AHRI Standard 1210 (I-P)

2019 Standard for

Performance Rating of Variable Frequency Drives

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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.

Note:

This standard supersedes AHRI Standard 1210 (I-P)-2017.

For SI ratings, see AHRI Standard 1211 (SI)-2019.

AHRI CERTIFICATION PROGRAM PROVISIONS

The current scope of the Variable Frequency Drives Certification Programs can be found on AHRI website www.ahrinet.org. The scope of the Certification Programs should not be confused with the scope of the standard, as the standard also includes ratings for products that are not covered by a certification program.

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PERFORMANCE RATING OF VARIABLE FREQUENCY DRIVES

Section 1. Purpose

1.1 *Purpose.* The purpose of this standard is to establish for Variable Frequency Drives (VFDs): definitions; classifications; general test requirements; rating requirements; minimum data requirements for Published Ratings; 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, within the heating, ventilating, air-conditioning and refrigeration (HVACR) context, to 60 Hz VFDs used in the control of asynchronous induction motors. The range includes all those found within a building including: low voltage ($\leq$ 600 V) and drives that are stand alone, not mechanically integrated into motors.

2.2 *Exclusions.* This standard does not apply to VFDs applied to motors other than those listed in Section 2.1.

Section 3. Definitions

All terms in this document shall 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 *Carrier Switching Frequency*. The frequency at which the power output devices of a VFD are switched on and off.

3.2 *Constant Torque (CT).* Applications where the torque requirement of the driven load remains constant or nearly so over the normal speed range of use. Positive-displacement pumps and reciprocating compressors are examples of constant-torque loads.

3.3 *Drive System Efficiency*. Ratio of the output power from the motor to the input power of the VFD including motor and VFD losses.

3.4 *Fundamental Current.* Root mean square (RMS) current of the first harmonic.

3.5 *Impedance*. The measure of the opposition that a circuit presents to current.

3.5.1 *Source Impedance*. The short-circuit power at the point of common coupling (PCC), divided by the rated apparent power of the drive and as defined in IEC Standard 61000-3-12, Section 3.14 Subsection C.

3.6 *Individual Harmonic Current.* The ratio between the RMS value of the individual harmonic and the Fundamental Current.

3.7 *Motor Insulation Stress.* The voltage stress placed on a motor's insulation due to high Peak Voltages and short-rise times that occur when the motor is driven by a VFD.

3.8 *Motor Thermal Equilibrium*. When the observed temperature rise of the motor winding does not vary more than 2°F over a period of 30 minutes, or when the observed motor frame or core temperature rise does not vary more than 2°F over a period of 60 minutes.

3.9 *Peak Voltage (V_{peak}).* The maximum instantaneous voltage measured at a motor's terminals when operated from a VFD.

3.10 *Percent Speed*. The ratio of the measured speed to motor nameplate speed, %.

3.11 *Percent Torque*. The ratio of the measured torque to the rated motor torque, %.

3.12 *Power Line Harmonics*. Components of the power line voltage and current at the input of the VFD that are integer multiples of the fundamental sinusoidal frequency of the power source (example 60 Hz).

3.13 *Published Rating.* A rating 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. As used herein, 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.

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

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

3.14 *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 (e.g. line voltage, ambient temperature).

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

3.15 *"Shall" or "Should."* "Shall" or "should" shall be interpreted as follows:

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

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

3.16 *Supply Voltage (V_s).* The line to line input voltage to the equipment at time of testing.

3.17 *System Loss ($Loss_{sys}$).* The combination of electrical and mechanical losses represented by the difference between input power to the drive and output power from the motor.

3.18 *Total Harmonic Current Distortion (THD_i).* A measure of power line current distortion that sums the contributions of the Individual Harmonic Currents.

3.19 *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.

3.20 *Variable Torque (VT).* Applications where the torque requirement of the driven load is reduced as speed is reduced. Centrifugal fans and pumps are examples of variable-torque (VT) loads.

3.21 *Voltage Rise Time.* The time required for the voltage to increase, measured at the motor terminals when operated from a VFD, from 10% to 90% of the VFD steady state DC bus voltage.

Section 4. Classifications

4.1 *Classifications*. VFDs falling within the scope of this standard are defined in Table 1.

Table 1. Voltage and Power Classifications[1]			
VFD Voltage Rating,V	200 to 240	380 to 480	550 to 600
Supply Voltage V_s,V	208	460	575
VFD Power, hp	1.0	1.0	1.0
	2.0	2.0	2.0
	3.0	3.0	3.0
	5.0	5.0	5.0
	7.5	7.5	7.5
	10.0	10.0	10.0
	15.0	15.0	15.0
	20.0	20.0	20.0
	25.0	25.0	25.0
	-	30.0	30.0
	-	40.0	40.0
	-	50.0	50.0
	-	60.0	60.0
	-	-	75.0
Note 1: Nominal horsepower ranges are determined for applied motors that fall within Sections 430.250 NEC Handbook full load current ratings table in amps.			

Section 5. General Test Requirements

5.1 *Test Requirements.* VFDs shall be tested in accordance with the procedures set forth in ANSI/ASHRAE Standard 222 and in this section.

5.1.1 *Electrical Conditions*. Tests shall be performed at the voltages listed in Table 1 per the rated Supply Voltage V_s and frequency of the motor drive systems unless otherwise specified in this standard.

Note: Since motor drive systems with a 230 V rating are commonly operated at a utilization voltage of 208 V, then all 230 V rated motors shall be tested at 208 V Class.

5.1.2 *Power Source Requirements*. The power source shall meet the following requirements while measurements are being taken during testing:

5.1.2.1 The power source voltage and frequency at the VFD input terminals shall be maintained during the test at the rated voltage of the motor (e.g. 208, 460, 575 V) and rated frequency with a tolerance of ± 0.5%.

5.1.2.2 The power source voltage unbalance during the test shall not exceed 0.5%. Phase voltage unbalance shall be determined as defined in IEEE Standard 141.

5.1.2.3 The source impedance of the power supply shall not exceed 1%.

5.1.3 *Test Motor*. The motor selected for testing shall be a NEMA MG 1 design B four-pole matching the VFD voltage and horsepower.

5.1.4 *Speed/Load Testing Points.* Table 2 shows the four (4) points for speed/load combinations where measurements are taken for Drive System Efficiency. Motor Insulation Stress and Power Line Harmonics will be tested at 100% speed and torque. Details of the procedure for each test are presented in ANSI/ASHRAE Standard 222.

Table 2. Speed/Torque Test Points for Drive System Efficiency Test[1]			
	Test Point	Percent Speed	Percent Torque
Variable Torque	1	40%	16%
	2	50%	25%
	3	75%	56%
	4	100%	100%
Constant Torque	1	40%	100%
	2	50%	100%
	3	75%	100%
	4	100%	100%
Note 1: Output frequency or other readouts from the VFD shall not be used to determine percent speed.			

5.1.5 *Drive Settings.* The VFD shall be set up according to the manufacturer's instructional and operational manual included with the product. Manufacturers shall also provide parameter set-up summary including at minimum:

5.1.5.1 Carrier Switching frequency, Hz
5.1.5.2 Max frequency, Hz
5.1.5.3 Max output voltage, V
5.1.5.4 Motor control method (i.e. V/f ratio, sensor less vector, etc.)
5.1.5.5 Load profile setting (Constant Torque, Variable Torque, etc.)
5.1.5.6 Saving energy mode (if used)

One summary sheet shall be supplied for Constant Torque and a separate summary sheet for Variable Torque testing. Deviation from the resulting settings, such as Carrier Switching Frequency or load torque curves, for the purpose of optimizing test results shall not be permitted. For example, parameters dealing with carrier frequency shall be unchanged from one test to the other.

5.1.6 *Motor Wires.* The three load current carrying conductors between the VFD and motor shall be part of a shielded cable intended for VFD/motor applications. This cable shall be a symmetrical type having copper conductors, type XHHW with 2 spiral insulations on the current carrying conductors, three smaller ground wires and an overall jacket made of type XLPE insulation. The cable shall be sized per Table 3. Where the cable is not available with the current carrying conductors in the sizes shown in Table 3, the next larger size shall be used.

Table 3. VFD to Motor Conductor Sizes (AWG)			
VFD Power, hp	Supply Voltage (V_s), V		
	208	460	575
	Wire Gauge (AWG)	Wire Gauge (AWG)	Wire Gauge (AWG)
1	14	14	14
2	14	14	14
3	14	14	14
5	12	14	14
7.5	10	14	14
10	8	14	14
15	6	10	12
20	4	8	10
25	3	8	8
30	2	6	8
40	-	4	6
50	-	3	4
60	-	2	3
75	-	-	2

5.1.7 *Motor Thermal Equilibrium.* Apply the rated voltage and frequency to the drive and full load torque to the motor until thermal equilibrium is reached. Individual test steps in ANSI/ASHRAE Standard 222 shall indicate whether they are to be conducted at this thermal stabilization temperature.

5.1.8 *Ambient Temperatures.* The ambient temperature, as measured by ANSI/ASHRAE Standard 41.1, at the VFD vicinity (3 ft. away and not in the exhaust air stream of the VFD) during testing shall be maintained within the range of 70 °F – 80 °F.

5.1.9 *Reference Equations.* These equations are also used in ANSI/ASHRAE Standard 222.

5.1.9.1 The Total Harmonic Current Distortion (THD_i) shall be calculated using Equation 1:

$$\mathrm{THD_i} = \sqrt{\sum_{n=2}^{50} \left(\frac{I_n}{I_1}\right)^2} . 100 \qquad 1$$

Where:

I_1 = Fundamental Current
I_n = The value of an Individual Harmonic Current, A (amps)
THD_i = Total Harmonic Current Distortion, %

5.1.9.2 The output power (P_{out}) shall be calculated using Equation 2:

$$P_{out} = \frac{\tau \cdot \omega}{K} \quad (2)$$

Where:

P_{out} = Output power, hp
K = 5252 ft · lb rpm / hp
τ = Torque, ft · lb
ω = Speed, rpm

5.1.9.3 The Drive System Efficiency (η_{sys}) shall be calculated using Equation 3:

$$\eta_{sys} = \frac{P_{out}}{P_{in}} . 100 \quad (3)$$

Where:

P_{in} = Input power, hp
P_{out} = Output power, hp
η_{sys} = Drive System Efficiency, %

5.1.9.4 The rated motor torque (τ_{mtr}) shall be calculated using Equation 4:

$$\tau_{mtr} = \frac{P_{mtr} \cdot K}{\omega_{mtr}} \quad (4)$$

Where:

K = 5252 ft · lb rpm / hp
P_{mtr} = Motor nameplate output power, hp
τ_{mtr} = Rated motor torque, ft · lb
ω_{mtr} = Motor nameplate speed, rpm

5.1.9.5 The Impedance (Z) shall be calculated using Equation 5:

$$Z = \frac{Irated_{VFD}}{Iscc_{source}} \cdot 100 \quad (5)$$

Where:

$Irated_{VFD}$ = VFD rated current, A
$Iscc_{source}$ = Source short circuit current, A
Z = Impedance, %

5.1.9.6 The System Losses of the Drive System Efficiency shall be calculated using Equation 6:

$$Loss_{sys} = 100 - \eta_{sys} \quad (6)$$

Where:

$Loss_{sys}$ = System Loses, %
η_{sys} = Drive System Efficiency, %

Section 6. Rating Requirements

6.1 *Published Ratings*. Published Ratings shall include Drive System Efficiency, Motor Insulation Stress, and Power Line Harmonics.

6.1.1 Drive System Efficiency shall be expressed in terms of % and stated to the nearest 0.5 %.

6.1.2 Motor Insulation Stress shall be expressed in terms of Peak Voltage and Voltage Rise Time stated to the nearest 10 V_{peak} and 0.01 μsec, respectively.

6.1.3 Total Harmonic Current Distortion (THD_i) shall be expressed in terms of % and stated to the nearest 1%.

6.2 *Standard Ratings.* All Standard Ratings shall be based on combinations of VFDs and motors where the motor voltage and horse power are equivalent to the VFD voltage and horse power in Table 1 and shall be verified by tests in accordance with Section 5.

6.3 *Application Ratings.* Ratings for non-standard combinations of VFDs and motors shall be based on data determined by test requirements prescribed in Section 5 and conducted in accordance with the method of testing described in ANSI/ASHRAE Standard 222.

Note: Individual harmonics are not covered by this standard, the user is referred to IEC Standard 61000-4-7, IEEE Standard 519 and ISO/IEC Standard 17025:2017.

6.4 *Tolerances.* To comply with this standard, measured results of any single sample production audit shall be within the following tolerances of the Standard Rating:

6.4.1 *Drive System Efficiency*. The System Losses of the measured result of the Drive System Efficiency rating shall be less than 120% of the System Losses of the published Drive System Efficiency rating in percent. For example, if the published Drive System Efficiency rating is 90%, the System Losses of the published Drive System Efficiency is 10% as determined from Equation 6. The measured result of the Drive System Efficiency rating shall be greater than 88% or the System Losses of the measured result of the Drive System Efficiency rating shall be less than 12%.

6.4.2 *Motor Insulation Stress.* The measured result of Peak Voltage rating shall be less than 110% of the published Peak Voltage rating and the measured result of the Voltage Rise Time rating shall not be less than 0.03 μsec below the published Voltage Rise Time rating. For example, if the Peak Voltage rating is 1,000 V, the measured result of the Peak Voltage rating shall be less than 1,100 V. If the published Voltage Rise Time rating is 0.10 μsec, the measured shall be greater than 0.07 μsec.

6.4.3 *Power Line Harmonics*. The measured result of the Total Harmonic Current Distortion rating at maximum load ratings shall be less than 2% the published value. For example, if the published current distortion at the Total Harmonic Current Distortion is 40%, the measured shall be less than 42%. All Power Line Harmonics shall be reported with a source impedance of 1%.

Section 7. Minimum Data Requirements for Published Ratings

7.1 *Minimum Data Requirements for Published Ratings*. As a minimum, Published Ratings shall include Standard Ratings. The following information shall be published for all Standard Ratings:

7.1.1 Power Classification, hp, as determined by Table 1
7.1.2 Supply Voltage (V_s), V, as determined by Table 1
7.1.3 Drive System Efficiency, %, as determined by Section 5.1.9.3 and measured at points defined in Table 2
7.1.4 Motor Insulation Stress Peak Voltage (V_{peak}), V, as defined by Section 3.9
7.1.5 Motor Insulation Stress Voltage Rise Time, μsecs, as defined by Section 3.21
7.1.6 Power Line Harmonics, Total Harmonic Current Distortion, %, as defined by Sections 3.18 and 5.1.9.1

7.2 *Rating Claims*. All claims to ratings within the scope of this standard shall include the statement "Rated in accordance with AHRI Standard 1210 (I-P)." All claims to ratings outside the scope of this standard shall include the statement "Outside

the scope of AHRI Standard 1210 (I-P)." Wherever Application Ratings are published or printed, they shall include a statement of the conditions at which the ratings apply.

Section 8. Marking and Nameplate Data

8.1 *Marking and Nameplate Data.* As a minimum, the nameplate shall display the manufacturer's name, model designation, and electrical characteristics. Nameplate voltages for 60Hz systems shall include one or more of the equipment nameplate voltage ratings shown in Table 1 of AHRI Standard 110. Nameplate voltages for 50 Hz systems shall include one or more of the utilization voltages shown 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 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 cannot 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 this standard.

A1.1 AHRI Standard 110-2016, *Air-Conditioning and Refrigerating Equipment Nameplate Voltages*, 2016, Air-Conditioning, Heating, and Refrigeration Institute, 2311 Wilson Blvd, Suite 400, Arlington, VA 22201, U.S.A.

A1.2 ANSI/ASHRAE Standard 222-2018, *Standard Method of Test for Electrical Power Drive Systems*, 2018, ASHRAE, 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.3 ANSI/ASHRAE Standard 41.1-2013 (RA 06), *Standard Method for Temperature Measurement*, 2013, ASHRAE, 1791 Tullie Circle N.E., Atlanta, GA 30329, U.S.A.

A1.4 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.

A1.5 IEC Standard 60038-2009, *IEC Standard Voltages*, 2009, International Electrotechnical Commission, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

A1.6 IEC Standard 61000-3-2-2018, *Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*, 2018, International Electrotechnical Commission, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

A1.7 IEC Standard 61000-3-12-2011, *Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤75 A per phase*, 2011, International Electrotechnical Commission, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

A1.8 IEEE Standard 141-1993, *IEEE Recommended Practice for Electric Power Distribution for Industrial Plants*, 1993, IEEE, 3 Park Avenue, 17th Floor, New York, NY 10016-5997

A1.9 *National Electrical Code Handbook (NEC)*, 2017, National Fire Prevention Association, 1 Batterymarch Park, Quincy, Massachusetts, 02169-7471

A1.10 NEMA MG 1-2016, *Motors and Generators*, 2016, National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1752, Rosslyn, Virginia 22209

APPENDIX B. REFERENCES – INFORMATIVE

B1 Listed here are standards, handbooks, and other publications which may provide useful information and background but are not considered essential. References in this appendix are not considered part of the standard.

B.1.1 IEC Standard 61000-4-7-2002+AMD1 (2008), *Testing and measurement techniques – General guide on harmonics and inter harmonics measurements and instrumentation, for power supply systems and equipment connected thereto*, 2002, International Electrotechnical Commission, rue de Varembe, P.O. Box 131, 1211 Geneva 20, Switzerland.

B.1.2 IEEE Standard 519-2014, *IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems*, 2014, IEEE, 3 Park Avenue, 17th Floor, New York, NY 10016-5997

B.1.3 ISO/IEC Standard 17025:2017, *General Requirements for the Competence of Testing and Calibration Laboratories*, 2017, International Organization for Standardization, ISO Central Secretariat, Chemin de Blandonnet 8, CP 401 - 1214 Vernier, Geneva, Switzerland