ANSI C84.1-1995

AMERICAN NATIONAL STANDARD

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

Secretariat

National Electrical Manufacturers Association

Approved by:

American National Standards Institute

American National Standard

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Foreword (This Foreword is not part of American National Standard C84.1-1995)

This standard supersedes American National Standard for Electric Power Systems and Equipment - Voltage Ratings (60 Hz), ANSI C84.1-1989. Standard nominal system voltages and voltage ranges shown in the previous standard remain unchanged in this standard. Revisions have been made to the text of clauses 1.2(1), 1.2(6), 2.1.2. 1, 2.1.2.2, 2.3, 3.2(2) and to the equation in D3. As in the previous standard, reference information on extra-high voltage conforms to *American National Standard for Power Systems - Alternating-Current Electrical Systems and Equipment Operating at Voltages above 230 kV Nominal - Preferred Voltage Ratings*, ANSI C92.2-1987.

In 1942, the Edison Electric Institute published the document *Utilization Voltage Standardization Recommendations*, EEI Pub. No. J-8. Based on that early document, a joint report was issued in 1949 by the Edison Electric Institute (EEI Pub. No. R6) and the National Electrical Manufacturers Association (NEMA Pub. No. 117). This 1949 publication was subsequently approved as American National Standard EEI-NEMA Preferred Voltage Ratings for AC Systems and Equipment, ANSI C84.1-1954.

American National Standard C84.1-1954 was a pioneering effort in its field. It not only made carefully considered recommendations on voltage ratings for electric systems and equipment, but also contained a considerable amount of much-needed educational material.

After ANSI C84.1-1954 was prepared, the capacities of power supply systems and customers' wiring systems increased and their unit voltage drops decreased. New utilization equipment was introduced and power requirements of individual equipment were increased. These developments exerted an important influence both on power systems and equipment design and on operating characteristics.

In accordance with American National Standards Institute policy requiring periodic review of its standards, American National Standards Committee C84 was activated in 1962 to review and revise American National Standard C84.1-1954, the Edison Electric Institute and National Electrical Manufacturers Association being named cosponsors for the project. Membership on the C84 Committee represented a wide diversity of experience in the electrical industry. To this invaluable pool of experience were added the findings of the following surveys conducted by the committee:

(1) A comprehensive questionnaire on power system design and operating practices, including measurement of actual service voltages. (Approximately 65,000 readings were recorded, coming from all parts of the United States and from systems of all sizes, whether measured by number of customers or by extent of service areas.)
(2) A sampling of single-phase distribution transformer production by kilovolt-amperes and primary voltage ratings to determine relative uses of medium voltages.
(3) A survey of utilization voltages at motor terminals at approximately twenty industrial locations

The worth of any standard is measured by the degree of its acceptance and use. After careful consideration, and in view of the state of the art and the generally better understanding of the factors involved, the C84 Committee concluded that a successor standard to ANSI C84.1-1954 should be developed and published in a much simplified form, thereby promoting ease of understanding and hence its acceptance and use. This resulted in the approval and publication of American National Standard C84.1-1970, followed by its supplement, ANSI C84.1a-1973, which provides voltage limits established for the 600-volt nominal system voltage.

The 1977 revision of the standard incorporated an expanded Foreword that provided a more complete history of this standard's development. The 1970 revision included a significantly more useful Table 1 (by designating "preferred" system voltages), the 1977 revision provided further clarity, and the 1982 revision segmented the system voltages into the various voltage classes.

Suggestions for improvement of the standard will be welcome. They should be sent to the National Electrical Manufacturers Association, 1300 N. 17th Street, Rosslyn, Virginia 22209.

This standard was processed and approved for submittal to ANSI by Accredited Standards Committee on Preferred Voltage Ratings for AC Systems and Equipment, C84. Committee approval of the standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, the C84 Committee had the following members:

Daniel J. Ward, Chairman
Walter J. Ros, Vice-Chairman
Lawrence F. Miller, Secretary

Organizations Represented	*Name of Representative*
Accredited Standards Committee on Electric Lamps, C78 (Liaison)	A. Rousseau
Accredited Standards Committee on Industrial Gas Equipment, Installations and Utilization, Z83 (Liaison)	Gordon E. Willert
Accredited Standards Committee on National Electrical Code, C1 (Liaison)	Arthur E. Cote
Accredited Standards Committee on Power Switchgear (Liaison)	Charles T. Zegers
Air Conditioning & Refrigeration Institute	Gary Acton George W. Brandt Thomas A. Jacoby (Alt.) Leonard Van Tassel (Alt.)
Association of Home Appliance Manufacturers	John T. Weizeorick
Canadian Standards Association (Liaison)	(Representation Vacant)
Certified Ballast Manufacturers Association	Robert Babcock
Department of Water & Power, City of Los Angeles	Manuel De La Rosa Robert Glickman (Alt.)
Electronic Industries Association	John A. Wyatt
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National Rural Electric Cooperative Association	Robert Bergland (Alt.) Rob Church

Rural Electrification Administration U.S. Department of Agriculture................Edmond W. Overstreet
Telephone Group...(Representation Vacant)
Tennessee Valley Authority ....Frank Lewis

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

1 Scope and purpose

1.1 Scope

This standard establishes nominal voltage ratings and operating tolerances for 60-hertz electric power systems above 100 volts and through 230 kilovolts. 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.

NOTE—For completeness, information on extra-high voltage systems (345 kilovolts and higher) from *American National Standard for Power Systems – Alternating-Current Electrical Systems and Equipment Operating at Voltages above 230 kV Nominal – Preferred Voltage Ratings*, ANSI C92.2-1987, is also included as a footnote to table 1.

1.2 Purpose

The purposes of this standard are to:

(1) Promote a better understanding of the voltages associated with power systems and utilization equipment to achieve overall practical and economical design and operation
(2) Establish uniform nomenclature in the field of voltages
(3) Promote standardization of nominal system voltages and ranges of voltage variations for operating systems
(4) Promote standardization of equipment voltage ratings and tolerances
(5) Promote coordination of relationships between system and equipment voltage ratings and tolerances
(6) Provide a guide for future development and design of equipment to achieve the best possible conformance with the needs of the users
(7) Provide a guide, with respect to choice of voltages, for new power system undertakings and for changes in old ones

2 Voltage ratings for 60-hertz electric power systems

2.1 Definitions

2.1.1 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.

2.1.2 System voltage terms

2.1.2.1 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. (All voltages hereafter are rms phase-to-phase or phase-to-neutral voltages.)

2.1.2.2 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.

2.1.2.3 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 satisfactory continuous operation without derating of any kind. 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.

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

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

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

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 voltage at utilization points is normally somewhat lower than at the service point. 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.

2.1.3 System voltage classes

2.1.3.1 low voltage: A class of nominal system voltages 1000 volts or less.

2.1.3.2 medium voltage: A class of nominal system voltages greater than 1000 volts and less than 100 000 volts.

2.1.3.3 high voltage: A class of nominal system voltages equal to or greater than 100 000 volts and equal to or less than 230 000 volts.

2.2 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 continue 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 4160-volt, 6900-volt, and 13 800-volt 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 2.1.2.6. Two of these system voltages are shown in boldface type to indicate that they should be used for this purpose. It is not intended to recommend the use of these system voltages for utility primary distribution, for which four-wire voltages of 12 470Y/7200 volts or higher should be used.

2.3 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 remit from such causes as switching operations, motor starting currents, and the like.

2.4 Application of voltage ranges

2.4.1 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.

2.4.2 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.

2.4.3 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.

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.

3 Voltage ratings for 60-hertz electric equipment

3.1 General

Voltage ratings and other characteristics of the various classes of 60-hertz electric equipment are established in other standards. A partial list of these standards is given in Annex E.

For the principal types of electric utilization equipment, nameplate voltage ratings and the corresponding nominal system voltages to which they are applicable are listed in tables C1, C2, and C3 in Annex C. Detailed tables for electric equipment other than utilization equipment are not included. Those requiring detailed information on voltage ratings of these other types of equipment should consult the appropriate standards or the manufacturers to ensure proper application.

Review of the nameplate voltage ratings in Annex C and in current equipment standards listed in Annex E indicates many inconsistencies in the relationships among equipment nameplate ratings and between these ratings and nominal system voltages to which the equipment is applicable. For 120-volt base systems, equipment voltage ratings are variously based upon 115 volts, 120 volts, and 125 volts. The same one of these bases is not always used consistently for all equipment of the same general class.

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

3.2 Recommendation

Insofar as practicable, whenever electric equipment standards are revised:

(1) 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
(2) 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) Two-wire	Three-wire	Four-wire	Nominal Utilization Voltage (Note i) Two-wire Three-wire Four-wire	Voltage Range A (Note b) Maximum: Utilization and Service Voltage (Note c)	Voltage Range A Minimum: Service Voltage	Voltage Range A Minimum: Utilization Voltage	Voltage Range B (Note b) Maximum: Utilization and Service Voltage	Voltage Range B Minimum: Service Voltage	Voltage Range B Minimum: Utilization Voltage
Low Voltage (Note 1)	**Single-Phase Systems**									
	120			**115**	126	114	110	127	110	106
		120/240		**115/230**	**126/252**	**114/228**	**110/220**	**127/254**	**110/220**	**106/212**
	Three-Phase Systems									
			208Y/120 (Note d)	**200**	**218Y/126**	**197Y/114**	**191Y/110**	**220Y/127**	**191Y/110** (Note 2)	**184Y/106** (Note 2)
			240/120	**230/115**	**252/126**	**228/114**	**220/110**	**254/127**	**220/110**	**212/106**
		240		**230**	252	228	220	254	220	212
			480Y/277	**460**	**504Y/291**	**456Y/263**	**440Y/254**	**508Y/293**	**440Y/254**	**424Y/245**
		480		**460**	**504**	**456**	**440**	**508**	**440**	**424**
		600 (Note e)		**575**	630 (Note e)	570	550	635 (Note e)	550	530
Medium Voltage		2400			2520	2340	2160	2540	2280	2080
			4160Y/2400		4370/2520	4050Y/2340	3740Y/2160	4400Y/2540	3950Y/2280	3600/2080
		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**	
			13800/7970		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					
		46000			(Note g) 48300					
		69000			**72500**					
High Voltage		**115000**			**121000**					
		138000			**145000**					
		161000			169000					
		230000			**242000**					
	(Note h)									
Extra-High Voltage		**345000**			**362000**					
		500000			**550000**					
		765000			**800000**					
Ultra-High Voltage		**1100000**			**1200000**					

Notes: (1) Minimum utilization voltages for 120-600 volt circuits not supplying lighting loads are as follows:

	Nominal System Voltage	Range A	Range B
	120	108	104
	120/240	108/216	104/208
(Note 2)	208Y/120	187Y/108	180Y/104
	240/120	216/108	208/104
	240	216	208
	480Y/277	432Y/249	416Y/240
	480	432	416
	600	540	520

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

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 240/120-volt 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 120-600-volt 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 120/208Y-volt 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 regulations to suit their requirements.

(h) Standard voltages are reprinted from American National Standard C92.2-1987 for convenience only.

(i) Nominal utilization voltages are for low-voltage motors and control. See Annex C for other equipment nominal utilization voltages (or equipment nameplate voltage ratings.)

Annex A
(informative)
Principal transformer connections to supply the system voltages of table 1
(See figure A1)

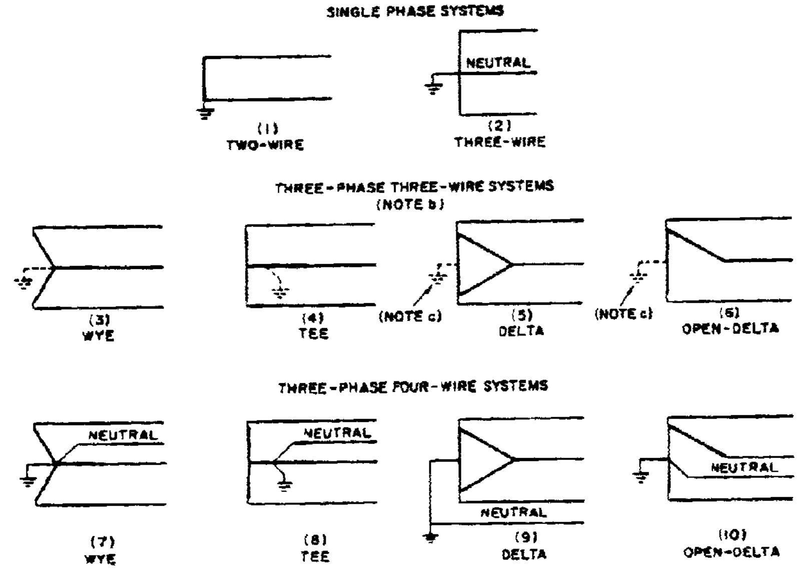

Figure A1

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
(informative)
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 120-volt base. [For exceptions, see note (d) to figure B1.]

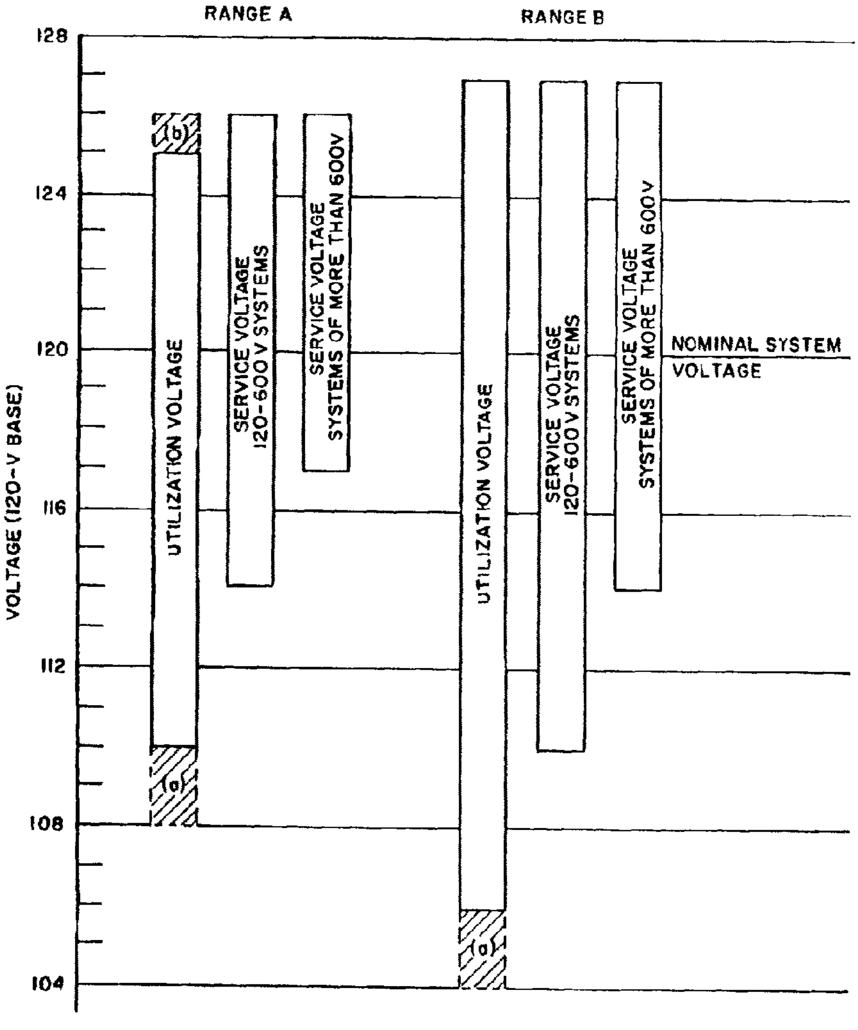

Figure B1

NOTES
(a) These shaded portions of the ranges do not apply to circuits supplying lighting loads. See note 1 to table 1.
(b) This shaded portion of the range does not apply to 120-600-volt systems. See note (c) to table 1.
(c) 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.
(d) The Range B utilization voltage limits in table 1 for 6900-volt and 13800-volt systems are 90% and 110% of the voltage ratings of the standard motors used in these systems and deviate slightly from this figure.

Annex C
Voltage ratings for 60-hertz electric utilization equipment

(Refer to Annex E for a partial list of applicable standards.)
In tables C1 and C2 only representative categories of equipment are listed because the sheer number of present and prospective equipment makes it impractical to cover all of them.

Table C1 – Lamps, ballasts, and miscellaneous appliances

Equipment	Applicable to All Nominal System Voltages Containing This Voltage(s)	Equipment Nameplate Voltage Rating
Lighting devices		
Incandescent lamps	120	120
	120	120
Fixtures and ballasts for fluorescent and	208	208
high-pressure vapor lamps [Notes (a) and	240	240
(b)]	277	277
	480	480
Motor-operated appliances [Note (c)]		
Hair dryers		
Clocks	120	120
Dryers – clothes	120	120
Fans	120/240, 240/120, 208Y120	120/240
Food mixers		120
Food waste disposers		120
		115
Timers		
Vacuum cleaners	120	120
Washers		120
Clothes		
Dishes		115
		115
Communication appliances		
Projectors, silent and sound	120	120
Small	120/240, 240/120	120/240
Large	208Y/120	120/208
Phonographs		
Radios		
Tape recorders	120	120
Television		
Heating and cooking appliances		
Blankets		
Cooking appliances, table and counter	120	120
Household – small		
Household – large	120	120
Commercial – small		
	240	240
Commercial – large	208	208
	480	480
Heaters, portable air		120
Heating pads		120
Irons	120	
Hand		120
Soldering		120
Rangers – household type	120/240, 240/120	120/240
	208Y/120	120/208
Water heaters	120	120/240
Tank – small	240	
Tank – large	240	240
	280	280

NOTES

(a) Lighting systems incorporating two ungrounded wires for service may require special ballasts and auxiliaries.

(b) Some ballasts are rated for use on more than one system voltage by use of taps or multiple primary windings.

(c) Attention is called to the fact that under emergency conditions on electric systems, voltages below Range B of table 1 may be encountered. This should be taken into account particularly in the design of motor-operated appliances for automatic starting and in the application of motors and control.

Table C2 – Heating, refrigeration, and air-conditioning equipment

Equipment	Phase	Applicable to All Nominal System Voltages Containing This Voltage(s)	Equipment Nameplate Voltage Rating
Gas and oil furnaces and fractional hp coil units	1	120	115
		240	230
Stokers	1	120	115
Refrigerators and freezers	1	120	115
Room air conditioners	1	120	115
		208	208, (200)*
		240	230
		208, 240	208/230†, (200/230)*†
Unitary air conditioners and heat pumps			
Motor compressors			
Condensing units	1 and 3	208	208, (200)*
Water-chilling packages	1 and 3	240	230
Integral hp fan coil units, etc.	1 and 3	208,240	208/230†, (200/230)*†
Duct and auxiliary electric heaters for	1	277	265
air-conditioning units and heat pumps	3	480	460
	3	600	575
Electric furnaces	1 and 3	240	230
	3	208	208, (200)*
		120	120
Comfort heating	1	208	208
		240	240
		277	277
Refrigerated drinking-water coolers	1	120	115
Dehumidifiers	1	120	115

* Parenthetical values are under consideration for future design.
† Slant between voltage values denotes 'either-or.'

For the purposes of this Annex, the term 'motor control equipment' is used in a general sense and includes some types of equipment classified as 'switchgear.' For applicable standards, see Annex E.

The single-phase and three-phase motor and control voltage ratings shown in table C3 are well suited to the nominal system voltages indicated. It should be generally understood that motors with these ratings are to be considered as suitable for ordinary use on their corresponding system; for example, a 230-volt motor is suited for use on a nominal 240-volt system. Operation of 230-volt motors on 208-volt systems is not recommended because the utilization voltage encountered will commonly be below the -10% tolerance on the voltage rating for which the motor is designed.

APPENDIX

Suitable measures should be taken by manufacturers and power suppliers to indicate to the purchaser that equipment is intended to be used on the system whose nominal voltage is associated with, but may both be numerically equal to, the equipment nameplate voltage rating; for example, a motor and its control rated 230 volts is intended for use on a nominal 240-volt system.

It should be noted that successful operation of a motor under given running conditions does not necessarily mean that it will be able to start and accelerate all loads to which it may be applied under these same operating conditions.

It should be recognized that synchronous motors, especially those rated 0.8 power factor, are reactive power sources and consequently may increase the voltage at their terminals to higher values than those experienced for induction motors under similar conditions.

Table C3 – Motor and motor control equipment

Applicable to All Nominal System Voltages Containing This Voltage	All Motor and Motor Control Equipment Nameplate Voltage Ratings Containing This Voltage			
	Integral Horsepower		Fractional Horsepower	
	Three-Phase	Single-Phase	Three-Phase	Single-Phase
120	–	115	–	115
208	200	–	200	–
240	230	230	230	230
480	460	–	460	–
600*	575	–	575	–
2400	2300	–	–	–
4160	4000	–	–	–
4800	4600	–	–	–
6900	6600	–	–	–
13800	13200	–	–	–

* 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 ensure proper application.

Annex D
Polyphase voltage unbalance

D.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.

Field surveys and statistics indicate that:

(1) Each motor rating is associated with a unique optimal range of voltage unbalance
(2) These ranges vary from 0–2.5 percent to 0–4.0 percent voltage unbalance with the average at approximately 0–3.0 percent
(3) 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 lass

D.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 2.4. 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.

D.3 Definitions

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

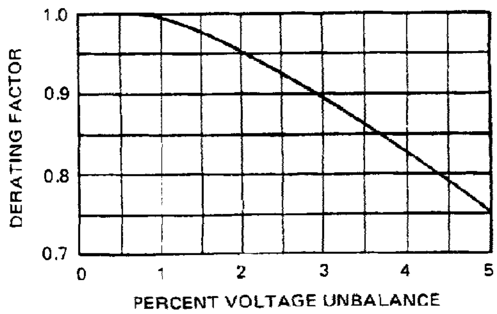

Figure D1 – Derating factor

NOTE—See 14.35 of NEMA MG 1-1993 for more complete information about the derating factor.

$$\text{Percent voltage unbalance} = 100 \times \frac{(\text{max. deviation from average v})}{(\text{Average Voltage})}$$

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 X 4)/229 = 1.75 percent.

D.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 D1, used in the application of polyphase induction motors.

D.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 E
Applicable standards

E.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 260
Automatic commercial ice makers	ARI 810
Cable terminating devices (power)	IEEE 48
Central forced-air electric heating equipment	ARI 280
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	ANSI C78 Series
Incandescent lamps	
Lamp ballasts	
Low-voltage fuses	ANSI C82 Series
Low-voltage molded-case circuit breakers	ANSI/NEMA FU 1
Mechanical transport refrigeration units	NEMA AB 1
Oil-fired furnaces	ARI 1110
Packaged terminal air conditioners	CS 195
Positive displacement refrigerant compressor and condensing units	ARI 310
Power switchgear	ANSI/ARI 520
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	ANSI C37 Series
Manual and automatic station control	
Power circuit breakers	
Power fuses	
Relays and relay systems	
Secondary fuses	
Supervisory and associated telemetering equipment	
Switchgear assemblies including metal enclosed bus	
Reciprocating water-chilling packages	ANSI/ARI 590
Recreational vehicle air-conditioning equipment	ARI 250
Remote mechanical draft air-cooled refrigerant condensers	ARI 460
Room air conditioners	ANSI/AHAM RAC-1
Equipment	**Standard***
Room fan-coil air conditioners	ARI 441
Rotating electrical machinery	
AC induction motors	

*See list of organizations in Section E2.

table continued on next page

Cylindrical rotor synchronous generators	ANSI C50 Series and
Salient pole synchronous generator and condensers	NEMA MG 1
Synchronous motors	
Universal motors	ANSI/ARI 620
Self-contained humidifiers	ANSI/ARI 1010
Self-contained mechanically refrigerated drinking-water coolers	ANSI/IEEE 18
Shunt power capacitors	
Solenoid valves for liquid and gaseous flow	ARI 760
Static power conversion equipment	ANSI C34
Surge arresters	ANSI C62.61 & NEMA LA 1
Transformers, regulators, and reactors	
Arc furnace transformers	
Constant-current transformers	
Current-limiting reactors	
Distribution transformers, conventional subway-type	
Dry type	ANSI C57 Series
Instrument transformers	ANSI/NEMA ST 20
Power transformers	
Rectifier transformers	
Secondary network transformers	
Specialty	
Step-voltage and induction-voltage regulators	
Three-phase load-tap-changing transformers	
Unit ventilators	ARI 330
Unitary air-conditioning equipment	ARI 210
Commercial and industrial unitary air-conditioning equipment	ANSI/ARI 360
Unitary heat-pump equipment	ARI 240
Wiring devices	ANSI C73 Series

*See list of organizations in Section E2.

E.2 Organizations Referred to in Section E.1

AEIC	Association of Edison Illuminating Companies P.O. Box 2641 Birmingham, AL 35291-0992
AHAM	Association of Home Appliance Manufacturers 20 North Wacker Drive Chicago, IL 60606
AMCA	Air Movement and Control Association 30 West University Drive Arlington Heights, IL.60004
ANSI	American National Standards Institute, Inc 11 West 42nd Street, 13th Floor New York, N.Y. 10036
ARI	Air Conditioning and Refrigeration Institute 4301 N. Fairfax Drive; Suite 425 Arlington, VA 22203
CS	Commercial Standards Office of Commodity Standards National Institute of Standards and Technology, U.S. Department of Commerce Gaithersburg, MD 20899-0001
IBR*	Hydronics Institute 35 Russo Place, P.O. Box 218 Berkeley Heights, NJ 07922
IEEE	The Institute of Electrical and Electronics Engineers, Inc. 445 Hoes Lane Piscataway, NJ 08855
ICEA	Insulated Cable Engineers Association Box P South Yarmouth, MA 02664
NEMA	National Electrical Manufacturers Association 1300 North 17th Street; Suite 1847 Rosslyn, VA 22209

*Institute of Boiler and Radiator Manufacturers.