



National Differences For

UL 61800-5-1

**Standard for Adjustable Speed Electrical Power Drive Systems - Part 5-1: Safety Requirements -
Electrical, Thermal and Energy**

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Standard for Adjustable Speed Electrical Power Drive Systems - Part 5-1: Safety Requirements -
Electrical, Thermal and Energy

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Adoption of IEC 61800-5-1, Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy (Second edition, issued by the IEC July 2007) as a new IEC-based UL standard, UL 61800-5-1.

Please note that the national difference document incorporates all of the U.S. national differences for UL 61800-5-1.

This document provides a single listing of the National Differences included in the UL adoption of the corresponding IEC standard.

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Preface

This document provides a single listing of the technical National Differences included in the UL adoption of the corresponding IEC standard.

In its IEC-based standards, UL uses the notations indicated below to identify national difference type, and these types are additionally noted in this document. The standard may not use all types of these deviations.

D1 - These are deviations which are based on basic safety principles and requirements, elimination of which would compromise safety for U.S. consumers and users of products.

D2 - These are deviations based on safety practices. These are deviations for IEC requirements that may be acceptable, but adopting the IEC requirements would require considerable retesting or redesign on the manufacturer's part.

DC - These are deviations based on the component standards and will not be deleted until a particular component standard is harmonized with the IEC component standard.

DE - These are deviations based on editorial comments or corrections.

DR - These are deviations based on the national regulatory requirements.

Each national difference contains a description of what the national difference entails. Typically one of the following words is used to explain how the text of the national difference is to be applied to the base IEC text:

Addition / Add - An addition entails adding a complete new numbered clause, subclause, table, figure, or annex. Addition is not meant to include adding select words to the base IEC text.

Deletion / Delete - A deletion entails complete deletion of an entire numbered clause, subclause, table, figure, or annex without any replacement text.

Modification / Modify - A modification is an altering of the existing base IEC text such as the addition, replacement or deletion of certain words or the replacement of an entire clause, subclause, table, figure, or annex of the base IEC text.

National Differences

1DV.1 D2 Modification to add the following:

DV.1.1 This document is only applicable to the power conversion and drive control equipment, servo drives and integral servo drive/motor combinations.

DV.1.2 Only devices connected to line voltages of up to 1,5 kV a.c. are covered.

DV.1.3 A component of a product covered by this standard shall comply with the requirements for that component. See Annex DVA for a list of additional standards covering components used in the products covered by this standard.

1DV.2 DR Modification to add the following:

This equipment is for use in ordinary locations in accordance with Articles 430 and 440 of the National Electrical Code, NFPA 70.

1DV.3 D2 Modification to add the following:

Specifications provided in other parts of the 61800 Series of Standards (for example EMC in part 3) apply only on agreement between the manufacturer and the customer.

2DV D2 Modification to add the following:

See Annex DVA for USA Normative References and Component Standards. See Annex DVB for IEC Normative References that do not apply and for IEC Normative References replaced by USA Standards.

Table 1DV DE Modification to add the following terms to Table 1:

AMBIENT TEMPERATURE	3.1ADV
CONTROL CIRCUIT	3.6ADV
GROUP INSTALLATION	3.12ADV
INSULATED LIVE PART	3.14ADV
SOLID STATE MOTOR OVERLOAD PROTECTION	3.36ADV
SOLID STATE SHORT CIRCUIT PROTECTION	3.36BDV
SURROUNDING AIR TEMPERATURE RATING	3.37ADV
THERMAL MEMORY	3.40DV
THERMAL MEMORY RETENTION	3.41DV
TRIPPING CURRENT	3.40ADV

3.1ADV D2 Addition:

AMBIENT TEMPERATURE: the temperature of the room or chamber in which the equipment under test is located

3.6ADV D2 Addition:

CONTROL CIRCUIT: a circuit that carries the electric signals directing the performance of a controller, and does not carry the main power circuit (see IEEE Standards Dictionary of Electrical and Electronic Terms). A **CONTROL CIRCUIT** is mostly limited to 15 A.

3.12ADV D2 Addition:

GROUP INSTALLATION: A motor branch circuit for two or more motors, or one or more motors with other loads and protected by a circuit breaker or a single set of fuses.

3.13DV D2 Modification:

Equipment operating at more than 600 Vac is considered high-voltage equipment with respect to the requirements in the National Electrical Code.

3.14ADV D2 Addition:

INSULATED LIVE PART: An electrically **LIVE PART** that is provided with complete protection against electric shock and does not rely upon other parts for insulation

3.18DV D2 Modification:

Equipment operating at more than 600 Vac is not considered low-voltage equipment with respect to the requirements in the National Electrical Code.

3.36ADV D2 Addition:

SOLID STATE MOTOR OVERLOAD PROTECTION: Circuitry integral to the power conversion equipment that acts to protect a motor under overload conditions by reducing current flow to the motor output terminals. This protection is typically achieved through an algorithm based on the I^2t of the current to the motor. The protection circuitry is usually comprised of hardware, firmware and software components.

3.36BDV D2 Addition:

SOLID STATE SHORT CIRCUIT PROTECTION: Circuitry integral to power conversion equipment that acts to suspend current flow to the motor output terminals upon sensing a preset or predetermined condition such as a rapid rate of change in output current or bus voltage. The protection circuitry may be comprised of hardware, firmware and software components.

3.37ADV D2 Addition:

SURROUNDING AIR TEMPERATURE RATING: a rating assigned to **OPEN TYPE** equipment that refers to the maximum **AMBIENT TEMPERATURE** of air immediately surrounding the equipment inside of the ultimate enclosure

3.40DV D2 Addition:

THERMAL MEMORY: The ability of an overload protective system to approximate the heating and cooling of a protected motor during operation.

3.40ADV D2 Addition:

TRIPPING CURRENT: Current level greater than rated output motor current at which the motor overload protection circuitry will function. May be provided as a percent of motor current or as an actual stated current value.

3.41DV D2 Addition:

THERMAL MEMORY RETENTION: The maintaining of the THERMAL MEMORY upon shutdown or power loss. This includes retention of the last thermal value, and may include an ongoing reduction of this thermal value to reflect the cooling of the motor. This information will be used by the overload protective system to approximate the thermal state of the motor upon restart.

4.1DV.1 DR Modification to add the following:

Power conversion equipment shall be constructed so that it complies with the rules for INSTALLATION and use of such equipment as given in the National Electrical Code, ANSI/NFPA 70.

4.1DV.2 D2 Modification to add the following:

4.1DV.2.1 Power conversion equipment shall employ materials that are evaluated for the use.

4.1DV.2.2 The acceptability of insulating materials is to be determined with respect to properties such as flammability, arc-resistance, and similar properties, based on an operating temperature equal to the measured temperature adjusted to the minimum anticipated end use ambient of 40°C (104°F), unless the equipment is marked in accordance with 6.3.3 for a higher end use ambient.

4.1DV.2.3 Iron and steel parts shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means. This applies to all springs and other parts upon which proper mechanical operation may depend other than the following items:

- 1) Bearings, thermal elements, sliding surfaces of a hinge, or shaft, and the like, where such protection is impracticable;
- 2) Small parts of iron or steel, such as washers, screws, bolts, and the like, that are not current carrying, if the corrosion of such parts would not be likely to result in a risk of fire, electric shock, or injury to persons; and
- 3) Parts made of stainless steel that are polished or treated.

4.1DV.3 D2 Modification to add the following:

For Isolated Secondary Circuits the requirements in Annex DVC can be used to determine if any of the requirements for risk of electric shock, thermal or energy hazards may be waived.

4.2DV.1 D2 Modification to add the following:**4.2DV.1.1 Critical components**

4.2DV.1.1.1 The use of probability of failure for waiving circuit analysis on components is not applicable. The circuit analysis shall be used to identify critical components with respect to resulting thermal or electric shock hazard. Further analysis shall be used to determine the components to be subjected to the test in 5.2.3.6.4.

4.2DV.1.1.2 The breakdown of components testing is not required for:

- a) Components in Class 2 circuits as defined in Annex DVC;
- b) Components in limited voltage/current secondary circuits as defined in Annex DVC;
- c) Components in limiting impedance circuits as defined in Annex DVC; and
- d) Components complying with the requirements applicable to the component where those requirements address the failure mode under evaluation for the circuit conditions in which the component is used within the drive.

4.2DV.2 D2 Modification to add the following:**4.2DV.2.1 Contactor overload**

4.2DV.2.1.1 A contactor in a power circuit shall be suitable for controlling the connected load, including making, carrying and breaking the overload current that can be delivered by the equipment. A contactor with lower ratings may be used when it is interlocked or sequenced such that in normal operation the contactor does not make or break load current and meets the requirements of 5.2.4.5.5DV.

4.2DV.3 D2 Modification to add the following:**4.2DV.3.1 Current limiting control**

4.2DV.3.1.1 Power conversion equipment incorporating a current limiting control is to be tested in accordance with 5.2.4.5.6DV.

4.3.3.1DV DC Modification:

In the US, motor requirements are provided in UL 2111 and the UL 1004 series of standards.

4.3.3.3DV.1 D2 Modification:

It is permitted to open enclosures or remove barriers without the use of a tool and without de-energization of LIVE PARTS of DVC A, B or C circuits.

4.3.3.3DV.2 D2 Modification:

Accessibility of LIVE PARTS of DVC B or C circuits shall be determined in accordance with Annex DVD.

4.3.4.3DV D2 Modification:

Impulse voltage testing is not required.

4.3.5.1DV D2 Modification:

Protection by means of CLASS II methods are not applicable.

4.3.5.3.1DV.1 D1 Modification:

Item b) is not applicable.

4.3.5.3.1DV.2 D2 Modification to add the following:**4.3.5.3.1DV.2.1 Bonding**

4.3.5.3.1DV.2.1.1 Other than as noted in 4.3.5.3.1DV.2.1.2 and 4.3.5.3.1DV.2.1.3, an enclosure made of insulating material, either wholly or in part, shall have bonding means to provide continuity of grounding between all conduit openings. The bonding means shall be either completely assembled on the product or provided as separate parts for field INSTALLATION.

4.3.5.3.1DV.2.1.2 A bonding means required in 4.3.5.3.1DV.2.1.1 is not required for an enclosure that is intended to be connected to a single conduit. Enclosures shall be marked in accordance with 6.3.6.6DV.3.

4.3.5.3.1DV.2.1.3 A bonding means required in 4.3.5.3.1DV.2.1.1 is not required to be provided with each enclosure when such means is available in the form of a kit from the manufacturer and the equipment complies with the marking requirements in 6.3.6.6DV.2.

4.3.5.3.1DV.2.1.4 Other than as noted in 4.3.5.3.1DV.2.1.5, the continuity of a conduit system shall be provided by metal-to-metal contact not relying on a polymeric material.

4.3.5.3.1DV.2.1.5 The continuity of the grounding system is not prohibited from relying on the integrity of the polymeric enclosure when samples have been subjected to the creep test requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. Overcurrent Tests shall be conducted at 200 percent of the rated current of the branch circuit-protective device.

4.3.5.3.1DV.2.1.6 A separate bonding conductor whether in a plastic or metal enclosure shall be copper, a copper alloy, or other material determined to be usable as an electrical conductor. Ferrous metal parts in the grounding path shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means. A separate bonding conductor shall:

- a) Be protected from mechanical damage or be located within the confines of the outer enclosure or frame; and
- b) Not be secured by a removable fastener used for any purpose other than bonding unless the bonding conductor is unable to be omitted after removal and replacement of the fastener.

4.3.5.3.1DV.2.1.7 Other than as noted in 4.3.5.3.1DV.2.1.8, the size of a separate component bonding conductor shall not be less than the applicable size specified in Table 4.3.5.3.1DV.1 or the size of the conductor supplying the component, whichever is smaller.

4.3.5.3.1DV.2.1.8 A bonding conductor is not required to be as large as specified in 4.3.5.3.1DV.2.1.7 when:

- a) It does not open when carrying, for the time specified in Table 4.3.5.3.1DV.2, a current equal to twice the branch-circuit overcurrent-device rating – see 4.3.5.3.1DV.2.1.9 – and not less than 40 A; and
- b) None of three samples of the bonding conductor opens during a limited-short-circuit test with a current as specified in Table 4.3.5.3.1DV.3 when in series with a fuse as described in 4.3.5.3.1DV.2.1.9.

Table 4.3.5.3.1DV.1 – Size of bonding conductor

Maximum rating or setting of automatic overcurrent device in circuit ahead of equipment, A	Minimum size of bonding conductor ^a	
	Copper wire AWG (mm ²)	Aluminum wire AWG or kcmil (mm ²)
15	14 (2,1)	12 (3,3)
20	12 (3,3)	10 (5,3)
30	10 (5,3)	8 (8,4)
40	10 (5,3)	8 (8,4)
60	10 (5,3)	8 (8,4)
100	8 (8,4)	6 (13,3)
200	6 (13,3)	4 (21,2)
300	4 (21,2)	2 (33,6)
400	3 (26,7)	1 (42,4)
500	2 (33,6)	1/0 (53,5)
600	1 (42,2)	2/0 (67,4)
800	1/0 (53,5)	3/0 (85,0)
1 000	2/0 (67,4)	4/0 (107,0)
1 200	3/0 (85,0)	250 (127,0)

^aOr equivalent cross-sectional area.

Table 4.3.5.3.1DV.2 – Duration of current flow for bonding-conductor test

Overcurrent device rating, A	Minimum duration of current flow, min
30 or less	1
31 – 60	4
61 – 100	6

Table 4.3.5.3.1DV.3 – Bonding conductor short-circuit test capacity

Controller rating		V	Circuit capacity, A
hp	(kW output)		
1/2	(0,373)	0 – 250	200
1/2	(0,373)	251 – 600	1 000
over 1/2 to 1	(0,374 – 0,746)	0 – 600	1 000
1 to 3	(0,747 – 2,24)	0 – 250	2 000
over 3 to 7-1/2	(2,25 – 5,59)	0 – 250	3 500
over 7-1/2 to 10	(5,60 – 7,46)	0 – 250	5 000
over 10 to 50	(7,47 – 37,3)	251 – 600	5 000
over 50 to 200	(37,4 – 149)	0 – 600	10 000
over 200	(over 150)	0 – 600	a

^aSee Table 4.3.9DV.1.

4.3.5.3.1DV.2.1.9 The circuit for the test required by 4.3.5.3.1DV.2.1.8 is to have a power factor of 0,9 – 1,0 and is to be limited to the current specified in Table 4.3.5.3.1DV.3. The open-circuit voltage of the test circuit is to be 100 to 105 percent of the specified voltage. The circuit is to be connected through a nonrenewable fuse that conducts twice its rated current for at least 12 s. The fuse rating is to be that of the branch-circuit overcurrent device to which the equipment is intended to be connected and not less than 20 A. One test is to be performed on each of three samples of the bonding conductor.

4.3.5.4DV.1 DR Modification to add the following:

The PROTECTIVE EARTHING CONDUCTOR shall be sized as specified in Article 250.122 and table 250.122 of the National Electrical Code, ANSI/NFPA 70.

4.3.5.4DV.2 D2 Modification:

For cord connected equipment, it shall not be possible to disconnect the PROTECTIVE EARTHING CONDUCTOR before power is removed.

4.3.5.4DV.3 D2 Modification:

For the internal grounding and bonding conductor color, see 4.3.8.3DV.

4.3.5.5DV DR Modification to add the following:

4.3.5.5DV.1 Means for grounding shall be provided as follows:

a) Fixed equipment shall be provided with a means of attachment of a terminal or the equivalent for connecting an equipment grounding conductor. The terminal shall be sized to receive a grounding conductor as specified in Section 250.122 and Table 250.122 of the National Electrical Code, ANSI/NFPA 70;

b) Portable equipment shall be provided with a power-supply cord with a grounding conductor. The grounding conductor shall be connected to the grounding blade of a grounding attachment plug and shall be connected to the frame or enclosure of the equipment. The surface of the insulation on the grounding conductor shall be green with or without one or more yellow stripes.

4.3.5.5DV.2 A wire binding screw intended for the connection of a field-installed equipment grounding conductor shall have a green colored head that is hexagonal, slotted, or both.

4.3.5.5DV.3 A pressure wire connector intended for connection of a field-installed equipment grounding conductor shall be plainly identified, such as being marked "G," "GR," "GRD," "Ground," "Grounding," or similar designation, or with the grounding symbol (IEC Publication 417, Symbol 5019).

4.3.5.5DV.4 A terminal for an equipment grounding conductor shall have no other function.

4.3.5.5DV.5 Grounding means provided in the form of a kit meets the requirement of 4.3.5.5DV.1(a). When the grounding means is not provided on the equipment as shipped, the equipment shall be marked in accordance with 6.3.6.4DV.9.

4.3.5.5.2DV D2 *Modification by replacing 4.3.5.5.2 with the following:*

For all cord-connected portable and stationary equipment, rated for a nominal 120-, 208-, or 240-V supply, employing a standard grounded, 3-wire attachment plug rated 20 A or less, the maximum permitted LEAKAGE CURRENT is 3,5 mA, measured in accordance with 5.2.3.5DV.

4.3.5.6DV DR *Deletion:*

The use of class II methods are not applicable. (National Electrical Code, ANSI/NFPA 70 article 250.112)

4.3.6.1.1DV D2 *Modification:*

The motor insulation system shall meet the requirements of the UL 1004 series of standards.

4.3.6.1.2DV.1 D2 *Modification:*

Item b) is not applicable.

4.3.6.1.2DV.2 D2 *Modification to add the following:*

Pollution degree 1 is obtainable by the encapsulation or hermetic sealing of the product. Typical constructions that meet this requirement are:

- a) The use of conformal coating on printed wiring board foil traces that complies with the requirements for Conformal Coatings in the Standard for Polymeric Materials – Electrical Equipment Evaluations, UL 746C;
- b) The use of any potting material or encapsulation, such as epoxy;
- c) The use of silicone rubber at a thickness of at least 1/32 in (0,8 mm);
- d) The use of a case or enclosure that is hermetically sealed against the entrance of an external atmosphere by means of fusion – such as from soldering, brazing, welding, or the fusion of glass to metal.

4.3.6.1.2DV.3 D2 Modification to add the following:

Pollution degree 2 is obtainable by reducing possibilities of conductive pollution and reducing possibilities of condensation or high humidity at the creepage distances:

- a) Typical constructions that reduce the possibility of conductive pollution are:
 - 1) The use of an un-ventilated enclosure; or
 - 2) The use of a ventilated enclosure when all ventilation openings are filtered.
- b) Typical constructions that reduce the effects of condensation or high humidity are:
 - 1) The use of a ventilated enclosure;
 - 2) The continuous application of heat through the use of heaters;
 - 3) The application of heat through continuous energization of the equipment, with interruptions such that cooling to the point of condensation does not occur; or
 - 4 The use of any coatings, such as solder masking, on printed wiring board foil traces.

4.3.6.1.3DV D2 Modification to add the following:

PDS shall be evaluated at least as Overvoltage Category III.

4.3.6.1.4DV DR Modification:

The use of a TT system is not applicable.

4.3.6.2.1DV D2 Modification:

For evaluating the clearances and creepage distances between uninsulated LIVE PARTS and the surface on which the equipment is mounted, the mounting surface is evaluated as part of an enclosure, unless any deformation of the enclosure will not reduce the clearances and creepage distances between the mounting surface and any uninsulated LIVE PART.

4.3.6.2.2DV D2 Modification to add the following:

PDS shall be evaluated at least as Overvoltage Category III.

4.3.6.2.4DV.1 DR Modification to add the following.

Conductors of different circuits must be separated, unless all conductors have an insulation rating equal to at least the maximum voltage of any of the circuits. See also DVC.1.1.3.

4.3.6.2.4DV.2 DR Modification to add the following:

4.3.6.2.4DV.2.1 Class 1, Class 2, and Class 3 remote-control, signaling, and power-limited circuits

4.3.6.2.4DV.2.1.1 In the field-wiring area, provisions for wiring for Class 2 and Class 3 circuits must meet the requirements for separation from Class 1 circuits in accordance with Section 725 of the National Electrical Code, ANSI/NFPA 70. See also DVC.1.1.3.

4.3.6.3DV DE Modification for clarification:

See 4.3.6.8.2.3 for additional information.

4.3.6.4DV.1 D1 Modification to add the following:**4.3.6.4DV.1.1 Measurement considerations**

4.3.6.4DV.1.1.1 Clearance distances at field wiring terminals shall comply with the requirements in Annex DVF, unless the design of the field wiring terminals precludes the possibility of reduced clearances due to stray strands or improper wiring INSTALLATION, in which case the requirements of the remainder of this clause are applicable.

4.3.6.4DV.1.1.2 The clearance distances at fuses and fuseholders are to be measured with the fuses having maximum standard dimensions in place, and shall be at least the spacings specified for the clearance and creepage distances to comply with Table 9 and Table 10.

4.3.6.4DV.1.1.3 For an enclosure without conduit openings or knockouts, spacings not less than the minimum specified in annex DVF shall be provided between uninsulated LIVE PARTS and a conduit bushing installed at any location to be used during INSTALLATION. A permanent marking on the enclosure, a template, or a full-scale drawing furnished with the equipment is usable to identify such locations.

4.3.6.4DV.1.1.4 For the spacing between an uninsulated LIVE PART and a bushing installed in a knockout, it is to be assumed that a bushing having the dimensions specified in Table 4.3.6.4DV.1 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

Table 4.3.6.4DV.1 – Dimensions of bushings

Trade size of conduit, in	Bushing dimensions, in (mm)			
	Maximum overall diameter		Height	
1/2	1	(25,4)	3/8	(9,5)
3/4	1-15/64	(31,4)	27/64	(10,7)
1	1-19/32	(40,5)	33/64	(13,1)
1-1/4	1-15/16	(49,2)	9/16	(14,3)
1-1/2	2-13/64	(56,0)	19/32	(15,1)
2	2-45/64	(68,7)	5/8	(15,9)
2-1/2	3-7/32	(81,8)	3/4	(19,1)
3	3-7/8	(98,4)	13/16	(20,6)
3-1/2	4-7/16	(113)	15/16	(23,8)
4	4-31/32	(126)	1	(25,4)
5	6-7/32	(158)	1-3/16	(30,2)
6	7-7/32	(183)	1-1/4	(31,8)

4.3.6.4DV.1.1.5 For Clamped insulating joints, clearance and creepage distances shall be measured through cracks illustrated in Figure C.1DV.1 unless the clamped joint complies with the test requirements in 5.2.13DV and complies with the additional requirements in C.1DV.

4.3.6.4DV.2 D1 Modification to add the following:

4.3.6.4DV.2.1 Feeder circuits

4.3.6.4DV.2.1.1 Equipment rated 600 V or less and intended for INSTALLATION in a feeder circuit, on the line side of branch circuit protective devices, shall comply with Table 4.3.6.4DV.2.

Table 4.3.6.4DV.2 – Equipment intended for INSTALLATION in a feeder circuit

Voltage between parts involved	Minimum clearances and creepage distances in inches (mm)			
	Between uninsulated parts of opposite polarity on line side		Between uninsulated parts on line side and any grounded dead metal	
	Creepage distance	Clearance	Creepage distance	Clearance
0 – 125	3/4 (19,1)	1/2 (12,7)	1/2 (12,7)	1/2 (12,7)
126 – 250	1-1/4 (31,8)	3/4 (19,1)	1/2 (12,7)	1/2 (12,7)
251 – 600	2 (50,8)	1 (25,4)	1 (25,4)	1 (25,4)

4.3.6.4.1DV.1 DE Modification to add the following informative note:

Use of Table 9 for determination of required clearances from mains connected circuits to earth is as follows:

- Determine impulse voltage from Table 7 for the circuit based on the SYSTEM VOLTAGE and appropriate overvoltage category
- Enter Table 9 column 1 with the impulse voltage value determined above

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- Verify that voltages in the circuit do not exceed the values indicated in columns 2 and 3
- If either of the values in columns 2 and 3 are exceeded then the appropriate row for the higher value shall be used for determining the minimum clearance
- If the values in columns 2 and 3 are not exceeded then the row for the impulse voltage shall be used for determining the minimum clearance based on the pollution degree in columns 4, 5 and 6

For columns 2 and 3, see the definition of **WORKING VOLTAGE** in 3.43.

4.3.6.4.1DV.2 D2 Modification to add the following:

4.3.6.4.1DV.2.1 Special coatings

4.3.6.4.1DV.2.1.1 Spacings required to be greater than 1/32 in (0,8 mm) may be reduced to 1/32 in (0,8 mm) on a printed wiring board when the printed wiring board spacings are:

- a) Covered by a layer of silicone rubber at least a 1/32 in (0,8 mm) thick; or
- b) Encapsulated by epoxy or potting material, without air bubbles. The silicone rubber and the potting material, when used, shall comply with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, or the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, or the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

4.3.6.5DV.1 D1 Modification:

Creepage distances at field wiring terminals shall comply with Annex DVF, unless the design of the field wiring terminals precludes the possibility of reduced creepage distances due to stray strands or improper wiring **INSTALLATION**, in which case the requirements of the remainder of this clause are applicable.

4.3.6.5DV.2 D1 Modification

Equipment rated 600 V or less and intended for **INSTALLATION** in a feeder circuit, on the line side of branch circuit protective devices, shall comply with Table 4.3.6.4DV.2.

4.3.6.5DV.3 D2 Modification to add the following:

4.3.6.5DV.3.1 Special coatings

Spacings of only 1/32 in (0,8 mm) on a printed wiring board are acceptable when the printed wiring board spacings are:

- a) Covered by a layer of silicone rubber at least a 1/32 in (0,8 mm) thick; or
- b) Encapsulated by epoxy or potting material, without air bubbles. The silicone rubber and the potting material, when used, shall comply with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances,

UL 94, or the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, or the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

4.3.6.5.1DV DE Modification to clarify:

The WORKING VOLTAGE in column 1 of Table 10 is the RMS value of the WORKING VOLTAGE across the creepage distance.

4.3.6.7DV D2 Modification:

The requirements in the second paragraph are not applicable. See 4.3.6.6.

4.3.6.8.1DV D2 Modification:

4.3.6.8.1DV.1 For solid insulation evaluation, impulse voltage test and partial discharge test are not required.

4.3.6.8.1DV.2 Compliance with the applicable test requirements of this standard satisfies the ageing requirement for insulation materials.

4.3.6.8.2.1DV D2 Modification:

For solid insulation evaluation, impulse voltage test is not required.

4.3.6.8.4.1DV.1 D2 Modification to add the following:

PWB shall conform with the Standard for Printed-Wiring Boards, UL 796 or the Standard for Flexible Materials Interconnect Constructions, UL 796F as appropriate, and shall be identified as suitable for direct support of LIVE PARTS with a minimum flammability rating of V-2.

4.3.6.8.4.1DV.2 DE Modification to clarify:

It should be noted that the voltage used to evaluate the clearance and creepage distances (when not treated as solid insulation) between adjacent tracks will be the WORKING VOLTAGE, peak or rms respectively, between those tracks.

4.3.6.8.5DV DE Modification to clarify;

Wound components shall also meet the requirements of 4.3.6.8.3. For example, this applies to transformers, solenoids, contactor coils and the like.

4.3.7DV D2 Modification to replace 4.3.7 with the following:

See Annex DVD for enclosure requirements.

4.3.8.1DV.1 D2 Modification to add the following:**4.3.8.1DV.1.1 CONTROL CIRCUIT Wiring**

4.3.8.1DV.1.1.1 Other than as noted in 4.3.8.1DV.1.1.2, through 4.3.8.1DV.1.1.5, Primary and secondary circuit internal wiring shall be provided with additional protection that complies with 4.3.8.1DV.1.1.6 when it is:

- a) Connected to the load side of the branch circuit short circuit protection (see 4.3.9DV.1);
- b) Located in a circuit that incorporates the coil of an internal or external motor control contactor (such as for bypass); and
- c) Sized from 22 – 12 AWG (0,324 – 3,3 mm²).

4.3.8.1DV.1.1.2 Wiring located in a Class 1 power-limited or Class 3 remote-CONTROL CIRCUIT or located in a Class 2 (see Annex DVC.1.4), Limited Voltage/Current (see Annex DVC.1.5), Limited Energy (see Annex DVC.1.6) or Limiting Impedance (see Annex DVC.1.7) secondary circuit is not required to be additionally protected.

4.3.8.1DV.1.1.3 Any wiring measuring a maximum of 12 in (305 mm) long is not required to be additionally protected.

4.3.8.1DV.1.1.4 Any wiring connected to a printed wiring board having no connections external to the drive and having no more than casual contact with insulated or un-insulated parts of opposite polarity or with grounded parts is not required to be additionally protected.

4.3.8.1DV.1.1.5 When an instantaneous trip circuit breaker is used or intended for use as the branch circuit short circuit protection (see 4.3.9DV.1) and its rating or trip setting is not more than the applicable value specified in Table 4.3.8.1DV.1, then wiring is not required to be additionally protected when the drive is marked in accordance with 6.3.7DV.4.1.

Table 4.3.8.1DV.1 – Branch-circuit short-circuit protection

Control-circuit wire size, AWG (mm ²)		Maximum rating of branch-circuit-protective device, A	
		Conductors within enclosure	Conductors outside enclosure
22	(0,32)	12	3
20	(0,52)	20	5
18	(0,82)	25	7
16	(1,3)	40	10
14	(2,1)	100	45
12	(3,3)	120	60

4.3.8.1DV.1.1.6 Other than as noted in 4.3.8.1DV.1.1.7 and 4.3.8.1DV.1.1.8, The additional wiring protection required by 4.3.8.1DV.1.1.1 shall:

- a) Be located within the drive;
- b) Be rated in accordance with Table 4.3.8.1DV.2;
- c) Be provided in each ungrounded conductor;
- d) Be located no more than 12 in (305 mm) from the point where the wiring is connected to its source of power;
- e) Either be a supplementary or a branch circuit type fuse in accordance with the UL 248 series or a branch circuit breaker in accordance with the Standard for Molded Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures, UL 489; and
- f) Be provided with a marking in accordance with 6.3.7DV.4.1.2.

4.3.8.1DV.1.1.7 The additional protection noted in 4.3.8.1DV.1.1.6 is not required to be included within the drive when it is shipped from the factory and meets the following:

- a) The manufacturer makes available an accessory kit that complies with 4.3.8.1DV.1.1.6;
- b) This accessory kit is evaluated for field INSTALLATION; and
- c) The drive is marked in accordance with 6.3.7DV.4.1.3.

4.3.8.1DV.1.1.8 The additional protection noted in 4.3.8.1DV.1.1.6 is not required to be shipped with the drive when the fuseholder is included within the drive and the unit is marked in accordance with 6.3.7DV.4.1.4.

Table 4.3.8.1DV.2 – Overcurrent protection

Control-circuit wire Size, AWG (mm ²)		Maximum protective device rating, A
22	(0,32)	3
20	(0,52)	5
18	(0,82)	7
16	(1,3)	10
14	(2,1)	20
12	(3,3)	25

4.3.8.1DV.1.1.9 For drives with a short circuit current rating in excess of 10 000 A, the additional wiring protection required by 4.3.8.1DV.1.1.1 shall comply with 4.3.8.1DV.1.1.6 and be rated greater than or equal to the marked short circuit current rating of the drive. When fuses are used for this protection, they shall be Class CC, CF, G, J, L, R, or T and be provided with an appropriate branch circuit type fuseholder. These fuses are not required to be factory installed.

4.3.8.1DV.2 D2 Modification to add the following:

4.3.8.1DV.2.1 Other than CONTROL CIRCUIT wiring

4.3.8.1DV.2.1.1 Primary overcurrent protection (not power circuit)

4.3.8.1DV.2.1.1.1 All wiring including bus bars and interconnecting cables used in the distribution of primary electric energy within and between units of equipment and all transformers and other loading devices connected to the primary circuit shall be protected against burnout and damage to insulation resulting from any overload or short-circuit condition that occurs during operation of the equipment. The protection shall be sized based on the levels identified in Tables 4.3.8.1DV.1 and 4.3.8.1DV.2.

4.3.8.1DV.2.1.1.2 The protection referenced in 4.3.8.1DV.2.1.1.1 shall be provided by overcurrent devices included as integral parts of the control equipment or, when rated in accordance with 4.3.8.1DV.2.1.1.4, from the protection associated with the branch circuit to which the equipment is connected.

4.3.8.1DV.2.1.1.3 Overcurrent protective devices that are provided within the equipment and are types that set the requirements for branch-circuit protection in accordance with the National Electrical Code, ANSI/NFPA 70 – for example, circuit breakers or Class CC, CF, J, T, G, H, K, L, RK1, or RK5 cartridge fuses or Type S fuses – comply with the requirement in 4.3.8.1DV.2.1.1.2. Other types of overcurrent protection devices are to be investigated to determine their acceptability for the application.

4.3.8.1DV.2.1.1.4 The ratings of an overcurrent device in series with connecting wiring shall not exceed the following:

- a) For motor loads alone – 300 percent of the motor full-load current observed during the maximum normal operation of the system.
- b) For resistive loads, and for combination resistive and reactive loads, with or without motor loads – 250 percent of the full-load current of the circuit under evaluation.

4.3.8.1DV.2.1.1.5 A device providing overcurrent protection shall be of a type that is intended for use when supplied directly by the branch circuit to which the equipment is connected unless additional protection intended for the use is provided in the equipment.

4.3.8.1DV.2.1.1.6 An overcurrent protective device shall be connected between the ungrounded branch-circuit supply conductor and the load.

4.3.8.1DV.2.1.2 Secondary overcurrent protection

4.3.8.1DV.2.1.2.1 Cables and wiring located in Class 2 circuits do not require any additional overload or short-circuit protection.

4.3.8.1DV.2.1.2.2 All external secondary-circuit interconnecting cables and all secondary-circuit wiring between units shall be protected against burnout and damage to the insulation resulting from any overload or short-circuit condition that occurs during use of the equipment.

4.3.8.1DV.2.1.2.3 The overcurrent protection provided in the primary circuit of a transformer is considered to provide protection for the secondary circuit wiring, when it operates to protect the secondary circuit under all overload conditions including short circuit.

4.3.8.1DV.2.1.2.4 A conductor provided with overcurrent protection complying with the National Electrical Code, ANSI/NFPA 70, complies with 4.3.8.1DV.2.1.2.2.

4.3.8.1DV.2.1.2.5 Secondary circuits that are derived from power supplies or other sources are not prohibited from being used when the output wiring carries the maximum current available from the power supply without discoloration or softening of insulation, and when the power supplies or other sources:

- a) Are inherently limited; or
- b) Include sensing devices whose operation achieves the same result (prevention of burnout and damage to insulation resulting from overload) or de-energizes the equipment.

4.3.8.3DV D2 *Modification to add the following:*

Internal Grounding and Bonding Conductor Color Insulated grounding and bonding conductors smaller than 4 AWG shall be identified by the color green with or without one or more yellow stripes throughout the entire product. Insulated conductors sized 4 AWG or larger shall be identified in this manner, or shall be identified at each termination point by a green marking, such as green tape wrapped around the conductor. No other leads shall be so identified. This requirement does not apply to a green or green/yellow conductor provided in a wiring harness, ribbon cable, or similar prefabricated wiring assembly, which is not likely to be mistaken for a grounding conductor.

4.3.8.4DV.1 D2 *Modification to add the following:*

When stranded internal wiring is connected to a wire-binding screw, the construction shall be such that loose strands of wire do not contact:

- a) Other uninsulated LIVE PARTS not always of the same polarity as the wire; and

b) De-energized metal parts.

Means, that meet the intent of the requirement, include machine- or tool-applied pressure terminal connectors, soldering lugs, crimped eyelets, or the soldering of all strands of the wire together.

4.3.8.4DV.2 D2 Modification to add the following:

4.3.8.4DV.2.1 A splice shall be provided with insulation equivalent to that of the wires involved.

4.3.8.4DV.2.2 In determining when splice insulation consisting of coated-fabric, thermoplastic, or other types of tubing is usable, electrical and mechanical properties including dielectric voltage-withstand ability, heat resistance, and moisture resistance shall be evaluated. For requirements of additional insulation, 4.3.8.4DV.2.3 applies. Thermoplastic tape shall not be wrapped over a sharp edge or connection.

4.3.8.4DV.2.3 Additional insulation, when used, shall be insulating sleeving, tubing, or a wrapping of not less than two layers of insulating tape. The insulation shall be made of materials rated for the temperature and voltage involved.

4.3.8.6DV D2 Modification to add the following:

4.3.8.6DV.1 Flexing

4.3.8.6DV.1.1 Wiring that is subject to flexing during servicing, such as that from a stationary part to a part mounted on a hinged door or other moveable part, shall be provided with insulation not less than 1/32 in (0,8 mm) thick. The wiring shall be flexible cord or shall comply with 4.3.8.6DV.1.2 or 4.3.8.6DV.1.3.

4.3.8.6DV.1.2 Wiring other than flexible cord may be used when provided with additional insulation at any point where it is flexed. This additional insulation shall be insulating sleeving, tubing, or a wrapping of not less than two layers of insulating tape. The insulation shall be made of materials rated for the temperature and voltage involved.

4.3.8.6DV.1.3 Wiring other than flexible cord may be used without additional insulation when damage to the wiring is not evident and the wiring withstands the Dielectric Voltage-Withstand Test, 5.2.3.2 applied between conductors and between conductors and ground, after the wiring is mounted as intended and tested by opening the door or other moveable part as far as possible and then returning it to the original position for 500 cycles of operation (restraints such as a chain are to remain in place).

4.3.8.7DV DR Modification to add the following:

4.3.8.7DV.1 The equipment shall be constructed so that the INSTALLATION can comply with requirements as specified in Article 310 and Tables 310-16 or 310-17, as appropriate, of the National Electrical Code, ANSI/NFPA 70.

4.3.8.7DV.2 Power conversion equipment intended for permanent connection to the power supply shall have provision for connection of one of the applicable wiring systems in accordance with the National Electrical Code, ANSI/NFPA 70, unless it is intended to be drilled or punched in the field to accommodate a wiring system and is provided with appropriate INSTALLATION instructions.

4.3.8.7DV.3 A tapped hole in a cast metal enclosure for the attachment of threaded rigid conduit shall be provided with:

- a) An integral bushing having a smooth, rounded inlet hole with a diameter the same as the internal diameter of a standard bushing to provide protection for the conductors equivalent to that provided by such a bushing, or shall be located so that a standard bushing is able to be attached to the end of the conduit; and
- b) At least three full threads when tapped all the way through the wall of an enclosure, or with at least 3-1/2 full threads when used with an integral bushing.

4.3.8.7DV.4 It is assumed that power conversion equipment having a current rating or a horsepower rating with a full-load motor current as specified in Table DVE.1 or DVE.2 is intended to be connected with wire of a size determined in accordance with Table 310-16 of the National Electrical Code, ANSI/NFPA 70. Unless marked in accordance with 6.3.6.4DV.2 for use only with wire rated 75°C (167°F), the size is to be based upon wire rated for a temperature 60°C (140°F) for equipment rated 100 A or less; and upon wire rated for 75°C for equipment rated greater than 100 A. The type of insulation is not specified.

4.3.8.7DV.5 Cord-connected equipment

4.3.8.7DV.5.1 Power conversion equipment intended to be cord connected to the power supply shall be provided with a length, size, and type of hard-service or junior hard-service flexible cord, such as Type S, SJ, or the equivalent, evaluated for the use conditions, that is terminated in a grounding type attachment plug and is rated for the temperature and voltage involved.

4.3.8.7DV.5.1.1 Equipment is able to be cord-connected to the power supply when the equipment is:

- a) Portable;
- b) Free standing or stationary (not permanently connected to building wiring);
- c) As described in 4.3.8.7DV.5.7.

4.3.8.7DV.5.1.2 The cord ampacity, as specified in Table 4.3.8.7DV.1, shall not be less than the ampacity required for the equipment in 4.3.8.8.2DV.1.

Table 4.3.8.7DV.1 – Ampacity of flexible cord

Conductor size, AWG	Number of conductors	
	2	3 ^a
18	10	7
16	13	10
14	18	15
12	25	20
10	30	25
8	40	35
6	55	45
4	70	60
2	95	80

^a Where more than three current-carrying conductors are provided, the ampacity of each of the conductors shall be: 80 percent of these values for 4–6 conductors; 70 percent of these values for 7–9 conductors; 50 percent of these values for 10 – 20 conductors; 45 percent of these values for 21 – 30 conductors; 40 percent of these values for 31 – 40 conductors; and 35 percent of these values for 41 or more conductors.

4.3.8.7DV.5.1.3 Cord-connected equipment provided with a standard attachment plug whose ampere rating exceeds the ampacity of the power supply cord shall be provided with an integral overcurrent protective device rated not more than the ampacity of the conductors. Cord-connected equipment provided with a multi-pin connector or without any attachment plug or connector shall be:

- a) Provided with integral overcurrent protection rated not more than the ampacity of the conductors; or
- b) Marked as in 6.3.7DV.6.1.1 to indicate the ratings of the overcurrent protection required to be installed in the field.

4.3.8.7DV.5.2 Strain relief shall be provided on power supply or signal multicable cords. The strain relief shall be tested in accordance with 5.2.12DV.1.

4.3.8.7DV.5.3 At the point at which the cord passes through the enclosure wall, protection shall be provided to prevent cord abrasion.

4.3.8.7DV.5.4 When a knot serves as strain relief in an attached flexible cord, any surface that the knot contacts shall be free from projections, sharp edges, burrs, fins and similar irregularities, that abrade insulation on the conductors.

4.3.8.7DV.5.5 Means shall be provided to prevent the supply cord from being pushed into the enclosure of the equipment through the cord entry hole when such displacement results in:

- a) Subjecting the supply cord to mechanical damage;
- b) Exposing the supply cord to a temperature higher than that for which it is rated;
- c) Reducing spacings, such as to a metal strain-relief clamp, below the minimum required values; or

d) Damaging internal connections or components.

To determine compliance, the supply cord shall be tested in accordance with 5.2.12DV.1.2, Push-Back Relief Test.

4.3.8.7DV.5.6 A power-supply or signaling connecting cord, used on equipment having a:

- a) Type 3, 3R, 3S, 4, 4X, 6, or 6P enclosure shall be evaluated for outdoor use;
- b) Type 6 or 6P enclosure shall be water resistant; and
- c) Type 12, 12K, or 13 enclosure shall be oil resistant (such as SO, SJO, or STO).

4.3.8.7DV.5.7 For a device that is intended to provide a signaling function, an attachment plug is not required.

4.3.8.7DV.6 A lead that is intended to be spliced in the field to a circuit conductor shall not be smaller than 18 AWG (0,82 mm²) and the insulation, when of rubber or thermoplastic, shall not be less than 1/32 in (0,8 mm) thick.

4.3.8.8.1DV D2 *Modification to add the following:*

4.3.8.8.1DV.1 Terminals shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310, the Standard for Wire Connectors, UL 486A-486B, the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E or the Standard for Terminal Blocks, UL 1059 as appropriate. Terminals that will be wired in the field shall be suitable for field wiring.

4.3.8.8.1DV.2 A pressure terminal connector, including one that is compression tool applied, for field connection to line or load is not required to be provided for equipment with field wiring larger than 10 AWG (5,3 mm²) when the construction complies with the following conditions:

- a) Component terminal connectors are available from the equipment manufacturer and one or more are specified for field INSTALLATION on the equipment.
- b) A fastening device, such as a stud, nut, bolt, spring or flat washer, or similar device, that is required for INSTALLATION is:
 - 1) Provided as part of the component terminal assembly; or
 - 2) Mounted on or separately packaged with the equipment.
- c) The INSTALLATION of the terminal assembly does not involve the loosening or disassembly of a part other than a cover or other part giving access to the terminal location. The means for securing the terminal connectors shall be accessible for tightening before and after INSTALLATION of the conductor.
- d) When the pressure connector provided in a component terminal assembly requires the use of a special tool for securing the conductor, instructions referencing use of the tool shall be included with the component assembly or with the equipment.

e) **INSTALLATION** of a pressure terminal connector in the intended manner shall result in a product that complies with the requirements in this standard.

f) The equipment is marked in accordance with 6.3.6.4DV.9.

4.3.8.8.1DV.3 A terminal to which field wiring greater than 10 AWG (5,3 mm²) is to be connected shall be a soldering lug or pressure wire connector. A terminal to which a 10 AWG (5,3 mm²) or smaller wiring connection is to be made shall consist of a clamp or binding screw with a terminal plate having upturned lugs or the equivalent to hold the wire in position, or shall be a soldering lug or pressure wire connector.

4.3.8.8.1DV.4 A wire-binding screw to which field-wiring connections of conductors larger than 14 AWG (2,1 mm²) are made shall be No. 8 or larger.

4.3.8.8.1DV.5 A wire-binding screw intended only for field-wiring connection of a conductor sized 14 AWG (2,1 mm²) or smaller shall be No. 6 or larger.

4.3.8.8.1DV.6 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0,030 in (0,76 mm) thick for a 14 AWG (2,1 mm²) or smaller wire, and not less than 0,050 in (1,27 mm) thick for a wire larger than 14 AWG (2,1 mm²). There shall be at least two full threads in the plate unless fewer threads result in a secure connection in which the threads do not strip upon application of a 20 lb-in (2.3 N-m) tightening torque.

4.3.8.8.1DV.7 A terminal plate formed from stock having the required thickness specified in 4.3.8.8.1DV.6 is able to have the metal extruded at the tapped hole for the binding screw to provide two full threads.

4.3.8.8.1DV.8 A wire-binding screw shall thread into metal.

4.3.8.8.1DV.9 A field-wiring terminal made with an aluminum body or intended for connection of aluminum wire shall be rated AL7CU or AL9CU.

4.3.8.8.2DV *DR Modification to add the following:*

4.3.8.8.2DV.1 The terminals of power conversion equipment shall each be provided with wiring terminals or leads for connection of conductors having an ampacity as follows:

a) For line terminals, not less than 125 percent of maximum rated input current and not less than 125 percent of full load motor current.

b) For motor load terminals, not less than 125 percent of the maximum marked output current and not less than 125 percent of the full-load motor current specified in Table DVE.1 or DVE.2 for output horsepower ratings.

c) For terminals of a DC bus circuit intended to supply one or more inverters, not less than 125 percent of the maximum marked current for those terminals.

d) For power terminals not addressed in a), b), c) or e), not less than 100 percent of the maximum marked current for those terminals.

e) Unless marked in accordance with 6.3.6.4DV.10, for equipment controlling a direct-current motor intended to be operated from a rectified single-phase power supply.

1) One-hundred ninety percent of full load current when a half wave rectifier is used.

2) One-hundred fifty percent of full load current when a full wave rectifier is used.

Where field wiring conductors will be larger than 10 AWG (5,3 mm²), the wiring terminals or leads may be omitted in accordance with 4.3.8.8.1DV.2.

4.3.8.8.2DV.2 The conductor size shall be determined from the 60°C or 75°C column of Table 4.3.8.8.2DV.1 based on the value calculated in 4.3.8.8.2DV.1.

4.3.8.8.2DV.2.1 Unless marked otherwise, use the 60°C wire for 100 A and less and 75°C wire above 100 A.

4.3.8.8.2DV.2.2 For conductors in parallel, conductors shall not be smaller than 1/0 AWG.

4.3.8.8.2DV.3 When a wiring terminal is able to receive the next larger size conductor than that required in 4.3.8.8.2DV.2, the terminal shall comply with secureness and pullout requirements with that size conductor, unless the equipment is marked to restrict its use to only the smaller size conductor in accordance with 6.3.6.4DV.8.

Table 4.3.8.8.2DV.1 – Ampacities of insulated conductors

Wire size AWG (mm ²)		60°C (140°F)		75°C (167°F)	
		Copper	Aluminum	Copper	Aluminum
24	(0,2)	2	–	–	–
22	(0,3)	3	–	–	–
20	(0,5)	5	–	–	–
18	(0,8)	7	–	–	–
16	(1,3)	10	–	–	–
14	(2,1)	15	–	15	–
12	(3,3)	20	15	20	15
10	(5,3)	30	25	30	25
8	(8,4)	40	30	50	40
6	(13,3)	55	40	65	50
4	(21,2)	70	55	85	65
3	(26,7)	85	65	100	75
2	(33,6)	95	75	115	90
1	(42,4)	110	85	130	100
1/0	(53,5)	–	–	150	120
2/0	(67,4)	–	–	175	135
3/0	(85,0)	–	–	200	155
4/0	(107,2)	–	–	230	180
–	–	–	–	–	–
kcmil	–	–	–	–	–
250	(127)	–	–	255	205
300	(152)	–	–	285	230
350	(177)	–	–	310	250
400	(203)	–	–	335	270
500	(253)	–	–	380	310
600	(304)	–	–	420	340

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Table 4.3.8.8.2DV.1 – Ampacities of insulated conductors Continued

Wire size AWG (mm ²)		60°C (140°F)		75°C (167°F)	
		Copper	Aluminum	Copper	Aluminum
700	(355)	–	–	460	375
750	(380)	–	–	475	385
800	(405)	–	–	490	395
900	(456)	–	–	520	425
1 000	(506)	–	–	545	445
1 250	(633)	–	–	590	485
1 500	(760)	–	–	625	520
1 750	(887)	–	–	650	545
2 000	(1 013)	–	–	665	560

NOTES

1. For multiple-conductors of the same size (1/0 AWG or larger) at a terminal, the ampacity is equal to the value in Table 4.3.8.8.2DV.1 for that conductor multiplied by the number of conductors that the terminal accommodates.
2. These values of ampacity apply only when not more than three conductors are to be field-installed in the conduit. When four or more conductors, other than a neutral that carries the unbalanced current, are to be installed in a conduit (as occurs because of the number of conduit hubs provided in outdoor equipment, the number of wires required in certain polyphase systems, or other reasons), the ampacity of each of the conductors shall be 80 percent of these values when 4 – 6 conductors are involved, 70 percent of these values when 7 – 24 conductors, 60 percent of these values when 25 – 42 conductors, and 50 percent of these values when 43 or more conductors.

4.3.8.8.2DV.4 Control terminals

4.3.8.8.2DV.4.1 Terminals for control, signal, or sensor circuits shall accept 14 AWG (2,1 mm²) minimum, unless marked (on the product or INSTALLATION instructions) for the connection of 18 AWG (0,82 mm²) and 16 AWG (1,3 mm²) conductor size(s).

4.3.8.8.4DV DR Modification to replace 4.3.8.8.4 with the following:

4.3.8.8.4DV.1 Wire bending space for wires 8 AWG (8,4 mm²) and greater

4.3.8.8.4DV.1.1 The space between the end of the soldering lug or pressure wire connector for the connection of field-installed wire and the wall of the enclosure toward which the wire is directed upon leaving the lug or connector shall be at least that specified in Table 4.3.8.8.4DV.1.

4.3.8.8.4DV.1.2 The space specified in 4.3.8.8.4DV.1.1 is to be the length of a straight line extending from the end of the soldering lug or pressure wire connector where the wire is connected toward and perpendicular to the enclosure wall toward which the wire is initially directed.

4.3.8.8.4DV.1.3 When a wire is restricted by barriers or other means from being bent where it leaves the connector, the distance required by 4.3.8.8.4DV.1.1 and Table 4.3.8.8.4DV.1 is to be measured from the end of the barrier. A terminal lug or connector as described in 4.11DV.1.2 is to be repositioned anywhere within the limits to obtain the shortest distance for measurement.

4.3.8.8.4DV.1.4 The wire size used to determine the wire bending space is based on 125 percent of the motor full-load current rating. See Tables DVE.1 or DVE.2 for the full-load current rating of horsepower rated motors.

Table 4.3.8.8.4DV.1 – Wire bending space at the terminals of enclosed power conversion equipment

Size of wire ^a AWG or kcmil (mm ²)		Minimum bending space, Terminal to wall, in (mm)					
		Wires per terminal					
		1		2		3	
14 – 10	(2,1 – 5,3)	–	–	–	–	–	–
8 – 6	(8,4 – 13,3)	1-1/2	(38)	–	–	–	–
4 – 3	(21,2 – 26,7)	2	(51)	–	–	–	–
2	(33,6)	2-1/2	(64)	–	–	–	–
1	(42,4)	3	(76)	–	–	–	–
1/0	(53,5)	5	(127)	5	(127)	7	(178)
2/0	(67,4)	6	(152)	6	(152)	7-1/2	(191)
3/0	(85,0)	7	(178)	7	(178)	8	(203)
4/0	(107,2)	7	(178)	7	(178)	8-1/2	(216)
250	(127)	8	(203)	8	(203)	9	(229)
300	(152)	10	(254)	10	(254)	11	(279)
350	(177)	12	(305)	12	(305)	13	(330)
400	(203)	12	(305)	12	(305)	14	(356)
500	(253)	12	(305)	12	(305)	15	(381)
600	(304)	14	(356)	16	(406)	18	(457)
700	(355)	14	(356)	16	(406)	20	(508)
750 – 800	(380 – 405)	18	(457)	19	(483)	22	(559)
900	(456)	18	(457)	19	(483)	24	(610)

NOTE – Where provision for more than three conductors per terminals is provided, the bending space shall be in accordance with the appropriate tables for cabinets and boxes in Article 312 of the National Electrical Code, ANSI/NFPA 70.

^a The wire size is to be based on 4.3.8.8.2DV.1.

4.3.9DV.1 D2 Modification:

4.3.9DV.1.1 The number, arrangement, and ratings or settings of protective devices intended to provide motor branch-circuit short-circuit and ground-fault protection shall be as required by Part IV, Article 430 of the National Electrical Code, ANSI/NFPA 70.

4.3.9DV.1.2 The first sentence of the second paragraph is replaced by: For co-ordination with upstream protection devices, the manufacturer shall specify a maximum PROSPECTIVE SHORT-CIRCUIT CURRENT rating. The short-circuit current rating shall be no less than the current specified in Table 4.3.9DV.1 based on the horsepower rating of the drive. For a drive rated only in current and not in horsepower, the equivalent horsepower rating shall be as specified in Tables DVE.1 and DVE.2.

4.3.9DV.2 D2 Modification to add the following:

4.3.9DV.2.1 Other than as noted in 4.3.9DV.2.2, a drive series shall comply with the Short Circuit Test – High Fault Currents, 5.2.3.6.2.1DV.5, and the Short Circuit Test – Standard Fault Currents, 5.2.3.6.1DV, when it is intended to be rated with:

- a) A standard fault current value in accordance with Table 4.3.9DV.1; and
- b) A high fault current value in excess of the standard fault current value.

4.3.9DV.2.2 A drive series is in compliance with the Short Circuit Test – High Fault Currents, 5.2.3.6.2.1DV.5, without additional testing when:

- a) The drive series uses SOLID STATE SHORT CIRCUIT PROTECTION circuitry for compliance with the standard fault current short circuit test; and
- b) The SOLID STATE SHORT CIRCUIT PROTECTION circuitry is used in accordance with 4.3.9DV.2.3.

Table 4.3.9DV.1 – Short circuit test current values for devices rated 600 V or less

Ratings		Test current
hp	(kW)	A
0 – 50	(0 – 37,3)	5 000
51 – 200	(39 – 149)	10 000
201 – 400	(150 – 298)	18 000
401 – 600	(299 – 447)	30 000
601 – 900	(448 – 671)	42 000
901 – 1 600	(672 – 1 193)	85 000
1 601 or more	(1 194 or more)	100 000
		125 000
		150 000 or 200 000

4.3.9DV.2.3 Any model is able to serve as the representative model from a series that uses SOLID STATE SHORT CIRCUIT PROTECTION circuitry for compliance with this test. As an example, for a drive series with models rated from 25 hp to 700 hp (18,64 – 521,99 kW), the testing of the 25 hp model at 5 000 A represents the testing of any models at 10 000 A, 18 000 A, 30 000 A, or 42 000 A. In addition, short circuit testing may be conducted at 5 000 A to represent higher short circuit test values when all of the following requirements are met:

- a) The same solid state protection circuitry is used throughout the series;
- b) Any revisions to the protection circuitry requires re-evaluation;
- c) The protection circuitry turns off the output devices (Insulated Gate Bi-polar Transistor (IGBT), bi-polar, and similar devices prior to the time in which the devices are damaged by any increase in current. This is based on the manufacturer's rating of the output devices (typically 10 µs for IGBTs, and 50 µs for bi-polars);
- d) Any increase in current experienced by the output devices is the result of the DC bus capacitor bank discharging;
- e) The output devices are turned off by the protection circuitry prior to any significant increase in the input current;

f) In response to a higher standard fault current (for example 42 000 A vs. 5 000 A), the protection circuitry shall react to the higher standard fault current (42 000 A) in the same or shorter time as the lower standard fault current (5 000 A). This may be verified through testing at the higher fault current value or through inspection of the SOLID STATE SHORT CIRCUIT PROTECTION hardware and software circuitry; and

g) When relying on current sensing (as opposed to output device collector voltage sensing) to actuate the protection circuitry, either the DC bus or all main motor output lines shall be monitored.

4.3.9DV.2.4 A drive that does not rely solely on solid-state short circuit protection shall also comply with the short circuit test power factor requirements in the Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A.

4.3.10DV D2 Deletion:

The requirements of 4.3.10 are not applicable.

4.3.11DV D1 Modification:

4.3.11DV.1 In modification of the first sentence, the discharge requirement is to achieve a voltage less than 50 V within 1 min after the removal of power from the PDS/CDM/BDM.

4.3.11DV.2 In the case of plugs or similar devices that can be disconnected without the use of a tool, the discharge voltage requirement is to achieve a voltage less than 50 V within 1 s.

4.3.12DV D2 Deletion:

This clause is not applicable because high-voltage products are outside of the scope of this document.

4.3.13DV DR Addition:

4.3.13DV.1 CONTROL CIRCUIT Transformer grounding

4.3.13DV.1.1 Where the secondary of a CONTROL CIRCUIT transformer is intended to supply an external circuit, the secondary shall be grounded under any of the following:

- a) If the transformer primary voltage exceeds 150 V to ground, and the secondary voltage is 50 V or less;
- b) If the secondary voltage is 50 V to 1 000 V, and the secondary can be grounded such that the maximum voltage to ground for the ungrounded conductors does not exceed 150 V.

4.3.14DV DR Addition:**4.3.14DV.1 Transformers protection****4.3.14DV.1.1 CONTROL CIRCUIT transformer**

4.3.14DV.1.1.1 Other than as noted in 4.3.14DV.1.1.3, a transformer whose secondary supplies a circuit incorporating the coil of an internal or external motor control contactor (such as for soft starting) shall be provided with additional protection that complies with 4.3.14DV.1.1.2.

4.3.14DV.1.1.2 The additional transformer protection required by 4.3.14DV.1.1.1 shall either be a supplementary or a branch circuit type fuse or circuit breaker in accordance with the UL 248 series or the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit Breaker Enclosures, UL 489, respectively and shall:

a) For the primary:

- 1) Be provided in each ungrounded conductor of the transformer primary and rated or set in accordance with Table 4.3.14DV.1; and either,
- 2) Be provided in the transformer primary and rated or set at a maximum of six times the rated transformer primary current when the transformer has no more than 6 percent impedance and coordinated thermal overload protection is arranged to interrupt the primary circuit; or,
- 3) Be provided in the transformer primary and rated or set at a maximum of four times the rated transformer primary current when the transformer has more than 6 percent and less than 10 percent impedance and coordinated thermal overload protection is arranged to interrupt the primary circuit;

b) For the primary and secondary:

- 1) Be provided in the transformer primary and rated or set at not more than 250 percent of the rated transformer primary current and provided in the transformer secondary and rated or set at not more than 125 percent of the rated transformer secondary current; or
- 2) Be provided in the transformer primary and rated or set at not more than 250 percent of the rated transformer primary current and provided in the transformer secondary and rated or set in accordance with line 2 of Table 4.3.14DV.1 when the rated transformer secondary current is 2 A or more.

4.3.14DV.1.1.3 A transformer is not required to be additionally protected when any of the following conditions exist:

- a) The transformer secondary supplies a Class 1 power-limited or Class 3 remote-CONTROL CIRCUIT or supplies a Class 2 (see DVC.1.4), Limited Voltage/Current (see DVC.1.5), Limited Energy (see DVC.1.6) or Limiting Impedance (see DVC.1.7) secondary circuit;**

- b) The transformer secondary is rated less than 50 VA, is inherently protected and is an integral part of the drive;
- c) The branch circuit protection provides the required additional protection; or,
- d) The additional protection is provided by other means that comply with the applicable requirements in the National Electrical Code, NFPA 70.

Table 4.3.14DV.1 - Maximum rating of overcurrent device

Rating primary current, A	Maximum rating of overcurrent protective device expressed as a percent of transformer primary current rating
Less than 2	500
2 to less than 9	167
9 or more	125 ^a
^a When 125 percent of the current does not correspond to a standard fuse or nonadjustable circuit breaker rating, then the next higher standard rating shall be used. See Section 240-6 of the National Electrical Code, ANSI/NFPA 70.	

4.3.14DV.1.2 CONTROL CIRCUIT wiring and transformer combination

4.3.14DV.1.2.1 For a single phase transformer with only one 2-wire secondary, compliance with the additional wiring and transformer protection requirements of 4.3.8.1DV.1.1 and 4.3.14DV.1.1.1 is obtainable by protective devices in any ungrounded primary conductor. The protective devices shall:

- a) Be located in the primary of the transformer;
- b) Have its maximum rating or setting limit calculated by using the appropriate protective device value from Table 4.3.8.1DV.2 based on the AWG of the secondary wiring and multiplying this value by the secondary-to-primary voltage ratio of the transformer; and
- c) Have its actual rating or setting be within this maximum limit and also be in accordance with 4.3.14DV.1.1.2 (a) and (b).

4.3.14DV.1.3 Transformers

4.3.14DV.1.3.1 Other than as noted in 4.3.14DV.1.3.2, a transformer employed in PDS/CDM/BDM shall comply with the appropriate standard for transformers, unless the load is part of the equipment, in which case the transformer shall comply with the Temperature Test, 5.2.3.8, and the AC or DC Voltage Test, 5.2.3.2.

4.3.14DV.1.3.2 Pulse and current transformers constructed in a manner other than required by the applicable UL transformer Standard are in compliance with the requirement of 4.3.14DV.1.3.1 when they withstand, without breakdown, a dielectric voltage withstand potential in accordance with the AC or DC Voltage Test, 5.2.3.2, applied between the primary and secondary windings. An example of transformer constructions for which this applies are those that rely upon magnet wire coating to provide isolation instead of interwinding tape.

4.3.15DV D2 Addition:

4.3.15DV.1 Blower motors

4.3.15DV.1.1 Other than blower motors located in a Class 2 (see DVC.1.4), Limited Voltage/Current (see DVC.1.5) or Limiting Impedance (see DVC.1.7) secondary circuit, each blower motor shall be provided with:

- a) Locked rotor protection in accordance with 4.3.15DV.1.2; and,
- b) An enclosure in accordance with Enclosures, DVD.

4.3.15DV.1.2 The locked rotor protection required by 4.3.15DV.1.2 shall:

- a) Comply with the thermal protection requirements in the Standard for Overheating Protection for Motors, UL 2111; or,
- b) Comply with the impedance protection requirements in the Standard for Overheating Protection for Motors, UL 2111; or,
- c) Involve an alternative protection means that is shown by test to be equivalent to the protection specified in (a).

4.3.15DV.1.3 Regarding 4.3.15DV.1.2(c), an example of an alternative protection means is the use of fusing to limit the locked rotor temperature of the blower motor windings in accordance with the thermal protection requirements in the Standard for Overheating Protection for Motors, UL 2111. The fusing in this example shall be branch circuit or supplementary types in accordance with the UL 248 series.

4.3.16DV D2 Addition:

4.3.16DV.1 Fuseholders

4.3.16DV.1.1 Other than as noted in 4.3.16DV.1.2 and 4.3.16DV.1.3, power conversion equipment incorporating a disconnect switch and a fuseholder shall be so constructed that when the switch contacts are open, the fuse may be replaced without touching any energized part.