STD.NEMA BU 1-ENGL 1999 6470247 0527609 780

NEMA STANDARDS PUBLICATION

BU 1

BUSWAYS

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

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STD.NEMA BU 1-ENGL 1999 ■ 6470247 0527610 4T2 ■

NEMA Standards Publication No. BU 1-1999

Busways

Published by:

National Electrical Manufacturers Association
1300 N 17th Street, Suite 1847
Rosslyn, VA 22209

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Foreword

This Standards Publication is intended to provide a basis of common understanding within the electrical community.

The purpose of this Standards Publication is to provide a basis for understanding between the manufacturers and users of feeder busway, plug-in busway, and busway accessories.

Publication No. BU 1-1999 revises and supersedes the NEMA Standards Publication for Busway, BU 1-1994.

User needs have been considered throughout the development of this publication. Proposed or recommended revisions should be submitted to:

Vice President, Engineering Department
National Electrical Manufacturers Association
1300 N 17th Street, Suite 1847
Rosslyn, VA 22209

This Standards Publication was developed by the Busway Section. Section approval of the standard does not necessarily imply that all section members voted for its approval or participated in its development. At the time it was approved, the Group/Section was composed of the following members:

GE Industrial Systems—Plainville, CT
Siemens Energy & Automation, Inc.—Alpharetta, GA
Square D Company—Palatine, IL
Eaton Corporation—Pittsburgh, PA

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Section 1
GENERAL

1.1 SCOPE

This Standards Publication covers products for distribution of electric power at 600 volts or less, consisting of enclosed sectionalized prefabricated busbars rated at 100 amperes or more, and associated structures and fittings, classified as follows:

a. Feeder busways (indoor or outdoor)
b. Plug-in busways (indoor only)
c. Accessories required to complete the busway system

It does not pertain to metal-enclosed busways as described in ANSI/IEEE C37.23, *Guide for Metal-Enclosed Bus and Calculating Losses in Isolated-Phase Bus.*

1.2 REFERENCED STANDARDS

In this publication, reference is made to the standards listed below:

American National Standards Institute
1430 Broadway
New York, NY 10018

ANSI C37.16-1997	*Preferred Ratings, Related Requirements, and Application Recommendations for Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors*
ANSI Z535.4-1998	*Product Safety Signs and Labels*

Institute of Electrical and Electronic Engineers
Publication Sales Department
445 Hoes Lane
Piscataway, NJ 08854

ANSI/IEEE Std. 141-1993	*Recommended Practice for Electric Power Distribution for Industrial Plants*

National Electrical Manufacturers Association

1300 N 17th Street
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NEMA AB 1-1993	*Molded Case Circuit Breakers and Molded Case Switches*
NEMA FU 1-1986	*Low Voltage Cartridge Fuses*
NEMA ICS 1-1993	*Industrial Control and Systems: General Requirements*
NEMA ICS 2-1993	*Industrial Control and Systems: Controllers, Contactors, and Overload Relays, Rated Not More Than 2000 Volts AC or 750 Volts DC*
NEMA ICS 3-1993	*Industrial Control and Systems: Factory Built Assemblies*
NEMA KS 1-1996	*Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum)*

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National Fire Protection Association
Publications Sales Department
Batterymarch Park
Quincy, MA 02269

NFPA 70-1999 *National Electrical Code®*

Underwriters Laboratories
333 Pfingsten Rd.
Northbrook, IL 60062

UL 248 *Low-Voltage Fuses*

ANSI/UL 857-1994 *Standard for Busway and Associated Fittings*

1.3 DEFINITIONS

accessory: A current-carrying component of a busway system used to mount or adapt the busway to the building structure.

adapter: A fitting which permits the joining together of lengths and fittings of different shapes or designs.

ambient temperature: The temperature of the surrounding air that comes in contact with the outside of the busway enclosure, device, or fitting.

asymmetrical current: The alternating current having a wave form which is offset with respect to the zero axis. The offset occurs at the initiation of a short circuit or other change in current. The offset usually decays quickly until steady-state conditions are reached and the current becomes symmetrical. Asymmetrical current is composed of the alternating symmetrical component and a direct component. It is expressed in rms asymmetrical amperes at a specific time (normally 1/2 cycle) after initiation of a short circuit or other change in current. Peak current refers to the maximum instantaneous amperes within this first 1/2 cycle.

available short-circuit current: The maximum current which a circuit is capable of delivering at the system terminals ahead of the apparatus being applied. Available short-circuit current may be expressed in either rms symmetrical amperes or rms asymmetrical amperes.

bolt-on device: A power take-off means which can be bolted to the busways at a joint between lengths and fittings, at the end of a run, or at any predetermined location, and which makes electrical connection to the busbars.

busbars: Conductors which carry current through busway lengths and fittings, and which have one of the following arrangements:

a. Single Bar—A single-bar arrangement refers to a busway having one conductor per phase or pole.
b. Multibar—A multibar arrangement refers to a busway having two or more conductors for one or more of its phases or poles.

busway: A prefabricated electric distribution system consisting of busbars in a protective enclosure, including straight lengths, fittings, devices, and accessories. Busways are of the following types:

a. Feeder Busway—A feeder busway is a busway having no plug-in openings and intended primarily for conducting electric power from the sources of supply to centers of distribution, but can have provisions for bolt-on devices.

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b. Plug-in Busway—A plug-in busway is a busway having plug-in openings on one or both sides at spaced intervals, offering means for electrical connection of plug-in or bolt-on devices to the busbars.

center cable tap box: A fitting or device which provides for the attachment of cables at a location other than the end of a busway run.

circuit breaker: A device designed to open and close a circuit by non-automatic means, and to open the circuit automatically on a predetermined over-current, without injury to itself when properly applied within its rating.

continuous current rating: The designated maximum direct current or alternating current in rms amperes at rated frequency which a busway can carry continuously without exceeding its temperature rise limits when subjected to specified heating tests.

cross: A fitting suitable for connection in four directions.

cubicle: An enclosure attached to a length or fitting for the purpose of enclosing electrical components.

device: An enclosed component used on, rather than in, a run of a busway system. The device may carry current from the busway system to supply a load circuit or be a non-load-supplying unit, such as a ground detector.

elbow: An angular fitting.

end cable tap box: A fitting that provides for the attachment of cables and conduits at the end of the busway run.

end closure: A fitting which terminates and closes the end of the busway run.

expansion fitting: A fitting which accommodates expansion and contraction of the busway or building.

fitting (busway): A component in a run of a busway system, other than a straight length. It may be either current-carrying such as an elbow, tee or cross or non-current-carrying such as an end closure.

flanged end (or switchboard stub): A fitting which provides means for mechanically and electrically connecting a busway run to other apparatus.

floor flange: An accessory on the outside of the busway enclosure that provides means for the installer to cover the floor opening penetrated by the busway.

equipment grounding conductor: A conductor which is used to connect noncurrent-carrying metal parts of the busway.

indoor: Suitable for installation within a building which protects the busway from exposure to the weather.

neutral conductor: A conductor which is connected to the midpoint of a three-wire single-phase system, center point of a wye-connected three-phase system or the midpoint of one side of a delta-connected three-phase system.

offset fitting: A fitting providing two or more angles.

outdoor: So constructed that exposure to the weather will not interfere with successful operation.

NOTE—Outdoor busway is not suitable for outdoor use until completely and properly installed as recommended by the manufacturer.

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plug-in circuit breaker: A plug-in device containing an externally operable circuit breaker.

plug-in device (or busplug): A power take-off means which can be plugged into a plug-in busway and which makes electrical connection to the busbars.

plug-in fusible switch: A plug-in device containing an externally operable fusible switch.

a. Handle-Operated—A handle-operated switch is a switch that is externally operated without opening or closing the cover.

b. Cover-Operated—A cover-operated switch is a switch that is operated by opening and closing the cover.

plug-in ground detector: A plug-in device which indicates a ground on any of the normally ungrounded busway conductors.

rating: The designated limit(s) of the rated operating characteristic(s) of a busway length, fitting or device.

NOTE—Such operating characteristics as current, voltage, frequency, etc., may be given in the rating.

reducer: A fitting designed for connection between lengths and fittings of different ampere ratings.

roof flange: An accessory on the outside of the busway enclosure that provides means for the installer to weatherproof the roof opening penetrated by the busway.

straight length: A straight section of a busway system.

switch: A device for opening and closing, or for changing the connection of a circuit.

symmetrical current: Alternating current having no offset or transient component and, therefore, having a wave form essentially symmetrical about the zero axis. Symmetrical current is expressed in terms of rms amperes.

tee: A fitting suitable for connection in three directions.

totally enclosed: So constructed as to prevent the free exchange of air between the inside and outside of the housing, but not sufficiently enclosed to be termed air tight.

transformer tap: A fitting having busbars extended through its housing or end barrier for connections by open cable to terminals of the transformer(s).

transformer throat connection: A fitting which provides enclosed busbar connections to transformer terminals.

transposition fitting: A fitting wherein the busbar positions are interchanged to equalize the impedance of the different phases or to change the phase relationship.

transverse barrier: A dividing barrier or other means of restricting the free flow of either air or moisture through the inside of a busway.

vault termination: A fitting having open busbars extending from one end which provides for connections to vault equipment.

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ventilated: So constructed as to provide for the circulation of external air through the enclosure to remove heat.

voltage drop: The arithmetical difference between the voltage at the load and supply ends.

wall flange: An accessory on the outside of the busway enclosure that provides means for the installer to cover the wall opening penetrated by the busway.

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Section 2
GENERAL AND RATING STANDARDS

2.1 SAFETY REQUIREMENTS

Busways shall comply with the Underwriters Laboratories Inc., Publication No. UL 857, or latest revision thereof.

2.2 LENGTH

A busway length shall normally be 10 feet, or less, between joint centers.

2.3 SERVICE CONDITIONS

2.3.1 Usual Service Conditions

Busways conforming to this Standards Publication shall be suitable for operation.

a. When and where the ambient temperature is within the limits of the busway.
b. Where the altitude does not exceed 6600 feet (2000 meters).

See Table 2-1 for usual ambient temperature limits.

Table 2-1
AMBIENT TEMPERATURE LIMITS

	Ambient Temperature limits	NEMA Standards Publication No.
Busway lengths and fittings	-30°C through + 40°C	In this document
Molded case circuit breakers	0°C through + 40°C	NEMA AB 1
Enclosed switches	-30°C through + 40°C	NEMA KS 1
Low-voltage cartridge fuses	UL 248 Standards	NEMA FU 1
Electromagnetic and manual motor controls at 6000 feet and less	0°C through + 40°C maximum	NEMA ICS 1, ICS 2, and ICS 3

2.3.2 Unusual Service Conditions

For applications where the ambient temperature is higher than 40°C, the busway current rating should be derated in accordance with the manufacturer's recommendations, if furnished, or according to Table 2-2.

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Table 2-2
BUSWAY CURRENT RATINGS
(Ambient Temperatures Above 40°C)

Ambient Temperature	Multiplier
40°C	1.00
45°C	0.95
50°C	0.90
55°C	0.85
60°C	0.80
65°C	0.74
70°C	0.67

For applications where the ambient temperature is lower than the ambient temperature limits shown in Table 2-1 or at altitudes greater than 6600 feet (2000 meters), consult the manufacturer.

There are other service conditions that may require further consideration. Where such conditions exist, it is recommended that they be brought to the manufacturers attention. (See 5.11 and 5.15.)

2.4 RATINGS OF BUSWAY

2.4.1 Continuous Current Ratings

The following are common current ratings for Plug-in and Feeder Busway: 100, 225, 400, 600, 800, 1000, 1200, 1350, 1600, 2000, 2500, 3000, 3200, 4000 and 5000 amperes.

2.4.2 Voltage Ratings

Voltage ratings shall be 600 volts or less.

2.4.3 Short-Circuit Current Rating

The short-circuit current rating of a busway or fitting shall be one or more of the values shown in Table 2-3. The ratings apply phase to phase, phase to neutral, phase to enclosure, and phase to ground conductor (when applicable). (See 5.5.)

Table 2-3
SHORT-CIRCUIT CURRENT RATINGS

RMS symmetrical or DC amperes		
5 000	25 000	75 000
7 500	30 000	85 000
10 000	35 000	100 000
14 000	42 000	125 000
18 000	50 000	150 000
22 000	65 000	200 000

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2.4.4 Voltage Drop Ratings

Voltage drop ratings should be expressed as the average line-to-line voltage drop per 100 feet in one of the following ways:

a. Load concentrated at the end of the busway run.
b. Load evenly distributed along the busway run (usually considered to be one-half of the values in item 1).

Voltage drops vary with the load power factor of the circuit and are at a maximum when the power factor of the load circuit is the same as the power factor of the busway. Voltage drop values can be expressed by curves showing the values for a range of load power factors or can be expressed as a single value at a specific load power factor. If a single value is expressed without reference to power factor, it shall be the maximum average value (see 3.2 and 5.3).

Voltage drop deviation shall be expressed as the voltage by which the individual line-to-line voltage drop differs from the average line-to-line voltage drop. It shall be expressed with the load either concentrated or distributed in accordance with item 1 or 2 above (see 3.5).

2.5 RATINGS OF CIRCUIT BREAKER PLUG-IN OR BOLT-ON DEVICES

2.5.1 Current and Voltage Ratings

The current and voltage ratings shall be the same as those shown for circuit breakers in NEMA Standards Publication No. AB 1 or ANSI C37.16.

2.5.2 Frequency Rating

The frequency rating of ac devices shall be 60 Hz.

2.5.3 Short-Circuit Current Rating

The short-circuit rating shall be no greater than the interrupting current rating or series connected rating of the circuit breaker used or the maximum short-circuit current rating of the device itself.

For molded case circuit-breaker ratings, see NEMA Standards Publication No. AB 1. For low-voltage power circuit-breaker ratings, see ANSI C37.16.

2.6 RATINGS OF FUSIBLE SWITCH PLUG-IN OR BOLT-ON DEVICES

2.6.1 Current Ratings

The current ratings of devices incorporating switches shall be 30, 60, 100, 200, 400, 600, 800, 1200, and 1600 amperes.

2.6.2 Voltage Ratings

The voltage ratings of devices shall be the same as those given for switches in NEMA Standards Publication No. KS 1.

2.6.3 Frequency Rating

The frequency rating of ac devices shall be 60 Hz.

2.6.4 Horsepower Rating

Horsepower ratings for devices incorporating switches shall be the same as those specified in NEMA Standards Publication No. KS 1.

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2.6.5 Short-Circuit Current Ratings

The short-circuit current ratings shall be 25, 50, 100, or 200 kiloamperes symmetrical for devices used with Class J, L, R, or T fuses having equal or greater interrupting ratings.

Tests to verify the short-circuit current ratings of enclosed plug-in and bolt-on devices shall be made in accordance with UL 857.

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Section 3
TESTING STANDARDS

3.1 GENERAL

Busways and associated fittings shall be tested in accordance with all applicable tests required by Underwriters Laboratories, Inc., Publication No. 857.

In addition, the following tests shall be performed:

a. Voltage-drop tests for three-phase busways (see 3.2 through 3.5).
b. Any other tests required for special applications as agreed to by the manufacturer and user.

3.2 VOLTAGE DROP TEST FOR THREE-PHASE BUSWAYS-GENERAL

The voltage drop tests for three-phase busways shall be conducted under the same conditions as the temperature-rise tests described in Underwriters Laboratories Inc., Publication No. 857, and the readings specified in 3.3 shall be taken after the maximum temperature rise has been reached. The ambient temperature shall be not less than 20°C.

3.3 METHOD OF TEST TO DETERMINE RESISTANCE, REACTANCE, AND IMPEDANCE

After the temperature has stabilized, accurate readings of the total power input ($W_1 + W_2$), the power in each phase (W_A, W_B, and W_C), the phase-to-phase voltage at the input end (V_{AB}, V_{BC}, and V_{CA}), the voltage drop along each phase (V_A, V_B, and V_C), the current in each phase (I_A, I_B, and I_C), and the test length (L) from the phase-to-phase measuring point to centerline of shorted busbars shall be taken. See Figure 3-1.

3.4 DETERMINATION OF PARAMETERS

3.4.1 The following shall be calculated from the test data obtained during the temperature-rise test:

V_{avg} = The average phase-to-phase voltage in volts. Take the readings of the three phases on a three-phase test and calculate V_{avg} in accordance with the formula:

$$V_{avg} = \frac{V_{AB} + V_{BC} + V_{CA}}{3}$$

I_{avg} = The average current in amperes. On a three-phase test, the currents in each of the three phases shall not vary more than 3 percent from the average current. Calculate I_{avg} in accordance with the formula:

$$I_{avg} = \frac{I_A + I_B + I_C}{3}$$

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3.4.2 Calculate the average phase-to-neutral impedance Z, the ac resistance R, and the inductive reactance X, in ohms per foot on a phase-to-neutral basis, as follows:

$$Z_{avg} = \frac{V_{avg}}{\sqrt{3}\, I_{avg} L}$$

$$R_{avg} = \frac{W}{3 I^2_{avg} L}$$

$$X_{avg} = \sqrt{Z^2_{avg} - R^2_{avg}}$$

Where:

W = W1 + W2, the total three phase power in watts.

L = The length in feet from the voltmeter leads connected at the input end to the center of where the busbars are.

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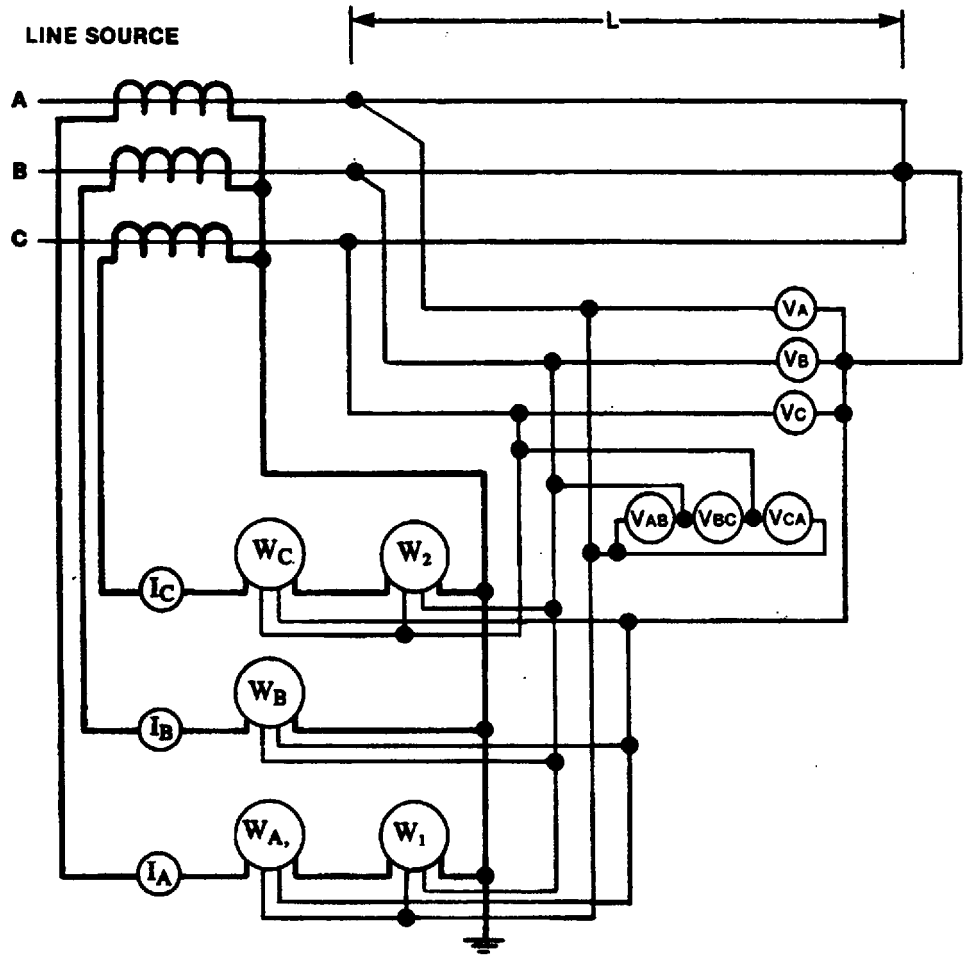


Figure 3-1
METER CONNECTIONS

The above diagram shows the meter connections for taking all necessary current, voltage, and power readings simultaneously. If preferred, single meters with suitable switches may be used. See 3.3.

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3.4.3 Calculate for each individual phase the impedance Z_{avg} the alternating-current resistance R_{avg}, and the inductive reactance X_{avg}, in ohms per foot on a phase-to-neutral basis, as follows:

$$Z_A = \frac{V_A}{I_A L} \qquad Z_B = \frac{V_B}{I_B L} \qquad Z_C = \frac{V_C}{I_C L}$$

$$R_A = \frac{W_A}{I_A^2 L} \qquad R_B = \frac{W_B}{I_B^2 L} \qquad R_C = \frac{W_C}{I_C^2 L}$$

$$X_A = \sqrt{Z_A^2 - R_A^2} \qquad X_B = \sqrt{Z_B^2 - R_B^2} \qquad X_C = \sqrt{Z_C^2 - R_C^2}$$

$$R_{avg} = \frac{R_A + R_B + R_C}{3} \qquad X_{avg} = \frac{X_A + X_B + X_C}{3}$$

R_{avg} and X_{avg} for the three individual phases should agree with the average three-phase phase-to-neutral values calculated in accordance with paragraph 3.4.2.

IMPORTANT: To adjust resistance values to 25°C ambient temperature, increase the calculated resistance R by 0.32 percent for each 1°C by which the test ambient is less than 25°C. Likewise, decrease the calculated resistance R by 0.32 percent for each l°C by which the test ambient exceeds 25°C. Within the accuracy of the parameter measurements, this method will provide a close approximation for either copper or aluminum.

3.5 CALCULATION OF THREE-PHASE VOLTAGE DROP AND VOLTAGE DROP DEVIATION

3.5.1 The average phase-to-phase voltage drop (VD_{avg}) per 100 feet at rated load versus the load power factor (COS θ) shall be calculated as follows:

$$VD_{avg} = 100\sqrt{3}\, I(R_{avg} \cos\theta + X_{avg} \sin\theta)$$

Where:

I = Current rating in amperes
R_{avg} = Average three-phase phase-to-neutral resistance in ohms per foot
X_{avg} = Average three-phase phase-to-neutral inductive reactance in ohms per foot
θ = Load power factor angle

3.5.2 The phase-to-phase voltage drop (VD) for each phase, the average voltage drop (VD_{avg}) and the voltage drop deviation (VD_{dev}) for each phase per 100 feet at rated load versus power factor shall be calculated as follows:

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$$VD_{AB} = 100\left(\frac{\sqrt{3}}{2}\right) I\left[(R_A + R_B)\cos\theta + (X_A + X_B)\sin\theta\right]$$

$$VD_{BC} = 100\left(\frac{\sqrt{3}}{2}\right) I\left[(R_B + R_C)\cos\theta + (X_B + X_C)\sin\theta\right]$$

$$VD_{CA} = 100\left(\frac{\sqrt{3}}{2}\right) I\left[(R_C + R_A)\cos\theta + (X_C + X_A)\sin\theta\right]$$

$$VD_{avg} = \frac{VD_{AB} + VD_{BC} + VD_{CA}}{3}$$

$$VD_{dev\text{-}(AB)} = \left|VD_{AB} - VD_{avg}\right|$$

$$VD_{dev\text{-}(BC)} = \left|VD_{BC} - VD_{avg}\right|$$

$$VD_{dev\text{-}(CA)} = \left|VD_{CA} - VD_{avg}\right|$$

3.5.3 The VD_{avg} calculated in paragraph 3.5.2 should agree with average phase-to-phase voltage drop calculated in accordance with paragraph 3.5. 1.

3.5.4 The percent voltage drop deviation per 100 feet shall be calculated for phases AB, BC, and CA as follows:

$$\text{Percent } VD_{dev} = \frac{VD_{dev}}{V_{line} - VD_{avg}} \times 100$$

3.5.5 All voltage drops and deviations indicated in paragraph 3.5 are for a concentrated load. For busway with uniformly distributed loads these values would be approximately 50% of those calculated.

IMPORTANT: The voltage drop of the busway varies according to the power factor of the external load. The maximum average drop in volts per 100 feet at rated load (VD_{max}) occurs when the power factor of the external load is equal to the power factor of the busway, in which case for three phase:

$$\cos\theta = \frac{R_{avg}}{\sqrt{R_{avg}^2 + X_{avg}^2}}$$

$$\sin\theta = \frac{X_{avg}}{\sqrt{R_{avg}^2 + X_{avg}^2}}$$

$$VD_{max} = 100\sqrt{3}\, I\sqrt{R_{avg}^2 + X_{avg}^2} \quad \text{or } 100\sqrt{3}\, I\, Z_{avg}$$

The foregoing voltage drop formulas give very close approximations as long as the voltage drop of the busway run remains small in comparison to the system voltage.

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Section 4
MANUFACTURING STANDARDS

4.1 GENERAL

Busways shall meet the manufacturing standards given in the Underwriters Laboratories Inc., Publication No. 857.

4.2 MARKINGS

4.2.1 Rating Nameplate

Each length of busway and each busway fitting or device shall be marked with the following:

a. Manufacturer's name or trademark
b. Manufacturer's catalog number or equivalent
c. Maximum permissible electrical rating

All markings shall be on non-removable parts and shall be readily visible after the busway is installed.

4.2.2 Other Markings

The following markings shall appear on the rating nameplate or on individual nameplates in close proximity to the rating nameplate.

4.2.2.1 Rating Based on Mounting

When the current rating is dependent upon the mounting position, the busway shall be plainly marked to so indicate.

4.2.2.2 Vertical Riser Mounting

Each length of busway that is suitable for use in a vertical riser position shall be plainly marked to indicate such suitability.

4.2.2.3 Increased Support Spacing

Each length of busway that is suitable for supporting at intervals of more than 5 feet (but not more than 10 feet horizontally or 16 feet vertically) shall be plainly marked to indicate such suitability.

4.2.2.4 Outdoor Busway

Each length of busway and each busway fitting that is suitable for outdoor use shall be plainly marked to indicate such suitability. If drain holes are provided, each busway length and busway fitting shall be plainly marked to indicate the proper mounting position, so that the drain holes will function as intended.

4.2.3 Product Safety Labels and Associated Markings

To make users aware of immediate or potential hazards in their application, installation, use, or maintenance, busway and associated equipment shall be conspicuously marked with labels that comply with ANSI Z535.

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Section 5
APPLICATION INFORMATION

Manufacturers provide application guidelines for their products. This information and the latest *National Electrical Code®* should be rigorously followed. In addition, the following information should be helpful.

5.1 AMPERE RATINGS

For proper application, the ampere rating of a busway should be not less than the calculated continuous load or, in the case of intermittent loads, the calculated equivalent continuous load. (See *National Electrical Code* Section 220-10.)

5.2 FREQUENCY

Busway is usually rated at 60 hertz maximum, unless some frequency rated equipment is in the circuit such as transformers, electronic devices, etc. For application at other frequencies, consult the manufacturer.

5.3 VOLTAGE DROP (GENERAL)

Good practice indicates that the voltage drop in feeder circuits up to the final distribution point where the load is divided into individual branch circuits should not exceed 3 percent for power, heating or lighting loads or combination thereof. Total voltage drop for feeders and individual branch circuits up to the final utilization point should not exceed 5 percent overall.

NOTE—See section 3 for voltage drop calculations using the busway parameters provided by the manufacturer. See 5.4 for voltage drop on resistance welding applications.

5.4 RESISTANCE WELDING APPLICATION

The busway distribution system for a resistance welder installation should meet two requirements. First, it should provide sufficient current-carrying capacity to avoid overheating the busway. Second, it should not allow the permissible voltage drop to be exceeded.

The operation of resistance welders may be considered as either constant or varying. Constant operation means that the actual primary current during weld and the duty cycle are known and do not vary. In varying operation, the duty cycle and type and thickness of material being welded will not be constant; thus reasonable assumptions should be made for these varying quantities.

To determine the current carrying capacity required, it is necessary to convert the intermittent welder loads to an equivalent continuous load or effective kVA. If the during-weld kVA demand and the duty cycle for a welder are known, the effective kVA can be obtained by multiplying the during-weld kVA demand by the square root of the duty cycle divided by 100. The duty cycle is the percentage of the time during which the welder is loaded.

The multipliers for various duty cycles are listed in Table 5.1.

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Table 5-1
DUTY CYCLE MULTIPLIERS

Percent Duty Cycle	Multiplier
50	0.71
40	0.63
30	0.55
25	0.50
20	0.45
15	0.39
10	0.32
7.5	0.27
5 or less	0.22

If the during-weld kVA demand is unknown, it can be assumed to be 70 percent of the welder secondary short-circuit kVA. If both the during-weld kVA and the duty cycle are unknown, the effective kVA can be assumed to be 70 percent of the nameplate kVA rating for seam and automatic welders and 50 percent of the nameplate kVA for manually operated welders other than seam. Nameplate kVA rating is defined as the maximum load that can be imposed on the welding machine transformer at a 50 percent duty cycle.

It has been found by actual measurement that the total effective kVA of a group of welders is equal to the effective kVA of the largest welder plus 60 percent of the sum of the effective kVA of the remaining welders.

Once the effective kVA has been determined, the current carrying requirement can be easily calculated as follows:

5.4.1 Single-Phase Distribution Systems

$$\text{Current carrying requirement} = \frac{\text{Total Effective kVA x 1000}}{\text{Line to Line Voltage}}$$

5.4.2 Three-Phase Distribution Systems

$$\text{Current carrying requirement} = \frac{\text{Total Effective kVA x 1000}}{\text{Line to Line Voltage x } \sqrt{3}}$$

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To assure consistently good welds, the voltage drop in a distribution system should be limited to 10 percent. In some instances this may be excessive; therefore, specific permissible voltage drop information should be obtained whenever possible. The 10 percent value includes voltage drop in the primary distribution system, the distribution transformers, and the secondary distribution system.

The voltage drop in the primary distribution system can be obtained from the power company provided the maximum kVA demand and the power factor of the largest welder is furnished.

The voltage drop in the distribution transformer can be found from the formula:

$$\text{Voltage drop (\%)} = \frac{\text{During-weld kVA x Transformer Impedance (\%)}}{\text{Transformer kVA Rating}}$$

Voltage drop curves for busway can be used as a basis for determining the voltage drop in the secondary distribution system. It is general practice to permit 2 percent voltage drop in the primary distribution system, 5 percent in the distribution transformer, and the remaining 3 percent in the secondary distribution system.

Voltage drop can be determined in the same way as for conventional circuits based on the current as calculated from the during-weld kVA. If the during-weld kVA is unknown, it can be assumed to be approximately 4 times the nameplate kVA rating for large projection or butt welders and 2 1/2 times the nameplate kVA rating for other types. Large welders are sometimes interlocked to prevent excessive voltage drop caused by the possibility of simultaneous firing. In such cases, it is necessary to consider only the largest of the interlocked welders in calculating voltage drop.

5.4.3 Example

It is desired to determine the minimum size busway that will meet current carrying and voltage drop requirements for an industrial plant with 440-volt, 3-phase, 3-wire service. The busway is to supply the following group of welders which are balanced on the phases and evenly distributed along a 200 foot feeder run: 1 to 300 kVA butt, 1 to 175 kVA butt, 1 to 150 kVA seam, 4 to 100 kVA spot, 5 to 50 kVA spot, 10 to 5 kVA spot. The welders are manually operated and the 300 and 175 kVA welders are interlocked to prevent their firing simultaneously. Power factor of the welders is given as 40 percent and permissible voltage drop in the feeder duct is 3 percent. Specific information regarding during-weld kVA and duty cycles is not available.

5.4.4 Current Carrying Requirement Calculations

a. Effective kVA of largest welder 300 x 50% = 150 kVA.
b. Effective kVA of seam welder 150 x 70% = 105 kVA.
c. Effective kVA of remaining welders 700 x 50% = 350 kVA excluding the interlocked 175 kVA welder.
d. Total effective kVA 150 + (105 + 350) x 60% = 423 kVA.
e. Equivalent continuous current:

$$\frac{423 \text{ kVA}}{440} \times \frac{1000}{\sqrt{3}} = 555 \text{ amp}$$

Thus, 600-amp low-impedance busway will meet the current carrying requirement.

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5.4.5 Voltage Drop Requirement Calculations

a. Total nameplate kVA of butt welders-300 kVA excluding the interlocked 175 kVA welder.
b. Total nameplate kVA of remaining welders-850 kVA.
c. During-weld kVA of butt welders 4 x 300 = 1200 kVA.
d. During-weld kVA of remaining welders: 2 1/2 x 850 = 2125 kVA.
e. During-weld kVA is 1200 + 2125 = 3325 kVA.
f. Three-phase during-weld current:

$$\frac{3325\ \text{kVA} \times 1000}{440 \times \sqrt{3}} = 4370\ \text{amp}$$

For example, use the voltage drop formula shown in 3.5. At 40 percent power factor the voltage drop per 100 feet of 600 ampere low impedance busway carrying rated load would be about 2.7 volts. Since the load is distributed, use half this value, 1.35. Voltage drop for feeder system is:

$$1.35 \times \frac{4370}{600} \times \frac{200\ \text{feet}}{100\ \text{feet}} = 19.6\ \text{volts}$$

$$\text{Percent voltage drop is } \frac{19.6}{440} \text{ or } 4.5\%.$$

This exceeds the permissible voltage drop of 3 percent, and it will be necessary to go to a larger size busway. An 800 ampere low impedance busway would have a voltage drop of 3.3 percent. Because of the conservative nature of the assumptions made, this would be the logical choice.

Since it is difficult to obtain specific information concerning the operation of welders (particularly in new installations) and to determine accurately the possibilities for simultaneous firing of the welders, exact solutions to problems of distribution systems for resistance welders are not feasible.

In the example, it was stated that the load was balanced and distributed. In actuality, it is extremely difficult to balance the load, and distribution may be far from uniform. In the case of unevenly distributed loads, it may be necessary to individually compute the voltage drop for each welder and use the sum of the results. By obtaining as much information as possible concerning a proposed installation, by tabulating this information in logical sequence, and by using good judgment in the making of reasonable and conservative assumptions where missing data are concerned, a busway distribution system can be chosen in a size necessary to serve the load adequately and most efficiently.

5.5 SHORT-CIRCUIT CURRENT

Available short-circuit current calculations should be made and compared to the short-circuit rating of the busway, fittings and devices. In no case should the available symmetrical short-circuit current (including motor contribution, see 5.8) exceed the symmetrical short-circuit current ratings the manufacturer has assigned to the lowest rated device in the circuit.

For proper application on direct current circuits, the short-circuit current rating of the busway should be at least as great as the maximum current available.

Short-circuit ratings of busways not marked for use with current-limiting devices are established on a test basis of three cycles, since there is no increase in mechanical force after the maximum offset current of the first cycle has decayed.

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Busway may be used on circuits having available short-circuit currents greater than the 3 cycle rating of the busway rating when properly coordinated with current-limiting devices. Consult the manufacturer for recommendations.

Short-circuit current ratings marked on each device shall apply to phase-to-neutral, phase-to-phase, phase-to-enclosure, and phase-to-ground conductor (when applicable) short-circuit currents.

5.6 GROUNDING

The enclosure of a UL listed busway marked with a short-circuit current rating is recognized as an equipment grounding conductor. However, the enclosure must be properly bonded to other equipment grounding conductors in the system, and all of these conductors must be properly connected to a suitable system ground. Consult the *National Electrical Code* for proper system grounding procedures.

5.7 INSPECTION AFTER SHORT CIRCUIT

When any installation of busway has been subjected to a short-circuit current at or near its rating, good practice requires careful inspection and removal of the cause of the difficulty before the busway is re-energized.

5.8 DETERMINATION OF SYMMETRICAL CURRENT

The symmetrical current consists of the sum of system and motor contributions, calculated in the following manner:

5.8.1 System Contribution

System contribution is determined for all sources and all impedance up to the busway.

5.8.2 Motor Contribution

Induction and synchronous motors connected to the system ahead of a short-circuit act as generators and, at one-half cycle after the short-circuit occurs, contribute current which may be calculated from the subtransient reactance of the motors. Where the reactance of the motors is not known, current values are assumed to be 3.6 times motor full-load current for induction motors and 4.8 times motor full-load current for synchronous motors.

When the motor load of the installation is not known, assumptions may be based on system voltages.

For a system voltage of 208Y/120 volts or 480Y/277 volts in industrial plants, it is usual that the connected load is 50 percent lighting and 50 percent motor load. This corresponds to an equivalent symmetrical current contribution of twice the full connected load.

For a system voltage of 240 to 600 volts in industrial plants, it is usual to assume that the load is 100 percent motor load and, in the absence of exact information, that the motors are 25 percent synchronous and 75 percent induction. This corresponds to an equivalent symmetrical current contribution of 4 times the full connected load.

NOTE—IEEE Publication No. Std. 141 contains additional information for the calculation of short-circuit currents.

5.9 ARCING PROTECTION

Ground fault protection (GFP) is recommended to minimize damage in the event that a ground fault is of a low enough magnitude so that the overcurrent protective device would not trip or would take an extended time to trip. Except when already provided on the line side, GFP shall be provided for busway rated 1000 A or more in a solidly grounded wye system with greater than 150 V to ground.

When GFP is not used, experience has indicated that damage from arcing faults can be reduced if the device used for overload and short-circuit protection is set to operate instantaneously (that is, without

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intentional time delay) at 115 percent of the highest phase current which is likely to occur as a result of any anticipated peak motor starting or welding currents.

A ground bus is sometimes used to reduce the impedance of the ground return path. When used, it is usually of a physical size equal to 25 or 50 percent of the cross section of the phase busbars. If a separate ground bus is provided it shall be installed in the busway enclosure. The enclosure itself, if designed for that purpose, can serve as the ground bus. A ground bus is not recommended as a satisfactory substitute for ground fault protection, but rather as additional protection to reduce damage to the electrical system in case of a ground fault.

5.10 TRANSVERSE BARRIERS

Where a busway extends through a floor or inside wall and where temperature differences could result in condensation, an internal transverse barrier, which is designed to restrict the free flow of air, should be provided.

Where a busway extends through a roof or outside wall, a suitable weather barrier should be installed in accordance with the manufacturer's instructions.

5.11 BUSWAY MOUNTING

5.11.1 Horizontal Mounting

A busway which is mounted horizontally should be supported at a maximum of 5-foot intervals and in no case at more than 10-foot intervals if it is marked as being suitable for such intervals.

The supports and/or the busway should be braced to minimize swaying.

Bus plugs or cubicles which have considerable weight and which are mounted with a horizontal run of busway should be separately supported by the building structure to prevent twisting or deformation of the busway.

5.11.2 Vertical Mounting

A busway which is to be mounted vertically should be marked to indicate that it is suitable for that service. When the distance between floor supports is more than the busway is marked as suitable for, the manufacturer's recommendation regarding intermediate supports should be followed, but in no case should support intervals exceed 16 feet. Heavy cubicles, panel boards and bus plugs should be separately supported by the building structure when so recommended by the manufacturer.

5.11.3 Mounting Across Building Expansion Joints

A busway section which spans a building expansion joint should be provided with suitable expansion means for both the busbars and the busway housing unless the length of busway beyond the expansion joint is sufficiently short so that the supporting means can be designed to withstand the expected building motion.

5.12 UNUSUAL SERVICE CONDITIONS

Unless specifically designed for such, do not locate busway so that it is exposed to dust, vapors, abnormal vibration, shock or other such unusual operating conditions. A busway should not be installed in wet locations or outdoors unless specifically identified as an outdoor busway.

5.13 ACCESSIBLE LOCATIONS

Busways may be installed only where located in the open and are visible, except that they may be installed behind panels. If means of access are provided, and, if all the conditions of Article 364 of the *National Electrical Code* are met.

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5.14 NEUTRAL BUSBARS

Neutral busbars having half the current-carrying capacity of the phase bars are available from some manufacturers. Before specifying reduced ampacity neutral busbars, the anticipated load should be checked carefully to make certain it will not exceed the neutral current rating. Full neutral is required between transformer line and neutral taps. Full neutral is required for individual line and neutral connections to single-phase transformers of a three-phase bank.

5.15 EXPANSION JOINTS

Expansion joints may be required: (1) where a busway crosses a building expansion joint (see 5.11.3), and (2) on unusually long, straight runs or vertical risers.

Consult the busway manufacturer for recommendations on specific layouts.

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