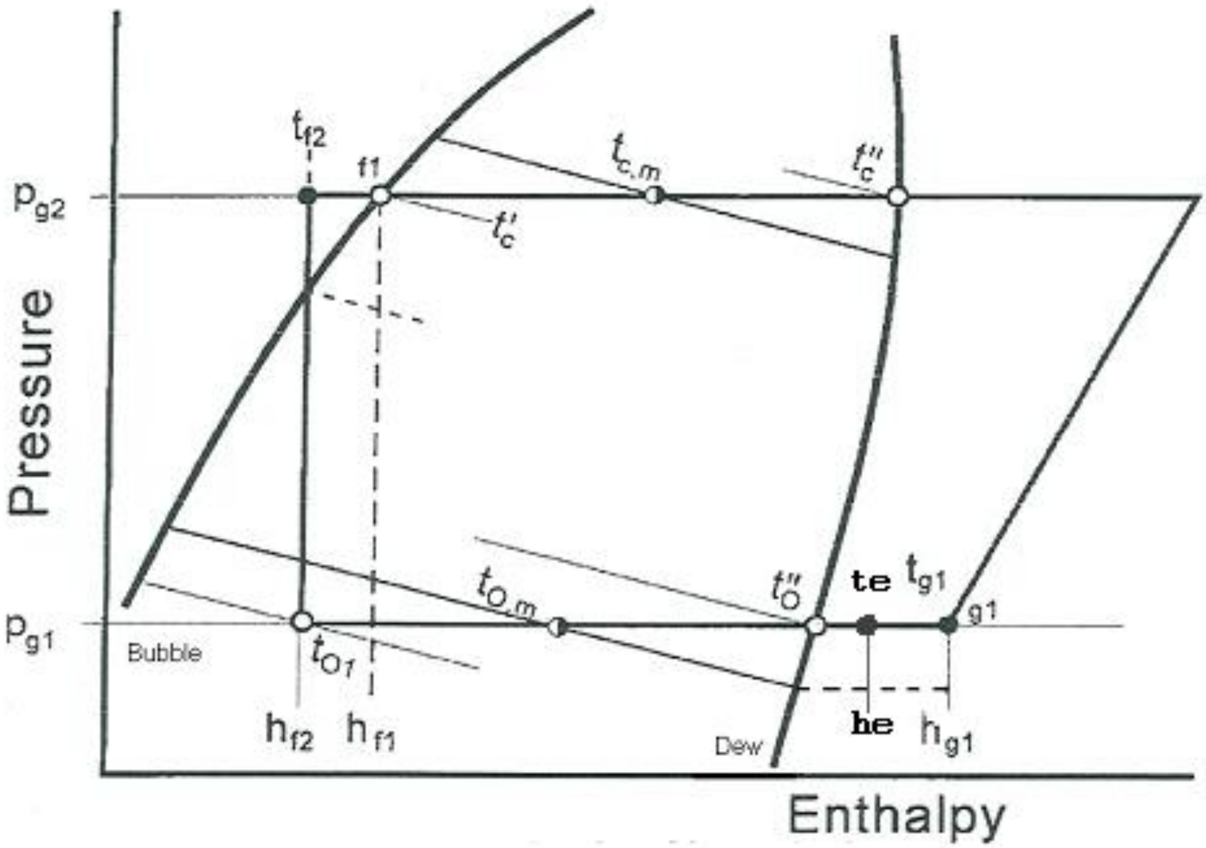


**Figure C2. Cycle Process for Zeotropic Refrigerant Mixtures**

**C1.3** *Mean Evaporating / Condensing Temperature and Refrigerant Superheating / Subcooling*. The following equations may be used to calculate the mean evaporating temperature, mean condensing temperature, refrigerant superheating, and refrigerant subcooling:

| | | | |
|---|---|---|---|
| **C1.3.1** Mean evaporating temperature: | $t_{0,m} = (t_{01} + t_o'')/ 2$ | C1 |
| **C1.3.2** Mean condensing temperature: | $t_{c,m} = (t_c' + t_c'')/ 2$ | C2 |
| **C1.3.3** Refrigerant superheating: | $\Delta t_{Sg} = t_{g1} - t_o''$ | C3 |
| **C1.3.4** Refrigerant subcooling: | $\Delta t_{Sf} = t_c' - t_{f2} = t_{f1} - t_{f2}$ | C4 |

Note: Because $t_{01} = t_o''$ and $t_c' = t_c''$ for single-component refrigerants and azeotropic multi-component refrigerants, the cycle process model represents a particular kind of model for zeotropic refrigerant mixtures.

**C1.4** *Refrigerating Capacity*. In all reference systems, Refrigerating Capacity of the Compressor is calculated by Equations C5 and C6.

| | | |
|---|---|---|
| **C1.4.1** Refrigerating Capacity: | $Q = \dot{m}\,(h_{g1} - h_{f2})$ | C5 |
| **C1.4.2** Refrigerating Capacity Assuming no subcooling: | $Q_0 = \dot{m}\,(h_{g1} - h_{f1})$ | C6 |

Evaporator capacity or net refrigeration effect can also be used as a reference using Equation C7.

**C1.4.3** Refrigerating Evaporator Capacity: $Qe = \dot{m}\,(he - h_{f2})$
C7

**C1.5** *Reference Systems*. The reference systems described above allow one to calculate and present performance data for all kinds of refrigerants in a similar way.

**C1.6** *Definitions of Subcooling and Superheating in Zeotropic Mixtures*. In connection with zeotropic mixtures, different definitions of the expressions for superheating and subcooling can be found in technical documentation (Figure C3). The Equations C3 and C4 are equivalent to A in Figure C3 and shall be used for the purpose of calculating ratings. For reference only, B in Figure C3 with mean temperatures as reference points, uses the following equations:

**C1.6.1** Refrigerant superheating: $\Delta t_{Sg} = t_{g1} - t_{0,m}$ C8

**C1.6.2** Refrigerant subcooling: $\Delta t_{Sf} = t_{cm}' - t_{f2} \neq t_{f1} - t_{f2}$ C9

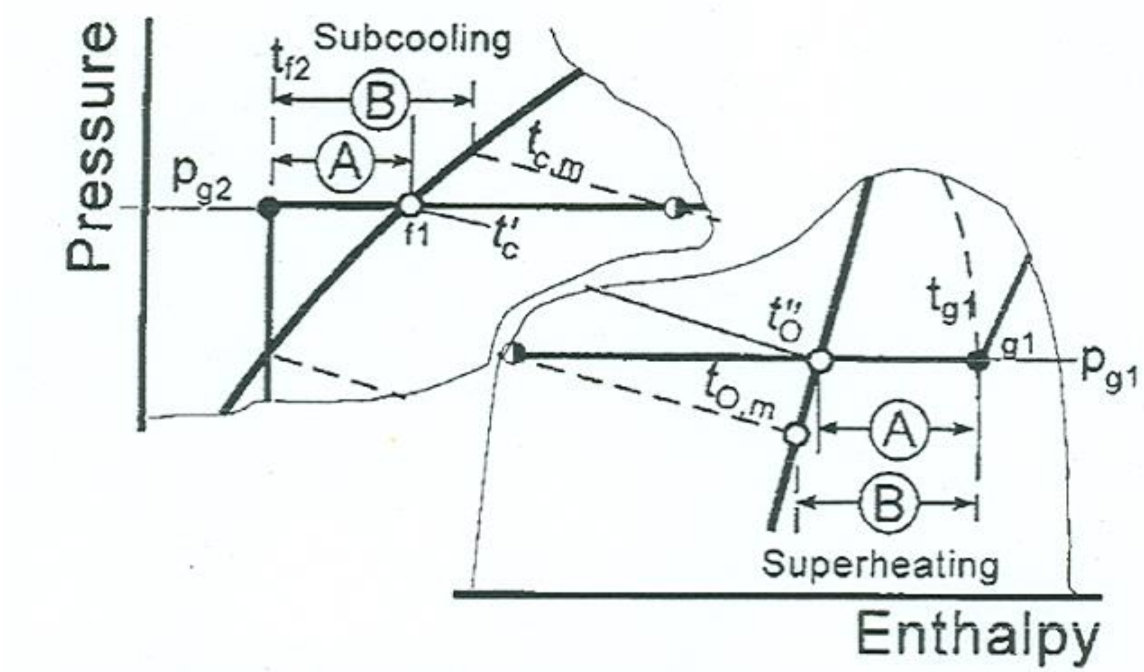


**Figure C3. Definitions of Subcooling and Superheating**

**C1.7** *System Capacities*. The reference system used for Zeotropic mixtures when used for rating purposes should use the dew point conditions as outlined in Section C1.6. For system calculations, refrigeration performance at the evaporator or condenser may be more appropriate. In this case, the evaporator and condenser mean saturated conditions at $t_{o,m}$ and $t_{c,m}$ , respectively, could be used as the operating condition of the heat exchangers. The compressor saturated suction condition is not the mean temperature of the evaporator but the dew point condition at the inlet of the compressor.

For example, if an evaporator is designed to operate at a mean temperature of $t_{o,m}$ per requirement, the corresponding dew point value (pressure) for compressor selection and superheat calculation would be $t_o''$ (assuming no pressure drop) which is higher than $t_{o,m}$. A similar logic would be applied at the condenser.

Superheat should always be calculated from the dew point at the inlet to the compressor or evaporator exit and subcooling calculated at the bubble point at the exit of the condenser to ensure desired quality of refrigerant.

**C2** *Symbols and Subscripts.*

Symbols:

$f_1$ = Bubble point at condensing process
$g_1$ = Point where the refrigerant enters the compression process
$g_2$ = Point where the refrigerant leaves the compression process
$h_{f1}$ = Enthalpy of the refrigerant at bubble point of condensing process
$h_{f2}$ = Enthalpy of the subcooled refrigerant liquid entering the expansion process
$h_{g1}$ = Enthalpy of the refrigerant gas entering the compression process
$h_e$ = Enthalpy of the refrigerant gas exiting the evaporator
$\dot{m}$ = Refrigerant Mass Flow Rate
$P_{g1}$ = Compressor suction dew point pressure
$P_{g2}$ = Compressor discharge dew point pressure
$Q$ = Refrigerating capacity
$Q_0$ = Refrigerating capacity assuming no subcooling
$t_c$ = Condensing temperature
$t'_c$ = Bubble point temperature at condensing process
$t''_c$ = Dew point temperature at condensing process
$t_{c,m}$ = Mean condensing temperature
$t_{f1}$ = Exiting temperature for the subcooled liquid through the expansion process
$t_{f2}$ = Entering temperature for the subcooled liquid to the expansion process
$t_{g1}$ = Temperature of the refrigerant entering the compression process
$t_0$ = Evaporating temperature
$t_0''$ = Dew point temperature at evaporation process
$t_{01}$ = Temperature at the outlet of the expansion process and inlet to the evaporation process
$t_{0,m}$ = Mean evaporating temperature
$t_e$ = Temperature of the refrigerant at the exit of the evaporator
$\Delta t_{Sf}$ = Refrigerant subcooling
$\Delta t_{Sg}$ = Refrigerant superheat

Subscripts:

c = Condensing process
c′ = Bubble point of condensing process
c″ = Dew point of condensing process
c,m = Mean condensing process
e = Exit of the evaporator
f1 = Bubble point of condensing process
f2 = Point at which the subcooled refrigerant liquid enters the expansion process
g1 = Dew point at Compressor suction
g2 = Dew point at Compressor discharge
0 = Evaporating process
01 = Outlet of the expansion process and inlet to the evaporation process
0,m = Mean evaporating process
tsf = Temperature, saturated fluid
tsg = Temperature, saturated gas

# APPENDIX D. SUPERHEAT CORRECTION – INFORMATIVE

**D1** *Mass Flow Correction*. Testing Compressors over the entire Published Operating Envelope at various superheat is impractical in most cases. Mass flows can be adjusted for various superheats by using the change in suction density. The formula below, referenced from a 1981 A. E. Dabiri and C. K. Rice publication in ASHRAE Transactions and a 2009 B. Shen, J. E. Braun, and E. A. Groll publication in the International Journal of Refrigeration (see Sections B1.1 and B1.2 of Appendix B), provides a calculation typically used to adjust the mass flow at different superheats. A change of superheat has negligible impact on power consumption.

$$\dot{m}_{corrected} = \{ 1 + F_v [(\nu_{rated} / \nu_{corrected}) - 1] \} \cdot \dot{m}_{rated} \qquad \text{D1}$$

Where:

| | | |
|---|---|---|
| $F_v$ | = | Volumetric efficiency correction factor – the correction factor will vary based on volumetric efficiency of the compression technology used, a value of one (1) can be used for an approximation. Contact the manufacturer for a more precise value. |
| $\dot{m}_{corrected}$ | = | Refrigerant Mass Flow Rate at suction condition, lbm/h, kg/s |
| $\dot{m}_{rated}$ | = | Refrigerant Mass Flow Rate at rated superheat, lbm/h, kg/s |
| $\nu_{corrected}$ | = | Specific volume at suction condition, $ft^3/lb$, $m^3/kg$ |
| $\nu_{rated}$ | = | Specific volume at rated condition, $ft^3/lb$, $m^3/kg$ |

# APPENDIX E. HISTORICAL RATING CONDITIONS – INFORMATIVE

**E1** *Historical Rating Conditions*. The historical rating conditions shown in this appendix have been included from the previous version of the standard (AHRI Standard 540-2004) to provide historical reference.

**E1.1** *Historical Rating Conditions for Compressors Used in Commercial Refrigeration Applications*. The rating when operated under one of the historical reference rating conditions presented in Table E1.

**Table E1. Historical Rating Conditions for Compressors Used in Commercial Refrigeration Applications (Based on 95°F, 35°C Ambient Temperature Surrounding the Compressor)[1]**

| Suction Dew Point Temperature | | Compressor Type | Discharge Dew Point Temperatures | | Return Gas Temperature[3] | | Subcooling | |
|---|---|---|---|---|---|---|---|---|
| °F | °C | | °F | °C | °F | °C | °F | °C |
| 45 | 7.2 | All | 130 | 54.4 | 65 | 18 | 15 | 8.3 |
| 20 | -6.7 | All[2] | 120 | 48.9 | 40/65[2,3] | 4.4/18[2,3] | 0 | 0 |
| -10 | -23 | Hermetic | 120 | 48.9 | 40 | 4.4 | 0 | 0 |
| -25 | -32 | All[2] | 105 | 40.6 | 40/65[2,3] | 4.4/18[2,3] | 0 | 0 |
| -40 | -40 | All[2] | 105 | 40.6 | 40/65[2,3] | 4.4/18[2,3] | 0 | 0 |

Notes:

1) If airflow across the Compressor is used to determine ratings, it should be specified by the compressor manufacturer.

2) For Hermetic Refrigerant Compressors, 40°F, 4.5°C return gas temperature should be used.

3) For accessible Hermetic Refrigerant Compressors with external drives of accessible type, 65°F, 18.5°C return gas temperature should be used.

**E1.2** *Historical Rating for Compressors Used in Air-conditioners and Heat Pumps*. The ratings when operated under one of the historical rating conditions presented in Table E2.

**Table E2. Historical Rating Conditions for Compressors Used In Air Conditioners and Heat Pumps (Based on 95°F, 35°C Ambient Temperature Surrounding the Compressor)[1,2]**

| Rating Test Point | Intended Use | Suction Dew Point Temperature | | Discharge Dew Point Temperature | | Return Gas Temperature | |
|---|---|---|---|---|---|---|---|
| | | °F | °C | °F | °C | °F | °C |
| A | Air Source (Cooling) | 45 | 7.2 | 130 | 54.4 | 65 | 18 |
| B | Air Source (Cooling) | 45 | 7.2 | 115 | 46.1 | 65 | 18 |
| C | Air Source (Heating & Cooling) | 45 | 7.2 | 100 | 37.8 | 65 | 18 |
| D | Air Source (Heating) | 30 | -1.1 | 110 | 43.3 | 50 | 10 |
| E | Air Source (Heating) | 5 | -15 | 95 | 35 | 25 | -3.9 |
| F | Air Source (Cooling) | 45 | 7.2 | 80 | 27 | 65 | 18 |
| G | Air Source (Heating) | 35 | 1.7 | 90 | 32 | 55 | 13 |
| H | Water Source (Cooling & Heating) | 45 | 7.2 | 120 | 48.9 | 65 | 18 |

Notes:

1) If airflow across the Compressor is used to determine ratings, it should be specified by the compressor manufacturer.

2) For all conditions, 15°F, 8.3°C subcooling should be used.

# APPENDIX F. VERIFICATION OF PUBLISHED RATINGS FOR BATCHES OF EQUIPMENT – INFORMATIVE

**F1** *General Discussion*. To characterize the performance of a Batch of Equipment, it is necessary to provide an estimate of the average performance for the batch and to also provide information on the uncertainty that can be expected. The uncertainty is the result of a number of factors that include manufacturing/product tolerances, testing procedures, instrument accuracies, random variation during testing in a given lab and random variation between different testing locations. In this standard, additional uncertainty is introduced when using a regression model to represent the performance over the entire operating envelop using a curve fit of a limited set of data.

The total uncertainty is generally assumed to follow a normal distribution and can therefore be described in terms of a total standard deviation or the percentage of the batch that falls within a specified uncertainty limit. Historically, this standard has not addressed the verification for a Batch of Equipment explicitly as it has not provided specific expectations or guidance regarding the interpretation of the Published Ratings relative to the average value for the batch and the total standard deviation for the batch. Very accurate estimates of the average values and standard deviations for a batch over an operating envelop can be difficult, time consuming, and expensive to obtain and so the verification process should represent a reasonable balance between the accuracy of the published ratings and to cost to develop them. The purpose of this appendix is to provide additional information and a proposed method to verify Published Ratings for a Batch of Equipment.

**F2** *Verification Requirements*. The Published Ratings provide an estimate of the average value for the Batch of Equipment. The uncertainty is represented by a normal distribution and expressed in terms of a total standard deviation and is quantified by specifying the portion of the batch which is expected to be within the uncertainty limit. To verify the Published Ratings, verification test results should meet the acceptability requirements given below. This standard uses the verification process described in ISO 7574 which is based on information from ISO 3951 and ISO 3534. There are two cases to be considered when verifying Published Ratings for a batch. In the first case, the product design is complex and/or product production volume is small so testing of multiple samples may not be practicable. For this case, published data will be verified using a single sample. In the second case, the product design is reasonably simple and production volumes are reasonably large so that the testing of multiple samples is practicable. For this case, published ratings will be verified using a sample size of three.

**F3** *Rating Uncertainties*. For verification purposes, it is necessary to specify both an uncertainty limit and the size of the portion that can be expected to fall within the limit. The uncertainty limits are given in Table F1 and for this standard it is assumed that 95% of the batch will fall within these limits. Given the uncertainty limit, the size of the portion of the batch within the limit, and the distribution, it is possible to calculate the corresponding total standard deviation which is given in Table F2. The total standard deviation includes all of the uncertainties listed above. The actual product performance may or may not match the assumption used in the verification process. To the extent that a manufacturer's product performs at a level equal to or better than the assumptions made in the standard then the risk to the manufacturer and consumer will be equal to or less than the risks defined in the standard. To the extent that the product performs at a level worse than the assumptions made in this standard, then the risks will be higher. The actual level of performance required by a particular customer for a particular application is the responsibility of the manufacturer and customer. This allows the manufacturer and customer to properly balance the cost and effort to develop the published information with the actual requirements for a given application.

**Table F1. Rating Uncertainty Limits for the Verification of Published Ratings of Batches of Equipment**

| Published Rating | Region 1 | Region 2 | Region 3 |
|---|---|---|---|
| Minimum Refrigerant Mass Flow, lbm/h, kg/s | 90% | 92.5% | 95% |
| Minimum Refrigerating Capacity, Btu/h, W | 90% | 92.5% | 95% |
| Maximum Power Input, W, W | 110% | 107.5% | 105% |

| Table F2. Total Standard Deviations Associated with the Rating Uncertainty Limits for the Verification of Published Ratings of Batches of Equipment | |
|---|---|
| Uncertainty Limit | Total Standard Deviation |
| 5% | 3.0 |
| 7.5% | 4.6 |
| 10% | 6.1 |

**F4** *Verification Risk*. A statistically based sampling approach requires the definition of a level of risk or confidence level. The verification process is based on a 95% probability of acceptance of the verification test, if no more than 6.5% of values are outside of the appropriate uncertainty limit.

**F5** *Verification for a Batch of Equipment Using a Single Compressor*. Determine the measured performance value $V_m$ in accordance with Section 4. If $V_m$ is within the acceptance criteria given in Table F3, the Published Rating is verified. Note that for this case with a sample size of one, the acceptance criteria is equivalent to the uncertainty limits given in Table F1.

| Table F3. Acceptance Criteria for the Verification of Published Ratings Using a Sample Size of 1 | | | |
|---|---|---|---|
| Published Rating | Region 1 | Region 2 | Region 3 |
| Minimum Refrigerant Mass Flow, lbm/h, kg/s | 90% | 92.5% | 95% |
| Minimum Refrigerating Capacity, Btu/h, W | 90% | 92.5% | 95% |
| Maximum Power Input, W, W | 110% | 107.5% | 105% |

**F6** *Verification for a Batch of Equipment Using a Sample Size of 3*. A sample size of n=3 is taken at random from the batch. The measured performance values $V_i$ are determined in accordance with Section 4 and the average value for the sample is calculated using Equation F1.

$$V_{avg} = \frac{1}{n}\sum_{i=1}^{n} V_i \qquad \text{F1}$$

Where:

i = Counter
n = Sample size
$V_{avg}$ = Average performance value
$V_i$ = Measured performance value for sample i

If $V_{avg}$ is within the acceptance criteria for the average of three samples as given in Table F4, the Published Rating is verified. Note that for this case when the sample size is larger than one, the acceptance criteria is less than the uncertainty limit as given in Table F1. This is a reflection of the fact that you have a better estimate of the average value with the larger sample size and so for the same risk of passing the verification test, the average value for the larger sample should be closer to the Published Rating.

| Table F4. Acceptance Criteria for the Verification of Published Ratings Using a Sample Size of 3 | | | |
|---|---|---|---|
| Published Rating | Region 1 | Region 2 | Region 3 |
| Minimum Refrigerant Mass Flow, lbm/h, kg/s | 94.5% | 95.5% | 97.0% |
| Minimum Refrigerating Capacity, Btu/h, W | 94.5% | 95.5% | 97.0% |
| Maximum Power Input, W, W | 105.5% | 104.5% | 103.0% |

**F7** *Examples.*

**F7.1** *Example 1 (I-P).*

A Batch of Equipment has a published value for power input of 3000 W at -25/105 °F.

A single compressor is selected for verification and tested at -25/105° as outlined in Section 4. The tested value is 3225 W. The ratio of the tested value to the published value is 107.5%. For this case, the published value is verified.

Three compressors are selected for verification and tested at -25/105°F as outlined in Section 4. The tested values are 3225 W, 3100 W, and 3270 W respectively. The average for the three samples is 3198 W. The ratio of the average value to the published value is 106.6%. For this case the published value is not verified.

**F7.2** *Example 2 (SI).*

A Batch of Equipment has a published refrigerating capacity of 8,200 W at 10/46 °C.

A single compressor is selected for verification and tested at 10/46 °C as outlined in Section 4. The tested value is 7,878 W. The ratio of the tested value to the published value is 96.1%. For this case, the published value is verified.

Three compressors are selected and tested at 10/46 °C as outlined in Section 4. The tested values are 7,878 W, 8,294 W, and 7,913 W respectively. The average for the three samples is 8,028 W. The ratio of the average value to the published value is 97.9%. For this case the published value is verified.