

AHRI Standard 540

**2020 Standard for
Performance Rating of Positive
Displacement Refrigerant
Compressors**



we make life better®

2311 Wilson Boulevard, Suite 400
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 ANSI/CAN/AHRI Standard 540 (E)-2015.

This standard is now updated to include the following previous standards which are now retired:

- Ammonia compressors (AHRI Standard 510)
- Carbon dioxide compressors (AHRI Standards 570 (I-P) and 571 (SI))
- Modulating compressor (AHRI Standard 545)

This standard has been expanded to include multistage compressors, intermediate cooling, and refrigerant injection.

TABLE OF CONTENTS

SECTION		PAGE
Section 1.	Purpose.....	1
Section 2.	Scope.....	1
Section 3.	Definitions.....	1
Section 4.	Test Requirements.....	3
Section 5.	Rating Requirements.....	4
Section 6.	Minimum Data Requirements for Published Ratings.....	13
Section 7.	Operating Requirements.....	14
Section 8.	Marking and Nameplate Data	14
Section 9.	Conformance Conditions.....	15

TABLES

Table 1.	Rating Methods	6
Table 2 (I-P).	Application Envelope	6
Table 2 (SI).	Application Envelope.....	6
Table 3.	Rating Uncertainty Limits.....	10
Table 4 (I-P).	Reference Rating Conditions	11
Table 4 (SI).	Reference Rating Conditions	12
Table 5.	Published Ratings.....	13

FIGURES

Figure 1 (I-P).	Subcritical Application Envelope with Reference Rating Conditions Shown	7
Figure1 (SI).	Subcritical Application Envelope with Reference Rating Conditions Shown	7
Figure2 (I-P).	Supercritical and Transcritical Application Envelope with Reference Rating Conditions Shown	8
Figure 2 (SI).	Supercritical and Transcritical Application Envelope with Reference Rating Conditions Shown	8
Figure 3.	Rating Uncertainty Limits.....	10

TABLE OF CONTENTS (Continued)

APPENDICES

Appendix A. References - Normative..... 16

Appendix B. References - Informative..... 17

Appendix C. Method to Handle Zeotropic Mixtures - Informative..... 18

Appendix D. Superheat Correction - Informative..... 22

Appendix E. Verification of Published Ratings a Population of Compressors - Informative 23

TABLES FOR APPENDICES

Table E1. Rating Uncertainty Limits Using a Sample Size of 3..... 23

FIGURES FOR APPENDICES

Figure C1. Cycle Process for Single Component Refrigerants and Azeotropic Mixtures..... 18

Figure C2. Cycle Process for Zeotropic Refrigerant Mixtures..... 19

Figure C3. Definitions of Subcooling and Superheating..... 20

PERFORMANCE RATING OF POSITIVE DISPLACEMENT REFRIGERANT COMPRESSORS

Section 1. Purpose

1.1 Purpose. The purpose of this standard is to establish for positive displacement 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 positive displacement Compressors for use in an 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 Compressors and their presentation of performance in heating, ventilation, air-conditioning, 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 intended for use in:

2.2.1.1 Household refrigerators and freezers

2.2.1.2 Automotive air-conditioners

2.2.1.3 Household dehumidifiers

2.2.1.4 Industrial products other than heating and cooling

2.2.1.5 Compressed air applications

2.2.2 This standard does not apply to compressors when using an Interstage Port for the purpose of an independent load (commonly known as a side load), except in the case of Economizer Operation.

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 Compression Chamber. A volume with at least one inlet and outlet port.

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. For clarity of this standard, the term Compressor implies Model Number.

3.3 Modulating Compressor. A compressor with more than one displacement capacity. There are two types: Continuous Modulating Compressor and Discrete Modulating Compressor.

3.3.1 *Continuous Modulating Compressor.* A Compressor with more than four (4) Displacement Capacities or variable Displacement Capacities. This includes but is not limited to variable speed, continuously variable mechanical unloading, or cyclic modulation of discrete unloading Steps.

3.3.2 *Discrete Modulating Compressor.* A Compressor with two (2) to four (4) discrete Displacement Capacities.

3.4 *Displacement Capacity.* Theoretical volumetric flow rate through the Compressor expressed in ft³/min, m³/h.

3.5 *Fixed Displacement Compressor.* A Compressor with one (1) Displacement Capacity.

3.6 *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.

3.7 *Individual Published Rating.* A mathematical model used to represent the nominal performance of a Compressor at a single Step.

3.8 *Intermediate Port.* An inlet port for vapor or liquid within a Compression Chamber.

3.9 *Interstage Heat Rejection.* Heat removed between two stages of compression.

3.10 *Interstage Port.* An inlet port for vapor or liquid between two stages of compression.

3.11 *Model Number.* The identifier for a product containing one or more Compressors and any accessories that are supplied by the manufacturer, required to sustain operation of the Compressor(s) at the Rating Conditions or that impact the Published Rating.

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

3.12 *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.

3.13 *Population of Compressors.* 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.

3.14 *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 Rating Condition. If accessories are not included, it shall be explicitly stated.

3.15 *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.

3.16 *Published Rating.* A mathematical model used to represent the nominal performance of a Compressor.

3.17 *Rating Condition.* A saturated suction temperature and saturated discharge temperature point used to determine the number of Steps required to be published per Section 5.

3.18 *Rating Uncertainty Limit.* The limit within which the measured performance of an individual Compressor shall fall relative to the Published Rating.

3.19 *Reference Rating Conditions.* A specific operating condition selected from Table 4 for quick reference or comparison.

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

3.21 *Refrigerating Evaporator Capacity.* The capacity associated with the increase in total enthalpy between the refrigerant entering the evaporator and the gas leaving the evaporator. Heat transfer effects in the suction line shall be considered non-

useful and not included in the calculation of Refrigerating Evaporator Capacity, Btu/h, W.

3.22 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. Heat transfer effects in the suction line shall be considered useful and included in the calculation of Refrigerating Capacity, Btu/h, W.

Terms used to determine the number of Steps required to be published per Section 5:

3.22.1 Maximum Rated Capacity. The rated Refrigerating Capacity of the Modulating Compressor operating at the Maximum Rated Step for a manufacturer defined Rating Condition, Btu/h, W.

3.22.2 Minimum Rated Capacity. The rated Refrigerating Capacity of the Modulating Compressor operating at the Minimum Rated Step for a manufacturer defined Rating Condition, Btu/h, W.

3.22.3 % Capacity. The capacity at a specific step divided by the Maximum Rated Capacity at the manufacturer defined Rating Condition, %.

3.23 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.

3.24 Step. A level of modulation achieved by changing the Displacement Capacity not limited to the examples listed below:

3.24.1 Step Method.

3.24.1.1 Compressor operating frequency, Hz

3.24.1.2 Compressor speed, RPM

3.24.1.3 Mechanical unloading setting (fixed or time weighted average) (%). Note: This “%” is a representation or name of the Step and not necessarily an actual % Capacity.

3.24.1.4 VFD frequency, Hz

3.24.2 Maximum Rated Step. The Step producing the highest Displacement Capacity of the Modulating Compressor.

3.24.3 Minimum Rated Step. The Step producing the lowest Displacement Capacity of the Modulating Compressor.

3.25 "Shall" or "Should," shall be interpreted as follows:

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

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

3.26 Vapor Injection (Economizer Operation). A method of (a) increasing Refrigerating Capacity using an economizer to subcool liquid refrigerant exiting the condenser, and (b) reducing discharge temperature. Refrigerant vapor or wet vapor that exits the economizer enters an Intermediate Port or an Interstage Port on the Compressor.

3.27 Variable Frequency Drive (VFD). A power electronic device that regulates the speed of an alternating current (AC) motor by adjusting the frequency and the voltage of the electrical power supplied to the motor.

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 or 23.2, as applicable.

4.2 Ambient Temperature. Published Ratings shall be established with an ambient temperature around the Compressor and its accessories of 95 °F, 35 °C.

4.3 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.

4.4 Power Input. For Hermetic or Semi-hermetic Refrigerant Compressors with a factory integrated or factory specified VFD, the Power Input is measured at the VFD input terminals.

Section 5. Rating Requirements

5.1 Published Rating. A Published Rating is one or more Individual Published Rating that represents Refrigerating Capacity, Power Input, and Refrigerant Mass Flow Rate parameters across the entire operating envelope of the Compressor.

5.2 Individual Published Rating. The Individual Published Rating of the Compressor shall consist of parameters which are established through coefficients used in the polynomial equation (Equation 1) in Section 5.4, tested as specified in Section 4, and rated with a method as specified in section 5.5. The accuracy of the Individual Published Ratings shall conform to the requirements of Section 5.6.

In the case of a Modulating Compressor, the Published Rating is a set of Individual Published Ratings at unique Steps. The number of unique Steps to comprise each set of Published Ratings is specified in Section 5.3.

Parameters to be reported:

- 5.2.1 Power Input, W, W
- 5.2.2 Refrigerant Mass Flow Rate, lbm/h, kg/s
- 5.2.3 Refrigerating Capacity, Btu/h, W

5.3 Number of Individual Published Ratings Requirement.

5.3.1 Fixed Displacement Compressor. The Published Rating of a Fixed Displacement Compressor shall consist of an Individual Published Rating at its single Step.

5.3.2 Discrete Modulating Compressor. The Published Rating of a Discrete Modulating Compressor shall be provided at every discrete Step to comprise each set of Individual Published Ratings. All of the discrete Steps of the Compressor shall be included in the Published Rating of the Compressor unless the number of Steps can be satisfied by the requirements of a Continuous Modulating Compressor in Section 5.3.3.

5.3.3 Continuous Modulating Compressor, The Published Rating of a Continuous Modulating Compressor shall be provided per the following requirements to comprise each set of Individual Published Ratings.

- 5.3.3.1 An Individual Published Rating of the Compressor at the Maximum Rated Step.
- 5.3.3.2 An Individual Published Rating of the Compressor at the Minimum Rated Step.
- 5.3.3.3 If the Minimum Rated Capacity is greater than or equal to 40% of the Maximum Rated Capacity, at least one Individual Published Rating of the Compressor at an evenly spaced Step (or Steps) between the Maximum and Minimum Rated Capacity.
- 5.3.3.4 If the Minimum Rated Capacity is less than 40% of the Maximum Rated Capacity, at least two Individual Published Ratings of the Compressor at evenly spaced Steps between the Maximum and Minimum Rated Capacity.
- 5.3.3.5 Each Step shall be evenly spaced between the Maximum and Minimum Rated Capacity within $\pm 5\%$.

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

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

Where:

X = Refrigerating Capacity, Power Input, or Refrigerant Mass Flow Rate
 t_D = Discharge dew point temperature, °F, °C, Discharge pressure, psi, bar
 t_S = Suction dew point temperature, °F, °C
 C_1 through C_{10} = Regression coefficients provided by the manufacturer

$$\text{Power Input Coefficient Set, Step N: } \{P_N\} = P_{N-1}, P_{N-2}, \dots P_{N-10} \quad 2$$

$$\text{Mass Flow Coefficient Set, Step N: } \{M_N\} = M_{N-1}, M_{N-2}, \dots M_{N-10} \quad 3$$

$$\text{Refrigerating Capacity Coefficient Set, Step N: } \{R_N\} = R_{N-1}, R_{N-2}, \dots R_{N-10} \quad 4$$

$$\text{Individual Published Rating at Step N: } \{IPR_N\} = \{P_N\}, \{M_N\}, \{R_N\} \quad 5$$

$$\text{Published Rating of the Compressor: } \{PR\} = \{IPR_1\}, \{IPR_2\}, \dots \{IPR_N\} \quad 6$$

Where:
 N = Step designation number of the Individual Published Rating

The coefficients to be used in Equation 1 shall be established using the following requirements:

5.4.1 Least Squares Method. The method of “Least Squares” shall be used.

5.4.2 Return Gas Temperatures. Superheat and/or return gas temperature conditions specified in Table 4 shall be used. The same superheat or return gas temperature shall be used over the entire Published Operating Envelope. The manufacturer shall clearly state the superheat and/or return gas temperature conditions at which the Published Ratings apply.

5.4.3 Subcooling. 0 R, 0 K subcooling shall be used. For coefficient sets derived with other than 0 R, 0 K subcooling, the manufacturer shall clearly state the subcooling at which the Published Ratings apply.

5.5 Rating Methods. Compressors or compressor units shall be rated in one of four ways shown in Table 1. Manufacturers shall declare which rating method is used when providing Published Ratings. If no method is referenced it is assumed that ANSI/CAN/AHRI Standard 540 Method 1 is used.

Method	Vapor Injection (Economizer Operation)	Fluid Entering Economizer (Subcritical)	Fluid Entering Economizer (Transcritical)	Economizer	Fluid Exiting Economizer (Subcritical)	Fluid Exiting Economizer (Transcritical)
1	N/A	N/A	N/A	None	N/A	N/A
2	Note 3	Note 4	Note 5	Manufacturer Specified Heat Exchanger	Stated by manufacturer	Stated by manufacturer
3	Note 3	Note 4	Note 5	Non-Specified Heat Exchanger	Note 6	
4	Note 3	Note 4	Note 5	Flash Tank	Note 7	

Notes:

- For all methods, other than mechanical sub-cooling in the economizer, there is no parasitic heat gain or loss in the liquid line.
- For all methods, suction superheat is 20 R, 10 K or return gas temperature is 65 °F, 20 °C entering the compressor.
- Manufacturer shall report Refrigerating Capacity including the increased refrigeration effect by the subcooling or gas cooling provided by the Vapor Injection (Economizer Operation).
- Liquid temperature leaving the condenser shall be assumed to have 0 R, 0 K subcooling.
- Manufacturer shall report gas cooler outlet temperature and compressor discharge pressure.
- Liquid temperature leaving the economizer shall be 9 °F, 5 °C above the bubble point temperature corresponding to the pressure at the Intermediate or Interstage Port of the compressor.
- Liquid temperature leaving the economizer shall be equal to the bubble point temperature corresponding to the pressure at the Intermediate or Interstage Port of the compressor.

5.6 Rating Uncertainty Limits of Published Ratings. To comply with this standard, single sample product verification test results, conducted at conditions within the application envelope defined in Table 2 (I-P) and Table 2 (SI), shall meet the Published Ratings of the Compressor within the Rating Uncertainty Limits defined in Table 3.

Operating Parameters	Region 1	Region 2	Region 3
Suction Dew Point, °F	≥-40 and <0	≥0 and <30	≥30 and ≤70
Discharge Dew Point, °F Subcritical Condensing Applications	≥-5 and ≤140	≥20 and ≤140	≥50 and ≤140
Discharge Pressure, psia CO ₂ Transcritical Applications	≥300 and ≤1800	≥575 and ≤1800	≥425 and ≤1800

Operating Parameters	Region 1	Region 2	Region 3
Suction Dew Point, °C	≥-40 and <-20	≥-20 and <-5	≥-5 and ≤20
Discharge Dew Point, °C Subcritical Condensing Applications	≥-20 and ≤55	≥-10 and ≤55	≥5 and ≤55
Discharge Pressure, bar CO ₂ Transcritical Applications	≥20 and ≤120	≥26 and ≤120	≥38 and ≤120

5.6.1 Figure 2 (I-P), Figure 2 (SI), Figure 3 (I-P), and Figure 3 (SI) are graphical representations of the Application Envelopes shown in Table 2 (I-P) and Table 2 (SI). Reference rating conditions are shown in Table 4 (I-P) and Table 4 (SI). See Section 5.7 for Reference Rating Conditions.

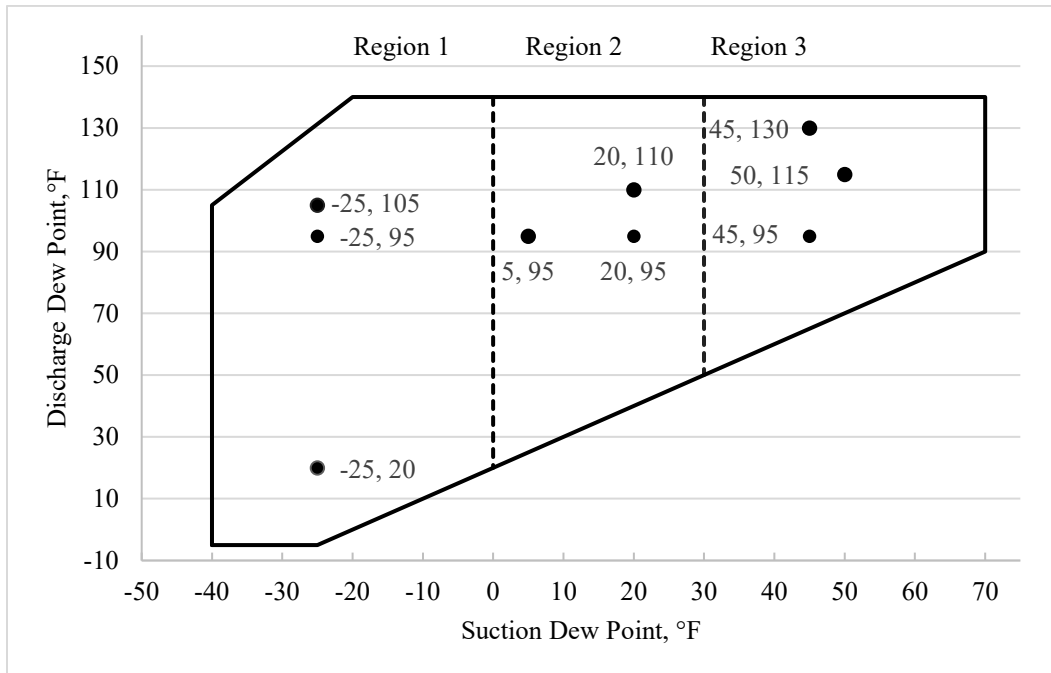


Figure 1 (I-P). Subcritical Application Envelope with Reference Rating Conditions Shown

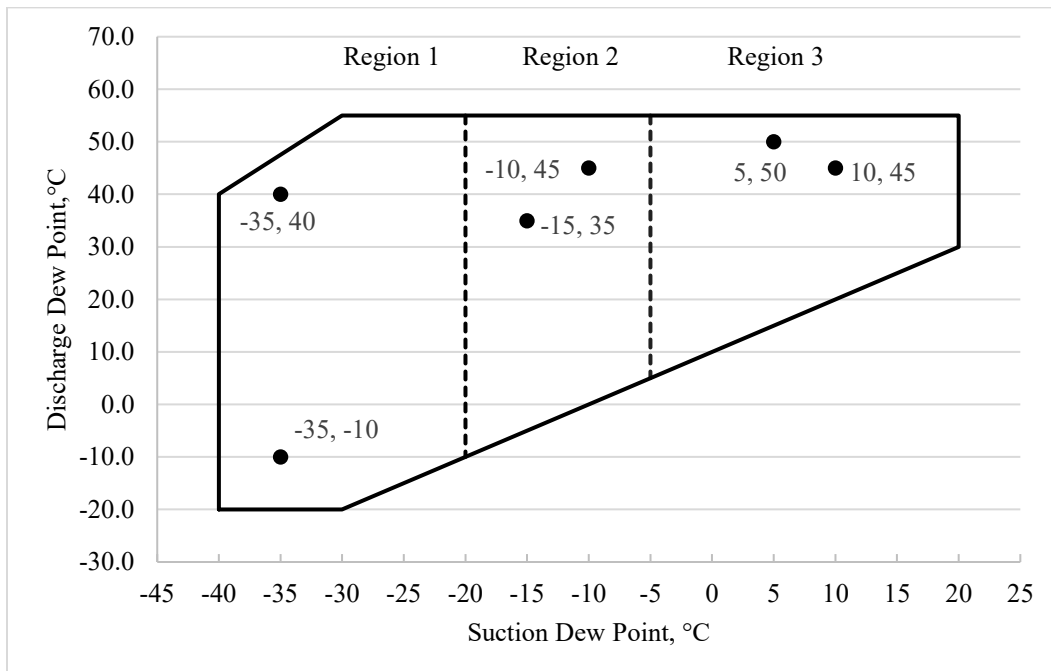


Figure 1 (SI). Subcritical Application Envelope with Reference Rating Conditions Shown

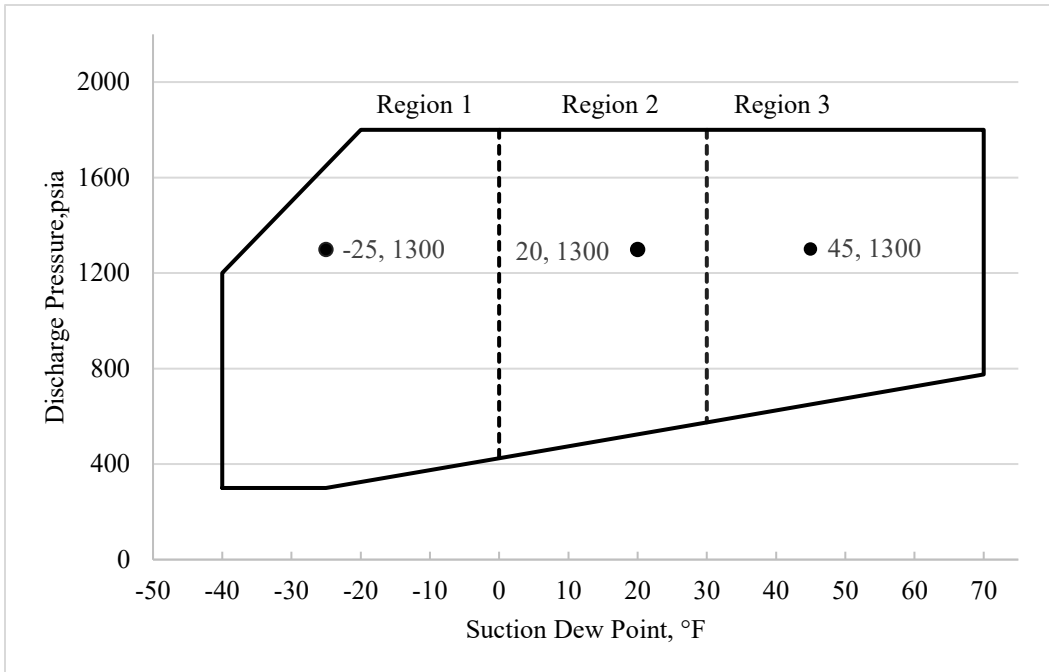


Figure 2 (I-P). Supercritical and Transcritical Application Envelope with Reference Rating Conditions Shown

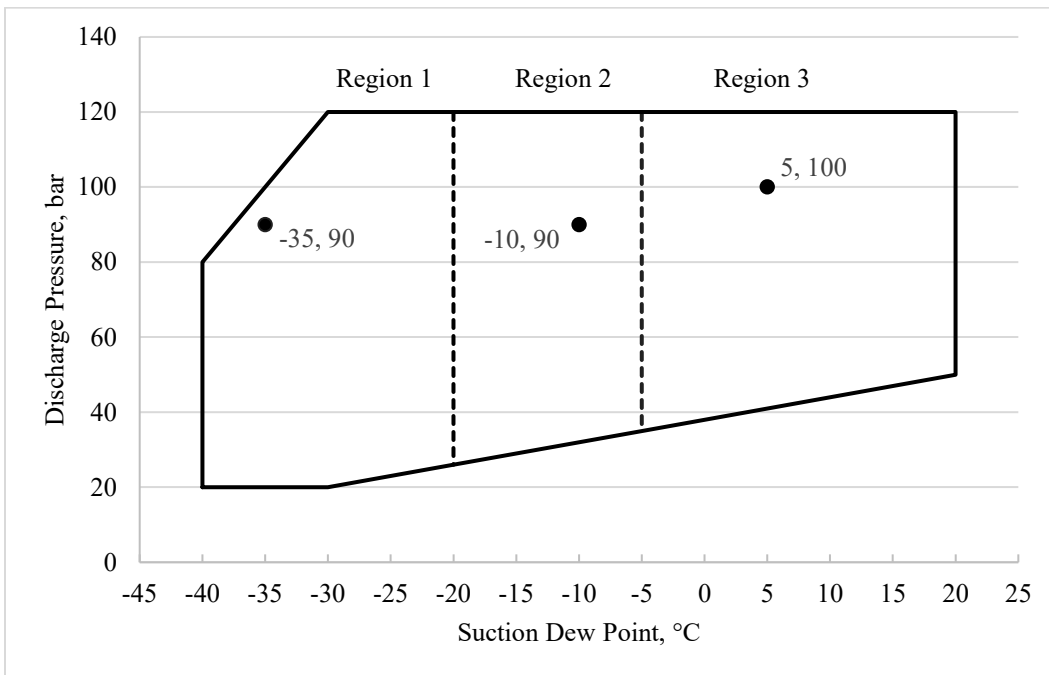


Figure 2 (SI). Supercritical and Transcritical Application Envelope with Reference Rating Conditions Shown

Table 3. Rating Uncertainty Limits				
Published Rating		Region 1	Region 2	Region 3
Refrigerant Mass Flow, lb/min Refrigerating Capacity, Btu/h EER, Btu/W·h COP, W/W	Full Load	Tested Rating ≥ 90.0% of Published Rating	Tested Rating ≥ 92.5% of Published Rating	Tested Rating ≥ 95.0% of Published Rating
	Part Load	Tested Rating ≥ (100% - UL _{R1}) of Published Rating	Tested Rating ≥ (100% - UL _{R2}) of Published Rating	Tested Rating ≥ (100% - UL _{R3}) of Published Rating
Power Input, kW	Full Load	Tested Rating ≤ 110.0% of Published Rating	Tested Rating ≤ 107.5% of Published Rating	Tested Rating ≤ 105.0% of Published Rating
	Part Load	Tested Rating ≤ (100% + UL _{R1}) of Published Rating	Tested Rating ≤ (100% + UL _{R2}) of Published Rating	Tested Rating ≤ (100% + UL _{R3}) of Published Rating

5.6.2 *Calculation of Rating Uncertainty Limits.* Rating Uncertainty Limits are calculated as follows:

$$UL_{R1} = (\% \text{ Capacity}) \cdot (-0.0625) + 0.1625 \quad 7$$

$$UL_{R2} = (\% \text{ Capacity}) \cdot (-0.0625) + 0.1375 \quad 8$$

$$UL_{R3} = (\% \text{ Capacity}) \cdot (-0.0625) + 0.1125 \quad 9$$

Where:

UL_{R1} = Rating Uncertainty Limit in Region 1

UL_{R2} = Rating Uncertainty Limit in Region 2

UL_{R3} = Rating Uncertainty Limit in Region 3

5.6.3 *Graphical Representation of Rating Uncertainty Limits.*

5.6.3.1 Figure 1 is a graphical representation of the Rating Uncertainty Limits for minimum Refrigerating Capacity, Refrigerant Mass Flow Rate, EER, COP, and Power Input shown in Table 3.

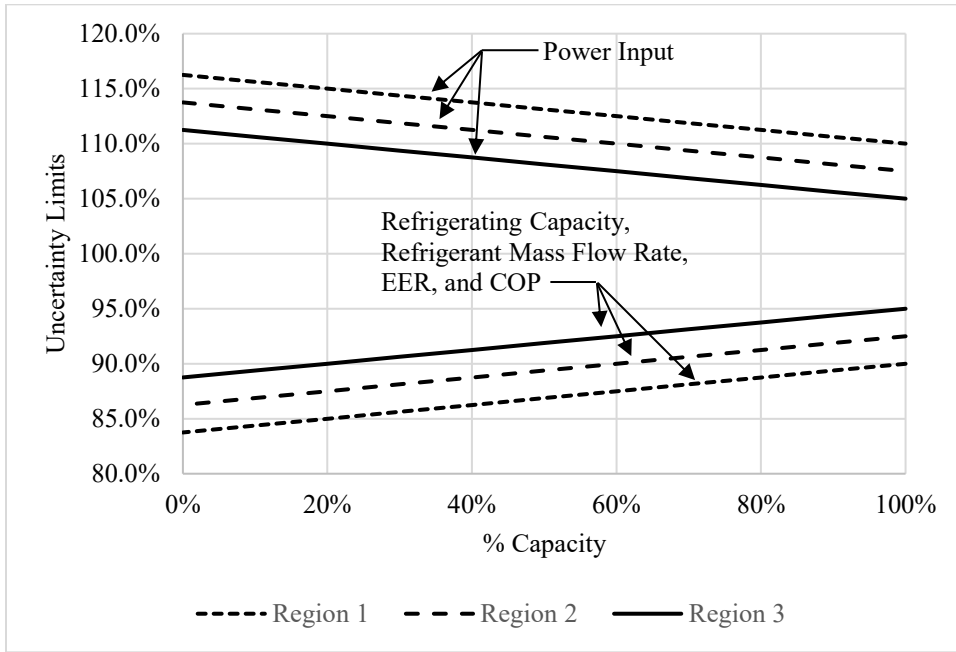


Figure 3. Rating Uncertainty Limits

5.7 *Reference Rating Conditions.* The manufacturer shall identify the operating condition when publishing single point rating information. Reference rating conditions are shown in Table 4 (I-P) below and Table 4 (SI) on the following page.

Table 4 (I-P). Reference Rating Conditions^{1,2,3}

Compression Cycle			Low Side		High Side – Subcritical		High Side – Transcritical	
Application	Rating Test Point	Cycle Type	Suction Dew Point Temperature, °F	Superheat, R (or Return Gas Temperature) ^{4,5} , °F	Discharge Dew Point Temperature, °F	Condenser Exit Sub Cooling ⁶ , R	Discharge Pressure, psia	Gas Cooler Exit Temperature, °F
AC and HP	Heating	Subcritical	5	20 (25)	95	0	NA ⁷	
	Cooling	Subcritical	50	20 (70)	115	0	NA ⁷	
Refrigeration	High	Subcritical	45	20 (65 ⁸)	130	0	NA ⁷	
		Subcritical (NH ₃)		10 (55)	95	0	NA ⁷	
		Transcritical (CO ₂)		20 (65 ⁸)	NA ⁷		1300	95
	Medium	Subcritical	20	20 (65 ⁸)	110	0	NA ⁷	
		Subcritical (NH ₃)		10 (30)	95	0	NA ⁷	
		Transcritical (CO ₂)		20 (65 ⁸)	NA ⁷		1300	95
	Low	Subcritical	-25	20 (40 ⁸)	105	0	NA ⁷	
		Subcritical (NH ₃)		10 (-15)	95	0	NA ⁷	
		Transcritical (CO ₂)		20 (40 ⁸)	NA ⁷		1300	95
		Cascade / Booster		20 (40 ⁸)	20	0	NA ⁷	

- Notes:**
1. If airflow across the compressor or other external methods of cooling are used to determine ratings, they shall be specified by the compressor manufacturer.
 2. If liquid refrigerant injection is used to control compressor discharge temperature, without any derived subcooling benefits of the liquid entering the evaporator, it shall be specified by the compressor manufacturer.
 3. Ratings are based on 95 °F ambient temperature surrounding compressor.
 4. Return gas temperature entering the compressor is assumed to be useful superheat for Refrigerating Capacity calculation.
 5. Refer to Appendix D for superheat correction for Refrigerating Capacity.
 6. Refer to Appendix C for subcooling calculation for Refrigerating Capacity.
 7. NA: Not Applicable
 8. Alternate return gas temperatures provided intentionally.

Table 4 (SI). Reference Rating Conditions^{1,2,3}

Compression Cycle		Low Side		High Side – Subcritical		High Side – Transcritical		
Application	Rating Test Point	Cycle Type	Suction Dew Point Temperature, °C	Superheat, K (or Return Gas Temperature) ^{4,5} , °C	Discharge Dew Point Temperature, °C	Condenser Exit Sub Cooling ⁶ , K	Discharge Pressure, bar	Gas Cooler Exit Temperature, °C
AC and HP	Heating	Subcritical	-15	10 (-5)	35	0	NA ⁷	
	Cooling	Subcritical	10	10 (20)	45	0	NA ⁷	
Refrigeration	High	Subcritical	5	10 (20 ⁸)	50	0	NA ⁷	
		Subcritical (NH ₃)		5 (10)	50	0	NA ⁷	
		Transcritical (CO ₂)		10 (15)	NA ⁷		100	40
	Medium	Subcritical	-10	10 (20 ⁸)	45	0	NA ⁷	
		Subcritical (NH ₃)		5 (-5)	45	0	NA ⁷	
		Transcritical (CO ₂)		10 (0)	NA ⁷		90	35
	Low	Subcritical	-35	10 (20 ⁸)	40	0	NA ⁷	
		Subcritical (NH ₃)		5 (-30)	40	0	NA ⁷	
		Transcritical (CO ₂)		10 (-25)	NA ⁷		90	35
		Cascade / Booster		10 (5 ⁸)	-10	0	NA ⁷	

Notes:

1. If airflow across the compressor or other external methods of cooling are used to determine ratings, they shall be specified by the compressor manufacturer.
2. If liquid refrigerant injection is used to control compressor discharge temperature, without any derived subcooling benefits of the liquid entering the evaporator, it shall be specified by the compressor manufacturer.
3. Ratings are based on 35 °C ambient temperature surrounding compressor.
4. Return gas temperature entering the compressor is assumed to be useful superheat for capacity calculation.
5. Refer to Appendix D for superheat correction for capacity.
6. Refer to Appendix C for subcooling calculation for capacity.
7. NA: Not Applicable
8. Alternate return gas temperatures provided intentionally.

Section 6. Minimum Data Requirements for Published Ratings

6.1 Minimum Data Requirements for Published Ratings. Table 5 provides minimum data requirements for publishing polynomial equations and data points. At a minimum a data point at a Reference Rating Condition shall be published. Any exceptions to the ambient temperature and airflow per Sections 4.2 and 4.3 shall be stated.

Table 5. Published Ratings			
Published Values	Units	Rating Type	
		Polynomial Equation	Single Point
General			
Model Number	-	■	■
Refrigerant Designation per ANSI/ASHRAE Standard 34	-	■	■
Voltage	V	■	■
Phase	-	■	■
Frequency	Hz	■	■
Capacitor Size (single phase only)	-	■	■
Operating Range			
Range for suction dew point temperature ratings	°F	■	
Range for discharge dew point temperature ratings or Range for discharge pressure	°F, °C or psia, kPa	■	
Performance Data			
Suction dew point temperature	°F, °C		■
Discharge dew point temperature or Discharge Pressure (transcritical CO ₂ only)	°F, °C or psia, kPa		■
Suction return gas temperature or Superheat	°F, °C or R, K	■	■
Liquid temperature (condenser outlet) or Subcooling or Gas cooler outlet temperature	°F, °C or R, K or °F, °C	■	■
Coefficients for Power Input	W, W	■	
Coefficients for Refrigerant Mass Flow Rate	lbm/h, kg/s	■	
Coefficients for Refrigerating Capacity	Btu/h, W	■	
Power Input	W, W		■
Current	A		■
Refrigerant Mass Flow Rate	lbm/h, kg/s		■
Refrigerating Capacity	Btu/h, W		■
Performance Factor	EER, COP, or bhp/ton		■
Additional Data for Modulating Compressors^{1,2,3,4}			
Step	Hz, RPM, %, Hz	■	■
Step Method	Compressor operating frequency, Compressor speed, Mechanical unloading setting, VFD frequency	■	■

Table 5. Published Ratings (continued)			
Additional Data for Rating Methods 2, 3, and 4 or Interstage Heat Rejection (all Rating Methods)			
Published Values	Units	Rating Type	
		Polynomial Equation	Single Point
Rating Method (2, 3, or 4) ⁵	-	■	■
Intermediate or Interstage Port dew point temperature	°F, °C		■
Temperature or superheat at the Intermediate or Interstage Port	°F, °C or R, K		■
Liquid temperature (outlet of economizer heat exchanger)	°F, °C		■
Interstage Heat Rejection	Btu/h, kW		■
Power required for Interstage Heat Rejection	W, W		■
Notes:			
<ol style="list-style-type: none"> 1. If operation at the Published Ratings requires external input or control, manufacturer shall provide instructions necessary to achieve the Published Rating performance. 2. VFD part number shall be published if VFD power is included in ratings and the VFD is not shipped with the Modulating Compressor. 3. If Published Ratings include the power of the VFD and are established with additional cooling means, or an ambient temperature other than defined in Section 4, the details of the cooling fluid, fluid flow rate and entering fluid temperature cooling the VFD shall be stated by the manufacturer. 4. If liquid refrigerant injection is used to control compressor discharge temperature, without any derived subcooling benefits of the liquid entering the evaporator, it shall be specified by the compressor manufacturer. 5. If using rating method 1(see Table 1), it is not required to report the method. 			

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

6.3 *Claims to Ratings.* All claims to ratings within the scope of this standard shall include the statement “Rated in accordance with ANSI/CAN/AHRI Standard 540”. All claims to ratings outside the scope of this standard shall include the statement “Outside the scope of ANSI/CAN/AHRI Standard 540”. Wherever ratings are published or printed, they shall include a statement of the conditions at which the ratings apply. If no Rating Method is explicitly identified, Rating Method 1 is assumed.

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 2 hours at the minimum and maximum utilization voltage as described in 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, Input (For Hermetic and Semi-hermetic Refrigerant Compressors)
 - 8.1.3.1 Voltage, V
 - 8.1.3.2 Phase
 - 8.1.3.3 Frequency, Hz
- 8.1.4 Maximum Permissible Speed (For Open Type Refrigerant Compressors)

Nameplate voltages for 60 Hz systems shall include one or more of the utilization voltages specified in Table 1 of AHRI Standard 110. Nameplate voltages for 50 Hz 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 AHRI Standard 110-2016, *Air-Conditioning, Heating, and Refrigerating Equipment Nameplate Voltages*, 2016, Air-Conditioning, Heating, and Refrigeration Institute, 2311 Wilson Boulevard, Suite 400, Arlington, VA 22201, U.S.A.

A1.2 ANSI/ASHRAE Standard 23.1-2019, *Methods of Testing for Rating the Performance of Positive Displacement Refrigerant Compressors and Condensing Units That Operate at Subcritical Temperatures*, 2010, ASHRAE, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.3 ANSI/ASHRAE Standard 23.2-2014, *Methods of Test for Rating the Performance of Positive Displacement Compressors that Operate at Subcritical Pressures of Refrigerants*, 2014, ASHRAE, 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.4 ANSI/ASHRAE Standard 34-2019 with Addenda, *Number Designation and Safety Classification of Refrigerants*, 2019, ASHRAE, 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

A1.5 ASHRAE *Terminology*, <https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology>, 2019, ASHRAE, 1791 Tullie Circle, N.E., Atlanta, GA 30329, U.S.A.

A1.6 IEC 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*, 2013, International Organization for Standardization, Case Postale 56, CH-1211, Geneva 21 Switzerland.

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

B1.5 ISO 7574:1985, *Statistical methods for determining and verifying stated noise emission values of machinery and equipment*, 1985, International Organization for Standardization, Case Postale 56, CH-1211, Geneva 21 Switzerland.

B1.6 AHRI/ASERCOM White Paper: January 2017, *Tolerances and Uncertainties in Performance Data of Refrigerant Compressors*, Air- Conditioning, Heating, and Refrigeration Institute, 2311 Wilson Boulevard, Suite 400, Arlington, VA 22201, U.S.A., Association of European Refrigeration Component Manufacturers, Rue du Congrès 35, 1000 Brussels, Belgium.

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 .

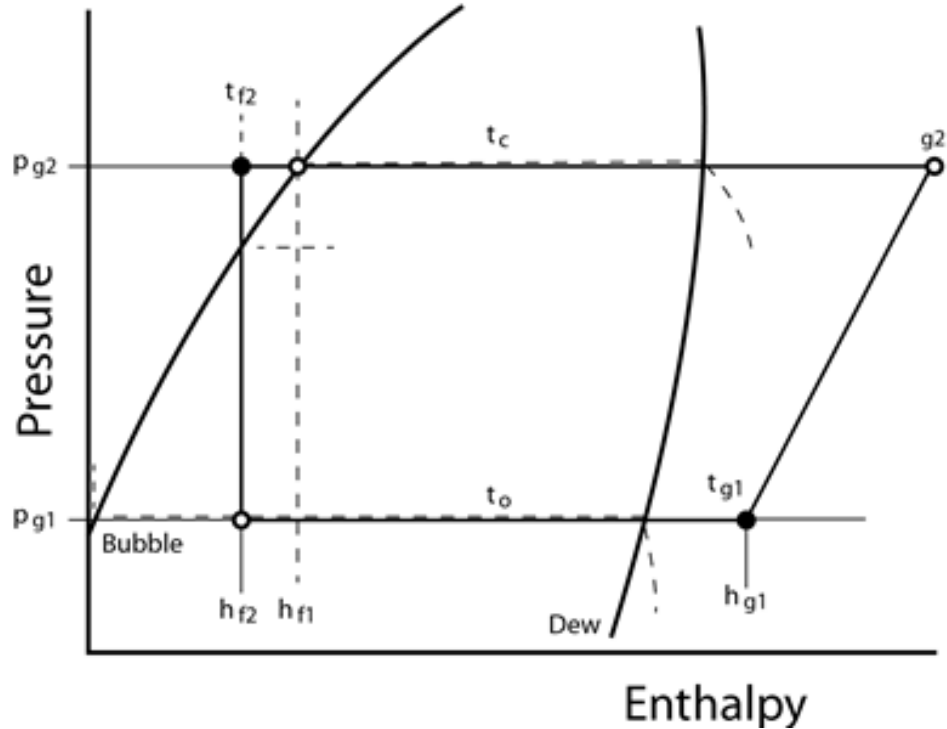


Figure C1. Cycle Process for Single Component Refrigerants and Azeotropic Mixtures

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} .

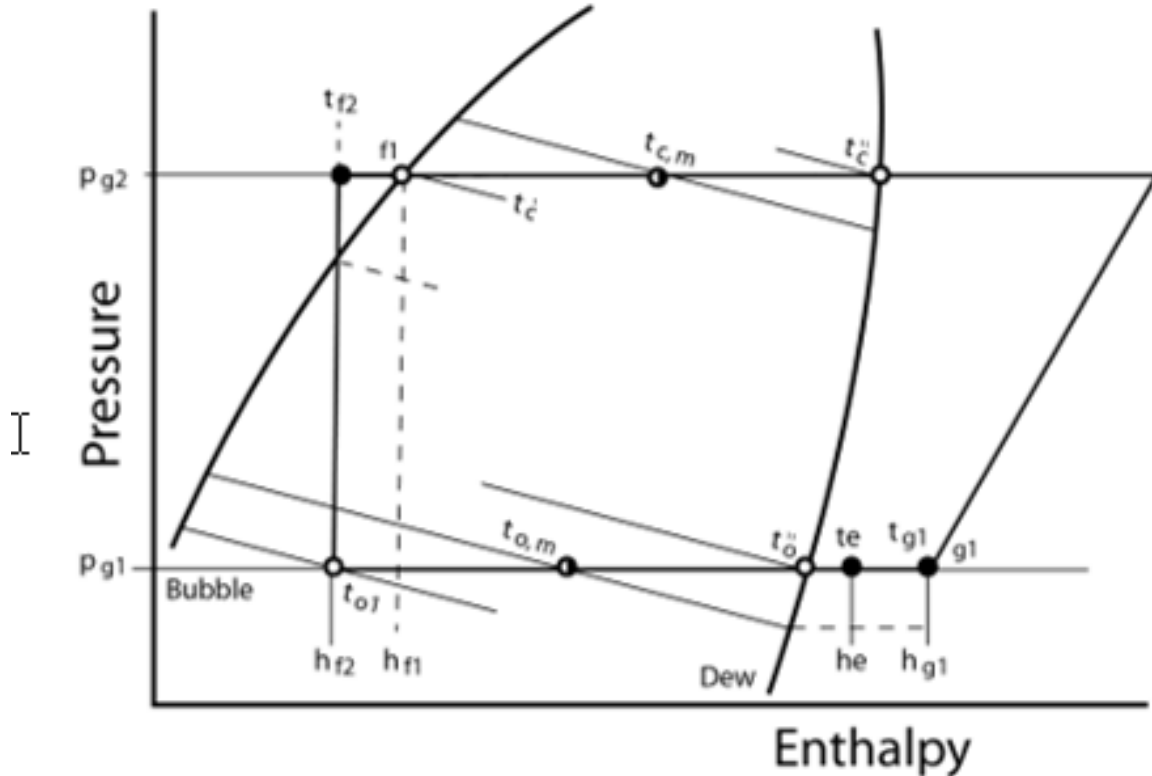


Figure C2. Cycle Process for Zeotropic Refrigerant Mixtures

C1.3 Mean Evaporating / Condensing Temperature and Refrigerant Superheating / Subcooling. Equations C1 through C4 can be used to calculate the mean evaporating temperature, mean condensing temperature, refrigerant superheating, and refrigerant subcooling:

- C1.3.1** Mean evaporating temperature: $t_{0,m} = (t_{o1} + t_o'') / 2$ 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 $t_{o1} = t_o''$ 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: $Q_e = \dot{m} (h_e - h_{f2})$ 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 Equations C8 and C9:

- | | | | |
|---------------|---------------------------|---|----|
| C1.6.1 | Refrigerant superheating: | $\Delta t_{sg} = t_{g1} - t_{o,m}$ | C8 |
| C1.6.2 | Refrigerant subcooling: | $\Delta t_{sf} = t_{c,m} - t_{f2} \neq t_{f1} - t_{f2}$ | C9 |

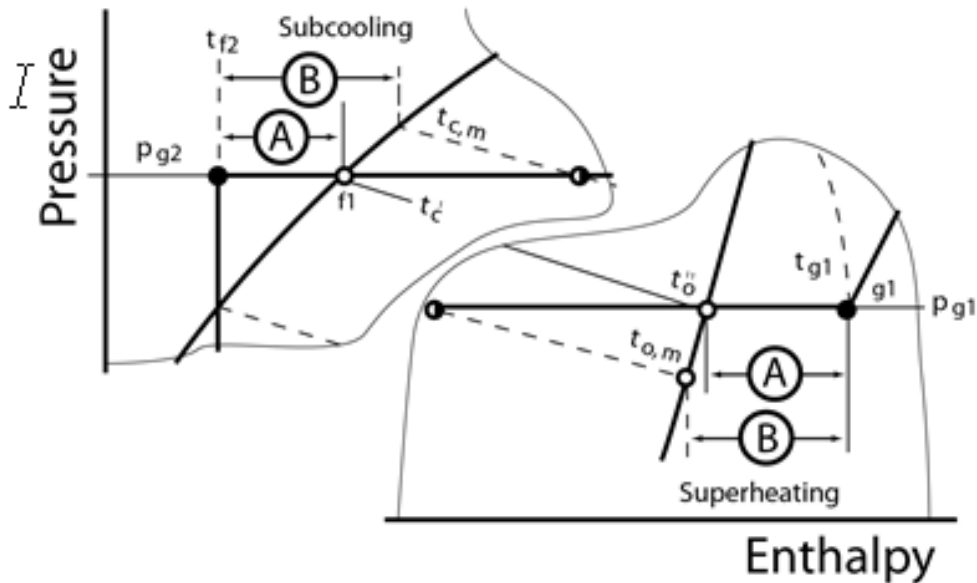


Figure C3. Definitions of Subcooling and Superheating

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.

C2.1 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}	=	Temperature at which the subcooled liquid exits the expansion process
t_{f2}	=	Temperature at which the subcooled liquid enters 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
Δt_{sf}	=	Refrigerant subcooling
Δt_{sg}	=	Refrigerant superheat

C2.2 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
f_1	=	Bubble point of condensing process
f_2	=	Point at which the subcooled refrigerant liquid enters the expansion process
g_1	=	Dew point at Compressor suction
g_2	=	Dew point at Compressor discharge
0	=	Evaporating process
0_1	=	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. Equation D1, 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.

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

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.

$\dot{m}_{\text{corrected}}$ = 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

$v_{\text{corrected}}$ = Specific volume at suction condition, ft³/lbm, m³/kg

v_{rated} = Specific volume at rated condition, ft³/lbm, m³/kg

APPENDIX E. VERIFICATION OF PUBLISHED RATINGS FOR A POPULATION OF COMPRESSORS – INFORMATIVE

E1 The purpose of this appendix is to provide additional information and a proposed method to verify Published Ratings for a Population of Compressors using a sample of a normally distributed population.

General Discussion. To comply with this standard, single sample product verification test results shall meet the Published Rating of the Compressor within the Rating Uncertainty Limits defined in Table 3. Therefore, to publish the performance rating of a Population of Compressors, it is necessary to provide a nominal value representing the average performance of the compressor, and to also provide information on the uncertainty that can be expected for that representative rating. This uncertainty is the result of a number of factors that include measurement uncertainty, lab to lab testing reproducibility uncertainty, manufacturing uncertainty, performance prediction uncertainty, and tested vs rated condition uncertainty, all of which are described in the AHRI/ASERCOM White Paper.

E2 *Rating Uncertainty Limits.* 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 E1 and it can be assumed that 95% of a Population of Compressors will fall within these limits.

E3 *Rating Uncertainty Limits of Published Ratings for a Population of Compressors Using a Sample Size of 3.* Rating Uncertainty Limits of Published Ratings for a Population of Compressors using a sample size of three are determined with the following method.

A sample size of $n=3$ is taken at random from the Population of Compressors. The measured performance values are each measured to calculate an averaged test value (V_{avg}).

If V_{avg} is within the Rating Uncertainty Limits for the average of three samples as given in Table E1, the Published Rating is verified. Note that for this case when the sample size is larger than one, the Rating Uncertainty Limits (Table E1) are less than the Rating Uncertainty Limits in Table 3. This is due to the decreased uncertainty of the rating due to the increased sample size of the measurement.

Table E1. Rating Uncertainty Limits Using a Sample Size of 3				
Published Rating		Region 1	Region 2	Region 3
Refrigerant Mass Flow, lb/min Refrigerating Capacity, Btu/h EER, Btu/W·h COP, W/W	Full Load	Tested Rating \geq 94.5% of Published Rating	Tested Rating \geq 95.5% of Published Rating	Tested Rating \geq 97.0% of Published Rating
	Part Load	Tested Rating \geq (104.5% - UL_{R1}) of Published Rating	Tested Rating \geq (103% - UL_{R2}) of Published Rating	Tested Rating \geq (102% - UL_{R3}) of Published Rating
Power Input, kW	Full Load	Tested Rating \leq 105.5% of Published Rating	Tested Rating \leq 104.5% of Published Rating	Tested Rating \leq 103.0% of Published Rating
	Part Load	Tested Rating \leq (100% + UL_{R1}) of Published Rating	Tested Rating \leq (100% + UL_{R2}) of Published Rating	Tested Rating \leq (100% + UL_{R3}) of Published Rating

E4 *Examples.*

E4.1 *Example 1 (I-P).*

A Population of Compressors has a published value for Power Input of 3.000 kW at -25/105 °F.

A single compressor is selected for verification and tested at -25/105 °F as outlined in Section 4. The tested value is 3.225 kW. 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 3.225 kW, 3.100 kW, and 3.270 kW respectively. The average for the three samples is 3.198 kW. The ratio of the average value to the published value is 106.6%. For this case the published value is not verified.

E4.2 *Example 2 (SI).*

A Population of Compressors has a published Refrigerating Capacity of 8.200 kW 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 kW. 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 kW, 8.294 kW, and 7.913 kW respectively. The average for the three samples is 8.028 kW. The ratio of the average value to the published value is 97.9%. For this case the published value is verified.