

Contents

Compilation of the most important symbols used	X
1 Electric strength	1
1.1 Electric field and breakdown voltage	1
1.1.1 Determination of electric fields	1
1.1.2 Maximum field strengths in geometrically similar configurations	6
1.1.3 Formulation for the calculation of the breakdown voltage	8
1.1.4 Breakdown probability	10
1.2 Breakdown of gases	14
1.2.1 Charge carriers in gases	14
1.2.2 Self-sustaining discharges	18
1.2.3 Breakdown mechanism in a strongly inhomogeneous field	22
1.2.4 Breakdown under lightning impulse voltages	25
1.2.5 Breakdown under switching impulse voltages	28
1.3 Breakdown of solid insulating materials	30
1.3.1 Charge carriers at low field strengths	30
1.3.2 Intrinsic breakdown	31
1.3.3 Thermal breakdown	37
1.3.4 Partial discharge breakdown	41
1.4 Breakdown of liquid insulating materials	47
1.4.1 Electric strength of technical configurations with insulating liquids	47
1.4.2 Breakdown mechanisms	50
1.5 Breakdown in high vacuum	52
1.6 Pollution flashover	54
1.6.1 Development and effect of contamination layers	54
1.6.2 Mechanism of pollution flashover	57
1.6.3 Pollution tests	60
2 Insulating materials in high-voltage technology	62
2.1 Requirements for insulating materials	62
2.2 Properties and testing of insulating materials	63
2.2.1 Electrical properties	63
2.2.2 Thermal properties	63
2.2.3 Chemical properties	70
2.3 Natural inorganic insulation materials	71
2.3.1 Natural gases	71
2.3.2 Quartz and mica	72

2.4	Synthetic inorganic insulating materials	72
2.4.1	Sulphurhexafluoride (SF ₆)	72
2.4.2	Glass	74
2.4.3	Ceramic insulating materials	76
2.5	Natural organic insulating materials	79
2.5.1	Mineral oil	79
2.5.2	Paper	81
2.5.3	Oil-impregnated paper	82
2.6	Synthetic organic insulating materials	86
2.6.1	Molecular configuration and polymerisation reactions	86
2.6.2	Polyethylene (PE)	87
2.6.3	Polyvinylchloride (PVC)	89
2.6.4	Polytetrafluoroethylene (PTFE)	90
2.6.5	Epoxy resin (EP)	91
2.6.6	Polyurethane resin (PUR)	93
2.6.7	Silicone elastomer	94
2.6.8	Chlorinated diphenyls	94
2.6.9	Silicone oil	96
3	Design and manufacture of high-voltage equipment	97
3.1	Structural details in high-voltage technology	97
3.1.1	Basic arrangement of the insulation system	97
3.1.2	Measures to avoid intensification of electric stress	101
3.1.3	Rigid and leak-proof connections to insulating parts	106
3.1.4	Measures for air sealing oil-insulated devices	108
3.1.5	Temperature rise calculation of insulation systems	109
3.2	High-voltage capacitors	111
3.2.1	Basic configurations	111
3.2.2	Design of wound capacitors	114
3.2.3	Types of design	118
3.3	Bushings and lead-outs	120
3.3.1	Basic configurations	120
3.3.2	Calculation of capacitive gradings	123
3.3.3	Types of design	128
3.4	Transformer windings	130
3.4.1	Design factors for magnetic circuits	130
3.4.2	Assembly and connection of windings	135
3.4.3	Insulation of high-voltage windings	137
3.4.4	Impulse voltage performance and winding construction	138
3.4.5	Types of transformer winding	140
3.5	Instrument transformers	142
3.5.1	Inductive voltage transformers	143
3.5.2	Capacitive voltage transformers	148
3.5.3	Current transformers	152

Appendix: Tables and diagrams	159
A.1 Utilization factors for simple electrode configurations	159
A.1.1 Spherical configurations	159
A.1.2 Cylindrical configurations	161
A.1.3 Point and knife-edge configurations	163
A.1.4 Circular ring configurations	165
A.2 Electric strength of gas-insulated configurations	168
A.2.1 Breakdown voltage in the homogeneous field	168
A.2.2 Breakdown field strength of plate, cylinder and sphere electrodes.	169
A.2.3 Breakdown voltage of rod gaps in air.	171
A.3 Properties of insulating materials	173
A.4 Properties of magnetic materials.	177
Bibliography	180
Index	187