

**AHRI Standard 570 (I-P)**

**2012 Standard for  
Performance Rating of  
Positive Displacement  
Carbon Dioxide Refrigerant  
Compressors and Compressor  
Units**



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This standard is a new standard.  
For SI ratings, see AHRI Standard 571 (SI)-2012.

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# PERFORMANCE RATING OF POSITIVE DISPLACEMENT CARBON DIOXIDE REFRIGERANT COMPRESSORS AND COMPRESSOR UNITS

## Section 1. Purpose

**1.1 Purpose.** The purpose of this standard is to establish for positive displacement carbon dioxide refrigerant compressors and compressor units: definitions; test requirements; rating requirements; minimum data requirements for Published Ratings; operating requirements; marking and nameplate data and conformance conditions.

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

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

## Section 2. Scope

**2.1 Scope.** This standard applies to electric motor driven, single and variable capacity, single and two stage Positive Displacement Refrigerant Compressors and Compressor Units operating with carbon dioxide in both subcritical and transcritical applications for refrigeration. This standard also applies to the presentation of performance data for Positive Displacement Compressor and Compressor Units operating with carbon dioxide.

**2.1.1 Refrigerant.** The rating points in this standard are based on R-744 (carbon dioxide).

**2.2 Exclusions.**

**2.2.1** This standard does not apply to compressors and compressor units intended for use in:

- 2.2.1.1** Household refrigerators and freezers
- 2.2.1.2** Automotive air-conditioners
- 2.2.1.3** Dehumidifiers
- 2.2.1.4** Industrial products other than heating and cooling

**2.2.2** This standard does not apply to compressors that are coupled with condensers or gas cooler heat exchangers.

**2.2.3** This standard does not apply to carbon dioxide compressors used in heat pump and air-conditioning applications.

## Section 3. Definitions

All terms in this document will follow the standard industry definitions in the current edition of *ASHRAE Terminology of Heating, Ventilation, Air Conditioning and Refrigeration* unless otherwise defined in this section.

**3.1 Compressor Efficiency or Compressor Unit Efficiency.** A ratio of theoretical to actual power as defined in Appendix C.

**3.2 Energy Efficiency.** A ratio of Refrigerating Capacity to Power Input at specified operating conditions. Using consistent units, a parameter called the energy efficiency ratio (EER) can be used to express the ratio of capacity, Btu/h, to the Power Input, W (Equation 1). The Energy Efficiency may also be expressed as the ratio of Power Input to Refrigerating Capacity (Equation 2).

$$EER = \frac{C}{P} \qquad 1$$

$$EE = \frac{k \cdot bhp}{C} \qquad 2$$

Where:

- bhp = Brake horse power, bhp
- C = Refrigerating Capacity, Btu/h
- EE = Energy Efficiency, bhp/ton
- k = 12,000 Btu/(ton·hr)
- P = Power Input, W

**3.3 Positive Displacement Refrigerant Compressor.** A 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 shall include desuperheaters, head fans or other accessories required to sustain operation of the compressor at the rating conditions.

**3.3.1 Hermetic Refrigerant Compressor.** A compressor and motor assembly, both of which are enclosed in the same housing, with the motor operating in the refrigerant.

**3.3.2 Semi-Hermetic Refrigerant Compressor.** A compressor and motor assembly contained within a gas-tight housing that contains sealed joints to provide access for servicing internal parts.

**3.3.3 Open Drive Refrigerant Compressor.** A compressor with a shaft or other moving part extending through its casing that is driven by an external source of power.

**3.4 Positive Displacement Refrigerant Compressor Unit.** A Positive Displacement Refrigerant Compressor(s) with accessories, such as condensers, gas coolers, interstage coolers, desuperheaters, head fans, strainers, service valves, check valves, suction filters, oil separators, external power source (for Open Drive Refrigerant Compressor), as provided by the manufacturer. This will also include variable capacity controls, electronic or electro-mechanical, as supplied or specified by the manufacturer.

**3.5 Power Input.** The time rate of energy usage of the compressor (compressor power) or compressor unit (compressor unit power).

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

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

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

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

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

**3.8 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).

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

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

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

**3.10** *Single Stage Compressor.* A compressor that has one or more compression chambers and it has only two ports for refrigerant communication with the refrigeration system: a low pressure suction port and a high pressure discharge port. A Single Stage Compressor may or may not have refrigerant injection.

**3.11** *Subcritical Cycle.* A refrigeration cycle where the transfer of heat from the low-temperature reservoir and transfer of heat to the high-temperature reservoir both occur at pressures lower than the critical pressure of the refrigerant.

**3.12** *Transcritical Cycle.* A refrigeration cycle where the transfer of heat from the low-temperature reservoir occurs at a pressure lower than the critical pressure of the refrigerant and transfer of heat to the high-temperature reservoir occurs at a pressure higher than the critical pressure of the refrigerant.

**3.13** *Two Stage Compressor.* A compressor that has one or more compression chambers and has at least three refrigerant communication ports: a low pressure suction port, a high pressure discharge port, and at least a third, intermediate pressure inlet port. When the term intermediate port is used for refrigerant injection, for the sole purpose of controlling discharge gas temperature, the compressor shall be considered a Single Stage Compressor.

#### **Section 4. Test Requirements**

**4.1** *Test Requirements.* All Published Ratings shall be verified by tests conducted in accordance with Appendix C for transcritical applications and ASHRAE Standard 23.1 for subcritical applications.

**4.2** *Ambient Temperature.* The ambient temperature specified in AHRI Standard 570 (I-P) may be different than the value in ASHRAE Standard 23.1. For the purpose of rating to AHRI Standard 570 (I-P), the ambient temperature specified herein shall supersede any requirement in ASHRAE Standard 23.1.

#### **Section 5. Rating Requirements**

**5.1** *Standard Ratings.* The Standard Ratings of a compressor or compressor unit shall consist of a refrigerating capacity rating, Btu/h, mass flow rate rating, lb/h, power input rating, kW, and an energy efficiency rating, Btu/W·h or bhp/ton, identified at the Standard Rating Conditions, when tested as specified in Section 4.

**5.1.1** *Standard Rating of a Refrigeration Compressor or Compressor Unit.* The rating when operated at one of the Standard Rating Conditions presented in Table 1.

**5.2** *Application Ratings of Compressor and Compressor Units.* Application Ratings shall consist of a refrigerating capacity rating, Btu/h, mass flow rate rating, lb/h, power input rating, W, and energy efficiency rating, Btu/W·h or bhp/ton, when tested at stated conditions other than those presented in Table 1, as specified by the manufacturer.

**5.3** *Nameplate Voltages for Rating.* Rating tests shall be performed at the nameplate rated voltage and frequency.

For dual nameplate voltage ratings, rating tests shall be performed at both voltages, or at the higher of the two voltages, if only a single rating is to be published.

**5.4** *Tolerances.* To comply with this standard, measured test results shall not be less than 90% of Published Ratings for Refrigerating Capacity (or mass flow), shall not be more than 105% of Published Ratings for Power Input and shall not be less than 90% of Published Ratings for Energy Efficiency.

**5.5 Rating Methods.** Compressors or compressor units shall be rated in one of four ways described below. Manufacturers shall declare which rating method is used when providing Published Ratings.

**5.5.1 Method 1: Standard Applications.** This test method should be referenced as “AHRI Standard 570 (I-P) Method 1”

*Subcritical Cycles:* Under this rating method, manufacturers shall report Refrigerating Capacity at condenser exit subcooling specified in Table 1. [Refer to Figure C5]

*Transcritical Cycles:* Under this rating method, manufacturers shall report Refrigerating Capacity at the gas cooler exit temperature specified in Table 1. [Refer to C6]

**5.5.2 Method 2: Compressor Units with Manufacturer Specified or Supplied Subcoolers Only.** This test method should be referenced as “AHRI Standard 570 Method 2”

*Subcritical Cycles:* Under this rating method, manufacturers shall report Refrigerating Capacity including the increased refrigeration effect provided by the manufacturer specified or supplied subcooler. Note: Liquid entering the subcooler shall be at the condenser exit subcooling specified in Table 1. [Refer to Figure C7]

*Transcritical Cycles:* Under this rating method, manufacturers shall report Refrigerating Capacity including the increased refrigeration effect provided by the manufacturer specified or supplied subcooler. Note: Fluid entering the subcooler shall be at the gas cooler exit temperature specified in Table 1. [Refer to Figure C8]

**5.5.3 Method 3: Compressors Applied with Non-Specified Subcoolers.** This test method should be referenced as “AHRI Standard 570 Method 3”.

*Subcritical Cycles:* Under this rating method, manufacturers shall report Refrigerating Capacity including increased refrigeration effect provided by the subcooler. Note: Liquid entering the subcooler shall be at the condenser exit subcooling specified in Table 1. Liquid temperature leaving the subcooler shall be 9 °F above the saturated intermediate temperature. [Refer to Figure C9]

*Transcritical Cycles:* Under this rating method, manufacturers shall report Refrigerating Capacity including increased refrigeration effect provided by the subcooler. Note: Fluid entering the subcooler shall be at the gas cooler exit temperature specified in Table 1. Liquid temperature leaving the subcooler shall be 9 °F above the saturated intermediate temperature. [Refer to Figure C10]

**5.5.4. Method 4: Compressors or Compressor Units Applied with Open Flash Style Liquid Subcoolers.** This test method should be referenced as “AHRI Standard 570 Method 4.”

*Subcritical Cycles:* Under this rating method, manufacturers shall report Refrigerating Capacity including increased refrigeration effect provided by the subcooler. Note: Liquid entering the subcooler shall be at the condenser exit subcooling specified in Table 1. Liquid temperature leaving the subcooler shall be equal to the saturated intermediate temperature. [Refer to Figure C11]

*Transcritical Cycles:* Under this rating method, manufacturers shall report Refrigerating Capacity including increased refrigeration effect provided by the subcooler. Note: Fluid entering the subcooler shall be at the gas cooler exit temperature specified in Table 1. Liquid temperature leaving the subcooler shall be equal to the saturated intermediate temperature. [Refer to Figure C12]

**5.6 Interstage Heat Rejection.** For compressors requiring interstage heat rejection, manufacturers shall specify the inlet and outlet refrigerant temperatures and maximum allowable refrigerant pressure drop for the interstage heat exchanger.

**5.6.1 Compressor Units with Manufacturer Specified or Supplied Air-Cooled Interstage Heat Rejection.** The manufacturer shall include the power consumed for heat rejection at ambient air conditions specified in Table 1.

**5.6.2 Compressor Units with Manufacturer Specified Or Supplied Water-Cooled Interstage Heat Rejection.** The manufacturer shall specify the required heat rejection in Btu/h at entering water temperature of 85 °F and water flow rate of 3.0 gpm per ton of heat rejection.



## Section 6. Minimum Data Requirements for Published Ratings

**6.1** *Minimum Data Requirements for Published Ratings.* As a minimum, Published Ratings shall include all Standard Ratings. All claims to ratings within the scope of this standard shall include the statement “Rated in accordance with AHRI Standard 570 (I-P)”. All claims to ratings outside the scope of this standard shall include the statement “Outside the scope of AHRI Standard 570 (I-P)”. Wherever Application Ratings are published or printed, they shall include a statement of the conditions at which the ratings apply.

**6.2** *Tabular Data.* General performance data, covering the operational spectrum of the equipment, shall be presented in tabular form within defined accuracies and ranges of operation. The tables shall include:

- 6.2.1** Suction dew point temperature range, °F
- 6.2.2** Discharge dew point temperature range for subcritical compression cycles, °F, or Discharge pressure range for transcritical compression cycles, psia
- 6.2.3** Applicable superheat, °F
- 6.2.4** Subcooling for subcritical compression cycles, °F, or gas cooler exit temperature for transcritical compression cycles, °F
- 6.2.5** Liquid temperature leaving the subcooler (for Methods 2, 3 and 4 in Section 5.5), °F
- 6.2.6** Refrigerating Capacity, Btu/h
- 6.2.7** Suction mass flow rate, lb/h
- 6.2.8** Intermediate mass flow rate, lb/h (for Two Stage Compressors and compressor units)
- 6.2.9** Power Input, kW
- 6.2.10** Energy Efficiency, Btu/W-h or bhp/ton
- 6.2.11** Current, A
- 6.2.12** Refrigerant designation per ASHRAE Standard 34 with Addenda
- 6.2.13** Shaft or compressor speed for open drive and variable speed compressors, rpm

The manufacturer's tabular data shall be based on data obtained from tests performed or calculated at conditions within the range of application usage specified in Sections 6.3.1 and 6.3.2.

**6.3** *Data to be Reported.* The tabular data shall be reported at the following conditions for the compressor or compressor unit application usage intended. The extreme ends of the tabular data may be omitted and not reported due to limits of acceptable operation of the compressor or compressor unit as determined by the manufacturer.

### **6.3.1** *Medium Temperature (fresh food display cases, for example):*

- 6.3.1.1** Suction dew point temperature, -4 °F to 32 °F
- 6.3.1.2** Discharge dew point temperature for subcritical compression cycle, 32 °F to 77 °F or discharge pressure for transcritical compression cycle, 1160 psia to 1595 psia
- 6.3.1.3** Useful superheat of 18 °F for all operating points
- 6.3.1.4** For subcritical applications, condenser exit subcooling of 0 °F
- 6.3.1.5** For transcritical applications, gas cooler exit temperature of 95 °F
- 6.3.1.6** Refrigerating Capacity may include increased refrigeration effect provided by the subcooler per rating methods of Section 5.5

### **6.3.2** *Low Temperature (freezer cases, for example):*

- 6.3.2.1** Suction dew point temperature, -58 °F to 14 °F
- 6.3.2.2** Discharge dew point temperature for subcritical compression cycle, 32 °F to 77 °F, or discharge pressure for transcritical compression cycle, 1160 psia to 1595 psia
- 6.3.2.3** Useful superheat of 18 °F for all operating points
- 6.3.2.4** For subcritical applications, condenser exit subcooling of 0 °F
- 6.3.2.5** For transcritical applications, gas cooler exit temperature of 95 °F
- 6.3.2.6** Refrigerating Capacity may include increased refrigeration effect provided by the subcooler per rating methods of Section 5.5

**6.4 Polynomial Equation.** The polynomial equation that shall be used to represent the tabular data is a third degree equation of ten coefficients in the form of:

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

Where:

C<sub>1</sub> through C<sub>10</sub> = Regression coefficients.

t<sub>D</sub> = Discharge dew point temperature for subcritical compression cycles, °F, or discharge pressure for transcritical compression cycles, psia

t<sub>S</sub> = Suction dew point temperature for subcritical compression cycles, °F, or suction pressure for transcritical compression cycles, psia

X = Any of the following variables:

- 6.4.1** Power Input, kW
- 6.4.2** Refrigerating Capacity, Btu/h
- 6.4.3** Suction or intermediate mass flow rate, lb/h
- 6.4.4** Current, A
- 6.4.5** Energy Efficiency, Btu/W·h or bhp/ton

Values of the same performance characteristics calculated from the ten coefficient third order equation and the coefficients provided by the compressor manufacturer shall agree with the tabular values within ± 1%. In the event that the compressor manufacturer determines that the values calculated from the ten coefficient equation may differ by more than 1% from the tabulated values in portions of the operating range, the compressor manufacturer will indicate this by shading, cross-hatching or otherwise identifying those affected data points in the table.

## Section 7. Operating Requirements

**7.1 Loading Requirements.** The compressor or compressor unit shall be capable of operating continuously at all operating points in the manufacturers’ published data for a minimum period of two hours at the minimum and maximum utilization voltage as described in ANSI/AHRI Standard 110, Table 1 and at the ambient and return gas temperatures as specified in Table 1 of this standard.

## 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** Input voltage, V, phase and frequency, Hz
- 8.1.4** Locked-rotor current of all motors furnished as part of the compressor, A

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

**8.2 Compressor Unit Nameplate Marking.** As a minimum, each compressor unit shall have a nameplate, affixed to its housing or base, on which the following information, in addition to that required under Section 8.1, shall be marked:

- 8.2.1** Compressor unit manufacturer's name and/or symbol
- 8.2.2** Compressor unit model number
- 8.2.3** Refrigerant designation per ASHRAE Standard 34 with Addenda
- 8.2.4** Input voltage, V and frequency, Hz
- 8.2.5** Rated-load current (where applicable), A

## 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.

**Table 1. Standard Rating Conditions for CO<sub>2</sub> Compressors and Compressor Units for Refrigeration Applications<sup>1,2,3</sup>**

Compression Cycle			Low Side		High Side - Subcritical		High Side - Transcritical	
Application	Cycle Type	Rating Test Point	Suction Dew Point Temperature	Return Gas Temperature <sup>4</sup>	Discharge Dew Point Temperature	Condenser Exit Subcooling	Discharge Pressure	Gas Cooler Exit Temperature
			°F	°F	°F	°F	psia	°F
Medium Temperature	Subcritical	1.01	23	41	59	0	NA <sup>5</sup>	NA
		1.02	14	32	59	0	NA	NA
	Transcritical	1.03	23	41	NA	NA	1300	95
		1.04	14	32	NA	NA	1300	95
Low Temperature	Subcritical	1.05	-22	-4	23	0	NA	NA
		1.06	-31	-13	23	0	NA	NA
		1.07	-58	-40	23	0	NA	NA
		1.08	-22	-4	59	0	NA	NA
	Transcritical	1.09	-31	-13	59	0	NA	NA
		1.10	-22	-4	NA	NA	1300	95
Low Temp-Small Commercial	Transcritical	1.11	-31	-13	NA	NA	1300	95
		1.12	-13	90	NA	NA	1300	95
Low Temp-Industrial	Subcritical	1.13	23	90	NA	NA	1300	95
		1.14	-31	-13	41	0	NA	NA
		1.15	-58	-40	41	0	NA	NA

**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 the compressor.
4. Return gas temperature entering the compressor is assumed to be useful superheat for capacity calculation
5. NA: Not Applicable

## APPENDIX A. REFERENCES – NORMATIVE

**A.1** 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.

**A.1.1** ANSI/AHRI Standard 110-2012, *Air-Conditioning and Refrigerating Equipment Nameplate Voltages*, 2012, Air-Conditioning, Heating, and Refrigeration Institute, 2111 Wilson Blvd., Suite 500, , Arlington, VA 22201, U.S.A.

**A.1.2** ANSI/ASHRAE Standard 15-2010, *Safety Standard for Refrigeration Systems with ANSI/ASHRAE 34-2010: Designation and Safety Classification of Refrigerants*, 2010, American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers, 11 West 42<sup>nd</sup> Street, New York, NY 10036, U.S.A./1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

**A.1.3** ANSI/ASHRAE Standard 34-2010 with Addenda, *Number Designation and Safety Classification of Refrigerants*, 2010, American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers, 11 West 42<sup>nd</sup> Street, New York, NY 10036, U.S.A./1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

**A.1.4** ANSI/ASHRAE Standard 41.9-2011, *Standard Methods for Volatile-Refrigerant Mass Flow Measurements Using Calorimeters*, 2011, American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers, 11 West 42<sup>nd</sup> Street, New York, NY 10036, U.S.A./1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

**A.1.5** ANSI/ASHRAE Standard 41.10-2008, *Standard Methods for Volatile-Refrigerant Mass Flow Measurements Using Flowmeters*, 2008, American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers, 11 West 42<sup>nd</sup> Street, New York, NY 10036, U.S.A./1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

**A.1.6** 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 of the Refrigerant*, 2010, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

**A.1.7** ASHRAE *Terminology of Heating, Ventilation, Air Conditioning and Refrigeration* 1991 Second Edition, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

**A.1.8** IEC Standard 60038, *IEC Standard Voltages*, 2002, International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

**A.1.9** NIST Thermodynamic Properties of Refrigerants and Refrigerant Mixtures Database (REFPROP).

## APPENDIX B. REFERENCES – INFORMATIVE

**B.1.1** ISO 917: 1989, *Testing of Refrigerant Compressors*, 1989, International Organization for Standardization, Case Postale 56, CH-1211, Geneva 21 Switzerland.

**B.1.2** AHRI Standard 540-2004, *Performance Rating of Positive Displacement Compressors and Compressor Units*, 2004, Air-Conditioning, Heating, and Refrigeration Institute, , Arlington, VA 22203, U.S.A.

# APPENDIX C. METHOD OF TEST FOR TRANSCRITICAL AND TWO STAGE SUBCRITICAL CYCLES – NORMATIVE

## Section C1. Purpose

**C1.1** *Purpose.* The purpose of this appendix is to supplement ASHRAE Standard 23.1 and to provide a method of testing for rating Positive Displacement Refrigerant Compressors and compressor units that operate within transcritical and two stage subcritical refrigeration cycles.

## Section C2. Requirements

### C2.1 *Test Requirements.*

**C2.1.1** *Compressor or Compressor Unit Ratings.* Each test data point used for rating a compressor or compressor unit shall consist of a primary test and a simultaneous, independent confirming test at a specified set of operating conditions. Compressor or compressor unit ratings shall be determined from refrigerant mass flow rates obtained by the primary method of test. However, each refrigerant mass flow rate obtained from the primary test (a time-averaged flow rate for a specific test data point) shall be considered to be valid only if the measured refrigerant mass flow rate from the corresponding confirming test (a time-averaged flow rate for the same test data point over the same time span) is within  $\pm 3\%$  of the primary test measurement.

For the purpose of ratings, the refrigerant mass flow rate (used in Equations C1 through C14) is defined as being the compressor or compressor unit suction mass flow rate for each stage.

If an intermediate cooling means is included in the test article, the test shall be performed according to the manufacturer's instructions with respect to the parameters needed to operate the intermediate cooling means.

If a refrigerant injection scheme is included in the test article, the refrigerant injection shall be performed according to the manufacturer's instructions with respect to pressure, temperature, quality, and refrigerant mass flow rate at the injection location.

For example, when testing compressors or compressor units that use refrigerant injection for cooling and that includes a test method that measures total refrigerant mass flow rate on the supercritical discharge side of the test article, the refrigerant injection mass flow rate shall be measured by one of the methods listed in Table 1 and shall be subtracted from the total refrigerant mass flow rate to determine the compressor or compressor unit refrigerant mass flow rate. The resulting value for refrigerant mass flow rate shall be used in Equations C1 through C14.

**C2.1.2** *Power Input.* Power Input to the compressor or compressor unit shall be determined using the test method described in Section C5.2. This includes the Power Input to the shaft of Open Drive Refrigerant Compressors, the Power Input at the motor terminals for Hermetic Refrigerant Compressors, Semi-Hermetic Refrigerant Compressors, or Open Drive Refrigerant Compressors and the power absorbed by all ancillaries that are necessary to sustain the operation of the compressor or compressor unit (e.g., oil pump, fan motors, controls components, and circulating pumps.)

**C2.1.3** *Thermodynamic State Points.* The thermodynamic state points illustrated in Figures C1-C4 apply to the calculations described below. The single stage compressor efficiency calculations in Equation C1 apply for Figures C1 and C2. Specifically, Figure C2 shows the pressure versus enthalpy cycle for the single stage refrigerant system illustrated in Figure C1. Heat transfer into the evaporator ( $\dot{q}$ ) transforms the refrigerant into a superheated vapor between state points 1 and 2. The compressor increases the refrigerant pressure between state points 2 and 3. State point 3s illustrates the compressor discharge condition that would correspond to an isentropic compression process. Heat transfer out from the gas cooler ( $\dot{q}_c$ ) transforms the refrigerant into a relatively cool supercritical fluid at state point 4. The remaining step in the cycle between state points 4 and 1 is an isenthalpic pressure decrease through a metering device to transform the refrigerant to a liquid refrigerant two phase mixture at the thermodynamic conditions at the evaporator inlet.

Figures C3 and C4 show a two-stage system with intermediate pressure economization. The two-stage compressor efficiency calculations (C2) apply for Figures C3 and C4. Figure C4 shows the pressure versus enthalpy cycle for the two-stage economized refrigerant system illustrated in Figure C3. Heat transferred into the evaporator ( $\dot{q}$ ) transforms the refrigerant into a superheated vapor between state points  $1_1$  and  $2_1$  ( $2_{1s}$  is identical to  $2_1$ .) The first stage of the compressor increases the refrigerant pressure between state points  $2_1$  and  $3_1$ . State point  $3_{1s}$  illustrates the compressor discharge condition that would correspond to an isentropic compression process for stage 1. The intermediate pressure refrigerant saturated vapors flow ( $\dot{m}_1$ ) leaving the economizer at thermodynamic state point 5 combines with the first stage compressor discharge flow ( $\dot{m}_1$ ) to enter the second stage of the compressor ( $\dot{m}_2$ ) at state point  $2_2$ . The second stage of the compressor increases the refrigerant pressure between state points  $2_2$  and  $3_2$ . State point  $2_{2s}$  illustrates the thermodynamic state that corresponds to mixing of the intermediate pressure flow ( $\dot{m}_1$ ) from state point 5 with the theoretical isentropic compressor discharge at state  $3_{1s}$ . State point  $3_{2s}$  illustrates the compressor discharge condition that would correspond to an isentropic compression process for stage 2 from the second stage theoretical suction gas state  $2_{2s}$ . Heat transfer out from the gas cooler ( $\dot{q}_c$ ) transforms the refrigerant into a relatively cool supercritical fluid at state point  $4_2$ . The refrigerant expands at constant enthalpy through a metering device to the intermediate pressure state point  $1_2$ , where it separates in a flash tank to a saturated vapor state point 5 and a saturated liquid state point  $4_1$ . In the case of a direct expansion economizer, state point 5 could be a superheated vapor, saturated vapor or two-phase refrigerant. The intermediate pressure saturated vapor flow ( $\dot{m}_1$ ) combines with the 1<sup>st</sup> stage compressor flow ( $\dot{m}_1$ ), while the saturated liquid flow ( $\dot{m}_1$ ) expands at constant enthalpy through a metering device to state point  $1_1$  at the evaporator inlet.

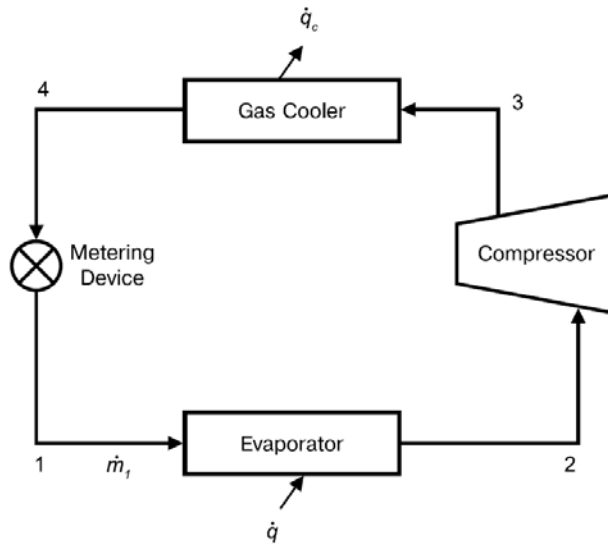


Figure C1. Single Stage Refrigeration Cycle Schematic with Thermodynamic State Point Numbers

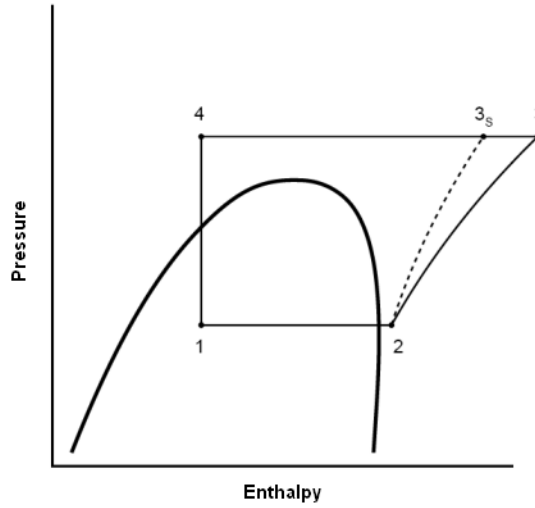


Figure C2. Single Stage Pressure Versus Enthalpy Diagram for the Refrigeration Cycle Shown in Figure C1

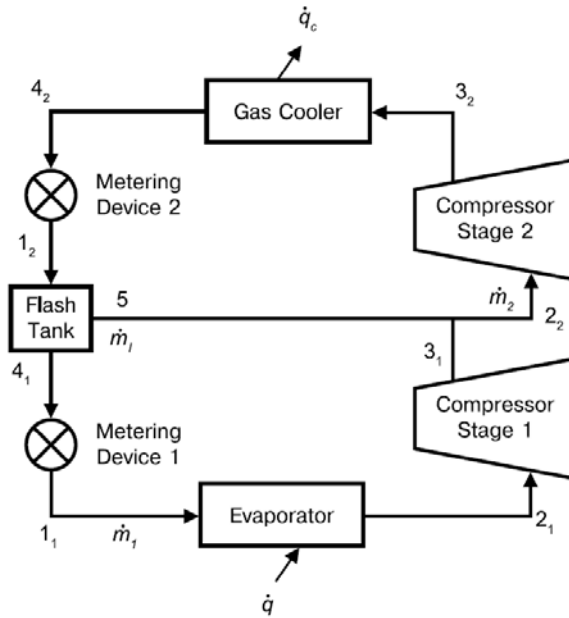
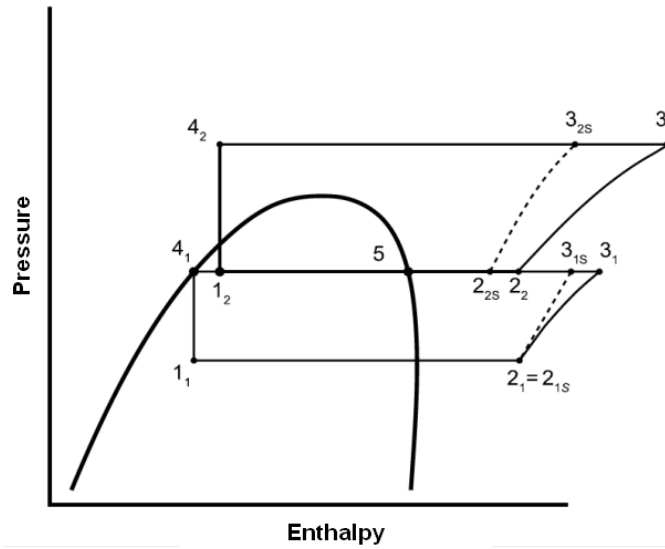


Figure C3. Two Stage Refrigeration Cycle Schematic with Thermodynamic State Point Numbers





**Figure C4. Two Stage Pressure Versus Enthalpy Diagram for the Refrigeration Cycle Shown in Figure C3**

**C2.1.4 Efficiency.** Compressor Efficiency, Compressor Unit Efficiency, or performance factor shall be computed as described in the paragraphs below. The refrigerant thermodynamic state  $2_1$  is defined by the pressure and temperature parameters.

**C2.1.4.1** Compressor Efficiency or Compressor Unit Efficiency, for single-stage compressors or compressor unit, shall be computed as shown in Equation C1:

$$\eta = \frac{[\dot{m}(h_{3s}-h_2)]}{P} \cdot 100 \tag{C1}$$

Where:

- $h_2$  = Specific enthalpy of refrigerant vapor entering the compressor or compressor unit, Btu/lb
- $h_{3s}$  = Specific enthalpy of refrigerant vapor at discharge pressure, following an isentropic compression of the refrigerant vapor entering the compressor or compressor unit, Btu/lb
- $\dot{m}$  = Refrigerant mass flow rate, lb/h
- $\eta$  = Compressor or Compressor Unit Efficiency, %
- $P$  = Power Input, kW

**C2.1.4.2** Compressor Efficiency or Compressor Unit Efficiency, for two-stage compressors, shall be computed as shown in Equation C2:

$$\eta = \frac{[\dot{m}_1(h_{3_{1s}}-h_{2_{1s}})+\dot{m}_2(h_{3_{2s}}-h_{2_{2s}})]}{P} \cdot 100 \tag{C2}$$

Where:

- $h_{2_{1s}}$  = Specific enthalpy of refrigerant vapor entering the first stage of the compressor or compressor unit, Btu/lb
- $h_{2_{2s}}$  = Specific enthalpy of refrigerant vapor entering the second stage of the compressor or compressor unit assuming an isentropic compression within the first compression stage, Btu/lb
- $h_{3_{1s}}$  = Specific enthalpy of refrigerant vapor leaving the first stage of the compressor or compressor unit assuming an isentropic compression within the first compression stage, Btu/lb

- $h_{3_{2S}}$  = Specific enthalpy of refrigerant vapor leaving the second stage of the compressor or compressor unit assuming an isentropic compression within the second compression stage, Btu/lb
- $\eta$  = Compressor or Compressor Unit Efficiency, %
- $P$  = Power Input, W

The thermodynamic state,  $h_{2_{2S}}$  is calculated as follows:

$$h_{2_{2S}} = \frac{\dot{m}_1 h_{3_{1S}} + \dot{m}_1 h_5}{\dot{m}_2} \tag{C3}$$

Where:

- $h_5$  = Specific enthalpy of refrigerant flow entering the compressor or compressor unit by the intermediate pressure refrigerant communication port, Btu/lb

**C2.1.5 Oil Circulation Rates.** Oil circulation rates through a calorimeter or liquid flowmeter shall not exceed 2%. Oil circulation rates through a gaseous flowmeter shall not exceed 1%.

**C2.1.5.1** If the compressor or compressor unit is designed to be used only in applications that include an efficient oil separator (i.e., oil circulation is less than 1,000 ppm), then an oil separator that meets this requirement should be included in the test setup and oil circulation measurement is not required.

**C2.1.5.2** If the compressor or compressor unit is designed to be applied without an efficient oil separator, the oil circulation must be measured as prescribed in ANSI/ASHRAE 41.9 or in ANSI/ASHRAE 41.10. If measurements show that the oil circulation rate will exceed 2% (1% for a gaseous flowmeter method), then an auxiliary oil separator capable of reducing the oil circulation rates to meet the requirements must be used.

**C2.1.5.3** Any oil removed from the refrigerant by an oil separator must be returned to the refrigerant circuit in a manner that does not affect the refrigerant mass flow measurement as described below:

**C2.1.5.3.1** If the oil separator is normally applied with the compressor or compressor unit as defined in ANSI/ASHRAE 41.9 or ANSI/ASHRAE 41.10, the oil from the separator should be returned in the normal way the equipment is applied.

**C2.1.5.3.2** If an auxiliary oil separator is required, the oil from the auxiliary separator should be returned to the refrigerant circuit at a location downstream of the calorimeter outlet or flowmeter outlet.

**C2.1.6 Suction Superheat.** Suction superheat is the difference between the refrigerant vapor temperature and the dew point temperature at the subcritical pressure of the refrigerant entering the compressor. Suction superheat is defined, specified, and measured for the lowest pressure suction port only and does not include interstage or second stage inlet conditions.

**C2.1.7 Expansion Device Inlet Temperature and Pressure.** The temperature and pressure of the refrigerant entering each metering device shall be determined for each test condition.

**C2.1.8 Capacity.** Capacity shall be computed as described in the paragraphs below.

**C2.1.8.1** Compressor or compressor unit Refrigerating Capacity, for Single Stage and Two Stage Compressors or compressor units, shall be computed as shown in Equation C4:

$$\dot{q} = \dot{m}_1 (h_2 - h_1) \tag{C4}$$

Where:

- $\dot{q}$  = Evaporator capacity at the specified operating conditions, Btu/hr
- $\dot{m}_1$  = Refrigerant mass flow rate through the evaporator, lb/h
- $h_1$  = Specific enthalpy of refrigerant entering the evaporator, Btu/lb

$h_2$  = Specific enthalpy of refrigerant entering the compressor or compressor unit, Btu/lb

**C2.1.9 Refrigerant Data.** The source from which refrigerant thermodynamic properties are obtained shall be stated in the test report including the version number of the property database. The preferred source is *NIST Thermodynamic Properties of Refrigerants and Refrigerant Mixtures Database (REFPROP)*.

**C2.1.10 Safety.** See ANSI/ASHRAE Standard 15, *Safety Standard for Refrigeration Systems* for all calorimeters and flowmeters used for these rating tests.

**C2.2 Specified Test Conditions.** Rating tests on a compressor or compressor unit shall be performed at one or more sets of steady-state operating test conditions. Each set of specified test conditions shall include the following parameters with acceptable tolerance limits provided for each parameter.

**C2.2.1** Electrical conditions for hermetic compressor, semi-hermetic compressor, open drive compressor, or compressor unit:

**C2.2.1.1** Voltage for each phase, V

**C2.2.1.2** Line frequency, Hz

**C2.2.2** Shaft rotational speed if the compressor is an Open Drive type, rpm

**C2.2.3** Ambient air temperature, °F

**C2.2.4** Refrigerant suction pressure entering the compressor, psia

**C2.2.5** The temperature of the suction superheated refrigerant vapor entering the compressor (see Section C2.1.6 for definition) shall be specified, °F

**C2.2.6** Refrigerant pressure leaving the compressor, psia

**C2.2.7** Suction superheat, the difference between the refrigerant vapor temperature and the dew point temperature at the pressure of the refrigerant entering the compressor, °F

**C2.2.8** The refrigerant inlet conditions at the expansion device before the evaporator

**C2.2.8.1** The thermodynamic state of the refrigerant at the inlet of the expansion device before the evaporator shall be consistent with the rating method declared from Section 5.5.

**C2.2.9** The refrigerant inlet conditions at the metering device for refrigerant rejection

**C2.2.9.1** For a compressor or a compressor unit with refrigerant injection, the temperature, °F, and pressure, psia, of the refrigerant entering the metering device shall be specified

**C2.3 Values to be Determined.**

**C2.3.1** Values that shall be determined at each test condition are:

**C2.3.1.1** Refrigerant mass flow rate obtained from both the primary and confirming test methods, lb/h. For Two Stage Compressors or compressor units, the refrigerant mass flow rate for each stage shall be determined, lb/h

**C2.3.1.2** Power Input, W

**C2.3.1.3** Compressor or Compressor Unit Efficiency, %

**C2.3.1.4** Energy Efficiency, Btu/W-h or bhp/ton

**C2.3.1.5** Oil circulation rate at suction pressure port (percent by mass) if required by Section C2.1.5

**C2.3.1.6** Suction superheat, as defined in Section C2.1.6, °F

**C2.3.1.7** Expansion device inlet temperature, as defined in Section C2.1.7, °F

**C2.3.1.8** Ambient air temperature surrounding the compressor, °F

**C2.3.1.9** Barometric pressure (required whenever a pressure-sensing device is referenced to atmospheric pressure), in Hg

**C2.3.2** Additional values that may also be determined include the following:

**C2.3.2.1** Capacity, Btu/h

**C2.3.2.2** Volumetric efficiency, %

**C2.3.2.3** Current, A

**C2.3.2.4** Compressor shaft rotational speed, rpm

**C2.3.2.5** Compressor torque, ft-lb<sub>f</sub>

**C2.3.2.6** Air circulation rate, ft<sup>3</sup>/min, air speed, ft/min, and/or airflow direction

**C2.3.2.7** The vapor intermediate pressure of the refrigerant entering the compressor, psia

**C2.3.2.8** The vapor temperature of the refrigerant entering the compressor at the intermediate pressure, °F

**C2.3.2.9** The vapor quality of the refrigerant entering the compressor at the intermediate pressure, %

**C2.3.2.10** Cooling fluid inlet and outlet temperature, °F

### **Section C3. Instruments**

Refer to ASHRAE Standard 23.1.

### **Section C4. Methods of Testing**

The method of testing is covered in this Appendix C and supplemented by ASHRAE Standard 23.1.

### **Section C5. Compressor Testing**

**C5.1** *Preparations.*

**C5.1.1** Leak-test the refrigerant system to ensure that no refrigerant leaves the system during the test.

**C5.1.2** Install the correct oil and refrigerant charges.

**C5.1.3** Provide a means for measuring air circulation (if required) in terms of quantity, velocity, temperature and orientation with respect to the compressor.

**C5.1.4** Provide a means for collecting refrigerant liquid/oil samples for oil circulation rate measurements if required by Section C2.1.5.

**C5.1.5** Insulate temperature sensors as required to ensure measurement accuracy.

**C5.2** *Operating Conditions and Limits.*

**C5.2.1** When Power Input is determined by electrical power measurement, regulate the voltage for each phase at the motor terminal to within  $\pm 1\%$  of the voltage specified.

**C5.2.2** When Power Input is determined by shaft power measurement, regulate the shaft speed to within  $\pm 1\%$  of the speed specified.

**C5.2.3** Adjust and maintain the compressor ambient temperature to within  $\pm 7$  °F of the specified value.

**C5.2.4** If using interstage heat rejection, adjust and maintain the cooling fluid temperature to within  $\pm 2$  °F of the specified value.

**C5.2.5** If required for rating, adjust and maintain the air circulation surrounding the compressor within the limits specified in the test plan. This may include volumetric airflow rate, speed, temperature and/or orientation with respect to the compressor.

**C5.2.6** Adjust and maintain the compressor suction pressure to within  $\pm 1\%$  of the absolute pressure specified.

**C5.2.7** Adjust and maintain the compressor suction vapor temperature to within  $\pm 2$  °F of the temperature specified.

**C5.2.8** If intermediate pressure flow exists, adjust and maintain the compressor intermediate pressure to within  $\pm 1\%$  of the measured absolute pressure value.

**C5.2.9** If intermediate pressure flow exists, adjust and maintain the temperature of the intermediate pressure vapor entering the compressor to within  $\pm 2$  °F of the measured temperature value.

**C5.2.10** Adjust and maintain the pressure leaving the compressor to within  $\pm 1\%$  of the specified absolute discharge pressure value.

**C5.2.11** Adjust and maintain the gas cooler supercritical vapor temperature to within  $\pm 2$  °F of the temperature specified.

**C5.2.12** A minimum of three trial sets of refrigerant mass flow rate measurements shall be made at stable test conditions to each refrigerant flow rate being measured. The average of all data values shall be used as the reported test measurement value. The variation of each individual value shall not differ from the averaged value by more than  $\pm 2\%$ .

**C5.2.13** Compressor mechanical equilibrium (“break-in”), as evidenced by steady-state values of power or current and capacity readings, is required. The manufacturer's recommendations for the break-in procedure and the period required should be followed.

**C5.2.14** For refrigerant injection compressors, the injection mass flow rate shall be adjusted and maintained for each compressor inlet to within  $\pm 1\%$  of the measured value.

**C5.3** *Compressor Test Report.***C5.3.1** *Test Identification.*

**C5.3.1.1** Date, place, time and duration of test

**C5.3.1.2** Operator's name

**C5.3.2** *Test Article Description.*

**C5.3.2.1** Test article description (e.g., model number, serial number)

- C5.3.2.2 Refrigerant number (according to ANSI/ASHRAE Standard 34 with Addenda)
- C5.3.2.3 Source of refrigerant thermodynamic property data
- C5.3.2.4 Lubricant identification
- C5.3.2.5 Type of compressor: single stage, two-stage, with or without refrigerant injection or intermediate cooling means
- C5.3.2.6 Type of rating method used per Section 5.5

**C5.3.3** *Primary Method Equipment Description.*

- C5.3.3.1 Calorimeter or flowmeter test method selected for each mass flow measurement
- C5.3.3.2 Test apparatus description, model number, and serial number

**C5.3.4** *Confirming Method Equipment Description.*

- C5.3.4.1 Calorimeter or flowmeter test method selected for each mass flow measurement
- C5.3.4.2 Test apparatus description, model number, and serial number

**C5.3.5** *Measured Operating Conditions.*

- C5.3.5.1 Ambient air temperature, °F
- C5.3.5.2 Ambient airflow conditions – temperature, circulation rate, speed, and/or direction (if required)
- C5.3.5.3 Barometric pressure (required whenever a pressure-sensing device is referenced to atmospheric pressure), in Hg
- C5.3.5.4 Electrical conditions for hermetic compressors, semi-hermetic compressors, or motor-compressors for each phase:
  - C5.3.5.4.1 Voltage, V
  - C5.3.5.4.2 Frequency, Hz
  - C5.3.5.4.3 Current, A, (if required)
- C5.3.5.5 Shaft rotational speed for Open Drive Refrigerant Compressors, rpm
- C5.3.5.6 Refrigerant pressure entering the compressor, psia
- C5.3.5.7 Refrigerant temperature entering the compressor, °F
- C5.3.5.8 Refrigerant pressure leaving the compressor, psia
- C5.3.5.9 Refrigerant temperature leaving the compressor, °F
- C5.3.5.10 Refrigerant pressure entering the calorimeter or flowmeter for both the primary and confirming test methods, psia
- C5.3.5.11 Refrigerant temperature entering the calorimeter or flowmeter for both the primary and confirming test methods, °F
- C5.3.5.12 Refrigerant pressure leaving the calorimeter or flowmeter for both the primary and confirming test methods, psia

- C5.3.5.13** Refrigerant temperature leaving the calorimeter or flowmeter for both the primary and confirming test methods, °F
- C5.3.5.14** Suction superheat as described in Section C2.1.6, °F
- C5.3.5.15** Expansion device inlet temperature as described in Section C2.1.7, °F
- C5.3.5.16** Expansion device inlet pressure as described in Section C2.1.7, psia.
- C5.3.5.17** For a two-stage or refrigerant injection compressor or compressor unit, C5.2.5.6 through C5.2.5.16 shall be measured for each stage inlet and outlet, where these can be measured external to the compressor or compressor unit.
- C5.3.5.18** If interstage heat rejection is used, then the parameters specified by the manufacturer for operating the compressor's interstage heat rejection shall be measured.

**C5.3.6** *Compressor Test Results.*

- C5.3.6.1** Refrigerant mass flow rate from the primary test, lb/h
- C5.3.6.2** Refrigerant mass flow rate from the confirming test, lb/h (for reference only)
- C5.3.6.3** Power Input, W
- C5.3.6.4** Uncertainty in refrigerant mass flow rate, lb/h
- C5.3.6.5** Uncertainty in Power Input, W
- C5.3.6.6** Compressor Efficiency, %
- C5.3.6.7** Energy Efficiency Btu/W-h or hp/ton
- C5.3.6.8** Oil circulation rate, %<sub>mass</sub> (if required)
- C5.3.6.9** Refrigerating Capacity, Btu/h (if required)
- C5.3.6.10** Electrical data – voltage, V, phase, frequency, Hz, and/or current, A (if required)
- C5.3.6.11** Compressor shaft rotational speed for Open Drive Refrigerant Compressors or (if required) for Hermetic Refrigerant Compressors, Semi-Hermetic Refrigerant Compressors, or open drive compressors, rpm
- C5.3.6.12** Compressor torque, ft-lb<sub>f</sub> (if required)
- C5.3.6.13** In rating Methods 3 and 4, the intermediate pressure shall be reported, psia
- C5.3.6.14** In rating Methods 3 and 4, the temperature of the intermediate pressure vapor entering the compressor shall be reported, °F.
- C5.3.6.15** For a two-stage or refrigerant injection compressor or compressor unit, refrigerant mass flow rates and uncertainty (as outlined in C5.3.6.1, C5.3.6.2, and C5.3.6.4) shall be reported for each stage inlet and outlet, lb/hr.
- C5.3.6.16** If interstage heat rejection is used, then the parameters specified by the manufacturer for operating the compressor's interstage heat rejection shall be reported.

## Section C6. Compressor Unit Testing

### C6.1 *Preparations.*

**C6.1.1** Leak-test the refrigerant system to ensure that no refrigerant leaves the system during the test.

**C6.1.2** Install the correct oil and refrigerant charges.

**C6.1.3** Provide a means for measuring air circulation (if required) in terms of quantity, velocity, temperature and orientation with respect to the compressor.

**C6.1.4** Provide a means for collecting refrigerant liquid/oil samples for oil circulation rate measurements if required by Section C2.1.5.

**C6.1.5** Insulate temperature sensors as required to ensure measurement accuracy.

### C6.2 *Operating Conditions and Limits.*

**C6.2.1** If Power Input is to be determined by electrical power measurement, regulate the voltage for each phase at the motor terminal to within  $\pm 1\%$  of the voltage specified.

**C6.2.2** When Power Input is to be determined by shaft power measurement, regulate the shaft speed to within  $\pm 1\%$  of the speed specified.

**C6.2.3** Adjust and maintain the compressor suction pressure to within  $\pm 1\%$  of the absolute pressure specified.

**C6.2.4** Adjust and maintain the compressor suction vapor temperature to within  $\pm 2$  °F of the temperature specified.

**C6.2.5** Adjust and maintain the cooling fluid temperature to within  $\pm 2$  °F of the specified value.

**C6.2.6** Adjust and maintain the pressure leaving the compressor to within  $\pm 1\%$  of the absolute pressure specified.

**C6.2.7** Adjust and maintain the supercritical vapor temperature at the gas cooler outlet to within  $\pm 2$  °F of the temperature specified.

**C6.2.8** If intermediate pressure flow exists, adjust and maintain the compressor intermediate pressure to within  $\pm 1\%$  of the measured absolute pressure value.

**C6.2.9** If intermediate pressure flow exists, adjust and maintain the temperature of the intermediate pressure vapor entering the compressor to within  $\pm 2$  °F of the measured temperature value.

**C6.2.10** A minimum of three trial sets of refrigerant mass flow rate measurements shall be made at stable test conditions to each refrigerant flow being measured. The average of all data values shall be used as the reported test measurement value. The variation of each individual value shall not differ from the averaged value by more than  $\pm 2\%$ .

**C6.2.11** Compressor mechanical equilibrium (“break-in”), as evidenced by steady-state values of power or current and capacity readings, is required. The manufacturer's recommendations for the break-in procedure and the period required should be followed.

**C6.2.12** For two-stage and refrigerant injection compressors, the mass flow rate shall be adjusted and maintained for each compressor inlet within 1% of the measured value.



**C6.3** *Compressor Unit Test Report.*

**C6.3.1** *Test Identification.*

**C6.3.1.1** Date, place, time and duration of test

**C6.3.1.2** Operator's name

**C6.3.2** *Test Article Description.*

**C6.3.2.1** Test article description (e.g., model number, serial number)

**C6.3.2.2** Refrigerant number (according to ANSI/ASHRAE Standard 34 with Addenda)

**C6.3.2.3** Source of refrigerant thermodynamic property data

**C6.3.2.4** Lubricant identification

**C6.3.2.5** Type of compressor: single stage, two-stage with or without refrigerant injection

**C6.3.2.6** Type of rating method used per Section 5.5

**C6.3.3** *Primary Method Equipment Description.*

**C6.3.3.1** Calorimeter or flowmeter test method selected for each mass flow measurement

**C6.3.3.2** Test apparatus description, model number, and serial number

**C6.3.4** *Confirming Method Equipment Description.*

**C6.3.4.1** Calorimeter or flowmeter test method selected for each mass flow measurement

**C6.3.4.2** Test apparatus description, model number, and serial number

**C6.3.5** *Measured Operating Conditions.*

**C6.3.5.1** Ambient air temperature, °F

**C6.3.5.2** Ambient airflow conditions – temperature, circulation rate, velocity, and/or direction (if required)

**C6.3.5.3** Barometric pressure (required whenever a pressure-sensing device is referenced to atmospheric pressure), in Hg

**C6.3.5.4** Electrical conditions for hermetic compressors, semi-hermetic compressors, or motor-compressors for each phase:

**C6.3.5.4.1** Voltage, V

**C6.3.5.4.2** Frequency, Hz

**C6.3.5.4.3** Current, A, (if required)

**C6.3.5.5** Shaft rotational speed for Open Drive Refrigerant Compressors, rpm

**C6.3.5.6** Refrigerant pressure entering the compressor unit, psia

**C6.3.5.7** Refrigerant temperature entering the compressor unit, °F

**C6.3.5.8** Refrigerant pressure leaving the compressor unit, psia

- C6.3.5.9** Refrigerant temperature leaving the compressor unit, °F
- C6.3.5.10** Refrigerant pressure entering the calorimeter or flowmeter for both the primary and confirming test methods, psia
- C6.3.5.11** Refrigerant temperature entering the calorimeter or flowmeter for both the primary and confirming test methods, °F
- C6.3.5.12** Refrigerant pressure leaving the calorimeter or flowmeter for both the primary and confirming test methods, psia
- C6.3.5.13** Refrigerant temperature leaving the calorimeter or flowmeter for both the primary and confirming test methods, °F
- C6.3.5.14** Suction superheat as described in Section C2.2.7, °F
- C6.3.5.15** Expansion device inlet temperature as described in Section C2.1.7, °F
- C6.3.5.16** Expansion device inlet pressure as described in Section C2.1.7, psia
- C6.3.5.17** For a two-stage or refrigerant injection compressor unit, pressure and temperature conditions described in Sections C6.3.5.6 through C6.3.5.16 shall be measured for each stage inlet and outlet.
- C6.3.5.18** If intermediate cooling means is used, then the parameters specified by the manufacturer for operating the compressor unit's intermediate cooling means shall be measured.

**C6.3.6** *Compressor Unit Test Results.*

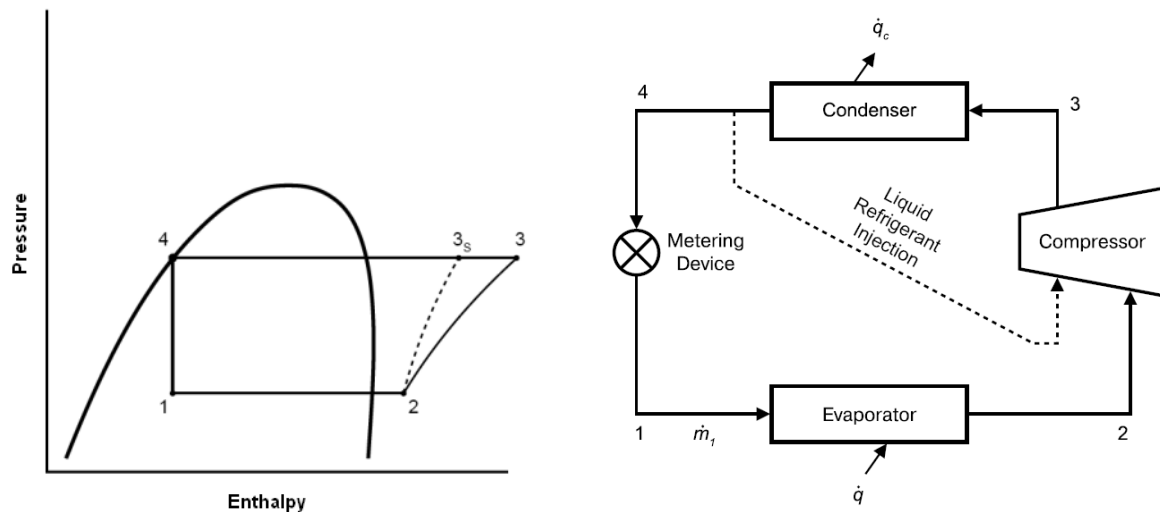
- C6.3.6.1** Refrigerant mass flow rate from the primary test, lb/h
- C6.3.6.2** Refrigerant mass flow rate from the confirming test, lb/h (for reference only)
- C6.3.6.3** Power Input, W
- C6.3.6.4** Uncertainty in refrigerant mass flow rate, lb/h
- C6.3.6.5** Uncertainty in Power Input, W
- C6.3.6.6** Compressor Unit Efficiency or performance factor, %
- C6.3.6.7** Oil circulation rate, %<sub>mass</sub> (if required)
- C6.3.6.8** Capacity, Btu/h (if required)
- C6.3.6.9** Volumetric efficiency, % (if required)
- C6.3.6.10** Electrical data – voltage, V, phase, frequency, Hz, and/or current, A (if required)
- C6.3.6.11** Compressor shaft rotational speed for Open Drive Refrigerant Compressors or (if required) for hermetic or semi-hermetic compressors, rpm
- C6.3.6.12** Compressor torque, ft-lb<sub>f</sub> (if required)
- C6.3.6.13** If intermediate pressure two-phase refrigerant injection is used, then the injected refrigerant vapor quality shall be reported, %.

- C6.3.6.14** For a two-stage or refrigerant injection compressor unit, the intermediate pressure shall be reported, psia.
- C6.3.6.15** For a two-stage or refrigerant injection compressor unit, the temperature of the intermediate pressure vapor entering the compressor shall be reported, °F.
- C6.3.6.16** For a two-stage or refrigerant injection compressor unit, refrigerant mass flow rates and uncertainty (as outlined in Sections C6.3.6.1, C6.3.6.2, and C6.3.6.4) shall be reported for each stage inlet and outlet.
- C6.3.6.17** If intermediate cooling means is used, then the parameters specified by the manufacturer for operating the compressor unit's intermediate cooling means shall be reported

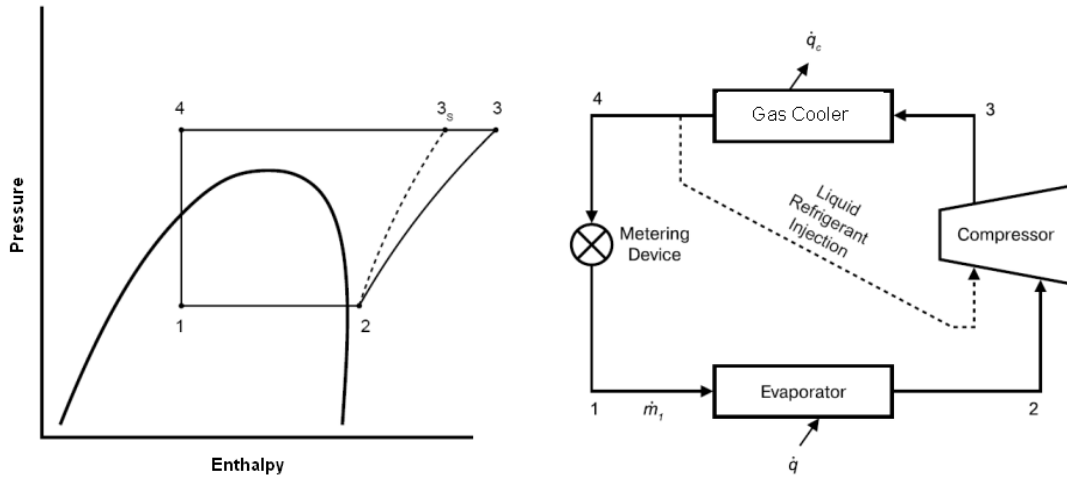
**Section C7. Sample Cycle Diagrams**

**C7.1** *Sample Cycle Diagrams and Supporting Capacity and Efficiency Equations.* This section provides sample cycle diagrams with reference to equations for calculating the Refrigerating Capacity and efficiency of Positive Displacement Refrigerant Compressors and Compressor Units that operate in subcritical, transcritical, single stage and two stage refrigeration cycles as described in the four rating methods of AHRI 570 Section 5.5.

**C7.1.1** *Sample Diagrams for Method 1: Standard Applications.* Figures C5 and C6 illustrate sample cycle diagrams for typical subcritical and transcritical single stage cycles, respectively. Compressor or compressor unit Refrigerating Capacity shall be calculated using Equation C4. Compressor Efficiency or Compressor Unit Efficiency shall be calculated using Equation C1.

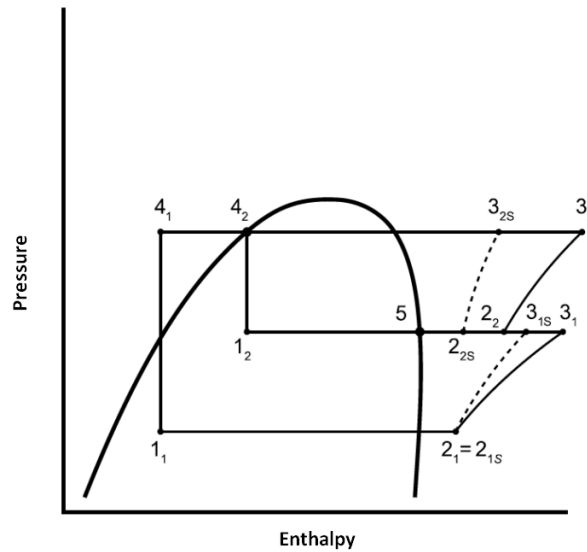


**Figure C5. Cycle Process for Subcritical Applications (AHRI Standard 570 Method 1)**



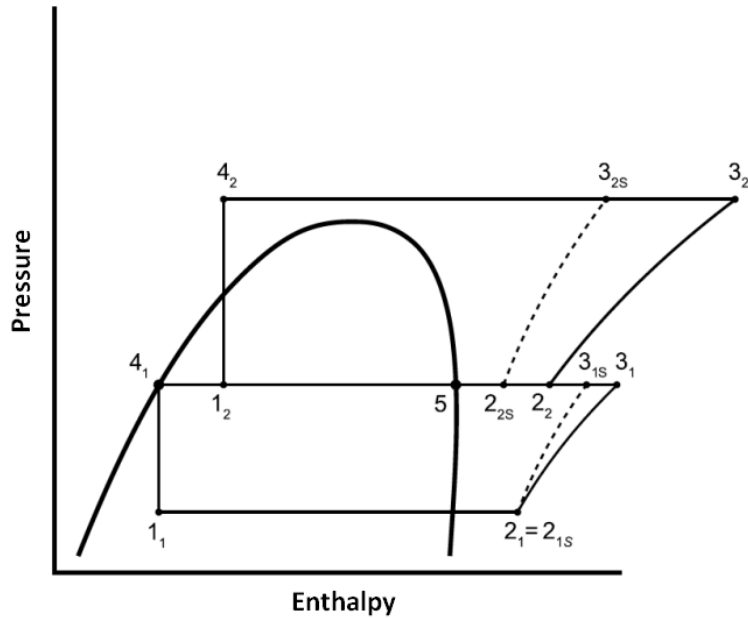
**Figure C6. Cycle Process for Transcritical Applications (AHRI Standard 570 Method 1)**

**C7.1.2 Sample Cycle Diagrams for Method 2: Compressor Units with Manufacturer Specified or Supplied Subcoolers Only.** Figures C7 and C8 illustrate sample cycle diagrams for subcritical and transcritical two stage cycles, respectively. Compressor unit Refrigerating Capacity shall be calculated using Equation C4. Compressor Unit Efficiency shall be calculated using Equation C2. In Figures C7 and C8, state point 5 is shown as a saturated vapor; however, as noted in Section C2.1.3 state point 5 could be a superheated vapor, saturated vapor or two-phase refrigerant.



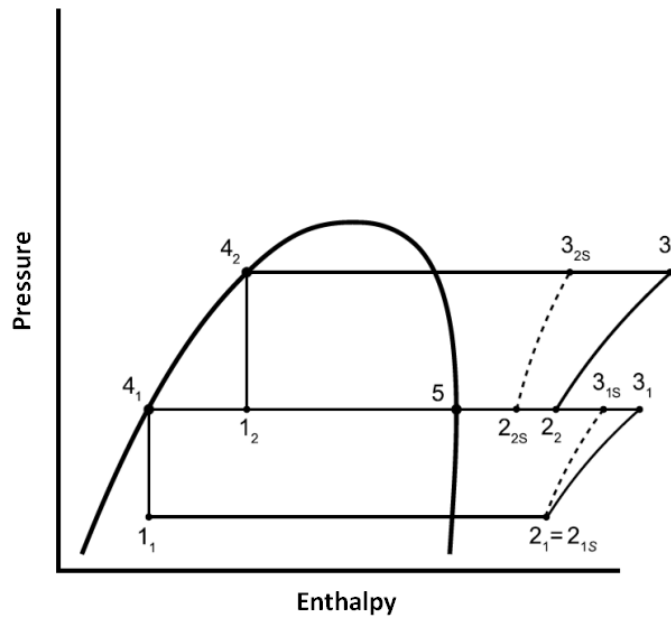
**Figure C7. Cycle Process for Subcritical Application for Compressor Units with Manufacturer Specified or Supplied Subcoolers (AHRI Standard 570 Method 2)**



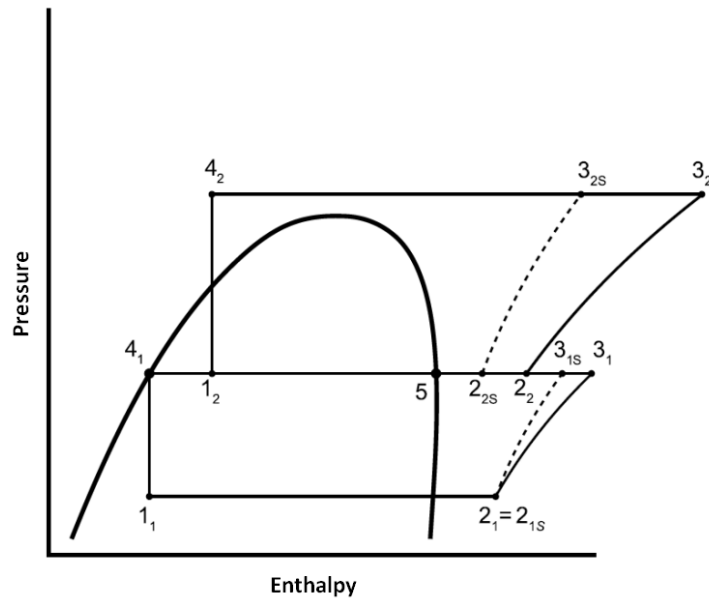


**Figure C10. Cycle Process for Transcritical Application for Compressors Applied with Non-Specified Subcoolers (AHRI Standard 570 Method 3)**

**C7.1.4 Sample Cycle Diagrams for Method 4: Compressors or Compressor Units Applied with Open Flash Style Liquid Subcoolers.** Figures C11 and C12 illustrate sample cycle diagrams for subcritical and transcritical two stage cycles, respectively. Compressor or compressor unit Refrigerating Capacity shall be calculated using Equation C4. Compressor or Compressor Unit Efficiency shall be calculated using Equation C2.



**Figure C11. Cycle Process for Subcritical Applications for Compressors and Compressor Units Applied with Open Flash Style Liquid Subcoolers (AHRI Standard 570 Method 4)**



**Figure C12. Cycle Process for Transcritical Applications for Compressors and Compressor Units Applied with Open Flash Style Liquid Subcoolers (AHRI Standard 570 Method 4)**