ANSI C84.1-20XX

American National Standard for Electric Power Systems and Equipment— Voltage Ratings (60 Hertz)

Secretariat:

National Electrical Manufacturers Association

Approved: ________

American National Standards Institute, Inc.

1 Scope and Purpose

1.1 Scope

This standard establishes nominal voltage ratings and operating tolerances for 60Hz electric power systems above 100 volts. It also makes recommendations to other standardizing groups with respect to voltage ratings for equipment used on power systems and for utilization devices connected to such systems.

This standard includes preferred voltage ratings up to and including 1200 kV maximum system voltage, as defined in the standard.

In defining maximum system voltage, voltage transients and temporary overvoltages caused by abnormal system conditions such as faults, load rejection, and the like are excluded. However, voltage transients and temporary overvoltages may affect equipment operating performance and are considered in equipment application.

1.2 Purpose

The purposes of this standard are to:

a) Promote a better understanding of the voltages associated with power systems and utilization equipment to achieve overall practical and economical design and operation
b) Establish uniform nomenclature in the field of voltages
c) Promote standardization of nominal system voltages and ranges of voltage variations for operating systems
d) Promote standardization of equipment voltage ratings and tolerances
e) Promote coordination of relationships between system and equipment voltage ratings and tolerances
f) Provide a guide for future development and design of equipment to achieve the best possible conformance with the needs of the users
g) Provide a guide, with respect to choice of voltages, for new power system undertakings and for changes in older ones

2 Definitions

2.1 system or power system: The connected system of power apparatus used to deliver electric power from the source to the utilization device. Portions of the system may be under different ownership, such as that of a supplier or a user.

2.2 system voltage terms: As used in this document, all voltages are rms phase-to-phase, except that the voltage following a slant-line is an rms phase-to-neutral voltage.

2.2.1 system voltage: The root-mean-square (rms) phase-to-phase voltage of a portion of an alternating-current electric system. Each system voltage pertains to a portion of the system that is bounded by transformers or utilization equipment.

2.2.2 nominal system voltage: The voltage by which a portion of the system is designated, and to which certain operating characteristics of the system are related. Each nominal system voltage pertains to a portion of the system bounded by transformers or utilization equipment.

NOTE: The nominal voltage of a system is near the voltage level at which the system normally operates. To allow for operating contingencies, systems generally operate at voltage levels about 5–10% below the maximum system voltage for which system components are designed.

2.2.3 maximum system voltage: The highest system voltage that occurs under normal operating conditions, and the highest system voltage for which equipment and other components are designed for continuous satisfactory operation without derating of any kind.

2.3 service voltage: The voltage at the point where the electrical system of the supplier and the electrical system of the user are connected.

2.4 utilization voltage: The voltage at the line terminals of utilization equipment.

2.4.1 nominal utilization voltage: The voltage rating of certain utilization equipment used on the system.

NOTE: The nominal system voltages contained in table 1 apply to all parts of the system, both of the supplier and of the user. The ranges are given separately for service voltage and for utilization voltage, these normally being at different locations. It is recognized that the utilization voltage is normally somewhat lower than the service voltage. In deference to this fact, and the fact that integral horsepower motors, or air conditioning and refrigeration equipment, or both, may constitute a heavy concentrated load on some circuits, the rated voltages of such equipment and of motors and motor-control equipment are usually lower than nominal system voltage. This corresponds to the range of utilization voltages in table 1. Other utilization equipment is generally rated at nominal system voltage.

2.5 voltage level: Voltage level is a generalized term that is synonymous with the rms voltage averaged over 10 minutes.

3 System Voltage Classes

3.1 Low Voltage (LV): A class of nominal system voltages 1000 volts or less.

3.2 Medium Voltage (MV): A class of nominal system voltages greater than 1000 volts and less than 100 kV.

3.3 High Voltage (HV): A class of nominal system voltages equal to or greater than 100 kV and equal to or less than 230 kV.

3.4 Extra-High Voltage (EHV): A class of nominal system voltages greater than 230 kV but less than 1000 kV.

3.5 Ultra-High Voltage (UHV): A class of nominal system voltages equal to or greater than 1000 kV.

4 Selection of Nominal System Voltages

When a new system is to be built or a new voltage level introduced into an existing system, one (or more) of the preferred nominal system voltages shown in boldface type in table 1 should be selected. The logical and economical choice for a particular system among the voltages thus distinguished will depend upon a number of factors, such as the character and size of the system.

Other system voltages that are in substantial use in existing systems are shown in lightface type. Economic considerations will require that these voltages stay in use, and in some cases, may require that their use be extended. However, these voltages generally should not be utilized in new systems or in new voltage levels in existing systems.

The 4160V, 6900V, and 13,800V three-wire systems are particularly suited for industrial systems that supply predominantly polyphase loads, including large motors, because these voltages correspond to the standard motor ratings of 4000 volts, 6600 volts, and 13,200 volts, as is explained further in 2.4.1. It is not intended to recommend the use of these system voltages for utility primary distribution, for which four-wire voltages of 12470Y/7200 volts or higher should be used.

5 Explanation of Voltage Ranges

For any specific nominal system voltage, the voltages actually existing at various points at various times on any power system, or on any group of systems, or in the industry as a whole, usually will be distributed within the maximum and minimum voltages shown in table 1. The design and operation of power systems and the design of equipment to be supplied from such systems should be coordinated with respect to these voltages so that the equipment will perform satisfactorily in conformance with product standards throughout the range of actual utilization voltages that will be encountered on the system. To further this objective, this standard establishes, for each nominal system voltage, two ranges for service voltage and utilization voltage variations, designated as Range A and Range B, the limits of which are given in table 1. These limits shall apply to sustained voltage levels and not to momentary voltage excursions that may result from such causes as switching operations, motor starting currents, and the like.

5.1 Application of Voltage Ranges

5.1.1 Range A—Service Voltage

Electric supply systems shall be so designed and operated that most service voltages will be within the limits specified for Range A. The occurrence of service voltages outside of these limits should be infrequent.

5.1.2 Range A—Utilization Voltage

User systems shall be so designed and operated that with service voltages within Range A limits, most utilization voltages will be within the limits specified for this range.

Utilization equipment shall be designed and rated to give fully satisfactory performance throughout this range.

5.1.3 Range B—Service and Utilization Voltages

Range B includes voltages above and below Range A limits that necessarily result from practical design and operating conditions on supply or user systems, or both. Although such conditions are a part of practical operations, they shall be limited in extent, frequency, and duration. When they occur, corrective measures shall be undertaken within a reasonable time to improve voltages to meet Range A requirements.

Insofar as practicable, utilization equipment shall be designed to give acceptable performance in the extremes of the range of utilization voltages, although not necessarily as good performance as in Range A.

5.1.4 Outside Range B—Service and Utilization Voltages

It should be recognized that because of conditions beyond the control of the supplier or user, or both, there will be infrequent and limited periods when sustained voltages outside Range B limits will occur. Utilization equipment may not operate satisfactorily under these conditions, and protective devices may operate to protect the equipment.

When voltages occur outside the limits of Range B, prompt, corrective action shall be taken. The urgency for such action will depend upon many factors, such as the location and nature of the load or circuits involved, and the magnitude and duration of the deviation beyond Range B limits.

6 Voltage Ratings for 60Hz Electric Equipment

6.1 General

This standard includes information, as given in Annex C, to assist in the understanding about the effects of unbalanced voltages on utilization equipment applied in polyphase systems.

6.2 Recommendation

Insofar as practicable, whenever electric equipment standards are revised:

a) Nameplate voltage ratings should be changed as needed in order to provide a consistent relationship between the ratings for all equipment of the same general class and the nominal system voltage on the portion of the system on which they are designed to operate.
b) The voltage ranges for which equipment is designed should be changed as needed in order to be in accordance with the ranges shown in table 1.

The voltage ratings in each class of utilization equipment should be either the same as the nominal system voltages or less than the nominal system voltages by the approximate ratio of 115 to 120.

Table 1
Standard Nominal System Voltages and Voltage Ranges (Preferred system voltages in bold-face type)

VOLTAGE CLASS	Nominal System Voltage (Note a)			Nominal Utilization Voltage (Note h)	Voltage Range A (Note b)			Voltage Range B (Note b)		
					Maximum	Minimum		Maximum	Minimum	
	2-wire	3-wire	4-wire	2-wire 3-wire 4-wire	Utilization and Service Voltage (Note c)	Service Voltage	Utilization Voltage	Utilization and Service Voltage	Service Voltage	Utilization Voltage
	Single-Phase Systems									
Low Voltage	**120**			**115**	**126**	**114**	**108**	**127**	**110**	**104**
		120/240		**115/230**	**126/252**	**114/228**	**108/216**	**127/254**	**110/220**	**104/208**
	Three-Phase Systems									
			208Y/120 (Note d)	**200**	**218Y/126**	**197Y/114**	**187Y/108**	**220Y/127**	**191Y/110** (Note i)	**180Y/104** (Note i)
			240/120	**230/115**	**252/126**	**228/114**	**216/108**	**254/127**	**220/110**	**208/104**
		240		**230**	**252**	228	216	254	220	208
			480Y/277	**460Y/266**	**504Y/291**	**456Y/263**	**432Y/249**	**508Y/293**	**440Y/254**	**416Y/240**
		480		**460**	**504**	**456**	**432**	**508**	**440**	**416**
		600 (Note e)		575	630 (Note e)	570	540	635 (Note e)	550	520
			690Y/400	660	720	655	630	725	635	610
Medium Voltage		2400			2520	2340	2160	2540	2280	2080
			4160Y/2400		4370/2520	4050Y/2340	3740Y/2160	4400Y/2540	3950Y/2280	3600Y/2080
		4160			**4370**	**4050**	**3740**	**4400**	**3950**	**3600**
		4800			5040	4680	4320	5080	4560	4160
		6900			**7240**	**6730**	**6210**	**7260**	**6560**	**5940**
			8320Y/4800		8730Y/5040	8110Y/4680		8800Y/5080	7900Y/4560	
			12000Y/6930		12600Y/7270	11700Y/6760		12700Y/7330	11400Y/6580	(Note f)
			12470Y/7200		**13090Y/7560**	**12160Y/7020**	(Note f)	**13200Y/7620**	**11850Y/6840**	
			13200Y/7620		**13860Y/8000**	**12870Y/7430**		**13970Y/8070**	**12504Y/7240**	
			13800Y/7970		**14490Y/8370**	**13460Y/7770**		**14520Y/8380**	**13110Y/7570**	
		13800			**14490**	**13460**	**12420**	**14520**	**13110**	**11880**
			20780Y/12000		21820Y/12600	20260Y/11700		22000Y/12700	19740Y/11400	
			22860Y/13200		24000Y/13860	22290Y/12870		24200Y/13970	21720Y/12540	(Note f)
		23000			24150	22430	(Note f)	24340	21850	
			24940Y/14400		**26190Y/15120**	**24320Y/14040**		**26400Y/15240**	**23690Y/13680**	
			34500Y/19920		**36230Y/20920**	**33640Y/19420**		**36510Y/21080**	**32780Y/18930**	
		34500			36230	33640		36510	32780	
					Maximum Voltage (Note g)					
		46000			48300					
		69000			**72500**					

Continued on next page

Table 1

Standard Nominal System Voltages and Voltage Ranges (continued)

(Preferred system voltages in bold-face type)

VOLTAGE CLASS	Nominal System Voltage (Note a)			Nominal Utilization Voltage (Note h)	Maximum Voltage (note g)
	2-wire	3-wire	4-wire		
High Voltage		**115000** **138000** 161000 **230000**			**121000** **145000** 169000 **242000**
Extra-High Voltage		**345000** **400000** **500000** **765000**			**362000** **420000** **550000** **800000**
Ultra-High Voltage		**1100000**			**1200000**

NOTES:

a) Three-phase three-wire systems are systems in which only the three-phase conductors are carried out from the source for connection of loads. The source may be derived from any type of three-phase transformer connection, grounded or ungrounded. Three-phase four-wire systems are systems in which a grounded neutral conductor is also carried out from the source for connection of loads. Four-wire systems in table 1 are designated by the phase-to-phase voltage, followed by the letter Y (except for the 240/120V delta system), a slant line, and the phase-to-neutral voltage. Single-phase services and loads may be supplied from either single-phase or three-phase systems. The principal transformer connections that are used to supply single-phase and three-phase systems are illustrated in Annex A.

b) The voltage ranges in this table are illustrated in Annex B.

c) For 120-600V nominal systems, voltages in this column are maximum service voltages. Maximum utilization voltages would not be expected to exceed 125 volts for the nominal system voltage of 120, nor appropriate multiples thereof for other nominal system voltages through 600 volts.

d) A modification of this three-phase, four-wire system is available as a 120/208YV service for single-phase, three-wire, open-wye applications.

e) Certain kinds of control and protective equipment presently available have a maximum voltage limit of 600 volts; the manufacturer or power supplier or both should be consulted to assure proper application.

f) Utilization equipment does not generally operate directly at these voltages. For equipment supplied through transformers, refer to limits for nominal system voltage of transformer output.

g) For these systems, Range A and Range B limits are not shown because, where they are used as service voltages, the operating voltage level on the user's system is normally adjusted by means of voltage regulators or load tap-changers to suit their requirements.

h) Nominal utilization voltages are for low-voltage motors and control.

i) Many 220V motors were applied on existing 208V systems on the assumption that the utilization voltage would not be less than 187V. Caution should be exercised in applying the Range B minimum voltages of table 1 to existing 208V systems supplying such motors.

Annex A

(informative)

Principal Transformer Connections to Supply the System Voltages of Table 1

(See Figure A1)

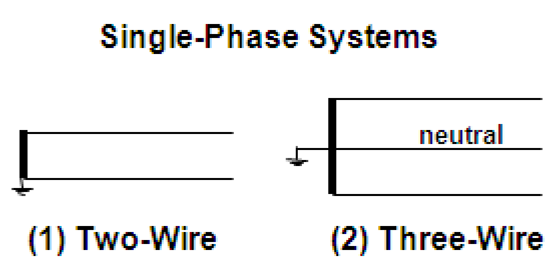


Figure A1

NOTES:

a) The above diagrams show connections of transformer secondary windings to supply the nominal system voltages of table 1. Systems of more than 600 volts are normally three-phase and supplied by connections (3), (5) ungrounded, or (7). Systems of 120-600 volts may be either single-phase or three phase, and all of the connections shown are used to some extent for some systems in this voltage range.

b) Three-phase, three-wire systems may be solidly grounded, impedance grounded, or ungrounded but are not intended to supply loads connected phase to-neutral (as the four-wire systems are).

c) In connections (5) and (6) the ground may be connected to the midpoint of one winding as shown (if available), to one phase conductor ("corner" grounded), or omitted entirely (ungrounded).

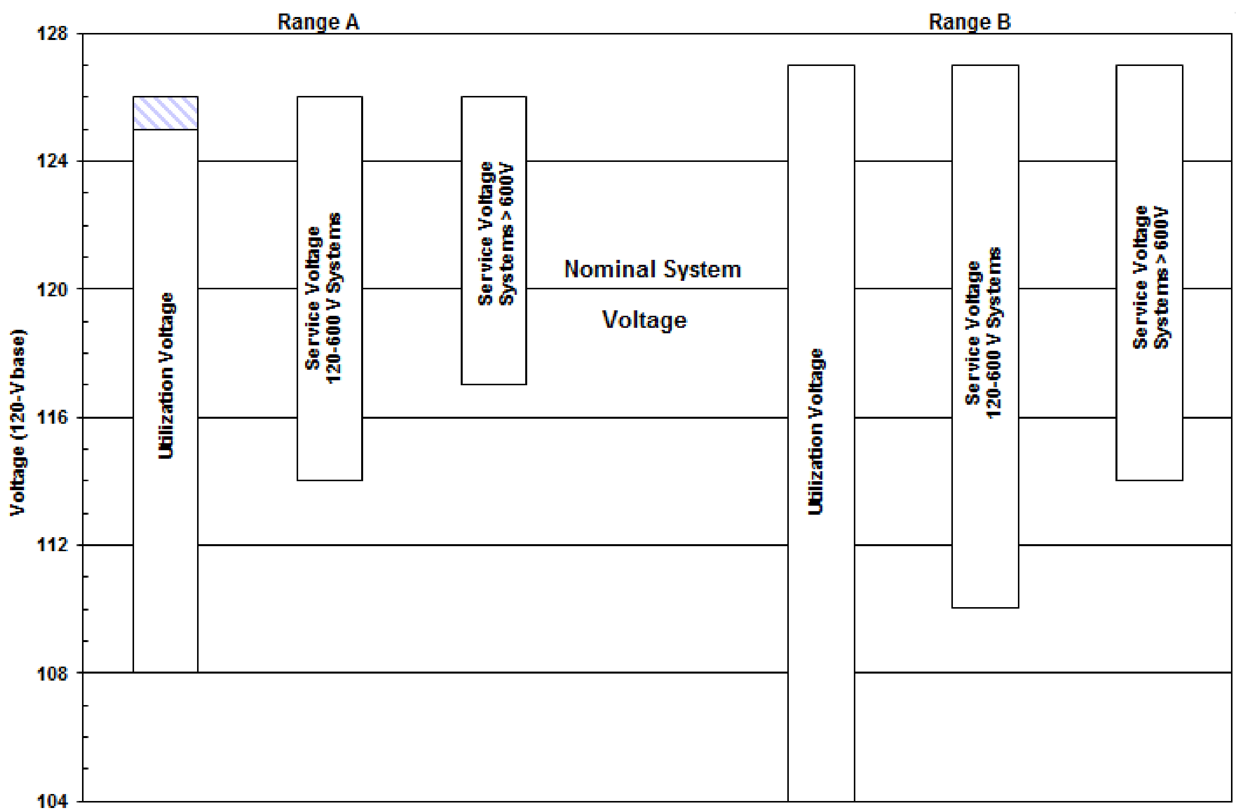
d) Single-phase services and single-phase loads may be supplied from single-phase systems or from three-phase systems. They are connected phase-to-phase when supplied from three-phase, three-wire systems and either phase-to-phase or phase-to-neutral from three-phase, four-wire systems.

Annex B

Illustration of Voltage Ranges of Table 1

Figure B1 shows the basis of the Range A and Range B limits of table 1. The limits in table 1 were determined by multiplying the limits shown in this chart by the ratio of each nominal system voltage to the 120V base. [For exceptions, see note (c) to Figure B1.]

A technique commonly called Conservation Voltage Reduction (CVR) is sometimes used for energy and or demand reduction. Determination of the value of CVR is beyond the scope of this standard. However, it is recommended that the application of CVR should be limited to voltages in Range A for normal operation. Range B should be reserved for emergency, infrequent operation. CVR systems should not be designed to operate below Range B for any condition.



(informative)

Figure B1

NOTES:

a) The shaded portion of Range A does not apply to 120-600-volt systems. See note (c) to table 1.
b) The difference between minimum service and minimum utilization voltages is intended to allow for voltage drop in the customer's wiring system. This difference is greater for service at more than 600 volts to allow for additional voltage drop in transformations between service voltage and utilization equipment.
c) The Range B utilization voltage limits in table 1 for 2400V through 13,800V systems are based on 90% and 110% of the voltage ratings of the standard motors used in these systems with some having a slight deviation from this figure.

Annex C
(Informative)
Polyphase Voltage Unbalance

C.1 Introduction

Studies on the subject of three-phase voltage unbalance indicate that: (1) all utility-related costs required to reduce voltage unbalance and all manufacturing-related costs required to expand a motor's unbalanced voltage operating range are ultimately borne directly by the customer, (2) utilities' incremental improvement costs are maximum as the voltage unbalance approaches zero and decline as the range increases, and (3) manufacturers' incremental motor-related costs are minimum at zero voltage unbalance and increase rapidly as the range increases.

When these costs, which exclude motor-related energy losses, are combined, curves can be developed that indicate the annual incremental cost to the customer for various selected percent voltage unbalance limits.

The optimal range of voltage unbalance occurs when the costs are minimum.

a) Field surveys tend to indicate that the voltage unbalances range from 0–2.5 percent to 0–4.0 percent with the average at approximately 0–3.0 percent
b) Approximately 98 percent of the electric supply systems surveyed are within the 0–3.0 percent voltage-unbalance range, with 66 percent at 0–1.0 percent or less

C.2 Recommendation

Electric supply systems should be designed and operated to limit the maximum voltage unbalance to 3 percent when measured at the electric-utility revenue meter under no-load conditions.

This recommendation should not be construed as expanding the voltage ranges prescribed in 5. If the unbalanced voltages of a polyphase system are near the upper or lower limits specified in table 1, Range A or Range B, each individual phase voltage should be within the limits in table 1.

C.3 Calculation for Voltage Unbalance

Voltage unbalance of a polyphase system is expressed as a percentage value and calculated as follows:

$$\text{Percent voltage unbalance} = 100 \times \frac{(\text{maximum deviation from average V})}{(\text{Average Voltage})}$$

Example: with phase-to-phase voltages of 230, 232, and 225, the average is 229; the maximum deviation from average is 4; and the percent unbalance is (100 × 4)/229 = 1.75 percent.

C.4 Derating for Unbalance

The rated load capability of polyphase equipment is normally reduced by voltage unbalance. A common example is the derating factor, from figure C1, used in the application of polyphase induction motors.

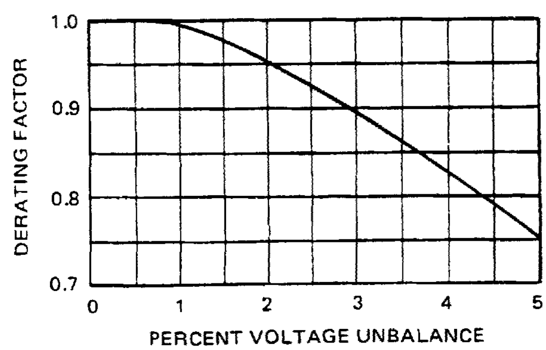


Figure C1
Derating factor

NOTE: See 14.36 of NEMA MG 1-2009 for more complete information about the derating factor.

C.5 Protection from Severe Voltage Unbalance

User systems should be designed and operated to maintain a reasonably balanced load.

In severe cases of voltage unbalance, consideration should be given to equipment protection by applying unbalance limit controls.

Annex D
(Informative)
Applicable Standards

D.1 List of Standards

The following is a partial list of standards (by general number) for equipment from which voltage ratings and other characteristics can be obtained.

Equipment	Standard
Air-conditioning and refrigerating equipment nameplate voltages	ARI 110
Air filter equipment	ARI 680
Ammonia compressors and compressor units	ARI 510
Application, installation, and servicing of unitary systems	ARI Series
Automatic commercial ice makers	ARI 810
Cable terminating devices (power)	IEEE 48
Central forced-air electric heating equipment	ARI Series
Central-station air-handling units	ARI 430
Connectors for electric utility applications	ANSI C119.1
Definite purpose magnetic contactors	ARI 780
Dehumidifiers	ANSI/AHAM DH-1
Electrical measuring instruments	ANSI C39 Series
Electrical power insulators	ANSI C29 Series
Electricity metering	ANSI C12 Series
Forced circulation, free-delivery air coolers for refrigeration	ARI 420
Gas-fired furnaces	ANSI Z21 Series
Industrial control apparatus	ANSI/NEMA ICS Series
Insulated conductors	ANSI/NFPA 70 AEIC Series ICEA Series
Lamps Bactericidal lamps Electrical discharge lamp Incandescent lamps	ANSI C78 Series
Lamp ballasts	ANSI C82 Series
Low-voltage fuses	ANSI/NEMA FU 1
Low-voltage molded-case circuit breakers	NEMA AB 1
Mechanical transport refrigeration units	ARI 1110
Packaged terminal air conditioners	ARI 310/380
Positive displacement refrigerant compressor and compressor units	ANSI/ARI 520 ANSI/ARI 540

Equipment	Standard
Power switchgear Automatic circuit reclosers Automatic line sectionalizers Capacitor switches Distribution current-limiting fuses Distribution cutout and fuse links Distribution enclosed single-pole air switches Distribution oil cutouts and fuse links Fused disconnecting switches High-voltage air switches Manual and automatic station control Power circuit breakers Power fuses Relays and relay systems Supervisory and associated telemetering equipment Switchgear assemblies including metal enclosed bus	ANSI C37 Series
Reciprocating water-chilling packages	ANSI/ARI 550 ANSI/ARI 590
Remote mechanical draft air-cooled refrigerant condensers	ARI 460
Room air conditioners	ANSI/AHAM RAC-1
Room fan-coil airs	ARI 440
Rotating electrical machinery AC induction motors Cylindrical rotor synchronous generators Salient pole synchronous generator and condensers Synchronous motors Universal motors	ANSI C50 Series NEMA MG1
Central system humidifiers	ANSI/ARI 620
Self-contained mechanically refrigerated drinking-water coolers	ANSI/ARI 1010
Shunt power capacitors	ANSI/IEEE 18
Solenoid valves for liquid and gaseous flow	ARI 760
Static power conversion equipment	ANSI C34
Surge arresters	ANSI/IEEE C62.2 ANSI/IEEE C62.21 NEMA LA1
Transformers, regulators, and reactors Arc furnace transformers Constant-current transformers Current-limiting reactors Distribution transformers, conventional subway-type Dry type Instrument transformers Power transformers Rectifier transformers Secondary network transformers Specialty Step-voltage and induction-voltage regulators Three-phase load-tap-changing transformers	ANSI/IEEE C57 Series ANSI/NEMA ST20
Unit ventilators	ARI 840
Unitary air-conditioning and air-source heat pump equipment	ARI 210/240
Commercial and industrial unitary air-conditioning equipment	ARI 340/360
Wiring devices	ANSI C73 Series

*See list of organizations in Section D2.

D.2 Organizations Referred to in Section D.1

AEIC	Association of Edison Illuminating Companies P.O. Box 2641 Birmingham, AL 35291
AHAM	Association of Home Appliance Manufacturers 1111 19th Street NW, Suite 402 Washington, DC 20036
AMCA	Air Movement and Control Association 30 West University Drive Arlington Heights, IL 60004
ANSI	American National Standards Institute 25 West 43rd Street, 4th Floor New York, NY 10036
ARI	Air Conditioning and Refrigeration Institute (Air-Conditioning, Heating, and Refrigeration Institute) 4100 N. Fairfax Drive; Suite 200 Arlington, VA 22203
HI	Hydronics Institute Division of GAMA Gas Appliance Manufacturers Association 2107 Wilson Blvd. Arlington, VA 22201-3042
IEEE	The Institute of Electrical and Electronics Engineers, Inc. 445 Hoes Lane Piscataway, NJ 08855
ICEA	Insulated Cable Engineers Association PO Box 1568 Carrollton, GA 30112
NEMA	National Electrical Manufacturers Association 1300 North 17th Street; Suite 900 Rosslyn, VA 22209
NFPA	National Fire Protection Association 1 Batterymarch Park Quincy, MA 02169-7471

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