Testing of HV Cables – Supplmentary Information Quick Reference Guide

1. PURPOSE AND SCOPE

This reference is intended to give a basic overview of insulating materials that can be used during high voltage withstand testing, in particular cable testing.

The selection and use of an insulating material will depend on a number of factors including:

- The test voltages applied to the cables during the test.
- Clearance between the phase being tested and the adjacent phases and earthed metalwork. If the installed insulation, including air clearances, provides sufficient dielectric strength then additional insulating material will not be required.
- Atmospheric conditions (Insulation provided by air changes with atmospheric changes).
- The dielectric properties and dimensions of the insulating material selected.
- Need for the material to be tested regularly to check its dielectric strength

When selecting or maintaining tools, instruments, and equipment, you should address a number of factors to ensure electrical safety. The following are some of the factors to be considered:

- The device must be fit for purpose.
- Equipment and test instruments that can be visually confirmed as functioning correctly should have visual confirmation of correct function each time before use.
- Equipment and test instruments that are not able to be visually confirmed as functioning correctly must be tested at least every 6 months to ensure proper working order.
- Repairs and maintenance should meet appropriate standards and manufacturer's instructions.

Appropriate guidance and standards for testing, inspecting, calibrating, and maintaining these devices can be obtained from sources that include:

- Manufactures and suppliers.
- Industry groups.
- National and international codes and standards such as Standards Australia e.g., AS and AS/NZS publications and International Electrotechnical Commission e.g., IEC publications.

2. TEST VOLTAGES

Commissioning Tests for HV Cables (up to 66kV) SWP - 2902074 defines the procedure and test voltages to be used during a cable test.

3. AIR GAPS

Air at normal atmospheric pressure and temperature breaks down at 30kV/cm (peak or crest value) or 21.1kV/cm (r.m.s.). [ASTM D 2477 X1.3]

Material	Dielectric Constant	Dielectric Strength (V/m)
Air (atmospheric pressure)	1.0	3×10^6
Mineral Oil	2.3	15×10^6
Paper	2 – 4	15×10^6
Polystyrene	2.6	20×10^6
Rubber	2.3 – 4.0	25×10^6
Glass	4 – 10	30×10^6
Mica	6.0	200×10^6

Table 1 Dielectric Constants and Dielectric Strengths of some Common Materials [David K. Cheng]

IEC Standard reference atmospheric conditions:

Temperature = 20°C (Specified as 25°C in some ASTM standards)
Pressure = 101.3 kPa
Absolute Humidity = $11 g/m^3$

Relative Humidity = Absolute Humidity / Absolute Humidity in Saturation (Temperature Dependant)

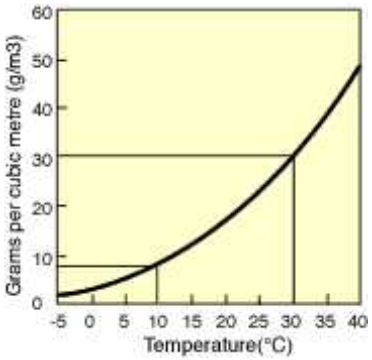

Figure 1 Change in amount of water vapour in saturated air with temperature.

The air's capacity for water vapour increases as the air temperature increases. Air at 30°C can hold more than three times as much water vapour as air at 10°C.

An **"atmospheric correction factor"** needs to be applied to account for the difference between the atmospheric conditions in service and the standard atmospheric conditions. Refer to Appendix B: Standards for Insulation Coordination (Air Gaps)

Taking into account a number of correction factors the **minimum** recommended clearance to grounded objects for AC insulation testing is 10kV AC (r.m.s.) / inch. This figure is based on practical experience and is over 5 times higher than the nominal dielectric strength of air to allow for varying atmospheric conditions, contamination of the insulation, and sharp edges producing high local stresses.

10 kV/inch (RMS) = 4 kV/cm (RMS) = 0.4 kV/mm (RMS) = 0.56 kV/mm (peak)

Note that minimum clearances may need to be increased for excessive deviations away from the standard atmospheric conditions (e.g., extremely humid or windy weather).

The table below compares the electrical clearances recommended for fixed plant at the voltages used for cable testing against IEC & ASTM minimum clearances for test electrodes and also the 3kV/mm (peak) and 10kV/inch (RMS) figures.

	Cable Designation kV	Test Voltage KV (Phase-to-Earth)	Standard short-duration power-frequency withstand voltage kV (r.m.s. value)	Standard lightning impulse withstand voltage kV (peak value)	Recommended Air Gap Clearances (mm)					
					AS 1824 AS 2067 AS 2374.3.1	BS 6435 (Phase-to-Earth)	Based on 3kV/mm (peak) 2.11kV/mm (r.m.s)	Based on 10kV / inch (AC r.m.s)	Based on IEC test electrode clearances	Based on ASTM test electrode clearances
DC (average)	3.3	7	10	40	60		3.3	18.0	80	76
	6.6	15	20	60	90		6.7	35.9	80	76
	11	25	28	95	160	76	11.3	61.1	150	102
	22	50	50	145	280	140	16.7	89.8	260	152
	33	70	70	200	380	222	25	134.7		> 305
	66	140	140	325						
50Hz AC (r.m.s)	3.3	10	10	40	60		4.7	25.4	80	76
	6.6	20	20	60	90		9.5	50.8	80	76
	11	28	28	95	160	76	13.3	71.1	150	127
	22	50	50	145	280	140	23.7	127.0	300	254
	33	70	70	200	380	222	33.2	177.8		
	66	140	140	325						
VLF (peak)	3.3	6	10	40	60		2.7	14.4	80	76
	6.6	12	20	60	90		5.3	28.7	80	76
	11	19	28	95	160	76	9.0	48.5	150	102
	22	38	50	145	280	140	18.0	97.0	300	152
	33	57	70	200	380	222	27.0	145.5		> 305
	66	114	140	325						

Table 2 Electrical Clearances

Note that the fixed plant clearances are for the lightning impulse and short duration power-frequency withstand voltages stated. Refer to section Appendix B: Standards for Insulation Coordination (Air Gaps).

4. INSULATING MATERIALS

This section provides an overview of various forms of insulating materials.

4.1. ELASTOMERS (RUBBERS)

From the range of natural and synthetic “rubbers” which may be classed as elastomers probably only two have the properties suitable for electrical insulation; butyl and ethylene-propylene (EPR). The latter has been well developed for high voltage applications and is used, in extruded form, for some 33kV cables.

Common types of rubber insulation include Matting, Sleeves, Blankets, Covers, Line Hoses and Sheeting. These are classified and tested as per Appendix A: Standards relating to insulated mats, covers, etc.

Class of Insulating Equipment	Nominal Maximum Use Voltage, Phase-Phase		ASTM Standards		IEC Standards	
	A.C. r.m.s. V	D.C. V	AC Proof-Test Voltage RMS V	DC Proof-Test Voltage Average V	AC Proof-Test Voltage rms V	DC Proof-Test Voltage Average V
0	1 000	1 500	5 000	20 000	5 000	10 000
1	7 500	11 250	10 000	40 000	10 000	20 000
2	17 000	25 500	20 000	50 000	20 000	30 000
3	26 500	39 750	30 000	60 000	30 000	40 000
4	36 000	54 000	40 000	70 000	40 000	60 000

Table 3 Proof test voltages and maximum use voltages for various classes of insulating equipment

Note that Australian Standards for Mats and Covers are for voltages up to 650V only. Refer to Appendix A: Standards relating to insulated mats, covers, etc.

4.2. PAPERS

A variety of insulating papers are available specifically designed for insulating electrical circuits. Rag and kraft paper often called Transformer Paper is often used to separate windings in transformers or in applications where no sharp edges might poke through the relatively weak paper. Fishpaper is a curious name referring to a grey cotton rag paper usually vulcanized and often laminated with Mylar. The Mylar may have paper on one or both sides and many thickness grades are available. Other "sandwich materials" are available including 100% polyester laminates and are usually a distinct colour. The paper/Mylar laminates resist soldering heat better since the paper doesn't melt and the Dacron/Mylar laminates resist moisture best. Laminates with thicker polyester centres are fashioned into insulating plates in many electro-mechanical devices. A typical application may be observed inside most older electrical timers where a printed and folded piece of laminated paper keeps the user's fingers away from the high voltage when adjusting the position of the on and off trippers. Papers made with temperature resistant nylon and/or glass weaves have excellent electrical properties and good temperature resistance. Thin sheets of epoxy-fibreglass usually green in colour are commonly used for insulating PCB's and electronic assemblies with potentially sharp projections. Puncture resistance is superb even for sheets thin enough to be quite flexible. A simple clear polyester sheet is sometimes used for insulation but is offers far less puncture and temperature resistance than the laminates.

Kraft paper is 95% to 97% cellulose. When cellulose is subject to normal atmospheric conditions, it could contain water to approximately 8% of its own weight depending on the humidity and temperature of the surrounding atmosphere. Cellulose material such as paper, pressboard and wood, commonly used as insulation and supports in power transformers, is very hygroscopic. In fact, paper is just one third as effective as a desiccant, as silica gel. Water in such a material reduces the insulation strength, increases loss angle, and adversely affects the ageing characteristics. As the water content increases, paper swells, and conversely shrinks as it is dried.

Typical Dielectric Strengths: Rag Paper – 300V/mil (11.8kV/mm)
Kraft Paper – 250V/mil (9.8kV/mm)
Fish Paper – 200 to 400V/mil (7.9 to 15.8kV/mm)
* These values will vary depending on manufacturing process, atmospheric conditions, etc.

NOMEX: NOMEX® is a Dupont aromatic polyamide with an operating temperature range over 220 degrees centigrade and with superb high voltage breakdown. It is an excellent choice for standardisation since it outperforms many other materials. In densified form, NOMEX® products withstand short-term electrical stresses of 18 to 40 kV/mm depending on product type and thickness, with no need for further treatment with varnishes or resins. In equilibrium at 95 percent relative humidity, densified NOMEX® papers and pressboards maintain 90 percent of their bone-dry dielectric strength while many mechanical properties are actually improved.

4.3. TAPES

Tapes are made from many materials. Vinyl tapes are commonly used for wire insulation and are available in all the colours necessary for colour coding. Mylar tapes are common in electronics: film capacitors often have a final wrap of yellow Mylar tape. Acetate tapes are used where good conformability is desired as when covering coils as is white cotton cloth tape. Glass cloth electrical tape with thermosetting adhesive (adhesive that permanently sets with temperature) is used to secure and protect heater windings or insulate components exposed to heat. Kapton, Teflon, and other insulators are used to make high performance specialty tapes for harsh temperature or chemical environment.

KAPTON: Polyimide film has exceptionally good heat resistance and superb mechanical and electrical properties. Kapton tapes are fairly expensive but often indispensable. (Typical Dielectric Strength 80 to 165kV/mm).

POLYESTER (MYLAR): A strong material often used in film sheets and tapes for graphic arts and electronics. Those shiny balloons and "space blankets" are usually made from metallised Mylar. Mylar is also used as a dielectric in capacitors.

PVC: Polyvinylcloride or PVC is perhaps the most common insulating material. Most wiring is insulated with PVC including house wiring. Irradiated PVC has superior strength and resistance to heat. PVC tapes and tubing are also quite common. Electrical and electronic housings are commonly moulded from PVC.

TFE (TEFLON): Teflon is an excellent high temperature insulation with superb electrical properties. Teflon tubing and wire insulation comes in a variety of colours and typically feels slippery. The insulation is impervious to the heat and chemicals normally encountered in electronics manufacturing but the material will "cold flow" so Teflon insulation is avoided where sharp corners or points are encountered. Laminated TFE circuit boards take advantage of Teflon's excellent microwave characteristics. Teflon emits a dangerous gas when exposed to extreme heat. White Teflon terminals are commonly used where extremely good insulation is required. The slick surface repels water so the insulation properties are fantastic even in high humidity. High quality I.C. sockets are made from Teflon to reduce leakage currents. Teflon and Teflon composite tapes with adhesive are available. FEP is a lower temperature Teflon.

	Voltage Rating	Dielectric Strength (Thickness)	Dielectric Breakdown	Test Standard
3M™ Vinyl Electrical Tape				
Highland Vinyl Electrical Tape	600V	1200V/mil (47.2kV/mm)		
Scotch 22 Heavy Duty Vinyl Electrical Tape	600V		12,000V	ASTM D 1000
Scotch 33 Vinyl Electrical Tape		1000V/mil (39.4kV/mm)		ASTM D 1000
Scotch 35 Vinyl Electrical Colour Coding Tape	600V	1250V/mil (49.2kV/mm)		ASTM D 1000
Scotch 66R Vinyl Electrical Tape	600V		10,000V	ASTM D 1000
Scotch Super 33 Plus Vinyl Electrical Tape	600V	1150V/mil (45.2kV/mm)		ASTM D 1000
Super 88 Vinyl Electrical Tape	600V		10,000V	ASTM D 1000

	Voltage Rating	Dielectric Strength (Thickness)	Dielectric Breakdown	Test Standard
Temflex 1700 Vinyl Electrical Tape	600V	1000V/mil (39.4kV/mm)		ASTM D 1000
3M™ Insulating and Splicing Tape				
2155 Rubber Splicing Tape	600V	600V/mil (23.6kV/mm)		
77 Fire Retardant Elec. Arc Proofing		700V/mil (27.6kV/mm)		ASTM D 1000
Scotch 130C Linerless Rubber Splicing Tape	69kV	750V/mil (29.5kV/mm)		ASTM D 4325
Scotch 2242 Linerless Electrical Rubber Tape		750V/mil (29.5kV/mm)		ASTM D 4325
Scotch 23 All-Voltage Splicing Tape	69kV	850V/mil (33.5kV/mm)		ASTM D 4325
Scotch 2510 and 2520 Varnished Cambric Tape		800V/mil (31.5kV/mm)		ASTM D 295
Scotch 70 Self-Fusing Silicone Rubber Electrical Tape		875V/mil (34.5kV/mm)		ASTM D 1000
Scotchfil Electrical Insulation Putty	600V	575V/mil (22.6kV/mm)		
3M™ Sealing and Insulating Tape				
Scotch 2200, 2210 Vinyl Mastic Pads & Rolls	600V	300V/mil (11.8kV/mm)		ASTM D 1000
Scotch 2228 Rubber Mastic Tape		500V/mil (19.7kV/mm)		ASTM D 4325
Scotch-Seal 2229 Mastic Tape and Pads		379V/mil (14.9kV/mm)		ASTM D 1000
3M™ Special Use Tapes				
27 Glass Cloth Electrical Tape	600V		3,000V	ASTM D 1000
Scotch 69 Glass Cloth Tape	600V		3,500V	ASTM D 1000
Plymouth Bishop Vinyl Plastic Tapes				
Heavy Duty 2	600V		10,000V	ASTM-D-1000
Revere ® 7	600V		7,000V	ASTM-D-1000
Premium 37	600V		7,000V	ASTM-D-1000
Premium 85 CW	600V		11,000V	ASTM-D-1000
Premium 111	600V		10,000V	ASTM-D-1000
Columbia	600V	1100V/mil (43.3kV/mm)		ASTM-D-1000
Plymouth Bishop Low Voltage Tapes				
125 Electrical Filler Tape	5kV	585V/mil (23kV/mm)		ASTM-D-4325
150 ASTM Rubber Tape	2kV	350V/mil (13.8kV/mm)		ASTM-D-4325
122 Rubber Tape	600V	350V/mil (13.8kV/mm)		UL510
10 Plyseal ® Insulating Mastic	600V	500V/mil (19.7kV/mm)		ASTM-D-4325
4000 Plyseal ® -V Insulating Mastic	1000V	500V/mil (19.7kV/mm)		ASTM-D-4325
5000 Bus-Seal ® Insulating Mastic (EPR-Backed)		500V/mil (19.7kV/mm)		ASTM-D-4325
Rubber Mastic (RM) Tape		400V/mil (15.8kV/mm)		ASTM-D-4325
Vinyl Mastic (VM) Tape	600V	500V/mil (19.7kV/mm)		ASTM-D-4325
Plymouth Bishop High Voltage Tapes				
W962 EPR High Voltage Tape	138kV	950V/mil (37.4kV/mm)		ASTM-D-4325
W963 Plysafe ® EPR High Voltage Tape	69kV	750V/mil (29.5kV/mm)		ASTM-D-4325
L969 Plyvolt ® Linerless EPR High Voltage Tape	69kV	780V/mil (30.7kV/mm)		ASTM-D-4325
3 Bi-Seal ® 20 Polyethylene & EPR High Voltage Tape	69kV	900V/mil (35.4kV/mm)		ASTM-D-4325
3 Bi-Seal ® 30 Polyethylene & EPR High Voltage Tape	69kV	900V/mil (35.4kV/mm)		ASTM-D-4325
20 Plysil ® Silicone Rubber Tape	69kV	600V/mil (23.6kV/mm)		ASTM-D-2148
Plymouth ® PIB Medium Voltage Tape	46kV	900V/mil (35.4kV/mm)		ASTM-D-4325
Plymouth Bishop Mining Products				
L969 Plyvolt ® Linerless EPR High Voltage Tape	69kV	780V/mil (30.7kV/mm)		ASTM-D-4325
Plymouth Bishop Special Tapes				
77 Plyglas ® Glass Cloth Tape	600V		2,500V	ASTM-D-1000
60 and 60A Varnished Cambric Tape		1000V/mil (39.4kV/mm)		ASTM-D-295

Table 4 Dielectric strength of common types of electrical tapes

4.4. HEAT SHRINKABLE MATERIALS

An important development was the introduction of heat shrinkable polymeric materials. This led to changes in the techniques adopted for 11kV (and above) cable terminations. Much testing has been completed in the laboratory and at outdoor test sites. Assessment included the determination of the behaviour of the

shrunken material when subjected to thermal cycling, as in a cable. Air gaps must not appear between the sleeve and the cable insulation (plastic or impregnated), as this could result in partial discharges with subsequent failure.

Dielectric strength of some common heat shrink products:

	Dielectric Strength (Thickness)	Standard
3M™ Heat Shrink		
EPS-200 Tubing	800V/mil (31.5kV/mm)	MIL-DTL-23053/4, Class 2
EPS-300 Tubing	700V/mil (27.6kV/mm)	MIL-I-23053/4, Class 3
EPS-400 Tubing	700V/mil (27.6kV/mm)	MIL-I-23053/4.
FP-301 Tubing	900V/mil (35.4kV/mm)	MIL-I-23053/5, Class 1 and 2
HDT Tubing	500V/mil (19.7kV/mm)	MIL-I-23053/15, Class 1
IMCSN Medium Wall Tubing	500V/mil (19.7kV/mm)	MIL-I-23053/15, Class 2
ITCSN Heavy Wall Tubing	500V/mil (19.7kV/mm)	UL 486D
MW Tubing	900V/mil (35.4kV/mm)	MIL-I-23053/4, Class 1
SFTW-202 GYS Tubing	700V/mil (27.6kV/mm)	MIL-DTL-23053/5, Class 1
SFTW-203 Tubing	700V/mil (27.6kV/mm)	MIL-DTL-23053/5, Class 1
SMS Heat Shrink Tubing	500V/mil (19.7kV/mm)	
SR-350 Tubing	800V/mil (31.5kV/mm)	MIL-DTL-23053/6, Class 1, 2
TES Tubing	500V/mil (19.7kV/mm)	
TMW Tubing	900V/mil (35.4kV/mm)	
TP Tubing	800V/mil (31.5kV/mm)	
VFP-876 Tubing	800V/mil (31.5kV/mm)	MIL-R-46846, Type V
MDT Medium Wall Tubing	500V/mil (19.7kV/mm)	MIL-I-23053/15, Class 1
KYNAR Thin Wall Tubing	900V/mil (35.4kV/mm)	MIL-DTL-23053/18, Class 1; MIL-DTL-23053/8
Raychem Heat Shrink		
ZCSM Heat-shrinkable heavy-wall tubing	305V/mil (12kV/mm)	IEC 60243
WCSM Heat-shrinkable heavy-wall insulating tubing	305V/mil (12kV/mm)	IEC 60243
MWTM Heat-shrinkable medium wall insulating tubing	508V/mil (20kV/mm)	IEC 60243
CABAC Heat Shrink		
XDW - Heatshrink - Dual - Walled Flexible Glue Lined	508V/mil (20kV/mm)	MIL-1-23053/4
XLP - Heatshrink - Thin Wall - Flame Retarded	635V/mil (25kV/mm)	MIL-1-23053/5 Class 3
SMDW – Medium Walled Heatshrink	457V/mil (18kV/mm)	
SRE - Heatshrink - End Caps	254V/mil (10kV/mm)	
HST20 Heatshrink tape	762V/mil (30kV/mm)	

Table 5 Dielectric strength of common heat shrink products (1 Mil = 0.0254 millimetres)

APPENDIX A: STANDARDS RELATING TO INSULATED MATS, COVERS, ETC.

This section provides an overview of the relevant industry standards relating to insulated protective covers, etc. The use of covers will depend on their approved application (Codes of Practice, etc).

AUSTRALIAN STANDARDS

AS/NZS 2978:1995 Insulating mats for electrical purposes
AS 4202:1994 Insulating covers for electrical purposes

These standards do not apply to insulating materials rated at voltages greater than 650V.

Insulating mats to **AS/NZS 2978** are tested to 15kV AC r.m.s.
Insulating covers to **AS 4202** are tested to 5kV AC r.m.s.

IEC STANDARDS

IEC 60984 Sleeves of Insulating Material for Live Working Edition 1.1; Edition 1: 1990 Consolidated with Amendment 1: 2002
IEC 61111 Matting of Insulating Material for Electrical Purposes Edition 1.1; Edition 1: 1992 Consolidated with Amendment 1: 2002
IEC 61112 Blankets of Insulating Material for Electrical Purposes Edition 1.1; Edition 1: 1992 Consolidated with Amendment 1: 2002
IEC 61479 Live Working - Flexible Conductor Covers (Line Hoses) of Insulating Material Edition 1.1; Edition 1: 2001 Consolidated with Amendment 1: 2002
IEC 61229 - Rigid Protective Covers for Live Working on a.c. Installations Edition 1.2; Edition 1: 1993 Consolidated with Amendments 1: 1998 and 2: 2002

Class of Insulating Equipment	AC Proof-Tests		DC Proof-Tests	
	rms, V	mm	avg, V	mm
0	5 000	80 (40)	10 000	80
1	10 000	80 (90)	20 000	80
2	20 000	150 (135)	30 000	150
3	30 000	200 (180)	40 000	200
4	40 000	300 (230)	60 000	300
NOTE In cases where high humidity (above 55%) or low barometric pressure (below 99.3kPa) (see IEC 60160) is encountered, the specified clearances may be increased by a maximum of 50mm. Clearances in (brackets) are specified in IEC 61229 for Rigid Protective Covers.				

Table 6 Clearances between Test Electrodes

Class of Insulating Equipment	A.C. r.m.s. V		D.C. Average V	
	Proof	Withstand	Proof	Withstand
0	5 000	10 000	10 000	20 000*
1	10 000	20 000 (15 000)	20 000 (30 000)	40 000*
2	20 000	30 000	30 000 (35 000)	60 000*
3	30 000	40 000 (45 000)	40 000 (50 000)	70 000*
4	40 000	50 000 (62 000)	60 000	90 000*
* Taken from IEC 60903 (Gloves of Insulating Materials).Clearances in (brackets) are specified in IEC 61229 and IEC 61479.				

Table 7 Test Voltages

The maximum use voltage recommended for each class of sleeve is designated in the following table:

Class of Insulating Equipment	A.C. r.m.s. V	D.C. V
0	1 000	1 500
1	7 500	11 250
2	17 000	25 500
3	26 500	39 750
4	36 000	54 000

Table 8 Maximum use voltage

Maximum use voltage is the voltage rating of the protective equipment that designates the maximum nominal voltage of the energised system that may be safely worked.

On multiphase circuits, the nominal voltage is equal to the phase-to-phase voltage. If there is no multiphase exposure in a system area, and the voltage exposure is limited to the phase (polarity on DC systems) to earth potential, the phase (polarity on DC systems) to earth potential shall be considered to be the nominal voltage.

If electrical equipment and devices are insulated, or isolated, or both, such that the multiphase exposure of an earthed neutral star circuit (grounded wye) is removed, then the nominal voltage may be considered as the phase-to-earth voltage on that circuit.

ASTM STANDARDS

ASTM D 178 Standard Specification for Rubber Insulating Matting
ASTM D 1051 Standard Specification for Rubber Insulating Sleeves
ASTM F 496 REV A Standard Specification for In-Service Care of Insulating Gloves and Sleeves
ASTM D 1049 Standard Specification for Rubber Insulating Covers R (2002)
ASTM D 1050 Standard Specification for Rubber Insulating Line Hose R (1999)
ASTM F 478 Standard Specification for In-Service Care of Insulating Line Hose and Covers R (1999)
ASTM D 1048 Standard Specification for Rubber Insulating Blankets
ASTM F 479 Standard Specification for In-Service Care of Insulating Blankets R (2001)
ASTM F 1742 - Standard Specification for PVC Insulating Sheeting
ASTM F 2320 - Standard Specification for Rubber Insulating Sheeting
ASTM F 968 Standard Specification for Electrically Insulating Plastic Guard Equipment for Protection of Workers R (2002)
ASTM F 712 Standard Test Methods for Electrically Insulating Plastic Guard Equipment for Protection of Workers R (2000)

Class of Insulating Equipment	Nominal Maximum Use Voltage[A], Phase-Phase ac, rms	AC Proof-Test Voltage rms V	DC Proof-Test Voltage Average V
0	1 000	5 000	20 000
1	7 500	10 000	40 000
2	17 000	20 000	50 000
3	26 500	30 000	60 000
4	36 000	40 000	70 000

Table 9 Proof-Test/Use Voltage Relationship

The AC voltage (rms) classification of the protective equipment designates the maximum nominal design voltage of the energised system that may be safely worked. The nominal design voltage is equal to:
1. The phase to phase on multiphase circuits or
2. The phase to ground voltage on single phase grounded circuits.

[A]Except for Class 0 equipment, the maximum use voltage is based on the following formula:
Maximum use voltage (maximum nominal design voltage) = 0.95 ac proof-test voltage – 2000 V

Class of Insulating Equipment	AC Proof-Test		DC Proof-Test	
	V (RMS)	mm	V (AVG)	mm
0	5 000	76	20 000	76
1	10 000	76	40 000	102 (76)
2	20 000	127	50 000	152
3	30 000	178	60 000	203
4	40 000	254 (178)	70 000	305 (254)
Clearances in (brackets) are specified in other ASTM standards.				

Table 10 Clearances between Test Electrodes ABC

[A]Clearance is the shortest electrical path from electrode to electrode around the open edge of the equipment. Permissible tolerance equals ± 25mm.
[B]These nominal clearances are intended to avoid flashover and may be increased by no more than 51mm when required by a change in atmospheric conditions from the standard of 100kPa (1 atm) barometric pressure and average humidity conditions. These clearances may be decreased if atmospheric conditions permit.
[C]DC proof –test voltages were determined using negative polarity.

APPENDIX B: STANDARDS FOR INSULATION COORDINATION (AIR GAPS)

IEEE 1313.1 - Standard for Insulation Coordination - Definitions, Principles, and Rules
IEEE 1313.2 - Guide for the Application of Insulation Coordination
IEC 60071-1 Insulation Co-Ordination Part 1: Definitions, Principles and Rules Seventh Edition; Cancels and Replaces IEC 71-3: 1982
IEC 60071-2 Insulation co-ordination - Part 2: Application guide Third Edition (not in Ergon subscription)

AS 1824.1—1995 (IEC 71-1:1993) Insulation co-ordination Part 1: Definitions, principles and rules

For phase-to-phase insulation, range I, the standard short-duration power-frequency and lightning impulse phase-to-phase withstand voltages are equal to the relevant phase-to-earth withstand voltages (table 2). The values in brackets, however, may be insufficient to prove that the required withstand voltages are met and additional phase-to-phase withstand tests may be needed.

Highest voltage for equipment U_m KV (RMS value)	Standard short- duration power-frequency withstand voltage kV (RMS value)	Standard lightning impulse withstand voltage kV (Peak value)
3.6	10	20
		40
7.2	20	40
		60
12	28	60
		75
		95
17.5	38	75
		95
24	50	95
		125
		145
36	70	145
		170
		200
52	95	250
72.5	140	325
123	(185)	450
	230	550
145	(185)	(450)
	230	550
	275	650
170	(230)	(550)
	275	650
	325	750
245	(275)	(650)
	(325)	(750)
	360	850
	395	950
	460	1050

Table 11 Standard Insulation Levels for Range 1 ((1 kV < $U_m \leq$ 245 kV)

NOTES:
1. If values in brackets are considered insufficient to prove that the required phase-to-phase withstand voltages are met, additional phase-to-phase withstand tests are needed.
2. For single wire earth return (SWER) systems used in Australia, the nominal voltages are 12.7 kV and 19.1 kV. These are r.m.s. line to earth voltages chosen as approximations to the phase to neutral voltages of 22 kV and 33 kV systems for which the highest voltages for equipment (Um) are 24 kV (r.m.s.) and 36 kV (r.m.s.) respectively. The insulation level for these SWER systems may be chosen from Table ZZ2 according to the applicable highest voltage for equipment (Um).

AS 1824.2—1985 (IEC 71-2:1976 and IEC 71-3:1982) Insulation co-ordination Part 2: Application Guide (Appendix D – Clearances in air to assure a specified impulse withstand voltage in installations)

D2 GUIDE TO CLEARANCE IN RELATION TO INSULATION LEVEL. Table D1 is suitable for general application, as it provides a specified minimum clearance in relation to the insulation level. These clearances may be lower if it has been proved by tests on actual or similar configurations that the required rated impulse withstand voltages are fulfilled, taking into account all relevant environmental conditions which can create irregularities on the surface of the phase electrode, for example, rain, pollution.

No distance is indicated for equipment which has a phase-to-phase impulse test included in the specification, since mandatory clearances might hamper the design of the equipment, increase its cost and impede progress.

In Table D1 (Um < 300 kV), column 1, the rated lightning impulse withstand voltages are listed. Column 2 lists air clearances for unfavourable configurations of energised parts with a relatively small radius of curvature. These clearances have been derived by the testing procedure described in Section 7 of AS 1824, Part 1.

The values of air clearance given in Table D1 are dictated by dielectric considerations. Other factors such as construction tolerances, the effect of short circuits, wind, safety of personnel, maintenance, corona effects, etc, are not included.

The indicated values are valid for altitudes not exceeding 1000 m. The effects of higher altitudes are under consideration.

Rated lightning impulse withstand voltage kV	**Minimum phase-to-earth and phase-to-phase air clearances mm**
40	60
60	90
75	120
95	160
125	220
150	280
170	320
200	380
325	630
450	900
550	1100
650	1300
750	1500
850	1700
950	1900
1050	2100

Table D1 Correlation between insulation levels and minimum air clearances Um < 300kV

AS 2067:1984 Switchgear assemblies and ancillary equipment for alternating voltages above 1 kV.

Rated voltage kV r.m.s.	Rated lightning impulse withstand voltage kV peak	Rated switching impulse withstand voltage kV peak	Minimum phase-to-earth clearance (see Notes 1 and 2) mm
Up to 3.6 (see Note 3)	40		60
7.2	60		90
12	75 (95) (see Note 4)		120 (160) (see Note 5)
24	125 (150)		220 (280)
36 (see Note 6)	170 (200)		320 (380)
72.5	325		630
123	450 550		900 1100
145	550 650		1100 1300
245	850 950 1050		1700 1900 2100
300	950 1050	750 850	1700 1900
362	1050 1175	850 950	1900 2200
525	1425 1550	1050 1175	2600 3100
(765) (see Note 7)	1800 2100	1300 1425	3600 4200

Table 9.1 Clearance in Air to Earth of Switchgear Assemblies

NOTES TO TABLE 9.1:

1. The phase-to-earth clearances given in column 4 for rated voltages up to and including 245 kV r.m.s. are for unfavourable configurations of live and earthed parts, i.e. the 'rod-structure' arrangement, and may be used for determining clearances to earth from live parts of any configuration.
2. The phase-to-earth clearances given in column 4 for 300 kV r.m.s. and above are for 'conductor-structure' configurations normally employed at the higher voltages. For further information on electrode configurations, refer to Electra No 29, Phase-to-ground and Phase-to-phase Air Clearances in Substations (CIGRE).
3. The values in the table are derived from AS 1824, Part 1 and Part 2.
(AS 1824, Parts 1 and 2 are in course of revision to cover both phase-to-earth and phase-to-phase insulation coordination).
4. The higher values shown in parentheses in column 2 are included to cover those distribution installations which may be severely exposed to over-voltages; for other installations the lower values are preferred.
5. The values shown in parentheses in column 4 correspond to the rated lightning impulse withstand voltages shown in parentheses in column 2.
6. For voltages below 36 kV r.m.s., it may be desirable to increase the phase-to-earth and phase-to-phase clearances where the presence of birds or vermin could cause a hazard or for constructional or other reasons.
7. The value shown in parentheses in column 1 is not an Australian standard voltage and is included only to designate additional impulse withstand voltages available.

EFFECT OF ALTITUDE ON CLEARANCES IN AIR. Where switchgear assemblies not subject to impulse test are intended for service at an altitude exceeding 1000 m, the clearances in air as given in Table 9.1 shall be increased by 1 percent for each 100 m in excess of 1000 m above sea level.

AS 2374.3.1:1992 Power Transformers Part 3.1: Insulation levels and dielectric test – External clearances in air. The same distances shall apply for clearances phase-to-earth, phase-to-neutral, phase-to-phase, and towards the terminals of a lower voltage winding. The recommended minimum clearances are given in Table I with reference to standard voltages, which appear in IEC Publication 76-3.

Highest voltage for equipment U m (r.m.s.) (kV)	Rated short duration power frequency withstand voltage (r.m.s.) (kV)	Rated lightning impulse withstand voltage (peak) (kV)	Minimum Clearance (mm)
≤ 1.1	3	-	-
3.6	16	40	60
7.2	20	60	90
12	28	75(95)	120(160)
(17.5)	38	95(110)	160(190)
24	50	125(150)	220(280)
36	70	170(200)	320(380)
(52)	95	250	480
72.5	140	325	630
123	185	450	900
	230	550	1100
145	230	550	1100
	275	650	1300
245	325	750	1500
	360	850	1700
	395	950	1900
	460	1050	2100

Table 1 Recommended clearances from bushing live parts on power transformers having windings with highest voltage for equipment U m <300kV

NOTES:
1 The highest voltages for equipment shown in parenthesis are non-standard in Australia and are included only to designate additional power frequency, impulse withstand levels and minimum clearances available for choice.
2 The higher lightning impulse withstand voltages shown in parenthesis and the corresponding minimum clearance values are included to cover those distribution installations which may be severely exposed to over-voltages. For other installations the lower values are preferred.
Um = highest r.m.s. voltage (phase to phase).

BS 6435 Unfilled Enclosures for the Dry Termination of HV Cables for Transformers and Reactors R (1993)

Definitions

Fully Insulated Enclosure. An unfilled enclosure where those parts of the bushings inside the enclosure, including all live metal parts and cable cores, are fully shrouded for the appropriate highest system voltage.

Partially Insulated Enclosure. An unfilled enclosure in which the cable cores only are fully shrouded for the appropriate highest system voltage.

Rated voltage kV	Type of enclosure	Clearance between live metal of different phases mm	Clearance between live metal and earth mm	Creepage over insulator mm
12	Fully insulated	45	32	*
	Partially insulated	127	76	127
17.5	Fully insulated	75	60	*
	Partially insulated	165	102	153
24	Fully insulated	100	75	*
	Partially insulated	242	140	203
36	Fully insulated	125	100	*
	Partially insulated	356	222	305

Table 1 Minimum Electrical Clearances

APPENDIX C: STANDARDS THAT MAY PROVIDE FURTHER INFORMATION

ASTM D 149 and IEC 60243 Part 1 provide a list of ASTM / IEC standards for various insulating materials.

ASTM D 149 REV A Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
ASTM D 2477 - Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Insulating Gases at Commercial Power Frequencies
ASTM D 3283 - Standard Specification for Air as an Electrical Insulating Material
ASTM D 3426 - Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials Using Impulse Waves R(2004)
ASTM D 3755 - Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials under Direct-Voltage Stress R(2004)

IEC 60085 - Thermal Evaluation and Classification of Electrical Insulation Second Edition
IEC 61472 - Live Working - Minimum Approach Distances - Method of Calculation First Edition
IEC 60243-1 Electrical Strength of Insulating Materials - Test Methods - Part 1: Tests at Power Frequencies Second Edition
IEC 60243-2 Electric Strength of Insulating Materials - Test Methods - Part 2: Additional Requirements for Tests Using Direct Voltage Second Edition
IEC 60243-3 Electric Strength of Insulating Materials - Test Methods - Part 3: Additional Requirements for 1,2/50 us Impulse Tests Second Edition

AS/NZS 1660.3:1998 Test methods for electric cables, cords and conductors; Method 3: Electrical tests
AS/NZS 3808:2000 Insulating and sheathing materials for electric cables

ASTM F 819 Standard Terminology Relating to Electrical Protective Equipment for Workers E(2000)

IEEE 48 Standard Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV Through 765 kV R(2003)
IEEE 82 Standard Test Procedure for Impulse Voltage Tests on Insulated Conductors
IEEE 400 Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems
IEEE 576 Recommended Practice for Installation, Termination, and Testing of Insulated Power Cable as Used in Industrial and Commercial Applications
IEEE 404 Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500 V to 500 000 V

IEC 60060-1 High-Voltage Test Techniques Part 1: General Definitions and Test Requirements Second Edition; Corrigendum-03/1990; Corrigendum-03/1992
IEC 60060-2 High-Voltage Test Techniques Part 2: Measuring Systems Second Edition; Amendment 1-1996; Replaces 60060-3: 1976
IEC 60230 Impulse Tests on Cables and Their Accessories First Edition
IEC 61442 Electric Cables - Test Methods for Accessories for Power Cables with Rated Voltages from 6 kV (Um=7,2 kV) up to 30 kV (Um=36 kV) First Edition

ELECTRICAL INSULATING SLEEVING AND TUBING (HEAT SHRINK)

IEC 60684-1 Flexible insulating sleeving Part 1: Definitions and general requirements Second Edition
IEC 60684-2 Flexible Insulating Sleeving - Part 2: Methods of Test Edition 2.1; Edition 2: 1997 Consolidated with Amendment 1:2003
IEC 60684-3-100 TO 105 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheets 100 to 105: Extruded PVC Sleeving Second Edition
IEC 60684-3-116 AND 117 Flexible insulating sleeving Part 3: Specifications for individual types of sleeving Sheets 116 and 117: Extruded polychloroprene General purpose Second Edition
IEC 60684-3-121 TO 124 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheets 121 and 124: Extruded Silicone Sleeving Second Edition
IEC 60684-3-136 Flexible Insulating Sleeving - Part 3: Specification for Individual Types of Sleeving - Sheet 136: Extruded Fluorosilicone Sleeving - General Purpose First Edition; Corrigendum: 02-1999
IEC 60684-3-145 TO 147 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheets 145 to 147: Extruded PTFE Sleeving First Edition
IEC 60684-3-151 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 151: Extruded PVC/Nitrile Rubber - General Purpose First Edition

IEC 60684-3-201 Specification for Flexible Insulating Sleeving Part 3: Specification Requirements for Individual Types of Sleeving Sheet 201: Heat Shrinkable Sleeving, General Purpose, Flexible, Cross-Linked PVC, Shrink Ratio 2:1 First Edition
IEC 60684-3-209 Flexible insulating sleeving Part 3: Specifications for individual types of sleeving Sheet 209: Heat-shrinkable polyolefin sleeving, general purpose, flame retarded, shrink ratio 2:1 Second Edition
IEC 60684-3-211 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 211: Heat-Shrinkable Sleeving, Semi-Rigid Polyolefin, Shrink Ratio 2:1 Second Edition
IEC 60684-3-212 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 212: Heat-Shrinkable Polyolefin Sleeving, Flame Retarded, Shrink Ratio 2:1 First Edition
IEC 60684-3-213 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 213: Heat-Shrinkable Polyolefin Sleeving, Not Flame Retarded, Shrink Ratio 2:1 First Edition
IEC 60684-3-214 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 214: Heat-Shrinkable, Polyolefin Sleeving, Not Flame Retarded, Shrink Ratio 3:1 - Thick and Medium Wall First Edition
IEC 60684-3-216 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 216: Heat-Shrinkable, Flame-Retarded, Limited-Fire-Hazard Sleeving First Edition; Amendment 1: 02/2003
IEC 60684-3-217 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 217: Heat-Shrinkable Polyolefin Sleeving, Flame Retarded, Shrink Ratio 3:1 First Edition
IEC 60684-3-218 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 218: Heat-Shrinkable Polyolefin Sleeving, Not Flame Retarded, Shrink Ratio 3:1 First Edition
IEC 60684-3-228 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 228: Heat-Shrinkable Semi-Rigid, Polyvinylidene Fluoride Sleeving, Flame Retarded, Fluid Resistant, Shrink Ratio 2:1 First Edition
IEC 60684-3-229 Flexible insulating sleeving Part 3: Specifications for individual types of sleeving Sheet 229: Heat-shrinkable semi-flexible, polyvinylidene fluoride sleeving, flame retarded, fluid resistant, shrink ratio 2:1 First Edition
IEC 60684-3-233 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 233: Heat-Shrinkable Fluoroelastomer Sleeving, Flame Retarded, Fluid Resistant, Shrink Ratio 2:1 First Edition
IEC 60684-3-240 TO 243 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheets 240 to 243: Heat-Shrinkable PTFE Sleeving Second Edition
IEC 60684-3-246 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 246: Heat-Shrinkable Polyolefin Sleeving, Dual-Wall, Not Flame-Retarded Second Edition
IEC 60684-3-271 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 271: Heat-Shrinkable Elastomer Sleeving, Flame Retarded, Fluid Resistant, Shrink Ratio 2:1 First Edition
IEC 60684-3-272 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 272: Heat-Shrinkable Elastomer Sleeving, Flame Retarded, Fluid Resistant, Shrink Ratio 2:1, Thin Wall First Edition
IEC 60684-3-300 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 300: Glass Textile Fibre Sleeving, Braided, Uncoated
IEC 60684-3-320 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 320: Polyethylene Terephthalate Textile Sleeving, Lightly Impregnated Second Edition
IEC 60684-3-340 TO 342 Flexible insulating sleeving Part 3: Specifications for individual types of sleeving Sheets 340 to 342: Expandable braided polyethylene terephthalate textile sleeving Second Edition
IEC 60684-3-343 TO 345 Flexible Insulating Sleeving - Part 3: Specification for Individual Types of Sleeving - Sheets 343 to 345: Expandable Braided Ethylene Chlorotrifluoroethylene (E-CTFE) Textile Sleeving, Uncoated Second Edition
IEC 60684-3-400 TO 402 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheets 400 to 402: Glass Textile Sleeving with Silicone Elastomer Coating Second Edition
IEC 60684-3-403 TO 405 Flexible Insulating Sleeving - Part 3: Specification Individual Types of Sleeving - Sheets 403 to 405: Glass Textile Sleeving with Acrylic Based Coating Second Edition
IEC 60684-3-406 TO 408 Flexible insulating sleeving Part 3: Specifications for individual types of sleeving Sheets 406 to 408: Glass textile sleeving with PVC coating Second Edition
IEC 60684-3-409 Flexible Insulating Sleeving - Part 3: Specifications for Individual Types of Sleeving - Sheet 409: Glass Textile Sleeving with Polyurethane (PUR)-Based Coating First Edition
IEC 60684-3-420 TO 422 Flexible Insulating Sleeving - Part 3: Specification for Individual Types of Sleeving - Sheets 420 to 422: Polyethylene Terephthalate Textile Sleeving with Acrylic Based Coating Second Edition

ASTM D 2671 - Standard Test Methods for Heat-Shrinkable Tubing for Electrical Use
ASTM D 2902 - Standard Specification for Fluoropolymer Resin Heat-Shrinkable Tubing for Electrical Insulation
ASTM D 2903 - Standard Specification for Crosslinked Chlorinated Polyolefin Heat-Shrinkable Tubing for Electrical Insulation R(1998)
ASTM D 3144 - Standard Specification for Crosslinked Poly(Vinylidene Fluoride) Heat-Shrinkable Tubing for Electrical Insulation
ASTM D 3149 - Standard Specification for Crosslinked Polyolefin Heat-Shrinkable Tubing for Electrical Insulation

ASTM D 3150 - Standard Specification for Crosslinked and Non crosslinked Poly (Vinyl Chloride) Heat-Shrinkable Tubing for Electrical Insulation

MILSPEC MIL-DTL-23053/10D CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, SILICONE RUBBER, FLEXIBLE (REFER TO SAE AMS-DTL-23053/10)
MILSPEC MIL-DTL-23053/11C CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, FLUORINATED ETHYLENE PROPYLENE, NON-CROSSLINKED (REFER TO SAE AMS-DTL-23053/11)
MILSPEC MIL-DTL-23053/12C CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, POLYTETRAFLUOROETHYLENE (REFER TO SAE AMS-DTL-23053/12)
MILSPEC MIL-DTL-23053/13B CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, FLUOROELASTOMER, FLEXIBLE (REFER TO SAE ASM-DTL-23053/13)
MILSPEC MIL-DTL-23053/14B CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, ETHYLENE-TETRAFLUOROETHYLENE FLUOROPOLYMER, SEMI-RIGID (REFER TO SAE AMS-DTL-23053/14)
MILSPEC MIL-DTL-23053/15B CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, POLYOLEFIN, HEAVY-WALL, COATED, FLEXIBLE, OUTER WALL CROSSLINKED (REFER TO SAE AMS-DTL-23053/15)
MILSPEC MIL-DTL-23053/16B CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, CROSSLINKED, ELASTOMERIC POLYOLEFIN, FLEXIBLE (REFER TO SAE AMS-DTL-23053/16)
MILSPEC MIL-DTL-23053/17B CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, FLAME RETARDED, MODIFIED POLYOLEFIN, FLEXIBLE, CROSSLINKED (REFER TO SAE AMS-DTL-23053/17)
MILSPEC MIL-DTL-23053/18B CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, MODIFIED FLUOROPOLYMER, CROSSLINKED (REFER TO SAE AMS-DTL-23053/18)
MILSPEC MIL-DTL-23053/1C CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, CROSSLINKED CHLORINATED POLYOLEFIN, FLEXIBLE (REFER TO SAE AMS-DTL-23053/1)
MILSPEC MIL-DTL-23053/4D CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, POLYOLEFIN, DUAL-WALL, OUTER WALL CROSSLINKED (REFER TO SAE AMS-DTL-23053/4)
MILSPEC MIL-DTL-23053/5C CANC NOTICE 1- INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, POLYOLEFIN, FLEXIBLE, CROSSLINKED (REFER TO SAE AMS-DTL-23053/5)
MILSPEC MIL-DTL-23053/6D CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, POLYOLEFIN, SEMI-RIGID, CROSSLINKED (REFER TO SAE AMS-DTL-23056/6)
MILSPEC MIL-DTL-23053/7C CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, POLYETHYLENE TEREPHTHALATE, NON-CROSSLINKED (REFER TO SAE AMS-DTL-23053/7)
MILSPEC MIL-DTL-23053/8C CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, POLYVINYLIDENE FLUORIDE, SEMI-RIGID, CROSSLINKED (REFER TO SAE AMS-DTL-23053/8)
MILSPEC MIL-DTL-23053E CANC NOTICE 3 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, GENERAL SPECIFICATION FOR (REFER TO SAE AMS-DTL-23053)
MILSPEC MIL-I-13042A CANC NOTICE 1 - INSULATION SLEEVING, THERMAL, TUBULAR, FLEXIBLE (REFER TO A-A-52152)
MILSPEC MIL-I-13548A CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL (CABLE SPLICING) FT-96, FT-97, FT-98, AND FT-472
MILSPEC MIL-I-23053/2C CANC NOTICE 2 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, POLYVINYL CHLORIDE, FLEXIBLE, CROSSLINKED AND NON-CROSSLINKED (REFER TO SAE AMS-I-23053/2)
MILSPEC MIL-I-23053/3A CANC NOTICE 2 - INSULATION SLEEVING, ELECTRICAL, HEAT SHRINKABLE, POLYVINYL CHLORIDE, SEMI RIGID, CROSSLINKED AND NON-CROSSLINKED (REFER TO SAE AMS-I-23053/3)
MILSPEC MIL-I-3190/2A (1) - INSULATION SLEEVING, ELECTRICAL, FLEXIBLE, COATED, CLASS 130, TYPE B, CATEGORY B
MILSPEC MIL-I-3190/3A - INSULATION SLEEVING, ELECTRICAL, FLEXIBLE, COATED, CLASS 155, TYPE A, CATEGORY A
MILSPEC MIL-I-3190/5B - INSULATION SLEEVING, ELECTRICAL, FLEXIBLE, COATED, CLASS 200, TYPE C, CATEGORY C
MILSPEC MIL-I-3190/6A - INSULATION SLEEVING, ELECTRICAL, FLEXIBLE, COATED, CLASS 200, TYPE D, CATEGORY C
MILSPEC MIL-I-3190/7A - INSULATION SLEEVING, ELECTRICAL, FLEXIBLE, COATED CLASS 220 DEG. C, TYPE E, CATEGORY C
MILSPEC MIL-I-3190/8A - INSULATION SLEEVING, ELECTRICAL, FLEXIBLE, SILICONE COATED, CLASS 220 DEG. C, TYPE D CATEGORY C
MILSPEC MIL-I-3190/9 (1) - INSULATION SLEEVING, ELECTRICAL, FLEXIBLE, SILICONE COATED CLASS 240 DEG. C, TYPE D, CATEGORY C
MILSPEC MIL-I-3190F (2) - INSULATION SLEEVING, ELECTRICAL, FLEXIBLE, COATED, GENERAL SPECIFICATION FOR

MILSPEC MIL-I-47100 NOTICE 4 - INSULATION SLEEVING, FLEXIBLE, BRAIDED, 200 DEGREES CELSIUS (HIGH TEMPERATURE POLYAMIDE)
MILSPEC MIL-I-47203 CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, BRAIDED (USE MIL-S-47053)
MILSPEC MIL-I-7444D NOTICE 2 - INSULATION SLEEVING, ELECTRICAL, FLEXIBLE
MILSPEC MIL-I-82799 CANC NOTICE 1 - INSULATION SLEEVING, ELECTRICAL, HEAT-SHRINKABLE

ELECTRICAL INSULATING TAPES

ASTM D 1458 - Standard Test Methods for Fully Cured Silicone Rubber-Coated Glass Fabric and Tapes for Electrical Insulation
ASTM D 1459 - Standard Specification for Silicone Varnished Glass Cloth and Tape for Electrical Insulation R(2003)
ASTM D 1931 - Standard Specification for Fully Cured Silicone Rubber-Coated Glass Fabric and Tapes for Electrical Insulation
ASTM D 2301 - Standard Specification for Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape
ASTM D 2400 - Standard Specification for Varnished Glass-Polyester Cloth Used for Electrical Insulation
ASTM D 2484 - Standard Specification for Polyester Film Pressure-Sensitive Electrical Insulating Tape
ASTM D 2686 - Standard Specification for Polytetrafluoroethylene-Backed Pressure-Sensitive Electrical Insulating Tape
ASTM D 3005 - Standard Specification for Low-Temperature Resistant Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape
ASTM D 3006 - Standard Specification for Polyethylene Plastic Pressure-Sensitive Electrical Insulating Tape
ASTM D 2754 - Standard Specification for High-Temperature Glass Cloth Pressure-Sensitive Electrical Insulating Tape
ASTM D 372 - Standard Specification for Flexible Treated Sleeving Used for Electrical Insulation
ASTM D 4388 - Standard Specification for Non-metallic Semi-Conducting and Electrically Insulating Rubber Tapes
ASTM D 2518 - Standard Specification for Woven Glass Fabrics for Electrical Insulation
ASTM D 3308 - Standard Specification for PTFE Resin Skived Tape

IEC 60454-1 - Specifications for Pressure-Sensitive Adhesive Tapes for Electrical Purposes Part 1: General Requirements Second Edition
IEC 60454-2 - Specification for Pressure-Sensitive Adhesive Tapes for Electrical Purposes Part 2: Methods of Test Second Edition
IEC 60454-3-1 - Pressure-sensitive adhesive tapes for electrical purposes Part 3 Specifications for individual materials Sheet 1: PVC film tapes with pressure-sensitive adhesive Edition 2.1; Edition 2: 1998 Consolidated with Amendment 1: 2001
IEC 60454-3-10 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes Part 3: Specifications for Individual Materials - Sheet 10: Requirements for Cellulose-Acetate-Butyrate Film Tapes with Rubber Thermosetting Adhesive First Edition
IEC 60454-3-11 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes - Part 3: Specifications for Individual Materials - Sheet 11: Combination Tapes Made of Creped Cellulosic Paper and Polyethylene Terephthalate Film with Rubber Thermosetting Adhesive First Edition
IEC 60454-3-12 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes - Part 3: Specifications for Individual Materials - Sheet 12: Polyethylene Film Tapes with Pressure-Sensitive Adhesive First Edition
IEC 60454-3-13 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes Part 3: Specifications for Individual Materials - Sheet 13: Requirements for Combined Cellulose-Viscose Woven Fabric Tapes, One Side Covered with a Thermoplastic Material, the Other Side with Rubber Thermosetting Adhesive First Edition
IEC 60454-3-14 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes - Part 3: Specifications for Individual Materials - Sheet 14: Polytetrafluoroethylene Film Tapes with Pressure-Sensitive Adhesive First Edition
IEC 60454-3-15 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes - Part 4: Specifications for Individual Materials - Sheet 15: Polyester Film/Polyester Non-Woven Combinations with Rubber Thermosetting Adhesive First Edition
IEC 60454-3-16 - Pressure-sensitive adhesive tapes for electrical purposes Part 3: Specifications for individual materials Sheet 16: Polyester film/glass filament combinations with pressure-sensitive adhesive First Edition
IEC 60454-3-17 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes - Part 3: Specifications for Individual Materials - Sheet 17: Polyester/Epoxy Combinations with Pressure-Sensitive Adhesive First Edition
IEC 60454-3-18 - Pressure-sensitive adhesive tapes for electrical purposes Part 3: Specifications for individual materials Sheet 18: Polypropylene film tapes with pressure-sensitive adhesive First Edition
IEC 60454-3-19 - Pressure-sensitive adhesive tapes for electrical purposes Part 3: Specifications for individual materials Sheet 19: Tapes made from various backing materials with pressure-sensitive adhesive on both sides First Edition

IEC 60454-3-2 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes - Part 3: Specifications for Individual Materials - Sheet 2: Polyester Film Tapes with Rubber Thermosetting or Acrylic Crosslinked Adhesives Second Edition
IEC 60454-3-3 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes - Part 3: Specifications for Individual Materials - Sheet 3: Polyester Film Tapes with Rubber Thermoplastic Adhesive Second Edition
IEC 60454-3-4 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes - Part 3: Specifications for Individual Materials Sheet 4: Cellulosic Paper, Creped, with Rubber Thermosetting Adhesive Second Edition
IEC 60454-3-5 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes - Part 3: Specifications for Individual Materials - Sheet 5: Cellulosic Paper, Non-Creped, with Rubber Thermosetting Adhesive Second Edition
IEC 60454-3-6 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes - Part 3: Specifications for Individual Materials - Sheet 6: Polycarbonate Film Tapes with Acrylic Thermoplastic Adhesive Second Edition
IEC 60454-3-7 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes - Part 3: Specifications for Individual Materials - Sheet 7: Polyimide Film Tapes with Pressure-Sensitive Adhesive Second Edition
IEC 60454-3-8 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes - Part 3: Specifications for Individual Materials - Sheet 8: Glass Fabric with Pressure-Sensitive Adhesive Second Edition
IEC 60454-3-9 - Pressure-Sensitive Adhesive Tapes for Electrical Purposes - Part 3: Specifications for Individual Materials - Sheet 9: Cellulose Acetate Woven Fabric Tapes with Rubber Thermosetting Adhesives First Edition

ELECTRICAL INSULATING PAPERS

Notes from ESAA Short Course “Transformer Technology” September 1999.

IEC 60554-1 - Specification for Cellulosic Papers for Electrical Purposes Part 1: Definitions and General Requirements First Edition; Erratum-03/1979; Amendment 1-1983
IEC 60554-2 - Cellulosic papers for electrical purposes Part 2: Methods of test Second Edition
IEC 60554-3-1 - Specification for Cellulosic Papers for Electrical Purposes Part 3: Specifications for Individual Materials Sheet 1: General Purpose Electrical Paper First Edition
IEC 60554-3-2 - Specification for Cellulosic Papers for Electrical Purposes Part 3: Specifications for Individual Materials Sheet 2: Capacitor Paper First Edition
IEC 60554-3-3 - Specification for Cellulosic Papers for Electrical Purposes Part 3: Specification for Individual Materials Sheet 3: Crepe Paper First Edition
IEC 60554-3-4 - Specification for Cellulosic Papers for Electrical Purposes Part 3: Specifications for Individual Materials Sheet 4: Electrolytic Capacitor Paper First Edition
IEC 60554-3-5 - Specification for Cellulosic Papers for Electrical Purposes Part 3: Specifications for Individual Materials Sheet 5: Special Papers First Edition

IEC 60641-1 - Specification for Pressboard and Presspaper for Electrical Purposes Part 1: Definitions and General Requirements First Edition; (Amendment 1-1993) (CENELEC EN 60641-1: 1995)
IEC 60641-2 - Specification for Pressboard and Presspaper for Electrical Purposes Part 2: Methods of Test First Edition; Amendment 1-1993; Corrigendum-10/1994; CENELEC EN 60 641-2: 1995
IEC 60641-3-1 - Specification for Pressboard and Presspaper for Electrical Purposes Part 3: Specifications for Individual Materials - Sheet 1: Requirements for Pressboard, Types B.0.1, B.2.1, B.2.3, B.3.1, B.3.3, B.4.1, B.4.3, B.5.1, B.6.1 and B.7.1 First Edition
IEC 60641-3-2 - Specification for Pressboard and Presspaper for Electrical Purposes Part 3: Specifications for Individual Materials - Sheet 2: Requirements for Presspaper, Types P.2.1, P.4.1, P.4.2, P.4.3, P.6.1 and P.7.1 First Edition; CENELEC EN 60641-3-2: 1994

IEC 60819-1 - Non-Cellulosic Papers for Electrical Purposes Part 1: Definitions and General Requirements Second Edition; (CENELEC EN 60819-1: 1995) (Amendment 1-1996)
IEC 60819-2 - Non-Cellulosic Papers for Electrical Purposes - Part 2: Methods of Test First Edition
IEC 60819-3-1 - Non-Cellulosic Papers for Electrical Purposes - Part 3: Specification for Individual Materials - Sheet 1: Filled Glass Paper First Edition
IEC 60819-3-2 - Non-Cellulosic Papers for Electrical Purposes - Part 3: Specifications for Individual Materials - Sheet 2: Hybrid Inorganic-Organic Paper First Edition
IEC 60819-3-3 - Specification for Non- Cellulosic Papers for Electrical Purposes Part 3: Specifications for Individual Materials Sheet 3: Unfilled Aramid (Aromatic Polyamide) Papers First Edition
IEC 60819-3-4 - Non-Cellulosic Papers for Electrical Purposes - Part 3: Specifications for Individual Materials - Sheet 4: Aramid Fibre Paper Containing Not More Than 50 % of Mica Particles First Edition

ASTM D 4063 - Standard Specification for Pressboard for Electrical Insulating Purposes
ASTM D 1305 - Standard Specification for Electrical Insulating Paper and Paperboard - Sulfate (Kraft) Layer Type