EUROPEAN POWER SUPPLY MANUFACTURERS ASSOCIATION
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Guideline for the Safety Requirements of AC / DC Power Supplies

Part 1: Safety Approval of DIN RAIL Power Supplies

20th June 2007

This Guideline gives an extensive overview of design issues, definitions and useable standards currently used in AC/DC Power supplies for DIN rail mounting. It should give a common understanding what safety rules and certifications should be used depending on the final application of the standard.

Furthermore gives this paper a general interpretation how different standard - requirements are in practice realized in power supplies.

This paper does NOT intend to be a standard

Paper prepared by the EPSMA Technical Committee and Innova. Special thanks and acknowledgements to Johann Humer (Siemens), for his contribution to this document.

The European Power Supply Manufacturers Association was established in 1995, to represent the European power supply industry.

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INNOVA Product Service	**Application Note**	
IEC60950 EN60204	Safety Approval of DIN RAIL Power Supplies	September 21, 2006

DIN Rail Power Supplies are power supplies available as standard catalogue products. They are used in different applications, but mainly in :

- **Industrial applications**
- **IT-equipment**
- *Medical (most permanent connection)*
- *Household applicance*
- *Semiconductor industry*
- *Hazardous location applications*
- MTBF

The standard products are sold worldwide. This application note will describe base requirements for approval in Europe and USA/Canada.

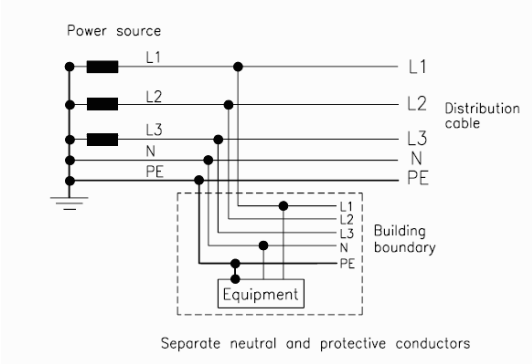
1.0 Relevant Standards

	Europe		USA/ Canada	
Application	**Standard**	**Mains**	**Standard**	**Mains**
IT – application, also covering measuring and laboratory equipment (over voltage category II)	IEC60950	TN (star mains) (phase to phase 400 Vac, phase to PE 230 Vac) , IT-mains phase – phase voltage 230Vac in Norway and France	UL60950 / CSA22.2-60950	TN- mains, TN-S mains (center tap) with PE between two times 120 Vac
Industrial application (over voltage category III)	EN60204 / IEC62103 or EN50178	TN, IT (PE not earthed) ,	UL508 / CSA22.2-107-1	TN, IT, Delta mains with one phase connected to PE – phase to phase voltage 500 Vac
Medical applications	IEC/EN60601	TN, IT mains	UL60601, CSA22.2-60601	TN, IT
Household appliances	IEC61558-2-17	TN mains	Various	TN, TN-S
Hazardous locations	EN60079-15	TN, IT	ANSI/ISA 12.12.01 UL1604	TN, IT, Delta mains

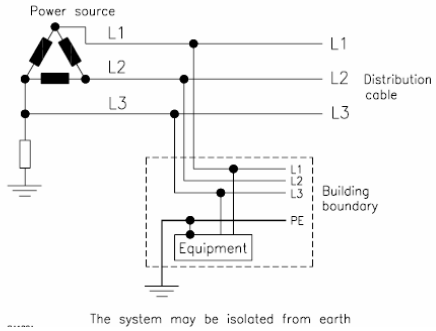
Railway application	EN50124-1 EN50155	TN	N/A	N/A

1.1 Overview of mains:

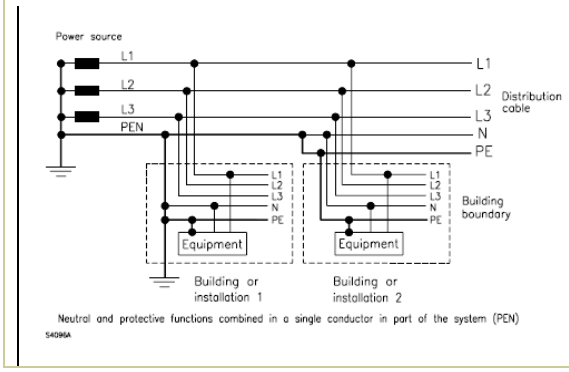
TN- mains in Europe and USA



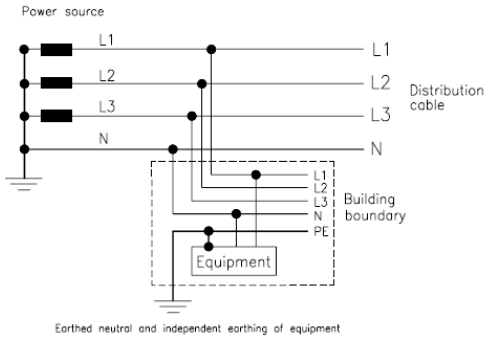
IT (PE insulated) mains : (do not mix with office applications = IT applications)
See also application note "leakage current test"



DELTA mains (TN-S) :



„Centre Tap mains" (TN-C)



1.2 Recommendation for the design of DIN Rail power supplies:

- IEC60950: for use in TN and TN-C mains single phase 240 Vac and three phase 500 Vac
- USA Industrial UL508 : for use in 500 Vac delta mains
- Europe industrial: for use in TN mains (500 Vac phase to phase) and IT mains 400 or 500 Vac phase to phase voltage (IT mains 500 V is used in the car industry also in Europe.)

It makes no sense to apply the spacing for mains systems, which do not exist like a 500 V delta mains for office environment, which would result in higher spacing requirements, without any real use.

2.0 Creepage and Clearance Requirements:

Some manufacturers are using a larger spacing than the standard requires gaining a marketing advantage by benchmarking. In this note we will only define the minimum spacing based on the requirements of the standard.

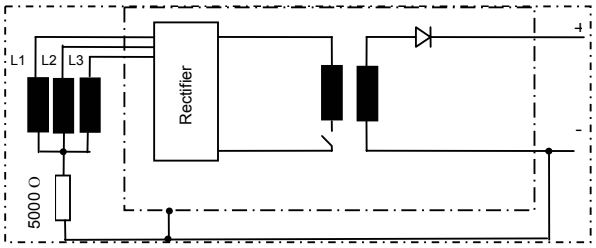
2.1 Definition of the parameters:

Some parameters have to be defined, before the spacing can be looked up in the tables of the standard.

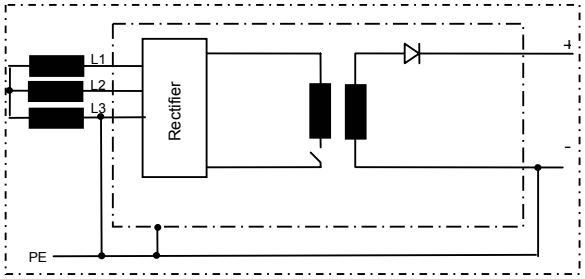
- Over voltage category II (office) or III (industrial)
- CTI (comparative tracking index) IIIb
- Pollution degree II (built in use, not in wet atmosphere)
- Height < 2000 m (It is recommended to measure the actual clearance and adjust the height in the documentation to the maximum possible with the design)
- Output SELV (safety extra low voltage)
- Working voltage and input voltage – the standards define, that the greater voltage of either the nominal input voltage or the real measured working voltage has to be used to define the spacing.

2.2 Example : Working voltage measurement:

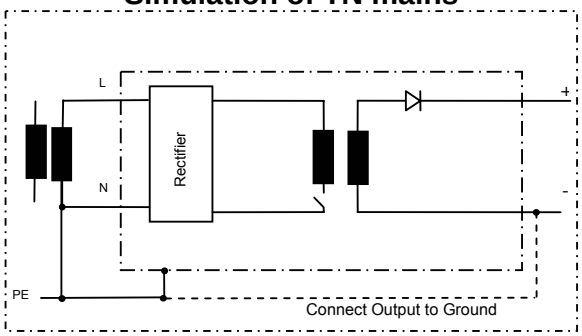
Simulation of IT mains



Simulation of Delta mains



Simulation of TN mains



Use insulation transformer and simulate the relevant mains.

Connect the output to PE to avoid floating.

TN mains for single phase and three phases will show same or equal results, because the phase to PE voltage is relevant.

In order to mark the three phase units with 500 Vac rated input voltage, the nominal voltage for Information technology was also assumed to be 500 V phase to phase and therefore 290 Vac phase to PE.

Typical measurement results on a single phase equipment:

	IEC60950 (Europe and USA) Star mains (TN) with 400 Vac phase to phase voltage and IT mains with 230Vac phase to phase)		EN60204 (based on IEC60664) or EN50178 or IEC62103 spacing, Star mains (TN) and IT mains phase to phase voltage 230Vac		USA: UL508	
	Vpeak	Vrms	Vpeak	Vrms	Vpeak	Vrms
Measured prim-sec on transformer	528	300	528	300	528	300

Based on a typical Single switch forward topology measured values are 380 Vrms and 480 V peak This means the nominal voltage of 400 V / 566 V peak has to be applied if unit should be designed for IT mains of 400 V.

Remark: other topologies might give lower (e.g. bridge configurations) or higher (e.g. flyback topologies) values

2.3 Spacing for Single phase equipment: TN and IT (insulated PE) 240 Vac												
	IEC60950 (Europe and USA) Star mains (TN) with 400 Vac phase to phase voltage and IT mains with 230 Vac phase to phase)				EN60204 (based on IEC60664) or EN50178 or IEC62103 spacing,				USA: UL508 120 / 240 Vac			
	Vpk	**CL**	**Vrms**	**CR**	**Vpk**	**CL**	**Vrms**	**CR**	**Vpk**	**CL**	**Vrms**	**CR**
A Prim-Prim before fuse (functional) On PCB	340	***1,5***	240	***2,5***	4 KV	3,0	240	1,0	340	1,5	240	1,0
B Prim-Prim after fuse (functional) On PCB	340	***1,5***	240	***2,5***	4 KV	3,0 (1,5)	240	1,0	340	1,5	240	1,0
C Prim – Sec (input circuit) PCB	340	***4,0***	240	***5,0***	4 KV	5,5	240	2,0	340	1,5	240	1,0
D Prim – Sec (optical insulator)	340	***4,0***	240	***5,0***	4 KV	5,5	240	5,0	340	1,5	240	2,5
E Prim to Sec (Transformer)	528	4,4	300	***6,4***	4 KV	***5,5***	300	6,4	528	1,5	300	3,2
F Prim to earth (PCB)	340	2,0	240	***2,5***	4 KV	***3,0***	240	1,0	340	1,5	240	1,0
G Prim to Earth (not PCB)	340	2,0	240	***2,5***	4 KV	***3,0***	240	2,5	340	1,5	240	2,5
H Sec to Earth (60 Vdc was assumed)	60	0,4	60	***1,4***	60	***0,2***	60	0,063	60	0,2	60	0,063
I Sec to Sec (functional) 60 Vdc was assumed, PCB	60	0,4	60	***1,4***	60	***0,2***	60	0,063	60	0,2	60	0,063
The red marked, italicized figures have to be used for the design of a power supply (single phase)												

Comments on the spacing of IEC62103 (equal to EN60204 or EN50178)

Varistor of 340 Vac clamping voltage is used – therefore over voltage category II was assumed phase to phase – therefore use table 4 for input. Prim – Secondary use table 3, - interpolation is not allowed.

When IT (insulated PE) mains 400 or 500 Vac phase to phase voltage has to become assumed, then a clearance of 8 mm prim – to secondary according to table 3 is required.

Comments on UL508 spacing:

Use of UL840 is allowed.

Defined clearance as table 8.1 with the clamping voltage of the varistor (< 2,5 KV)

Use table 9.1 for Creepage and 9.2 for Creepage on PCB.

See also application note "MOV and Varistors"

As a summary of 2.3 the following spacings should be used for the design of a single phase power supply

	CL (clearance)	**CR (Creepage)**
A Prim-Prim before fuse (functional) On PCB	**3,0**	**1,5 (min. 1,0) (1)**
B Prim-Prim after fuse (functional) On PCB	**3,0 (1,5) (see note 4)**	**1,5 (2)**
C Prim – Sec (input circuit and optical insulator)	**5,5**	**5,0**
E Prim to Sec (Transformer) and PCB adjacent to the transformer	**5,5**	**6,4 (3)**
F Prim to earth (on PCB and other spacing)	**3,0**	**2,5**
H Sec to Earth (60 Vdc was assumed)	**0,2**	**1,4**
I Sec to Sec (functional) 60 Vdc was assumed, PCB	**0,2**	**1,4**

Note (1): Shorting of the functional insulation is allowed for IEC60950 as an alternative. UL 508 requires shorting, if the spacing is below the requirements. The external fuse is not allowed to open for UL508, therefore a min. spacing of 1,0 mm is mandatory.

Note (2): functional insulation – short as alternative method is allowed.

Note (3): based on working voltage measured below 320 Vrms, otherwise higher spacing is required (see table 2L in IEC60950.

Note (4): Overvoltage category III to IEC60664 (EN50178) will require 3 mm for functional. The clearance may be reduced to 1,5 mm after the EMC filter, if the transients are reduced from 4 KV to 2,5 KV. Spacing in approved connectors will not become evaluated in the application again.

2.4 Creepage and clearance for Three Phase Systems:

Typical measurement results - three phase equipment:

	IEC60950 (Europe and USA) Star mains (TN) with 500 Vac phase to phase voltage and IT mains with 230 Vac phase to phase)		EN60204 (based on IEC60664) or EN50178 or IEC62103 spacing, TN-mains : 500 V IT mains: 400 Vac phase to phase		USA: UL508 500 V delta mains	
	Vpeak	Vrms	Vpeak	Vrms	Vpeak	Vrms
Measured prim-sec on transformer	490	360	520 (570 V_{pnom})	320 (V_{nom}= 400 V)	710 Vp (use 760 V_{pnom})	483 V_{rms} (use 500 V_{rmsnom})

The standards require that the greater voltage of either the nominal input voltage or the real measured working voltage has to be used to define the spacing.

Spacing for three phase equipment:

	IEC60950 (Europea and USA) Star mains (TN) with 500 Vac phase to phase voltage and IT mains with 230 Vac phase to phase)				EN60204 (based on IEC60664) or EN50178 or IEC62103 spacing, TN mains with 500 V and IT mains with 400 V phase to phase voltage				USA: UL508 500 Vac phase to phase and phase to PE mains.			
	Vpk	CL	Vrms	CR	Vpk	CL	Vrms	CR	Vpk	CL	Vrms	CR
A Prim-Prim before fuse (functional) On PCB	710	3,0 **	500	5,2 **	710	***3,0***	500	2,5	2,5 KV	1,5	500	***2,5***
B Prim-Prim after fuse and after EMC filter (functional) On PCB	710	3,0 **	500	5,2 **	710	***3,0*** ***1,5***	500	2,5	2,5 KV	1,5	500	***2,5***
C Prim – Sec (input circuit) PCB	500	6,4	300	6,4	688	***8,0***	500	4,0	2,5 KV	1,5	500	2,5
D Prim – Sec (optical insulator)	500	6,4	300	6,4	688	***8,0***	400	***8,0***	2,5 KV	1,5	500	5,0
E Prim to Sec (Transformer)	750	6,4	390	8,0	688	***8,0***	400	***8,0***	2,5 KV	1,5	500	5,0
F Prim to earth (PCB)	500	3,2	300	***3,2***	688	***3,0***	400	2,0	2,5 KV	1,5	500	2,5
G Prim to Earth (not PCB)	500	3,2	300	***3,2***	688	3,0	400	***4,0***	2,5 KV	1,5	500	2,5
H Sec to Earth (60 Vdc was assumed)	60	***1,0***	60	***1,4***	60	0,2	60	1,25	60	0,2	60	0,063
I Sec to Sec (functional) 60 Vdc was assumed, PCB	60	***1,0***	60	***1,4***	60	0,2	60	0,063	60	0,2	60	0,063

The red marked, italicized figures have to be used for the design of a power supply (single phase)

Comments on the spacing of IEC62103 (equal to EN60204or EN50178)

Varistor of 340 Vac clamping voltage is used – therefore over voltage category II was assumed phase to phase after EMC filter.– therefore use table 4 for input.

Prim – Secondary used table 3, - interpolation is not allowed, resulting in a spacing of 8 mm

Prim to earth – interpolation is allowed, assumed 400 V due to IT –mains (PE insulated), used table 3

Comments on UL508 spacing:

Use of UL840 is allowed.

Defined clearance as table 5.1 with the clamping voltage of the varistor (< 2,5 KV)

Used table 6.1 for Creepage and 6.2 for Creepage on PCB.

As a summary of 2.3 the following spacing should be used for the design of a three phase power supply		
	CL (clearance)	**CR (Creepage)**
A Prim-Prim before fuse (functional) On PCB	3,0	2,5 (1)
B Prim-Prim after fuse (functional) On PCB	3,0 1,5 if EMC filter is reducing to overvoltage category II	2,5 (2)
C Prim – Sec (input circuit) PCB	8,0	6,4
D Prim – Sec (optical insulator)	8,0	8,0
E Prim to Sec (Transformer)	8,0	8,0
F Prim to earth (PCB)	3,0	3,2
G Prim to Earth (not PCB)	4,0	3,2
H Sec to Earth (60 Vdc was assumed)	1,0	1,4 (3) (2)
I Sec to Sec (functional) 60 Vdc was assumed, PCB	1,0	1,4 (3) (2)
Note 1: Shorting of the functional insulation is allowed for IEC60950 as an alternative. UL 508 requires shorting, if the spacing is below the requirements. The external fuse is not allowed to open for UL508, therefore a min. spacing of 2,5 mm is mandatory. Note 2: functional insulation – short as alternative method is allowed. If no fuse is used, then for UL508 the min. spacing of 2,5 mm is mandatory on the PCB. Note 3: value was not interpolated.		

2.5 Spacing requirements for DC systems.

2.5.1 Rectified single phase mains

For single-phase systems the working voltage of the DC system has to be applied. Example 110 Vdc – 370 Vdc would be the input voltage range.

Creepage Prim-Sec based on 370 Vdc would result in 8 mm primary to secondary (not interpolated)

Prim – Prim before fuse: 4 mm creepage (IEC60950)

Prim – Secondary : 8 mm (IEC60950)

Prim to Earth : 4 mm (IEC60950)

All other standards require less spacing. Overvoltage category II or III can be assumed for Industrial, depending of the client requirement.

2.5.2 Rectified three phase mains

Example: Input voltage range 300 Vdc to 800 Vdc.

DC Mains voltage of 800 Vdc would result in a creepage of:

Prim- Prim : 8,0 mm (IEC60950-1:2003)

Prim – Sec : 16 mm (IEC60950-1:2003)

Prim to earth : 8 mm. (IEC60950-1:2003)

The above creepage and clearance exceeds the spacing, achievable for most designs. The following solutions are available:

Alternative one:

Apply IEC60950-1:2006: The new edition of IEC60950 has the same table as IEC60664 for creepage.

Prim-Prim: 4,0 mm on PCB before fuse (is functional anyway and can be tested via dielectric testing instead)

Prim – Secondary (PCB) : 8 mm for the transformer you might use triple insulated wire.

Prim – Earth (PCB) : 4 mm

Alternative two:

Assume that the DC voltage plus or minus is earthed in the application.

Assume, that the DC voltage is not mains. Most of the time, the DC voltage for example is generated by a generator, for example when mains is lost and the motor voltage is converted to DC In this case it might be assumed, that the bridge is outside of the power supply instead of inside and all working voltages are identical

In this case the same creepage and clearance requirements as with AC voltage applies, as long as the DC range is within AC voltage multiplied by 1,42.

The assumption will be recorded in the “summary of Testing”.

3.0 Components

The components require USA and European approval. Details are given in appendix B.

Nevertheless here we like to mention some specialties:

UL508 :

- PCB board has to be approved for Support of live parts. The datasheet of the boards has to be available at the time of the approval.
- Connectors have to be approved for field wiring FW = 2.
- Fuse is not allowed to get physically broken during abnormal testing’. 5 by 20 mm rated 250 Vac is allowed for input voltage 500 Vac
- If the unit is rated also for DC input voltage, and then additional fuse testing is required.
- Varistor has to be UL approved to use it for reduction of the spacing.
- Special care has to be taken with plastic parts. Barriers have to comply with the requirements of Chapter 15; Insulation foil min. thickness 0, 71 mm or a 5000 V test has to be performed after humidity treatment.

See also application note “safety critical components”

4.0 Temperature measurements

UL508 is specifying the max. Temperature rise at an ambient of 40 °C, UL/IEC60950 is mentioning absolute maximum temperatures to be measured at maximum ambient. UL 508 requirements are less compared to IEC60950. (max. values of temperature rise according IEC60950 are shown in brackets).

Class A	65 deg C Temp. rise resulting in max. 105 deg C (90)
Class B	85 deg C Temp. rise resulting in max. 125 deg C (110)
Class F	95 deg C Temp. rise resulting in max. 135 deg C (130)

UL requires an UL insulation system OBJY2 in case the temperature class exceeding class A.
It might be an alternative to specify the unit for 40 °C ambient for UL508 use only to avoid the requirements of an insulation system.

See also application note "UL Insulation systems"

5.0 Some comments on the marking

Fuse rating adjacent to fuse or in the manual.
UL508 requires the information about the torque and size of the wire in the manual or on the type label.
PE connection has to be marked.
Warning marks recommended:

- Do not open the unit, not serviceable.
- Read manual before operation.
- Remove power before disconnection.

See also application note "Marking".

6.0 UL508 and CSA22.2-107-1

When a product complies with IEC60950-1:2003 , then the spacing of UL508 and CSA22.2-107 is lower.

The main differences between these and IEC60950 are as follows :

CSA22.2-107-1:

C22.2 no 107.1 cl. 6.6.1 (a) has abnormal test with secondary terminal short-circuited for 7h.

UL508:
See appendix

- Temperature test at maximum specified ambient
- Barriers to be tested with 5000 Vac after humidity testing
- Connectors field wiring FW=2
- Different limits for temperature test

Please note, that Power Supplies approved for IEC60950 are always useable for UL508 and CSA Industrial applications. The additional approval to UL508 and CSA22.2-107 is often done due to marketing issues.

7.0 Recommended certifications

Besides the many certification marks on the market we recommend the following:

	Europe	USA and Canada
Certification marks.	INNOVA GS	UL-NRTL/C or CSA-NRTL/C

Specifically in Europe there are DIN Rail manufacturer, which do only UL via the client test data program. This means, the manufacturer is doing all testing without additional control. There is a high pressure on prices and INNOVA's experience in the past was that UL approved DIN Rail power supplies without European mark does not always fulfill the requirements of the standard or the specification.
We recommend the GS certification. GS is the only mark in Europe backed up by a law. (Not mandatory).

GS contains:

- Safety
- - EMC testing (can be done even by the manufacturer)
- - proper manual

In case of any law issues in Europe, the GS mark gives a maximum of protection for the manufacturer.

Appendix A: Explanation of the tables for spacing

Use the mains voltage to define clearance to table 2H, if Vpeak exceeds the value, then use table 2J in addition

The abstract of Table 2H in IEC950 lists the minimum clearances for insulation in primary circuits and between primary and secondary circuits

CLEARANCES in millimeters

WORKING VOLTAGE up to and including		MAINS TRANSIENT VOLTAGE 1 500 V (Nominal AC MAINS SUPPLY voltage ≤ 150 V)						MAINS TRANSIENT VOLTAGE 2 500 V (Nominal AC MAINS SUPPLY voltage > 150 V ≤ 300 V						MAINS TRANSIENT VOLTAGE 4 000 V (Nominal AC MAINS SUPPLY voltage > 300 V ≤600 V)		
Voltage peak or d.c.	Voltage r.m.s. (sinu-soidal)	Pollution Degrees I and 2			. Pollution Degree 3			Pollution Degrees 1 and 2			. Pollution Degree 3			. Pollution Degrees 1. 2 and 3		
V	V	F	B/S	R	F	B/S	R	F	B/S	R	F	B/S	R	F	B/S	R
71	50	0.4	1,0 (0.5)	2,0 (1.0)	0,8	1,3 (0,8)	2,6 (1,6)	1,0	2,0 (1,5)	4,0 (3,0)	1,3	2,0 (1,5)	4,0 (3,0)	2,0	3,2 (3,0)	6,4 (6,0)
210	150	0,5	1,0 (0,5)	2,0 (1,0)	0,8	1,3 (0,8)	2,6 (1,6)	1,4	2,0 (1,5)	4,0 (3,0)	1,5	2,0 (1,5)	4,0 (3,0)	2,0	3,2 (3,0)	6,4 (6,0)
420	300	F 1,5 B/S 2,0 (1,5) R 4,0 (3,0)												2,5	3,2 (3,0)	6,4 (6,0)
840	600	F 3.0 B/S 3.2 (3.0) R 6.4 (6.0)														
1 400	1 000	F/B/S 4.2 R 6,4														

1) The values in the table are applicable to FUNCTIONAL INSULATION *(F),* BASIC INSULATION (B), SUPPLEMENTARY INSULATION (S) and REINFORCED INSULATION (R).

2) The values in parentheses are applicable to BASIC INSULATION. SUPPLEMENTARY INSULATION or REINFORCED INSULATION only if manufacturing is subjected to a quality control programme that provides at least the same level of assurance
as the example given in R.2 in particular, DOUBLE INSULATION and REINFORCED INSULATION shall be subjected to ROUTINE TESTS for electric strength

3) For WORKING VOLTAGES between 2 800 V peak or d.c. and 42 000 V peak or dc, linear interpolation is permitted between
the nearest two points, the calculated spacing being rounded up to the next higher 0,1 mm increment.

Table 2J — Additional clearances for insulation in primary circuits with peak working voltages exceeding the peak value of the nominal a.c. mains supply voltage

Nominal AC MAINS SUPPLY voltage ≤ 150 V		Nominal AC MAINS SUPPLY voltage 150V ≤ 300V	Additional CLEARANCE rem	
Poilution Degrees I and 2	Pollution Degree 3	Pollution Degrees 1, 2 and 3	FUNCTiONAL , BASIC or SUPPLEMENTARY INSULATION	REINFORCED INSULATION
Maximum PEAK WORKING VOLTAGE	Maximum PEAK WORKING VOLTAGE	Maximum PEAK. WORKING VOLTAGE		
210(210)	210(210)	420(420)	0	0
298(288)	294(293)	493(497)	0,1	0,2
386 (366)	379(376)	567(575)	0,2	0,4
474(444)	463(459)	640 (652)	0.3	0,6
562(520)	547(541)	713 (729)	0,4	0,8
650 (600)	632 (624)	787(807)	0,5	1
738 (678)	715 (707)	860 (884)	0,6	1,2
826 (756)	800 (790)	933 (961)	0,7	1,4
914 (839)		1006 (1039)	1,0	0,5
1002 (912)		1060 (1116)	0,8	1,6
1090(990)		1153 (1193)	1	2
		1226 (1271)	1,1	2.2
		1300 (1348)	1,2	2,4
		- (1425)	1,3	2.6

The values In parentheses shall apply:
- when the values in parentheses In table 2H are used at accordance with item 2) of table 2H, and
-for FUNCTIONAL. INSULATION

To calculate the creepage, take the rated input voltage or the working voltage as measured.

Pollution degree normally is 2, most materials have CTI - factor of III. II is only used, if there is no test report available for better CTI - properties.

Table 2L in IEC 950 indicates the minimum creepage distances

CREEPAGE DISTANCES in millimeters

WORKING VOLTAGE V r.m.s. or d.c.	FUNCTIONAL BASIC and SUPPLEMENTARY INSULATION						
	Pollution Degree 1	Pollution Degree 2			Pollution Degree. 3		
	Material Group	Material Group			Material Group		
	I, II, IIIa or IIIb	I	II	IIIa or IIIb	I	II	IIIa or III b
≤50	**see 1)**	0,6	0,9	1.2	1,5	1,7	1,9
100		0,7	1,0	1,4	1.8	2.0	2,2
125		0,8	1,1	1,5	1.9	2,1	2.4
150		0,8	1,1	1.6	2,0	2,2	2,5
200		1,0	1,4	2,O	2.5	2.8	3,2
250		1,3	1,8	2,5	3.2	3,6	4.0
300		1,6	2,2	3.2	4,0	4,5	5.0
400		2,0	2,8	4.0	5.0	5.6	6.3
600		3,2	4,5	6.3	8,0	9,6	10,0
800		4,0	5.6	8.0	10.0	11,0	12,5
1000		5,0	7,1	10.0	12,5	14,0	16,0

1) No minimum CREEPAGE DISTANCE is specified for insulation in Pollution Degree 1, However, the minimum CLEARANCE. as previously determined in 2.10.3 or annex G, still applies
2) Linear interpolation is permitted between the nearest two points. The calculated spacing being rounded to the next 0.1 mm increment.

Table 3 of IEC62103 (equal to EN50178) indicates the Clearances between mains-circuits and their environment
(impulse withstand voltages according to overvoltage category III)

Rated insulation voltage (Definition. see 5.2.16.1. par. 1)	Basic insulation. supplementary insulation					Reinforced insulation	
	Pollution degree				Impulse withstand voltage 1.2/50 μs		Impulse withstand voltage 1.2/ 50 μs
	1	2	3	4			
	mm	mm	mm	mm	kV	mm	kV
≤50 x $\sqrt{2}$ V = 71 V	0,1	0.2	0.8	1.6	0.8	0,5	1,5
100 x $\sqrt{2}$ V = 141V	0,5	0.5	0.8	1.6	1.5	1.5	2.5
150 x $\sqrt{2}$ V = 212 V	1.5	1.5	1,5	1.6	2.5	3,0	4,0
300 x $\sqrt{2}$ V = 424 V	3.0				4.0	5.5	6.0
600 x. $\sqrt{2}$ V = 849V	5,5				6.0	8.0	8.0
1 x. $\sqrt{2}$ kV = 1.41kV	8,0				8.0	14.0	12.0
	Inhomogeneous field		Homogeneous field			Inhomo-geneous field	Homo-geneous field
1.5x $\sqrt{2}$ kV = 2.12kV	11.5		4.0		10.5	20	6.5	16.5
3 X $\sqrt{2}$ kV= 4.24 kV	21,0		6.5		17.0	36	11	27.0
6x $\sqrt{2}$ kV = 8.49 kV	47,0		14,0		33,0	80	24	53.0
10x $\sqrt{2}$ kV = 14,1kV	78.0		23.0		52.0	135	36	83.0
above 10 x $\sqrt{2}$ kV	according to IEC 60071-1 and IEC 60071-2							

Interpolation up to 1000 x $\sqrt{2}$ V not permitted, but is permitted above 1 000 x $\sqrt{2}$ V.

NOTE 1 A homogeneous field is an electric field which has an .ess $\sqrt{2}$ entially constant voltage gradient between electrodes (uniform field). such as that between two spheres where the radius of each sphere is greater than the distance between them,
NOTE 2 A inhomogeneous field is an electric field which does not have an essentially constant voltage gradient between electrodes (non-uniform field)

EN50178/IEC62103 – Creepage (which is identical to EN60204)

The abstract of Table 4 of IEC 62103 shows the clearances between non-mains-circuits and their environment (Impulse withstand voltages according to overvoltage category II)

Rated insulation voltage (Definition see 5.2.16.2, paragraph 1)	Basic Insulation. supplementary insulation					Reinforced insulation	
	Pollution degree				Impulse withstand voltage.		Impulse withstand voltage
	1	2	3	4	1.2/50 **us**		1.2/50 us
	mm	mm	mm	mm	kV	mm	kV
≤ 50 x $\sqrt{2}$ V= 71 V	0.04	0.2 [1)]	0.8	1.6	0.5	0.2	0,8
100 x $\sqrt{2}$ V =141 V	0.1	0.2	0.8	1.6	0.8	0.3	1,3
150 x $\sqrt{2}$ V= 212 V	0.5	0.5	0.8	1.0	1.5	1.3	2.4
.300 x $\sqrt{2}$ V = 424 V	1,5	1,5	1,5	1.8	2.5	3.0	4,0
600 x $\sqrt{2}$ V =849 V	3,0				4,0	6.0	6,4
1 x $\sqrt{2}$ kV =1.41 kV	5.5				6.0	10,4	9,6
	Inhomogeneous field		Homogeneous field			Inhomo-geneous field	Homo-geneous field
1.5 x $\sqrt{2}$ kV = 2,12kV	8,0		3.0		8.0	15	4,8	12,8
3 x $\sqrt{2}$ kV =4.24 kV	17.0		5.2		14.0	29	9	22.4
6 x $\sqrt{2}$ kV = 8.49kV	33.0		10.0		25.0	60	17	40,0
10 x $\sqrt{2}$ kV =14,1 kV	55.0		10,0		92	27	38.0	60,8
above 10x$\sqrt{2}$ kV=1.41kV	according to IEC 80071.1 and 1EC 80071.2							

Interpolation permitted.
1) on PWBs 0.1 mm
2) This table also applies to clearances between live parts at the connections of the EE to the supply mains according to the last sentence in paragraph 2 of 5.2.16.3

The clearances given in the columns 2 to 5 of Table 4 sustain at least the impulse withstand voltages given in column 6. Where transient surge voltages are expected to be higher than those given In column 6, then the clearances in columns 2 to 5 shall be determined based on this (higher) value in co umn 6. The clearances in column 7 for reinforced insulation shall also be chosen according to this line of Table 4 if required. Interpolation is permitted.
In case of rated insulation voltages up to 1 000 x .ffv, te clearances of Table 4 correspond to the requirements of

inhomogeneous distribution of the electric field across the electrodes of the clearance. This corresponds to the conditions of practice. In case of homogeneous field distribution and rated insulation voltages above 1 000 X .5v, the clearances may be selected corresponding to the lower values In this case, however, an impulse voltage test is required according to 19.1 of IEC 60061.1 with a 2 L internal impedance of the test generator. For testing see 9.4.5.1.

UL508 (UL840) clearance :

Table 8.1
Minimum clearances for equipment [1]

Phase-to-ground [2] rated system voltage (mis and dc)				Rated impulse withstand **voltage** peak, kV	Clearance. mm			
Overvoltage category					Pollution degree			
I	II	III	IV		1	2	3	4
50	—	—	—	0:33	0.01	0.2	0.8	1.6
100	50	—	—	0:50	0.04	0.2	0.8	1.6
ISO	100	50	—	0:80	0.10	0.2	0.8	1.6
300	150	100	50	1:5	0.5	0.5	0.8	1.6
600	300	150	100	2:%	1.5	1.5	1.5	1.6
1000	600	300	150	4:0	3.0	3.0	3.0	3.0
1500	1000	600	300	6.0	5.5	5.5	5.5	5.5
—	1500	1000	600	8:0	8.0	8.0	8.0	8.0
—	—	1500	1000	12:0	14.0	14.0	14.0	14.0
—	—	—	1500	16:0	19.4	19.4	19.4	19.4

[1] The minimum values for pollution degrees 2,3, and 4 are premised on the concept that pollution which may be present in these micro-environments may bridge small clearances.
For ungrounded systems or systems with one phase grounded, the phase-to-ground voltage is considered to be the same as the phase-to-phase voltage for the purposes of using this table

Typical examples of categories for products are given below. Users of this standard will need to establish that rated impulse voltage values are appropriate for the expected applications of the products covered.

Category IV - Primary Supply Level. Overhead lines and cable systems including distribution and its associated overcurrent protective equipment (equipment installed at the service entrance
Category Ill - Distribution Level. Fixed wiring and associated equipment (not electrical loads) connected to the primary supply level. Category IV
Category II- Load Level. Appliances aid portable equipment and the like connected to the distribution level, Category III.
Category I - Signal Level Special equipmenl or parts of equipment such as low-voltage electronic logic systems, remote controls, signaling and power limited (per NEC Article 725) circuits connected to the load level, Category II

Value to use based on the rating of the overvoltage protection means
• Linear interpolation of the values is permitted
* See 9.3 .

8.8 Except as noted in 1.7, clearances may be.
a) Evaluated by the dielectric voltage-withstand test in 14.2 1: or
b) Selected and measured in accordance with the dimensions in Table 8.1.
8.9 Clearances selected and measured in accordance with the dimensions in Table 8 1 do not require testing

The “clamping voltage” of the varistors is used to calculate the clearance
“clamping voltage” = rated impulse voltage.

This is not the opinion of INNOVA:

Alternatively to the “clamping voltage” the left column of “over voltage category” depending on the lower level might be used. UL 508 means: Over voltage category III applies.

UL508 (UL840) requires the minimum creepages as listed below :

Abstract of Table 9.1 of UL508 (UL840)
Minimum acceptable creepage distances [3]

Operating voltage, volts ac rms or dc	Creepage distances for equipment subject to long-term stress, mm										
	Pollution degree 1	Pollution degree 2			Pollution degree 3				Pollution degree 4		
	All material groups	Material group [4]			Material group [4]				Material group [4]		
		I	II	IIIa.b	I	II	IIIa	IIIb	I	II	IIIa
10	0.08	0.4	0.4	0.4	1.0	1.0	1.0	1.0	1.6	1.6	1.6
125	0.09	0.42	0.42	0.42	1.05	1.06	1.05	1.05	1.6	1.6	1.6
16	0.1	0.45	0.45	0.45	1.1	1.1	1.1	1.1	1.6	1.6	1.6
20	0.11	0.48	0.48	0.48	1.2	1.2	1.2	1.2	1.6	1.6	1.6
25	0.125	0.5	0.5	0.5	1.26	1.26	1.25	1.25	1.7	1.7	1.7
32	0.14	0.53	0.53	0.53	1.3	1.3	1.3	1.3	1.8	1.8	1.8
40	0.16	0.56	0.8	1.1	1.4	1.6	1.8	1.8	1.9	2.4	3.0
50	0.18	0.6	0.86	1.2	1.5	1.7	1.9	1.9	2.0	2.5	3.2
63	0.2	0.63	0.9	1.25	1.6	1.8	2.0	2.0	2.1	2.6	3.4
80	0.22	0.67	0.96	1.3	1.7	1.9	2.1	2.1	2.2	2.8	3.6
100	0.25	0.71	1.0	1.4	1.8	2.0	2.2	2.2	2.4	3.0	3.8
125	0.28	0.75	1.05	1.6	1.9	2.1	2.4	2.4	2.5	3.2	4.0
160	0.32	0.8	1.1	1.6	2.0	2.2	2.5	2.5	3.2	4.0	5.0
200	0.42	1.0	1.4	2.0	2.5	2.8	3.2	3.2	4.0	5.0	6.3
250	0.56	1.25	1.8	2.5	3.2	3.6	4.0	4.0	5.0	6.3	8.0
320	0.75	1.6	2.2	3.2	4.0	4.5	5.0	5.0	6.3	8.0	10.0
400	1.0	2.0	2.8	4.0	5.0	5.6	6.3	6.3	8.0	10.0	12.5
500	1.3	2.5	3.6	6.0	6.3	7.1	8.0	8.0	10.0	12.6	16.0
630	1.8	3.2	4.5	6.3	8.0	9.0	10.0	10.0	12.5	16.0	20.0
800	2.4	4.0	5.6	8.0	10.0	11.0	12.5	y	16.0	20.0	25.0
1000	3.2	6.0	7.1	10.0	12.5	14.0	16.0	y	20.0	25.0	32.0

[3] Linear interpolation of the values is permitted.
[4] See 9.2.

UL508 (UL840) requires the minimum creepage on the PCB as listed below

Table 9.2
Minimum acceptable creepage distances on printed wiring boards [a,d]

Operating voltage, volts ac rms or dc	Minimum creepage, mm	
	Pollution degree	
	1 [b]	2 [c]
10—5O	0,025	0,04
63	0.04	0.063
80	0,063	0,1
100	0.1	0.16
125	0.16	0.25
160	0.25	0.4
200	0.4	0.63
250	0.56	1.0
320	0.75	1.6
400	1.0	2.0
500	1.3	2.5
630	1.8	3,2
800	2.4	4.0
1000	3,2	5,0

a) Use Table 9.1 for pollution degrees 3 and 4.
b) Material Groups I. II. IIIa. IIIb.
c) Material Groups I, II. IIIa. For Material Group IIIb use Table 9.1
d) Linear interpolation of the values is permitted.

Appendix B: UL508: Requirements for „UL – Listed"

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TO:		**DATE:**	August14, 2001
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PAGES:	3	**E-MAIL:**	Walter.Hofmair@de.ul.com
RE:	UL60950 R/C to UL508 Listed		

Dear Client,

This fax is to help clarify the earlier misunderstandings related for UL508-listing of already UL60950-R/C approved power supplies.

One major misunderstanding is that listing can only be done in accordance with UL508 under CCN (NMTR/7) for miscellaneous apparatus and not with UL508C.

Please use the following guidelines as a reference:

1. **Remove the "Conditions of Acceptability"** from the UL1950 - R/C report. This means evaluating the conditions and determining if the device meets the requirements for Listing with the conditions being removed. For example, a condition that states, "The temperature test was performed with fans rated at 100CFM" cannot be removed unless the test requirements can be met without the fan being used, or if the fan is included in the report.
2. **Perform Temperature Test** on the bench in a test box having 150% of the power supply dimensions (length, width, height). The temperatures have to be extrapolated to an ambient temperature of 40°C (e.g. 25°C outside the box → add 15°C to the measured temperatures).

    a. in a box greater than 150% of the dimensions of the power supply, if the unit is marked with a box factor or the information is provided on a stuffer sheet.

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b. in an oven (only possible when equipment is rated at least for 40°C ambient) with rated ambient temperature. This means the temperature around the power supply → surrounding air temperature.
The temperature test is to be conducted without forced air and without a box.
Allowable Temperature Limits see UL508 Table 43.1.

c. A dielectric test with 1000Vac + 2 times the supply voltage for 1 Minute has to be conducted whichever heating test method is used.

3. **Check Spacings** according to UL840 or UL508 (possible to use both at the same time)
The power supply can be evaluated to pollution degree 2, if the manufacturer don't want to specify pollution degree 3 and must be evaluated to over voltage category III.

   a. Primary and secondary connectors have to be R/C(XCFR2), suitable for field wiring (FW Code 2) and have to be in "Use Group C" (Industrial, General) or "Use Group D" (Devices having limited ratings, max. 1 horse power, 746W, see UL508 Par. 36.7.).

   b. General: If a R/C-varistor is used to reduce over voltages, then Table 5.1 of UL840 can be used. Use the clipping voltage of the R/C-varistor from Table 5.1 middle column ("Rated impulse withstand voltage peak") and ignore the left side of the table.

      For all spacings, UL840 **OR** UL508 can be used except for the spacings to an **OUTER** enclosure (here only UL508 Table 36.1 is applicable, this do not apply for an open type enclosure). Spacings are required between opposite polarity (e.g. L to N, L/N to PE, High DC-Primary+ to ground) but not on components (e.g. Switching transistors, Bulk Capacitors, terminal blocks ...)

      On PCB's UL840, Table 6.2 else UL840 Table 6.1 for creepage distance and UL840 Table 5.1 for clearances. (also UL508 Table 36.1 is possible).

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c. On PCB's, which have at least a flammability rating of V-0, if spacings are less than required, the Printed Wiring Board Abnormal Test in accordance with UL508 Paragraph 60 can be done (e.g. on the bulk capacitor or switching transistor where the soldering pads are too narrow). For these tests a listed 3A-fuse must be in line with the ground connection.

A branch circuit protection in front of the unit cannot open.
If a internal fuse opens, a marking in accordance with 63.20 (fuse rating with current and voltage near fuse holder) is required.

If a component opens during testing (e.g. a switching transistor) the test has to be done twice. If a trace or a wire opens, the gap is to be electrically shorted and the test continued until ultimate results occur.
Unit has to be placed in cheesecloth. For additional information see UL508 Paragraph 60.

In the descriptive report the PCB must be described with CTI and Flammability better V-0.

4. **Insulating Materials-Insulating Barriers**- This material, generally used for insulating Solid State devices mounted to the heat sink, must meet the requirements of UL508 para. 15.1 (direct support of live parts) and UL508 para. 37 (Insulating barriers) at the thickness used. In addition other materials that meet the definition of para. 15.1 a and b for direct support of live parts must meet the requirements of Section 15, in particular the bobbin of a transformer must be checked to see if it is considered direct support of live parts.

If the thickness requirement for a barrier will not be fulfilled, a 5000Vac dielectric test after a humidity preconditioning (96h, 30°C, 95% rel. Hum.) is acceptable. The barrier material has then to be described with Mfr., Type and min. thickness as tested.

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General remarks:

a. Fuses have to be appropriately rated for their usage. A Fuse for DC-Supply has to be recognized or Listed for DC.
Acceptable is also the test for AC-fuses in DC-circuits as outlined in UL60950 (overload at 200% of the rated current with max. rated DC-Voltage, three times; apply a stiff source with the highest rated DC-Voltage to the fuse, 5 times). A yearly follow up test is in addition required.

b. Marking of R/C and Listing on one Label is allowed. This marking should be done in a way, that no confusion between the rating and approval occurs (e.g. two boxes including each rating and approval mark).
The electrical rating (not the operating voltage, input and output voltage, frequency, current or power) is required.
The following information must be provided on the product or on a stuffer sheet:
- Tightening torque for the field wiring terminals.
- Pollution degree 2
- Surrounding air temperature (if applicable)
- size of the branch circuit protection if not usual.

c. PCB's must be suitable for direct support of live parts (see yellow card).

d. The grounding test with the Canadian requirements must be conducted related to the specified branch circuit protection.

e. A 5 by 20mm fuse (rated 250Vac) used in a 500Vac circuit is acceptable if the fuse opens properly in all single fault conditions twice. For all testing a stiff source is required. (Similar with a resistor acting as a fuse in a primary circuit for single fault)

f. A listed 30A-fuse must be wired in the grounding for all single fault tests.

Please don't hesitate to contact us if you need further assistance.

Sincerely yours,

Walter Hofmair
Project Engineer

Reviewed by

Kevin Connelly
Senior Project Engineer

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Exception No. 5: A material that is used in a device that incorporates contacts but is not used within 1/2 inch (12.7 mm) of the contacts need not comply with the HAI PLC requirements.

Exception No. 6: A material without a CTI PLC value or with a CTI PLC value area greater (worse) than the value required by Table 15.1 may alternatively be subjected to the end-product Special Arcing Test specified in the Standard for Polymeric Materials — Use in Electrical Equipment Evaluations, UL 746G.

Exception No, 7: A material without a CTI PLC value or with a CTI PLC value greater (worse) than the value required by Table 15.1 shall be considered in compliance with the CTI PLC requirements if:

a) It has a High-Voltage-Arc Tracking (HVTR) PLC value of 1 or less; or

b) The over surface spacings between the uninsulated live parts are at least 1/2 inch (12.7 mm).

Table 15.1
Minimum material characteristics necessary for the direct support of uninsulated live parts

UL 94 Flame Class	RTI Elec	Performance Level Category (PLC)		
		HWI[a]	HAI[b]	CT1[C]
HB	a	2	1	4
V-2	a	2	2	4
V-1	a	3	2	4
V-0	a	4	3	4

a The electrical Relative Thermal Index (RTI) value of a material is to be determined in accordance with the Standard for Polymeric Materials — Long Term Property Evaluations, UL 746B. by test or by use of the generic RTI table. This material characteristic is dependent upon the minimum thickness at which the material is being used and shall not be exceeded during the Temperature Test, Section 43.

b The High Current Arc Resistance to Ignition (HAI) and Hot Wire Ignition (HWI) value of a material is to be determined by test in accordance the Standard for Polymeric Materials — Short Term Property Evaluations, UL 746A. This material characterstic is dependent upon the minimum thickness at which the material is being used.

c The Comparative Tracking Index (CTI) PLC value of a material is to be determined by test in accordance with UL 746A. This material characteristic is not dependent upon the minimum thickness at which the material is being used.

Table 15.2 Generic materials for direct support of uninsulated live parts

Table 15.2 revised July 16, 1999

Generic Material	Thickness,		
	Inch	(mm)	RTI. °C
Diallyl Phthalate	0.028 .	(0.71) -.	105
Epoxy	0.028	(0.71)	105
Melamine	0.028	(0.71)	130
Melamine-Phenolic	0.028	(0.71)	130
Phenotic	0.028	(0.71)	150
Unfilled Nylon	0.028	(071)	105
Unfilled Polycarbonate	0.028	(0.71)	**105**
Urea Formaldehyde	0.028	(0.71)	100
Ceramic, Porcelain, and Slate	No limit		No limit
Beryllium Oxide	No limit		No limit

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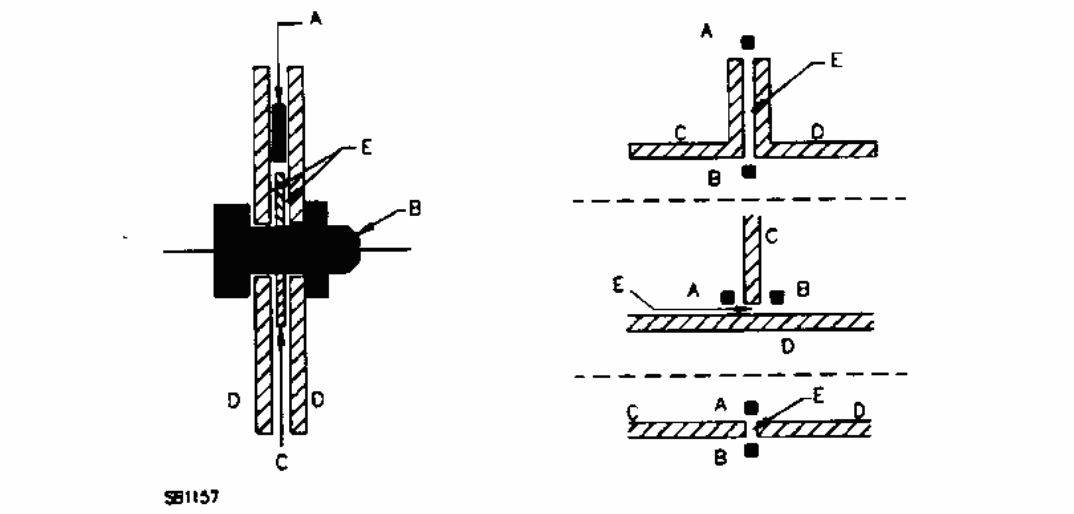
Table 37.1
Generic materials suitable as a barrier

Generic **material** -	**Minimum thickness,**		**RTI, °C**
	Inch	**(mm)**	
Aramid Paper	0010	(0.25)	105
Cambric	0.028	(0.71)	105
Electrical Grade Paper	0.028	(0.71)	105
Epoxy	0.028	(0.71)	105
Mica	0.006	(0.15)	105
Mylar (PETP)	0.007	(0.18)	105
RTV	0.028	(0.71)	105
Silicone	0.028	(0.71)	105
Treated Cloth	0.028	(0.71)	105
Vulcanized Fiber	0028	(0.71)	105
NOTE — Each material shall have at least the minimum thickness specified and its Relative Thermal Index (RTI) value shall not be exceeded during the Temperature Test.			

38 Clamped Insulating Joints in Lieu of Spacings

38.1 In the case of a clamped insulating joint, spacings are to be measured through cracks unless a clamped joint has passed the test described in 49.3.2. A clamped joint is a joint between two pieces of insulation that are under pressure as shown in Figure 38.1 . Adhesives, cements, and the like, if used to effect a seal in place of a tightly mated joint, shall comply with the Standard for Polymeric Materials — Use in Electrical Equipment Evaluations, UL 746C.

Figure 38.1
Clamped joint



Parts A, B — Live parts of opposite polarity, or a live part and grounded metal part with spacing through the crack between C and D less than required in Table 36.1 or 36.3.

Parts C, D — Insulating barriers clamped tightly together so that the dielectric strength between A and B is greater than the equivalent air spacing.

Part E — The clamped joint,