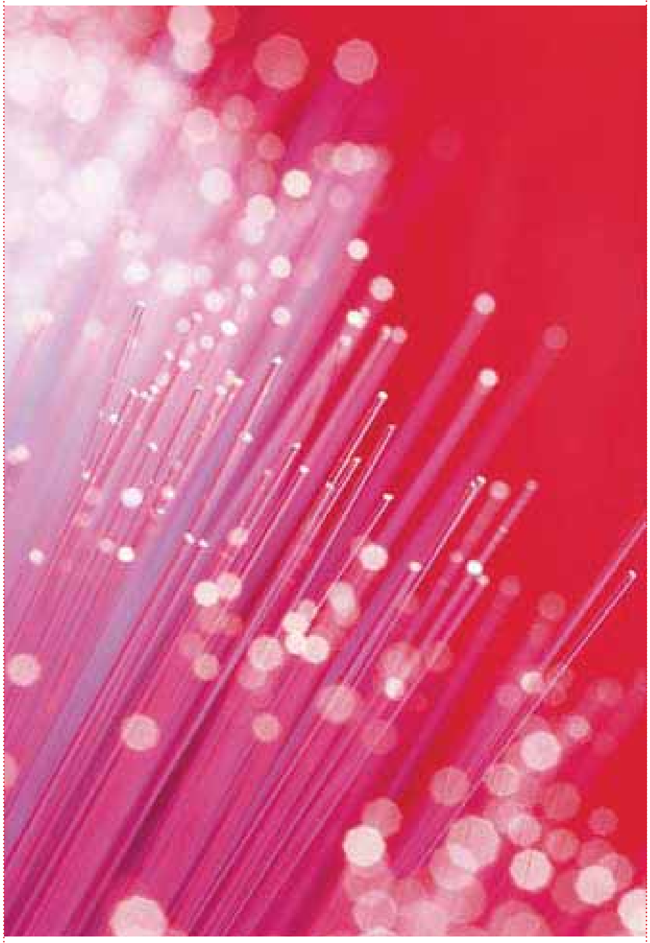
Tables /Explanations



Technical Data

Design Features

Type/trademark

Trademarks for flexible electric cables for cranes and material handling equipment

Flexible cables

CORDAFLEX®	Tough rubber-sheathed reeling cable (N)SHTÖU
PLANOFLEX®	Flat rubber-sheathed festoon cable NGFLGÖU
RONDOFLEX®	Round rubber-sheathed festoon cable also suitable for simple reeling NGRDGÖU
SPREADERFLEX®	Special cable for gravity-fed collector basket operation YSLTÖ
OPTOFLEX®	Rubber-sheathed flexible fibre-optic cable
PROTOLON®	H.V. reeling cables (N)TSCGEWÖU

Special compounds

PROTODUR®	Insulating compound PVC, used in lift control cables and SPREADERFLEX
PROTOFIRM®	Sheathing compound PCP, used in CORDAFLEX, PROTOLON. Compound with special resistance to abrasion and tearing, 5GM5 quality
PROTOLON®	Insulating compound EPR, used in CORDAFLEX, PROTOLON. Rubber compound with excellent electrical properties, resistant to heat and weather

Type/type designation

The **type** designates a group of flexible electric cables which have the same design features and which are intended for a specific range of technical applications.
The **type designation** is a letter combination according to DIN VDE, which describes the type in coded form[1].
For details of the design features, please refer to table 4/1, page 4/5.
For details of the application, please refer to the application and installation guidelines, table 4/2 (pages 4/6 and 4/7).

LYSLTK	Lightweight lift control cable, up to 30 m suspension length
NGFLGÖU	Flat rubber-sheathed flexible festoon cable PLANOFLEX
NGRDGÖU	Round rubber-sheathed flexible festoon cable also suitable for simple reeling RONDOFLEX
(N)SHTÖU	Tough rubber-sheathed flexible reeling cable CORDAFLEX
(N)TSCGEWÖU	H.V. reeling cables PROTOLON, 3 to 30 kV
YSLTK	Lift control cable, up to 50 m suspension length
YSLTÖ	Special cable for gravity-fed collector basket operation SPREADERFLEX
YSLYCYK	Lift control cable, up to 150 m suspension length

The type designation can be deciphered as follows:

..C..	Conducting metal casing over the stranded cores or between the inner and outer sheath (shield)
(C)	Additional information about the shield for the conductor cross-sections, e.g. 12 x 1 (C) which means 1 mm^2 individually shielded or 6 x (2 x 1)C which means 2 x 1 mm^2 twisted and shielded pairs
..CE..	Conducting metal casing over the insulation of the outer conductors
..CG..	Conducting non-metal casing over the stranded cores or between the inner and outer sheath (shield)
..CGE..	Conducting non-metal casing over the insulation of the outer conductors
FL	Flat cable
FM	Telecommunication lines within the cable
FO	Fibre-optic (German LWL)
G	Rubber compound
HS	High-voltage (H.V.)
-J	Additional information about the type: with green/yellow marked core
K	Rubber cross in the centre of the cable or low-temperature resistant in the case of lift control cables and (K) as a supplement to the trademark, e.g. CORDAFLEX(K)
KON	Concentric protective conductor between the inner and outer sheath or concentric control/monitoring conductor
L...	Lightweight cable design
LWL	Fibre-optic (FO)
(M)	Suffix to the trademark, e.g. OPTOFLEX (M) for Mining
MS	Medium-voltage (M.V.)
N	Design according to the corresponding standard
(N)	Based on a standard
-O	Additional information about the type: without green/yellow marked core
Ö[1]	Oil-resistant outer sheath (according to DIN VDE 0473, Part 2-1, Para. 10) (OE)
RD	Round cable
..SHT...	1 kV reeling cable
..SL..	Control cable
(SM)	Flexible cables for extremely high mechanical stress, previously used as supplement to the trademarks CORDAFLEX(SM) and PROTOLON(SM) (previously derived from Siemens machine cable)
(SMK)	New cable generation combining the high requirement profiles of (SM) and (K)
(SM-R)	"R" for reduced, i.e same diameter as PROTOLON standard cable, otherwise advanced PROTOLON(SM) design
ST	Control cores within the cable
..T..	Support element
..TS..	Reeling cable
U	Flame-retardant outer sheath (according to DIN VDE 0472, Part 804) "non-inflammable"
ÜL[1]	Monitoring conductor within the cable (UEL)
..W..	Weather resistant
Y	PVC compound
Z	Printed numbers
/3	Protective-earth conductor uniformly distributed in the three interstices
/3E	Protective-earth conductor uniformly distributed over the insulation of the outer conductor

[1] The German characters "Ö" and "Ü" are transformed into the international "OE" and "UE", respectively.

Approvals/standards

Flexible electric cables for cranes and material handling equipment have to be able to cope with the expected operation and installation conditions. Details are given in the application and installation guidelines. In addition, flexible electric cables for cranes and material handling equipment are described with regard to design and tests as laid down in national and international standards (design regulations).

Application and installation guidelines

DIN VDE 0298, Part 3	Application of cables and flexible cords in power installations • General information on cables
DIN VDE 0298, Part 4	Application of cables and flexible cords in power installations • Recommended values for current-carrying capacity of cables
DIN VDE 0100, Part 726	Erection of power installations with rated voltages up to 1000 V • Cranes
DIN VDE 0101	Erection of power installations with rated voltages above 1 kV
DIN VDE 0118	Specification for the erection of electrical installations in underground mines
DIN VDE 0168	Specification for the erection of electrical installations in open-cast mines, quarries and similar works
EN 81 Part 1	Safety regulations for the construction and installation of passenger lifts, goods lifts and service lifts

Design regulations

The summary in table 4/1 (page 4/5) shows all the design regulations/standards, according to which the flexible electric cables for cranes and material handling equipment are designed and manufactured. The following distinctions are made between national and international regulations:

National standard

DIN VDE (DIN = German Standards Institute; VDE = Association of German Electrical Engineers)

Germany is the only country which has issued special design regulations for flexible electric cables for cranes and material handling equipment. The tough-rubber sheathed flexible reeling cables CORDAFLEX NSHTÖU, the H.V. reeling cables PROTOLON NTS..WÖU and the flat rubber-sheathed flexible cables PLANOFLEX NGFLGÖU are described and standardized in DIN VDE 0250. This set of standards has found recognition in Europe and in many countries outside Europe and is accepted as or specified as “state of the art“.

The new generation of reeling cables (described in this catalog) generally conforms to these standards, however, they deviate in a number of points, where it is necessary to achieve an enhanced feature profile. Efforts are being made to have these modifications incorporated in the relevant standards.

No such design regulations exist for RONDOFLEX, SPREADERFLEX, OPTOFLEX and lift control cables. These are Pirelli special cables, the design of which is based on existing design regulations or general regulations of DIN VDE.

International standard

International standards have been taken into account for all our cables where this was possible.

For use at an international level, some design features of flexible electric cables for cranes and material handling equipment covered by DIN VDE are also listed or certified in line with UL or MSHA.

UL = **U**nderwriters **L**aboratories Inc.
UL is an approval and standardization institute in the USA.
The UL standard is requested in North America and also to some extent in the Far East.

MSHA = **M**ine **S**afety and **H**ealth **A**dministration
The MSHA listing was specially issued for the corresponding electric cables by the “Deep Mine Safety“ office at Harrisburg, USA. The flame-retardant behaviour of the cables was tested.

Appovals/standards

Flexible cables	Type	German standard DIN VDE	International standards
CORDAFLEX(SMK) /-V	(N)SHTÖU	DIN VDE 0250, Part 814	GOST R `
PLANOFLEX	NGFLGÖU	DIN VDE 0250, Part 809	UL File R 113313 GOST R `
RONDOFLEX	NGRDGÖU	Based on DIN VDE 0250, Part 814 VDE Reg. No. 9809	GOST R `
SPREADERFLEX	YSLTÖ	Based on DIN VDE 0250	GOST R `
OPTOFLEX		Based on DIN VDE 0888 Based on DIN VDE 0168	Based on FDDI, ISO/ IEC 9314, Part 3, MSHA SC 189-1
PROTOLON(SMK)	(N)TSCGEWÖU	DIN VDE 0250, Part 813	MSHA P GOST R `
PROTOLON(SMK) LWL	(N)TSKCGEWÖU	DIN VDE 0250, Part 813	MSHA P GOST R `
Lift control cable	LYSLTK, YSLTK YSLYCYK	Based on DIN VDE 0250 VDE Reg. No. 5920	SEMKO, SS 424 02 35

Table 4/1

Application

Flexible electric cables for cranes and material handling equipment are to be selected in accordance with the application for which they are intended (cable guidance system) and in accordance with the expected operation and installation conditions.
If necessary, the cables are to be protected against mechanical, thermal or chemical influences and also against the penetration of moisture from the ends of the cables.

Flexible electric cables for cranes and material handling equipment must **not** be installed in the ground. Ducts through fire barriers in the form of sand, etc, or temporary covering with soil, sand or similar material, e.g. on construction sites, do **not** count as being in the ground.

In general, fixing materials must not damage the flexible cables.
Flexible electric cables for cranes and material handling equipment have to be relieved of tension when they are connected to mobile equipment (cranes, material handling equipment) and must be secured to prevent them from twisting, sharp bending and axial compression. The sheaths of the flexible electric cables must not be damaged at the entries or by the stress-relief devices.

Table 4/2 shows the mechanical stressability and the normal applications of flexible electric cables for cranes and material handling equipment.

Flexible cables/Application
CORDAFLEX(SMK) / - V (N)SHTÖU
Flexible reeling cable for high and very high mechanical stresses on mobile equipment, mobile cable tender systems, festoon systems and for vertical reeling operation. Also for applications to which DIN VDE 0168 and 0118 apply: Open-cast and underground mining.
PLANOFLEX NGFLGÖU
Flexible power and control cable, for use on festoon systems and for connecting movable parts of machine tools, material handling equipment, etc. associated with high mechanical stresses and frequent bending during operation and for bending in one plane only.
RONDOFLEX NGRDGÖU
Flexible power and control cable, for use on festoon systems and for connecting movable parts of machine tools, material handling equipment, etc. associated with high mechanical stresses and frequent bending during operation. Suitable for simple reeling.
RONDOFLEX(C)-FC NGRDGCGÖU
For use on festoon systems, e.g. on gantry cranes, hall gantry cranes, rack material handling equipment, transportation systems or machine tools. In particular for applications, where there is a danger of interference to data transmission systems from power cables. The cables are used for high mechanical stresses and frequent bending. Also suitable for use as a flexible motor power supply cable.
SPREADERFLEX YSLTÖ
Feeder cable for load-lifting equipment, e.g. spreader with high mechanical stress in gravity-fed collector basket operation.
OPTOFLEX
For optical signal and data transmission on cranes and material handling equipment; suitable for forced guidance (e.g. reels, festoon systems, cable tenders) at high data rates, large bandwidth and absolute immunity to electromagnetic interference.
PROTOLON(SMK) (N)TSCGEWÖU
Flexible H.V. reeling cable, also suitable for festoon systems, with high to extreme mechanical stresses, e.g. high travel speeds, dynamic tensile loads, multiple changes of direction into different planes, churning on running over rollers and torsional stresses. Mainly for mobile equipment, e.g. fast-moving container cranes, cranes, large mobile equipment and excavators. Also for applications to which DIN VDE 0168 and 0118 apply: Open-cast and underground mining.
PROTOLON(SMK) LWL (N)TSKCGEWÖU
Flexible H.V. reeling cable, also suitable for festoon systems, for combined power and data transmission, with high to extreme mechanical stresses, e.g. high travel speeds, dynamic tensile loads, multiple changes of direction into different planes, churning on running over rollers and torsional stresses. Mainly for mobile equipment, e.g. fast-moving container cranes, cranes, large mobile equipment and excavators. Also for applications to which DIN VDE 0168 and 0118 apply: Open-cast and underground mining.
Lift control cable
For connecting lifts and similar transport and material handling equipment with medium mechanical stresses with suspension lengths up to 30 m, 50 m and 150 m in dry, damp and wet locations.

Table 4/2

	Mechanical stress			Forced guidance	Application						
	Medium	High	Very high (extreme)		Outdoors	Hazardous areas	Construction sites	Indoors	Industr. plant & machinery	Mining	
										open-cast	underground
🟪	●	●	●	**Yes**	●	●	●	●	●	●	●
🟦	●	●		**Yes** Bending in one plane allowed, no reeling	●	●		●	●	●	●
🟨	●	●		**Yes** For festoon operation and simple reeling	●	●	●	●	●	●	●
🟨	●	●		**Yes** For festoon operation	●	●	●	●	●	●	●
⬛	●	●		**Yes** For gravity-fed collector basket operation	●			●	●		
🟧	●	●		**Yes** Random cylindrical reeling not allowed	●	●	●	●	●	●	●
🟩	●	●	●	**Yes**	●		●	●	●	●	●
🟩	●	●	●	**Yes**	●		●	●	●	●	●
🟨	●			**Yes** In lift systems				●	●		

● Normal application

Installation of reeling cables

To ensure proper and fault-free operation of flexible electric reeling cables for mining applications such as PROTOLON and CORDAFLEX, it is necessary to observe certain rules for cable attachment (installation on the operating drum).

The cable can be directly wound from the supply drum to the operating drum. Pulling off the drum and laying stretched on the ground or “dekinking“ prior to taking up the cable on the operating drum should not be carried out.

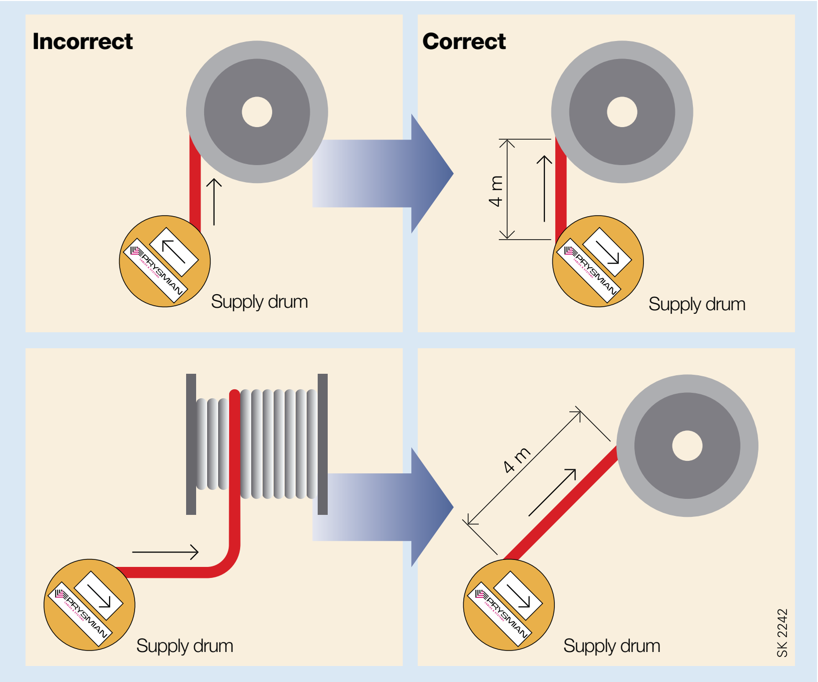


Fig. 4/1

The direction of lay employed in manufacture of **power cables** is always left-hand (S-type). It is therefore recommended that the start of the winding of reeling power cables on cylindrical reels should always be at the left side.
This measure ensures a clean and correct winding pattern, even when no guidance helical slot has been provided on the reel body.

The direction of lay employed in manufacture of **control cables** is always right-hand, for which reason such cables should be operated with the start of the winding at the right side.

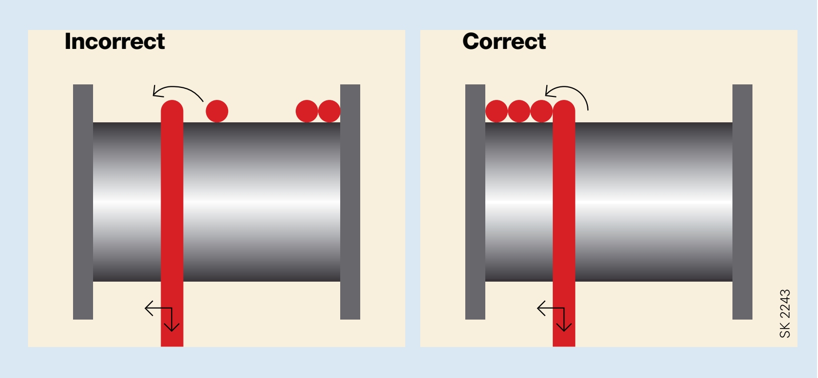


Fig. 4/2 Start of winding for power cables

Centre feeding point

In many installations, e.g. bunkering equipment, the power infeed point is located at the centre of the guideway. The flexible electric reeling cables such as CORDAFLEX and PROTOLON (M)-R are normally connected through underfloor infeeds (Fig. 4/3).

In order to achieve effective strain relief in conjunction with cable-wear minimizing deflection from the infeed point, we recommend the use of underfloor infeeds (Fig. 4/4). It is important that the specified bending radius be maintained and that the cable be fastened at the compensation cylinder by means of a clip, which, however, should be attached only after the 2nd winding.


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Fig. 4/3

1	Flexible electric reeling cable
2	Entry bell for infeed
3	Cable tray
4	Cable straight-through joint
5	Buried cable
6	Compensation cylinder
7	Cable clip (large area design)
d	Max. cable diameter
R_{min}	Bending radius of entry bell and bending radius of compensation cylinder

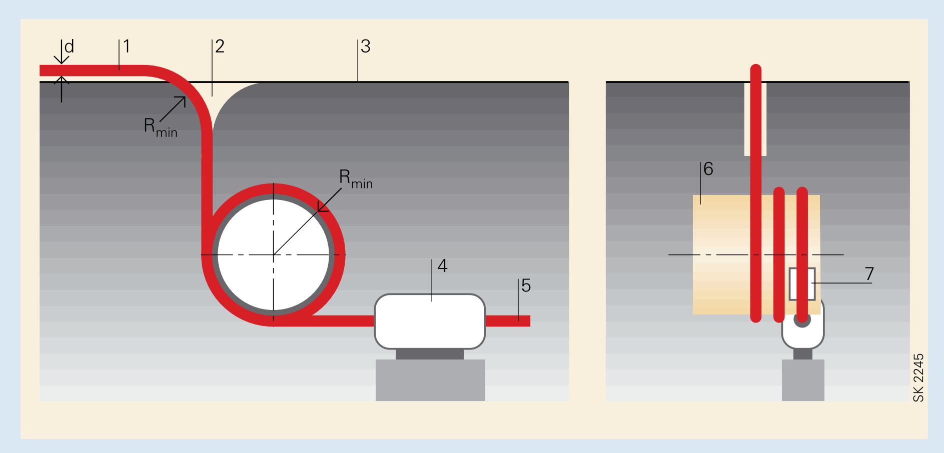


Fig. 4/4

Min. permissible bending radius as a function of the cable diameter

Flexible cables	**CORDAFLEX**				**PROTOLON**
Rated voltage U_0/U	Up to 0.6/1 kV				Above 0.6/1 kV
d in mm	Up to 8	Above 8 to 12	Above 12 to 20	Above 20	
R_{min}	3 x d	4 x d	5 x d	5 x d	10 x d

Table 4/4

Electrical parameters

Voltages

For the rated, operating and test voltages of cables, the definitions given in DIN VDE 0298, Part 3, apply. Some of these are mentioned in table 4/3 below.

AC - alternating current
DC - direct current

Rated voltage

The rated voltage of an insulated electric cable is the voltage which is used as the basis for the design and the testing of the cable with regard to its electrical characteristics.

The rated voltage is expressed by the two values of power frequency voltage U_0/U in V.

U_0 rms value between one conductor and "earth"
U rms value between two conductors of a multi-core cable or of a system of single-core cables

In a system with AC voltage, the rated voltage of a cable must be at least equal to the rated voltage of the system for which it is used. This requirement applies both to the value U_0 and the value U.

In a system with DC voltage, its rated voltage must not be more than 1.5 times the value of the rated voltage of the cable.

Operating voltage

The operating voltage is the voltage applied between the conductors and earth of a power installation with respect to time and place with trouble-free operation.

- Cables with a rated voltage U_0/U up to 0.6/1 kV
  These cables are suitable for use in three-phase AC, single-phase AC and DC installations, the maximum continuously permissible operating voltage of which does not exceed the rated voltage of the cables by more than 10% for cables with a rated voltage U_0/U up to and including 450/750 V
  20% for cables with a rated voltage U_0/U = 0.6/1 kV.
- Cables with a rated voltage U_0/U greater than 0.6/1 kV
  These cables are suitable for use in three-phase and single-phase AC installations, the maximum operating voltage of which does not exceed the rated voltage of the cable by more than 20%.
- Cables in DC installations
  If the cables are used in DC installations, the continuously permissible DC operating voltage between the conductors must not exceed 1.5 times the value of the permissible AC operating voltage. In single-phase earthed DC installations, this value should be multiplied by a factor of 0.5.

Test voltage

Regarding the test voltage of flexible cables, the values given in the corresponding parts of DIN VDE 0250 apply. If the relevant shield is missing, as for example with CORDAFLEX and PLANOFLEX cables,"core against core" is tested in appropriate combinations. The values are to be regarded as AC test voltages (unless stated otherwise) for single-phase testing, i.e. the AC test voltage is applied between the core and the corresponding shielding (e.g. semiconductive layer, earth conductor, shield). Telecommunication cores (pairs) and other shielded pairs (e.g. (2x1)C) are tested "core against core" and "core against shield" whereby the test voltages are correspondingly different.

With single-core cables without shielding, the corresponding opposite pole is a water bath.

Flexible cables	Rated voltage U_0/U	Max. permissible operating voltage			Test voltage applied to the complete cable			
		in AC systems U_0/U	in DC systems unearthed U kV	single-phase earthed U kV	Power cores kV	Control cores kV	Pilot cores kV	Tele-comm. cores kV
	220/380 V	241/418 V	0.627	0.314	2			
PLANOFLEX[1)]	300/500 V	0.7/1.2 kV	1.8	0.9	2.5	2		
SPREADERFLEX		318/550 V	0.825	0.413	2			
Lift control cable								
	450/750 V	476/825 V	1.238	0.619	2.5			
CORDAFLEX	0.6/1 kV	0.7/1.2 kV	1.8	0.9	3.5	3.5		
RONDOFLEX								
PROTOLON	0.6/1 kV	0.7/1.2 kV	1.8	0.9	4	2	2	1
	1.8/3 kV	2.1/3.6 kV	5.4	2.7	6	2	2	1
	3.6/6 kV	4.2/7.2 kV	10.8	5.4	11	2	2	1
	6/10 kV	6.9/12 kV	18	8	17	2	2	1
	8.7/15 k1V	10.4/18 kV	27	14	24	2	2	1
	12/20 kV	13.9/24 kV	36	18	29	2	2	1
	14/25 kV	17.3/30 kV	45	23	36	2	2	1
	18/30 kV	20.8/36 kV	54	27	43	2	2	1
	20/35 kV	24.3/42 kV	63	32	50	2	2	1

Table 4/3

1) As a result of its excellent insulation characteristics, PLANOFLEX is approved for applications at the 0.6/1 kV level.

Electrical parameters

Current-carrying capacity

If, after all selection criteria have been taken into account, the type of flexible electric cable to be used for cranes and material handling equipment has been decided on, the necessary cross-section of the conductor can be determined either from the current to be transmitted or from the power.

Installation conditions (stretched laying, suspended freely in the air, reeled), variations in ambient temperature, grouping, type of operation (continuous duty, intermittent periodic duty) and the use of multi-core cables are to be taken into account.
Table 4/4 is valid for continuous duty at 30 °C ambient temperature and three loaded cores, rubber-insulated or PVC-insulated cables.

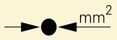
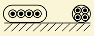
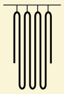
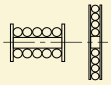
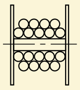
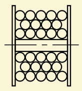
Rubber-insulated

CORDAFLEX

PROTOLON H.V. reeling cables up to 10 kV

PLANOFLEX

RONDOFLEX

									
Cross-section mm²	Stretched laying A	Suspended freely in air A	Reeled in 1 layer A	2 layers A	3 layers[1] A	4 layers A	5 layers A	6 layers A	7 layers A
	Factor 1	**1.05**	**0.8**	**0.61**	**0.49**	**0.42**	**0.38**	**0.27**	**0.22**
1	18	19	14	11	9	8	6	5	4
1.5	23	24	18	14	11	10	8	6	5
2.5	30	32	24	18	15	13	10	8	7
4	41	43	33	25	20	17	14	11	9
6	53	56	42	32	26	22	18	14	12
10	74	78	59	45	36	31	25	20	16
16	99	104	79	60	49	42	34	27	22
25	131	138	105	80	64	55	45	35	29
35	162	170	130	99	79	68	55	44	36
50	202	212	162	123	99	85	69	55	44
70	250	263	200	153	123	105	85	68	55
95	301	316	241	184	147	126	102	81	66
120	352	370	282	215	172	148	120	95	77
150	404	424	323	246	198	170	137	109	89
185	461	484	369	281	226	194	157	124	101
240	540	567	432	329	265	227	184	146	119
300	620	651	496	378	304	260	211	167	136
PROTOLON H.V. reeling cables above 10 kV									
16	105		84	64	51	44	36	28	23
25	139		111	85	68	58	47	38	31
35	172		138	105	84	72	58	46	38
50	215		172	131	105	90	73	58	47
70	265		212	162	130	111	90	72	58
95	319		255	195	156	134	108	86	70
120	371		297	226	182	156	126	100	82
150	428		342	261	210	180	146	116	94
185	488		390	298	239	205	166	132	107
240	574		459	350	281	241	195	155	126
300	660		528	403	323	277	224	178	145

PVC-insulated

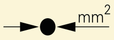
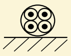
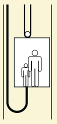
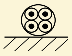
Lift control cable			**SPREADERFLEX**		
					
0.5	10	9.5	**0.5**	10	8
0.75	13	12	**0.75**	13	10
1	16	15	**1**	16	12
1.5	19	18	**1.5**	19	14
2.5	27	26	**2.5 (3.5)**	34 (34)	25 (25)

Table 4/4
Current-carrying capacity of flexible cables for cranes and material handling equipment

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1) The reduction factor is also valid for flat reeling cables (spirally)

Electrical parameters

De-rating factors

The de-rating factors take into account the installation and operating conditions, such as temperature, grouping, intermittent periodic duty and the number of simultaneously loaded cores. They are to be used for determining the current-carrying capacity in accordance with table 4/4 (page 4/9).

De-rating factors for varying ambient temperatures

Flexible cables	Ambient temperature °C												
	10	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**
CORDAFLEX	1.15	1.12	1.08	1.04	1.00	0.96	0.91	0.87	0.82	0.76	0.71	0.65	0.58
PLANOFLEX	1.15	1.12	1.08	1.04	1.00	0.96	0.91	0.87	0.82	0.76	0.71	0.65	0.58
RONDOFLEX	1.15	1.12	1.08	1.04	1.00	0.96	0.91	0.87	0.82	0.76	0.71	0.65	0.58
PROTOLON	1.15	1.12	1.08	1.04	1.00	0.96	0.91	0.87	0.82	0.76	0.71	0.65	0.58
SPREADERFLEX	1.22	1.17	1.12	1.06	1.00	0.94	0.87	0.79	0.71	0.61	0.50		
Lift control cable	1.22	1.17	1.12	1.06	1.00	0.94	0.87	0.79	0.71	0.61	0.50		

Table 4/5

De-rating factors for grouping

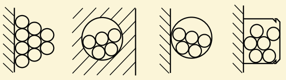
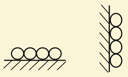
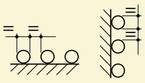
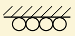
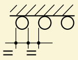
Arrangement		Number of multi-core cables or number of single or three-phase circuits made up of single-core cables (2 or 3 loaded conductors)														
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**14**	**16**	**18**	**20**
Bunched directly at the wall, the floor, in conduit or ducting, on or in the wall		1.0	0.8	0.7	0.65	0.6	0.57	0.54	0.52	0.5	0.48	0.45	0.43	0.41	0.39	0.38
Single layer on the wall or floor, touching		1.0	0.85	0.79	0.75	0.73	0.72	0.72	0.72	0.71	0.70					
Single layer on the wall or floor, spaced with a clearance of 1 x cable diameter between adjacent cables		1.0	0.94	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Single layer under ceiling, touching		0.95	0.81	0.72	0.68	0.66	0.64	0.63	0.62	0.61						
Single layer under ceiling, spaced with a clearance of 1 x cable diameter between adjacent cables		0.95	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85

Table 4/6

Electrical parameters

De-rating factors for intermittent periodic duty

Ambient temperature	30 °C	Nominal cross-section mm^2	Duty factor ED %			
			60	**40**	**25**	**15**
Duty cycle	**10 min**	**0.75**	1.00	1.00	1.00	1.00
		1	1.00	1.00	1.00	1.00
		1.5	1.00	1.00	1.00	1.00
		2.5	1.00	1.00	1.04	1.07
		4	1.00	1.03	1.05	1.19
		6	1.00	1.04	1.13	1.27
		10	1.03	1.09	1.21	1.44
		16	1.07	1.16	1.34	1.62
		25	1.10	1.23	1.46	1.79
		35	1.13	1.28	1.53	1.90
		50	1.16	1.34	1.62	2.03
		70	1.18	1.38	1.69	2.13
		95	1.20	1.42	1.74	2.21
		120	1.21	1.44	1.78	2.26
		150	1.22	1.46	1.81	2.30
		185	1.23	1.48	1.82	2.32
		240	1.23	1.49	1.85	2.36
		300	1.23	1.50	1.87	2.39

Table 4/7

De-rating factors for multi-core cables with conductor cross-sections up to 10 mm^2

Number of loaded cores	De-rating factors
5	0.75
7	0.65
12	0.53
18	0.44
24	0.40
30	0.37
36	0.36
42	0.35
61	0.30

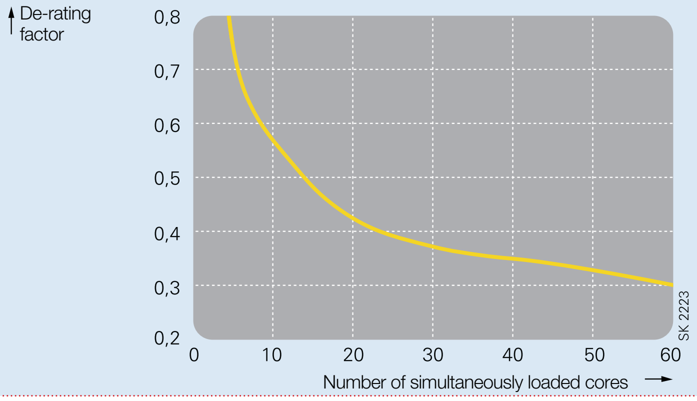


Table 4/8

Permissible short-circuit current at max. permissible short-circuit temperatures of the conductor surface and for a fault duration t_{kr} = 1 s

Cross-section mm^2	**1**	**1.5**	**2.5**	**4**	**6**	**10**	**16**	**25**	**35**	**50**	**70**	**95**	**120**	**150**	**185**	**240**	**300**
CORDAFLEX	Short-circuit current (kA)																
RONDOFLEX	0.143	0.215	0.358	0.572	0.858	1.43	2.29	3.58	5.01	7.15	10.01	13.6	17.16	21.45	26.46	34.32	42.9
PROTOLON																	

Table 4/9

The short-circuit current-carrying capacity I_{thz} for a short-circuit duration t_k deviating from t_{kr} = 1s, is: $I_{thz} = I_{thr} \cdot \sqrt{\frac{t_{kr}}{t_k}}$

Electromagnetic compatibility

Electromagnetic compatibility is the capability of an electrical or electronic device to function correctly in its electromagnetic environment and not to cause interference to the environment to an impermissible degree.

This matter is of immediate concern for all those engaged in planning and manufacturing electrical equipment and installations. On the one hand, the EMC legislation introduced in Germany from 1.1.1996, and, on the other hand, the high processing speed and transmission rates of modern electronics necessitate increased attention being paid to the question of the influence of transmitted and received interference. Non-observance of the currently valid EMC standards can lead to imposition of fines.

Standards

Standards, which directly address the question of cable construction or cable characteristics, do not exist. Whether a cable causes interference or not, is solely dependent on the manner in which it is used. From the point of view of the user, those standards, which specify limit values for permissible levels of interference, are relevant. These refer to equipment, plants or other electrical installations and thus refer indirectly to the cables. Those responsible for erection or manufacture thereof must confirm or prove that their equipment meets the EMC requirements.

The currently valid standards and regulations, which are important for use of insulated cables, are listed in Fig. 4/1.

Criteria for EMC cable selection

Selection of the most suitable cable and application/connection at site from the point of view of EMC can be carried out employing the criteria listed below:

- Use of a cable shield with low transfer impedance
- Symmetrical design and operation of the cable
- Choice of suitable materials by reason of the higher voltage stress of the insulation by reflections at frequencies above 100 MHz; low loss figure
- Large clearance between the interference source and the interference sink (power cables layed spatially separated from the data cables)
- Earthing at both ends and coaxial connection of the shield
- Use of filters
- Laying on earthed surfaces

The design of a cable is of decisive importance for the evaluation of EMC. The most commonly employed constructional designs of power and control cables regarding their EMC characteristics are listed in Fig. 4/2.

Selection of EMC cables for applications on cranes and material handling equipment

Power cables

In recent years, a new generation of high-speed switching transistors (IGBT) has been employed for converters for variable-speed motors. Use of such converters results in high rates of voltage rise and high-frequency harmonics. For this reason consequent interference must be taken into account. In order to counteract this interference, special measures are required for the power cables. We recommend the use of RONDOFLEX(C) shielded EMC cables. As a result of an optimized design regarding shield, materials and geometry, this cable type fulfills all the requirements with respect to mechanical characteristics for flexible cables for festoon system and cable tender operation and is also distinguished by superior shield characteristics. Consequently interference emission is reduced to an acceptable degree or even completely suppressed.

Moreover, the RONDOFLEX(C) cable design helps manufacturers and operators of electrical installations to maintain the limit values specified in the EMC legislation. PROTOLON H.V. reeling cables and CORDAFLEX (from 35 mm² conductor cross-section) are also eminently suitable as EMC cables as a result of their precise and symmetrical three-core design.

Control cables, data transmission and bus cables (e.g. PROFIBUS)

Interference-free data transmission can only be achieved, especially when power and data transmission cables lie close together, by implementation of special measures.

Cable designs with twisted and shielded pairs have proven their suitability for such applications, in particular as bus cables. The laid-up length and the shield are matched so that the transfer impedance and the shield attenuation are optimized at 30 MHz. The following cable designs are eminently suitable for use as data and bus cables:

- CORDAFLEX (SMK) with 3, 6, 9 or 12 twisted and shielded pairs
- CORDAFLEX (SMK) with combined pairs / single cores
- PLANOFLEX with 4 or 6 twisted and shielded pairs
- RONDOFLEX with 6 or 9 twisted and shielded pairs

Table 4/10 shows the specific characteristics of crane cables with twisted and shielded pairs ...x(2x1)C as a function of the frequency.

Cables with fibre-optics

The optimum solution as regards EMC is the use of glass fibre-optics. In addition to the well-known design OPTOFLEX, we are in a position to offer all the types of cables manufactured by us as combined copper / fibre-optic cables to special order. Prices and delivery times are available on request. In most cases, the overall diameter of the combined cables is identical to that of pure copper cables. Attention is drawn here, in particular, to the PROTOLON design with integrated fibre-optics, which has formed part of our standard delivery program since 1984.

Standards and regulations relevant to EMC of cables

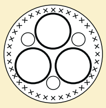
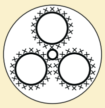
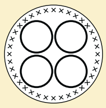
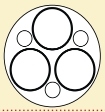
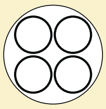
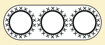
IEC 801-3	This standard defines electromagnetic compatibility for instrumentation and control equipment for industrial process applications. It describes methods for evaluation of the susceptibility to electromagnetic interference. It further describes tests, by means of which the influence of electromagnetic interference from external sources on the operational behaviour of cables and their maximum achievable transmission rates can be determined.
IEC 801-4	Tests based on this standard reveal the maximum loading limits of LAN cables as a result of uniform, random and periodic interference.
EN 55011 (DIN VDE 0875, Part 11)	In this standard the limit values and measuring procedures for radio frequency interference caused by industrial, scientific and medical high-frequency equipment (ISM devices) are defined.
EN 55022	This standard corresponds to DIN VDE 0878, Part 3: Limit values and measuring procedures for radio frequency interference caused by information processing equipment (ITE). The radiated energy of a cable can be measured in simulated operation. In addition, the limit value classes A and B for radio frequency interference voltages are defined.
Official Journal Regulation 243/1991	This regulation of the German Federal Ministry for Post and Telecommunication deals with radio frequency interference and interference voltage emission.

Information on this subject is also to be found in FTZ TL-6145-3000 issued by the Research and Technology Centre of the German Post Office.

Fig. 4/1

Electrical parameters

EMC power cables

Construction		Shield	EMC evaluation
	Symmetrical 3 + 3	Cu braid (possibly with Cu fleece)	Optimum
	Symmetrical 3-core	Cu braid (single core)	Good
	Unsymmetrical 4-core	Cu braid (possibly with Cu fleece)	Good
	Symmetrical 3 + 3	–	Satisfactory
	Unsymmetrical 4-core	–	Mediocre
	Unsymmetrical parallel cores or flat cable	Cu braid	Mediocre
	Unsymmetrical parallel cores or flat cable	–	Poor

EMC control cables

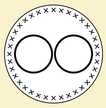
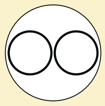
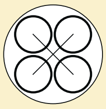
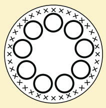
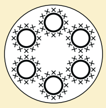
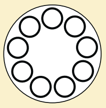
	Symmetrical 2-core	Cu braid (possibly with Cu fleece)	Optimum
	Symmetrical 2-core	–	Very good
	Symmetrical 4-core	–	Good (with symmetrical operation)
	Unsymmetrical concentrically stranded	Cu braid overall shield	Often adequate (with adjacent cores)
	Unsymmetrical concentrically stranded	Cu braid individually shielded cores	Often adequate (with adjacent cores)
	Unsymmetrical concentrically stranded	–	Poor

Fig. 4/2

Cable characteristics of crane cables with twisted and shielded pairs ... x(2 x 1)C

Twisted and shielded pairs (2x1)C can be employed without modification in the cable designs CORDAFLEX, RONDOFLEX, PLANOFLEX, SPREADERFLEX, PROTOLON and lift control cables.

Cable characteristics and frequency dependency		Unit	Frequency in kHz			
			1	10	100	1000
Resistance	R	Ω/km	38	40	106	314
Inductance	L	µH/km	780	720	606	493
Leakance	G	µS/km	18	128	1305	10770
Capacitance	C	nF/km	105	102	101	99
Characteristic impedance	Z	Ω	240	97	79	71
Attenuation	α	dB/km	0.9	2	6.3	22.6

Table 4/10

Thermal parameters

The different temperature limits of the individual flexible electric cables for cranes and material handling equipment are summarized in table 4/11.

Under no circumstances may the values shown be exceeded due to interaction of internal Joule heat and the ambient temperature.

If cables are exposed to radiation, e.g. sunlight, the temperature of the outer sheath of the flexible electric cable can rise to a level which is significantly higher than the ambient temperature. This situation must be compensated for by corresponding reduction of the current-carrying capacity.

The temperatures on the surface of the cable are limits for the ambient temperature.

All insulating and sheathing compounds of the flexible electric cables become stiffer as the temperature drops. If the temperature falls below the specified limit, a point can be reached below which the compounds used become brittle.

In addition to this, more force (sometimes considerably more) is needed for bending a flexible electric cable due to the increase of stiffness of the insulating and sheathing compounds at lower temperatures. This can create problems in the use of flexible electric cables for cranes and material handling equipment (e.g. with the reel drive).

Temperature limits

Flexible cables	Type	Temperature limit during operation, storage, installation and transport (°C)			
		of the conductor during operation	of the conductor during short-circuit	on the surface of the cable, fixed installation	on the surface of the cable, fully flexible operation
CORDAFLEX(SMK)	(N)SHTÖU	90	250	– 50 to + 80	– 35 to + 60
PLANOFLEX	NGFLGÖU	90	250	– 50 to + 80	– 35 to + 60
RONDOFLEX	NGRDGÖU	90	250	– 50 to + 80	– 35 to + 60
SPREADERFLEX	YSLTÖ	70	150	– 20 to + 60	– 20 to + 60
OPTOFLEX		–	–	– 40 to + 80	– 20 to + 60
PROTOLON(FL) / LWL	(N)TSFLCGEWÖU	90	250	– 50 to + 80	– 35 to + 60
PROTOLON(SMK) / LWL	(N)TSKCGEWÖU	90	250	– 50 to + 80	– 35 to + 60
Lift control cable	For suspension lengths up to 50 m	70	150	– 20 to + 50	– 20 to + 50
	For suspension lengths up to 150 m	70	150	– 30 to + 40	– 30 to + 40

Table 4/11

Thermal parameters

The relationship between the bending stiffness of flexible electric cables for cranes and material handling equipment and the temperature is shown in Fig. 4/3.

The ratio of the bending force is given as F/F_0, with $F_0 = F_{20\,°C}$.

A comparison of the low-temperature flexibility of our cables using the old and new designs (PROTOLON and CORDAFLEX) is shown in Fig. 4/4.

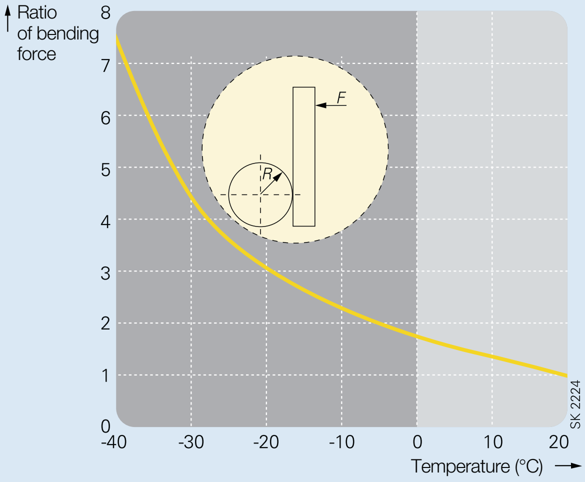


Fig. 4/3

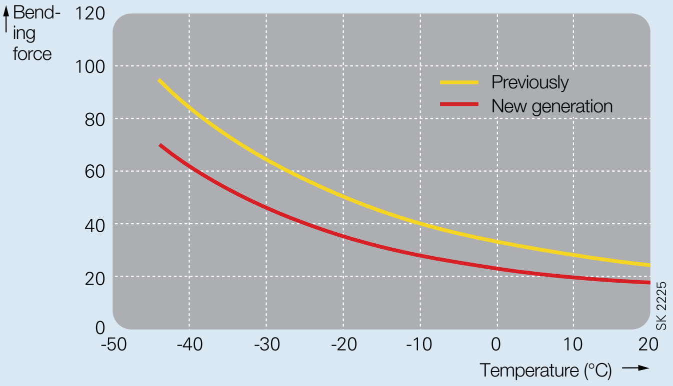


Fig. 4/4

The temperature limits on the surface of the cable are specified to ensure problem-free and healthy operation during forced guidance of flexible electric cables for cranes and material handling equipment, especially while running over sheaves and during reeling operation.

Higher temperatures influence the hardness, abrasion, resistance to tear propagation and the transverse pressure stability of the insulating and sheathing compounds and can thus lead to a reduction of their service life.

Flexible electric cables should be selected, installed and operated so that the expected dissipation of Joule heat is not hindered in any way and therefore no risk of fire is incurred.

Mechanical parameters

Tensile loads

The tensile loads of copper conductors in flexible electric cables for cranes and material handling equipment as specified by DIN VDE 0298, Part 3, should not exceed 15N/mm². However, higher values are allowed for some cables as shown in table 4/12. These values refer to tensile load only.

These maximum permissible limits of tensile load are to be regarded as the sum of the static and dynamic loads.

When the permissible tensile force is being calculated, shields, concentric conductors and split protective-earth conductors as well as integrated control cores and monitoring cores of power cables must **not** be included in the calculation.

For higher tensile loads, appropriate steps have to be taken such as increasing the bending radii or using special cable designs with stress relieving support elements. In some cases, a shorter service life can be expected. In this case, the cable manufacturer should be consulted.

The maximum permissible tensile load for installing **fixed laying** flexible cables is 50 N/mm² referred to the cross-section of the conductor.

Maximum tensile load during installation and operation of flexible electric cables for cranes and material handling equipment

Flexible cables	Type	DIN VDE N/mm^2	Prysmian N/mm^2
CORDAFLEX(SMK)	(N)SHTÖU	15	30
PLANOFLEX	NGFLGÖU	15	15
RONDOFLEX	NGRDGÖU	15	15
SPREADERFLEX	YSLTÖ	15	15 refer also to design features, page 4/29
OPTOFLEX		–	500 N for the complete cable
PROTOLON(FL) / LWL	(N)TSFLCGEWÖ	15	15
PROTOLON(SMK) / LWL	(N)TSKCGEWÖU	15	20
Lift control cable		15	15 refer also to design features, page 4/29

Table 4/12

Torsional stresses

Flexible electric cables for cranes and material handling equipment are generally **not** designed for torsional stresses. The latter can, however, not be avoided during operation.

The maximum permissible torsional stresses which occur during operation at entries, slewing gears, windmills, etc., are summarized in table 4/13.

If the limits are exceeded, this can lead to a reduction in service life. In critical cases, the cable manufacturer should be consulted.

Torsional stresses created by the systems involved (e.g. due to misalignment of cable guidance systems, oblique cable pay out) should be avoided and are not included here.

Maximum torsional stresses during operation of flexible electric cables for cranes and material handling equipment

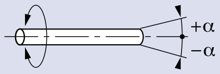
Flexible cables	Type	α (°/m) 
CORDAFLEX(SMK)	(N)SHTÖU	± 50
PLANOFLEX	NGFLGÖU	Not permissible
RONDOFLEX	NGRDGÖU	± 25°
SPREADERFLEX	YSLTÖ	Corresponding to application, designed for best torsional properties
OPTOFLEX		± 50
PROTOLON(FL) / LWL	(N)TSFLCGEWÖU	n.a.
PROTOLON(SMK) / LWL	(N)TSKCGEWÖU	± 25

Table 4/13

Mechanical parameters

Minimum bending radii

If the bending radii are smaller than those permitted, a reduced service life can be expected depending on the stress conditions. The values given in table 4/14 should be taken as a basis.

The minimum bending radii are shown as the product of the overall diameter of the cable and a factor, which is dependent on the diameter of the cable (e.g.: 3 x d).

The minimum permissible bending radii are valid within the specified ambient temperature range (see thermal parameters, page 4/14) subject to the provision that the permissible tensile loads are not exceeded (see mechanical parameters, page 4/16).

In critical cases, the cable manufacturer should be consulted.

Minimum permissible bending radii *R*

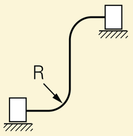
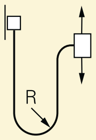
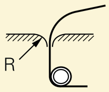
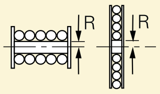
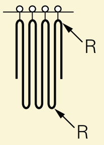
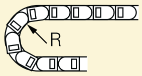
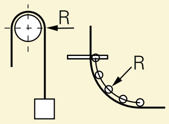
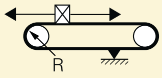
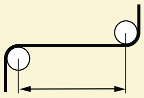
Flexible cables		**CORDAFLEX, PLANOFLEX, RONDOFLEX, SPREADERFLEX, PROTOLON, Lift control cable**				**PROTOLON**	**OPTOFLEX** minimum permissible bending radius
Rated voltage U_0 / U		Up to 0.6/1 kV				Above 0.6/1 kV	
Maximum overall diameter of the cable or maximum thickness of the flat cable (mm)		Up to 8	Above 8 to 12	Above 12 to 20	Above 20		mm
	Fixed installation	**3 x d**	**3 x d**	**4 x d**	**4 x d**	**6 x d**	**125**
	Fully flexible operation	**3 x d**	**4 x d**	**5 x d**	**5 x d**	**10 x d**	**125**
	For the entry, e.g. at a centre feed point	**3 x d**	**4 x d**	**5 x d**	**5 x d**	**10 x d**	**250**
	For forced guidance with reeling operation	**5 x d**	**5 x d**	**5 x d**	**6 x d**	**12 x d**	**250**
	For forced guidance with festoon operation	**3 x d**	**4 x d**	**5 x d**	**5 x d**	**10 x d**	**125**
	For forced guidance with power tracks	**4 x d**	**4 x d**	**5 x d**	**5 x d**	**10 x d**	**125**
	For forced guidance with sheaves	**7.5 x d**	**7.5 x d**	**7.5 x d**	**7.5 x d**	**15 x d**	**250**
	For forced guidance with cable tenders	**7.5 x d**	**7.5 x d**	**7.5 x d**	**7.5 x d**	**15 x d**	**250**
	Minimum distance with double or S-type directional changes	**20 x d**	**20 x d**	**20 x d**	**20 x d**	**20 x d**	**50 x d**

Table 4/14

Travel speeds

Flexible electric cables for cranes and material handling equipment are intended for use on mobile equipment and are designed to cope with the technical requirements of the application.

In order to collect, pay out and move flexible electric cables, there are different cable guidance systems, such as reels, festoons, tenders, power tracks, baskets, sheave guided cable storage systems and lifts as well as sheaves and multi-roller guides.

The cranes and material handling equipment, and consequently also the cable guidance systems, are operated at different travel speeds and are therefore subjected to stress which can vary from low to very high.

During operation of the mobile equipment, the flexible electric cables are subjected to stress such as tension, transverse pressure, torsion and bending. Thus, the travel speed and the acceleration are to be considered as indirect criteria for the stresses applied to the flexible electric cables.

The maximum permissible travel speeds for the individual flexible electric cables are summarized in table 4/15.

In the case of gantry crane drives, the travel speed of the actual mobile equipment is implied. Usually, cylindrical or mono-spiral reels are employed.

The trolley drive carries out horizontal movement of the hoisting gear and the driver's cabin. Festoons, tenders and power tracks or sheave guided cable storage systems are used here as cable guidance systems.

In the case of the hoisting gear, the speed of the load-lifting device, such as the spreader or grab, is implied.

Normally, either reels located in the trolley or baskets on the load-lifting device are used for the cable guidance system.

If the travel-speed limits are exceeded, a reduction in service life cannot be excluded. The cable manufacturer should be consulted.

Maximum travel speed of flexible electric cables for cranes and material handling equipment

Flexible cables		Gantry crane drive (reeling) m/min	Trolley drive (festoons and tenders) m/min	Hoist drive (vertical run reeling or basket) m/min
CORDAFLEX(SMK) /-V	(N)SHTÖU	No restriction. For speeds over 180 m/min, consult the cable manufacturer	**240**	**160**
PLANOFLEX	NGFLGÖU	No application	**180** For speeds over 180 m/min, consult the cable manufacturer	No application
RONDOFLEX	NGRDGÖU	**60**	**180** For speeds over 180 m/min, consult the cable manufacturer	No application
SPREADERFLEX	YSLTÖ	No application	No application	**160**
OPTOFLEX		**120** No random wound reel	**240**	No application
PROTOLON(FL) / LWL	(N)TSFLCGEWÖU	**120**	No application	No application
PROTOLON(SMK) / LWL	(N)TSKCGEWÖU	No restriction. For speeds over 240m/min, consult the cable manufacturer	**120**	No application
Lift control cable	For suspension lengths up to 50 m For suspension lengths up to 150 m	No application	No application	**90** **600**

Table 4/15

Mechanical parameters

Additional tests

Adequate testing of the good operating characteristics needed for flexible electric cables for cranes and material handling equipment is not possible with the tests specified by DIN VDE. Prysmian flexible electric cables for cranes and material handling equipment are therefore subjected to additional and continuous mechanical tests at the manufacturer’s works (Kabel- und Leitungswerk at Neustadt near Coburg). These additional tests facilitate time-compressed examination of the running and service characteristics under different kinds of mechanical stress, such as reversed bending strength, running over sheaves, flexing work and reeling operation in relation to tensile load and bending radii.

The additional tests can be seen in table 4/16.

Schematic representation of the additional tests

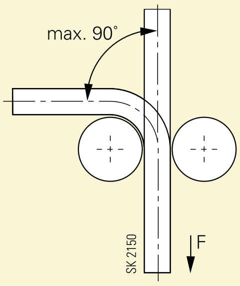
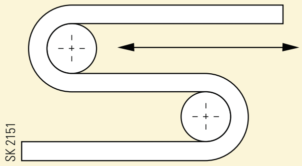
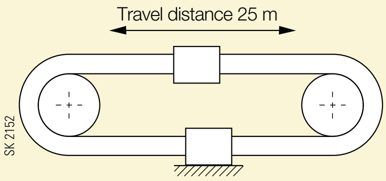
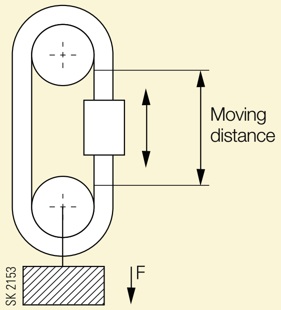
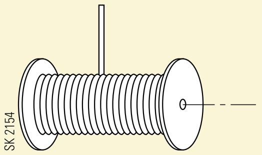
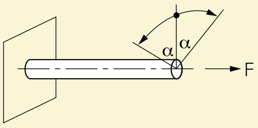
Reversed bending test Based on DIN VDE 0281, Part 2 Testing of flexible electric cables for cranes and material handling equipment under increased loads. Cable diameter up to 50 mm, maximum tensile load 3000 N. Each movement from one extreme position to another (180°) is counted as a cycle.	
Roller bending test type A Testing the roller bending characteristics of flexible electric cables for cranes and material handling equipment based on DIN VDE 0282, Part 2. Cable diameter up to 50 mm. Each movement between the extreme positions is counted as a cycle.	
Roller bending test type B (Tender test) Practice-oriented testing of flexible electric cables for cranes and material handling equipment with reference to running and service characteristics. Cable diameter from 20 up to 60 mm. Each movement between the extreme positions is counted as a cycle.	
Roller bending test type C (Flexing test) Testing the running characteristics (flexing) of flexible electric cables for cranes and material handling equipment for evaluation of the mechanical service characteristics. Cable diameter from 60 up to 120 mm. Each movement between the extreme positions is counted as a cycle. Moving distance 2 m.	
Reeling test Practice-oriented testing of flexible electric cables for cranes and material handling equipment with reference to running and service characteristics. Cable diameter up to 25 mm. Each reeling or unreeling operation is counted as a cycle. The reeled length is 8 m.	
Torsional stress test The cable is alternately twisted left and right through an angle α by application of the tensile force F. Torsional angle ± 360 ° Torsional torque 200 Nm Tensile force 4000 N	

Table 4/16

Mechanical parameters

Table 4/17 shows the test conditions for the individual flexible electric cables for cranes and material handling equipment. The tensile loads and the bending and sheave radii are specified and the minimum number of cycles which must be achieved.

The decisive criterion for passing a test is the number of broken individual wires in the copper conductor and/or the breaking of the electrical conductor.

In the roller bending tests type A and B, the degree of deformation (corkscrewing effect) is tested additionally.

Test conditions for the additional mechanical tests

Additional test	Flexible cable	CORDAFLEX(SMK)	PROTOLON(SMK)	PLANOFLEX		
				Control cable	Power cable	<4 mm^2 shielded
Reversed bending test	Tensile load	20 N/mm^2		5 N/mm^2		5 N/mm^2
	Bending diameter	10 x D		DIN VDE 0298, P3 Tab 2		10 x D
	Number of cycles	60 000		30 000		30 000
Roller bending test (type A) D < 50 mm	Tensile load	5 N/mm^2				
	Bending diameter	10 x D				
	Number of cycles	200 000				
Roller bending test (type B) 20 mm < D < 60 mm (Tender test)	Tensile load	5 N/mm^2				
	Bending diameter	320 mm				
	Number of cycles	300 000				
Roller bending test (type C) 60 mm < D < 120 mm (flexing test)	Tensile load	20 N/mm^2	20 N/mm^2			
	Bending diameter	10 x D	10 x D			
	Number of cycles	30 000	60 000			

Table 4/17.1

Additional test	Flexible cable	RONDOFLEX		OPTOFLEX	Lift control cable		
		Control cable	Power cable		up to 150 m	up to 50 m	up to 30 m
					Suspension length		
Reversed bending test	Tensile load	15 N/mm^2		300 N			
	Bending diameter	DIN VDE 0298, P3 Tab 2		250 mm			
	Number of cycles	60 000	30 000	100 000			
Roller bending test (type A) D < 50 mm	Tensile load			300 N	5 N/mm^2	5 N/mm^2	5 N/mm^2
	Bending diameter			250 mm	10 x D	10 x D	10 x D
	Number of cycles			100 000	300 000	200 000	150 000
Roller bending test (type B) 20 mm < D < 60 mm (Tender test)	Tensile load				5 N/mm^2	5 N/mm^2	
	Bending diameter			40 N	320 mm	20 mm	
	Number of cycles			200 000	100 000	100 000	
Roller bending test (type C) 60 mm < D < 120 mm (flexing test)	Tensile load			**Reeling test,**			
	Bending diameter			**mono-spiral reeling**			
	Number of cycles			Reel dia. 250 mm			
				Number of cycles 15 000			

Table 4/17.2

Chemical parameters

Resistance to chemicals

The individual basic types of materials used for flexible electric cables for cranes and material handling equipment, such as PCP or EPR can be very different from each other in their resistance to chemicals depending on the required properties. Furthermore, the properties of the materials can vary greatly from manufacturer to manufacturer.

Other factors which influence flexible electric cables for cranes and material handling equipment, such as the concentration and degree of wetting of the chemicals, their temperature and the penetration time have different effects on the resistance to chemicals and have to be investigated from case to case.

The chemical industry has drawn up a table which shows a rough summary of the resistance to chemicals of various basic types of material; the overview in table 4/18 is **not** to be deemed a substitute for a detailed examination.

Chemical	Material				
	EPR	**PVC**	**CSM**	**PCP**	**PU**
Aceton	🟨	🟥	🟦	🟦	⬜
Acetic acid, 30 %	🟥	🟥	🟦	🟦	🟦
Aluminium chloride solution	🟨	🟨	🟨	🟨	⬜
Aluminium sulfate solution	🟨	🟨	🟦	🟦	⬜
Ammonia, analhydrous	🟨	🟦	🟨	🟨	⬜
Ammonium chloride solution	🟨	🟨	🟨	🟨	⬜
Ammonium hydroxide solution	🟨	⬜	🟨	🟨	⬜
Ammonium sulfate solution	🟨	🟨	🟨	🟨	⬜
Amyl acetate	🟦	⬜	🟦	🟦	⬜
Aniline	🟦	🟥	🟥	🟥	⬜
Asphalt	🟥	🟦	🟦	🟦	🟨
Benzine	🟥	🟥	🟦	🟨	🟨
Benzole	🟥	🟥	🟥	🟥	🟥
Borax solution	🟨	🟨	🟨	🟨	⬜
Boric acid solution	🟨	🟨	🟨	🟨	⬜
Butyl acetate	🟦	🟥	🟥	🟥	⬜
Calcium bisulphite solution	🟨	⬜	🟦	🟦	⬜
Calcium chloride solution	🟨	🟨	🟨	🟨	⬜
Calcium hydroxide solution	🟨	⬜	🟨	🟨	⬜
Carbon disulphide	🟥	🟥	🟥	🟥	⬜
Carbon tetrachloride	🟥	🟥	🟥	🟥	🟥
Chlorobenzene	🟥	🟥	🟥	🟥	⬜
Chloroacetic acid	🟦	⬜	🟦	🟦	⬜
Chlorine gas, wet	🟦	🟥	🟥	🟦	⬜
Chlorine gas, dry	🟦	🟥	🟦	🟦	⬜
Chloroform	🟥	🟥	🟥	🟥	⬜
Copper chloride solution	🟨	⬜	🟨	🟨	⬜
Copper sulphate solution	🟨	⬜	🟨	🟨	⬜
Cyclohexane	🟥	🟥	🟦	🟥	⬜
Dibutyl phtalate	🟦	🟥	⬜	🟥	⬜
Diesel oils	🟥	🟨	🟨	🟨	🟨
Ethyl acetate	🟦	🟥	🟥	🟥	⬜
Ethyl alcohol	🟨	⬜	⬜	⬜	⬜
Ethylene glycol	🟨	🟦	🟨	🟨	🟨
Ethylen oxide	🟥	⬜	🟦	🟥	⬜
Formaldehyde, 10 %	🟨	⬜	🟨	🟨	⬜
Fuel oil	🟥	⬜	🟦	🟦	⬜
Glycerine	🟨	⬜	🟨	🟨	⬜
Hydaulic oils	🟥	🟦	🟨	🟨	🟨
Hydrochloric acid, 20 %	🟨	🟨	🟨	🟦	🟥
Hydrogen sulphide	🟨	🟨	🟨	🟦	⬜
Kerosine	🟥	🟦	🟥	🟥	⬜
Lactic acid	🟨	⬜	🟨	🟦	⬜
Linseed oil	🟥	⬜	🟦	🟦	⬜
Lubricating oils	🟥	🟨	🟦	🟦	⬜
Magnesium chloride solution	🟨	🟨	🟨	🟨	⬜
Methanol	🟨	🟨	🟨	🟨	🟨
Methyl chloride	🟥	🟥	🟥	🟥	⬜
Methyl ethyl ketone	🟨	🟥	🟦	🟦	⬜
Methyl alcohol	🟨	🟦	🟨	🟨	🟥
Mineral oil	🟥	🟥	🟦	🟦	⬜
Naphta	🟥	⬜	🟥	🟦	⬜
Naphtalene	🟥	🟥	🟥	🟦	⬜
Nitric acid, 10 %	🟨	🟨	🟦	🟦	⬜
Perchlor ethylene	🟥	🟥	🟥	🟥	⬜
Petroleum	🟥	🟥	🟦	🟦	🟨
Phenol	🟥	🟥	🟥	🟥	⬜
Phosphoric acid	🟨	🟨	🟨	🟨	🟦
Picric acid	🟨	🟨	🟨	🟨	🟥
Potassium chloride	🟨	🟨	🟨	🟨	🟨
Pyridine	🟥	🟥	🟥	🟥	⬜
Soap solution	🟨	🟨	🟨	🟨	⬜
Sodium hydroxide, 25 %	🟨	🟦	🟨	🟨	🟥
Sodium hypochloride	🟨	⬜	🟨	🟦	⬜
Soya bean oil	🟥	🟥	🟦	🟦	⬜
Sulphur	🟨	🟨	🟨	🟨	🟦
Sulphurous acid	🟨	🟨	🟨	🟦	⬜
Sulphuric acid <50 %	🟨	🟨	🟨	🟨	🟥
Stearic acid	🟨	🟦	🟨	🟨	⬜
Toluene	🟥	🟥	🟥	🟥	⬜
Transformer oil	🟥	🟨	🟨	🟨	🟨
Tributyl phosphate	🟦	⬜	🟥	🟦	⬜
Trichlorethylene	🟥	🟥	🟥	🟥	🟥
Triethanolamine	🟨	⬜	🟨	🟦	⬜
Turpentine	🟥	🟥	🟥	🟥	⬜
Vegetable oils and grease	🟦	🟦	🟨	🟨	🟨
Water	🟨	🟨	🟨	🟨	🟦
Xylene	🟥	🟥	🟥	🟥	⬜
Zinc chloride solution	🟨	🟨	🟨	🟨	⬜

Table 4/18

🟨	Resistant
🟦	Limited resistance
🟥	Non-resistant
⬜	Not tested

Conductors

Conductors for flexible electric cables are designed according to DIN VDE 0295. Nowadays, the conductors are made of copper (Cu). Aluminium and other materials have not found general acceptance. An overview of the common kinds of conductors is shown in table 4/19.

Common types of conductors

Abbreviation	Designation	Specification/regulation
RE conductor	Circular, solid	DIN VDE 0295 Class 1
RM conductor	Circular, stranded	DIN VDE 0295 Class 2
RMV conductor	Circular, stranded, compacted	DIN VDE 0295 Class 2
F conductor	Finely stranded	DIN VDE 0295 Class 5
FS conductor	Very finely stranded	Pirelli specification
FF conductor	Extremely finely stranded	DIN VDE 0295 Class 6

Table 4/19

In many countries, the design of the conductors according to DIN VDE 0295 is accepted. The regulation corresponds to CENELEC HD 383.S2 and IEC 228.

The conductor classes F, FS and FF are employed for flexible electric cables for cranes and material handling equipment. The conductor classes are divided into nominal cross-sections. The individual conductor classes F, FS and FF and the nominal cross-sections are defined by specification of the maximum diameter of the single wires and by the maximum resistance of the conductor at 20 °C (see also table 4/20).

These flexible conductors are made of bare or tinned annealed copper. The conductors are constructed of many single wires, all of which must have the same diameter.

Nominal cross-section	**Max. diameter of the single wires** mm			**Resistance of the conductor at 20 °C** Ω/km	
mm^2	F conductor (Class 5)	FS conductor (Pirelli)	FF conductor (Class 6)	Bare single wires	Tinned single wires
0.5	0.21	0.16	0.16	39.0	40.1
0.75	0.21	0.16	0.16	26.0	26.7
1	0.21	0.16	0.16	19.5	20.0
1.5	0.26	0.21	0.16	13.3	13.7
2.5	0.26	0.21	0.16	7.98	8.21
4	0.31	0.26	0.16	4.95	5.09
6	0.31	0.26	0.21	3.30	3.39
10	0.41	0.26	0.21	1.91	1.95
16	0.41	0.31	0.21	1.21	1.24
25	0.41	0.31	0.21	0.780	0.795
35	0.41	0.31	0.21	0.554	0.565
50	0.41	0.36	0.31	0.386	0.393
70	0.51	0.36	0.31	0.272	0.277
95	0.51	0.41	0.31	0.206	0.210
120	0.51	0.41	0.31	0.161	0.164
150	0.51	0.41	0.31	0.129	0.132
185	0.51	0.41	0.41	0.106	0.108
240	0.51	0.41	0.41	0.0801	0.0817
300	0.51	0.41	0.41	0.0641	0.0654

Table 4/20

The conductors used in flexible electric cables for cranes and material handling equipment are summarized in table 4/21.

The conductor for flexible electric cables is designed according to DIN VDE 0295, as described in the adjacent table and especially in table 4/21. The construction of the conductor itself and its design features are open to variation.

Flexible cable	Type	Conductor used
CORDAFLEX(SMK)	(N)SHTÖU	Electrolytic copper, tinned, very finely stranded Class "FS"
PLANOFLEX	NGFLGÖU	Electrolytic copper, not tinned, up to 25 mm^2 extremely finely stranded, Class 6 from 35 mm^2 finely stranded, Class 5
RONDOFLEX	NGRDGÖU	Electrolytic copper, tinned, finely stranded, Class 5
SPREADERFLEX	YSLTÖ	Electrolytic copper, not tinned, very finely stranded, Class "FS"
OPTOFLEX		Fibre-optics, no copper conductors
PROTOLON(SMK)	(N)TSCGEWÖU	Electrolytic copper, tinned, very finely stranded, Class "FS" (protective-earth conductor, likewise)
PROTOLON(SMK) LWL	(N)TSKCGEWÖU	
Lift control cable	LYSLTK, YSLTK, YSLYCY	Electrolytic copper, not tinned, 0.5 mm², extremely finely stranded, Class 6, otherwise finely stranded, Class 5

Table 4/21

Conductors

Fig. 4/5 shows the design elements of a conductor for flexible electric cables for cranes and material handling equipment. Depending on the cross-section of the conductor, a flexible conductor consists of one or more strands which are laid up around a central strand in several layers. In the diagram, six individual strands (second layer) are laid up around a central strand (first layer). A third layer would then be made from 6 + 6 = 12 individual strands, arranged around the second layer.

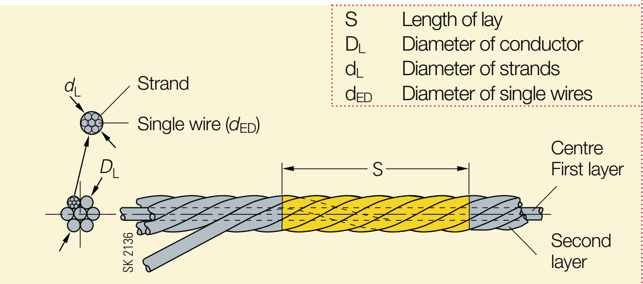


Fig. 4/5 Conductor design

The strands of the flexible conductors consist of many single wires bunched together. The single wires can be laid up (bunched) to the right or left, thus determining the direction of lay. This is shown in Fig. 4/6 as the Z direction of lay (right) or the S direction of lay (left).

This also applies to a conductor which is laid up of single strands.

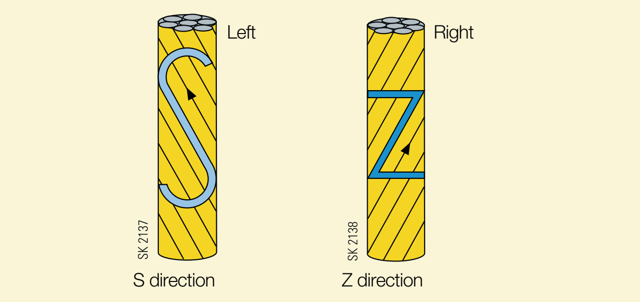


Fig. 4/6 Direction of lay

The conductor design and the nominal cross-section of the flexible F, FS and FF conductors for flexible electric cable are usually as shown in table 4/22.

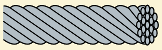
Conductor design		
	Bunched	Stranded
F conductor	up to 10 mm^2	from 16 mm^2
FS conductor	up to 2.5 mm^2	from 4 mm^2
FF conductor	up to 2.5 mm^2	from 4 mm^2

Table 4/22

Depending on the combination of the individual design elements of a conductor, there are three basic types of conductors (see table 4/23):

The main advantage of the **uniform-lay conductor** is its high flexibility. As a result of its design, the conductor also has a smaller diameter than other types of conductors. Disadvantages are its susceptibility to torsional loads (unstable) and its poor resistance to axial compression and sharp bending.

The **alternating-lay conductor** is very stable with respect to torsional loads and is not sensitive to axial compression and sharp bending. A disadvantage is its relatively low flexibility. As a result of its design the many crossing points of the single wires cause a lot of friction, which can lead to early breaking of the conductor, as compared to the other two types of conductors. The alternating-lay conductor has the largest diameter compared to the other two types of conductors.

The design of the **opposite-lay conductor** best meets the requirements of flexible electric cables for cranes and material handling equipment. It combines the advantages of both the uniform-lay conductor and the alternating-lay conductor without any of their disadvantages. This conductor is highly flexible, remains stable with respect to torsional loads and exhibits high axial compession and sharp bending strength. It has proven its excellent characteristics in many years of practice. The opposite-lay conductor is used for CORDAFLEX, PLANOFLEX, RONDOFLEX, SPREADERFLEX, PROTOLON and lift control cables.

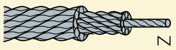
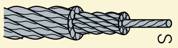
Types of conductors				
Uniform-lay conductor		Design	Strand	Layer
		Centre	Z	
		2nd layer	Z	Z
		3rd layer	Z	Z
Alternating-lay conductor		Design	Strand	Layer
		Centre	Z	
		2nd layer	S	Z
		3rd layer	Z	S
Opposite-lay conductor		Design	Strand	Layer
		Centre	S	
		2nd layer	S	Z
		3rd layer	S	Z

Table 4/23

Insulating and sheathing compounds

Table 4/24 gives an overview of all common compounds used for flexible electric cables.
A basic distinction is made between thermoplastics and elastomers.

Thermoplastics, generally known as plastic, are usually **not cross-linked**.

Elastomers, generally known as rubber, are always **cross-linked**.

Serial No.	Material	Abbreviation	Type designation	
			VDE	Harm.
	Thermoplastics			
1	Polyvinyl chloride	PVC	Y	V
2	Cross-linked polyvinyl chloride	PVC	X	V4
3	Polyethylene	PE	2Y	E
4	Cross-linked polyethylene		2X	X
5	Low-pressure polyethylene	PE	2Yn	E2
6	Foam polyethylene	PE	02Y	
7	Polystyrene	PS	3Y	Q3
8	Polyamide	PA	4Y	Q4
9	Polytetrafluor ethylene	PTFE	5Y	E4
10	Perfluor ethylene propylene	PEP	6Y	E5
11	Ethylene tetrafluor ethylene	ETFE	7Y	E6
12	Polyimide	PI	8Y	Q5
13	Polypropylene	PP	9Y	E7
14	Polyvinyldene fluoride	PVDF	10Y	Q6
15	Polyurethane	TPU/PU	11Y	Q
16	Polyterephthalic acid ester	PETP	12Y	Q2
17	Polyester thermoplastic		13Y	
18	Perfluor ethylene oxyalkane	PFA	14Y	
19	Polychlorotrifluor ethylene	ECTFE	15Y	
	Elastomers			
20	Natural rubber	NR	G	R
21	Synthetic rubber	SR	G	R
22	Styrene-butadiene rubber	SBR	G	R
23	Silicon rubber	SIR	2G	S
24	Isobuthylene-isoprene rubber	IIR	3G	B3
25	Ethylene-propylene rubber	EPR/EPDM	3G	B
26	Ethylene vinylacetate	EVA	4G	G
27	Chloroprene rubber	CR/PCP	5G	N
28	Chlorosulfonated polyethylene	CSM	6G	N4
29	(Hypalon)			
30	Fluor elastomers		7G	
31	Nitrile butadiene rubber	NBR	8G	N5
32	Chlorated polyethylene	CM/CPE		

Table 4/24

Notes

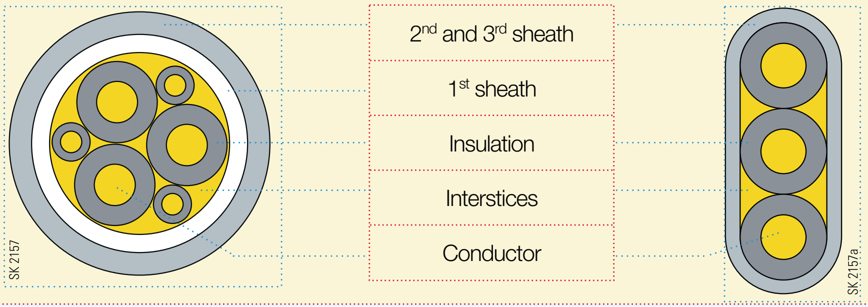
Y: Type designation for a thermoplastic material
G: Type designation for an elastomeric material
X: Type designation for a cross-linked thermoplastic material (the letter “X“ replaces the “Y“ in “2X“ for cross-linked polyethylene)
0: Additional designation for foam materials (the zero is placed in front of the relevant type designation, e.g. “02Y“ for foamed PE)

Compounds

In table 4/25, the compounds normally used for flexible electric cables for cranes and material handling equipment are compared to the compounds specified for these cables by DIN VDE standards. In many cases, a compound of a higher quality is used than that specified by DIN VDE standards.

Nowadays, the insulating and sheathing compounds of flexible electric cables are made almost exclusively of elastomeric materials. Thermoplastic materials have not been widely accepted. The great advantage of elastomers under heavy-duty operating conditions lies in their very good mechanical properties, such as reversible (elastic) force-elongation characteristic and their high resistance to abrasion and tear propagation. In addition, these compounds are excellently suited for unrestricted use outdoors. They are characterized by their good resistance to the weather, temperature variations, chemicals and their flame retardance.

Furthermore, elastomeric materials can be adapted to match their technical properties for particular applications. The elastomer EPR / EPDM with its high resistance to ozone and UV and its superior flexibility under cold conditions combined with excellent electrical characteristics is worthy of special mention as an insulating material. CORDAFLEX, PROTOLON, PLANOFLEX and RONDOFLEX employ this insulation material.
The tough, flame-retardant and weather-resistant PCP is a tried-and-tested sheathing compound for flexible electric cables. This sheathing compound is used in 5GM3 and 5GM5 quality for CORDAFLEX, PROTOLON, PLANOFLEX, RONDOFLEX and OPTOFLEX cables.
Exceptions are lift control cables, SPREADERFLEX and partly OPTOFLEX cables. Here, compounds such as PVC, ETFE and PU are used, which on account of their technical properties have been selected for these flexible cables for particular applications.



*1 Normally
*2 VDE certificate

Type of cable	Compounds to VDE				Prysmian compounds				Flexible cables
	Insulation	Interstices	Inner sheath	Outer sheath	Insulation	Interstices	1st sheath	2nd + 3rd sheaths	
Flexible reeling cables (N)SHTÖU	GI1		GM1b	5GM2	3GI3	5GM3	5GM3	5GM5	**CORDAFLEX(SMK)**
	NR/SR*1		SR*1	CR*1	EPR	PCP	PCP	PCP	
Flat rubber-sheathed cables NGFLGÖU	GI1	5GM2	5GM2	5GM2	3GI3	5GM3	5GM3	5GM3	**PLANOFLEX**
	NR/SR*1	CR*1	CR*1	CR*1	EPR	PCP	PCP	PCP	
Round rubber-sheathed cables NGRDGÖU					3GI3	GM1b	GM1b	5GM3	**RONDOFLEX**
					EPR	EPR	EPR	PCP	
Special flexible cable for gravity-fed collector basket operation YSLTÖ					YI2	Lead ball cords		11YM1	**SPREADERFLEX**
					PVC	Textile threads		PU	
Rubber-sheathed flexible fibre-optic cables					7YI1		5GM3	5GM3	**OPTOFLEX**
					ETFE		PCP	PCP	
H.V. reeling cables (N)TSCGEWÖU	3GI3		GM1b	5GM3	3GI3	5GM3	5GM3	5GM5	**PROTOLON(SMK)**
	EPR*1		SR*1	CR*1	EPR	EPR	EPR	PCP	
Lift control cables YSLTK			*2		YI2		(YM2)	YM2	**Lift control cables**
					PVC		(PVC)	PVC	

Table 4/25

Compounds

The specific requirements for the insulating and sheathing compounds used in flexible electric cables for cranes and material handling equipment are shown in table 4/26. The characteristics are specified in DIN VDE 0207 and allow a preliminary estimation of the properties of these compounds. Special compounds have been developed for the new generation of H.V. reeling cables.

The characteristics of this new generation are specified under CORDAFLEX(SMK) and PROTOLON(SMK) in table 4/26. Recently, tests were added relating to abrasion, resistance to tear and tear propagation, shore hardness and resistance to ozone and electrical values, such as loss factor and dielectric constant.

Requirements	Unit	Compound				**CORDAFLEX(SMK)**			**PROTOLON(SMK)**		
		Insulation	Sheath	Sheath	Sheath	Insulation	1st sheath	2nd + 3rd sheath	Insulation	1st sheath	2nd + 3rd sheath
		EPR	SR	PCP	PCP	EPR	EPR	PCP	EPR	EPR	PCP
		3GI3	GM1b	5GM3	5GM5	3GI3	5GM3	5GM5	3GI3	5GM3	5GM5
Max. permissible operating temperature of the conductor max.	°C	90	90	90	90	90	90	90	90	90	90
Tensile strength before ageing min.	N/mm²	4.2	4.2	10	15	6	10	15	10	10	15
Ultimate elongation before ageing min.	%	200	200	300	300	400	400	400	300	400	400
Ageing											
at	°C	135±2	100±2	100±2	100±2	135±2	100±2	100±2	135±2	100±2	100±2
over	d	7	7	7	7	7	7	7	7	7	7
Tensile strength after ageing min.	N/mm²	-	-	-	-	-	6	-		6	-
Change in tensile strength after ageing max.	%	±30	-	±30	±30	±30	±30	±30	±30	-	±30
Ultimate elongation after ageing min.	%	-	200	250	250	-	250	300	-	400	300
Change in ultimate elongation after ageing max.	%	±30	-	±40	±40	±30	±40	±30	±30	±20	±30
Abrasion max.	mm³	-	-	-	300	-	-	200	-	-	200
Tear resistance min.	N/mm	-	-	-	-	-	-	40	-	-	40
Resistance to tear propagation min.	N/mm	-	-	-	30	-	-	30	-	-	30
Shore hardness A min.			-	-	-	-	-	70	-	-	70
Thermal expansion											
at	°C	200±3	-	100±2	100±2	250±3	250±3	250±3	250±3	250±3	250±3
over	min	15	15	15	15	15	15	15	15	15	15
with	N/cm²	20	20	20	20	20	20	20	20	20	20
loaded max	%	175	175	175	175	100	100	100	100	100	100
relieved max.	%	25	25	25	25	15	25	25	15	25	25
Resistance to oil											
at	°C	100±2	-	100±2	100±2	-	100±2	100±2	-	-	100±2
over	h	24	-	24	24	-	24	168	-	-	168
with	bar	5.5±0.2	-	-	-	-	5.5±0.2	5.5±0.2	-	-	5.5±0.2
Change in tensile strength after storing in oil	%	±30	-	±40	±40	-	±40	±40	-	-	±40
Change in ultimate elongation after storing in oil	%	±30	-	±40	±40	-	±40	±40	-	-	±40
Resistance to ozone											
at	°C	-	-	-	-	40	-	40	40	-	40
over	h	-	-	-	-	72	-	72	72	-	72
Ozone concentration	pphm	-	-	-	-	200	-	200	200	-	200
Relative humidity	%	-	-	-	-	55	-	55	55	-	55
Flow velocity	mm/s	-	-	-	-	0.5	-	0.5	0.5	-	0.5
Requirements		-	-	-	-	No tearing	-	No tearing	No tearing	-	No tearing
Surface resistance at 20 °C min.	Ω	-	10^9	10^9	10^9	-	10^{10}	10^{10}	-	10^{10}	10^{10}
Volume resistance at 20 °C min.	Ω x cm	10^{12}	-	-	-	10^{15}	-	-	10^{16}	-	-
Volume resistance at 90 °C min.	Ω x cm	-	-	-	-	10^{12}	-	-	$5x10^{12}$	-	-
Dielectric constant at 20 °C min.	ε_r	-	-	-	-	3.2	-	-	2.8	-	-
Loss factor at 20 °C	tan δ	-	-	-	-	0.035	-	-	0.02	-	-

Table 4/26

Shield

The shield is a “barrier” against electromagnetic fields and protects electric signals against external signals. The aim is to weaken or stop unwanted signals to such an extent that the wanted data signals can be transmitted without interference in the endangered signalling conductor. There are three basic types of shield structure:

- Overall shield over several cores
- Shielded pairs
- Individually shielded cores.

The overall shield over several cores, usually placed between the inner and outer sheaths, necessitates use of a special design for flexible electric cables for cranes and material handling equipment in order to prevent destruction of the shield by tensile forces and compressive pressures occurring with frequent movement. This has been taken into account in design of RONDOFLEX(C) flexible cables for festoon systems.

Shielded pairs and individually shielded cores, on the other hand, have proven themselves in practice and are successfully used in CORDAFLEX, PLANOFLEX, RONDOFLEX, SPREADERFLEX and lift control cables.

Braided screens are characterized by their transfer impedance which is defined as the ratio of the voltage drop along the shield on the interfered side to the parasitic current on the other side. The transfer impedance R_K (DIN 40500) is given for a specific frequency in mΩ/m and is usually plotted with respect to frequency. The lower the transfer impedance of a shield, the better the screening effect. The transfer impedance of the braided screens usually used for flexible electric cables for cranes and material handling equipment is optimized at 30 MHz and is therefore focussed on data-processing quality.

A typical transfer impedance characteristic is shown in the diagram in Fig. 4/7.

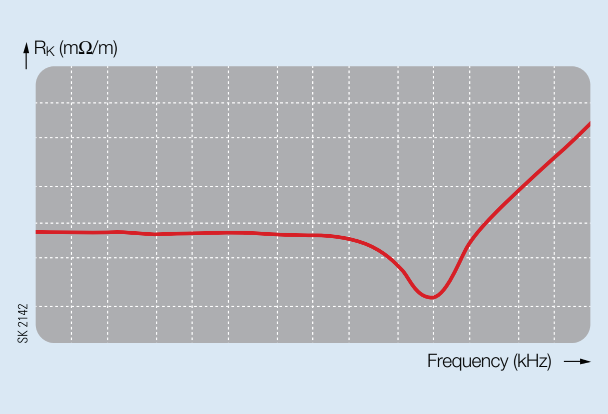


Fig. 4/7

Field control

The cores of PROTOLON H.V. reeling cables of voltage level 3 kV and above are always equipped with inner and outer semiconductive layers made of semiconductive rubber.

The inner and outer semiconductive layers are extruded with the insulation in a single-pass operation. Secure bonding to the insulation is obtained as a result of this method of extrusion.

The inner semiconductive layer prevents build-up of excessive electrical field strength at the individual wires of the flexible conductor and partial discharges between the conductor and the insulation.

The outer semiconductive layer serves as a core shield and performs the following tasks:

- Protection against electric shock
- Avoidance of partial discharges in the conductor assembly
- Generation of the radial electrical field in the insulation
- Discharge of current in the event of a fault.

The core shield is thus an integral component of the protective-earth conductor.

The resistance between the protective-earth conductor and any point on the outer semiconductive layer must not exceed 500 Ω. The protective-earth conductor, which touches the core shield, is covered with semiconductive rubber and ensures longitudinal conductivity of the system. Fig. 4/8 shows the cross-section of a PROTOLON H.V. reeling cable with inner and outer semiconductive layers.

In addition to the electrical requirements, the core shield in flexible electric cables for cranes and material handling equipment must also be able to cope with the high (sometimes very high) mechanical stresses.

Metal shields are more liable to become defective when used in flexible electric cables for cranes and material handling equipment and are inferior to shields made of semiconductive rubber material.

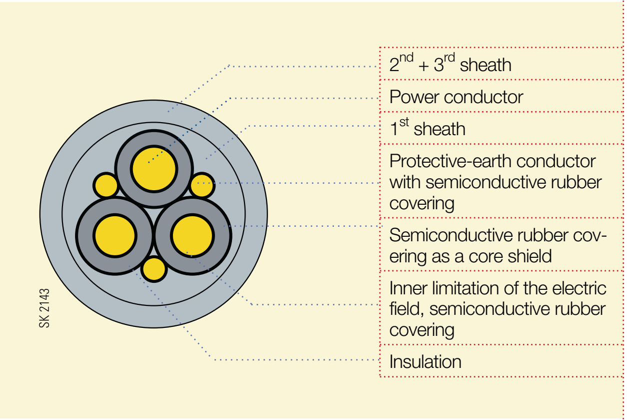


Fig. 4/8

Core arrangement

The basic criteria of the core arrangement for flexible electric cables for cranes and material handling equipment are summarized in the adjacent table.

In round flexible electric cables, the individual cores are arranged by laying them up. Up to three cores are laid up without a central element. Four cores and above are laid up around a centre, which can also consist of three-core stranded elements.

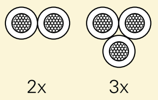
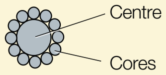
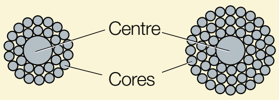
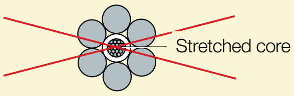
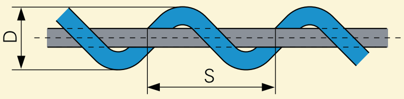
A stretched core in the centre of the flexible cable (as the actual centre or placed in the centre) is not permitted according to the DIN VDE standards. A stretched core at the centre of the flexible cable would quickly result in premature failure of the conductor due to breakage, especially in flexible electric cables for cranes and material handling equipment.

A maximum of three core layers is best for the conductor assembly. Investigations have shown that, if there are more than three layers, the internal stability of the flexible cable and in consequence the service life is reduced as a result of increasing secondary and relative forces between the cores.

The length of lay S is a design feature used for laying up the conductor assembly (see table 4/28) and influences the bending flexibility and the bending stability. The length of lay is an important factor for the service life of flexible electric cables for cranes and material handling equipment.

In the case of flat flexible cables, laying up is not usually necessary as the cores are arranged parallel to each other. Flat flexible cables with laid up bundles represent an exception to this rule. This special form of core arrangement is selected for large numbers of cores in order to ensure the required stability of the flat cables.

Round flexible cables

	Laying up of two to three cores without a centre
	Laying up of four or more cores with centre Special design: the centre comprises three cores
	Maximum three-layer design (standard up to 56 cores)
	A stretched core in the centre of a flexible cable is not permitted
	The length of lay S is the length, measured in the direction of the lay, over which a core circumscribes 360° around the laying axis. It is given as a multiple of the diameter D over the conductor assembly, e.g. S = 8 x D.

Flat flexible cables

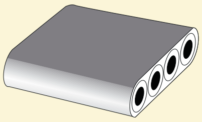
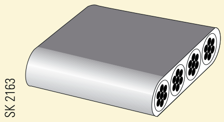
	Parallel arranged cores
	Cores laid up in bundles (refer to round flexible cables), parallel arranged bundles

Table 4/28

Colour designation of the fibre-optics

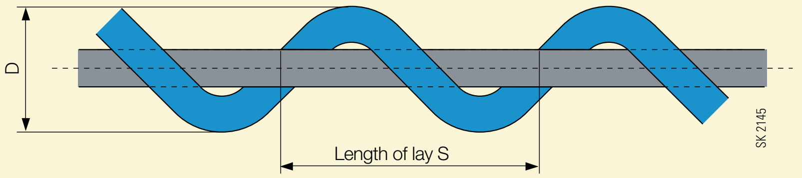
	No. of fibres	Fibre colour	Hollow core colours
Monomode design E9/125 µm	**6 x 1E9/125**	OG / BN / WH / RD / BK / **YE**	6 x nf
	6 x 2E9/125	OG-PK / BN-PK / WH-PK / RD-PK BK-PK / **YE**-PK	6 x nf
	6 x 3E9/125	BU / OG / GN	**YE** / BK / nf / nf / nf / nf
Graded-index fibre design G50/125 µm	**6 x 1G50/125**	OG / **GN** / BN / WH / RD / BK	6 x nf
	6 x 2G50/125	OG-PK / **GN**-PK / BN-PK / WH-PK RD-PK / BK-PK	6 x nf
	6 x 3G50/125	BU / OG / GN	**GN** / BK / nf / nf / nf / nf
Graded-index fibre design G62.5/125 µm	**6 x 1G62.5/125**	**BU** / OG / BN / WH / RD / BK	6 x nf
	6 x 2G62.5/125	**BU**-PK / OG-PK / BN-PK / WH-PK RD-PK / BK-PK	6 x nf
	6 x 3G62.5/125	BU / OG / GN	**BU** / BK / nf / nf / nf / nf

nf = natural colouring

Bold-faced colour designations are indices relative to the fibre type

Core arrangement

Table 4/29 shows the normal lengths of lay in flexible electric cables for cranes and material handling equipment.



Type of cable	Length of lay of cores for Pirelli flexible electric cables for use on cranes and material handling equipment	Flexible cables
Flexible reeling cables (N)SHTÖU	5 x D	**CORDAFLEX(SMK)**
Flat rubber-sheathed flexible cables NGFLGÖU	Parallel arranged cores or bundles	**PLANOFLEX**
Round rubber-sheathed flexible cables NGRDGÖU	10 x D	**RONDOFLEX**
Special flexible cables for gravity-fed collector basket operation YSLTÖ	Individual cores laid up in bundles 15 x D Bundles laid up around the centre 10 x D	**SPREADERFLEX**
Rubber-sheathed flexible fibre-optic cables	Especially laid up around a GFK support element	**OPTOFLEX**
H.V. reeling cables (N)TSCGEWÖU	7 x D	**PROTOLON(SMK)** **PROTOLON(SMK) LWL**
Lift control cables YSLTK	30 m suspension length 12 x D 50 m suspension length 12 x D 150 m suspension length Individual cores 9 x D Bundles 8 x D	**Lift control cables**

Table 4/29

Support elements

Flexible electric cables for cranes and material handling equipment should **not** be stressed above the limits set out in table 4/11 (page 4/14) for the permissible tensile forces. If higher tensile forces are to be expected, support elements have to be provided as part of the structure of the cable. There are several possibilities for integration of support elements in cables.
Two variants are normally used:

- A support element located in the centre of the cable
  or
- A braid between the inner and outer sheath

The force/elongation diagram in Fig. 4/9 shows the characteristic of these cables with different arrangements of support elements as compared to a cable without a support element.

After a compacting phase, in which the individual cable elements are initially pulled together, until the copper conductor begins to bear the tensile force, the cable without a support element remains linear in the first section of the curve (curve C). In the next phase elongation increases considerably on a slight increase of force.
Cables with a braid as a support element between the inner and outer sheath behave in the first section of the curve (curve B) in a similar manner to cables without a support element. The braid becomes effective as a support element and bears the applied force only after the force and the consequent elongation have increased over a certain period of time. The tensile force which is borne increases with less elongation than that of the cable without a support element. The braid as a support element can prevent the cable, e.g. from tearing.

Cables with a central support element behave differently provided that the support element was correctly dimensioned. The support element bears the tensile forces from the very beginning and thus relieves the copper conductor (curve A).

The force/elongation characteristics of the support elements and of the copper conductors are decisive for correct design of the support element and dimensioning of the flexible cables. The actual design should be worked out in close co-operation with the cable manufacturer.

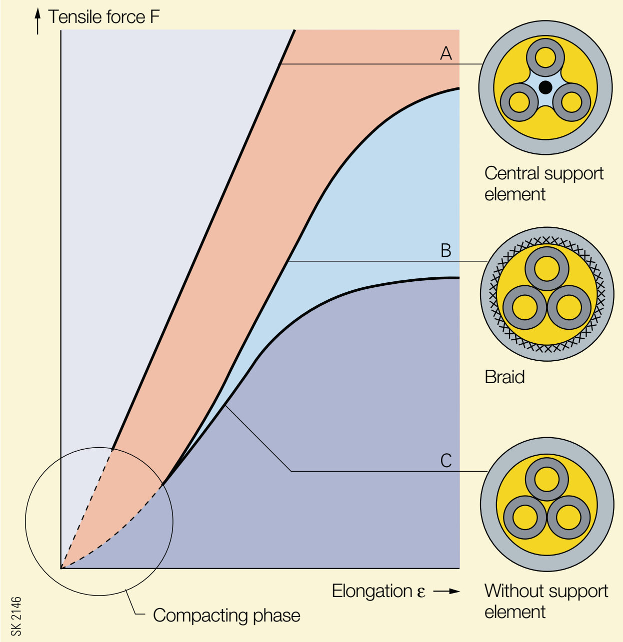


Fig. 4/9

Anti-torsion braid

Flexible electric cables for cranes and material handling equipment are often fitted with an anti-torsion braid between the inner and outer sheath in order to minimize twisting under torsional loads.
This applies to CORDAFLEX(SMK), PROTOLON(SMK) and lift control cables.

An anti-torsion braid is not used for PLANOFLEX (not possible for this particular type of cable), RONDOFLEX (not necessary for the application involved) and SPREADERFLEX (fully designed for best torsional properties).

The effect of an anti-torsion braid on the angle of torsion α with increasing torsional moment for comparable cables with and without an anti-torsion braid is shown in Fig. 4/10.

The flexible cable with anti-torsion braid tends to twist less than the flexible cable without a braid for the same torsional moment.

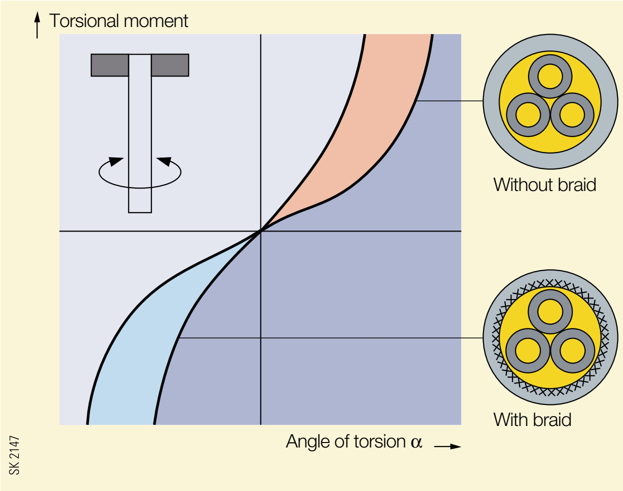


Fig. 4/10

Marking

Prysmian flexible electric cables for cranes and material handling equipment are marked on the outer sheath as shown in table 4/30.

In addition, some flexible cables contain company identification threads and/or VDE identification threads.

Flexible cables	Type	Marking on outer sheath	Company identification thread	VDE identification thread
CORDAFLEX(SMK) /-V	(N)SHTÖU	CORDAFLEX(SMK) /-V (N)SHTÖU-J/-O (number of cores) x (cross-section)	In the core assembly	In the core assembly
PLANOFLEX	NGFLGÖU	<VDE> PLANOFLEX NGFLGÖU-J/-O (number of cores) x (cross-section) 600 V 90 °C (UL) PLANOFLEX (AWG No.)AWG/(number of cores) (core type) OUTDOOR	In core 1 or in the green/yellow core	
RONDOFLEX	NGDGÖU	RONDOFLEX NGRDGÖU-J/-O (number of cores) x (cross-section)(0.6/1 kV VDE Reg. No.)	Under the sheath or insulation	No
SPREADERFLEX	YSLTÖ	SPREADERFLEX YSLTÖ-J (number of cores) x (cross-section)	In the core assembly	No
OPTOFLEX		(Year of manufacture) OPTOFLEX 6G62.5 or 50/125 micron Germany P-MSHA-SC 189/1	No	No
PROTOLON(SMK) **PROTOLON(SMK) LWL**	(N)TSCGEWÖU (N)TSKCGEWÖU	<VDE> PROTOLON(SMK) (N)TS ..(number of cores) x (cross-section) (rated voltage) (Year of manufacture) (serial number)	No	No
Lift control cable	LYSLTK YSLTK YSLYTK-JZ and YSLYCYTK-J	LYSLTK-30 m YSLTK-50 m	In the core assembly	No

Table 4/30

Cable Drum Overview

Drum Size	Weight kg	Dimensions Ø x width cm	Volume m^3
051	9	50 x 46	0.09
071	23	71 x 48	0.19
081	28	80 x 52	0.26
091	45	90 x 70	0.45
101	68	100 x 89	0.70
121	132	125 x 89	1,09
141	159	140 x 89	1.37
161	247	160 x 100	2,01
181	296	180 x 110	2,80
200	487	200 x 135	4,24
220	653	224 x 138	5.44
250	759	250 x 148	7.26
281	1051	280 x 164	10.10
300	1240	300 x 176	12.14
230	1340	320 x 225	18.10
340	2600	340 x 225	20.43

Comparison

Cross Section metrical mm^2	mm^2	AWG-Sizes 1)
0.75	0.823	**18**
1.5	1.31	**16**
2.5	2.08	**14**
4.0	3.31	**12**
6.0	5.26	**10**
10.0	8.37	**8**
16.0	13.30	**6**
25.0	21.15	**4**
35.0	33.63	**2**
50	53.48	**1/0**
70.0	67,43	**2/0**
95.0	107.20	**4/0**
120.0	126,64	**250 MCM**
150.0	152.00	**300 MCM**
	177,35	**350 MCM**
185.0	202.71	**400 MCM**
240.0	253.35	**500 MCM**
300.0	380.00	**750 MCM**
400.0		
500.0	506.71	**1000 MCM**
625.0		

1) AWG American Wire Gage

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