UNDERGROUND MINING CABLE CARE & MAINTENANCE

Prevent downtime and extend cable life

prysmian

The planet's pathways

MINIMIZE DOWNTIME, MAXIMIZE PERFORMANCE

Mining and production techniques have made significant advances with the introduction of higher output mining methods, placing greater importance on ensuring a continuous flow of current to mining machines. And in today's highly competitive economic environment, consistent power becomes even more essential.

Anaconda® Brand mining cables are designed to reduce cable-related downtime, which can seriously impact mine profitability. In operations of this scale, every minute of downtime is expensive, and once lost, can never be recovered.

This booklet contains critical information and tips on minimizing cable-related downtime in surface mining operations. We've distilled our recommendations to simple, shareable procedures for your operating personnel.

THE HUGE COST OF CABLE DOWNTIME TODAY

Modern underground cables' reliability and performance are essential to low-cost mining. The cost of unscheduled production interruption resulting from cable failures can be much higher than is generally realized. Lost tonnage, interest, depreciation, overhead and labor costs from downtime often surpasses the initial cable investment. It is vitally important in today's mining operations to minimize downtime through proper cable handling and maintenance.

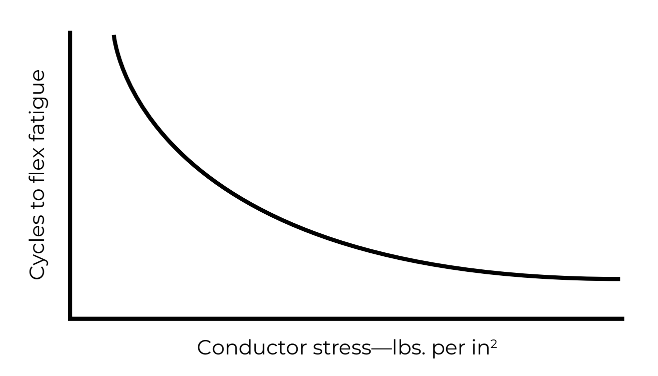
Reliable trailing cable performance is essential to low-cost mining.

UNDERGROUND MINING CABLE DESIGN

Mining machine cables typically consist of a flexible copper conductor, a wall of rubber insulation, and an outer covering of rubber material. As applications and service requirements changed, so have mining cables. Today's highly engineered designs take advantage of modern polymeric insulating and jacketing materials, as well as stranding and shielding techniques, providing optimum safety, durability and performance.

CONDUCTOR STRANDING

Mining cable conductors are stranded to provide both flexibility and flex life.



What is flex life?
Resistance to flex fatigue, or the number of times a cable can be bent back and forth before the strands fatigue

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Flex fatigue in any portable cable is unavoidable so, to prolong cable flex life, the tensile load must be balanced among the individual conductors as uniformly as possible. Manufacturers' recommended minimum bending radii and maximum tensile loads are calculated with this in mind; exceeding these recommendations will greatly accelerate failure rates.

Insulated Cable Engineers Association (ICEA) Recommended Minimum Bending Radii	
Braid-shielded portable cable	8x
Nonshielded portable cables	6x
Flat nonshielded cables	6x

INSULATION

Ethylene Propylene Rubber (EPR) is the standard insulation for mining cables. EPR has excellent mechanical properties over a temperature range of -50°C to +90°C. EPR also has high tensile strength; resistance to tearing, abrasion, and compression cut; and is flexible and easy to repair, making it well suited for rugged mining environments.

Increasing the bending radius practically eliminates strand damage

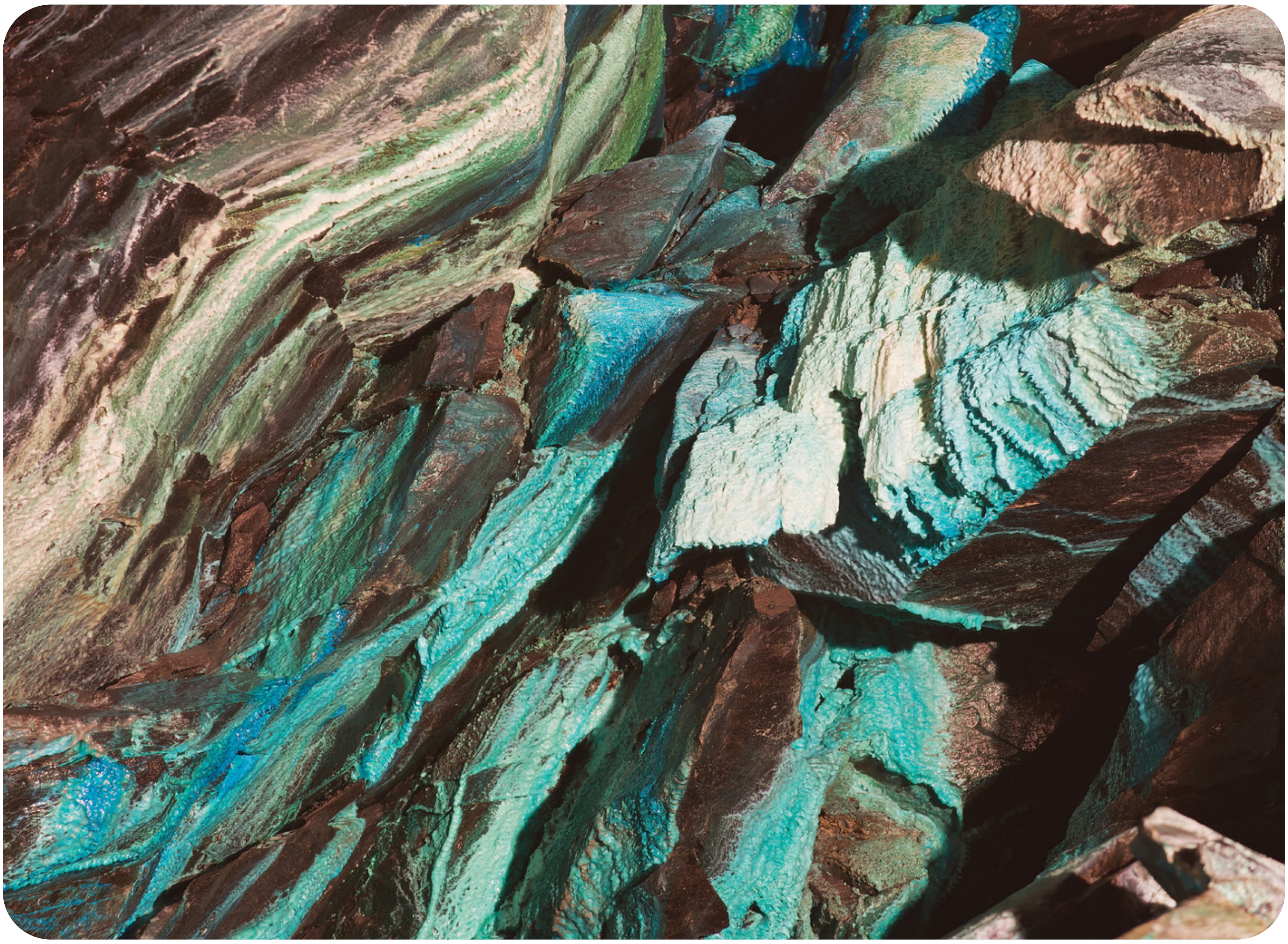
GROUNDING SYSTEM

Grounding conductors and shielding wires should be in continuous contact for effective ground impedence as, together, it forms the total grounding system. As such, little change in grounding system impedence occurs in the event of components suffering extreme flex fatigue. In fact, the grounding system will continue to function long after phase conductor failure renders the cable inoperative.

Grounding systems are designed to carry fault current and simultaneously limit the resulting voltage drop in the grounding circuit external to the grounding resistor to not more than 100 volts. This means that the fault current flowing in the grounding conductors and shield wires, all connected in parallel, multiplied by the resultant impedance cannot exceed 100. Parameters for sizing the grounding conductors are therefore defined by the limits placed on the maximum fault current by a grounding resistor.

A grounding system might be considered fail-safe, but continuous ground monitoring is required by Federal law to ascertain continuity through connections and to assure solid terminations.

Ground-check conductors are included in trailing cables to facilitate ground monitoring. Premature flex fatigue can be virtually eliminated by a heavy wall of polypropylene insulation that prevents kinking. If the ground-check conductor is smaller than the phase conductor, its flex life is best improved by increasing the insulation wall thickness. The objective is to derive maximum resistance to kinking.



UNDERGROUND MINING CABLE COMPONENTS

SHIELDING

High-voltage cables (higher than 2 kV) are shielded for well-established engineering reasons. The primary functions of the shield are:

1. To obtain symmetrical radial stress distribution within the insulation and to eliminate longitudinal stresses on the insulation surface
2. To provide a definite capacitance to ground for the insulated conductor, impeding a uniform surge and minimizing voltage wave reflection within the cable run
3. To reduce the hazard of shock and danger to both life and property

Shielding is important for ground continuity. This can be assured with grounding conductors laid in the cable and in contact with the shield throughout the length of the cable, providing an infinite number of parallel paths. There are two types of flexible shielding associated with surface mining: full copper braid and copper/textile braid. Tests have shown that the copper/textile braid shield is mechanically superior to a full copper braid, as the individual wires cross over threads instead of other wires. (Fig 2)

JACKET

Jacketing is essential in underground mining cables and is the first line of defense against adverse physical and mechanical environments, with lead-cured CPE as the standard for tough, flexible jackets. In addition to its superior tensile strength and abrasion resistance, it has a thermal range from -50°C to 90°C. CPE is naturally resistant to ozone, making it ideal for high voltage applications and it passes the Mining Safety and Health Administration (MSHA) Flame Test.

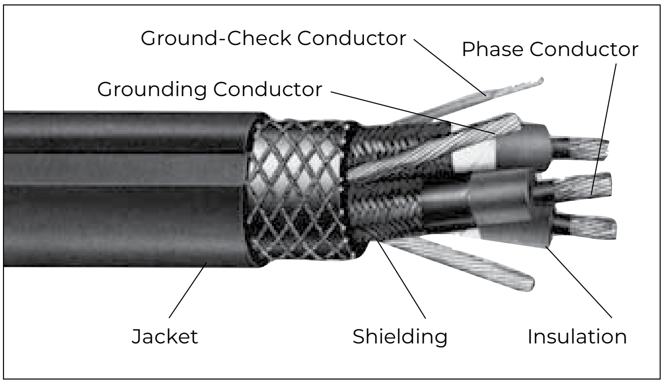


Fig 1

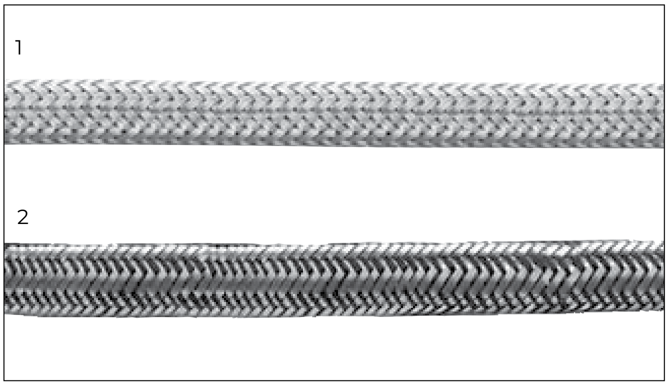


Fig 2

UNDERGROUND MINING CABLE APPLICATIONS

These components are not always common to every underground mining cable; there are some major differences in design dictated by the service conditions to which the cable will be subjected. These differences can include:

- **Trailing cables used on reels**
- **Trailing cables for non-reeling applications**
- **Feeder cables**

TRAILING CABLES USED ON REELS

Shuttle cars are the primary use for reeling cables. Shielded cables are rarely used in this application because of the belief that the shield would not survive the repeated flexing and tension in service. Cables with semi-conducting materials can provide the safety benefits of shielding without having the disadvantage of shield wire breakage.

Flat cable is often preferred because its relatively small minor diameter allows a tighter bending radius. Additionally, more cable can fit on a reel, providing the available space. (Fig 4)

A shuttle car imposes very severe conditions on a cable. High tensions, especially when back-spooling, usually exceed recommended limits, while bending radii often are below the limits that offer optimum performance. Both of these conditions lead to early flex fatigue.

These operating conditions demand the toughest insulation available, require a high degree of adhesion between insulation and jacket, and, in flat cables, rentention of conductors in a parallel plane. Such a bond is normally present with similar polymers but can be obtained with the aid of adhesives when using dissimilar materials, such as EPR and CPE.

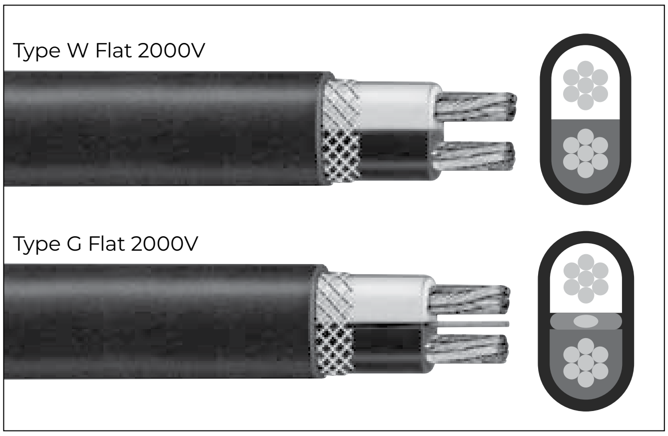


Fig 4

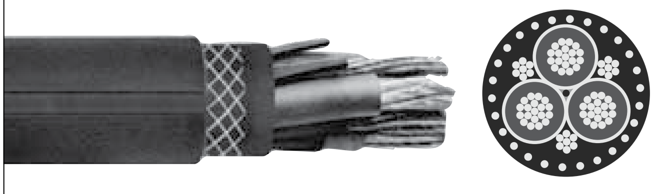
TRAILING CABLES FOR NON-REELING APPLICATIONS

Although not subject to the flexing stresses of reeling cables, these cables are often dragged along the ground, necessitating a high degree of abrasion resistance and tensile strength.

Currently, lead cured CPE jackets best meet these service conditions.

Although nonshielded cables have been most commonly used, the emphasis on maximum protection against shock hazard has led to the introduction of shielded cables in this service.

Unsymmetrical grounding systems in 3-phase cables cause induced voltages which are proportional to the length of the circuit and the magnitude of the phase current. With large currents, the resulting induced voltages in Type G-GC cables can cause dangerous sparking when continuous miners make contact with well-grounded shuttle cars. To alleviate this, the grounding system must be balanced, and a specially designed ground-check conductor is placed in the center interstice formed by the phase conductors. These are designated as Type G plus GC (Fig. 5) or SHD plus GC and offer better shock hazard protection by improving ground continuity and limiting the occurrence of induced voltages.



Type G Plus GC, 2kV

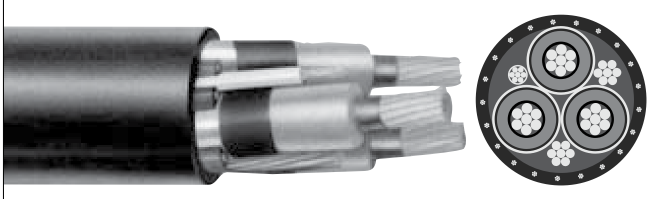
Fig 5

FEEDER CABLES

Underground distribution systems utilize high-voltage feeder cables and Mine Power Feeder (MP-GC) with Ground-Check conductor is designed for high-voltage distribution. MP-GC (Fig. 6) is typically used where the cable will be relocated less than once a year. If the cable is to be moved more frequently, Type SHD-GC should be considered (Fig. 7).

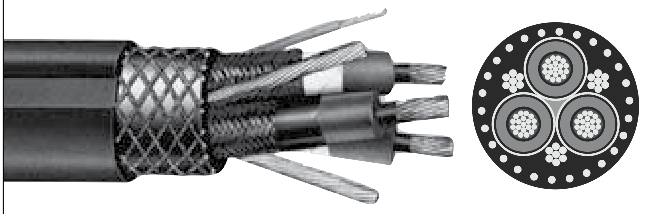
Today's smaller, lighter Mine Power Feeder cables lend themselves to more economical methods of suspension than the helical steel armor wire constructions previously used to provide additional tensile strength.

A typical Type MP-GC cable can be suspended by the phase conductors attached to strain insulators. This method is generally useful where vertical suspensions down boreholes are approximately 400 feet or less.



Type MP-GC, 15kV

Fig 6



Type SHD-GC, 15kV

Fig 7

MP-GC: Stationary HV Distribution	SHD-GC: Mobile/Surface HV Distribution
Annealed bare copper conductor, Compact Class B strand	Stranding is designed for optimum flexibility and flex life
Semi-conducting thermoset Extruded Strand Shield (ESS) is utilized in conjunction with Ethylene Propylene Rubber (EPR) insulation in thicknesses corresponding to normal power cable standards	Nominal insulation thickness is 20%-30% heavier than MP-GC to provide additional mechanical protection
Extruded Insulation Shield (EIS) and copper tape shield	Flexible copper/textile braid shield eliminates kinked copper tapes
Chlorinated Polyethylene (CPE) jacket protection	Double-layer reinforced CPE jacket for twice the protection

HOW UNDERGROUND MINING CABLES FAIL

Cable breakdowns can usually be traced to one or more of the following causes:

1. EXCESSIVE TENSION
2. MECHANICAL DAMAGE
3. CURRENT OVERLOAD
4. IMPROPER SPLICING & TERMINATION TECHNIQUES

1

EXCESSIVE TENSION

Many cable failures are the direct result of excessive tension. Tension on conductors subjects individual wires in the strand to compression and shear, damaging these thin wires so they break more easily when bent or flexed.

Jackets under tension lose a considerable part of their resistance to mechanical damage. A jacket under tension is much more likely to be cut or torn. Stretching also causes the copper conductors to take a permanent set. Of course, the insulation and jacket are stretched as well, but they will return to their original length when the tension is removed. This difference in the properties of rubber and copper when subjected to tension will cause the conductors to be wavy and fail prematurely.

To reduce cable tension:

- Avoid backspooling, if possible
- If backspooling is unavoidable, locate the tie point as far back from the haulageway as possible
- Tram slowly when passing the tie point
- Set hydraulic tension on the cable reel so that approximately 10 feet of cable is picked up off the mine bottom when starting to tram

Evidence of Excessive Tension
Cable necked down resembling an hourglass in shape
Jacket creeping back from temporary splice
Grounding conductor pulled in two

How to Avoid Damage
Install shock absorbers at tie points
Keep proper tension on trailing cable reel
Pull the cable into several loops (rather than a single long length) when moving

2

MECHANICAL DAMAGE

Cutting, compression (crushing), punctures and abrasion are among the most prevalent sources of trailing cable failures. In extreme cases, failure from mechanical damage is instant and can be identified on the spot. However, cable components are usually just "injured" by mechanical damage and become latent failures, making it more difficult to pinpoint the exact cause and take remedial action.

Evidence of Mechanical Damage
Short sections of cable crushed or flattened to a larger diameter
Excessive abrasion, cable grooved or shows uneven wear
Gouges, cuts and punctures

How to Avoid Damage
Avoid runovers
Do not pinch cable between equipment and rib, roof or mine bottom
Observe minimum bending radius
Replace broken sheaves or broken guides

3

CURRENT OVERLOAD

The temperature of the conductors, insulation and jacket are elevated when cables are subjected to an electrical load. Under these conditions, voltage drop resistance is increased, supplying a reduced voltage to the machine resulting in more current which further increases cable heating.

A trailing cable's insulation and jacket materials exhibit maximum resistance to physical damage at the rated conductor temperature of 90°C or less. These components' resilience decreases as temperature increases. As such, the insulation and jacket and much of its resistance to cutting, crushing, tearing and abrasion when exposed to prolonged elevated temperatures.

The section of the cable remaining on the reel is most likely to be damaged by electrical overload. Layering on the reel hinders ventilation and heat dissipation. Continued exposure to elevated temperatures will age the jacket, making it hard and brittle, and causing crazing or cracking upon subsequent reeling.

When cables are used with one or more layers wound on a reel, the ampacities should be derated as follows:

No. of Layers	Multiply Ampacities by
1	0.85
2	0.65
3	0.45
4	0.35

Evidence of Current Overload
Blistered jacket
Tinned copper conductor wires turn a blue-black color
Jacket on the bottom layer of cable on the cable reel hardens and cracks

How to Avoid Damage
Choose a cable with an adequate current rating
Consult cable manufacturer or mining machine manufacturer for recommendations
When operating only a short distance from the power source, remove cable from reel and place it where it will be well-ventilated
When cable is removed for permanent splices, reverse cable ends

4

IMPROPER SPLICING & TERMINATION TECHNIQUES

Splicing materials and techniques have improved substantially over the years. Unsatisfactory splice service usually results from:

1. A grounding or ground-check conductor shorter than the power conductors
2. Semi-conducting residue remaining on the insulation surface
3. Gaps, voids or soft spots in insulation tape build-up
4. Improper shielding system terminations, leaving inward-pointing projections
5. Damage to factory insulation by improper shielding system removal
6. Excessive slack in one or more individual conductors
7. Low tensile strength splice that is easily pulled in two
8. Damage to individual wires during connector application
9. Overly bulky splice that cannot pass through cable guides or over sheaves
10. Improper outer covering application, allowing water to enter the cable interior

Choosing a cable with an adequate current rating, avoiding excessive tension and mechanical damage, and using proper splicing techniques can reduce cable-related downtime by more than 50 percent.

Evidence of Temporary Splice/Termination
Bare conductors exposed in a temporary splice
Open grounding or ground-check conductor
Kinked cable

How to Avoid Damage
Carry insulating tapes back over the original conductor insulation
Replace temporary splices with permanent splices as soon as possible
Connect smaller conductors approx. ¼" longer than power conductors
Balance conductors in all splices and terminations to provide even stress on all conductors

AN EFFECTIVE MAINTENANCE PROGRAM

There is no magic formula for cable maintenance that fits all conditions, but these steps can be applied to many operations:

1

Choose a cable design that is consistent with voltage, safety and expected performance

2

Maintain a record of cable failure causes

3

Educate personnel to recognize the limitations of portable cable

4

Take remedial action based on records and education

PROPER CARE & MAINTENANCE GREATLY REDUCES DOWNTIME

The best means of minimizing the occurrence of these harmful situations is a workable cable maintenance program. Effective maintenance begins with choosing the most suitable cable construction obtainable for the application; cost considerations alone are a poor substitute for sound engineering.

When choosing a cable type and size, consider the following features:

- Safety
- Current-carrying capacity
- Voltage drop
- Ambient temperature
- Mechanical strength
- Unusual conditions that might require a special cable construction

The second step in a good maintenance program is performance analysis. An accurate record should be maintained and include installation date, a record of removal for repairs, and the cause of each failure. An accurate record of failure will demonstrate areas where maintenance is most urgently needed. It will also measure the effectiveness of any remedial actions.

Proper Splicing

No splice is as good as a new cable, but quality materials paired with proven techniques can dramatically improve the service life of a spliced cable. While a well-made, permanent-type splice with a vulcanized covering has all the necessary characteristics, but good resistance to fatigue is the most difficult to achieve.

As voltage ratings increase, the margin of safety decreases. It is essential that every aspect of installation is precisely engineered and supervised by capable individuals. The same applies to pre-fabricated splicing devices.

A GOOD SPLICE HAS:

- ✓ High tensile strength
- ✓ Balanced conductors
- ✓ Small outside diameter
- ✓ Low electrical resistance
- ✓ Adequate insulation
- ✓ High resistance to fatigue
- ✓ Moisture-resistant covering

SUMMARY

These best practices have proven effective in prolonging cable life:

1. Prevent twisting or kinking of cable during installation
2. Avoid excessive tension
3. Use the largest-size cable possible for the application; the extra tensile strength and current-carrying capacity of the next larger size can be more cost-effective in the long term
4. Keep runovers to a minimum
5. Reverse cable ends periodically
6. Replace damaged sheaves, guides and rollers

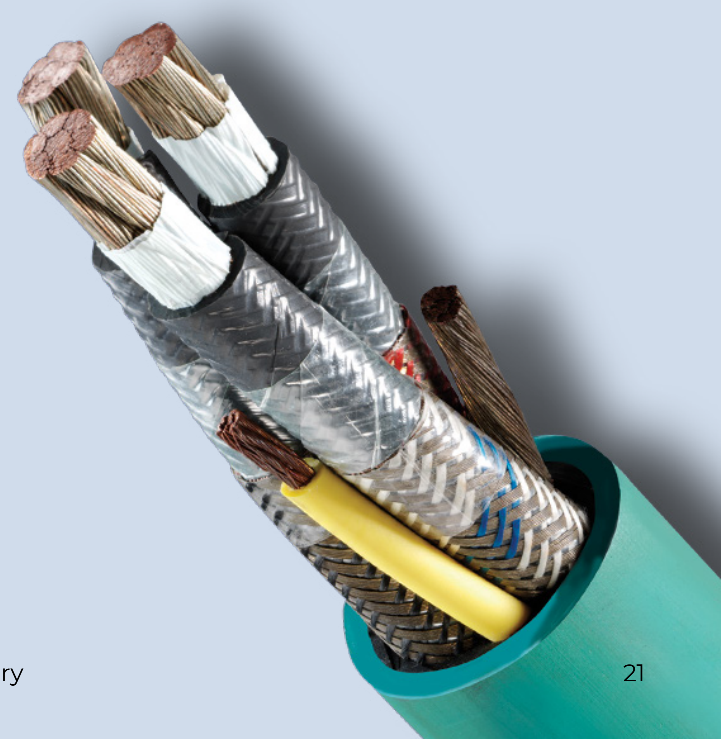
7 | Ensure cable guides are large enough for splices to pass through freely

8 | Repair cut or crushed cable even if a blowout has not occurred

9 | Provide a spare cable to allow for damaged cable removal in favor of making permanent repairs

10 | Keep water out of the cable interior

11 | Keep a record of failures and their causes



HOW PRYSMIAN HELPS YOU CUT DOWNTIME

Prysmian is glad to work closely with you to reduce cable-related downtime in your own mining operation. We have expertise not only in rugged cable design, but also in dedicated field assistance and cable testing.

ANACONDA® CABLES

We've long been the leading supplier of portable cables designed for reliable operation in the toughest of mining environments—and we're still pioneering advances today. Prysmian offers a full line of premium Anaconda® Brand cables engineered for superior performance in the most challenging applications. Specially designed conductors, insulation and jackets that exceed industry standards have made Anaconda® Brand cables the most reliable choice for mining equipment for more than 50 years.

FIELD ASSISTANCE

Take advantage of our teams' expertise in providing engineering assistance right at the mine site. We can even train your personnel in proper cable care and maintenance.

MINING CABLE TEST LAB

Our test lab has all the equipment necessary to simulate actual conditions in a mine in a fraction of the time it can take under normal field conditions. This fast, reliable feedback on trailing cable life can help you determine which cables to select as it improves our own cabling innovations attuned to the realities of the mining industry.

Cable Damage Source	Simulation Tests
Excessive tension and wire fatigue	Tension reeler Flexing machines Torsion bending machine
Mechanical damage	Compression cut machine Abrader Free-fall impact (crusher) Pile driver (repeating impacter)
Electrical stability	Current overload test Cyclic aging EMA ac life endurance test dc proof test
Flame and heat resistance	Flame test Air oven Electrical overloads
Splices and terminations	Mechanical and electrical tests
Environment	Chemical- and oil-resistance Oven aging Weather sunlight

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