solen
CABLE

TECHNICAL INFORMATION

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MAJOR INTERNATIONAL INSTITUTES & ORGANIZATIONS

Abbreviation	Name of the Organisation	Main Region
AENOR	Asociacion Espanola de Normalizacion y Certificacion	Spain
AFNOR	Association Française de Normalisation	France
ANS	American National Standards Institute	USA
AS	Australian Standard Australia	Australia
ASTM	American Standard of Testing Materials	USA
BASEC	British Approvals Service for Cables	United Kingdom
BSI	British Standard Institution	United Kingdom
BV	Bureau Veritas	France
CEI	Comitato Elettrotecnico Italiano	Italy
CENELEC	Comité Européen de Normalisation Electrotechniques	Europe
CSA	Canadian Standards Association	Canada
CSB TS (GB)	China State Bureau of Technical Supervision	China
DIN	Deutsches Institut für Normung	Germany
EAC	Eurassian Customs Union	Russi, Belarus, Kazakhstan, Armenia, Kyrgyzstan
EN	European Standards - Norms	Europe
GOST-R	Russian Standards	Russia
HD	Harmonization Documents	International
IEC	International Electrotechnical Commission	International
IEEE	Institute of Electrical and Electronics Engineers	USA
IMQ	Instituto Italiano de Marchio Qualita	Italy
ISO	International Organization for Standardization	International
JIS	Japanese Standards (English Language)	Japan
KEMA	Keuring van Elektrotechnische Materalien	Netherlands
MIL	Military Specification	USA
NEC	National Electrical Code	USA
NEK	Norsk Elektroteknisk Komite	Norway
NEMA	National Electrical Manufacturers Association	USA
NEN	Nederlands Normalisatie-Instituut	Netherlands
NF	Normes Françaises	France
NZS	Standards of New Zealand	New Zealand
ÖVE	Österreichischer Verband für Elektrotechnik	Austria
TSE	Turkish Standards Institution	Turkey
TUV	Technischer Überwachungs Verein	Germany
UL	Underwriters Laboratories Inc.	USA
UNE	Asociación Española de Normalización	Spain
UNI	Unificazione Nationale Italiana	Italy
VDE	Verein Deutscher Elektrotechniker e.V.	Germany

REFERENCE STANDARDS

IEC 62930: 2017 Electric cables for photovoltaic systems with a voltage rating of 1,5 kV DC

EN 50618: 2014 Electric cables for photovoltaic systems

UL 4703: 2014 Photovoltaic wire

CSA C22.2 No. 271: 2011 Photovoltaic cables

EN 50289-4-17: Communication cables – Specifications for test methods – Part 4-17: Test methods for UV resistance evaluation of the sheath of electrical and optical fibre cabl

EN 50395: 2005 Electrical test methods for low voltage energy cables

EN 50396: 2005 Non electrical test methods for low voltage energy cables

EN 50525-1: 2011 Electric cables – Low voltage energy cables of rated voltages up to and including 450/750 V (U0/U) – Part 1: General requirements

EN 50565-1: 2014 Electric cables – Guide to use for cables with a rated voltage not exceeding 450/750 V (U0/U) – Part 1: General guidance

EN 60068-2-78: Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state (IEC 60068-2-78)

EN 60216-1: Electrical insulating materials – Thermal endurance properties – Part 1: Ageing procedures and evaluation of test results (IEC 60216-1)

EN 60216-2: Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria (IEC 60216-2)

EN 60228: 2005 Conductors of insulated cables (IEC 60228:2004)

EN 60332-1-2: 2004 Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame (IEC 60332-1-2: 2004)

EN 60811-401: Electric and optical fibre cables – Test methods for non-metallic materials – Part 401:Miscellaneous tests – Thermal ageing methods – Ageing in an air oven (IEC 60811-401)

EN 60811-403: Electric and optical fibre cables – Test methods for non-metallic materials – Part 403: Miscellaneous tests – Ozone resistance test on cross-linked compounds (IEC 60811-403)

EN 60811-404: Electric and optical fibre cables – Test methods for non-metallic materials – Part 404: Miscellaneous tests – Mineral oil immersion tests for sheaths (IEC 60811-404)

REFERENCE STANDARDS

EN 60811-501: Electric and optical fibre cables – Test methods for non-metallic materials – Part 501: Mechanical tests – Tests for determining the mechanical properties of insulating and sheathing compounds (IEC 60811-501)

EN 60811-503: Electric and optical fibre cables – Test methods for non-metallic materials – Part 503: Mechanical tests - Shrinkage test for sheaths (IEC 60811-503)

EN 60811-504: Electric and optical fibre cables – Test methods for non-metallic materials – Part 504: Mechanical tests - Bending tests at low temperature for insulation and sheaths (IEC 60811-504)

EN 60811-505: Electric and optical fibre cables – Test methods for non-metallic materials – Part 505: Mechanical tests - Elongation at low temperature for insulations and sheaths (IEC 60811-505

EN 60811-506: Electric and optical fibre cables – Test methods for non-metallic materials – Part 506: Mechanical tests - Impact test at low temperature for insulations and sheaths (IEC 60811-506)

EN 60811-507: Electric and optical fibre cables – Test methods for non-metallic materials – Part 507: Mechanical tests - Hot set test for cross-linked materials (IEC 60811-507)

EN 61034-1: Measurement of smoke density of cables burning under defined conditions – Part 1: Test apparatus (IEC 61034-1)

EN 61034-2: Measurement of smoke density of cables burning under defined conditions – Part 2: Test procedure and requirements (IEC 61034-2)

EN 62230:2007: Electric cables – Spark-test method (IEC 62230:2006)

HD 60364-5-52:2011: Low-voltage electrical installations – Part 5-52: Selection and erection of electrical equipment – Wiring systems

HD 60364-7-712: Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems (IEC 60364-7-712)

IEC 60364-5-52: Low-voltage electrical installations - Part 5-52: Selection and erection of electrical equipment - Wiring systems.

IEC 61140, Protection againts electric shock - Common aspects for installation and equipment

IEC 63294-1: 2021 Test methods for electric cables with rated voltages up to and including 450/750 V

CABLE DESIGNATION CODES

HARMONISED CABLES (HD 361 S4 - DIN VDE 0281/0282/0292)

							-			X	
1	2	3	4	5	6	7		8	9	10	11

1) Relationship of cable to standards

H Cable conforming with harmonized standards – Non-harmonized cable

2) Rated Voltage

01 100/100 V
03 300/300 V
05 300/500 V
07 450/750 V
1 1000/1000 V (*)
(*) At present, the rated voltage is limited to PV-cables acc. to EN 50618.

3) Insulating and non-metallic sheathing materials

B Ethylene- propylene rubber for conductor temperature 90 °C
G Ethylene-vinyl-acetate
J Glass-fibre braid
M Mineral
N Polychloroprene-rubber (or equivalent material)
N2 Special-rubber compound of polychloroprene for sheathing of welding cable
N4 Chlorosulphonated polyethylene
N8 pecial-rubber compound of polychloroprene, water resistant
Q Polyurethane
Q4 olyimide
R Ethylene- propylene or equivalent synthetic rubber for conductor temperature 60 °C
S Silicone-rubber
T Textile braid, impregnated or not, on assembled cores
T6 Textile braid, impregnated or not, on individual cores of a multicore cable
V Ordinary PVC
V2 PVC compound for conductor temperature of 90 °C
V3 Ordinary PVC, for low temperature operating
V4 Ordinary PVC, crosslinked
V5 Ordinary PVC, special oil resistant
Z Crosslinked polyolefin-compound for cable with low smoke and non-corrosive gases in the case of fire
Z1 Thermoplastic polyolefin-compound for cable with low smoke and non-corrosive gases in the case of fire
Z2 Crosslinked polyolefin-compound for cable with low smoke and non-corrosive gases in the case of fire for photovoltaic cable
Z5 Thermoplastic compound EVM-1 for cable with non-corrosive gases in the case of fire for EV charging cable
Z6 Crosslinked compound EVM-2 for cable with non-corrosive gases in the case of fire for EV charging cable

4) Metallic coverings

C Concentric copper conductor
C4 Copper braid over assembled cores

5) Special constructional components of a cable

D3 Strain-bearing element consisting of one or more components (textile or metallic), placed at the centre of a round cable or distributed inside a flat cable
D5 Central heart (non-strain-bearing)

6) Special construction of cable

No Symbol Round cable construction
H Flat construction of „divisible“ cables and cores, either sheathed or non-sheathed
H2 Flat construction of „non-divisible“ cables and cords
H6 Flat cable having 3 or more cores, according to EN 50214
H7 Cables with extruded double layer insulation
H8 Coiled cable

7) Conductor material

no symbol Copper

–A Aluminium

8) Conductor form

–D Flexible conductor of welding cables (flexibility departing from EN 60228 class 5)

–E Highly flexible conductor of welding cables (flexibility departing from EN 60228 class 6)

–F Flexible conductor of a flexible cable or cord (flexibility according to EN 60228 class 5)

–H Highly flexible conductor of a flexible cable or cord (flexibility according to EN 60228 class 6)

–K Flexible conductor of a cable for fixed installations (unless otherwise specified, flexibility according to EN 60228 class 5)

–R Rigid, round conductor, stranded

–U Rigid, round conductor, solid

–Y Tinsel conductor

9-10-11) Number and size of conductors

X (**) Times, where a green/yellow core is not included

G Times, where a green/yellow core is included

Number (*) Nominal cross-section, size of conductor in mm2

Y For a tinsel conductor where the cross-section is not specified

(*) Countries are free to assign the symbol „N“ (placed after the conductor cross-section) to indicate that the cores are identified by numbers.

(**) Only capital letter shall be used.

Summary of symbols and their sequence in cable designation

1	2	3	4	5	6	7	8	9	10	11
Part 1		Part 2						Part 3		
Related standard	Rated voltage	Insulation material	Metallic coverings	Non-metallic sheath	Constructional components and special constructions	Conductor material	Conductor form	Number of cores	Times	Conductor cross - section mm^2
Symbols according to table(s)										
2	3	4	5	4	4 and 7	8	9	10		
H	01	B	C	B	D3	No symbols: copper	– D	1	X	Y
					D5		– E	2		0,5
	03	G	C4	G			– F	3	G	
							– H	4		0,75
	05	J		J		– A	– K	5		
					No symbol: circular construction of cable		– R	...		1
	07	M					– U			
							– Y			1,5
	1	N, N4		N, N_2, N4, N8						
										2,5
				Q, Q4	H					
					H2					4
		R		R	H6					
					H7					6
		S		S	H8					
										10
				T, T6						
										16
		V, V2, V3, V4		V, V2, V3, V4, V5						25
		Z, Z1, Z2		Z, Z1, Z2, Z5, Z6						...

Conductor Resistance at 20^{0}C (IEC 60228, DIN VDE 0295)

Conductor Resistance (mm^2)	Plain Copper Conductor (Ω/km)		Tinned Copper Conductor (Ω/km)	
	Class 1&2	Class 5&6	Class 1&2	Class 5&6
0,5	36,0	39,0	36,7	40,1
0,75	24,5	26,0	24,8	26,7
1	18,1	19,5	18,2	20,0
1,5	12,1	13,3	12,2	13,7
2,5	7,41	7,98	7,56	8,21
4	4,61	4,95	4,70	5,09
6	3,08	3,30	3,11	3,39
10	1,83	1,91	1,84	1,95
16	1,15	1,21	1,16	1,24
25	0,727	0,780	0,734	0,795
35	0,524	0,554	0,529	0,565
50	0,387	0,386	0,391	0,393
70	0,268	0,272	0,270	0,277
95	0,193	0,206	0,195	0,210
120	0,153	0,161	0,154	0,164
150	0,124	0,129	0,126	0,132
185	0,0991 (*)	0,106	0,100	0,108
240	0,0754 (*)	0,0801	0,0762	0,0817
300	0,0601 (*)	0,0641	0,0607	0,0654
400	0,0470 (*)	0,0486	0,0475	0,0495
500	0,0366 (*)	0,0384	0,0369	0,0391
630	0,0283 (*)	0,0287	0,0286	0,0292

Class 1: Single core conductor
Class 2: Stranded conductor
Class 5: Fine wire conductors
Class 6: Extra fine wire conductors
(*) Values are for Class 2 conductors

Temperature correction factor values to R 20 °C

$$k_{t,Cu} = \frac{254,5}{234,5 + t} = \frac{1}{1+0,00393(t-20)}$$

where is the temperature of measurement and kt,Cu is correction factor

Current carrying capacity of PV cables based on EN 50618

Nominal cross sectional area	Current carrying capacity according to method of installation		
	Single cable free in air	Single cable on a surface	Two loaded cables touching, on a surface
mm^2	**A**	**A**	**A**
1,5	30	29	24
2,5	41	39	33
4	55	52	44
6	70	67	57
10	98	93	79
16	132	125	107
25	176	167	142
35	218	207	176
50	276	262	221
70	347	330	278
95	416	395	333
120	488	464	390
150	566	538	453
185	644	612	515
240	775	736	620

Note :

At 60 °C ambient temperature

Max. conductor temperature: 120 °C.

The expected period of use at a max. conductor temperature of 120 °C and at a max. ambient temperature of 90 °C is limited to 20 000 h.

Current rating conversion factors for different ambient temperatures

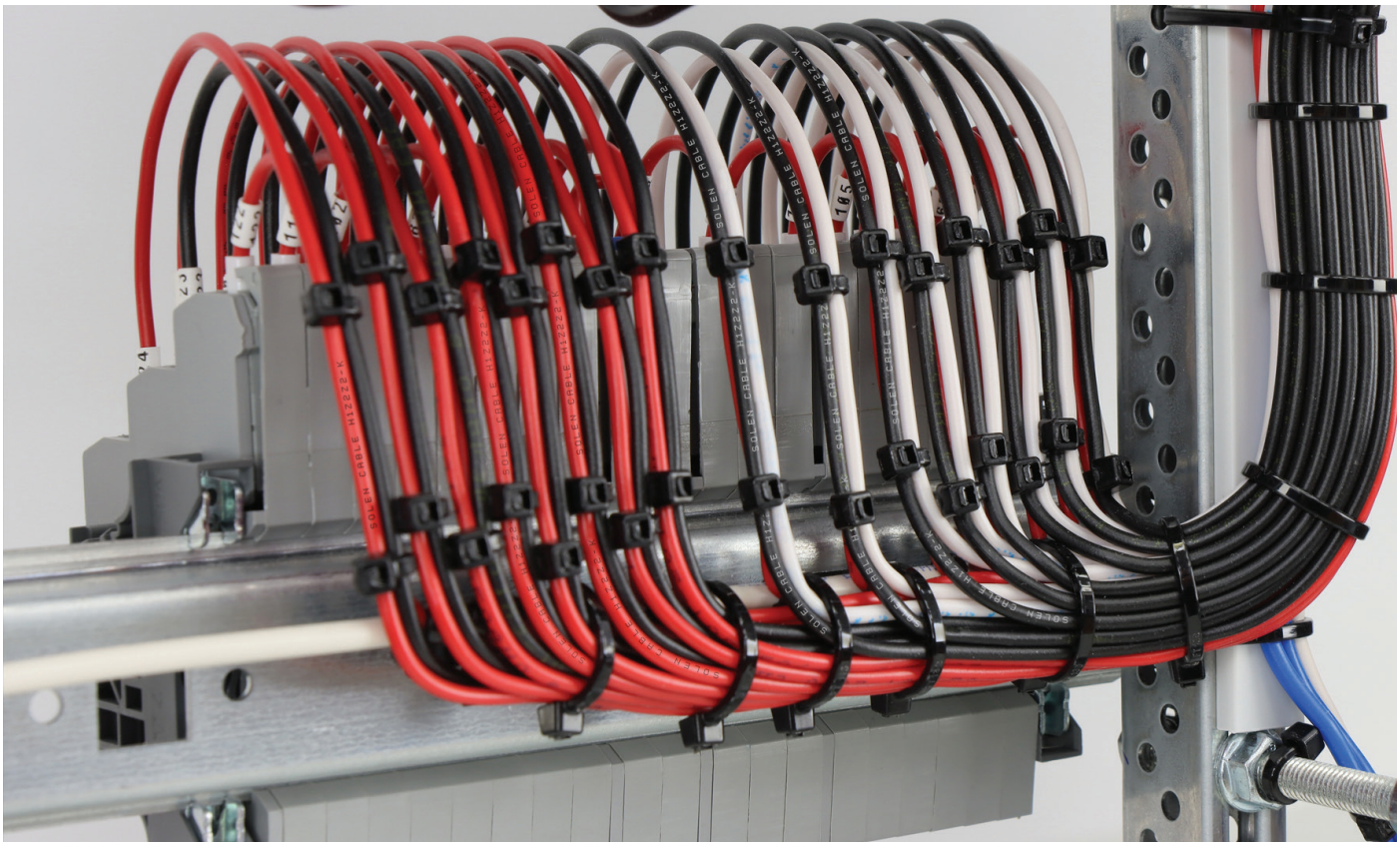
Ambient temperature	Conversion factor
°C	
up to 60	1,00
70	0,92
80	0,84
90	0,75

Groups

For installation in groups the reduction factors for current rating according to HD 60364-5-52:2011, Table B.52.17 shall apply.

Short-circuit-temperature

The permitted short-circuit-temperature is 250 °C referring to a period of 5 s.



Basic Electrical Equations

Quantitty	DC	Single Phase AC	Three Phase AC
Current (I)	$I = V / R$ $I = P / V$ $I = \sqrt{P / R}$	$I = P / (V \times \cos\theta)$ $I = (V / Z)$	$I = P / \sqrt{3} \times V \times \cos\theta$
Voltage (V)	$V = I \times R$ $V = P / I$ $V = \sqrt{(P \times R)}$	$V = P / (I \times \cos\theta)$ $V = I / Z$	$V_L = \sqrt{3} \times V_{PH}$
Power (P)	$P = I \times V$ $P = I^2 \times R$ $P = V^2 / R$	$P = V \times I \times \cos\theta$ $P = I^2 \times R \times \cos\theta$ $P = (V^2/R) \times \cos\theta$	$P = \sqrt{3} \times V_L \times I_L \times \cos \Phi$ $P = 3 \times V_{Ph} \times I_{Ph} \times \cos \Phi$
Resistance (R)	$R = V / I$ $R = P / I^2$ $R = V^2 / P$	$Z = \sqrt{(R^2 + X_L^2)}$ $Z = \sqrt{(R^2 + X_C^2)}$ $Z = \sqrt{(R^2 + (X_L - X_C)^2}$	

Where:

I = Current in Amperes (A)
V = Voltage in Volts (V)
P = Power in Watts (W)
R = Resistance in Ohm (Ω)
Z = Impedance = Resistance of AC Circuits in Ohms
Cosθ = Power factor = Phase difference between voltage and current in AC circuits
VPH = Phase Voltage
VL = Line Voltage
XL = Inductive reactance
XL = 2πfL…Where L = Inductance in Henry
XC = Capacitive reactance
XC = 1/2πfC… Where C = Capacitance in Farads. Also, **ω** = 2πf

AWG - METRIC CONVERSION CHART

AWG Number	Cross section mm^2	Cross section mm^2 (nearest metric size)	Conductor diameter mm
1000 MCM	507	500	29,3
900	456	-	27,8
750	380	400	25,4
600	304	300	22,7
550	279	-	21,7
500	253	240	20,7
450	228	-	19,6
400	203	-	18,5
350	177	185	17,3
300	152	150	16,0
250	127	-	14,6
4/0	107,2	120	11,68
3/0	85	95	10,4
2/0	67,4	70	9,27
0	53,4	-	8,25
1	42,4	50	7,35
2	33,6	35	6,54
3	26,7	-	5,83
4	21,2	25	5,19
5	16,8	-	4,62
6	13,3	16	4,11
7	10,6	-	3,67
8	8,34	10	3,26
9	6,62	-	2,91
10	5,26	6	2,59
11	4,15	-	2,30
12	3,31	4	2,05
13	2,63	-	1,83
14	2,08	2,5	1,63
15	1,65	-	1,45
16	1,31	1,5	1,29
17	1,04	-	1,15
18	0,823	1	1,024
19	0,653	0,75	0,912
20	0,519	0,5	0,812
21	0,412	-	0,723
22	0,324	0,34	0,644
23	0,259	-	0,573
24	0,205	0,25	0,511
25	0,163	-	0,455
26	0,128	0,14	0,405

1 mil = inch = 0.0254 mm 1 CM = 1 Circ. mil = 0.0005067 mm^2 1 MCM = 1000 Circ. mils = 0.5067 mm^2

CONVERSION OF MEASUREMENT UNITS

Length				
1	mil	=	0,0254	mm
1	in (inch)	=	25,4	mm
1	ft (foot)	=	0,305	m
1	yd (yard)	=	0,914	m
1	ch (chain)	=	20,1	m
1	mile (land mile)	=	1609 1760	km yards
1	mile (nautic mile)	=	1,852	km
1	mm	=	0,039370	inches
1	m	=	39,370079	inches

Area				
1	CM (circ. mil)	=	$0,507 \cdot 10^{-3}$	mm^2
1	MCM	=	0,5067	mm^2
1	sq. inch (sq. inch)	=	645,16	mm^2
1	sq. ft. (sq. foot)	=	0,0929	m^2
1	square yard	=	0,836	m^2
1	acre	=	4047	m^2
1	square mile	=	2,59	km^2

Volume				
1	cubic inch	=	16,39	cm^3
1	cubic foot	=	0,0283	m^3
1	cubic yard	=	0,765	m^3
1	pint	=	0,473	l
1	quart	=	0,946	l
1	Brit. gallon	=	4,55	l
1	US gallon	=	3,79	l
1	US barell	=	158,8	l

Mass				
1	grain	=	64,8	mg
1	dram	=	1,77	g
1	ounce (oz)= 16 drams	=	28,35	g
1	pound (lb)= 16 oz	=	453,59	g
1	stone = 14 lbs	=	6,35	kg
1	US ton (short ton)	=	907	kg
1	Brit. ton (long ton)	=	1,016	kg

Density				
1	lb/cu.ft	=	16,02	kg/m^3
1	lb/cu.in	=	27,68	t/m^3

Temperature			
	F (Fahrenheit)	=	$(1.8 \times C) + 3^0$
	C (Celcius)	=	$0,5556 \times (F-32^0)$

Force				
1	lb	=	4,448	N
1	brit. ton	=	9954	N
1	pdl (Poundal)	=	0,1383	N
1	kp	=	9,81	N
1	N	=	0,102	kp

Energy				
1	hp x h	=	1,0139	PS x h
		=	2,684x100000	J
		=	746	W x h
1	BTU (brit. therm.unit)	=	1055	Joul

Power				
1	PS	=	0,736	kW
1	kW	=	1,36	PS
1	hp	=	0,7457	kW
1	kW	=	1,31	hp

Electrical units				
1	ohm/1000 yd	=	1,0936	Ω/km
1	ohm/1000 ft	=	3,28	Ω/km
1	µF/mile	=	0,62	µF/km
1	megohm/mile	=	1,61	MΩ/km
1	µµf/foot	=	3,28	pF/m
1	decibel/mile	=	71,5	mN/m

Abbreviations for multiples and submultiples			
Prefix	mark	power	name
Tera	T	10^{12}	billion*
Giga	G	10^9	milliard*
Mega	M	10^6	million
Kilo	k	10^3	thousandth
Hekto	h	10^2	hundred
Deka	da	10^1	ten
Piko	p	10^{-12}	billionth*
Nano	n	10^{-9}	milliarth*
Mikro	µ	10^{-6}	millionth
Milli	m	10^{-3}	thousandth
Zenti	c	10^{-2}	hundredth
Dezi	d	10^{-1}	tenth

* In USA 10^9 indicates a billion and 10^{12} indicates a trillion

CPR CLASSES OF REACTION TO FIRE PERFORMANCE OF CABLES

Class	Test method(s)	Classification criteria	Additional classification
A_{ca}	EN ISO 1716	PCS ≤ 2,0 MJ/kg[1]	
$B1_{ca}$	EN 50399 (30 kW flame source) and	FS ≤ 1,75 m and THR_{1200s} ≤ 10 MJ and Peak HRR ≤ 20 kW and FIGRA ≤ 120 Ws^{-1}	Smoke production [2,5] and Flaming droplets/particles [3] and Acidity [4]
	EN 60332-1-2	H ≤ 425 mm	
$B2_{ca}$	EN 50399 (20,5 kW flame source) and	FS ≤ 1,5 m; and THR1200 ≤ 15 MJ; and Peak HRR ≤ 30 kW; and FIGRA ≤ 150 Ws^{-1}	Smoke production [2,6] and Flaming droplets/particles [3] and Acidity [4]
	EN 60332-1-2	H ≤ 425 mm	
C_{ca}	EN 50399 (20,5 kW flame source) and	FS ≤ 2.0 m; and THR_{1200s} ≤ 30 MJ; and Peak HRR ≤ 60 kW; and FIGRA ≤ 300 Ws^{-1}	Smoke production [2,6] and Flaming droplets/particles [3] and Acidity [4]
	EN 60332-1-2	H ≤ 425 mm	
D_{ca}	EN 50399 (20,5 kW flame source) and	THR_{1200s} ≤ 70 MJ; and Peak HRR ≤ 400 kW; and FIGRA ≤ 1300 Ws^{-1}	Smoke production [2,6] and Flaming droplets/particles [3] and Acidity [4]
	EN 60332-1-2	H ≤ 425 mm	
E_{ca}	EN 60332-1-2	H ≤ 425 mm	
F_{ca}	No performance determined		

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Z = Impedance = Resistance of AC Circuits in Ohms
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