ICS 4

Industrial Automation Control Products and Systems Section

Terminal Blocks

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NEMA Standards Publication No. ICS 4-2000
Terminal Blocks

Published by

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FOREWORD

This standards publication was prepared by a technical committee of the NEMA Industrial Automation Control Products and Systems Section. It was approved in accordance with the bylaws of NEMA and supersedes ICS 4-1993 (R 1997).

This standards publication provides practical information concerning ratings, construction, test, performance, and manufacture of industrial control equipment. These standards are used by the electrical industry to provide guidelines for the manufacture and proper application of reliable products and equipment and to promote the benefits of repetitive manufacturing and widespread product availability.

NEMA standards represent the result of many years of research, investigation, and experience by the members of NEMA, its predecessors, and its sections and committees. They have been developed through continuing consultation among manufacturers, users, and national engineering societies and have resulted in improved serviceability of electrical products with economies to manufacturers and users.

One of the primary purposes of this standards publication is to encourage the production of reliable control equipment, which, in itself, functions in accordance with these accepted standards. Some portions of these standards, such as electrical spacings and interrupting ratings, have a direct bearing on safety; almost all of the items in this publication, when applied properly, contribute to safety in one way or another.

Properly constructed industrial control equipment is, however, only one factor in minimizing the hazards that may be associated with the use of electricity. The reduction of hazard involves the joint efforts of the various equipment manufacturers, the system designer, the installer, and the user. Information is provided herein to assist users and others in the proper selection of control equipment.

The industrial control manufacturer has limited or no control over the following factors, which are vital to a safe installation:

a. Environmental conditions
b. System design
c. Equipment selection and application
d. Installation
e. Operating practices
f. Maintenance

This publication is not intended to instruct the user of control equipment with regard to these factors except insofar as suitable equipment to meet needs can be recognized in this publication and some application guidance is given.

This standards publication is necessarily confined to defining the construction requirements for industrial control equipment and to providing recommendations for proper selection for use under normal or certain specific conditions. Since any piece of industrial control equipment can be installed, operated, and maintained in such a manner that hazardous conditions may result, conformance with this publication does not by itself assure a safe installation. When, however, equipment conforming with these standards is properly selected and is installed in accordance with the National Electrical Code and is properly maintained, the hazards to persons and property will be reduced.

To continue to serve the best interests of users of industrial control and systems equipment, the Industrial Automation Control Products and Systems Section is actively cooperating with other standardization organizations in the development of simple and more universal metrology practices. In this publication, the

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U.S. customary units are gradually being supplemented by those of the modernized metric system known as the International Systems of Units (SI). This transition involves no changes in standard dimensions, tolerances, or performance specifications.

NEMA standards publications are subject to periodic review. They are revised frequently to reflect user input and to meet changing conditions and technical progress. Users should secure the latest editions.

Proposed revisions to this standards publication should be submitted to:

Vice President, Engineering Department
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CMC Torque Systems—Billerica, MA
Control Concepts Corporation—Beaver, PA
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The Lincoln Electric Company—Cleveland, OH
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Toshiba International Corporation—Houston, TX
Total Control Products, Inc.—Milford, OH
Turck, Inc.—Minneapolis, MN
WAGO Corporation—Brown Deer, WI
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Yaskawa Electric America, Inc.—Northbrook, IL
Zenith GE Controls, Inc.—Chicago, IL

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The standards or guidelines presented in a NEMA standards publication are considered technically sound at the time they are approved for publication. They are not a substitute for a product seller's or user's own judgment with respect to the particular product referenced in the standard or guideline, and NEMA does not undertake to guaranty the performance of any individual manufacturer's products by virtue of this standard or guide. Thus, NEMA expressly disclaims any responsibility for damages arising from the use, application, or reliance by others on the information contained in these standards or guidelines.

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INTRODUCTION

The standards pertaining to terminal blocks in NEMA Standards Publication ICS 4 are subdivided into the following clauses:

1 General
Referenced Standards
Scope
Normative References

2 Definitions
Terms that supplement the IEC International Electrical Vocabulary (IEV 441) or assist in clarifying the product standard.

3 Classification
Product classifications where they have been established.

4 Characteristics and Ratings
Descriptions of the kinds of ratings applicable to the product and tables of standard ratings for the product where they have been established.

5 Product Marking, Installation, and Maintenance Information
Product information to be provided to assist the user in the installation, use, and maintenance of the devices.

6 Service and Storage Conditions
A description of service and storage conditions for which the devices are intended.

7 Construction
Marking, color coding, and similar production requirements to be incorporated into the product as manufactured, as well as production test requirements where they have been established, i.e., the rules that the manufacturer follows in producing the product.

8 Performance Requirements and Tests
The performance required to pass each design test specified for the product.

9 Application
Information and performance considerations of importance to those who specify or use the product.

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1 GENERAL

1.1 REFERENCED STANDARDS

The following standards contain provisions, which, through reference in this text, constitute provisions of this NEMA standards publication. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
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ICS 1-2000 *Industrial Control and Systems General Requirements*

ICS 1.3 - 1986 (R1991, 2001) *Preventive Maintenance of Industrial Control and Systems Equipment*

ICS 6 - 1993 *Industrial Control and Systems – Enclosures*

NEMA 250 – 1997 *Enclosures for Electrical Equipment (1000 Volts Maximum)*

International Electrotechnical Commission
1, rue de Varembe
Geneva, Switzerland

IEV 441 *International Electrical Vocabulary*

IEC 60079-7 *Electrical Apparatus for Explosive Gas Atmospheres – Part 7: Increased Safety "e"*

IEC 60947-7-1 *Low-voltage Switchgear and Controlgear – Part 7: Ancillary Equipment Section One – Terminal Blocks for Copper onductors.*

Underwriters Laboratories Inc.
333 Pfingsten Rd.
Northbrook, IL 60062

UL 2279 *Electrical Equipment for Use in Class I, Zone 0,1, and 2 Hazardous (Classified) Locations*

ISA
67 Alexander Drive
Research Triangle Park, NC 27709

ANSI/ISA S12.16.01 *Electrical Equipment for Use in Class I, Zone 1 Hazardous (Classified)*

(IEC 79-7 Mod)-1998 *Locations: Type of Protection—Increased Safety "e"*

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02269

ANSI/NFPA 70-1999 *National Electrical Code*

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1.2 SCOPE

This standard applies to one piece, or modular, or two piece terminal blocks with screw-type or screw-less-type clamping units intended for industrial use, and fixed to a support or to a Printed Circuit Board (PCB) to provide electrical and mechanical connection for the following round, solid, or stranded conductors:

a. Copper conductors only, without special preparation, having a cross section of 24 AWG to 2000 kcmil (0.2 to 1014 mm^2), or 30 AWG to 8 AWG (0.05 to 8.37 mm^2) for Printed Circuit Board (PCB) terminal blocks.

b. Aluminum (uncoated) conductors only, without special preparation, having a cross section of 12 AWG to 6 AWG (2.5 to 16 mm^2) for solid conductors and of 12 AWG to 2000 kcmil (3.3 to 1014 mm^2) for stranded conductors.

c. Aluminum (uncoated) and copper conductors, without special preparation, having a cross section of 12 AWG to 6 AWG (2.5 to 16 mm^2) for solid conductors and of 12 AWG to 2000 kcmil (3.3 to 1014 mm^2) for stranded conductors.

The terminal blocks are intended for use in circuits of rated insulation voltage not exceeding 1000 volts AC at a frequency not greater than 60 hertz, or not exceeding 1500 volts DC.

This standard does not apply to connectors specifically designed for, and forming, an integral part of equipment, which are dealt with in the relevant equipment standards.

NOTE—This standard may be used as a guide for the termination requirements for disconnect type or other special terminal blocks for which there is no standard at this time.

1.3 NORMATIVE REFERENCES

The definitions and standards of ICS 1 apply to this publication, unless otherwise stated.

2 DEFINITIONS

For the purpose of this standards publication, the following definitions apply:

clamping unit: The part(s) of a terminal necessary for the mechanical clamping and the electrical connection of the conductor(s).

clearance: The distance between two conductive parts along a string stretched the shortest way between these conductive parts.

connecting capability: A range or number, or both, of connectable conductor cross-sections for which the terminal block is designed.

creepage distance: The shortest distance along the surface of an insulating material between two conductive parts.

A joint between two pieces of insulating material is considered part of the surface.

printed circuit board (PCB) terminal block: A one piece, or modular, or two piece terminal block fixed to a printed circuit board by soldering or other suitable means.

rated cross section: A value of connectable conductor cross section, stated by the manufacturer and to which certain thermal, mechanical, and electrical requirements are referred.

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rated insulation voltage: The value of voltage, U_i, stated by the manufacturer, by which the terminal block is designated and to which the electrical tests, clearance, and creepage distances are referred. In no case shall the maximum value of the rated operational voltage exceed that of the rated insulation voltage.
Note: For equipment not having a specified rated insulation voltage, the highest value of the rated operational voltage is considered to be the rated insulation voltage.

screw-type terminal: A terminal for the connection and subsequent disconnection of a conductor or the interconnection of two or more conductors capable of being dismantled, the connection being made, directly or indirectly, by means of screws or nuts of any kind.

screwless-type terminal: A terminal for the connection and subsequent disconnection of a conductor or the interconnection of two or more conductors capable of being dismantled, the connection being made, directly or indirectly, by means of springs, wedges, eccentrics, or cones.

special preparation (of conductor end): Alteration of the manufactured shape or surface of the conductor to enable it to be connected to the terminal.

NOTE—This definition differs from IEC 60947-7-1, in which "Special Preparation" means the use of crimped ferrules and similar terminal devices.

terminal: A conductive part of a device, provided for electrical connection to external circuits.

terminal assembly: One or more terminals fixed to the same conductive part.

terminal block: An insulating part carrying one or more mutually insulated terminal assemblies and intended to be fixed to a support.

terminal insulator: An insulating part intended for maintaining in position or for covering live parts.

3 CLASSIFICATION

Distinction is made between various types of terminal blocks according to:

a. Method of fixing the terminal blocks to a support or to a printed circuit board (PCB)
b. Number of terminal assemblies
c. Type of terminals, for example, screw-type terminals and screw-less-type terminals
d. Ability to receive conductors having particular terminations, for example, cable lugs
e. Terminal assemblies with identical or dissimilar clamping units
f. Number of terminals on each terminal assembly
g. Two piece, separable terminal blocks
h. Service conditions
i. Terminal blocks, suitable for the connection of copper conductor only (marked Cu)
j. Terminal blocks, suitable for the connection of aluminum conductors only (marked Al)
k. Terminal blocks, suitable for the connection of aluminum conductors as well as copper conductors (marked Al-Cu)

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4 CHARACTERISTICS AND RATINGS

The terminal block shall be rated in terms of the maximum cross section of a single 75°C insulated conductor.

5 PRODUCT MARKING, INSTALLATION, AND MAINTENANCE INFORMATION

5.1 PRODUCT INFORMATION

5.1.1 Connecting Capacity

The manufacturer shall state the types of conductors that can be connected, and their maximum and minimum cross sections, if applicable. Also stated is the number of such conductors simultaneously connectable to each terminal, while maintaining the spacing requirements of 7.4.

5.1.2 Mandatory Product Information

A terminal block shall be marked in a permanent and legible manner with:

a. The name of the manufacturer or trademark by which he may be readily identified.

b. A type reference to enable identification and the procurement of relevant information.

The following product information shall be marked either on the terminal block or contained in the manufacturer's data sheet or on the smallest packing unit:

a. The rated cross-section and the thermal rating of the conductor, if other than 75°C

NOTE—Tests in this standard are based on conductor ratings corresponding to 75°C thermal insulation rating and 30°C ambient. Results are also applicable to conductors of the same cross section and any higher thermal insulation rating.

b. The connecting capacity, including the type and number of conductors simultaneously connectable

c. The tightening torque values for the clamping screws

d. Rated insulation voltage

e. Service conditions if different from those stated in ICS 1, Part 6

f. Marking "Cu" for terminal blocks used for copper conductors only

g. Marking "Al" for terminal blocks used for aluminum conductors only

h. Marking "Al-Cu" for terminal blocks suitable for the connection of aluminum or copper conductors

5.2 MAINTENANCE

See NEMA Standards Publication ICS 1.3 for general maintenance instructions.

6 SERVICE AND STORAGE CONDITIONS

See NEMA Standards Publication ICS 1, Clause 6 for standard service and storage conditions.

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7 CONSTRUCTION

7.1 TERMINAL ASSEMBLIES

7.1.1 Mechanical and Electrical Connection of Conductors

The terminal assembly shall allow the conductors to be connected by means that ensure reliable mechanical and electrical connection. The construction of the terminal blocks shall not allow the conductors attached to the terminals, the terminals themselves, or the terminal assemblies to be displaced in a manner detrimental to the insulation. Likewise, under the above conditions, the construction shall not allow a reduction of clearance or creepage distance, or both. The terminal shall be able to withstand the forces that can be applied through the connected conductors under the conditions of 8.4.3 and 8.4.4.

7.1.2 Terminal Assembly Material

The main current carrying parts of a terminal shall be of copper or copper alloy, aluminum or aluminum alloy, or steel. The steel shall be coated with an electrically conductive coating that will inhibit oxidation and corrosion.

7.1.3 Protective Coating of Terminal Assembly

All combinations of terminal assembly and conductor materials shall have a protective coating, except the following combinations:

a. Aluminum or aluminum alloy terminal assemblies used only for the connection of aluminum conductors
b. Copper or copper alloy terminal assemblies used only for the connection of copper conductors

Where protective coating is necessary, tin coating is acceptable for all combinations of terminal assemblies, including the clamping screws.

7.1.4 Clamping of Conductors

Terminal assemblies shall be so designed that contact pressure is not transmitted through insulating material.

7.2 MOUNTING MEANS

Terminal blocks shall be provided with means that allow them to be securely attached to a rail, a mounting surface, or a printed circuit board (PCB). Tests shall be made in accordance with 8.4.1.

7.3 IDENTIFICATION

A terminal block shall be permitted to have provisions for identification marks or numbers for each terminal or terminal assembly to be related to the circuit of which it is to form a part.

7.4 CLEARANCE AND CREEPAGE DISTANCES

Clearances and creepage distances shall be in accordance with ICS 1, Clause 7. For information regarding verification of clearances by testing, see ICS 1, Annex A.

Clearances and creepage distances shall be determined with the terminal blocks installed and connected according to the instruction of the manufacturer and for the most unfavorable combination of conductor cross sections.

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8 PERFORMANCE REQUIREMENTS AND TESTS

8.1 DESIGN (TYPE) TESTS, GENERAL

Design or type tests are performed on terminal blocks of each design to determine compliance with the standard.

A particular design of terminal block, having one or more terminal assemblies, shall be permitted to be manufactured. Unless otherwise specified, terminal blocks with any number of terminal assemblies are permitted to be submitted for the tests.

For a range of terminal sizes of similar design, the largest, smallest, and 2 intermediate sizes shall be tested; except that for a range of 3 terminal sizes, the largest and the smallest, and for ranges of 4 and 5 sizes, the largest, smallest, and one intermediate size, need only be tested. A range of terminals is similar if all have the following common features:

a. Shape of terminal, shape of conductor opening, and the shape of wire clamping screw

b. Material and coating of terminal body

c. Material of wire clamping screw

d. Quantity of clamping screws

8.2 TEST CONDITIONS

8.2.1 Test Conductors

The stranding and construction for stranded copper and aluminum conductors shall be as given in Table 8-1.

Copper test conductors shall be soft annealed and uncoated.

The aluminum test conductors for terminals designated Al or Al-Cu shall be uncoated insulated aluminum conductors with the following characteristics:

a. Tensile strength: 14,000–17,000 psi (approximately 98–118 N/mm^2)

b. Elongation: 10 percent minimum

c. Specific resistance at 20°C: 17.01 ohm-circular mil/ft (0.0283 ohm-mm^2/M)

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Table 8-1
Stranded Test Conductor for Copper and Aluminum

Conductor Cross Section			Conductor Material**	
AWG/kcmil	(mm^2)	Number of Strands	Copper (Cu)	Aluminum (Al)
24 AWG	...	7	A	. . .
22	...	7	A	. . .
20	(0.52)	10	A	. . .
18	(0.82)	16	A	. . .
16	(1.3)	26	A	. . .
14*	(2.1)	7	A	. . .
12*	(3.31)	7	A	A
10*	(5.26)	7	A	A
8	(8.37)	7	A	A
6	(13.3)	7	A	A
4	(21.1)	7	A	A
2	(33.6)	7	A	B
0	(53.5)	19	A	B
00	(67.4)	19	A	B
000	(85.0)	19	A	B
0000	(107.0)	19	A	B
250kcmil	(127.0)	37	A	B
300	(152.0)	37	A	B
350	(177.0)	37	A	B
500	(253.0)	37	A	B
600 –1000	(304.0 - 507.0)	61	A	B
1250 – 1500	(634.0 - 760.0)	91	A	A
1750 – 2000	(887.0 - 1014)	127	A	A

** A = Concentric or compressed
B = Compact, unidirectional lay
* 10 - 14 AWG to be tested with solid wire also

8.2.2 Conductor Ends

Sufficient length of insulation shall be removed to enable a proper connection to be made. There shall be no mechanical removal or chemical treatment of the oxide surface from the conductor entering the clamping unit. However, oxide surface shall be removed at the points to which measuring leads are attached for the voltage drop test.

8.2.3 Terminal Block Mounting

Terminal blocks shall be mounted on a horizontal surface, using the mounting means provided, such as screwed to a flat surface or mounted on a rail.

8.2.4 Condition of Unit Under Test

Unless specified otherwise, terminal blocks are tested new and in a clean condition.

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8.2.5 Ambient Temperature

The ambient temperature during the tests shall be 20 ±5°C unless otherwise specified.

8.2.6 Adjustments

For all tests, except those performed in 8.4.2.2, there shall be no readjustment or retightening of the pressure screw after it initially has been tightened to the specified torque.

8.3 TEST SEQUENCE

Tests shall be performed in the sequence shown in Table 8-2. Each test series is to be performed in sequence on all test samples without adjustment.

Table 8-2
Test Sequences

Sequence Number	Quantity	Test	Referenced Clause
1	2*	Clamping Unit and Terminal Assembly	8.4.1
2	2	Conductor and Terminal Secureness Series*:	
2a		Initial Voltage Drop	8.4.2
2b		Secureness	8.4.3
2c		Pull	8.4.4
2d		Final Voltage Drop	8.4.2
3	1	Temperature Rise Series**	
3a		Initial Voltage Drop	8.4.2
3b		Temperature Rise	8.4.5
3c		Final Voltage Drop	8.4.2
3d		Dielectric	8.4.6
4	2	Current Cycling#	8.4.7
5	1	Thermoplastic Insulator Stress Relief+	8.4.8

Notes:
* Sample(s) not to be used for any other tests.
** Sequence number 2 consists of tests listed as 2a, 2b, 2c, and 2d.
\# Sequence number 3 consists of tests listed as 3a, 3b, 3c, and 3d.
\## Applies only to aluminum body terminals or terminals designated as suitable for use with aluminum or aluminum alloy conductors.
\+ Applies only to insulating parts made of thermoplastic material.

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8.4 TYPE TESTS

8.4.1 Clamping Unit and Terminal Assembly Test

8.4.1.1 Test Samples

This test requires two terminal assemblies mounted in a terminal block(s). The samples used for this test shall not be used for any other tests.

8.4.1.2 Test Procedure

Two separate terminal assemblies are required for this test: one terminal assembly for the maximum rated cross section conductor and one terminal assembly for the minimum cross section conductor.

The terminal block shall be mounted by its normal mounting means. A conductor of the maximum rated cross section shall be inserted in the terminal assembly, a conductor of the smallest cross section of the connecting capacity (if specified) shall be inserted in another terminal assembly, and the clamping screws shall be tightened to 110 percent of the torque specified by the manufacturer.

The clamping screws shall then be unscrewed, new conductors shall be inserted, and the screws shall be tightened again to 110 percent. The test shall be repeated five times using the same clamping units and five new conductors for each terminal. In the case of screw-less-type terminal blocks, which employ clamping springs, the conductors are connected and disconnected according to the manufacturer's instructions.

8.4.1.3 Test Criteria

When the terminal assembly is tested in accordance with 8.4.1.2, the conductor ends shall not be cut off or damaged in any way. No damage shall have occurred to the terminal assemblies, the terminal block, or the mounting means.

8.4.2 Voltage Drop Test

8.4.2.1 Test Samples

Two terminal assemblies in a terminal block(s) shall be the test samples for the conductor and terminal secureness test sequence shown in Table 8-2.

8.4.2.2 Test Procedure

The voltage drop is measured at the points indicated in Figure 8-1. The test is made with DC equal to 0.1 times the value of the test current corresponding to the cross section of the conductor, as specified in Table 8-3.

Once the clamping screws are tightened to the torque specified by the manufacturer, there shall be no readjustment or retightening of the pressure screws during the complete sequence of tests specified in Table 8-2.

8.4.2.3 Test Criteria

The voltage drop for the initial voltage drop test shall not exceed 3.2 millivolts. The voltage drop for the final voltage drop test shall not exceed 4.8 millivolts.

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Table 8-3
Test Currents Corresponding to Cross Section of Conductor

Rated Cross-Section		Test Current (Amperes)	
AWG/kcmil	**(mm²)**	**Copper**	**Aluminum**
24 AWG	(0.2)	1.8	. . .
22	(0.33)	3.0	. . .
20	(0.52)	4.6	. . .
18	(0.82)	7.3	. . .
16	(1.3)	11.6	. . .
14	(2.1)	18.4	. . .
12	(3.31)	26.0	22.0
10	(5.26)	35.0	29.5
8	(8.37)	46.5	39.0
6	(13.3)	62.0	52.0
4	(21.1)	83.0	67.0
3	(26.7)	96.0	76.0
2	(33.6)	110.0	87.0
1	(42.4)	130.0	100.0
0	(53.5)	150.0	115.0
00	(67.4)	172.0	135.0
000	(85.0)	200.0	155.0
0000	(107)	235.0	187.0
250	(127)	255.0	205.0
300	(152)	285.0	225.0
350	(177)	310.0	245.0
400	(203)	335.0	265.0
500	(253)	370.0	300.0
600	(304)	415.0	330.0
700	(355)	450.0	360.0
750	(380)	470.0	375.0
800	(405)	480.0	390.0
900	(456)	520.0	420.0
1000	(507)	550.0	440.0
1250	(634)	590.0	485.0
1500	(760)	620.0	515.0
1750	(887)	645.0	540.0
2000	(1014)	665.0	560.0

The value of the test current corresponding to the rated standard cross section of the conductor is given by the relationship:

$$\text{Log}A = m\text{Log}I + c$$

Where:

A = conductor cross-section in mm²

I = current in amperes

The values for the constants *m* and *c* are given in Table 8-3a

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Table 8-3a
Values of Constants *c* and *m* for Copper and Aluminum Conductors

Conductor Material	Rated Cross Section mm²	*m*	*c*
Al	0 - 100	1.6856	-1.7524
	101 - 507	1.7955	-2.0437
	508 - 1014	3.2624	-5.9597
Cu	0 - 2.5	1.0163	-0.9664
	2.6 - 100	1.5945	-1.7395
	101 - 507	1.8338	-2.3165
	508 - 1014	3.9287	-8.0839

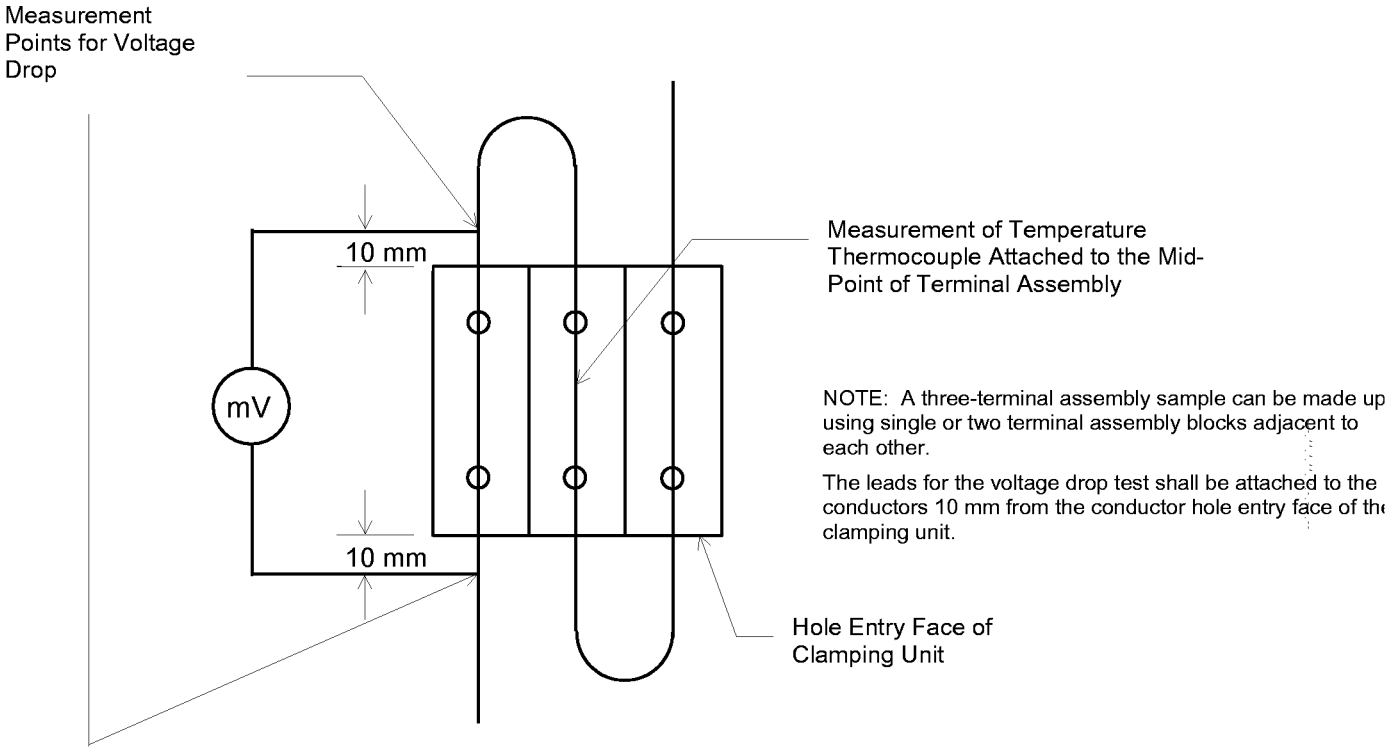


Figure 8-1
Arrangement for Voltage Drop and Temperature Rise Measurements

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8.4.3 Secureness Test

8.4.3.1 Test Samples

Two terminal assemblies in a terminal block(s) shall be the test samples for the sequence of tests shown in Table 8-2.

8.4.3.2 Test Procedure

Two separate terminal assemblies are required for this test.

For a clamping unit rated to accept a range of single conductors, the maximum rated cross section conductor shall be tested in one of the terminal assemblies, and the minimum cross section conductor shall be tested in the second terminal assembly.

For a clamping unit rated to accept more than one conductor simultaneously, in the same opening, one terminal assembly shall be tested with a combination of a minimum and a maximum rated cross section conductor, with the tests being performed on the conductor with the minimum cross section only.

The second terminal assembly shall be tested with a combination of the maximum rated cross section conductors, with the tests being performed on one of the conductors only.

A length of conductor of a rated cross section at least 3 inches (76 mm) longer than the height specified in Table 8-6 shall be connected to one terminal assembly and a suitable length to the other side of the same terminal assembly. The clamping screws shall be tightened to the torque specified by the manufacturer. For screw-less-type clamping units, the conductor shall be attached as specified by the manufacturer. Leads for the measurement of voltage drop shall be attached as shown in Figure 8-1.

The terminal block shall be secured as shown in Figure 8-2.

The end of the length of conductor specified above shall be passed through an appropriate size bushing positioned at a height below the terminal block as given in Table 8-4. The bushing is to be positioned in a horizontal plane concentric with the conductor. The bushing is to be moved so that its center describes a circle of 3 inches (76 mm) diameter about its centerline in the horizontal plane at a rate of approximately 9 rpm. The distance between the mouth of the clamping unit and the upper surface of the bushing shall be within 0.5 inch (13 mm) of the distance "height" in Table 8-4. The bushings are to be lubricated to prevent binding, twisting, or rotation of the insulated conductor. A weight as specified in Table 8-6 is to be suspended from the end of the conductor. The duration of the test shall be 30 minutes.

8.4.3.3 Test Criteria

When tested in accordance with 8.4.3.2, the conductor shall not pull out of the clamping unit and the terminal assembly shall not separate from the terminal insulator.

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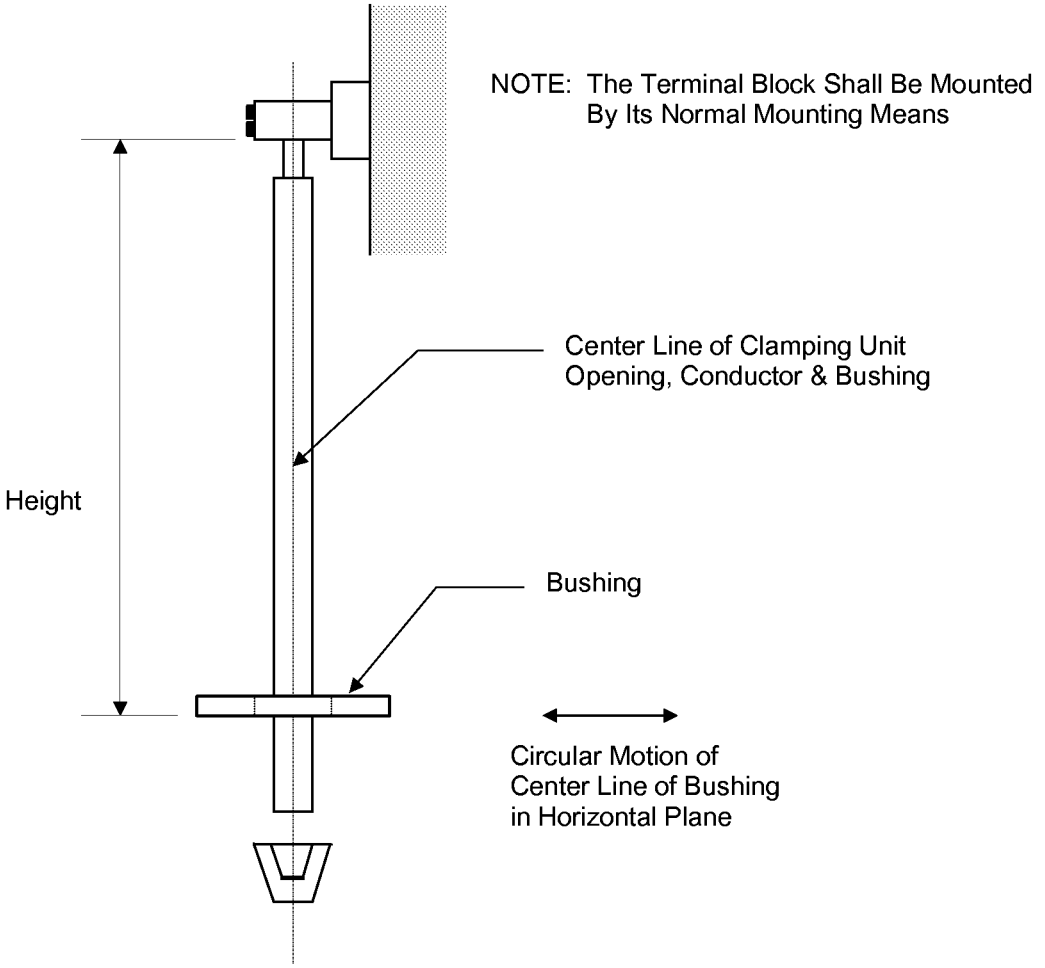


Figure 8-2
Arrangement for the Verification of Attachment of Conductor to the Clamping Unit and of the Terminal Assembly to the Insulator

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Table 8-4
Values for Secureness and Pullout Test

Size of Conductors AWG or kcmil	Diameter of Bushing Hole*		Height**		Secureness Weight		Copper		Aluminum	
	Inches	(mm)	Inches	(mm)	Lb.	(kg)	Lb.	(N)	Lb.	(N)
24 AWG	¼	(6.5)	10¼	(260)	0.66	(0.3)	2.25	(10)	. . .	. . .
22	¼	(6.5)	10¼	(260)	0.66	(0.3)	4.5	(20)	. . .	. . .
20	¼	(6.5)	10¼	(260)	0.66	(0.3)	6.75	(30)	. . .	. . .
18	¼	(6.5)	10¼	(260)	1	(0.45)	6.75	(30)	. . .	. . .
16	¼	(6.5)	10¼	(260)	1	(0.45)	9.0	(40)	. . .	. . .
14	_	(9.5)	11	(279)	1.5	(0.68)	11.5	(50)	. . .	. . .
12	_	(9.5)	11#	(279)	2	(0.9)	13.5	(60)	10	(45)
10	_	(9.5)	11#	(279)	3	(1.4)	18.0	(80)	10	(45)
8	_	(9.5)	11#	(279)	4.5	(2)	20.5	(90)	10	(45)
6	½	(13)	11¾#	(296)	6.5	(3)	21	(94)	28	(125)
4	½	(13)	11¾#	(296)	10	(4.5)	30	(133)	36	(160)
3	9/16	(14)	12½	(317)	13	(5.9)	35	(156)	42	(187)
2	9/16	(14)	12½	(317)	15	(6.8)	42	(187)	50	(223)
1	_	(16)	13½	(343)	19	(8.6)	53	(236)	61	(271)
1/0	_	(16)	13½	(343)	21	(9.5)	64	(285)	72	(320)
2/0	¾	(19)	14½	(368)	23	(10.4)	64	(285)	78	(347)
3/0	¾	(19)	14½	(368)	31	(14)	79	(351)	97	(432)
4/0	¾	(19)	14½	(368)	31	(14)	96	(427)	116	(516)
250 kcmil	_	(22)	16	(406)	31	(14)	96	(427)	116	(516)
300	_	(22)	16	(406)	33	(15)	99	(441)	116	(516)
350	1	(25)	17	(432)	37	(17)	113	(503)	129	(574)
400	1	(25)	17	(432)	37	(17)	113	(503)	129	(574)
500	1_	(29)	18¼	(464)	44	(20)	130	(578)	154	(685)
600	1_	(29)	18¼	(464)	50	(23)	130	(578)	154	(685)
700	1¼	(32)	19½	(495)	50	(23)	145	(645)	179	(796)
750	1¼	(32)	19½	(495)	50	(23)	155	(690)	179	(796)
800	1_	(35)	21¼	(540)	55	(25)	155	(690)	179	(796)
900	1_	(35)	21¼	(540)	55	(25)	158	(703)	181	(805)
1000	1½	(38)	22½	(572)	55	(25)	175	(779)	199	(885)
1250	1¾	(45)	26	(640)	75	(34)	217	(966)	251	(1120)
1500	2	(51)	28	(711)	90	(41)	264	(1175)	302	(1340)
1750	2_	(54)	30	(762)	99	(45)	303	(1348)	342	(1520)
2000	2_	(54)	30	(762)	119	(54)	342	(1522)	382	(1700)

* If a hole with the diameter specified is not adequate to accommodate the conductor, a bushing having the next larger hole diameter may be used.

** Tolerance for height is ±½ inch (12 mm).

\# For Aluminum conductors, sizes AWG 12 - 4, use height of 12½ inches.

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8.4.4 Pull Test

8.4.4.1 Test Samples

Two terminal assemblies in a terminal block(s) shall be the test samples for the sequence of tests shown in Table 8-2.

8.4.4.2 Test Procedure

A pulling force corresponding to the conductor cross section given in Table 8-4 shall be applied gradually to the conductor and maintained at that value for one minute.

8.4.4.3 Test Criteria

When tested in accordance with 8.4.4.2, the conductor shall not pull out of the clamping unit, and the terminal assembly shall not separate from the terminal insulator.

8.4.5 Temperature Rise Test

8.4.5.1 Test Samples

One terminal block containing three adjacent terminal assemblies is required for this sequence of tests.

8.4.5.2 Test Procedure

A sample consisting of three terminal assemblies shall be connected in series, as shown in Figure 8-1, using conductors of the rated cross section.

The length of each of the four conductors shall be 3 feet (1 m) for cross sections up to and including 8 AWG (10 mm^2) and 6 feet (2 m) for larger cross sections. Voltage drop measuring leads shall also be attached to one of the terminal assemblies as shown in Figure 8-1.

The clamping screws of screw-type clamping units shall be tightened to the torque specified by the manufacturer.

The currents for the temperature rise test shall be in accordance with the values stated in Table 8-3.

The test sample is considered to have attained a stable temperature when three measurements taken at not less than 10-minute intervals show no more than a 2°C variation between any two of the three measurements.

The shortened current-off period ends when the test sample reaches a temperature within 2°C of room temperature.

8.4.5.3 Test Criteria

When terminal blocks are tested in accordance with 8.4.5.2, the measured temperature rise of the terminal assembly shall not exceed 45°C.

8.4.6 Dielectric Strength

8.4.6.1 Test Sample

This test is to be performed on the test sample used for the temperature rise test series in the sequence shown in Table 8-2 following the final voltage drop test.

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8.4.6.2 Test Procedure

The test sample is mounted on a sheet metal support or on a rail as in normal use.

a. The conductors which connect adjacent terminals are cut.

b. The voltage specified in Table 8-5 shall be applied for one minute, first between the terminal assemblies, then between all the terminal assemblies connected together and the metal support or the rail, and then between the adjacent terminal assemblies.

8.4.6.3 Test Criteria

When tested in accordance with 8.4.6.2, there shall be no dielectric breakdown during the tests.

Table 8-5
Dielectric Test Voltage

Rated insulation voltage, U_I Volts	Dielectric Test Voltage Volts AC, rms
$U_i \leq 60$	1000
$60 < U_i \leq 300$	2000
$300 < U_i \leq 660$	2500
$660 < U_i \leq 800$	3000
$800 < U_i \leq 1000$	3500
$1000 < U_i \leq 1500^*$	4000
* for DC only	

8.4.7 Current-Cycling Tests

This test verifies the stability of the terminal assembly by comparing the temperature performance of the terminal assembly with that of the conductor under accelerated cycling conditions.

Combinations of terminal material and test conductors requiring a current-cycling test are shown in Table 8-6.

Terminal blocks with terminal assemblies made of various metals shall pass the current-cycling test of 8.4.7 using test conductor-terminal assembly combinations shown in Table 8-6 and designated by an X.

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Table 8-6
Terminal Assembly and Conductor Combinations
That Require Current-Cycling Tests

Terminal Designation	Terminal Assembly Material			Test Conductor
	Aluminum or Aluminum Alloy	Copper or Copper Alloy	Other	
Al	X	X	X	Al
Al-Cu	X	X	X	Al
Al-Cu	X	. . .	. . .	Cu
Cu	X	. . .	. . .	Cu
"X" indicates current-cycling test is to be performed.				

8.4.7.1 Test Samples

Two terminal assembly samples are required, each with two clamping units. The terminal assemblies are removed from the terminal block for this test.

Clamping units may be designed to employ either steel, aluminum, or brass clamping screws. Terminals with brass screws need not be subjected to the current-cycling test. Where aluminum or steel clamping screws are used, the terminals are subjected to the current-cycling test.

8.4.7.2 Test Conductors

Tests shall be performed using conductors of the rated cross section specified.

Tests shall be performed using the types of conductors for which the terminal block is rated: solid, stranded, or solid and stranded. When using aluminum, copper, or aluminum and copper, as given in Table 8-6 and designated by an X, separate samples shall be tested for each combination.

The insulation of the conductors shall be black.

8.4.7.3 Test Sample Preparation

a. The test sample shall consist of two terminal assemblies to which test conductors of the rated cross section are connected at each end as in service, in series with a control conductor of the same size. Figure 8-3 shows the arrangement with thermal barriers.

b. The length of the test conductor from the point of entry to the terminal to the equalizer bar shall be as in Table 8-7. The length of the control conductor shall be approximately twice the length of the test conductor.

c. The insulation shall be stripped from the conductor prior to the installation. The length of the stripped end shall be sufficient to make full contact with the clamping unit and a length of 0.25 inch to 0.5 inch (6.3 to 13 mm) of exposed conductor between the conductor entry face of the clamping unit and the beginning of the insulation. If the conductor can project through the clamping unit without interference, it shall not project more than 0.25 inch (6.3 mm).

   Where the manufacturer provides specific instructions for assembling the terminal to the wire, such instructions are to be followed except that the conductor is not to be brushed or abraded during or after removal of the insulation.

d. The conductor clamping screws shall be tightened to 80 percent of the torque values stated by the manufacturer. For screw-less-type clamping units, the manufacturer's instructions shall be followed.

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e. Each free end of the solid or stranded test and control conductor shall be welded or brazed to a short length of an equalizer bar of the same material as the conductor with cross section not greater than that given in Table 8-8. All strands of the conductor shall be welded or brazed to make a thorough electrical connection with the bar.

f. The series connection of the test and control conductors shall be by means of short lengths of bars so that the distance between the conductors is 6 inches (152 mm) if thermal barriers are used, and 18 inches (457 mm) if thermal barriers are not used. The bar cross section shall be the minimum size necessary to provide sufficient contact area for the equalizer bar; however, it shall not exceed a current density of 1000 amperes per square inch (1.55 amperes per square millimeter) for copper and 800 amperes per square inch (1.24 amperes per square millimeter) for aluminum. See Table 8-8.

g. The equalizer to bar and to the supply conductor connections shall be made so as not to produce undesirable heating.

h. The test sample shall be suspended in free air by supporting the equalizers by nonmetallic supports so as not to subject the terminals to a tensile load. Thermal barriers, if used, shall be installed between the conductors (mid-point) and shall extend one inch (25 mm) horizontally and 6 inches (152 mm) vertically beyond the conductors. The test sample shall be located at least 24 inches (610 mm) from the floor, wall, or ceiling.

i. The sample shall be located in a substantially vibration and draft free location and in an ambient temperature between 15°C and 35°C.

j. The temperature of the terminal shall be measured by means of a thermocouple located on the conductor entry side of the clamping unit as close as possible to the conductor/clamping unit contact surface. The temperature of the control conductor shall be measured by a thermocouple located in the middle of the conductor and under the conductor insulation.

   Thermocouple wire diameter shall be not smaller than AWG 30 (0.3 mm diameter) nor larger than AWG 24 (0.55 mm diameter). Iron-constantan is preferred.

   For the control conductor, the thermocouple shall be located at the midpoint of conductor length and under the conductor insulation. The thermocouple shall be secured by soldering, by use of thermally conductive adhesive, or by other equivalent means that will permit replacement of the conductor insulation over the thermocouple location and that will not require penetration of the surface of the conductor metal; for example, drilling and peening of the conductor is not acceptable.

   A small flap is to be cut into the conductor insulation and rolled back to expose the conductor.

   The thermocouple bead is to be positioned in the valley between conductor strands or on the surface of a solid conductor.

   The flap of insulation is to be repositioned and secured by a tightly wrapped double layer of black thermoplastic tape extending approximately 0.5 inch (13 mm) on each side of the flap, or by another acceptable means of holding the test conductor insulation in place.

   For the terminal, the thermocouple shall be located on one of the wire entry sides of the clamping unit and closest to the conductor/clamping unit contact surface.

The thermocouple is to be installed so as to obtain thermal and mechanical bonding with the surface of the terminal and without causing an appreciable change in the temperature of the terminal; for example, by peening thermocouples into small holes drilled in the terminal, or by the use of small quantities of thermally conductive adhesive.

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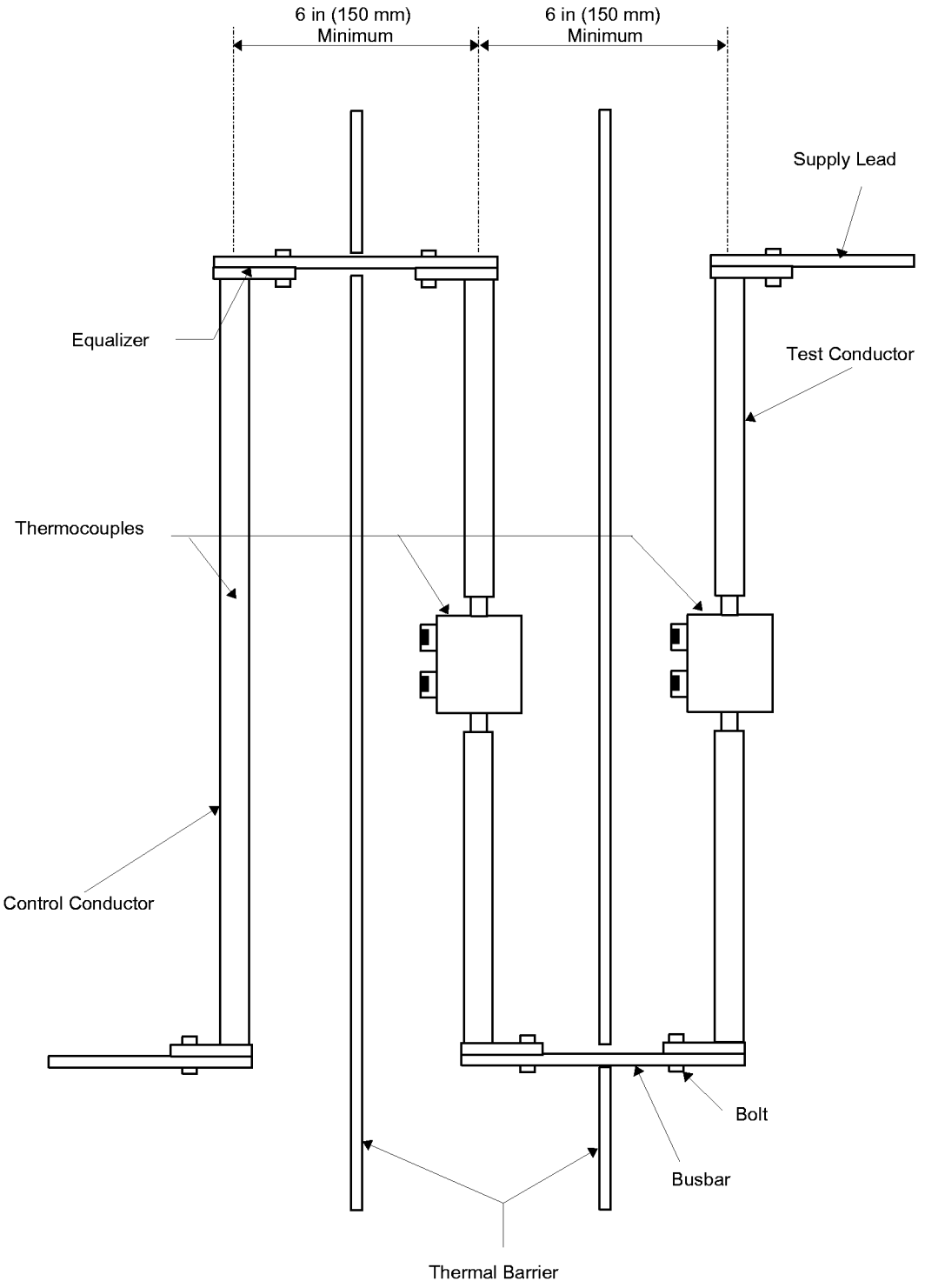


Figure 8-3
Arrangement of Sample for the Current-Cycling Test

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Table 8-7
Test Conductor Length

Conductor Size	Minimum Conductor Length	
	Inches	(mm)
18 - 8 AWG	8	(203)
6 - 3 AWG	12	(305)
2 AWG - 500 kcmil	18	(457)
Larger than 500 kcmil	26	(660)

Table 8-8
Equalizer Bar Dimensions

Range of Test Current Amperes	Maximum Cross Section, Inches*	
	Copper	Aluminum
0 - 50	1/8 x ½	1/8 x ½
51 - 125	1/8 x 1	1/8 x 1¼
125 - 225	1/8 x 11/8	1/8 x 2¼
226 - 400	¼ x 1½	¼ x 2
401 - 600	¼ x 2	¼ x 3
601 - 800	¼ x 3	¼ x 4
801 - 1000	¼ x 4	3/8 x 3½
1001 - 1400	½ x 3 or two ¼ x 3	½ x 3½
1401 - 2000	½ x 4 or two ¼ x 4	½ x 5

* SI equivalents of the values in table 8-8 are:

Inches	mm	Inches	mm	Inches	mm
1/8	3.2	1¼	31.8	3	76.2
¼	6.4	1½	38.1	3½	88.9
3/8	9.5	17/8	47.6	4	102
½	12.7	2	50.8	5	127
1	25.4	2¼	57.2		

8.4.7.4 Test Procedure

a. The ambient temperature shall be measured by means of two thermocouples attached to unplated copper plates approximately 2 inches (51 mm) square and 0.25 inch (6.3 mm) thick, and located 24 inches (610 mm) in front of the sample in the horizontal plane of the terminal assemblies.

b. The sample shall be subjected to 500 cycles of equal current-on and current-off operations for the periods of time and at the steady current corresponding to the conductor cross section specified in Table 8-9. Temperatures are to be recorded for at least one cycle during each work-

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day, and after approximately 25, 50, 75, 100, 125, 175, 225, 275, 350, 425, and 500 cycles (key temperature measurements).

c. The stability factor "S" for each of the 11 key temperature measurements from the 25th to the 500th operation shall not exceed ±10. The temperature deviation "d" for the 11 individual temperature measurements is obtained by subtracting the associated control conductor temperature from the terminal temperature. The value of "d" is positive if the terminal temperature is higher than that of the control conductor and negative if the terminal temperature is lower.

The stability factor "S" for each of the 11 temperature measurements is to be determined by subtracting algebraically the average temperature deviation "d" from the value of the temperature deviation for the temperature measurement. See Table 8-10 for example calculation.

d. Temperatures are to be measured no sooner than the last 5 minutes of the normal current on-time. If the size of the test sample set, or the speed of the data acquisition system is such that not all measurements can be completed within 5 minutes, the current on-time shall be extended, as necessary, to complete such measurements.

e. The current-off time specified in Table 8-9 may be shortened, after the first 25 cycles of testing, to 5 minutes more than the maximum time it takes any terminal assembly to reach a stable temperature during the current-off period. Forced-air cooling may be employed to shorten the current-off time with the concurrence of those concerned. See paragraph f.

f. The test sample is considered to have attained a stable temperature when three measurements taken at not less than 10-minute intervals show no more than 2°C variation between any two of the measurements.

The shortened current-off period ends when the test sample reaches a temperature within 2°C of room temperature.

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Table 8-9
Values of Test Current for Current-Cycling Test

Rated Cross-Section		Cycling Current, Amperes		ON and OFF Times Hours
AWG or kcmil	(mm^2)	Cu	Al	
22 AWG	(0.33)	11.7	. . .	1
20	(0.52)	14.7	. . .	1
18	(0.82)	19.3	. . .	1
16	(1.3)	25.2	. . .	1
14	(2.1)	33.0	. . .	1
12	(3.31)	43.0	34.0	1
10	(5.26)	57.5	45.5	1
8	(8.37)	77.3	61.0	1
6	(13.1)	104	82.0	1
4	(21.1)	140	110	1
3	(26.7)	163	128	1
2	(33.6)	189	148	1
1	(42.4)	219	171	1
0	(53.5)	254	199	1
00	(67.4)	295	230	1
000	(85)	342	267	1
0000	(107)	397	309	1.5
250l	(127)	443	345	1.5
300	(152)	497	386	1.5
350	(177)	548	425	1.5
400	(203)	598	465	1.5
500	(253)	689	534	2
600	(304)	775	600	2
700	(355)	850	660	2
750	(380)	894	692	2
800	(405)	920	720	2
900	(456)	983	777	2
1000	(507)	1044	830	2
1250	(634)	1183	958	3
1500	(760)	1310	1075	3
1750	(887)	1428	1185	3
2000	(1014)	1540	1290	3

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Table 8-10
Stability Factor "S" Calculation Example

Cycle Number	Control Terminal Temperature, °C	Conductor Temperature, °C	Temperature Deviation "d"	Stability Factor "S"
25	130	135	-5	-6.5
50	131	136	-5	-6.5
75	133	135	-2	-3.5
100	136	135	1	-0.5
125	136	135	1	-0.5
175	138	135	3	1.5
225	139	136	3	1.5
275	138	135	3	1.5
350	141	136	5	3.5
425	142	136	6	4.5
500	142	136	6	4.5
Sum = 16 Average = +1.5				

8.4.7.5 Test Criteria

The temperature rise of any terminal for any of the measurements shall not exceed 125°C.

8.4.8 Thermoplastic Insulator Stress Relief Test

This test shall be performed on one sample of each insulating part made from thermoplastic. This test is not required for rigid or low-pressure formed thermosetting molded parts.

8.4.8.1 Test Sample

The test sample shall be one terminal block with the maximum number of terminal assemblies.

8.4.8.2 Test Procedure

The terminal block shall be placed in a full-draft circulating oven for 7 hours. The oven is to be maintained at a temperature that is 10°C above the manufacturer's stated maximum operating temperature for the insulating material in the terminal block. There shall be no softening of the insulator material, and immediately after removal from the oven, while being handled, there shall be no distortion or bending under its own weight. After allowing the terminal block to cool down to the room ambient temperature, the insulator shall again be examined.

8.4.8.3 Test Criteria

There shall be no shrinkage, warping, or other distortion resulting in the reduction of clearances or creepage distances below the specified values.

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9 APPLICATIONS

9.1 APPLICATION OF TERMINAL BLOCKS IN HAZARDOUS LOCATIONS

(explosive gasses, dust)

9.1.1 Definition

Hazardous locations are defined in the National Electric Code, Articles 500 & 505.

9.1.2 Installations

The safe application of terminal blocks in these locations requires the correct determination of the hazard, division, or zone and the selection of the proper enclosure. The user is advised to carefully consult the following references.

NFPA 70	*National Electrical Code*
UL 2279	*Electrical Equipment for use in Class 1, Zone 0,1, and 2 Hazardous (Classified) Locations*
ANSI/ISA 12.16	*Electrical Equipment for Use in Class I, Zone 1 Hazardous (Classified) Locations: Type of Protection—Increased Safety 'e'*
IEC 60079-7	*Electrical Apparatus for Explosive Gas Atmospheres – Part 7: Increased Safety 'e' (Applies to Certain Non-US Applications Only)*
NEMA 250	*Enclosures for Electrical Equipment (1000 Volts Maximum)*
ICS 6	*Industrial Control and Systems, Enclosures*

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