IEEE Std 16-2004 review

The following document in a section by section review of the IEEE Std 16-2004. A brief description of each section is provided (Please refer to the IEEE Std 16 for the exact text). Commentary notes have been incorporated as follows:

- The problematic areas are highlighted in **RED**.
- The requirements identified as "**Test**" means that there was not enough feedback from the industry (at the time of the evaluation) to assess the requirement so that a test needed to be performed.
- The requirements identified as "**OK**" mean that there should be no problem with this requirement.

The document also contains concerns on the standards referenced by the IEEE-16.

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IEEE-16 references

IEEE-16 Section	Standard	Other Standards
4.2.3	ANSI C84.1-1995	
4.8.1	APTA RP-E-009-98	
4.4	APTA SS-E-010-98	
4.13	APTA SS-M-011-99	
4.12.2	APTA B172-2001A	
4.12.2	APTA B174-2002	
4.7.2	AREMA 2005	
4.12.2	ASTM B172-2001A	
4.12.2	ASTM B174-2002	
4.3.1.4, 4.3.1.5, 4.4.2	EN 50121-3-2 : 2000	EN 50155 EN 61000-4-3, &4, &-6
4.7	EN 50124-1 : 2001	
4.12.2	IEC 61024-1-1 : 1993	
	IEC 61287-1: 1995	
4.6.1	IEEE Std 1-2000	
5.8.2	IEEE Std 11-2000	
5.1	IEEE Std 100	
4.11	IEEE Std 1475-1999	
4.2.2 4.3.1.2 4.3.1.3	IEEE Std 1476-2000	ANSI C84.1-1995 IEC 61287-1 (1995-07) IEEE Std 519-1992 NEMA MG-1-1998
4.1, 4.8.1, 5.3, 5.8.8	IEEE Std 1478-2001	APTA RP-E-009-98
4.11	IEEE Std 1482.1-1999	
4.6.1	IEEE Std C37.20.2-1999	
4.6.1	IEEE Std C37.23-2003	
4.10	IPC-2220	
4.10	IPC-A-610-2001	
4.10	IPC-CC-830B-2002	
4.14	ISO 4406:1999	
4.8.1	MIL-DTL-5015	
4.8.3	MIL-M-81531	
4.10	NEMA LI 1-1998	
4.12.3	NEMA WD 6-2002	
4.7.2	NFPA 130-2003	
4.14	SAE AS4059	
4.12.3	UL 943-1993	
4.12.3	UL 498-2001	
4.8.2.3	UL-1059-2001	
4.12.3	W-C-596G-2001	

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4.1	**Service Conditions**
	Environmental conditions per **IEEE Std 1478-2001** unless otherwise agreed between the supplier and the authority having jurisdiction.

IEEE Std 1478-2001 Environmental Conditions

	4.1.2	Ambient operating temperature range of -40°C to +70°C. Equipments cannot operate at +70°C (158 °F) ambient temperatures. This section is in conflict with section 4.6 (Temperature rise limits) that state that all the temperature rise limits listed in this section is based on an maximum ambient temperature of 40°C.
Test	**4.1.3**	Ambient relative humidity tests of 10-100 % at +30°C.
Test	**4.1.4**	Elaborate vibration tests.
Test	**4.1.5**	Elaborate shock tests.
Test	**4.1.6.1**	Salt Fog tests per test method 509.3 of **MIL-STD-810E**.
Test	**4.1.6.3**	Blowing sand test (90 minutes) per test method 510.3 of **MIL-STD-810E**.
Test	**4.1.6.4**	Blowing dust test (6h at max temp.) per test method 510.3 of **MIL-STD-810E**.
OK	**4.2.1**	Rain test at 13 cm/h (5.1 inch/h) & wind of 18 m/s (59 ft/s) per test method 506.3 of **MIL-STD-810E**.

4.2	**Supply Voltage**	
Test	**4.2.1**	No damage for 1.0 Sec undervoltage and 0.2 Sec overvoltage
	4.2.2	Low Voltage DC Operating Range per **IEEE Std 1476-2000**.

IEEE Std 1476-2000 Auxiliary Power Systems Interfaces

4.4.3

Table 4- Low voltage outputs

Nominal Voltage	Nominal LVPS output voltage at 25°C	Minimum voltage at load	Maximum voltage at load
24	28.5	17.0	34.0
32	37.5	23.0	42.5
48	57.0	34.0	68.0
64	74.0	**46.0**	85.0

Standard 72 Vdc relays and contactors cannot operate down to 46 volts

	Nominal LVPS output voltage at 25°C	Minimum voltage at load	Maximum voltage at load
Jacksonville	24.0	16.0	33.0
R142	37.5	24.0	44.0
M-7	72.0	**50.0**	90.0

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4.2	Supply Voltage	
OK	**4.2.3**	Low voltage AC Operating Range per the utilization voltage limits of Voltage Range A specified in the **ANSI C84.1-1995**, Table 1.

ANSI C84.1-1995 Voltage Ratings (60 Hertz)

Table 1- Standard nominal system voltages and voltage ranges

Nominal System Voltage	Nominal Utilization Voltage	Maximum Utilization Voltage	Minimum Utilization Voltage
120/240	115/230	126/252	110/220
480	480	504	440

4.2	Supply Voltage	
OK	**4.2.4**	High Voltage DC Operating Range per Table 1. Usually all the technical specification call for their specific operating range that is different from the one listed. As stated in the IEEE 16 **"Unless otherwise agreed between the supplier and the authority having jurisdiction"**.
OK	**4.2.5**	High Voltage AC Operating Range per Table 2. Usually all the technical specification call for their specific operating range that is different from the one listed. As stated in the IEEE 16 **"Unless otherwise agreed between the supplier and the authority having jurisdiction"**.

Table 1 Standard voltages for high-voltage dc-powered traction and auxiliary

Nominal system voltage (V)	Operating voltage range (V)		
	Minimum continuous	Maximum continuous	Maximum short time
600	400	720	800
750	500	900	1000
1500	1000	1800	1950
3000	2000	3600	3900

Table 2 Standard voltages for high-voltage single-phase ac system

Nominal system voltage (V)	Nominal frequency (HZ)	Operating voltage range (V)			
		Minimum short time	Minimum continuous	Maximum continuous	Maximum short time
12000	25	8400	9600	13200	14400
12500	60	8750	10000	13750	15000
25000	60	17500	20000	27500	30000
50000	60	35000	40000	55000	60000

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4.3	Electrical Transient	
Test	4.3.1.1	**AC** system supply overvoltage and time duration per **Figure 3** of **IEC 61287-1:1995** (Curve 1 normal operation), (Curve 2 no damage)
Test	4.3.1.1	**DC** system supply overvoltage and time duration per **Figure 4** of **IEC 61287-1:1995** (Curve 1 normal operation), (Curve 2 no damage)

IEC 61287-1:1995 Power converters installed on board rolling stock

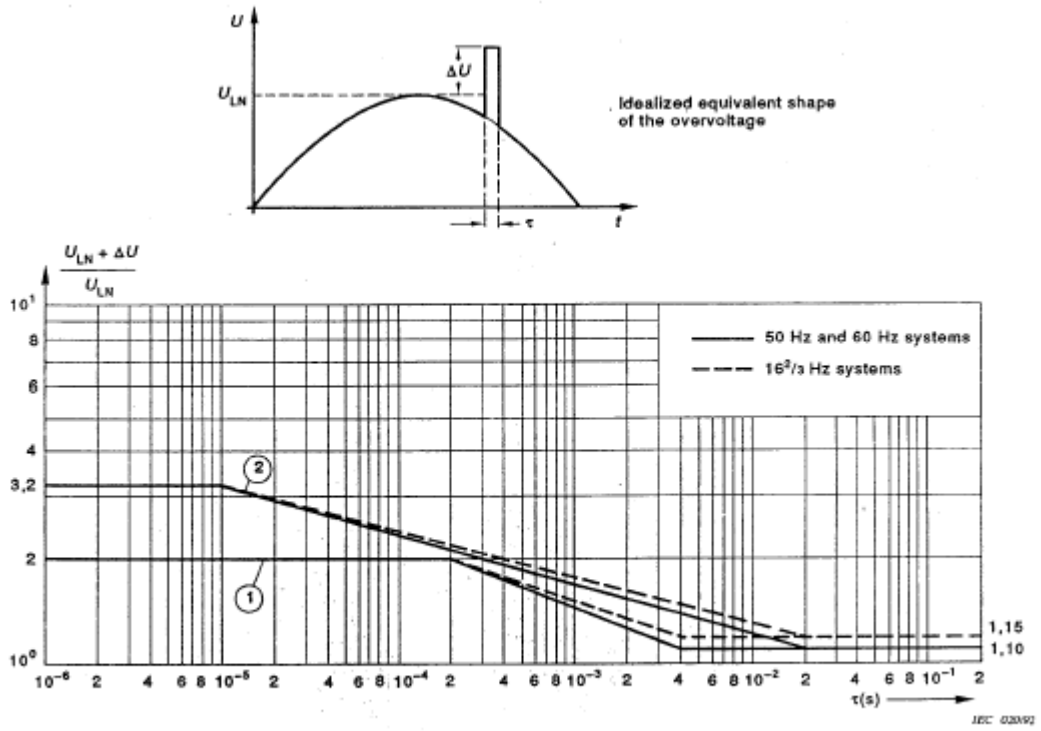

Figure 3 – AC supply system overvoltage levels

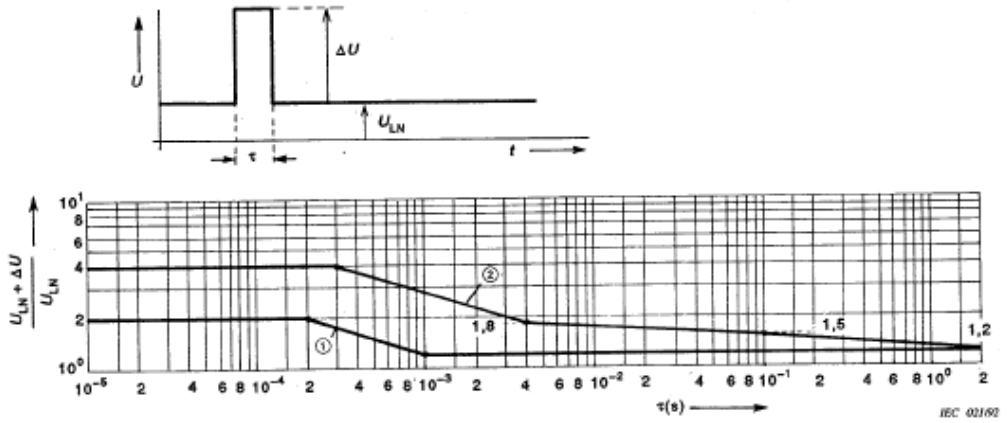

Figure 4 – DC supply system overvoltage levels

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4.3	Electrical Transient	
Test	4.3.1.2	Systems supplied by Auxiliary **AC** Systems shall sustain voltage fluctuations defined in 4.3.1 of **IEEE Std 1476-2000**

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4.3.1.1	Three phase power outputs voltages shall be in accordance with **ANSI C84.1-1995**
4.3.1.2	High power output voltage frequency and tolerance to be proposed by carbuilder for both fixed and variable frequency applications
4.3.1.3	Static inverter power output harmonics shall be per **NEMA MG-1-1998 (Subclause IV, Part 30)** and **IEEE Std 519-1992**.
4.3.1.4	Starting conditions of the power loads shall be considered in the static inverter design.
4.3.1.5	Static inverter power input connected directly to the supply line shall be per **IEC 61287-1 (1995-07)**. Galvanic isolation shall be provided between input and the AC outputs.

4.3	Electrical Transient	
	4.3.1.3	Low Voltage **DC** Systems shall sustain voltage fluctuations defined in 4.4.3.4 and 4.4.3.5 of **IEEE Std 1476-2000**

IEEE Std 1476-2000 Auxiliary Power Systems Interfaces

4.4.3.4 Voltage fluctuations shall be limited to **-40%** and **+40%** of the LVPS output voltage found in Table 4. These fluctuations shall not exceed **0.1 second**.

Table 4- Low voltage outputs

Nominal Voltage	Nominal LVPS output voltage at 25°C	Minimum voltage at load	Maximum voltage at load
24	28.5	17.0	34.0
32	37.5	23.0	42.5
48	57.0	34.0	68.0
64	74.0	**46.0**	85.0

Jacksonville	24.0	16.0	33.0
R142	37.5	24.0	44.0
M-7	72.0	50.0	90.0

Voltage fluctuations calculated values

Nominal Voltage	Nominal LVPS output voltage at 25°C	-40% for 0.1 second	+40% for 0.1 second
24	28.5	17.1	**39.9**
32	37.5	**22.5**	**52.5**
48	57.0	34.2	79.8
64	74.0	**44.4**	**103.6**

Standard 24 Vdc relays and contactors operating range 17 to 30 volts
Standard 37.5 Vdc relays and contactors operating range 26 to 47 volts
Standard 72 Vdc relays and contactors operating range 50 to 90 volts

4.4.3.5 Voltage fluctuations caused by LVPS failures shall be limited to **40%** above nominal LVPS output voltage found in Table 4. These fluctuations shall not exceed **1 second**.

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4.3	Electrical Transient	
Test	4.3.1.4	Electrostatic Discharge Immunity per **EN50121-3-2:2000** Table 9.
Test	4.3.1.5	Transient Immunity per **EN50121-3-2:2000** Table 7 and 8. Power supply inputs shall also withstand 20 Joules.

EN50121-3-2:2000 Rolling stock Electromagnetic Compatibility Table 7 to 9

Table 7: Immunity - Battery referenced ports (except at the output of energy sources), auxiliary a.c. power input ports (rated voltage ≤ 400 V_{rms})

	Environmental phenomena	Basic Standard	Severity	Performance criteria	Remarks
7.1	Fast transients bursts	EN 61000-4-4	2 kV 5/50 ns Tr/Th 5 kHz rep frequency	A	See note 1
7.2	Surges	EN 50155	1,8 kV waveform 5/50 µs Source impedance 100 Ω	B	
7.3	Conducted radio frequency	EN 61000-4-6	3 V_{rms} (carrier voltage) 150 kHz to 80 MHz 1 kHz, 80 % AM Source impedance 150 Ω	A	See note 2
7.4	Variations and interruptions of voltage supply	EN 50155	Refer to EN 50155	A	

NOTE 1 Direct coupling, positive and negative polarity.
NOTE 2 In applications where cables cross between cars (e.g. train communications) a severity level of 10 V⎓ shall be used.

Table 8: Immunity - Signal and communication, process measurement and control ports

	Environmental phenomena	Basic Standard	Severity	Performance criteria	Remarks
8.1	Fast transients bursts	EN 61000-4-4	2 kV 5/50 ns Tr/Th 5 kHz rep frequency	A	See note 1
8.2	Conducted radio frequency	EN 61000-4-6	3 V_{rms} (carrier voltage) 150 kHz to 80 MHz 1 kHz, 80 % AM Source impedance 150 Ω	A	See note 2

NOTE 1 Capacitive coupling, positive and negative polarity.
NOTE 2 In applications where cables cross between cars (e.g. train communications) a severity level of 10 V⎓ shall be used.

Table 9: Immunity - Enclosure ports

	Environmental phenomena	Basic standard	Severity	Performance criteria	Remarks
9.1	Radio frequency	EN 61000-4-3	10 V/m (rms carrier voltage) 80 MHz to 1 GHz 1 kHz, 80 % AM	A	See notes 1 and 3
9.2	Electrostatic discharge	EN 61000-4-2	6 kV contact discharge 8 kV air discharge	B	See note 2

NOTE 1 For equipment mounted in the passenger compartments, drivers cab or external to the rolling stock (roof, underframe) a severity level of 20 V/m shall be used to allow for the more prevalent use of mobile transmitters.
NOTE 2 Only applicable to equipment accessible to passengers and operational staff (not maintenance).
NOTE 3 For large apparatus (e.g. traction drives, auxiliary converters) it is often not practical to perform the immunity test to radiated electromagnetic fields on the complete unit. In such cases the manufacturer should test susceptible sub-systems (e.g. control electronics). The test report should justify the selection or not of sub-systems and any assumptions made (e.g. reduction of field due to case shielding).

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4.4	Electromagnetic Compatibility	
Test	4.4	Electromagnetic Compatibility Requirement per **APTA SS-E-010-98**
Test	4.4.1	Train to Wayside Compatibility to be defined by the Authority having jurisdiction
Test	4.4.2	On-board Equipment Emission and Suseptivity Compatibility per **EN50121-3-2:2000**

4.5	Breaking and Making Capacity	
OK	4.5	Breaking and making capacity (rating) shall be stated by the supplier.

4.6	Temperature Rise Limits	
	4.6.1	Temperature rise limits by insulation class and for buss bars per Table 3 & 4 with an ambient temperature of 40 °C further criteria are listed in **IEEE Std 1-2000**. Notes also specify that additional information can be found in the **IEEE Std C37.20.2-1999** and **IEEE Std C37.23-2003** • This section is in conflict with section 4.1 (Service Conditions) that state that the Environmental conditions shall be per **IEEE Std 1478-2001** (Ambient operating temperature range of -40°C to +70°C). • **IEEE Std C37.20.2-1999** Section 4: Ambient operating temperature (-30°C to +40°C). • **IEEE Std C37.23-2003** Section 4: Ambient operating temperature (-30°C to +40°C).

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Table 3—Allowable temperature rise and limits by insulation class

Insulation class	Limit of hottest spot temperature rise (°C)	Limit of hottest spot total temperature (°C)
90	50	90
105	65	105
130	90	130
155	115	155
180	140	180
220	180	220
240	200	240

NOTE—For additional information on temperature limits, see IEEE Std 1-2000 and IEEE Std C37.20.2-1999.

Table 4—Allowable temperature rise and limits for buses and connections

Type of bus or connection	Limit of hottest spot temperature rise (°C)	Limit of hottest spot total temperature (°C)
Buses and connections with silver surfaced, tin surfaced, or equivalent connecting joints	65	105
Connection to insulated cables, silver surfaced, tin surfaced, or equivalent	45	85

NOTE—For additional information on temperature limits, see IEEE Std C37.20.2-1999 and IEEE Std C37.23-2003.

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4.6	Temperature Rise Limits
	4.6.1 Temperature rise limits for selected electromagnetic devices per Table 5 with an ambient temperature of 40 °C. Additional information are listed in **IEEE Std 1-2000** and **IEC 60077**. • This section is in conflict with section 4.1 (Service Conditions) that state that the Environmental conditions shall be per **IEEE Std 1478-2001** (Ambient operating temperature range of -40°C to +70°C). • Note in table 5 say: "For additional information see **IEC 60077**" **IEC 60077-1** Section 7.3: Ambient operating temperature (-25°C to +40°C). **IEC 60077-1** Section 8.2.2.2 state that the temperature rise limits are based on 25 °C ambient air temperature for external locations and 55 °C for internal locations. • Per section 5.8.5 of IEEE Std 16 this criteria is applicable to all circuit breaker holding coils, magnet valve coils, electro-magnetic contactors operating coils, relay coils, transformers, etc. • Per section 5.8.6 of IEEE Std 16 this criteria is applicable to all bus bars, flexible connections and electrical contacts. • Per section 5.8.9 of IEEE Std 16 this criteria is applicable to insulated windings, flexible connections and electrical contacts of all electro-pneumatic devices. • Per section 5.8.10 of IEEE Std 16 this criteria is applicable to insulated windings, flexible connections and electrical contacts of all electro-hydraulic devices.

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Table 5—Allowable temperature rise and limits for selected electromagnetic devices and their connections

Component	Temperature rise limit (°C)
Bare wire coils	105
Contacts in Air	
Pure Copper in the form of a spring	35
Brass or bronze in the form of a spring	65
Pure copper or copper alloy not forming a spring	75
Solid silver or silver plate	100
Flexible Connections in Air	90
Accelerating and/or Braking Resistors	
Imbedded, outside of imbedding material	250
Open type, of strap, ribbon wound, formed, or similar configuration	600 (RMS) 800 (peak)

NOTE—For additional information on temperature limits, see IEC-60077 [B7].

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4.6	Temperature Rise Limits	
Test	4.6.2	Derating factor for altitudes greater than 1000 m per Part III, Clause 4 of **IEEE Std1-2000.**

IEEE Std 1-2000 General Principles for Temperature Limits in the Rating of Equipment

7.3	Derating factor for altitudes greater than 1000 m: ➔Air-cooled equipment where large part of cooling is by radiation **1%** per **303 m** ➔Air-cooled equipment where large part of cooling is by forced-air **5%** per **303 m**

4.7	Clearance and Creepage Distance	
Test	4.7	Clearance and creepage distances for power semiconductor per **EN50124-1:2001**

EN50124-1:2001 Railway Applications Electromagnetic Compatibility

?	Not available

4.7	Clearance and Creepage Distance	
	4.7.1	Clearance (mm)= 3.2+(0.0127 **X** nominal voltage). **Text and table of IEEE 16 is in conflict with text of NFPA-130**

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8.6.2.2	**8.6.2.2* Air Clearance.** The air clearance distances between voltage potentials (up to 2000 V) and ground shall comply with the following formula: Clearance (mm) = 3.175 + (0.0127 × nominal voltage) [Clearance (in.) = 0.125 + (0.0005 × nominal voltage)]

4.7	Clearance and Creepage Distance	
	4.7.2	Creepage distance (mm)= 3.2+(0.0476 **X** nominal voltage). **Text and table of IEEE 16 is in conflict with text of NFPA-130**

NFPA 130-2007

8.6.2.3	**8.6.2.3 Creepage Distance.** **8.6.2.3.1** Creepage distance for voltage potentials (up to 2000 V) to ground in ordinary enclosed environments shall comply with the following formula: Creepage (mm) = 3.175 + (0.047625 × nominal voltage) [Creepage (in.) = 0.125 + (0.001875 × nominal voltage)]

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4.7	Clearance and Creepage Distance	
	4.7.2	Creepage distances per Table 6 and **NFPA 130-2003.** **Table 6 of IEEE 16 is in conflict with Table E1 of NFPA-130-2007**

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Table 6—Creepage distance

Nominal voltage (V)	Surface	Class			
		Low Energy Electronic and protected electrical devices (0.5 A maximum)	**Ordinary (Enclosed environment with breathing)** Control and power devices mounted in control group enclosures (short circuit limits)	**Underfloor exposed** Power resistors Open disconnect devices mounted outside protective enclosures	**Highly exposed (No external protection)** Third rail shoe beams and current collection devices (short circuit current unlimited by onboard devices)
37.5	Horizontal	1.5 mm	4.5 mm	19 mm	N/A
See 4.2.2 Note	Vertical	1.5 mm	4.5 mm	13 mm	N/A
74	Horizontal	3.5 mm	6.5 mm	40 mm	N/A
See 4.2.2 Note	Vertical			25 mm	N/A
230	Horizontal	10 mm	16 mm	75 mm	100 mm
	Vertical	10 mm	16 mm	50 mm	55 mm
600	Horizontal	19 mm	32 mm	180 mm	255 mm
	Vertical	19 mm	32 mm	120 mm	150 mm
750	Horizontal	See Note 3 below	40 mm	See Note 3 below	See Note 3 below
	Vertical				
1500	Horizontal	See Note 3 below	75 mm	See Note 3 below	See Note 3 below
	Vertical				

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Table E.1 Minimum Creepage Distance for Transit Vehicles

Class		Low Energy		Ordinary (Enclosed environment with breathing)		Underfloor Exposed Environment		Highly Exposed (No external protection)	
Application		Electronic and Protected Electronic Devices (½ amp where max.)		Control and Power Devices Mounted in Control Group Enclosures (Short circuit limits)		Power Resistors Open Disconnect Devices Mounted Outside Protective Enclosures		Third Rail Shoe Beams and Current Collection Devices (Short circuit unlimited by on board devices)	
Nominal Voltage	Surface	mm	in.	mm	in.	mm	in.	mm	in.
37.5	Horizontal	1.6	1/16	3.2	1/8	19.1	3/4	N/A	N/A
	Vertical	1.6	1/16	3.2	1/8	12.7	1/2	N/A	N/A
74	Horizontal	3.2	1/8	6.5	1/4	40	1 3/16	N/A	N/A
	Vertical	3.2	1/8	6.5	1/4	25	1	N/A	N/A
230	Horizontal	8.3	3/8	15.9	5/8	76.2	3	101.6	4
	Vertical	8.3	3/8	15.9	5/8	50.8	2	57.2	2 1/4
600	Horizontal	19.1	1/4	31.8	1 1/4	177.8	7	254	10
	Vertical	19.1	1/4	31.8	1 1/4	127	5	152.4	6
750	Horizontal	See note below	See note below	40	1 9/16	See note below	See note below	See note below	See note below

Note: Where no value is given or for nonstandard values, the creepage distance shall be agreed between the supplier and the AHJ. EN 50124-1:2001, while not as conservative as the requirements of this standard, provides a basis for discussion of alternate requirements.

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4.7	Clearance and Creepage Distance	
Test	4.7.2	Clearance and creepage distances for signaling equipment per **AREMA 2005**

AREMA 2005

?	Have not found any clearance and creepage distances requirements

4.8	Apparatus Internal Wiring	
	4.8.1	Wires shall be rated per **IEEE Std 1478-2001** and **APTA RP-E-009-98.** IEEE Std 1478-2001 provide no wire rating criteria. APTA RP-E-009-98 applicable only to Exane 110°C cables
	4.8.2.1	Wires potential differing by 50 volts not in same routing and separated by metallic partitions. Unrealistic criteria.
	4.8.2.1	The following circuits shall not be intermixed in common wire and cable bundles: Traction power, DC control, AC control, Unprotected wiring (e.g. battery or power trainline to circuit breaker), Different trainline types (e.g. MU control, car control, communications, power, etc.), Safety control (cab signal, automatic train stop, etc.), Communication, Low level signal not in shielded cables, Wires connected to different source of energy, Wires connected to electronic control apparatus and wires connected to a higher voltage source of energy than control voltage. Unrealistic criteria.
	4.8.2.2	Wires shall be a minimum of 25 mm above bottom of the box. This can be done only for larger underfloor boxes. Difficult to apply to small equipment boxes installed under or within the car.
OK	4.8.2.3	Stud type terminal block per **UL-1059-2000**
OK	4.8.2.3	Connector with crimp contacts good for 500 operations per **MIL-DTL-501**
Test	4.8.3	Wires markers shall meet durability requirement per **MIL-M-81531** paragraph 4.6.2

4.9	Buss Bar Application
OK	Buss bars shall be fabricated from **UNS C10100** or **C11000** copper.
	Bolted connection conducting area consider only flat washer area. Unrealistic criteria.
	Bolted connection minimum contact pressure of 10 MPa (1450 Psi). Actual 1.37 MPa (200 Psi) but Copper Development Association (CDA) allow 15 MPa (2175 Psi).
	Buss bar current density shall be 0.75 A/mm² or not exceed 1.4 A/mm² if approve by the Authority. Actual 1.55 A/mm² (1000 A/Inch²) will increase buss bar area.

4.10	Printed Circuit Board

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OK	Category 1 (Repairable boards)
OK	Category 2 (Boards repairable only in sophisticated repair facilities)
OK	Category 3 (Non repairable boards)
OK	Boards shall be designed per **IPC-2220** Class 2 or better
OK	Board material per **NEMA LI 1-1998** type FR4 or better
OK	Boards shall be constructed and inspected per **IPC-A-610-2001** Class 2 or better
OK	Conformal coating per **IPC-CC-830B-2002** Class 2 or better with fluorescent indicators.

4.11	**Protective Functions**
OK	Fuses or crowbar circuits not recommended
OK	If protective function report to the event recorder it shall be per **IEEE Std 1482.1-1999.**
OK	Other protective function listed in **IEEE Std 1475-1999.**

4.12	**Grounding**	
Test	**4.12**	Maximum DC resistance of 0.0025 ohms and 0.025 ohms at 150 kilohertz
OK	**4.12.1**	Copper or stainless steel grounding pads.
Test	**4.12.2**	Ground brush and truck grounding connection sized for lightning per **IEC 61024-1-1:1993**
OK	**4.12.2**	Stranding per **ASTM B174-2002** for 14 AWG and smaller.
OK	**4.12.2**	Stranding per **ASTM B172-2001A** for larger than 14 AWG
OK	**4.12.3**	Hospital grade 120 Vac GFCI outlet with test and reset function not accessible to passengers per **NEMA WD 6-2002** and **UL 498-2001**

4.13	**Electro-pneumatic Devices**
	Ratio of max. to min. pressure shall be 1.8 or greater and max. pressure of 1.04 MPa (150.9 Psi) Normal Operating Range of Main Reservoir and Brake Pipe 130 – 150 Psi (max 160 Psi at compressor).
Test	Devices shall function with compressed air quality per **APTA SS-M-011-99**

4.14	**Electro-hydraulic Devices**
	Max. pressure of 16 MPa (2322 Psi) VIA Banking max. pressure ≈2000 Psi, NEC Banking max. pressure ≈2400 Psi, CTA Brake max. pressure ≈1000 Psi.
Test	Devices shall function with fluid cleanliness per **ISO 4406:1999** or **SAE AS4059**

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5.1	General Testing Requirements
OK	Type and routine tests shall be performed on all equipment
OK	Type tests (qualification tests) as defined in **IEEE 100**
OK	Routine tests (acceptance and production tests) as defined in **IEEE 100**
	Tests required by this standard are listed in Table 7 Many tests required in this section need to be modified or eliminated. We have problems with all the tests listed in the following table 7 that are highlighted in red.

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Table 7 —Outline of test requirements

Description of test	Corresponding design requirements subclause	Applicable test section	
		Type test	Routine test
Operational	—	5.2.1	5.2.2
Environmental conditions	4.1	5.3.1	5.3.2
Supply voltage variation	4.2	5.4.1	5.4.2
Transient voltage and interruption	4.3	5.5.1	—
Electromagnetic compatibility	4.4	5.6	—
Breaking and making capacity	4.5	5.7	—
Temperature rise	4.6	5.8	—
Insulation	4.7	5.9	5.9
Environmental stress	—	—	5.10
Protective devices	4.11	—	5.11
Air tightness	4.13	5.12.1	5.12.3
Pneumatic overpressure	4.13	5.12.2	—
Pneumatic device functionality	4.13	5.12.4	5.12.4
Hydraulic	4.14	5.13.1	5.13.2
Resistance and impedance	—	5.14	5.14

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5.2	Operational test	
	5.2.1	**Operational type testing** Tests shall be conducted at nominal operating conditions and also at minimum and maximum temperature, voltages, and pressure, as well as the combination creating the greatest stress. Usually we do not perform all these tests.
	5.2.2	**Operational routine testing** Tests shall include that each input and output is functional, at minimum, nominal, and maximum voltage and pressure for the application. The routine tests are performed only at nominal voltage.

5.3	Environmental testing	
	5.3.1	**Environmental type testing** Tests shall be performed in accordance with **IEEE Std 1478-2001**. Equipments cannot operate at +70°C (158 °F) ambient temperatures see comments listed in IEEE Std 16 section 4.1 Environmental Conditions. But we still have to perform this test at a more reasonable value
	5.3.2	**Environmental routine testing** Exterior mounted equipment shall be tested for watertightness per **IEEE Std 1478-2001**. See comment listed in IEEE Std 16 section 4.1 Environmental Conditions.

5.4	Supply voltage type testing	
	5.4.1	**Type tests** Tests shall be conducted at nominal operating conditions and also at minimum and maximum temperature, voltages, and pressure, as well as the combination creating the greatest stress. We do not perform all these tests
	5.4.2	**Routine tests** Tests shall include that each input and output is functional, at minimum, nominal, and maximum voltage and pressure for the application. The routine tests are performed only at nominal voltage.
	5.4.2	**Routine tests** For devices where operation is affected by temperature, routine tests shall include modifications to the supply voltage to simulate the simultaneous effects of voltage and temperature variations. The test shall be performed at voltage lower than the actual minimum operating voltage. Unrealistic requirement.

5.5	Electrical transient type testing	
Test	5.5.1	**Type tests** Tests shall be performed under the transient input voltage conditions specified in section 4.3.

5.6	Electromagnetic compatibility test	
Test	5.6.1	**Train-wayside type tests** Tests shall be performed according to section 4.4.1.
Test	5.6.2	**On-board type tests** Tests shall be performed according to section 4.4.2.

5.8	Temperature rise tests

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	5.8.1	Test shall be performed on the following equipments whether individually or as part of a system: -Buses and connections -Insulated wiring -Bare wire coils -Contacts in air -Flexible connections in air (e.g. braided shunts) -Accelerating and braking resistors -Heat sinks -Devices or assemblies whose life is a function of operating temperature -Other heat sensitive devices or assemblies Unrealistic requirement.
OK	**5.8.2**	**Temperature measurement** Temperature measurement shall be taken during the operational portion of the test. If it is not practical the temperature shall be taken as soon as possible after the completion of the test and the temperature shall be projected using the method described in section 6.4 of **IEEE Std 11-2000**
OK	**5.8.2.2**	**Determination of ambient temperature**
OK	**5.8.3**	**Test duration**
OK	**5.8.4**	**Test conditions**
	5.8.5	**Insulated windings** Temperature rise on windings (e.g., circuit breaker holding coils, magnet valve coils, electro-magnetic contactors operating coils, relay coils, transformers, etc.) shall be made at the voltage that produces the maximum continuous losses in the windings. …….Temperature rise shall not exceed the limit values given in table 3. Unrealistic requirement. It would take years to do such measurements on all those components in the car. In addition we rarely have a direct access to the coils.
	5.8.6	**Bare windings, contacts in air, flexible connections, and bus bars** Temperature rise for bus bars shall not exceed the limit values given in table 4. Temperature rise for bare windings, contacts in air, and flexible connections shall not exceed the limit values given in table 5. Unrealistic requirement. This mean that we have to measure all electrical contacts and the ground straps of the car.
OK	**5.8.7**	**Accelerating and braking resistors** Brake resistors shall meet the temperature rise limit values given in table 5.

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5.8	Temperature rise tests	
	5.8.8	**Electronic assemblies** Temperature test on electronic assemblies (e.g. circuit boards, modules, etc) shall be made at voltage that results in the maximum temperature rise. In no case the temperature rise over the limits of **IEEE Std 1478-2001** exceed the limit values imposed by suppliers of any component of the electronic assembly. Unrealistic requirement. The **IEEE Std 1478-2001** specify that the maximum ambient temperature of +70°C (158 °F) shall be considered for the test. Additional temperature rise shall be considered for equipments located within an equipment box or within an electrical locker in order to determine the ambient temperature local to the electronic assembly. The maximum ambient temperature of +70°C (158 °F) leave no margin for equipment box or electrical locker temperature rise. Industrial Integrated Circuits are used in many railroad applications The Industrial IC operational temperature range is -40°C (-40°F) to +85°C (+185°F) The Military IC operational temperature range is -55°C (-67°F) to +125°C (+257°F)
	5.8.9	**Electro-pneumatic devices** Temperature measurement shall be taken on insulated windings, flexible connections and electrical contacts of all electro-pneumatic devices. Unrealistic requirement.
	5.8.10	**Electro-hydraulic devices** Temperature measurement shall be taken on insulated windings, flexible connections and electrical contacts of all electro-hydraulic devices. Unrealistic requirement.

5.9	Insulation testing	
OK	5.9.2	**Insulation test sequences** After all cable, wiring and equipment installation on the vehicle, with the allowable exception of electrical connection of previously tested equipment, the insulation integrity of all vehicle circuits shall be tested at full test voltage.

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<table>
<tr><td>5.9</td><td colspan="2">Insulation testing</td></tr>
<tr><td>OK</td><td>5.9.3</td><td>Insulation resistance test
Tests shall be conducted to verify the state of insulation on all circuits of each voltage class to the following, where applicable;
-the equipment case.
-wiring of different voltage classes
-input and output circuit of high voltage line switches and circuit breakers
-vehicle chassis.

Table 8- Vehicle level insulation resistance limits
<table><tr><th>Nominal Circuit Voltage (Volts dc or ac rms)</th><th>Minimum Insulation Resistance</th></tr><tr><td>Bellow 90 volts</td><td>2 megohms at 500 Vdc</td></tr><tr><td>90 to 300 volts</td><td>4 megohms at 500 Vdc</td></tr><tr><td>Above 300 volts</td><td>5 megohms at 500 Vdc</td></tr></table>
Standard approach but we must ensure that the supplier’s equipments are not connected to the car wiring during these tests.</td></tr>
<tr><td>OK</td><td>5.9.4</td><td>Dielectric test
The dielectric test shall be conducted after the insulation resistance test is completed and passed. Tests shall be conducted to verify the state of insulation to the case or vehicle body, between wiring of different voltage classes, and between the input and output circuit of traction high voltage line switches and circuit breakers.

Table 8- Vehicle level insulation resistance limits
<table><tr><th>Nominal Circuit Voltage dc or ac rms</th><th>Test voltage, ac rms</th></tr><tr><td>Bellow 300 volts</td><td>2V+ 1000 Vac</td></tr><tr><td>Above 300 volts</td><td>2.25V+ 2000 Vac</td></tr></table>
Standard approach but we never test circuit breakers.</td></tr>
</table>

5.10	Environmental stress screening
OK	Environmental screening is not a mandatory requirement of this standard.

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5.11	Settings and operation of protective apparatus, relays, and static circuits
	Routine tests shall be performed on protective apparatus, relays, and static circuits to verify that they operate within tolerances given below. **± 3 %** for protective functions utilizing solid state sensors, active electronic circuitry or microprocessor computation. **± 5 %** for passive electronic circuitry or electromechanical components not equipped with mechanical latches. **± 7.5 %** for components equipped with mechanical latches. For apparatus having time delay feature **± 5 %** for protective functions utilizing solid state sensors, active electronic circuitry or microprocessor computation. **± 10 %** for all other protective functions. Unrealistic requirement. How can we measure in routine tests all the protective functions tolerances

5.12		Tests for pneumatically operated equipment
	5.12.1	**Air tightness type test** The device shall be tested at its maximum or minimum operating pressure, whichever is more severe. If the device tested includes a magnet valve and it is checked with the magnet valve energized, the coil shall be energized with a current equal to that obtained with the winding hot at the minimum allowed operating voltage. Unrealistic requirement. This mean that we have to operate the magnet valve bellow the coil operating voltage.
	5.12.4	**Functional type and routine test** The device shall be tested at its maximum or minimum operating pressure, whichever is more severe. Devices with set points shall verify that the switch point is within **± 0.21 Kg/cm^2** or **± 5%** whichever is less, of the specified value. Unrealistic requirement. This mean that we have to verify all devices with set points (pressure switches, etc) in both type and routine tests. .

5.13	Tests for hydraulically operated equipment
OK	

5.14	Measurement of resistance and impedance
	Routine tests of measurements of resistance shall be made on all electromagnetic control or other devices that include windings, the resistance of which may affect operation of the device. Unrealistic requirement. It mean that we would have to measure in routine test the coil impedance of all relays and contactors of the cars.