

16 Materials and Semi-Finished Products for Switchgear Installations

16.1 Iron and steel

16.1.1 Structural steel, general

The material specifications for structural steels to DIN EN 10 029 apply to carbon steels and low-alloy steels: these are used in the hot-worked condition, and to a lesser extent after normalizing, for reasons of tensile strength and yield strength. The specifications are also valid for forgings, section steel, strip, and heavy and medium plates made from these steels. This standard DIN EN 10 029 does not apply to the products given in Table 16-2.

Weldability is better with low-carbon steels having less than 0.22% C. Weldability is best with steels of grade 3, e.g. St 37-3 (S235 JR), and poorest with steels of grade 1. Killed steels are to be preferred to rimmed steel, especially if segregation zones might be encountered when welding.

Identification codes for structural steels are contained in DIN EN 10027. This also shows the chemical composition and method of melting or casting.

The standards giving the dimensions of general structural steels are listed in Table 16-1.

Table 16-1

Dimensional standards	
Round steel, general purpose	DIN 1013
Square steel	DIN 1014
Flat steel, general purpose	DIN 1017
Equal angle section and deep-web T bars, square edge	DIN 1022
T bars, round edge	DIN EN 10055
I bars and I beams	DIN 1025
Channel bars and beams	DIN 1026
Steel angle	DIN 1028
Steel angle, unequal widths	DIN 1029
Steel sheet less than 3 mm (thin sheet)	DIN EN 10131
Steel sheet 5 mm and above (heavy plate)	DIN EN 10130

Table 16-2

Dimensional standards	
Steel for screws, bolts and nuts	DIN 1654, DIN 17 240, DIN 59 130
Heat-treatable steel	DIN EN 10 083
Case-hardening steel	DIN 17 210
Thin sheet less than 3 mm thick	DIN 1623, Sheet 1 and DIN EN 10 130
Identification code for surface type and treatment	(DIN 1623)

16.1.2 Dimensions and weights of steel bars, sections and tubes

Table 16-3

Dimensions and weight of steel bars

Square and flat steel DIN 1014/1017

Dimensions mm	Cross-section cm ²	Weight kg/m	Dimensions mm	Cross-section cm ²	Weight kg/m
8 × 4	0.32	0.249	40 × 8	3.2	2.50
10 × 5	0.5	0.390	40 × 10	4.0	3.12
12 × 5	0.6	0.470	40 × 40	16.0	12.60
13 × 2.5	0.325	0.255	45 × 5	2.25	1.75
15 × 5	0.75	0.595	45 × 8	3.6	2.81
20 × 3	0.6	0.471	45 × 10	4.5	3.51
20 × 4	0.8	0.624	50 × 3	1.5	1.17
20 × 5	1.0	0.780	50 × 4	2.0	1.56
20 × 8	1.6	1.26	50 × 5	2.5	1.95
25 × 3	0.75	0.589	50 × 6	3.0	2.34
25 × 4	1.0	0.785	50 × 8	4.0	3.12
25 × 5	1.25	0.981	50 × 10	5.0	3.90
26 × 2 ¹⁾	0.52	0.408	60 × 5	3.0	2.34
30 × 3	0.9	0.705	60 × 8	4.8	3.74
30 × 3.5 ¹⁾	1.05	0.825	60 × 10	6.0	4.68
30 × 4	1.2	0.936	65 × 5	3.25	2.53
30 × 5	1.5	1.170	80 × 5	4.0	3.12
30 × 30	9.0	7.065	80 × 6	4.8	3.74
35 × 3	1.05	0.825	80 × 8	6.4	4.99
35 × 4	1.4	1.09	80 × 10	8.0	6.24
35 × 5	1.75	1.36	100 × 5	5.0	3.90
35 × 35	12.25	9.62	100 × 6	6.0	4.68
40 × 3	1.2	0.942	100 × 8	8.0	6.24
40 × 4 ¹⁾	1.6	1.26	100 × 10	10.0	7.8
40 × 5	2.0	1.56			
40 × 6	2.4	1.87			

¹⁾ also galvanized for earth conductors

Earthing plate 1000 · 1000 · 3 mm with strip 2.5 m long, approx. 30 kg

Earth rod 1" diameter, 2000 mm long, 5.3 kg

Earth rod 2" diameter, 3000 mm long, 16.5 kg

Table 16-4

Dimensions and weights of round steel and steel tubes

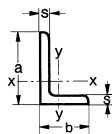
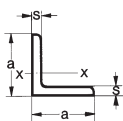
Round steel bright DIN 671			Steel tube		
Diameter mm	Cross- section cm ²	Weight kg/m	Out- side diameter inches	Outside diameter, wall thickness mm	Weight kg/m
1	0.0079	0.0062	Seamless precision tube DIN 2391		
2	0.0314	0.0247		5 × 1	0.10
3	0.0707	0.0555		6 × 1	0.12
4	0.1257	0.0986		10 × 1 ²⁾	0.222
5	0.1963	0.154		10 × 2 ²⁾	0.395
6	0.283	0.222		12 × 2	0.493
8	0.503	0.395		15 × 1	0.36
10	0.785	0.617		16 × 2	0.691
12	1.131	0.888		20 × 2	0.89
14	1.539	1.21		22 × 1	0.52
15	1.767	1.39		28 × 1.5	1.0
18	2.245	2.00		30 × 2	1.37
20	3.142	2.47		32 × 3 ²⁾	2.15
22	3.801	2.98		50 × 2	2.36
25	4.91	3.85			
28	6.158	4.83	Medium-heavy threaded tube DIN 2440		
30	7.069	5.55	1/4 "	13.5 × 2.35	0.65
32	8.042	6.31	3/8 "	17.2 × 2.35	0.852
36	10.18	7.99	1/2 "	21.3 × 2.65	1.22
38	11.34	8.9	3/4 "	26.9 × 2.65	1.58
40	12.57	9.86	1 "	33.7 × 3.25	2.44
42	13.85	10.9	1 1/4 "	42.4 × 3.25	3.14
45	15.9	12.5	1 1/2 "	48.3 × 3.25	3.61
48	18.10	14.2	2 "	60.3 × 3.65	5.10
50	19.63	15.4			
			Seamless tube DIN 2448		
				25 × 2.6 ¹⁾	1.44
				30 × 4	2.59
				30 × 2.6	1.77
				31.8 × 2.9 ¹⁾	2.08

1) also galvanized for earth conductors

2) Tube for operating mechanism linkages

Table 16-5

Steel angle



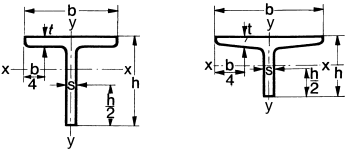
Equal width DIN 1208			Unequal width DIN 1029			
Symbol	Weight	Section modulus	Symbol	Weight	Section modulus	
L			L		W_x	W_y
$a \times s$	kg/m	cm ³	$a \times b \times s$	kg/m	cm ³	cm ³
mm			mm			
20 × 3	0.88	0.28	30 × 20 × 4	1.45	0.81	0.38
25 × 3	1.12	0.45	40 × 20 × 3	1.35	10.8	0.30
25 × 4	1.45	0.58	40 × 20 × 4	1.77	1.42	0.39
30 × 3	1.36	0.65	45 × 30 × 4	2.25	1.91	0.91
30 × 4	1.78	0.86	45 × 30 × 5	2.77	2.35	1.11
35 × 4	2.10	1.18	60 × 30 × 5	3.37	4.04	1.12
40 × 4	2.24	1.56	60 × 30 × 7	4.59	5.50	1.52
40 × 5	2.97	1.91	50 × 40 × 5	3.36	3.20	2.01
45 × 5	3.38	2.43	60 × 40 × 5	3.76	4.25	2.02
50 × 5	3.77	3.05	60 × 40 × 6	4.46	5.03	2.38
50 × 6	4.47	3.61	80 × 40 × 6	5.41	8.73	2.44
55 × 6	4.95	4.40	80 × 65 × 8	8.66	12.3	8.41
60 × 6	5.42	5.29	65 × 50 × 5	4.35	5.11	3.18
60 × 8	7.09	6.88	65 × 50 × 7	5.97	6.99	4.31
65 × 7	6.83	7.18	100 × 50 × 6	6.85	13.08	3.86
65 × 9	8.62	9.04	100 × 50 × 8	8.99	18.0	4.05
70 × 7	7.38	8.43	90 × 60 × 6	6.82	11.7	5.61
70 × 9	9.34	10.6	90 × 60 × 8	8.96	15.4	7.31
75 × 8	9.03	11.0	80 × 65 × 6	6.60	9.41	6.44
80 × 8	9.66	12.6	80 × 65 × 8	8.66	12.3	8.41
80 × 10	11.9	15.5	100 × 65 × 7	8.77	16.6	7.54
90 × 9	12.2	18.0	100 × 65 × 9	11.1	21.0	9.52
90 × 11	14.7	21.6	100 × 75 × 9	11.8	21.5	12.7
100 × 10	15.1	24.7	120 × 80 × 10	15.0	34.1	16.2
100 × 12	17.8	29.2	130 × 65 × 10	14.6	38.4	10.7
110 × 10	16.6	30.1	130 × 90 × 10	16.6	40.5	20.6
120 × 11	19.9	39.5	150 × 75 × 11	18.6	56.6	15.9
140 × 13	27.5	63.3	150 × 100 × 10	19.0	54.1	25.9
150 × 14	31.6	78.2	150 × 100 × 14	26.1	74.1	35.2
150 × 15	36.2	95.6				
Steel angle, square edge						
30 × 3.5	1.55	L section 121	30 × 16 × 4	1.32	L section 180	
40 × 4	2.39	L section 124	45 × 30 × 4	2.23	L section 203	
			60 × 40 × 5	3.73	L section 218	

Permissible tolerance up to 50 mm ± 1 mm, up to 100 mm ± 1.5 mm, above ± 2 mm.

For other angle sections, see:
DIN 1022, DIN 1028, DIN 1029,
DIN 59 370.

Table 16-6

T bars, normal lengths 3 to 12 m, DIN 1024

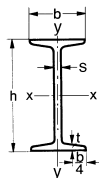


Symbol	Dimensions in mm			Weight kg/m	Section modulus for bending axis	
	<i>b</i>	<i>h</i>	<i>s = t</i>		x – x <i>W_x</i> cm ³	y – y <i>W_y</i> cm ³
T	Deep-web T bar DIN EN 10 055					
20	20	20	3	0.88	0.27	0.20
25	25	25	3.5	1.29	0.49	0.34
30	30	30	4.0	1.77	0.80	0.58
35	35	35	4.5	2.33	1.23	0.90
40	40	40	5	2.96	1.84	1.29
45	45	45	5.5	3.67	2.51	1.78
50	50	50	6	4.44	3.36	2.42
60	60	60	7	6.23	5.48	4.07
70	70	70	8	8.32	8.79	6.32
80	80	80	9	10.7	12.8	9.25
90	90	90	10	13.4	18.2	13.0
100	100	100	11	16.4	24.6	17.7
TB	Broad-flange T bar DIN EN 10 055					
30	60	30	5.5	3.64	1.11	2.87
35	70	35	6.0	4.66	1.65	4.31
40	80	40	7.0	6.21	2.50	7.13
50	100	50	8.5	9.42	4.78	13.5
60	120	60	10	13.4	8.09	22.8
T	Square-edge T bar					
16/16	16	16	2.5	0.58	Mannstädt I 596	
20/30	30	20	3.0	1.11	Mannstädt I 4966	
25/35	35	25	3.5	1.55	Mannstädt I 3981	
25/38	38	25	3	1.41	Mannstädt I 4981	

Tolerances: up to 50 mm ±1 mm, up to 100 mm ±1.5 mm.

Table 16-7

I beams, normal length 4 to 15 m, DIN 1025 Sheet 1

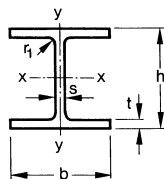


Symbol	Dimensions in mm				Weight kg/m	Section modulus for bending axis	
	<i>h</i>	<i>b</i>	<i>s</i>	<i>t</i>		x - x W_x cm ³	y - y W_y cm ³
I	I beams DIN 1025, Sheet 1						
80	80	42	3.9	5.9	5.94	19.5	3.00
100	100	50	4.5	6.8	8.34	34.2	4.88
120	120	58	5.1	7.7	11.1	54.7	7.41
140	140	66	5.7	8.6	14.3	81.9	10.7
160	160	74	6.3	9.5	17.9	117.0	14.8
180	180	82	6.9	10.4	21.9	161.0	19.8
200	200	90	7.5	11.3	26.2	214.0	26.0
220	220	98	8.1	12.2	31.1	278.0	33.1
240	240	106	8.7	13.1	36.2	354.0	41.7
260	260	113	9.4	14.1	41.9	442.0	51.0
280	280	119	10.1	15.2	47.9	542.0	61.2
300	300	125	10.8	16.2	54.2	653.0	72.2
320	320	131	11.5	17.3	61.0	782.0	84.7
340	340	137	12.2	18.3	68.0	923.0	98.4
360	360	143	13	19.5	76.1	1090.0	114.0
380	380	149	13.7	20.5	84.0	1260.0	131.0
400	400	155	14.4	21.6	92.4	1460.0	149.0

Height tolerances: up to 200 mm ± 2 mm, above ± 3 mm.

Table 16-8

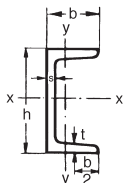
Wide flange beams with parallel flanges and normal web,
DIN 1025 Sheet 2



Symbol	Dimensions in mm					Weight kg/m	Section modulus for bending axis	
	h	b	s	t	r_1		$x-x$ W_x cm ³	$y-y$ W_y cm ³
IPB	IPB beams DIN 1025, Sheet 2							
100	100	100	6.5	10	10	21	89.3	33.4
120	120	120	7	11	11	28	144	52.9
140	140	140	8	12	12	36	217	78.6
160	160	160	9	14	14	47	329	120
180	180	180	9	14	14	53	426	151
200	200	200	10	16	15	66	595	214
220	220	220	10	16	15	73	732	258
240	240	240	11	18	17	89	974	346
260	260	260	11	18	17	97	1 160	406
280	280	280	12	20	18	116	1 480	523
300	300	300	12	20	18	124	1 720	600
320	320	300	13	22	20	138	2 020	661
340	340	300	13	22	20	140	2 170	661
360	360	300	14	24	21	153	2 510	721
380	380	300	14	24	21	156	2 680	721
400	400	300	14	26	21	168	3 030	781
425	425	300	14	26	21	170	3 270	781
450	450	300	15	28	23	186	3 740	841
475	475	300	15	28	23	189	4 010	841
500	500	300	16	30	24	204	4 530	902
550	550	300	16	30	24	211	5 100	902
600	600	300	17	32	26	232	6 030	962
650	650	300	17	32	26	239	6 670	962
700	700	300	18	34	27	259	7 720	1 020
750	750	300	18	34	27	267	8 430	1 020
800	800	300	18	34	27	274	9 160	1 020
900	900	300	19	36	30	305	11 250	1 080
1000	1000	300	19	36	30	321	12 900	1 080

Table 16-9

Steel channel, normal lengths 4 to 15 m, DIN 1026



Symbol	Dimensions in mm				Weight kg/m	Section modulus for bending axis	
	h	b	s	t		x - x W_x cm ³	y - y W_y cm ³
U	Channel DIN 1026						
30	30	33	5	7	4.27	4.26	2.68
40 × 20	40	20	5	5.5	2.87	3.79	0.86
40	40	35	5	7	4.87	7.05	3.08
50 × 25	50	25	5	6	3.86	6.73	1.48
50	50	38	5	7	5.59	10.6	3.75
60	60	30	6	6	5.07	10.5	2.16
65	65	42	5.5	7.5	7.09	17.7	5.07
80	80	45	6	8	8.64	26.5	6.36
100	100	50	6	8.5	10.6	41.2	8.49
120	120	55	7	9	13.4	60.7	11.1
140	140	60	7	10	16.0	86.4	14.8
160	160	65	7.5	10.5	10.5	116.0	18.3
180	180	70	8	11	22.0	150	22.4
200	200	75	8.5	11.5	25.3	191	27.0
220	220	80	9	12.5	29.4	245	33.6
240	240	85	9.5	13	33.2	300	39.6
260	260	90	10	14	37.9	371	47.7
280	280	95	10	15	41.8	448	57.2
300	300	100	10	16	46.2	535	67.8

U Square-edge channel

1 600	33	33	2.75	2.75	2.02
1 440	50	30	4	4	3.2
3 744	60	30	3	3	2.68
4 631	120	24	4	4	5.06

Height tolerances: up to 65 mm ± 1.5 mm, up to 200 mm ± 2.0 mm, above ± 3.0 mm.

16.1.3 Stresses in steel components

The permissible stresses in steel components for transmission towers and structures for outdoor switchgear installations are laid down in DIN VDE 0210, Table 9. Values for different kinds of stress, such as tensile, shear, compressive and bearing stresses are specified for the steel sections given in DIN VDE 0210, 8.4.2.

Permissible stresses:

- mechanical engineering materials, cf. "Hütte", 29th edition, and "Stahlschlüssel", 15th edition,
- structural steel, cf. DIN 18800, Part 1
- structural aluminium, cf. DIN 4113, Part 1.

Remarks:

Structural steels to DIN EN 10 025, screws and bolts to DIN 267. Permissible weld stresses for welded towers are given in DIN 18800, Part 1.

According to VDE 0210, structural steels of grade St 37-2 (S 235 JR) and above may be used for overhead power lines.

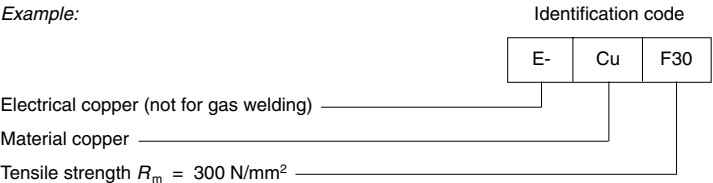
16.2 Non-ferrous metals

16.2.1 Copper for electrical engineering

Cathode copper is covered by DIN EN 1976 and DIN EN 1978. Semi-finished products, such as sheet, strip, tubes, rods, wire and cast and extruded sections, are covered by DIN 1787. Semis of electrical copper must conform to the specifications of DIN 40500. Oxygen-free copper (SE-Cu) is used to meet special requirements regarding formability, for gas welding or for flame soldering.

The identification code is important for ensuring conductivity, composition and strength characteristics.

Example:



For special properties as conductor material, see Section 13.1.1.

16.2.2 Aluminium for electrical engineering

High-purity aluminium, denoted Al 99.99 R, is obtained direct from primary aluminium or aluminium returns by metallurgical means, cast into ingots at the smelting plant and marked.

Primary aluminium, denoted Al 99.8 H, is aluminium obtained from the smelting process which conforms to the specified purity.

Aluminium for electrical engineering is available as:

- 1. Pure aluminium to DIN EN 573-2, supplied as primary aluminium (code 99.5 H) or pure aluminium (code 99.5) and unless specified otherwise must not contain more than 0.03 % Ti + Cr + V + Mn.
- 2. Wrought aluminium alloys to DIN EN 573-3.

The requirements specified in DIN 40501 and DIN EN 1715 must also be observed.
When ordering, for example, it is important to state the identification code for the conductivity, composition and strength characteristics.

Example:

Identification code		
E-	AlMgSi 0.5	F17
Electrical aluminium		
Wrought alloy with 0.5 % Si		
Tensile strength $R_m = 170 \text{ N/mm}^2$		

For special properties as conductor material, see Section 13.1.1.

16.2.3 Brass

Information regarding the use of copper-zinc alloys, their composition and types of semi-finished products is to be found in DIN 17660.

The corresponding strength properties and the technical terms of delivery are given in the following standards:

- DIN EN 1652 for sheet and strip,
- DIN EN 12168 for tubes,
- DIN EN 12163, 12164, 12165 and 12167 for rods,
- DIN EN 17673 for forgings,
- DIN EN 12167 and 12168 for extruded sections.

For special properties as conductor material, see Section 13.1.1.

16.3 Insulating materials

16.3.1 Solid insulating materials

Table 16-10

Abbreviations and properties of solid insulating materials

Abbrevia- tion	Material	Density DIN 53479 ρ kg/dm ³	Bending strength DIN 53452 σ_b MPa	Tensile strength DIN 53455 σ_z MPa	Impact strength ISO 180/C a_n kJ/m ²	Elasticity modulus DIN 53457 E MPa	Linear thermal expansion DIN 53328 α_1 10 ⁻⁴ /K	Thermal conductivity DIN 52612 λ W/(m · K)	Max. tempera- ture DIN 53458 °C	Tracking resistance DIN IEC 60112 Comparative figure	Break- down field strength DIN IEC 60243-2 E_d kV/mm	Resistivity DIN IEC 60093 ρ_D Ω · cm	Dielectric constant IEC 60250 ϵ_r (50 Hz)	Product label
Insulating materials for cables and conductors														
PVC-P	polyvinyl chloride non-rigid	1.3				150	1 – 2	0.2	60	600	10 – 25	10 ¹⁵	3.5 – 7.5	Astralon, Mipolam, Trovidur
PVC-U	polyvinyl chloride rigid	1.38	100	50	30	2 500	1.0	0.2	90	600	30 – 40	10 ¹⁵	3.3 – 4	Vestolit, Vinoflex, DC-Fix, Pegulan, Hostalit Fibres: PW, Rhovyl, Thermovyl
PE	high-pressure polyethylene	0.917	80	12	without rupture	100	1.8	0.3	80	600	40	10 ¹⁷	2.25	Lupolen H, Vestolen, Trolen
	low-pressure polyethylene	0.96	80	25	without rupture	1 400	2.0	0.5	95	600	45	10 ¹⁷	2.3	Hostalen, Marlex Foil: Baulen, Hellaflex Fibres: Polytrene, Trofil
XLPE (VPE)	cross-linked polyethylene				without rupture		2.5		130	600	>45	10 ¹⁷	2.4	Cable insulation (XLPE)

(continued)

Table 16-10 (continued)

Abbreviations and properties of solid insulating materials

Abbreviation	Material	Density	Bending strength	Tensile strength	Impact strength	Elasticity modulus	Linear thermal expansion	Thermal conductivity	Max. temperature	Tracking resistance	Break-down field strength	Resistivity	Dielectric constant	Product label
		DIN 53479 ρ kg/dm ³	DIN 53452 σ_b MPa	DIN 53455 σ_z MPa	ISO 180/C a_n kJ/m ²	DIN 53457 E MPa	DIN 53328 α_1 10 ⁻⁴ /K	DIN 52612 λ W/(m · K)	DIN 53458 °C	DIN IEC 60112 Comparative figure	DIN IEC 60243-2 E_d kV/mm	DIN IEC 60093 ρ_D $\Omega \cdot \text{cm}$	IEC 60250 ϵ_r (50 Hz)	
PC	Insulating materials for foils, semi-finished products, struct. comp.(thermoplastics, mouldings) polycarbonate (PC 300)	1.2	75	65	without rupture	2 200	0.6	0.2	130	275	25	10 ¹⁵	3.0	Lexan, Makrolon
PTFE	polytetrafluorethylene	2.2	19	20	without rupture	4 000	0.6	0.24	250	600	35	>10 ¹⁸	2.0	Teflon, Hostaflon TE, Fluon
PS	polystyrene	1.05	100		22	2 000	0.8	0.14	60-90	375-475	50	>10 ¹⁶	2.5	Polystyrol, Styroflex, Novodur, Trolitul, Styron, Vestyron Foils: Trolit, Elektroiso. Styropor
	foam polystyrene	0.02–0.06	0.3-2.5	0.3-5.5										
PET	polyethylene terephthalate	1.38	117	54	without rupture	2 800	0.6	0.2	120	250	30	10 ¹⁷	3.5	Foils: Hostaphan, Mylar Fibres: Diolen, Dacron
PF	phenolic formaldehyde resins	1.4–1.9	50–60	20–25	20–120	6 000–16 000	0.15–0.3	0.7–0.3	100-150	125-175	5–20	10 ⁸ –10 ¹¹	4–15	Albortit, Bakelite, Formica, Pertinax
	PF-Hgw 2072	1.6–1.8	200	100	50	14 000	0.2–0.4	0.3	130	25-150	20–25	10 ¹¹	5	with woven glass silk VDE 0334
MF	melamine resins	1.5	40–80	15–30	3.5–25	6 000–13 000	0.1–0.5	0.3–0.7	100–140	600	10–30	10 ⁸ –10 ¹²	6–10	Albamt, Chemoplast, Resopal, Ultrapas, Bakelite
	MF-Hgw 2272 (in sheet)	1.8–2.0	270	120	50	14 000	0.1–0.2	0.3	130	600	20–25	10 ¹⁰	7.0	Woven glass silk to VDE 0334
	melamine phenolic resins	1.6	70-80	30	6	6 000–8 000	0.15–0.3	0.35	120	600	30	10 ¹⁰	6.0–15.0	Aminoplast, Phenoplast Moulding compound

(continued)

Table 16-10 (continued)

Abbreviations and properties of solid insulating materials

Abbrevia- tion	Material	Density	Bending strength	Tensile strength	Impact strength	Elasticity modulus	Linear thermal expansion	Thermal conductivity	Max. tempera- ture	Tracking resistance	Break- down field strength	Resistivity	Dielectric constant	Product label
		DIN 53479 ρ kg/dm ³	DIN 53452 σ_b MPa	DIN 53455 σ_z MPa	ISO 180/C a_n kJ/m ²	DIN 53457 E MPa	DIN 53328 α_1 10 ⁻⁴ /K	DIN 52612 λ W/(m · K)	DIN 53458 °C	DIN IEC 60112 Comparative figure	DIN IEC 60243-2 E_d kV/mm	DIN IEC 60093 ρ_D $\Omega \cdot \text{cm}$	IEC 60250 ϵ_r (50 Hz)	
Insulating materials for structural components (thermoplastics)														
PA 66	polyamide A	1.13	50- 120	70	without rupture	2 000	0.7-1.0	0.2	120	600	25	10 ¹⁴	4-8	Ultramid A, Durethan A, Zytel
PA 66	polyamide A with fibreglass	1.35	270	190	50	10 000	0.15- 0.2	0.2	130	550	30	10 ¹²		Ultramid A, Durethan A, Zytel
PA 6	polyamide B	1.14		60	without rupture	1 500	0.7-1.0	0.2	110	600	20-50	10 ¹² - 10 ¹⁵	3.0- 7.0	Ultramid B, Durethan B, Zytel
PA 6	polyamide B with fibreglass	1.38	250	180	65	10 000	0.2-0.3	0.2	120	550	30	10 ¹²	3.0- 7.0	Ultramid B, Durethan B, Zytel
GFN	PPO-reinforced	1.21			15	6 500			180					Noryl GFNZ halogenfree
PBT	polybutylene- terephthalate	1.3	90		without rupture	2 500	0.8	0.2	140	600	22-30	10 ¹⁶	3.8	Vestadur, Pocan, Crastin
PBT	polybutyleneterephtha- late with fibreglass	1.42	210	140	56	10 000	0.3	0.3	150	250	28-34	10 ¹⁵	4.5	Vestadur, Pocan, Crastin
PUR	polyurethane (linear)	1.21	25-70	65	without rupture	2 200	0.6	0.2	130	220	20	10 ¹⁵	3.0	
ABS	acrylic butadiene styrene	1.06			without	2 400	0.8	0.2	80	575	22	>10 ¹⁵	3.3	Novodur, Terluran

(continued)

Table 16-10 (continued)

Abbreviations and properties of solid insulating materials

Abbreviation	Material	Density	Bending strength	Tensile strength	Impact strength	Elasticity modulus	Linear thermal expansion	Thermal conductivity	Max. temperature	Tracking resistance	Break-down field strength	Resistivity	Dielectric constant	Product label
		DIN 53479 ρ kg/dm ³	DIN 53452 σ_b MPa	DIN 53455 σ_t MPa	ISO 180/C a_n kJ/m ²	DIN 53457 E MPa	DIN 53328 α_t 10 ⁻⁴ /K	DIN 52612 λ W/(m · K)	53458 °C	DIN IEC 60112 Comparative figure	DIN IEC 60243-2 E_d kV/mm	DIN IEC 60093 ρ_D Ω · cm	IEC 60250 ϵ_r (50 Hz)	
Cast resin mouldings (duroplastics)														
EP	epoxy resins (with 60–70 % filler)	1.6–1.8	70–80	75	10–68	14 000	0.3	0.6	125	600	30	10 ¹⁵	4.2	Araldite 60 % powdered quartz, Resodip
	EP-Hgw 2372.2 (flame resistant)	1.7–1.9	350	220	100	18 000	0.1–0.2	0.3	155	180	40	10 ¹²	4.0	EP + woven glass silk to VDE 0334
UP	unsaturated polyester resins (with 60–70 % filler)	1.6–1.8	40–60		10–40		0.3		110–130	600	25	10 ¹⁵	4.5–7.5	Supraplast
	UP-Hgw 2472 (in sheet)	1.6–1.8	200	100	100	10 000	0.15–0.3	0.3	130	500–600	25–30	10 ¹²	5.0	Glass mat to VDE 0334
PUR	polyurethane resin with 60–70% filler	1.6–1.8	120	70–100	10–100	10 000	0.4	0.8	110	600	30	10 ¹⁵	4,3	Baygal, Baymidur

(continued)

Table 16-10 (continued)

Abbreviations and properties of solid insulating materials

Abbrevia- tion	Material	Density	Bending strength	Tensile strength	Impact strength	Elasticity modulus	Linear thermal expansion	Thermal conductivity	Max. tempera- ture	Tracking resistance	Break- down field strength	Resistivity	Dielectric constant	Product label	
		DIN 53479 ρ kg/dm ³	DIN 53452 σ_b MPa	DIN 53455 σ_z MPa	ISO 180/C a_n kJ/m ²	DIN 53457 E MPa	DIN 53328 α_1 10 ⁻⁴ /K	DIN 52612 λ W/(m · K)	DIN 53458 °C	DIN IEC 60112 Comparative figure	DIN IEC 60243-2 E_d kV/mm	DIN IEC 60093 ρ_D Ω · cm	IEC 60250 ϵ_r (50 Hz) $\epsilon_r \tan \delta \cdot 10^3$		
Ceramic insulating materials, e.g. post insulators, insulators, bushings															
KER 110.1	predominantly aluminium silicate	2.4	1) 60	2) 40	1) 30	2) 25	1.8	0.038	1.6		30–35	10 ¹¹ –10 ¹²	6	17/120	Porcelain, Hard porcelain, Melatith, Karbowid 1203
KER 110.2		2.5	100	80	60	45	2.2	0.045	2.3		30–35	10 ¹¹ –10 ¹²	6	17/120	
KER 220	predominantly magnesium silicate	2.6	120	120	60	45	3	0.07	2.3		20	10 ¹²	6	2.5/65	Skalit Frequentia, Calit, Dettan
KER 221		2.8	140	140	60	45	4	0.06	2.3		30	10 ¹²	6	1.0/15	
KER 310	predominantly titanium oxide	3.5–	900–	300–			0.06–				10–		60		
KER 311		3.9	1500	800			0.08				20		40		
KER 610	sintered corundum Al ₂ O ₃	3.4	–	120	183	40	0.07	16			25		7		AD 85 Degussit AD 99.9 furnace ceramic
KER 611		3.9	–	90			0.08	36							
	zirconium ceramic	3.1	552				0.04	110							furnace ceramic

1) Glazed 2) Unglazed 3) 20 °C / 100 °C

Note: The values given for mechanical properties may vary in practice, depending on how the materials are processed and the shape of the insulator.

16.3.2 Liquid insulating materials

Table 16-11

Types and properties of liquid insulating materials

Property	Unit	Mineral oil	Liquid silicone Polydimethyl siloxane	HTK mineral oil I	Synthetic ester I	Synthetic ester II
		¹⁾				
Density	g/ml at 25 °C	0.84/0.88	0.96	0.88	0.98	0.98
Kin. viscosity	mm ² /s at 25 °C	11/18	50	350	90	60
	mm ² /s at 100 °C	1.5/2.5	16	16	6	5.6
Pour point	°C	−40/−60	−55	−15/−30	−52	−50
Thermal conductivity	W/cmK at 25 °C	0.00132	0.00151	0.00130	0.00155	0.00155
Spec. heat	J/g K	1.93	1.53	1.93	2.1	2.1
Expansion coefficient	1/K	0.00083	0.00104	0.00080	0.00080	0.0011
Dielectric constant	at 25 °C	2.2/2.4	2.7	2.38	3.2	3.2
Flashpoint	°C	130/160	305	210/285	257	260
Firepoint	°C	150/175	360	310/320	310	300
Spontaneous ignition temp.	°C	330	430	540	435	435
Flammability	—	Flammable	Flame-retardant	Flame-retardant	Flame-retardant	Non-flammable
Gases	—	Explosive	Explosive	Explosive	Explosive	Explosive
Ecological aspects	—	Bio-degradable	Non-toxic, non-polluting	Bio-degradable	Bio-degradable	Bio-degradable

¹⁾ Class A (standard)/Class B (low-temperature oil)

16.3.3 Gaseous insulating materials

Table 16-12

Properties of air and SF₆

Gas	Density ¹⁾ kg/m ³	Breakdown field strength E _d kV/mm (50 Hz)	Dielectric constant ε _r (50 Hz)
Air (dry)	1.205	2.1	1.000576
Sulphur hexafluoride SF ₆	6.07	6	1.0021

¹⁾ at 20 °C and 1013 mbar

Curves of pressure, temperature and density for SF₆ gas are shown in Fig. 11-1. The insulating and arc-quenching properties of this gas are dealt with in Sections 10.4.4 and 11.2.2.

16.4 Semi-finished products

16.4.1 Dimensions and weights of metal sheets, DIN EN 10130

Table 16-13

Weight per 1 m² of sheet, in kg

Thickness s in mm	Steel	Aluminium	Copper	Brass	Zinc	Ribbed sheet	Profiled treadplate
0.5	3.925	1.34	4.45	4.275	3.6	—	—
0.75	5.888	2.01	6.657	6.413	5.4	—	—
1	7.85	2.68	8.9	8.55	7.2	—	—
1.5	11.775	4.02	13.35	12.825	10.8	—	—
2	15.7	5.36	17.8	17.10	14.4	—	—
2.5	19.63	6.7	22.25	21.38	18.0	—	—
3	23.6	8.04	26.7	26.65	21.6	30	25
4	31.4	10.72	35.6	34.20	28.8	38	34
5	39.3	13.4	44.5	42.75	36	46	42
6	47.2	16.08	53.4	51.3	43.2	54	51
8	64.0	21.6	71.6	68.4	57.6	70	67

Normal panel size 1000 mm × 2 000 mm

Switchboard sheet 1250 mm × 2 500 mm

Ribbed sheet and profiled treadplate 1250 mm × 2 500 mm

16.4.2 Slotted steel strip

Table 16-14

Slotted steel strip, hot-galvanized

Dimensions mm	Slot size mm	Weight kg / m	Standard roll, length m	in cut lengths 3 m approx., m / bundle
20 × 1.5	40 × 5.5	0.187	200	60
20 × 2	40 × 5.5	0.245	200	60
25 × 2	40 × 5.5	0.326	200	60
30 × 2.5	40 × 5.5	0.508	150	60
20 × 3	40 × 6.5	0.368	120	60
25 × 3	40 × 6.5	0.489	120	60
30 × 3	40 × 6.5	0.640	120	60
30 × 4	60 × 8.5	0.716	100	30
40 × 4	70 × 8.5	1.038	80	30
50 × 4	70 × 8.5	1.360	80	30

Steel earthing strip, hot-galvanized, DIN 48801

Dimensions mm	Weight kg / m	Standard roll m
20 × 2.5	0.400	100
30 × 3.5	0.840	100 (50)
30 × 4.0	0.961	30
40 × 5.0	1.600	50

































































Accessories, plastic anchor plugs

Size mm	Plug length mm	Hole dia. mm	For screws dia. mm
5	25	5	2.5 – 4
6	30	6	3.5 – 5
6	60	6	3.5 – 5
8	40	8	4.5 – 6
8	75	8	4.5 – 6
10	50	10	6 – 8
12	60	12	8 – 10

16.4.3 Screws and accessories

Table 16-15









































Standard screws and bolts (the figures denote DIN numbers)¹⁾



































 601 5917 960 6914 70613 EN ISO 24 014	 558 961 70614 EN ISO 24 017	 561	 564	 7990	 7964	 EN ISO 4762	 7984
 6912	 EN ISO 10 642	 84 8243	 85 8243	 63 87	 88 964 91	 925	 924
 7969	 7969	 EN ISO 7045	 7988	 7513	 7513	 261 25192	 186 7992
 188	 603	 603	 5906	 444 81698	 580	 173 923 58326	 316
 464 58531	 653 58530	 427	 551	 417	 553	 EN ISO 27 436	 926
 913	 915	 914	 916	 976	 975	 525	 529
 835 938	 5914	 7976	 EN ISO 1481	 7972	 7973	 7981	 7982
 7983	 571	 96	 97	 95	 7996	 7997	 7995

¹⁾ as DIN-Normblatt-Verzeichnis. Published by Deutscher Normenausschuß (DNA).
DIN and DIN ISO numbers shown abridged.

Table 16-16

Standard washers and nuts (the figures denote DIN numbers)¹⁾

 125	 126	 433	 125	 6916	 440	 436	 5917	 434	 435
 128	 7980	 137	 128	 6913	 137	 6904			
 6796	 6908	 6797	 6906	 6797	 6906	 6798	 6907		
 6798	 6798	 6907	 93	 463	 432				
 462	 5406	 70952	 526	 128	 6905	 128			
 EN ISO 1234	 7967								

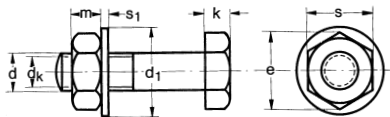
 431	 2950	 439	 555	 934	 970	555 934 970 971 972 6915 330386 64032 ISO 4032 EN 24032 ISO 4034		 6923	
 2510	 30387	 1587	 EN ISO 10511		 EN ISO 742, 10513	 30389		 6330	
 979	 937	 979	 935	 70617	 431	 80705		 467	 6303
 466	 58521	 315	 582	 80	 704	 28		 129	

¹⁾ as DIN-Normblatt-Verzeichnis. Published by Deutscher Normenausschuß (DNA).
DIN and DIN ISO numbers shown abridged.

16.4.4 Threads for bolts and screws

Table 16-17

Bolts and screws with metric thread, DIN 13 and DIN ISO 1502, dimensions in mm



Bolt threads Nominal diameter d	Minor thread diameter d_k	Lead h	Thick-ness of head k	Thick-ness of nut m	Width across flats s	angles e	Washer d_1	s_1	Drill hole pass through dia.	for thread dia.
2	1.509	0.4	1.4	1.6	4	4.6	5	0.3	2.4	1.6
3	2.387	0.5	2	2.4	5.5	6.4	7	0.5	3.4	2.5
4	3.141	0.7	2.8	3.2	7	8.1	9	0.8	4.5	3.3
5	4.019	0.8	3.5	4.7	8	9.2	10	1.0	5.5	4.2
6	4.737	1	4.0	5.2	10	11.6	12.5	1.6	6.6	5.0
8	6.466	1.25	5.3	6.8	13	15	17	1.6	9	6.8
10	8.160	1.5	6.4	8.4	16	18.5	21	2.0	11	8.5
12	9.853	1.75	7.5	10.8	18	20.8	24	2.5	14	10.2
14	11.546	2	9	12.8	21	24.3	28	2.5	16	12
16	13.546	2	10	14.8	24	27.7	30	3	18	14
18	14.933	2.5	11.5	15.8	27	31.2	34	4	20	15.5
20	16.933	2.5	12.5	18	30	34.7	37	3	22	17.5
22	18.933	2.5	14	19.4	34	38.3	39	3	24	19.5
24	20.319	3	15	21.5	36	41.6	44	4	26	21
27	23.051	3	17	23.8	41	47.4	50	4	30	24
30	25.706	3.5	18.7	25.6	46	53.2	56	4	33	26.5
33	28.706	3.5	21	28.7	50	57.8	60	5	36	29.5
36	31.093	4	22.5	31	55	63.5	66	5	39	32
39	34.093	4	25	32	60	69.3	72	6	42	35
42	36.479	4.5	26	34	65	75	78	7	45	37.5

Quality identification and mechanical properties of nuts and bolts: see technical terms of supply as per DIN 267, and also DIN ISO 8992, DIN EN 20898-2, DIN ISO 3269, DIN ISO 4042, DIN ISO 3506 and DIN EN ISO 2320.

16.4.5 Threads for electrical engineering

Table 16-18

Steel conduit threads, DIN 40430, dimensions in mm

Designa- tion	External threads				Lead <i>P</i>	Internal threads			
	Major diameter		Minor diameter			Major diameter		Minor diameter	
	<i>d</i>	<i>d</i>	<i>d</i> ₁	<i>d</i> ₁		<i>D</i>	<i>D</i>	<i>D</i> ₁	<i>D</i> ₁
	max.	min.	max.	min.		min.	max.	min.	max.
Pg 7	12.5	12.3	11.28	11.08	1.27	12.5	12.65	11.28	11.43
Pg 9	15.2	15	13.86	13.66	1.41	15.2	15.35	13.86	14.01
Pg 11	18.6	18.4	17.26	17.06	1.41	18.6	18.75	17.26	17.41
Pg 13.5	20.4	20.2	19.06	18.86	1.41	20.4	20.55	19.06	19.21
Pg 16	22.5	22.3	21.16	20.96	1.41	22.5	22.65	21.16	21.31
Pg 21	28.3	28	26.78	26.48	1.588	28.3	28.55	26.78	27.03
Pg 29	37	36.7	35.48	35.18	1.588	37	37.25	35.48	35.73
Pg 36	47	46.7	45.48	45.18	1.588	47	47.25	45.48	45.73
Pg 42	54	53.7	52.48	52.18	1.588	54	54.25	52.48	52.73
Pg 48	59.3	59	57.78	57.48	1.588	59.3	59.55	57.78	58.03

Table 16-19

Electrical threads, DIN 40400, dimensions in mm

Designa- tion	Bolt				Lead <i>P</i>	Nut		Minor	
	Major diameter		Minor diameter			Major diameter		diameter	
	<i>d</i> max.	<i>d</i> min.	<i>d</i> ₁ max.	<i>d</i> ₁ min.		<i>D</i> min.	<i>D</i> max.	<i>D</i> ₁ min.	<i>D</i> ₁ max.
E 14	13.89	13.70	12.29	12.10	2.822	13.97	14.16	12.37	12.56
E 16	15.97	15.75	14.47	14.25	2.500	16.03	16.25	14.53	14.75
E 18	18.50	18.25	16.80	16.55	3.000	18.60	18.85	16.90	17.15
E 27	26.45	26.15	24.26	23.96	3.629	26.55	26.85	24.36	24.66
E 33	33.05	32.65	30.45	30.05	4.233	33.15	33.55	30.55	30.95