TECHNICAL APPENDIX

Comprehensive Mining Cable Solutions

prysmian

The planet's pathways

DOWN TO THE CORE

Powering the Future of Mining

The mining industry demands power, control, and reliability in the harshest conditions. Prysmian delivers cutting-edge cable solutions engineered for durability, safety, and superior performance – whether in opencast, underground mining, or tunneling. Our advanced technology ensures seamless operation in the most extreme environments, meeting the needs of OEMs, contractors, installers, and mining companies worldwide.

COMPREHENSIVE CABLE SOLUTIONS FOR MINING & TUNNELING

Prysmian provides a full range of cables for both fixed installations and movable equipment, ensuring efficient power transmission and operational safety. With decades of expertise and close collaboration with leading mining companies, we continuously innovate to meet the evolving demands of the industry.

Why Choose Prysmian Mining Cables?

Our mining and tunneling cables are designed to excel in demanding applications, offering numerous benefits:

- **EXTENDED LIFE SPAN**
  Engineered for longevity, reducing down-time and maintenance costs.
- **SUPERIOR CLIMATE & CHEMICAL RESISTANCE**
  Withstanding extreme temperatures, oil, fuel, moisture, acids, and bases, as well as UV irradiation and ozone.
- **UNMATCHED MECHANICAL STRENGTH & FLEXIBILITY**
  Designed for high-speed reeling, acceler-ation, extreme bending, torsional loads, and misalignment.
- **COMPACT & LIGHTWEIGHT DESIGN**
  Up to 30% reduction in cable size and 40% weight reduction without com-promising performance.
- **TAILORED ENGINEERING**
  Customized solutions for specific mining requirements, including LV/MV, instrumentation, and optical fibre cables.
- **ENHANCED SAFETY STANDARDS**
  High-grade rubber sheathing ensur-ing optimal mechanical resistance and protection against harsh mining conditions.

ENGINEERED FOR THE TOUGHEST MINING APPLICATIONS

1. Opencast & Underground Mining
Large-scale mining operations rely on highly mobile, heavy-duty machinery that requires flexible and durable power cables. Prysmian provides Medium Voltage (MV) reeling and trailing cables, specially designed to perform under extreme stress, ensuring efficient power distribution for excavators, drills, and conveyor systems.

2. Tunneling: Beyond Mining
Tunneling technology is essential not only in mining but also in critical infrastructure projects worldwide, including subway systems and high-speed rail networks. From the Channel Tunnel to San Gottardo, Prysmian cables power the world's most challenging tunneling projects.

PROVEN RELIABILITY, WORLDWIDE

With manufacturing facilities strategically located near major mining regions across all continents, Prysmian ensures local availability, rapid delivery, and expert support. Our cables have been field-tested and proven in global mining and tunneling applications, reinforcing Prysmian's position as the trusted partner for the industry's most demanding projects.

PRYSMIAN: DRIVING MINING INNOVATION

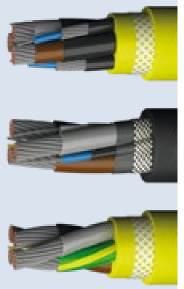
As the mining industry evolves, efficiency, safety, and sustainability are paramount. With our state-of-the-art cable solutions, we power the future of mining and tunneling, ensuring operational excellence in even the most challenging environments.
Explore Prysmian's mining and tunneling cable solutions and experience unmatched durability, reliability, safety, and performance down to the core.

INDEX

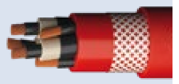
TYPE DESIGNATION

The type designates a group of flexible 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 in conformity with DIN VDE, which describes the type in coded form.

NSHTOEU
LHD cables for scoop operations: Tough rubber-sheathed 1 kV flexible reeling cable – CORDAFLEX (S), TENAX LK, PROTOMONT (S).

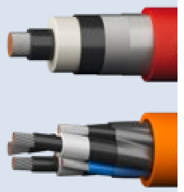


R-(N)TSCGEWOEU
Medium-voltage reeling cable, 6 to 30 kV – PROTOLON (M).



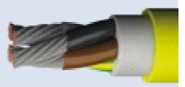
F-(N)TSCGEWOEU
Medium-voltage flexible cable, 6 to 30 kV – PROTOLON (M).

NTSCGEWOEU
Trailing cables, 3 to 35 kV – PROTOLON and TENAX.

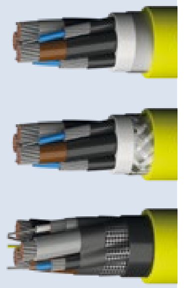


(N)SHOEU
Heavy tough rubber-sheathed flexible cable, 1 kV, for applications in opencast mining – PROTOMONT (M).

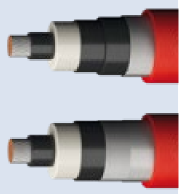
NSSHOEU
Heavy tough rubber-sheathed flexible cable, 1 kV, for applications in underground mining – PROTOMONT.



NSSHCGEOEU
Coal cutter cables for underground mining applications – PROTOMONT(Z), PROTOMONT(V) and TENAX CTE.



NTMCGCWOEU / NTMCWOEU
Trailing cables of single-sheath design for medium mechanical stresses.



(N)3GHSSYCY
EPR-insulated medium-voltage cables for fixed installation – SUPROMONT.

(N)3GHSSYCY
EPR-insulated medium-voltage cables for fixed installation – SUPROMONT.

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 mm² individually shielded or 6 x (2 x 1) C which means 2 x 1 mm² 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
F-	Definition of the application: Fixed installation, as supplement to the type designation
FM	Telecommunication lines within the cable
G	High-voltage (HV)
-J	Additional information about the type: With green/yellow marked core
...K...	Rubber cradle separator in the centre of the cables
KON	Concentric protective conductor between the inner and outer sheath or concentric control/ monitoring conductor
L...	Lightweight cable design
LWL	Fibre-optic (FO)
(M)	Appendix to trademark, "M = Mining"
N	Design according to the corresponding standard
(N)	Based on standard
-O	Additional information about the type – without green/yellow marked core
Ö*	Oil-resistant outer sheath (according to DIN VDE 0473, Part -2-1, Para. 10) (OE)
R-	Definition of application: Reeling, as appendix to the type designation
(SB)	Appendix to trademark: Trailing operation
..SH..	Heavy tough rubber-sheathed flexible mining-type cable (Rough handling)
...SHT...	1 kV reeling cable
..SL..	Control cable
ST	Control cores within the cables
(ST)	Appendix to trademark to denote water compatibility (submersible pump units)
..T..	Support element
..TM..	Trailing cable for medium mechanical stresses
..TS..	Trailing cables
U	Flame-retardant outer sheath (according to EN 60332-1-2)
ÜL*	Monitoring conductor within the cable (UEL)
(V)	Appendix to trademark for coal cutter cables (V = reinforced)
..W..	Weather resistant
Y	PVC compound
(Z)	Appendix to trademark for coal cutter cables (Z=tensile strength optimized)
2Y...	Definition of the insulation material (2Y = PE)
/3	Protective-earth conductor uniformly distributed in the three interstices
/3E	Protective-earth conductor uniformly distributed over the insulation of the outer conductor
..3G..	Definition of the insulating material (3G = EPR)

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

APPROVALS / STANDARDS

Flexible electric cables for mining applications 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 mining applications are described with regard to designs 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 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 opencast mines, quarries and similar works

IEC 621
Electrical installations for outdoor sites under heavy conditions (incl. opencast mines and quarries)

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 one of a few countries which has issued special design regulations for flexible electric cables for mining applications. The 1 kV tough rubber-sheathed flexible reeling cables NSHTOEU, the trailing cables NTS..WOEU and the rubber-sheathed flexible cables NSSHOEU are described and standardised in DIN VDE 0250.

INTERNATIONAL STANDARD

For use on an international level, some design features of flexible electric cables for mining applications covered by DIN VDE are also listed or certified.

MSHA
Mine Safety and Health Administration, USA

MA CHINA
Chinese mining approval

WUG
Approval of the Polish Mining Inspectorate, necessary for use of cables in Polish mines

BAS CERTIFICATE
Approval of the Institute for standardization of Bosnia and Herzegovina

EAC CERTIFICATE
Safety regulation for LV-cables in Russia, Belarus, Kazakhstan

FIRE CERTIFICATE
Russian Mining approval

GOST -R
Mining approval of Russian Federation for cables > 1 kV

GOST -B
Mining approval of Republic of Belarus for cables > 1 kV

GOST -K
Mining approval of Kazakhstan for cables > 1 kV

BIS CERTIFICATE
A BIS (Bureau of Indian Standards) certificate is a mandatory requirement for products to be exported to and sold in India

DESIGN REGULATIONS / STANDARDS

Flexible cables	Type	German standard DIN VDE	Certificates/Approvals
CORDAFLEX(S)	NSHTOEU	DIN VDE 0250-814	MSHA P-189-3, EAC certificate
FELTOFLEX	NTMCWOEU	DIN VDE 0250-813	Fire certificate, Gost -R/-K/-B
OPTOFLEX(M)	–	Based on DIN VDE 0888 and DIN VDE 0168	–
PROTOLON single-core	NTMCGCWOEU	DIN VDE 0250-813	Fire certificate, Gost -R/-K/-B
PROTOLON(M) single-core	(N)TMCGCWOEU	Based on DIN VDE 0250-813	Fire certificate, Gost -R/-K/-B
PROTOLON(M)	F-(N)TSCGEWOEU	Based on DIN VDE 0250-813	Fire certificate, Gost -R/-K/-B
PROTOLON(M)	R-(N)TSCGEWOEU	Based on DIN VDE 0250-813	Fire certificate, Gost -R/-K/-B
PROTOLON(M) with F.O.	R-(N)TSCGEWOEU	Based on DIN VDE 0250-813	Fire certificate, Gost -R/-K/-B
PROTOLON(SB)	NTSCGEWOEU	DIN VDE 0250-813	Gost -R/-K/-B
PROTOLON(SB-SAM)	(N)TSCGEWOEU	Based on DIN VDE 0250-813	Fire certificate, Gost -R/-K/-B
PROTOLON(ST)	NTSCGEWOEU .../3E	DIN VDE 0250-813	Fire certificate, Gost -R/-K/-B
PROTOLON(ST)	NTSCGEWOEU	DIN VDE 0250-813	Fire certificate, Gost -R/-K/-B
PROTOMONT	NSSHOEU	DIN VDE 0250-812	MA – China, MSHA P-189-3, EAC certificate
PROTOMONT	NSHXOEU	Based on DIN VDE 0250-812	–
PROTOMONT	NSSHOEU .../3E	DIN VDE 0250-812	MA-China, MSHA P-189-3, BAS certificate, EAC certificate
PROTOMONT festoon	NTSKCGECWOEU	DIN VDE 0250-813	MA – China, WUG – Poland, BAS certificate, Fire certificate, Gost -R/-B/-K
PROTOMONT EMV-FC	(N)SSHCOEU	Based on DIN VDE 0250-812	MSHA P-189-3, EAC certificate
PROTOMONT(M+)	(N)SHOEU	Based on DIN VDE 0250-812	–
PROTOMONT(MSR)	2YSLGCGOEU	Based on DIN VDE 0250-1	EAC certificate
PROTOMONT(MT)	(N)SSHOEU	Based on DIN VDE 0250-812	VDE-REG F546
PROTOMONT(V)	NSSHCGEOEU	DIN VDE 0250-812	MA – China, MSHA P-07-KA140034-MSHA, BAS-certificate, EAC certificate
PROTOMONT(V)	NTSKCGECWOEU	DIN VDE 0250-813	MA – China, MSHA P-07-KA140034-MSHA, WUG – Poland (6 kV only), Fire certificate, Gost -R/-K/-B
PROTOMONT(VO)	(N)TSKCGEWOEU	Based on DIN VDE 0250-813	MA – China, Gost -R/-K/-B
PROTOMONT(S)	(N)SSHCGEOEU	Based on DIN VDE 0250-812	MA - China, EAC certificate
PROTOMONT(Z)	NSSHKCGEOEU	DIN VDE 0250-812	MA – China, MSHA P-07-KA140034-MSHA, BAS certificate, EAC certificate
PROTOMONT TBM	(N)TSCGECWOEU	Based on DIN VDE 0250-813	Fire certificate, Gost -R/-K/-B
PROTOMONT TBM	(N)TSCGECWHXOEU	Based on DIN VDE 0250-813	Fire certificate, Gost -R/-K/-B
SUPROMONT	(N)3GHSSYCY	Based on DIN VDE 0250-605	VDE certificate of conformity
SUPROMONT	(N)3GHSSHCH	Based on DIN VDE 0250-605	VDE certificate of conformity
TENAX-CTE	NSSHKCGEOEU	DIN VDE 0250-812	EAC certificate
TENAX-HTT	(N)TSCGEWOEU	Based on DIN VDE 0250-813	Fire certificate, Gost -R/-K/-B
TENAX-LK	NTSKCGEWOEU	DIN VDE 0250-812	EAC certificate
TENAX-LUMEN	(N)TSCGEH3S	Based on DIN VDE 0250-813	–
TENAX-SAS	NTSCGEWOEU	DIN VDE 0250-813	Fire certificate, Gost -R/-K/-B

COLOUR CODING OF FIBRE-OPTICS

	No. of fibres	Fibre colours	Buffering tube 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 **GN**-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

Bold-faced colour codings are indices relative to the fibre type.

COLOUR CODE

BU Blue	BK Black	nf natural colouring
OG Orange	YE Yellow	BU-PK Blue-Pink
GN Green	VI Violet	OG-PK Orange-Pink
BN Brown	PK Pink	BN-PK Brown-Pink
WH White	TQ Turquoise	WH-PK White-Pink
RD Red	CY Cyan	GN-PK Green-Pink

INSTALLATION AND HANDLING

Reeling cables

WINDING FROM SUPPLY DRUM TO THE OPERATION DRUM

- Supply drum in parallel position to the operation drum
- Min. 4 m between two bendings
- Use operation guiding system to wind the cable on the operation drum
- No S-bendings
- No torsion
- Watch the max. tensile load during the rewinding process

Note! Never draw the cable over the flange “head over heels”, because this would cause 360° torsion with each loop.

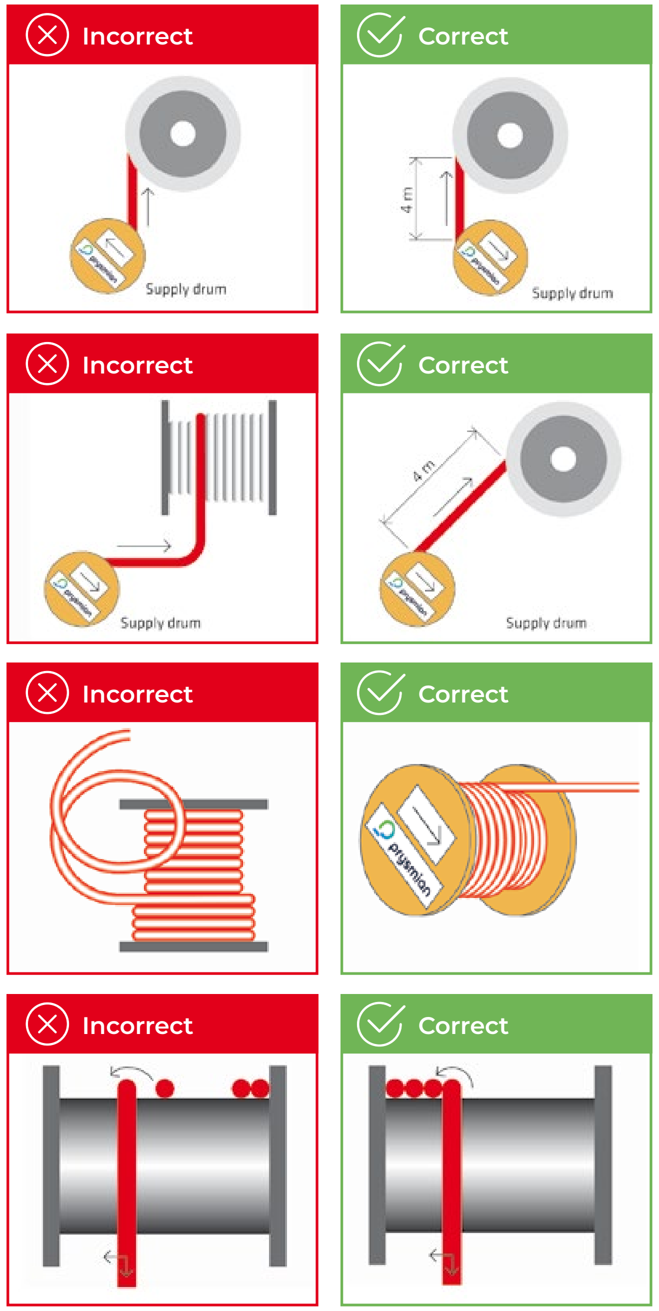
START WINDING ON CYLINDRICAL REELS

- Power cables – first loop (winding) at the left flange
- Control cables – first loop (winding) at the right flange

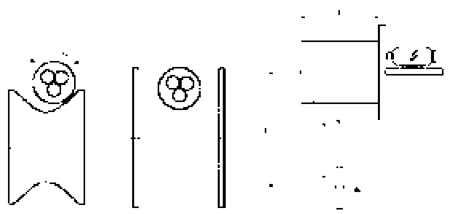
DURING OPERATION

- Tensile load – the max. tensile load is given in the corresponding cable data sheet
- Bending radius – see table below
- Torsional stress – may be caused by transversal moving in the sheaves or by misaligned guiding systems

Minimum permissible bending radius (for cable D_L > 20 mm)	
Fixed installation	6 x D_L
Fully flexible operation	10 x D_L
Entry e.g. at a centre feeding point	10 x D_L
Forced guidance with reeling operation	12 x D_L
Forced guidance with sheaves	15 x D_L



D_L = cable diameter



Transportation and handling on site

TRANSPORTATION ON SITE

- Either on the original supply drum or by using a transportation container or on a truck platform
- By using a transport container or the truck platform the cable has to be inserted in “8-shapes”

CABLE HANDLING ON SITE

- Pulling out of the transportation container and laying on the ground only manually
- Do not drag the cable over the flange when removing from the drum, because this would cause 360° torsion with each loop
- Do not undercut the minimum bending radius
- No torsion
- Do not kink the cable
- Watch the max. tensile load during the whole installation process

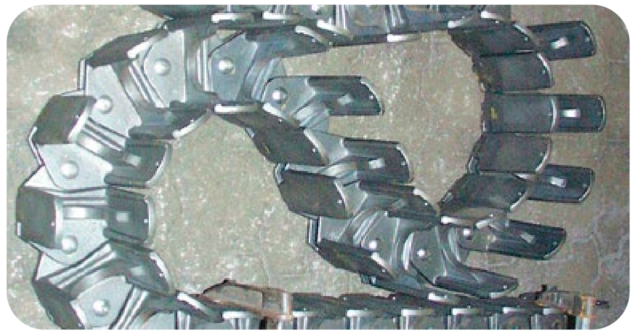
Note! Never draw or drag the cable by using the excavator or hoist equipment

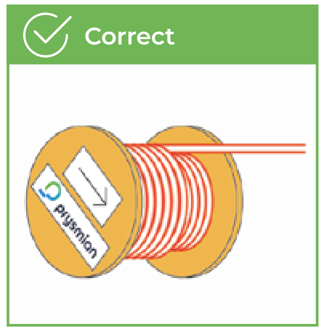
DURING OPERATION

- Use a cable strain relief to fix the cable at the top of the pole
- Use a pulling bow for moving the cable over the ground
- Do not exceed the maximum tensile forces during pulling the cable over ground

GUIDELINES FOR A LONG LIFETIME OF TRAILING CABLES

- Periodical control of the cable with respect to damages, squeezing and crushing
- Damages in the outer sheath should be repaired immediately by using a self-vulcanizing tape in order to avoid moisture penetration into the cable
- Avoid high tensile forces to the cable
- Avoid kinking and twisting the cable





INTEGRATION OF PROTOMONT (V); (VO) AND TENAX CTE INTO THE CABLE CHAIN (CABLE HANDLER)

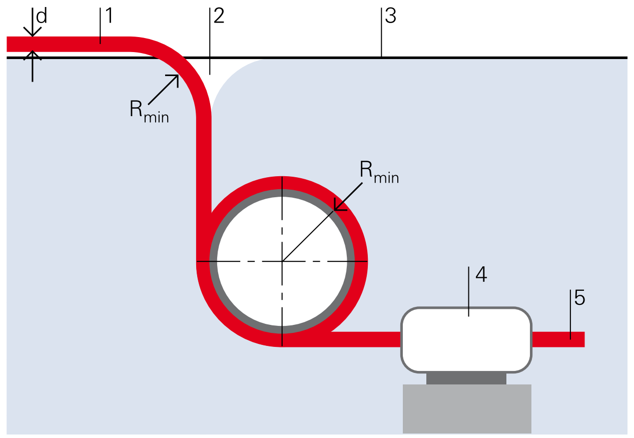
- The cable should have high latitude (mobility) in the chain along the complete length
- The cable should lay uncongested in the chain: means no clamping along the length. 3 mm to 5 mm distance between cable and chain is required
- Don’t use any cable straps to fix the cable at the chain
- The cable should have only one fixing point in the chain; directly behind the machine

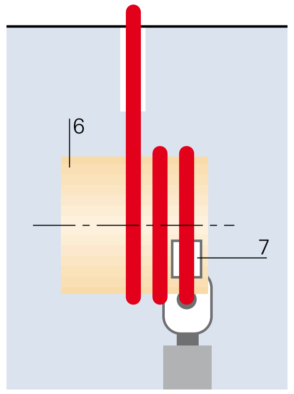
GUIDELINES FOR A LONG LIFETIME OF CHAIN CABLES

- Tensile force monitoring or shear pin (bolt) should be used to protect the cable against exceeding tensile forces
- The spill plate should be cleaned periodically from coal and rocks in order to guarantee a free trailing of the cable and the cable handler (cable chain)
- Periodical control of the cable with respect to damages, squeezing and crushing
- Damages in the outer sheath should be repaired immediately by using a self-vulcanizing tape in order to avoid moisture penetration into the cable.

Centre feeding point

Many installations, e.g. bunkering equipment, have the power infeed point located at the centre of the guideway. The flexible electric reeling cables are connected through underfloor infeeds (see picture "Underfloor infeeds").
To achieve effective strain relief in conjunction with cable-wear minimising deflection from the infeed point, we recommend the use of underfloor infeeds (see figure). It is important that the specified bending radius is maintained and that the cable is fastened at the compensation cylinder by means of a clip, which, however, should be attached only after the 2nd winding.





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
   Rmin = Bending radius of entry bell and bending radius of compensation cylinder

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

Determination of the sag on mast mounting

Flexible cables must sometimes be suspended above guideways (see picture below, right side). The minimum permissible bending radius at the cable suspension point and of the max. permissible tensile force for each type of cable design must be observed.

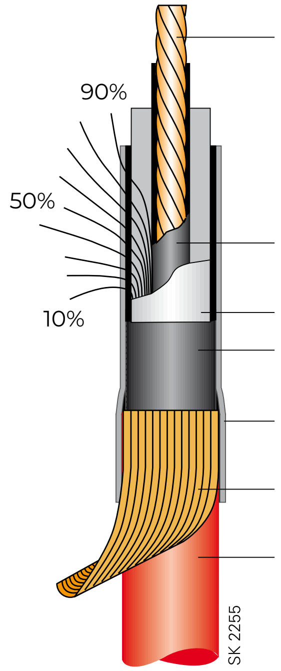
Underfloor infeeds

Cable suspended above guideways

Electrical field control in hybrid sealing ends

In order to control the electrical field in medium-voltage cables, the use of an inner semiconductive layer is required, which is applied as a smoothing layer directly on the metallic conductor, the insulation covering and the outer semiconductive layer, which is in contact with the protective-earth conductor. In cable systems the sealing ends are assigned the task of containing the electrical field.

Our hybrid sealing ends, which are specially designed for the operational requirements of flexible electric cables for mining applications, operate on the principle of resistive electrical field control, which achieves potential reduction as a result of the ohmic and capacitive characteristics and thus reduces the electrical field strength to an acceptable level over the length of the serving.



Stripping semiconductive layers

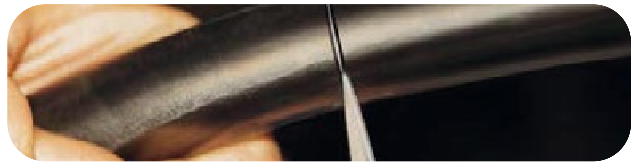
In the case of PROTOLON and TENAX with bright (light grey) core insulation, the semiconductive rubber layer over the insulation must be stripped carefully in order to mount the cable sealing end. To this end, the stripping point is marked and a circular indentation is made on the cable by slightly pressing a pipe cutter (picture 1).

Make a notch at the stripping point by means of a triangular-section file while bending the cable slightly. It is important hereby that the bright core insulation should not be damaged (picture 2).

Carefully cut through approx. 2/3 of the semiconductive rubber layer using between two to four longitudinal cuts. Warm the core end slightly using a propane gas flame and lift off the semiconductive layer at the end of the core using a wood rasp. Strip off the semiconductive layer in strips and remove it completely (picture 3).

Note! Problems can arise when stripping off the semiconductive layer due to tearing out of part of the insulation layer. In such case, the stripping procedure must be started from the opposite side. Use a smooth file, where necessary.

picture 1



picture 2

picture 3

STRIPPING SEMICONDUCTIVE COLD-STRIPPABLE LAYERS (ORANGE INSULATION COLOR)

The distinguishing feature of these cables is the cold-strippable semiconductive layer. In this case heating by means of a propane gas flame can be omitted completely. The work sequence should otherwise be carried out as described above.

Sealing ends

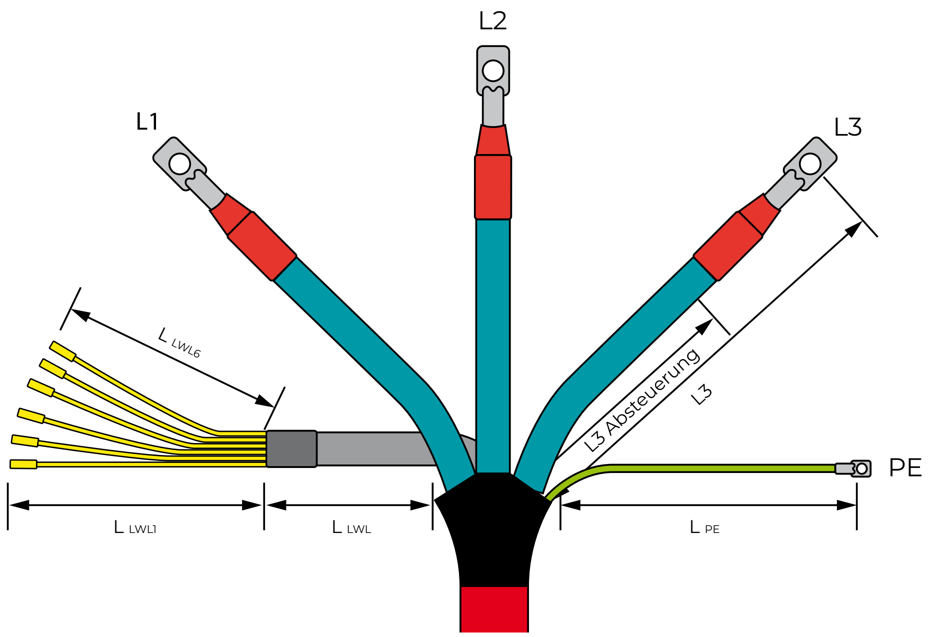
Sealing ends form the termination point of a medium voltage cable and serve as a connection to the electrical equipment (e.g. switchgears etc.).

SEALING ENDS COVER THE FOLLOWING OBJECTIVES:

- Connection of the conductor
- Sealing of the cable end against ambient influences (e.g. ingress of water)
- Controlled decrement of the electrical field strength
- Insulation from earthed parts

FOR THE COMPLETE RANGE OF PROTOLON, PROTOMONT AND TENAX MEDIUM VOLTAGE MINING CABLES PRYSMIAN OFFERS:

- Sealing end material sets for self-installation on site
- Termination in the factory according to customer specification



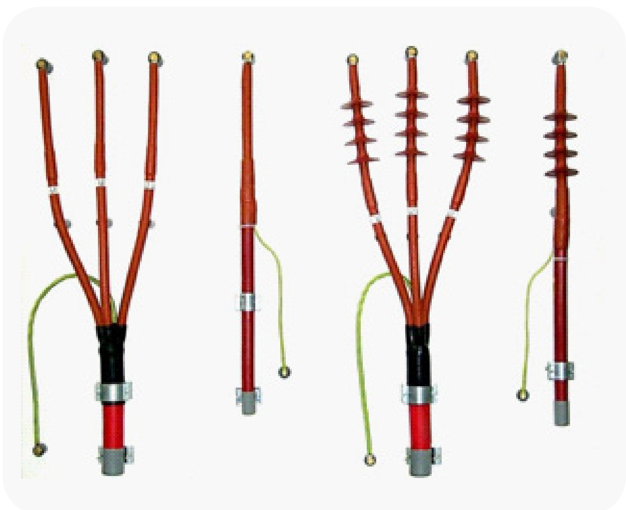
Core length:
L1:
L2:
L3:
LPE:

Borehole cable lug:
L1 ... L3: 16 Ø mm
PE: 12 Ø mm

FO-plug type:

Length of FO-element (mm)
LLWL:
LLWL1:
LLWL2:
LLWL3:
LLWL4:
LLWL5:
LLWL6:
LLWL7:
LLWL8:
LLWL9:
LLWL10:
LLWL11:
LLWL12:

The distances L_1, L_2, L_3 and PE are calculated between spread head and the center of the borehole cable lug.



Special sealing end termination for connection box.

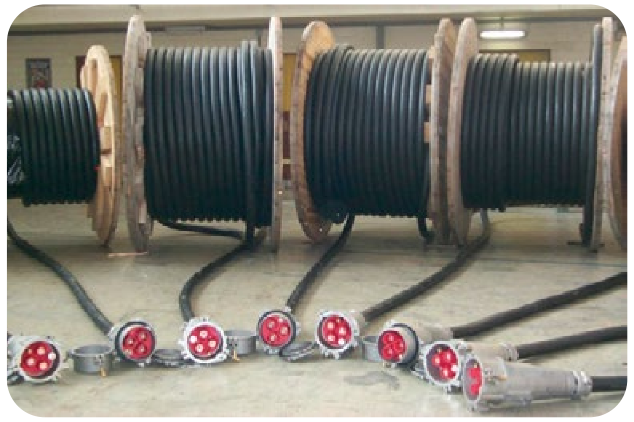
Couplers and cable services

For several applications the cables have to be connected by couplers. There is a wide range for underground and opencast couplers available, which our service department can apply to the cable.

Popular coupler-systems are the single core medium voltage connectors (interface A; B or C) e.g. Prysmian Formfit.

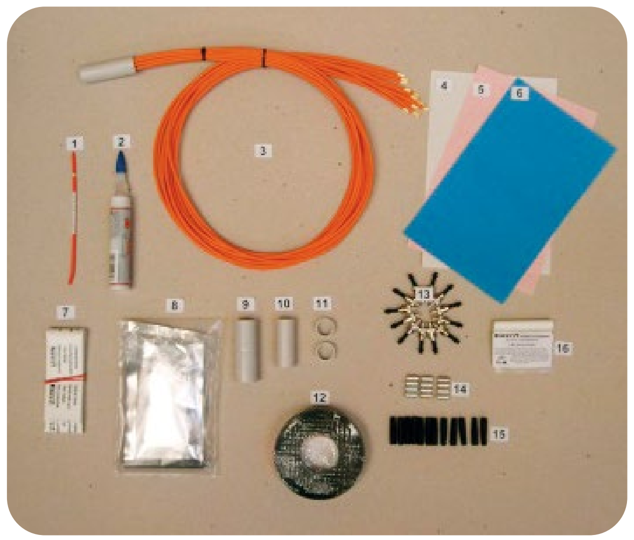
For outdoor applications (e.g. opencast mines) multicore couplers are available from different manufacturers.

Prysmian Formfit medium voltage connectors



Prysmian cable services

- Assembling in the factory
- Delivery of material sets
- Erectors training sessions on site or in the factory
- Vulcanizing system, tools sets and materials for the cable repair



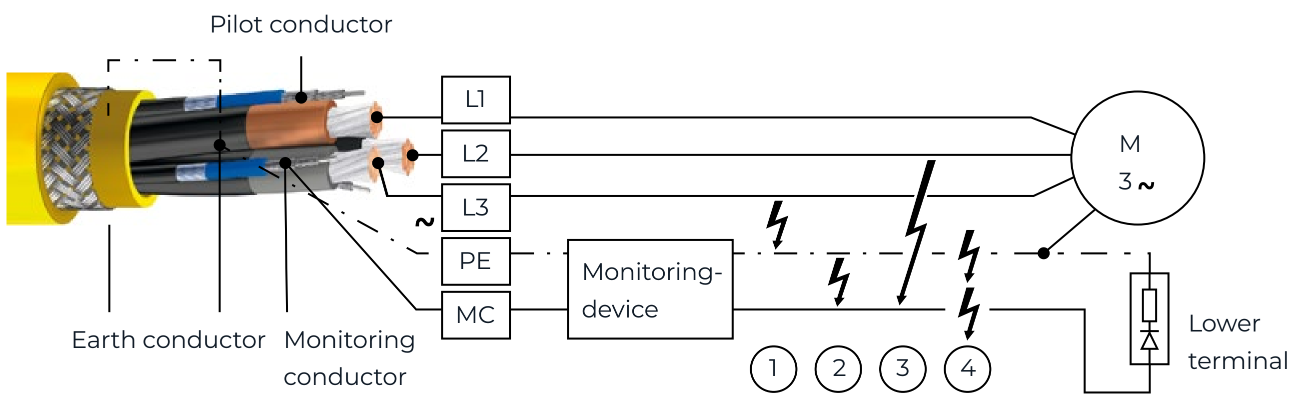
MONITORING

Prysmian mining cables are designed for all possibilities of monitoring the cable during operation. Different installation standards in the countries require different levels of monitoring safety.

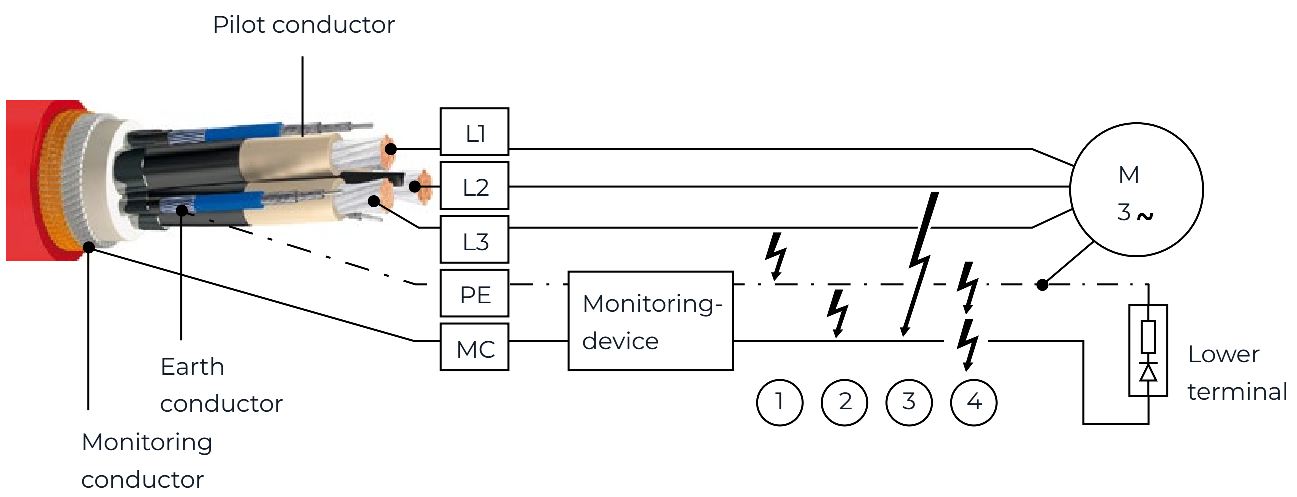
Below there are two monitoring possibilities using devices such as:

- Loop monitor
- Monitor/earth monitoring device
- Insulation monitor
- High-voltage monitor
- All Prysmian mining cables may be used with the mentioned monitoring systems.

SINGLE SCREEN MONITORING



DOUBLE SCREEN MONITORING



(1) = short circuit phase/protective earth conductor

(2) = short circuit protective earth conductor/ monitoring conductor

(3) = short circuit phase/monitoring conductor

(4) = break of protective earth or monitoring conductor

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 the following pages.

AC = Alternating Current
DC = Direct Current

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 UO/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 Uo/U up to and including 450/750 V
- 20 % for cables with a rated voltage Uo/U = 0.6/1 kV

CABLES WITH A RATED VOLTAGE UO/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.

RATED VOLTAGE

The rated voltage of an insulated electric cable is the expressed by the two values of power frequency voltage Uo/U in V.

Uo = 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 Uo 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.

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 PROTOMONT 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. See table „Table 2“.

SHORT-CIRCUIT CURRENT-CARRYING CAPACITY

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

The short-circuit current-carrying capacity Ithz for a short-circuit duration tk deviating from tkr = 1 s, is:

$$I_{thz} = I_{thr} \cdot \sqrt{\frac{t_{kr}}{t_k}}$$

Table 1

Cross-section mm²	1	1.5	2.5	4	6	10	16	25	35	50	70	95	120	150	185	240	300	400
Short-circuit current (kA)	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	71.5

VOLTAGE DROP

$$\Delta U = \sqrt{3} \times Ib \times l \times (R'W20 \times \cos\Phi + X'L \times \sin\Phi)$$

For deviating conductor temperatures (e.g. 90 °C instead of 20 °C) the effective resistance R‘W has to be converted:

$$R'W90 = R'W20\ (1 + (0.004 \times 70k))$$

For the practical use a more easier calculation may be sufficient:

$$\Delta U = \sqrt{3} \times Ib \times l \times R'W\Phi \times \cos\Phi$$

Ib = load current [A]
l = cable length [km]
R'W20 = effective resistance per unit length and 20 °C [Ω/km]
X'L = Reactance per unit length [Ω/km]
Φ = phase-angle

Table 2

Test voltage of flexible cables

Rated voltage	Max. permissible operating voltage			Test voltage applied to the complete cable				
	In AC systems	In DC systems		Power cores		Control cores	Pilot cores	Tele-communication cores
		unearthed	single-phase earthed					
U0/U	U0/U	U	U	AC	DC	kV	kV	kV
		kV	kV	kV	kV			
250/250 V	275/275 V	0.412	–	1.5	3.75	–	–	–
300/500 V	318/550 V	0.825	0.413	2	5	–	–	–
450/750 V	476/825 V	1 238	0.619	2.5	6.25	–	–	–
0.6/1 kV	0.7/1.2 kV	1.8	0.9	2.5	6.25	2		
1.8/3 kV	2.1/3.6 kV	5.4	2.7	6	15	2	2	1
3.6/6 kV	4.2/7.2 kV	10.8	5.4	11	27.5	2	2	1
6/10 kV	6.9/12 kV	18	8	17	42.5	2	2	1
8.7/15 kV	10.4/18 kV	27	14	24	60.0	2	2	1
12/20 kV	13.9/24 kV	36	18	29	72.5	2	2	1
14/25 kV	17.3/30 kV	45	3	36	90.0	2	2	1
18/30 kV	20.8/36 kV	54	27	43	107.5	2	2	1
20/35 kV	24.3/42 kV	63	32	50	125	2	2	1

Current-carrying capacity

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.

The table below is valid for continuous duty at 30 °C ambient temperature and three loaded cores.

Table 3 Current-carrying capacity

Cross-section	Stretched laying		Suspended freely in air	Reeled in						
				1 layer	2 layers	3 layers*	4 layers	5 layers	6 layers	7 layers
mm²	A	A	A	A	A	A	A	A	A	A
	Factor 1	Factor 1.36	1.05	0.8	0.61	0.49	0.42	0.38	0.27	0.22
RUBBER-INSULATED UP TO 10 KV: CORDAFLEX, FELTOFLEX, PROTOLON, PROTOMONT, SUPROMONT, TENAX										
1	18	24	19	14	11	9	8	7	5	4
1.5	23	31	24	18	14	11	10	9	6	5
2.5	30	41	32	24	18	15	13	11	8	7
4	41	56	43	33	25	20	17	16	11	9
6	53	72	56	42	32	26	22	20	14	12
10	74	101	78	59	45	36	31	28	20	16
16	99	135	104	79	60	49	42	38	27	22
25	131	178	138	105	80	64	55	50	35	29
35	162	220	170	130	99	79	68	62	44	36
50	202	275	212	162	123	99	85	78	55	44
70	250	340	263	200	153	123	105	95	68	55
95	301	409	316	241	184	147	126	114	81	66
120	352	479	370	282	215	172	148	134	95	77
150	404	549	424	323	246	198	170	154	109	89
185	461	627	484	369	281	226	194	175	124	101
240	540	734	567	432	329	265	227	205	146	119
300	620	843	651	496	378	304	260	236	167	136
RUBBER-INSULATED FROM 15 KV: FELTOFLEX, PROTOLON, PROTOMONT, SUPROMONT, TENAX										
16	105	143	–	84	64	51	44	40	28	23
25	139	189	–	111	85	68	58	53	38	31
35	172	234	–	138	105	84	72	65	46	38
50	215	292	–	172	131	105	90	82	58	47
70	265	360	–	212	162	130	111	101	72	58
95	319	434	–	255	195	156	134	121	86	70
120	371	505	–	297	226	182	156	141	100	82
150	428	582	–	342	261	210	180	163	116	94
185	488	664	–	390	298	239	205	185	132	107
240	574	781	–	459	350	281	241	218	155	126
300	660	889	–	528	403	323	277	251	178	145
PE-INSULATED: MSR-MINING										
2 x 2 x 1	12									
5 x2 x 1	8.5									
10 x 2 x 1	6.5									
20 x 2 x 1	5									

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

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 the table „Table 3“.

Table 4 De-rating factors for varying ambient temperatures

Ambient temperature °C	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
De-rating factor	1.15	1.12	1.08	1.04	1.0	0.96	0.91	0.87	0.82	0.76	0.71	0.65	0.58	0.50	0.41	0.29

Table 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 6 De-rating factors for intermittent periodic duty

Nominal cross-section	Duty factor ED %			
mm²	60	40	25	15
AMBIENT TEMPERATUR 30°C / 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

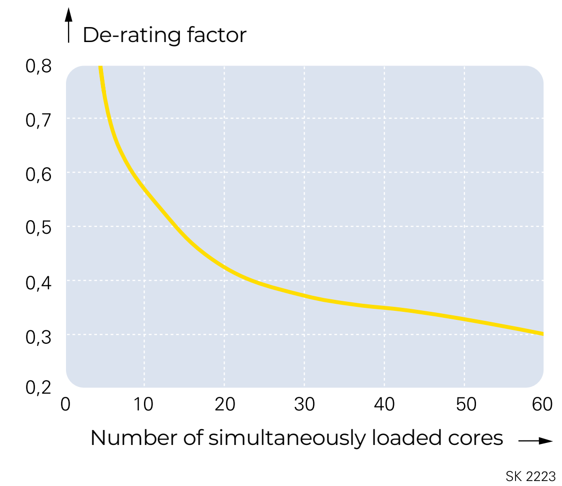


Table 7 De-rating factors for multi-core cables with conductor cross-sections up to 10

Number of loaded cores	5	7	10	12	14	18	19	24	30	36	40	42	61
De-rating factor	0.75	0.65	0.55	0.53	0.50	0.44	0.45	0.40	0.37	0.36	0.35	0.35	0.30

THERMAL PARAMETERS

The different temperature limits of the individual flexible electric cables for mining applications are summarised in the table „Table 8“.

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

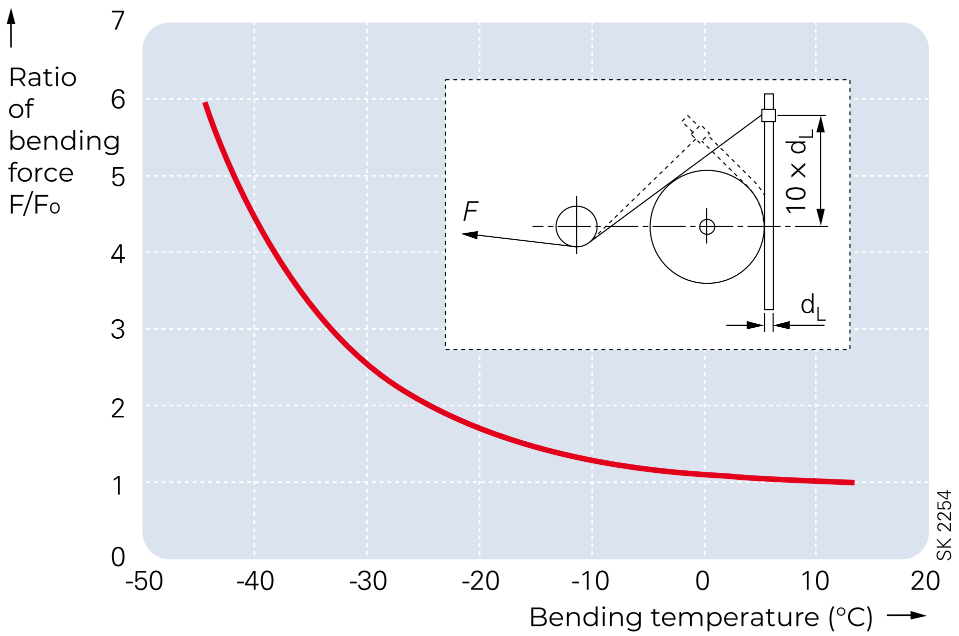
If cables are exposed to radiation, e.g. sunlight, the temperature of the outer sheath of the flexible electric cable can rise to a level which is significantly higher than the ambient temperature. This situation must be compensated for by corresponding reduction of the current-carrying capacity.

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 the flexible electric cables (e.g. with the reel drive).

The relationship between the bending stiffness of flexible electric cables for mining applications and the temperature is shown in the figure below.



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

d_L = Overall cable diameter
F = Force

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.

Table 8 Temperature limits of the individual flexible electric cables for mining applications

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 installation
CORDAFLEX(S)	NSHTOEU	90	250	-40 to +80	-25 to +60
FELTOFLEX	NTMCWOEU	90	250	-40 to +80	-25 to +80
OPTOFLEX(M)	–	–	–	-40 to +80	–
PROTOLON single-core	NTMCGCWOEU	90	250	-40 to +80	-25 to +60
PROTOLON(M) single-core	(N)TMCGCWOEU	90	250	-40 to +80	-25 to +60
PROTOLON(M)	F-(N)TSCGEWOEU	90	250	-40 to +80	-25 to +60
PROTOLON(M)	R-(N)TSCGEWOEU	90	250	-40 to +80	-35 to +80
PROTOLON(M) with F.O.	R-(N)TSCGEWOEU	90	250	-40 to +80	-35 to +80
PROTOLON(SB)	NTSCGEWOEU	90	250	-40 to +80	-20 to +60
PROTOLON(SB-SAM)	(N)TSCGEWOEU	90	250	-40 to +80	-30 to +60
PROTOLON(ST)	NTSCGEWOEU .../3E	90	250	-40 to +80	-25 to +60
PROTOLON(ST)	NTSCGEWOEU	90	250	-40 to +80	-25 to +60
PROTOMONT	NSSHOEU	90	250	-40 to +80	-25 to +60
PROTOMONT	NSHXOEU	90	250	-40 to +80	-25 to +60
PROTOMONT	NSSHOEU .../3E	90	250	-40 to +80	-25 to +60
PROTOMONT festoon	NTSKCGECWOEU	90	250	-40 to +80	-25 to +60
PROTOMONT EMV-FC	(N)SSHCOEU	90	250	-40 to +80	-25 to +60
PROTOMONT(M+)	(N)SHOEU	90	250	-40 to +80	-25 to +60
PROTOMONT(MSR)	2YSLGCGOEU	60	150	-40 to +80	-25 to +60
PROTOMONT(MT)	(N)SSHOEU	90	250	-40 to +80	-25 to +60
PROTOMONT(V)	NSSHCGEOEU	90	250	-40 to +80	-20 to +60
PROTOMONT(V)	NTSKCGECWOEU	90	250	-40 to +80	-20 to +60
PROTOMONT(VO)	(N)TSKCGEWOEU	90	250	-40 to +80	-20 to +60
PROTOMONT(S)	(N)SSHCGEOEU	90	250	-40 to +80	-20 to +60
PROTOMONT(Z)	NSSHKCGEOEU	90	250	-40 to +80	-20 to +60
PROTOMONT TBM	(N)TSCGECWOEU	90	250	-40 to +80	-20 to +60
PROTOMONT TBM	(N)TSCGECWHXOEU	90	250	-40 to +80	-20 to +60
SUPROMONT	(N)3GHSSYCY	90	250	-40 to +80	+5 to +60
SUPROMONT	(N)3GHSSHCH	90	250	-40 to +80	+5 to +60
TENAX-CTE	NSSHKCGEOEU	90	250	-40 to +80	-25 to +60
TENAX-HTT	(N)TSCGEWOEU	90	250	-40 to +80	-20 to +60
TENAX-LK	NTSKCGEWOEU	90	250	-40 to +80	-25 to +60
TENAX-LUMEN	(N)TSCGEH3S	90	250	-50 to +80	-50 to +60
TENAX-SAS	NTSCGEWOEU	90	250	-50 to +80	-50 to +60

MECHANICAL PARAMETERS

Tensile loads

The tensile loads as specified by DIN VDE 0298, Part 3, should not exceed 15 N/mm². Higher values are allowed for some cables as shown in the table below.

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 radius 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 15 N/mm² referred to the cross-section of the conductor.

Table 9 Maximum tensile loads during installation and operation of flexible electric cables for mining applications

Flexible cables	Type	DIN VDE N/mm²	Prysmian N/mm²
CORDAFLEX(S)	NSHTOEU	15	30
FELTOFLEX	NTMCWOEU	15	15
OPTOFLEX(M)	–	–	2000 N for the cable
PROTOLON single-core	NTMCGCWOEU	15	15
PROTOLON(M) single-core	(N)TMCGCWOEU	15	15
PROTOLON(M)	F-(N)TSCGEWOEU	15	15
PROTOLON(M)	R-(N)TSCGEWOEU	15	static: 20 (dynamic: 25)
PROTOLON(M) with F.O.	R-(N)TSCGEWOEU	15	static: 20 (dynamic: 25)
PROTOLON(SB)	NTSCGEWOEU	15	15
PROTOLON(SB-SAM)	(N)TSCGEWOEU	15	20
PROTOLON(ST)	NTSCGEWOEU .../3E	15	15
PROTOLON(ST)	NTSCGEWOEU	15	15
PROTOMONT	NSSHOEU	15	15
PROTOMONT	NSHXOEU	15	15
PROTOMONT	NSSHOEU .../3E	15	15
PROTOMONT festoon	NTSKCGECWOEU	15	15
PROTOMONT EMV-FC	(N)SSHCOEU	15	15
PROTOMONT(M+)	(N)SHOEU	15	15
PROTOMONT(MSR)	2YSLGCGOEU	15	15
PROTOMONT(MT)	(N)SSHOEU	15	15
PROTOMONT(V)	NSSHCGEOEU	15	15
PROTOMONT(V)	NTSKCGECWOEU	15	15
PROTOMONT(VO)	(N)TSKCGEWOEU	15	15
PROTOMONT(S)	(N)SSHCGEOEU	15	30
PROTOMONT(Z)	NSSHKCGEOEU	15	40
PROTOMONT TBM	(N)TSCGECWOEU	15	reeling: 15 (on TMB: 30)
PROTOMONT TBM	(N)TSCGECWHXOEU	15	reeling: 15 (on TMB: 30)
SUPROMONT	(N)3GHSSYCY	15	15
SUPROMONT	(N)3GHSSHCH	15	15
TENAX-CTE	NSSHKCGEOEU	15	15
TENAX-HTT	(N)TSCGEWOEU	15	15
TENAX-LK	NTSKCGEWOEU	15	30
TENAX-LUMEN	(N)TSCGEH3S	15	25
TENAX-SAS	NTSCGEWOEU	15	25

Torsional stresses

The torsional stresses occurring during operation of flexible electric cables for mining applications are low. In certain applications, such as for example laying on large mobile equipment (cable booms), torsional stresses are unavoidable.

The maximum permissible torsional stresses which occur during operation at entries, slewing gears, windmills, etc., are summarised in the table below.

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.

Table 10 Maximum torsional stresses during operation of flexible electric cables for mining applications

Flexible cables	Type	α (°/m)	
		With semi-conductive rubber layer	With copper core shield
CORDAFLEX(S)	NSHTOEU	±25	–
FELTOFLEX	NTMCWOEU	–	±25
OPTOFLEX(M)	–	±100	–
PROTOLON single-core	NTMCGCWOEU	–	±25
PROTOLON(M) single-core	(N)TMCGCWOEU	–	±25
PROTOLON(M)	F-(N)TSCGEWOEU	±100	–
PROTOLON(M)	R-(N)TSCGEWOEU	±100	–
PROTOLON(M) with F.O.	R-(N)TSCGEWOEU	±100	–
PROTOLON(SB)	NTSCGEWOEU	±100	±25
PROTOLON(SB-SAM)	(N)TSCGEWOEU	±100	±25
PROTOLON(ST)	NTSCGEWOEU .../3E	–	±25
PROTOLON(ST)	NTSCGEWOEU	±100	–
PROTOMONT	NSSHOEU	±100	–
PROTOMONT	NSHXOEU	±100	–
PROTOMONT	NSSHOEU .../3E	–	±25
PROTOMONT festoon	NTSKCGECWOEU	–	±25
PROTOMONT EMV-FC	(N)SSHCOEU	–	±25
PROTOMONT(M+)	(N)SHOEU	±25	–
PROTOMONT(MSR)	2YSLGCGOEU	–	±25
PROTOMONT(MT)	(N)SSHOEU	±100	–
PROTOMONT(V)	NSSHCGEOEU	±25	–
PROTOMONT(V)	NTSKCGECWOEU	±25	–
PROTOMONT(VO)	(N)TSKCGEWOEU	±50	–
PROTOMONT(S)	(N)SSHCGEOEU	±50	–
PROTOMONT(Z)	NSSHKCGEOEU	±10	–
PROTOMONT TBM	(N)TSCGECWOEU	–	±25
PROTOMONT TBM	(N)TSCGECWHXOEU	–	±25
SUPROMONT	(N)3GHSSYCY	–	±25
SUPROMONT	(N)3GHSSHCH	–	±25
TENAX-CTE	NSSHKCGEOEU	±50	–
TENAX-HTT	(N)TSCGEWOEU	±100	–
TENAX-LK	NTSKCGEWOEU	±100	–
TENAX-LUMEN	(N)TSCGEH3S	±100	–
TENAX-SAS	NTSCGEWOEU	±100	–

Minimum bending radius

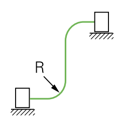
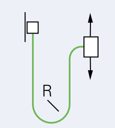
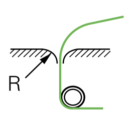
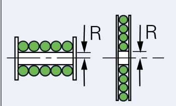
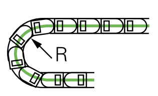
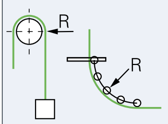
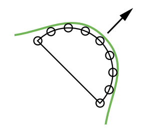
If the bending radius are smaller than those permitted, a reduced service life can be expected depending on the stress conditions. The values given in the table below should be taken as a basis.

The minimum bending radius 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).

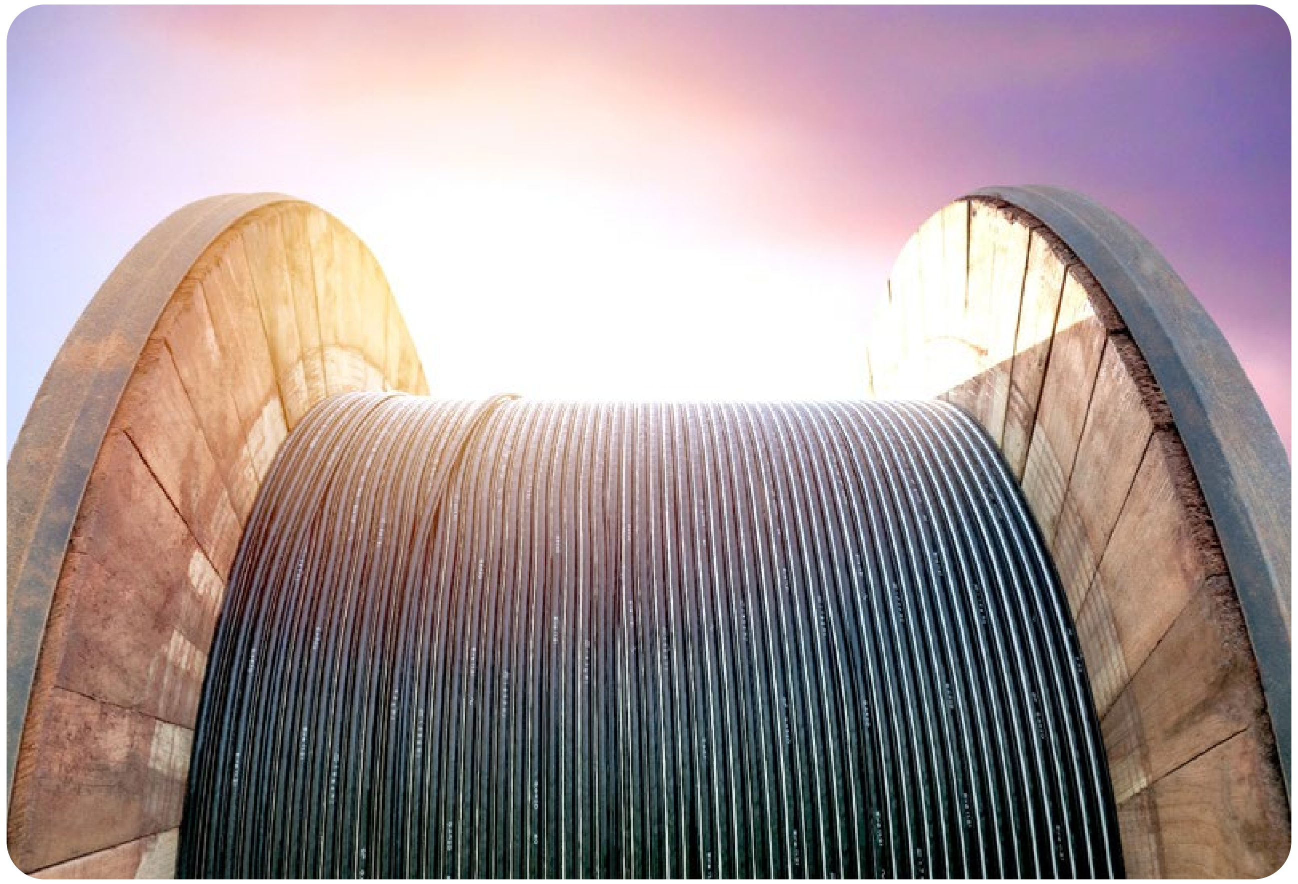
The minimum permissible bending radius are valid within the specified ambient temperature range (see „Table 8“), subject to the provision that the permissible tensile loads are not exceeded (see „Table 9“).

In critical cases, the cable manufacturer should be consulted.

Table 11 Minimum permissible bending radius R

Fexible cables	 Fixed installation	 Fully flexible operation	 For the entry, e.g. at a centre feed point	 For forced guidance with reeling operation	 For forced guidance with power tracks	 For forced guidance with sheaves	 Drawing by means of a roller stirrup
Rated voltage U_0/U	UP TO 0.6/1 KV						
	4 x d	5 x d	5 x d	6 x d	5 x d*	7.5 x d	4 x d
	ABOVE TO 0.6/1 KV						
	6 x d	10 x d	10 x d	12 x d	10 x d	15 x d	8 x d

d = Max. overall cable diameter. * PROTOMONT (V)/(VO), TENAX CTE at max. 5 N/mm²: 2.3 x d



Travel speeds

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

In order to collect, release and move flexible electric cables, there are different cable guidance systems such as reels, drum cars, power tracks, sheave guided cable storage systems as well as sheaves and multi-roller guides.

Mining equipment and consequently also the cable guidance systems are operated at different travel speeds and are therefore subject to stress which can vary from low to very high.

During operation of the mobile equipment, the flexible electric cables are subject 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 speed for the individual flexible electric cables are summarized in the table below.

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

Table 12 Maximum travel speed for flexible electric cables for mining applications

Flexible cables	Type	Material handling equipment on tracks	Material handling equipment on caterpillar-type running gear	Loader operation of tyre mounted equipment	Rewinding with drum car
		m/min	m/min	m/min	m/min
CORDAFLEX(S)	NSHTOEU	no application	no application	160	100
PROTOLON(M)	R-(N)TSCGEWOEU	120	10	60	100
PROTOLON(M) with F.O.	R-(N)TSCGEWOEU	120	10	60	100
PROTOLON(SB)	NTSCGEWOEU	no application	10	no application	100
PROTOLON(SB-SAM)	(N)TSCGEWOEU	no application	10	no application	100
PROTOMONT EMV-FC	(N)SSHCOEU	no application	no application	no application	100
PROTOMONT(M+)	(N)SHOEU	no application	no application	60	100
PROTOMONT(V)	NSSHCGEOEU	Max. travel speed of the coal cutter 15 m/min			
PROTOMONT(V)	NTSKCGECWOEU	Max. travel speed of the coal cutter 15 m/min			
PROTOMONT(VO)	(N)TSKCGEWOEU	Max. travel speed of the coal cutter 15 m/min			
PROTOMONT(S)	(N)SSHCGEOEU	160	160	160	100
PROTOMONT(Z)	NSSHKCGEOEU	Max. travel speed of the coal cutter 15 m/min			
PROTOMONT TBM	(N)TSCGECWOEU	30	30	no application	100
PROTOMONT TBM	(N)TSCGECWHXOEU	30	30	no application	100
TENAX-CTE	NSSHKCGEOEU	Max. travel speed of the coal cutter 15 m/min			
TENAX-HTT	(N)TSCGEWOEU	30	30	no application	100
TENAX-LK	NTSKCGEWOEU	160	160	160	160
TENAX-LUMEN	(N)TSCGEH3S	no application	10	no application	100
TENAX-SAS	NTSCGEWOEU	no application	10	no application	100

Additional tests

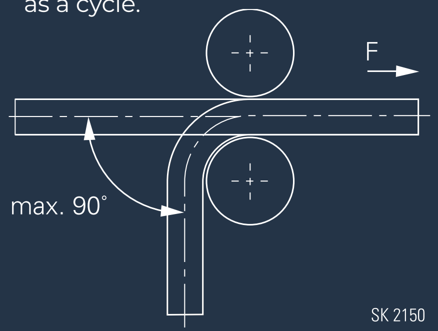
Our flexible electric cables for mining applications are subject to additional and continuous mechanical tests at the manufacturer's facilities. These additional tests facilitate time-compressed examination of the running and service characteristics under different kinds of mechanical stress, such as reserved bending strength, running over sheaves, flexing work and reeling operation in relation to tensile load and bending radius.

REVERSED BENDING TEST

Based on DIN VDE 0281, Part 2.

Testing of flexible electric cables 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.

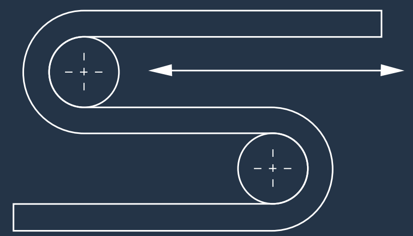


ROLLER BENDING TEST TYPE A

Based on DIN VDE 0281, Part 2.

Testing the roller bending characteristics.

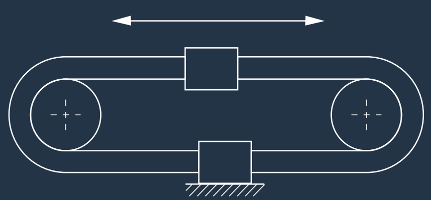
- Cable diameter up to 50 mm.
- Each movement between the extreme position is counted as a cycle.



ROLLER BENDING TEST TYPE B – TENDER TEST

Practice-oriented testing with reference to running and service characteristics.

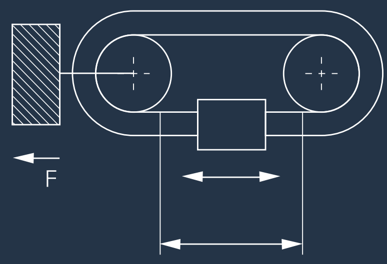
- Cable diameter from 20 up to 60 mm.
- Each movement between the extreme position is counted as a cycle.



ROLLER BENDING TEST TYPE C – FLEXING TEST

Testing the running characteristics (flexing) for evaluation of the mechanical service characteristics.

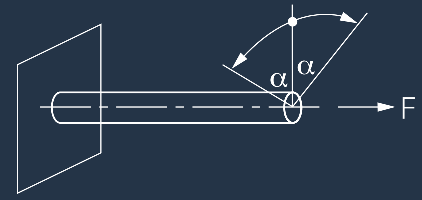
- Cable diameter from 60 up to 120 mm.
- Each movement between the extreme position is counted as a cycle. Moving distance 2 m.



TORSIONAL STRESS TEST

The cable is alternately twisted left and right through an angle α by application of the tensile force F.

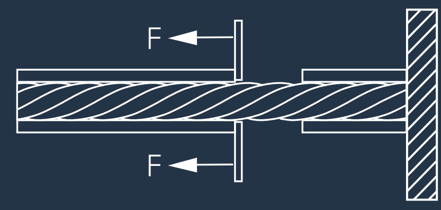
Torsional angle: max. ± 360°
Torsional torque: max. 200 Nm
Tensile force max.: 4000 N
Test duration at temperatures: - 40 °C to + 50 °C.



SHEATH SHIFTING TEST

Flexible electric cables are stressed by dragging over the underground in opencast applications.

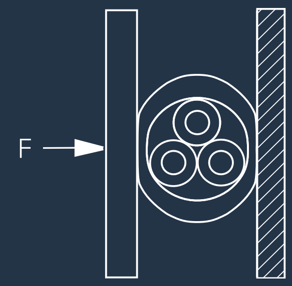
The test determines the magnitude of the force required to slide the sheath along the core.



TRANSVERSE PRESSURE TEST

This test demonstrates the behaviour of electric cables subjected to transverse pressure, e.g. as a result of jamming in plant components, being hit by falling stones (blocks of stones), etc.

The test is passed when no electrical event occurs up to the specified value (earth-fault or short-circuit).

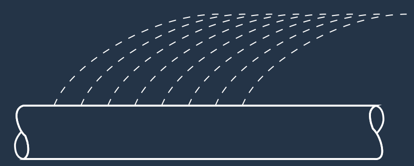


WELDING BEADS TEST

During constructional and maintenance work on large mobile equipment such as excavators, putting-down machines, etc., welding beads can fall on previously installed electric cables. This test verifies the resistance of the outer sheath to such stresses.

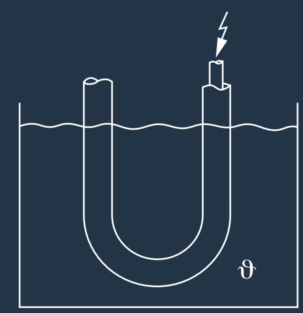
BRINE RESISTANCE

Automatic material handling and reloading installations (e.g. bunkering and blending plants) are sprayed with brine to prevent them from freezing. This test verifies the resistance of the outer sheath to such stresses.



WATER RESISTANCE

Verification of the resistance to water is carried out according to EN 50525-2-21.



The following tables depicts the test conditions for the individual flexible electric cables for mining applications. Under the severe conditions in mining operation, cables are subjected to considerable mechanical stresses, which by far exceed those defined in the requirement profile according to the VDE standards.

These additional tests assure compliance with the special requirement profile for mining applications and document the suitability of our electric cables.

The tensile loads and the bending and sheave radius are specified and the minimum number of cycles which must be achieved.

The decisive criterion for passing the mechanical test is the number of individual broken wires in the copper conductor and/or non-continuity of the electrical conductor.

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

Table 13.1 Test conditions for the individual flexible electric cables for mining applications

Additional mechanical tests		PROTOLON(M) R-(N)TSCGEWOEU PROTOLON(M) with F.O. R-(N)TSCGEWOEU	PROTOLON(M) F-(N)TSCGEWOEU	OPTOFLEX(M)	CORDAFLEX(S) NSHTOEU PROTOMONT(S) (N)SSHCGEOEU
Reversed bending test	Tensile load	20 N/mm^2	5 N/mm^2	300 N	20 N/mm^2
	Bending diameter	10 x D	10 x D	250 mm	10 x D
	Number of cycles	15 000	30 000	50 000	60 000
Roller bending test (test type A) D < 50 mm	Tensile load	15 N/mm^2	2.5 N/mm^2	300 N	5 N/mm^2
	Bending diameter	10 x D	10 x D	250 mm	10 x D
	Number of cycles	50 000	30 000	75 000	200 000
Roller bending test (test type B) 20 mm < D < 60 mm	Tensile load	–	–	–	5 N/mm^2
	Bending diameter	–	–	–	320 mm
	Number of cycles	–	–	–	300 000
Roller bending test (test type C) 60 mm < D < 120 mm	Tensile load	20 N/mm^2	20 N/mm^2	–	20 N/mm^2
	Bending diameter	10 x D	10 x D	–	10 x D
	Number of cycles	30 000	15 000	–	30 000
Torsional stress test	Tensile load	10 N/mm^2	10 N/mm^2	300 N	–
	Torsional angle	± 100 °/m	± 100 °/m	± 120 °/m	–
	Number of cycles	50 000	50 000	50 000	–
Sheath shifting test	Pulling speed	20 mm/min	20 mm/min	–	–
	Shifting force	> 20 kN	> 10 kN	–	–
Transverse pressure test	Pressure force	> 150 kN	> 150 kN	–	–
	Degree of deformation	< 50 %	< 50 %	–	–
Resistance to welding beads	Testing temperature	450 °C	450 °C	450 °C	450 °C
	Criterion	no damage	no damage	no damage	no damage
Brine resistance	Storage in	27 % brine solution	27 % brine solution	27 % brine solution	–
	Temperature	60 °C	60 °C	60 °C	–
	Duration	14 days	14 days	14 days	–
Water compabillity acc. to EN 50525-2-21	Duration of storage in water	100 days	100 days	100 days	–
	Temperature	50 °C	50 °C	50 °C	–

Table 13.2 Test conditions for the individual flexible electric cables for mining applications

Additional mechanical tests		TENAX-LK NTSKCGEWOEU	PROTOLON(SB) NTSCGEWOEU PROTOLON (SB-SAM) (N)TSCGEWOEU	TENAX-SAS NTSCGEWOEU	TENAX-LUMEN (N)TSCGEH3S
Reversed bending test	Tensile load	20 N/mm^2	–	20 N/mm^2	20 N/mm^2
	Bending diameter	10 x D	–	10 x D	10 x D
	Number of cycles	60 000	–	30 000	30 000
Roller bending test (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 (test type B) 20 mm < D < 60 mm	Tensile load	5 N/mm^2	–	–	–
	Bending diameter	320 mm	–	–	–
	Number of cycles	300 000	–	–	–
Roller bending test (test type C) 60 mm < D < 120 mm	Tensile load	20 N/mm^2	–	20 N/mm^2	20 N/mm^2
	Bending diameter	10 x D	–	10 x D	10 x D
	Number of cycles	30 000	–	30 000	30 000
Torsional stress test	Tensile load	–	–	–	–
	Torsional angle	–	–	–	–
	Number of cycles	–	–	–	–
Sheath shifting test	Pulling speed	–	20 mm/min	20 mm/min	20 mm/min
	Shifting force	–	> 10 kN	> 10 kN	> 10 kN
Transverse pressure test	Pressure force	–	–	–	–
	Degree of deformation	–	–	–	–
Resistance to welding beads	Testing temperature	450 °C	450 °C	450 °C	450 °C
	Criterion	no damage	no damage	no damage	no damage
Brine resistance	Storage in	–	–	–	–
	Temperature	–	–	–	–
	Duration	–	–	–	–
Water compabillity acc. to EN 50525-2-21	Duration of storage in water	–	–	–	–
	Temperature	–	–	–	–

Table 13.3 Test conditions for the individual flexible electric cables for mining applications

Additional mechanical tests		PROTOLON(ST) NTSCGEWOEU .../3E PROTOLON(ST) NTSCGEWOEU	PROTOMONT(Z) NSSHKCGEOEU	PROTOMONT(V) NSSHCGEOEU PROTOMONT(V) NTSKCGECWOEU PROTOMONT(VO) (N)TSKCGEWOEU	TENAX-CTE NSSHKCGEOEU
Roller bending test (test type C) 60 mm < D < 120 mm	Tensile load	–	30 N/mm^2	5 N/mm^2	5 N/mm^2
	Bending diameter	–	10 x D	5 x D	5 x D
	Number of cycles	–	5 000	3 000	3 000
Resistance to welding beads	Testing temperature	450 °C	450 °C	450 °C	450 °C
	Criterion	no damage	no damage	no damage	no damage

CONSTRUCTION CHARACTERISTICS

Conductors

Conductors for flexible electric cables are designed according to DIN EN 60228 (VDE 0295). The conductor classes F, FS and FF are employed for flexible electric cables for mining applications.

The conductor classes are divided into nominal cross-sections. The individual conductor classes F, FS and FF and the nominal cross-section are defined by specification of the maximum diameter of the single wires and by the maximum resistance of the conductor at 20 °C (see table).

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.

OVERVIEW OF COMMON KINDS 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	Finley stranded	DIN VDE 0295 Class 5
FS conductor	Very finely stranded	Prysmian specification
FF conductor	Extremely finely stranded	DIN VDE 0295 Class 6

Table 14 Conductors – construction characteristics

Nominal cross-section mm²	Max. diameter of the single wires mm			Resistance of the conductor at 20 °C Ω/km	
	F conductor (Class 5)	FS conductor (Prysmian)	FF conductor (Class 6)	Bare single wires	Tinned single wires
0.5	0.21	0.16	0.16	39	40.1
0.75	0.21	0.16	0.16	26	26.7
1	0.21	0.16	0.16	19.5	20
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

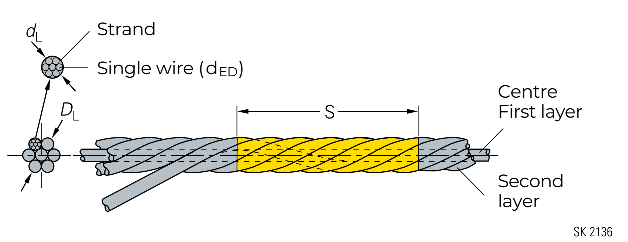
DESIGN ELEMENTS

Figure 1 shows the design elements of a conductor for flexible electric cables for mining applications.

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.

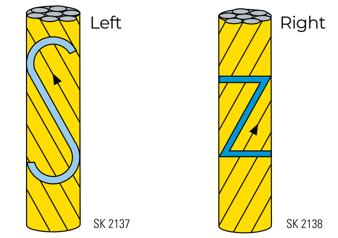
The strands of the flexible conductors consist of many single wires bunched together. The single wires can be laid up (bunched) to the right or left, thus determining the direction of lay. This is shown in figure 2 as the Z direction of lay (right) or the S direction of lay (left). This also applies to a conductor which is laid up of single strands.

Figure 1



S = Length of lay
D_L = Diameter of conductor
d_L = Diameter of strands
d_{ED} = Diamater of single wires

Figure 2



S direction Z direction

CONDUCTOR DESIGN

The conductor design and the nominal cross-section of the flexible F, FS and FF conductors for flexible electric cables are usually as shows in the table "Conductor design".

	F conductor	FS conductor	FF conductor
Bunched	up to 10 mm²	up to 2.5 mm²	up to 2.5 mm²
Stranded	from 16 mm²	from 4 mm²	from 4 mm²

CONDUCTOR TYPES

Depending on the combination of the individual design elements of a conductor, there are three basic types of conductors (see table "Conductor types").

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 uniform-lay conductor is used for all TENAX cables.

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 mining applications. It combines the advantages of both the uniform-lay conductor and the alternating-lay conductor without any of their disadvantages. The conductor is highly flexible, remains stable with respect to torsional loads and exhibits high axial compression and sharp bending strength. It has proven its excellent characteristics in many years of practice. The opposite-lay conductor is used for CORDAFLEX, PROTOMONT, SUPROMONT and PROTOLON.

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

Insulating and sheathing compounds

The table below 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

Table 15 Compounds used for flexible electric cables

Serial no.	Material	Abbreviation	Type designation*	
			VDE	Harm.
THERMOPLASTICS				
1	Polyvinyl chloride	PVC	Y	V
2	Cross-linked polyvinyl chloride	PVC	X	V4
3	Polyethylenen	PE	2Y	E
4	Cross-linked polyethylenen	XLPE	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	Polyvinylidene 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	5G	N
28	Chlorosulfonated polyethylene	CSM	6G	N4
29	Fluor elastomers		7G	
30	Nitrile butadiene rubber	NBR	8G	N5
31	Chlorated polyethylene	CM/CPE	9G	

***Type designation** 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).
Y: Type designation for a thermoplastic material.
0: Additional designation for foam materials (the zero is placed in front of the relevant type designation, e.g. "02Y" for foamed PE).

The insulating and sheathing compounds, which are employed in flexible electric cables for mining applications constructed according to the existing VDE standards listed below, are compared with respect to the individual requirements in the table below.

The characteristics are specified in DIN VDE 0207 or EN 50290 and allow a preliminary estimation of the properties of these compounds.

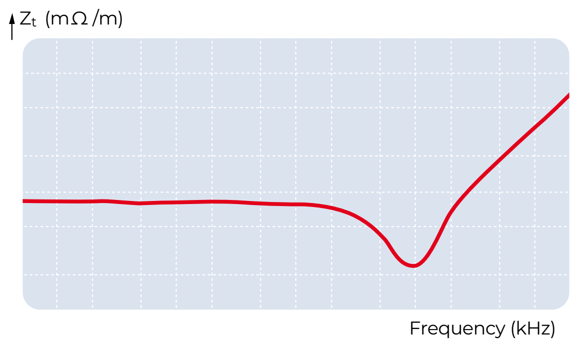
Table 16 Characteristics of insulating and sheathing compounds

Requirements		Unit	Compound			
			Sheath			Insulation
			CR/MR		SR	EPR
			5GM3	5GM5	GM1b	3GI3
Max. permissible operating temperature at the conductor		°C	90	90	90	90
Tensile strength before ageing	min.	N/mm²	10.0	15.0	4.2	4.2
Elongation at break before ageing	min.	%	300	300	200	200
Ageing	at	°C	100 ±2	100 ±2	100 ±2	135 ±2
	over	d	7.0	7.0	7.0	7.0
Change in tensile strength after ageing	max.	%	±30	±30	–	±30
Elongation at break after ageing	min.	%	250	250	200	–
Change in elongation at break after ageing	max.	%	±40	±40	–	±30
Abrasion	max.	mm³	–	300	–	–
Resistance to tear propagation	min.	N/mm	–	30	–	–
Thermal expansion	at	°C	100 ±2	100 ±2	–	200 ±3
	over	min.	15	15	15	15
	with	N/cm²	20	20	20	20
	loaded max.	%	175	175	175	175
	relieved max.	%	25	25	25	25
Resistance to oil (ASTM Oil no. 2)	at	°C	100 ±2	100 ±2	–	127 ±1
	over	h	24	24	–	40
	with	bar	–	–	–	5.5 ±1
Change in tensile strength	max.	N/mm²	±40	±40	–	±30
Change in elongation at break	max.	%	±40	±40	–	±30
Surface resistance at 20 °C	min.	Ω	109	109	109	–
Volume resistance at 20 °C	min.	Ω x cm	–	–	–	1012

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.



An overall sheath over several cores, which as a rule is situated between the inner and outer sheath of a cable, has not found general acceptance for reeling cables, because as a result of frequent bending the tensile and pressure forces within the cable lead to premature destruction of the shields and to failure of the cable.

Shielded pairs and individually shielded cores, on the other hand, have proven themselves in practice and are successfully used in Prysmian 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 Zt (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 mining applications is optimized at 30 MHz and is therefore focussed on data-processing quality. A typical transfer impedance characteristic is shown in the diagram to the left.

Electrical field control with cables

The cores of MV-reeling and trailing cables of voltage level 6 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:

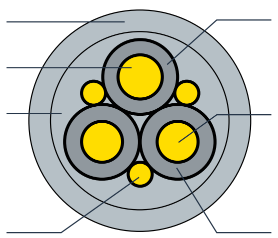
- Protection against electric shock
- Avoidance of partial discharges in the conductor assembly
- Generation of the radial electrical field in the insulation
- Discharge of current in the event of a fault.

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. The figure to the left shows the cross-section of a MV-cable with inner and outer semiconductive layers.

In addition to the electrical requirements, the core shield in flexible electric cables for mining applications 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 mining applications and are inferior to shields made of semiconductive rubber material.



Core arrangement

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

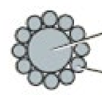
A stretched core in the centre of the flexible cable (as the actual centre or placed in the centre) is not permitted according to the DIN VDE standards. A stretched core at the centre of the flexible cable would quickly result in premature failure of the conductor due to breakage, especially in flexible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

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.

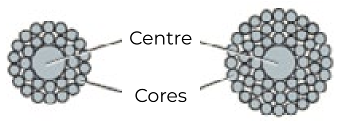
CORE ARRANGEMENTS IN ROUND FLEXIBLE CABLES:

Laying up of two to four cores without a centre.

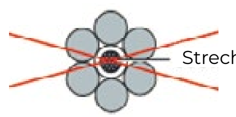
Laying up of five or more cores with centre. Special design: the centre comprises three cores.



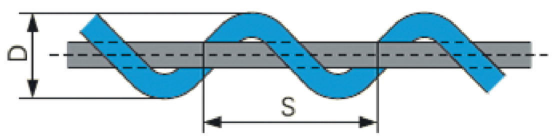
Maximum three-layer design (standard up to 44 cores).



A stretched core in the centre of a flexible cable is not permitted.



The length of lay S is a design feature used for laying up the conductor assembly (see table) 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 mining applications.



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

Table 17 Length of lay for flexible electric cables for mining applications

Flexible cables	Type	Length of lay
CORDAFLEX(S)	NSHTOEU	5 x D
FELTOFLEX	NTMCWOEU	not applicable
OPTOFLEX(M)	–	Especially laid-up around a GFK support element
PROTOLON single-core	NTMCGCWOEU	not applicable
PROTOLON(M) single-core	(N)TMCGCWOEU	not applicable
PROTOLON(M)	F-(N)TSCGEWOEU	12 x D
PROTOLON(M)	R-(N)TSCGEWOEU	7 x D
PROTOLON(M) with F.O.	R-(N)TSCGEWOEU	7 x D
PROTOLON(SB)	NTSCGEWOEU	10 x D
PROTOLON(SB-SAM)	(N)TSCGEWOEU	10 x D
PROTOLON(ST)	NTSCGEWOEU .../3E	10 x D
PROTOLON(ST)	NTSCGEWOEU	10 x D
PROTOMONT	NSSHOEU	Power cable: 15 x D (Control cable: 25 x D)
PROTOMONT	NSHXOEU	Power cable: 15 x D (Control cable: 25 x D)
PROTOMONT	NSSHOEU .../3E	20 x D
PROTOMONT festoon	NTSKCGECWOEU	7 x D
PROTOMONT EMV-FC	(N)SSHCOEU	20 x D
PROTOMONT(M+)	(N)SHOEU	10 x D
PROTOMONT(MSR)	2YSLGCGOEU	Laid-up pairs ≥ 25 x D / Laid-up cores ≥ 15 x D
PROTOMONT(MT)	(N)SSHOEU	Power cable: 15 x D (Control cable: 25 x D)
PROTOMONT(V)	NSSHCGEOEU	6 x D
PROTOMONT(V)	NTSKCGECWOEU	6 x D
PROTOMONT(VO)	(N)TSKCGEWOEU	6 x D
PROTOMONT(S)	(N)SSHCGEOEU	6 x D
PROTOMONT(Z)	NSSHKCGEOEU	6 x D
PROTOMONT TBM	(N)TSCGECWOEU	12 x D
PROTOMONT TBM	(N)TSCGECWHXOEU	12 x D
SUPROMONT	(N)3GHSSYCY	12 x D
SUPROMONT	(N)3GHSSHCH	12 x D
TENAX-CTE	NSSHKCGEOEU	6 x D
TENAX-HTT	(N)TSCGEWOEU	12 x D
TENAX-LK	NTSKCGEWOEU	7 x D
TENAX-LUMEN	(N)TSCGEH3S	6.5 x D
TENAX-SAS	NTSCGEWOEU	6.5 x D

Support elements

Flexible electric cables for mining applications should not be stressed above the limits set out in "Maximum tensile loads" in „Table 9" for the permissible tensile forces. If higher tensile forces are expected, support elements have to be provided as part of the structure of the cable.

Two variants are normally used:

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

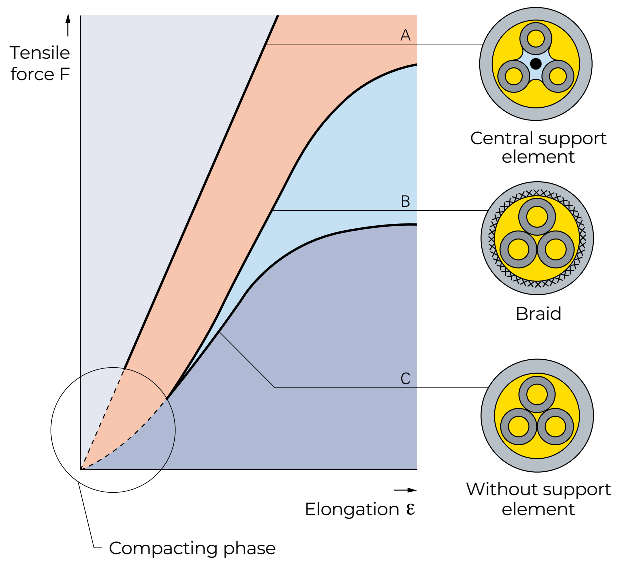
The force/elongation diagram in the figure shows the characteristic of these cables with different arrangements of support elements as compared to a cable without a support element.

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.

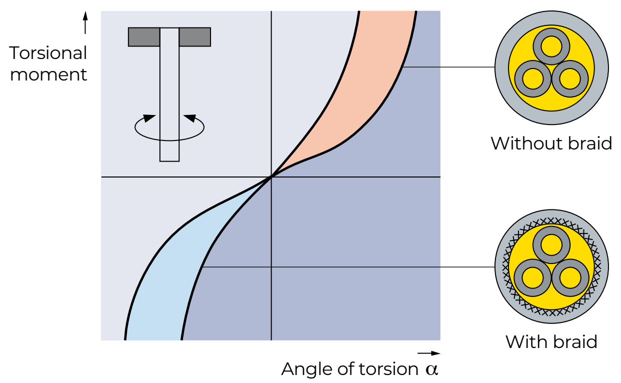


Anti-torsion braid

Flexible electric cables for mining applications are often fitted with an anti-torsion braid between the inner and outer sheath in order to minimize twisting under torsional loads.

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

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



CABLE DRUM OVERVIEW

Table 18 Cable drums

Drum size	Weight kg	Dimensions Ø x width cm	Volume m³
051	9	50x46	0.09
071	23	71x48	0.19
081	28	80x48	0.26
091	43	90x64	0.45
101	50	100x64	0.70
121	125	125x76	1.09
141	145	140x95	1.37
161	210	160x95	2.01
181	280	180x110	2.80
200	380	200x110	4.24
220	500	224x138	5.44
224	700	240x138	7.26
281	900	280x138	10.10
300	1,100	300x170	12.14
320	1,200	320x170	18.10
340	1,400	340x220	20.43

LOCAL STANDARDS

COMPARISON AWG

Table 19 AWG (American Wire Gage)

AWG size	Equivalent cross-section (mm²)	Closest metrical cross-section (mm²)
18	0.823	1.0
16	1.31	1.5
14	2.08	2.5
12	3.31	4.0
10	5.26	6.0
8	8.37	10.0
6	13.30	16.0
4	21.15	25.0
2	33.63	35.0
1/0	53.48	50.0
2/0	67.43	70.0
3/0	85.01	95.0
250 MCM	107.20	120.0
300 MCM	152.00	150.0
350 MCM	177.35	185.0
400 MCM	202.71	185.0
500 MCM	253.35	240.0
600 MCM	303.96	300.0
750 MCM	379.95	400.0
1000 MCM	506.71	500.0

WORLDWIDE PRYSMIAN MINING CABLES ACC. TO LOCAL STANDARDS

Table 20 Prysmian mining cables

Brandname	Cable type	Standard	Production location	Application
AUSTRALIA – AUSTRALIAN STANDARD (AS)				
MineMaster	Type 209 1.1-11 kV	AS/NZS 1802	Australia	Underground feeder cable for pumps, fans and crushers
MineMaster	Type 210 1.1 kV	AS/NZS 1802	Australia	Underground cable for hand-held boring machines
MineMaster	Type 240 1.1-11 kV	AS/NZS 1802	Australia	Underground feeder cable for continuous miner
MineMaster	Type 241 1.1-11 kV	AS/NZS 1802	Australia	Underground screened cable for continuous miner and feeder
MineMaster	Type 275 1.1 kV	AS/NZS 1802	Australia	Underground cable for high speed reeling on shuttle cars
MineMaster	Type 409 3.3-22 kV	AS/NZS 2802	Australia	Opencast screened cable for trailing application
MineMaster	Type 440 3.3-22 kV	AS/NZS 2802	Australia	Opencast screened cable for trailing application
MineMaster	Type 441 3.3-22 kV	AS/NZS 2802	Australia	Opencast screened cable for trailing application
MineMaster	Type 450 3.3-33 kV	AS/NZS 2802	Australia	Opencast screened cable for trailing application
CZECH REPUBLIC				
	1-CHBU 0.6/1 kV	Based on DIN VDE 0250	Germany	Semi-flexible installation
	3-CHBU 1.8/3 kV	Based on DIN VDE 0250	Germany	Semi-flexible installation
	6-CHBU 3.6/6 kV	Based on DIN VDE 0250	Germany	Semi-flexible installation
	6-CHCU 3.6/6 kV	Based on DIN VDE 0250	Germany	Semi-flexible installation along conveyor belts
	6-CHCU-TT 3.6/6 kV	Based on DIN VDE 0250	Germany	Cable for reeling application
	6-CHCU-TTAR 3.6/6 kV	Based on DIN VDE 0250	Germany	Cable for reeling and trailing application
	35-CHVU 20/35 kV	Based on DIN VDE 0250	Germany	Cable for slow reeling and trailing application
GREAT BRITAIN – BRITISH STANDARD (BS)				
PROTOMONT	Type 7 - 7M - 7S 1.1 kV	BS 6708	Germany	Flexible rubber cable for use in underground mines
PROTOMONT	Type 307 - 307M - 307S 3.3 kV	BS 6708	Germany	Flexible rubber cable for use in underground mines
PROTOMONT	Type 201 - 211 1.1 kV	BS 6708	Germany	Pliable wire armoured cables for underground use
PROTOMONT	Type 62 - 63 - 64 1.1 kV	BS 6708	Germany	Pliable wire armoured for use as roadway extension and lighting cables
PROTOMONT	Type 321 - 331 3.3 kV	BS 6708	Germany	MV pliable wired armoured for use as mine roadway extension cables
PROTOMONT	Type 631 6.6 kV	BS 6708	Germany	MV pliable wired armoured for use as mine roadway extension cables
PROTOMONT	Type 506 - 512 - 518 - 524	BS 6708	Germany	Pliable wire armoured signaling and auxiliary cables
INDIA – INDIAN STANDARD (IS)				
	TYPE FT7 1.1 kV	IS 14494	Germany	Flexible rubber cable for use in underground mines
	TYPE FT10 1.1 kV	IS 14494	Germany	Flexible rubber cable for use in underground mines
	TYPE FT11 1.1 kV	IS 14494	Germany	Flexible rubber cable for use in underground mines
	TYPE PLC2 - PLC3 - PLC4 - PLC5 1.1 kV	IS 14494	Germany	Pliable wire armoured cables for underground use
PROTOMONT	Type 506 - 524	IS 14494	Germany	Pliable wire armoured signaling and auxiliary cables
SERBIA				
	EPN 78	SRPS N.C5.374	Germany	MV cable for reeling, trailing and semi-flexible application
USA				
ANACONDA	Type W 2kV	ICEA S-75-381	USA	Flexible rubber cable for general purpose
ANACONDA	Type G - G-GC 2 kV	ICEA S-75-381	USA	Flexible rubber cable for general purpose
ANACONDA	Type SHD-GC 2-25 kV	ICEA S-75-381	USA	Flexible MV cable for trailing in opencast and undeground mines
ANACONDA	Type MP-GC 5-25 kV	ICEA S-75-381	USA	Semi-flexible installation

GLOBAL REACH, LOCAL EXPERTISE

Different Technologies for Different Challenges

No matter which country you are in, Prysmian offers local solutions and dedicated points of contact to support you.

SOLUTIONS DESIGNED TO MEET LOCAL NEEDS

At Prysmian, we understand that every region comes with its own unique set of challenges. That's why we ensure our portfolio includes tailored solutions, produced locally or sourced from our global Centres of Excellence, to meet the specific demands of each market.

Our approach combines deep local expertise with cutting-edge technology, ensuring that every solution aligns with both regional requirements and global standards. Additionally, we prioritize rapid delivery to keep your operations running smoothly and efficiently, no matter where you are.

HARNESSING THE POWER OF INNOVATION

From locally produced cables to advanced products developed in our global Centres of Excellence, we deliver the best solutions for every application. By leveraging our innovation hubs worldwide, we can address the most complex challenges with precision and reliability.

COMPREHENSIVE SUPPORT, WHEREVER YOU ARE

Prysmian provides end-to-end support to ensure your projects succeed. With a presence in over 50 countries, our global reach and local expertise enable us to respond quickly and effectively to your needs.
We are more than a cable provider—we are your trusted partner for overcoming challenges and achieving success, any time and any place.

CABLES. DELIVERED. NO MATTER WHAT.

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The world of international trade is evolving rapidly. New policies, like the Built America Buy America Act, Chinese market regulations, or rising international trade tariffs, present challenges for businesses worldwide. Despite these changes, our customers can rest assured that they will continue to receive our high-quality cable products without disruption.

With our global presence and local production facilities, we are fully prepared to adapt to new market demands – no matter where you operate. Our worldwide manufacturing and logistics network ensures consistent supply with our high-quality products, always in compliance with regional regulations.
At Prysmian, we believe that new trade regulations shouldn't hinder your access to the world's best cable solutions. We're here to support you every step of the way.

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