6.5.2 Insulation requirements for probe assemblies

6.5.2.1 GENERAL

Measuring circuits are subjected to WORKING VOLTAGES and transient stresses from the circuit to which they are connected during measurement or test. When the measuring circuit is used to measure mains supplies or circuits directly connected to them, the transient stresses can be estimated by the location within the installation at which the measurement is performed. When the measuring circuit is used to measure any other electrical signal, the transient stresses should be considered by the OPERATOR to ensure that they do not exceed the capabilities of the probe assembly.

6.5.2.2 CLEARANCES for probe assemblies of MEASUREMENT CATEGORIES II, III and IV

CLEARANCES for probe assemblies of MEASUREMENT CATEGORIES II, III and IV are specified in Table 6.

Table 6
CLEARANCES of probe assemblies RATED for MEASUREMENT CATEGORIES

Nominal a.c. r.m.s. line-to-neutral or d.c. voltage of mains to which the probe assembly is designed to be connected	CLEARANCE mm					
	BASIC INSULATION and SUPPLEMENTARY INSULATION			REINFORCED INSULATION		
V	MEASUREMENT CATEGORY II	MEASUREMENT CATEGORY III	MEASUREMENT CATEGORY IV	MEASUREMENT CATEGORY II	MEASUREMENT CATEGORY III	MEASUREMENT CATEGORY IV
≤ 50	0,04	0,1	0,5	0,10	0,32	1,4
> 50 ≤ 100	0,1	0,5	1,5	0,32	1,4	3,0
> 100 ≤ 150	0,5	1,5	3,0	1,4	3,0	6,0
> 150 ≤ 300	1,5	3,0	5,5	3,0	6,0	10,4
> 300 ≤ 600	3,0	5,5	8	6,0	10,4	15
> 600 ≤ 1 000	5,5	8	14	10,4	15	23,9
> 1 000 ≤ 1 500	8	11	18	16	22	36
> 1 500 ≤ 2 000	14	18	22	28	36	44
> 2 000 ≤ 3 000	18	22	25	36	44	50

Conformity is checked by inspection and measurement or by the a.c. voltage test of 6.6.5.1 with a duration of at least 5 s or the impulse voltage test of 6.6.5.3, or for probe assemblies stressed only by d.c., the 1 min d.c. voltage test of 6.6.5.2 or the impulse voltage test of 6.6.5.3, using the test voltage of Table 10 for the required CLEARANCE.

6.5.2.3 CLEARANCES for probe assemblies which are not RATED for MEASUREMENT CATEGORIES II, III, or IV

6.5.2.3.1 General

CLEARANCES for probe assemblies which are not RATED for MEASUREMENT CATEGORIES II, III, or IV are calculated according to 6.5.2.3.2.

If they have either of the following characteristics, CLEARANCES are also determined according to 6.5.2.3.3, and the larger of the two CLEARANCE values is the required CLEARANCE:

a) the WORKING VOLTAGE includes a recurring peak voltage that may include a periodic non-sinusoidal waveform or a non-periodic waveform that occurs with some regularity;

b) the WORKING VOLTAGE has a frequency above 30 kHz.

6.5.2.3.2 CLEARANCE calculation

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION are determined from the following formula:

$$\text{CLEARANCE} = D_1 + F \times (D_2 - D_1)$$

where

F is a factor, determined from one of the equations:

$F = (1{,}25 \times U_w/U_m) - 0{,}25$ if $U_w/U_m > 0{,}2$

$F = 0$ if $U_w/U_m \leq 0{,}2$

where

$U_m = U_w + U_t$;

U_w = the maximum peak value of the WORKING VOLTAGE;

U_t = the maximum additional transient overvoltage

D_1 and D_2 are values taken from Table 7 for U_m.

where

D_1 represents the CLEARANCE that would be applicable to a transient overvoltage with the shape of a 1,2 × 50 µs impulse

D_2 represents the CLEARANCE that would be applicable to the peak WORKING VOLTAGE without any transient overvoltage

CLEARANCES for REINFORCED INSULATION are twice the values for BASIC INSULATION.

Conformity is checked by inspection and measurement or by the a.c. voltage test of 6.6.5.1 with a duration of at least 5 s, or the impulse voltage test of 6.6.5.3, using the applicable voltage from Table 10 for the required CLEARANCE.

Table 7
CLEARANCE values for the calculation of 6.5.2.3.2

Maximum voltage	CLEARANCE		Maximum voltage	CLEARANCE	
U_m	D_1	D_2	U_m	D_1	D_2
V	mm	mm	V	mm	mm
14,1 to 266	0,010	0,010	4 000	2,93	6,05
283	0,010	0,013	4 530	3,53	7,29
330	0,010	0,020	5 660	4,92	10,1
354	0,013	0,025	6 000	5,37	10,8
453	0,027	0,052	7 070	6,86	13,1
500	0,036	0,071	8 000	8,25	15,2
566	0,052	0,10	8 910	9,69	17,2
707	0,081	0,20	11 300	12,9	22,8
800	0,099	0,29	14 100	16,7	29,5
891	0,12	0,41	17 700	21,8	38,5
1 130	0,19	0,83	22 600	29,0	51,2
1 410	0,38	1,27	28 300	37,8	66,7
1 500	0,45	1,40	35 400	49,1	86,7
1 770	0,75	1,79	45 300	65,5	116
2 260	1,25	2,58	56 600	85,0	150
2 500	1,45	3,00	70 700	110	195
2 830	1,74	3,61	89 100	145	255
3 540	2,44	5,04	100 000	165	290
Linear interpolation is allowed.					

NOTE The following is an example calculation:

CLEARANCE for REINFORCED INSULATION for a WORKING VOLTAGE with peak value of 3 500 V and an additional transient voltage of 4 500 V (this can be expected within an electronic switching-circuit):

Maximum voltage $U_m = U_w + U_t = (3\,500 + 4\,500)\ V = 8\,000\ V$

$U_w / U_m = 3\,500 / 8\,000 = 0,44 > 0,2$

thus $F = (1,25 \times U_w / U_m) - 0,25 = (1,25 \times 3\,500 / 8\,000) - 0,25 = 0,297$

Values derived from Table 7 at 8 000 V:

$D_1 = 8,25$ mm, $D_2 = 15,2$ mm

CLEARANCE $= D_1 + F \times (D_2 - D_1) = 8,25 + 0,297 \times (15,2 - 8,25) = 8,25 + 2,06 = 10,3$ mm

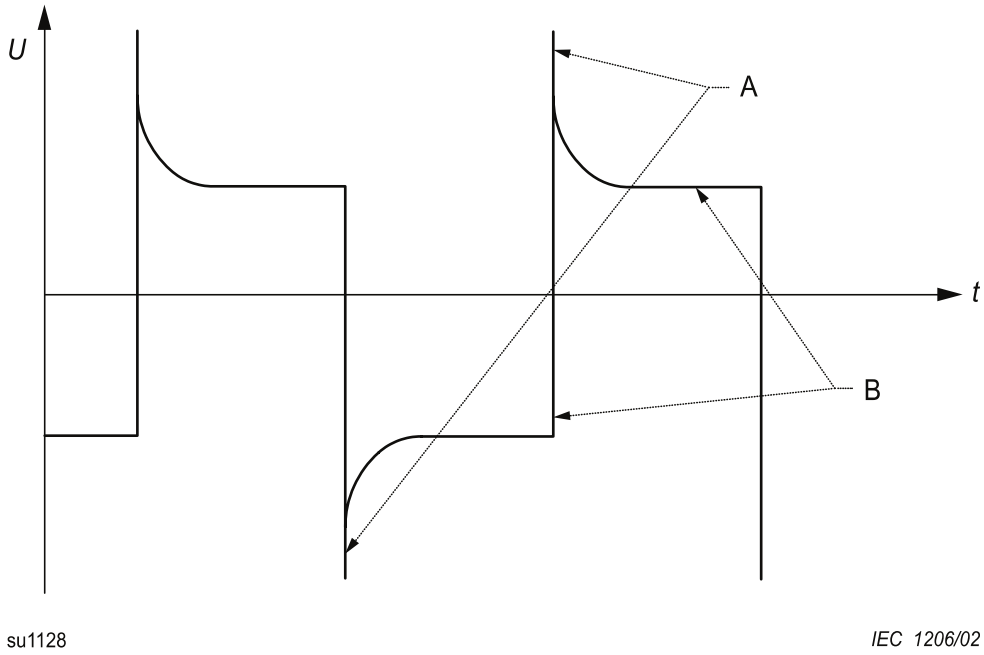
For REINFORCED INSULATION the value is doubled. CLEARANCE = 20,6 mm.

6.5.2.3.3 CLEARANCES for probe assemblies subjected to recurring peak voltages, or WORKING VOLTAGES with frequencies above 30 kHz, or both

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION for probe assemblies subjected to recurring peak voltages with frequencies not exceeding 30 kHz shall meet the values of the second

column of Table 8, using the recurring peak voltage as the index (see Figure 18 for an example of a recurring peak voltage).

NOTE In most practical recurring waveforms, the fundamental frequency has a substantially higher amplitude than the harmonics. Therefore, the fundamental frequency is to be used for determining whether the frequency of the waveform exceeds 30 kHz. However, the peak amplitude of the waveform, and not the peak amplitude of the fundamental component of the waveform, is to be used for determining SPACINGS. For more information, see E.2 of IEC 60664-4:2005.



Key

A peak value of recurring voltage

B WORKING VOLTAGE value

Figure 18

Example of recurring peak voltage

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION for probe assemblies that are subjected to WORKING VOLTAGES with frequencies above 30 kHz shall meet the values of the third column of Table 8, using the peak value of the WORKING VOLTAGE as the index.

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION for probe assemblies that may be subjected to both recurring peak voltages and WORKING VOLTAGES with frequencies above 30 kHz shall meet the higher of these requirements.

CLEARANCES for REINFORCED INSULATION are twice the values for BASIC INSULATION.

Conformity is checked by inspection and measurement.

Table 8
CLEARANCES for BASIC INSULATION in probe assemblies subjected to recurring peak voltages or WORKING VOLTAGES with frequencies above 30 kHz

Voltage peak value	CLEARANCE	
	Frequencies up to 30 kHz	Frequencies above 30 kHz
V	mm	mm
0 to 330	0,01	0,02
400	0,02	0,04
500	0,04	0,07
600	0,06	0,11
800	0,13	0,26
1 000	0,26	0,48
1 200	0,42	0,76
1 500	0,76	1,1
2 000	1,27	1,8
2 500	1,8	2,6
3 000	2,4	3,5
4 000	3,8	5,7
5 000	5,7	8
6 000	7,9	10
8 000	11	15
10 000	15,2	20
12 000	19	25
15 000	25	32
20 000	34	44
25 000	44	58
30 000	55	72
40 000	77	100
50 000	100	
Linear interpolation is allowed.		

6.5.2.4 CREEPAGE DISTANCES

CREEPAGE DISTANCES for BASIC INSULATION or SUPPLEMENTARY INSULATION for probe assemblies shall meet the applicable values of Table 9, based on the WORKING VOLTAGE which stresses the insulation. Values for REINFORCED INSULATION are twice the values for BASIC INSULATION.

Conformity is checked by inspection and measurement.

Table 9
CREEPAGE DISTANCES for BASIC INSULATION or SUPPLEMENTARY INSULATION

WORKING VOLTAGE a.c. r. m.s. or d.c.	CREEPAGE DISTANCES				
	Printed wiring board material		Other insulating material		
	POLLUTION DEGREE		POLLUTION DEGREE		
	1	2	1	2	3
V	mm	mm	mm	mm	mm
10	0,025	0,04	0,08	0,40	1,00
12,5	0,025	0,04	0,09	0,42	1,05
16	0,025	0,04	0,10	0,45	1,10
20	0,025	0,04	0,11	0,48	1,20
25	0,025	0,04	0,125	0,50	1,25
32	0,025	0,04	0,14	0,53	1,3
40	0,025	0,04	0,16	0,56	1,4
50	0,025	0,04	0,18	0,60	1,5
63	0,040	0,063	0,20	0,63	1,6
80	0,063	0,10	0,22	0,67	1,7
100	0,10	0,16	0,25	0,71	1,8
125	0,16	0,25	0,28	0,75	1,9
160	0,25	0,40	0,32	0,80	2,0
200	0,40	0,63	0,42	1,00	2,5
250	0,56	1,0	0,56	1,25	3,2
320	0,75	1,6	0,75	1,60	4,0
400	1,0	2,0	1,0	2,0	5,0
500	1,3	2,5	1,3	2,5	6,3
630	1,8	3,2	1,8	3,2	8,0
800	2,4	4,0	2,4	4,0	10,0
1 000	3,2	5,0	3,2	5,0	12,5
1 250	4,2	6,3	4,2	6,3	16
1 600	5,6	8,0	5,6	8,0	20
2 000	7,5	10,0	7,5	10,0	25
2 500	10,0	12,5	10,0	12,5	32
3 200	12,5	16	12,5	16	40
4 000	16	20	16	20	50
5 000	20	25	20	25	63
6 300	25	32	25	32	80
8 000	32	40	32	40	100
10 000	40	50	40	50	125
12 500	50	63	50	63	156
16 000	63	80	63	80	200
20 000	80	100	80	100	250
25 000	100	125	100	125	315
32 000	125	160	125	160	400
40 000	160	200	160	200	500
50 000	200	250	200	250	625
63 000	250	320	250	320	790
Linear interpolation is allowed.					

6.5.2.5 Solid insulation of probe assemblies RATED for MEASUREMENT CATEGORIES

6.5.2.5.1 General

6.5.2.5.1.1 Solid insulation of probe assemblies RATED for MEASUREMENT CATEGORIES shall withstand the electrical and mechanical stresses that may occur in NORMAL USE and in all RATED environmental conditions (see 1.4) during the intended life of the probe assembly.

The manufacturer should take the expected life of the probe assembly into account when selecting insulating materials.

Conformity is checked by both of the following tests:

a) the a.c. voltage test of 6.6.5.1 with a duration of at least 5 s using the applicable test voltage of Table 4 or the impulse voltage test of 6.6.5.3 using the applicable test voltage of Table 14;

b) the a.c. voltage test of 6.6.5.1 or if stressed only by d.c., the d.c. voltage test of 6.6.5.2, with a duration of at least 1 min using the test voltage determined by 6.5.2.5.1.2.

NOTE Test a) checks the effects of transient overvoltages, while test b) checks the effects of long-term stress of solid insulation.

Table 4
a.c. test voltages for testing electric strength of solid insulation in probe assemblies RATED for MEASUREMENT CATEGORIES

Nominal a.c. r.m.s. line-to-neutral or d.c. voltage of mains being measured V	a.c. test voltage V r.m.s					
	BASIC INSULATION and SUPPLEMENTARY INSULATION			REINFORCED INSULATION		
	MEASUREMENT CATEGORY II	MEASUREMENT CATEGORY III	MEASUREMENT CATEGORY IV	MEASUREMENT CATEGORY II	MEASUREMENT CATEGORY III	MEASUREMENT CATEGORY IV
≤ 50	370	500	840	500	720	1300
> 50 ≤ 100	500	840	1 400	720	1 300	2 200
> 100 ≤ 150	840	1 400	2 200	1 300	2 200	3 500
> 150 ≤ 300	1 400	2 200	3 300	2 200	3 500	5 100
> 300 ≤ 600	2 200	3 300	4 300	3 500	5 100	7 000
> 600 ≤ 1 000	3 300	4 300	6 600	5 100	7 000	10 000
> 1 000 ≤ 1 500	4 300	5 400	8 200	7 400	9 700	15 000
> 1 500 ≤ 2 000	6 600	8 200	9 700	12 000	15 000	18 000
> 2 000 ≤ 3 000	8 200	9 700	11 000	15 000	18 000	20 000

Table 14
Impulse test voltages for testing electric strength of solid insulation in probe assemblies RATED for MEASUREMENT CATEGORIES

Nominal a.c. r.m.s. line-to-neutral or d.c. voltage of mains being measured	Impulse test voltage V peak					
	BASIC INSULATION and SUPPLEMENTARY INSULATION			REINFORCED INSULATION		
V	MEASUREMENT CATEGORY II	MEASUREMENT CATEGORY III	MEASUREMENT CATEGORY IV	MEASUREMENT CATEGORY II	MEASUREMENT CATEGORY III	MEASUREMENT CATEGORY IV
≤ 50	500	800	1 500	800	1 280	2 400
> 50 ≤ 100	800	1 500	2 500	1 280	2 400	4 000
> 100 ≤ 150	1 500	2 500	4 000	2 400	4 000	6 400
> 150 ≤ 300	2 500	4 000	6 000	4 000	6 400	9 600
> 300 ≤ 600	4 000	6 000	8 000	6 400	9 600	12 800
> 600 ≤ 1 000	6 000	8 000	12 000	9 600	12 800	19 200
> 1 000 ≤ 1 500	8 000	10 000	15 000	13 500	17 900	27 100
> 1 500 ≤ 2 000	12 000	15 000	18 000	21 400	27 100	32 000
> 2 000 ≤ 3 000	15 000	18 000	20 000	27 100	32 000	36 000

6.5.2.5.1.2 Test voltage values for testing long term stress of solid insulation are determined as follows:

The test voltage for BASIC INSULATION and SUPPLEMENTARY INSULATION is calculated from:

$$U_T = A \times U_N + B$$

where

U_T is the test voltage;

U_N is the nominal a.c. r.m.s. line-to-neutral or d.c. voltage of mains being measured;

A and *B* are parameters determined as follows:

when $U_N \leq 1\,000$ V, $A = 1$ and $B = 1\,200$ V

when $U_N > 1\,000$ V, $A = 1{,}5$ and $B = 750$ V

The a.c. test voltage is equal to U_T and the d.c. test voltage is equal to $1{,}414 \times U_T$.

For REINFORCED INSULATION, the test voltage value is twice the value for BASIC INSULATION.

6.5.2.5.1.3 Solid insulation shall also meet the following requirements, as applicable:

1) for solid insulation used as an ENCLOSURE or PROTECTIVE FINGERGUARD, the requirements of Clause 8;

2) for moulded and potted parts, the requirements of 6.5.2.5.2;

3) for insulating layers of printed wiring boards, the requirements of 6.5.2.5.3;

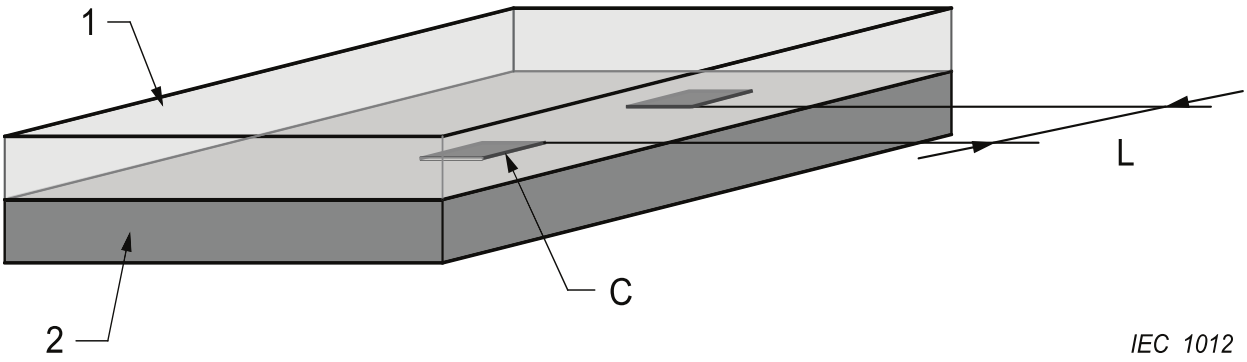
4) for thin-film insulation, the requirements of 6.5.2.5.4.

Conformity is checked as specified in 6.5.2.5.2 to 6.5.2.5.4, and in Clause 8, as applicable.

6.5.2.5.2 Moulded and potted parts

For BASIC INSULATION, SUPPLEMENTARY INSULATION, and REINFORCED INSULATION, conductors located between the same two layers moulded together (see Figure 15, item *L*) shall be separated by at least the applicable minimum distance of Table 5 after the moulding is completed.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.



su1104

Key

1 layer 1

2 layer 2

C conductor

L distance between conductors

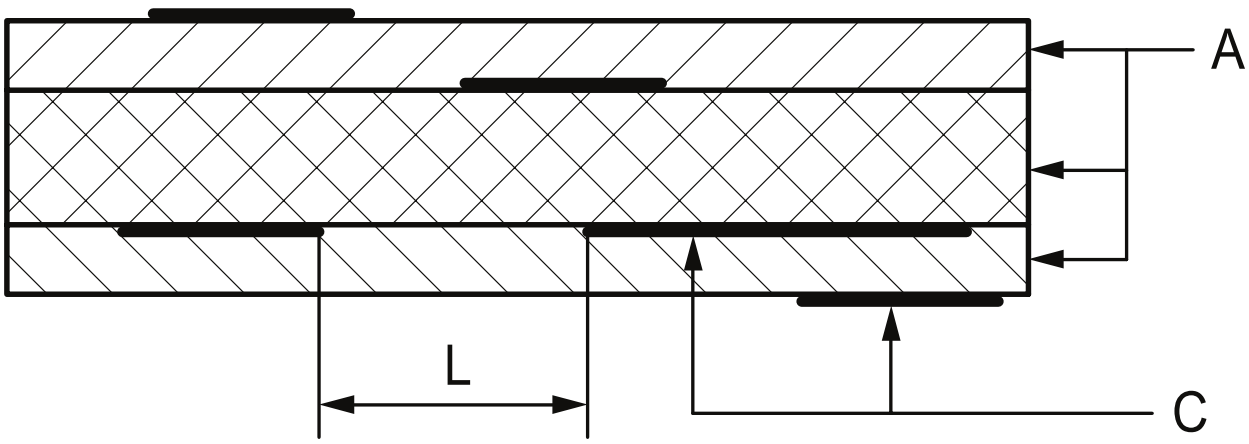
Figure 15

Distance between conductors on an interface between two layers

6.5.2.5.3 Insulating layers of printed wiring boards

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers (see Figure 16, item *L*) shall be separated by at least the applicable minimum distance of Table 5.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.



Key

L distance between conductors on the same surface

A layers

C conductors

Figure 16

Distance between adjacent conductors along an interface of two layers

Table 5
Minimum values for distance or thickness

WORKING VOLTAGE V	Minimum thickness mm	Minimum distance *L* (see Figure 16) [a] mm
≤ 300	0,4	0,4
> 300 ≤ 600	0,6	0,6
> 600 ≤ 1 000 [b]	1,0	1,0

[a] These values apply for BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION.

[b] For voltage above 1 000 V, a partial discharge test should be used (test procedure under consideration).

REINFORCED INSULATION of insulating layers of printed wiring boards (see Figure 16, item A) shall also have adequate electric strength through the respective layers. One of the following methods shall be used.

a) The thickness of the insulation is at least the value of Table 5.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.