AHRI Standard 540

2020 Standard for

Performance Rating of Positive Displacement Refrigerant Compressors

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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.

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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

Documents
Document Sharing Hub

Full document details: AHRI Standard 540-2020 - Performance Rating of Positive Displacement Refrigerant Compressors

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

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Full document details: AHRI Standard 540-2020 - Performance Rating of Positive Displacement Refrigerant Compressors

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.

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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 ft^3/min, m^3/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-

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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.

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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 ± 5%.

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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:

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

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

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

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

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

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

Published Rating of the Compressor: $\{PR\} = \{IPR_1\}, \{IPR_2\}, \ldots \{IPR_N\}$ 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.

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