

How To Cut Downtime And Extend Cable Life

Underground mining cable care
and maintenance



How To Cut Downtime And Extend Cable Life

Underground
mining cable care
and maintenance

contents

The huge cost of cable downtime today	3
Design of underground mining cables	3
Applications of underground mining cables	6
How underground mining cables fail	8
Proper care and maintenance greatly reduce downtime	10
Summary of ways to cut cable downtime	13
How General Cable helps you cut downtime	15

The information contained herein is intended for evaluation by technically skilled persons. Any person relying on this document does so at their own independent discretion and sole risk, assumes all risks and liability whatsoever in connection with such use, and General Cable will have no liability with respect thereto, whether the claim is based in contract, tort or other legal theory. General Cable makes no representations or warranties, expressed or implied, with respect to the accuracy, completeness or reliability of this document.

There have been significant advances made in mining and production techniques in the last 40 years, and with the introduction of these higher output mining methods, even greater importance has been placed on ensuring a continuous flow of current to these machines.

This has become even more important, given today's highly competitive economic environment.

General Cable's Anaconda Brand mining cables have been designed to reduce cable-related downtime, as this factor represents a serious impact to mine profitability. In operations of these magnitudes, every minute of downtime is very expensive and, once lost, can never be recovered. This has led us to assemble considerable information and know-how over the years on how such downtime can be minimized. This booklet represents a timely, updated body of knowledge for underground mining. It reduces our recommendations to simple procedures that can readily be passed on to all your operating personnel.

A companion piece is available on surface mining cable care and maintenance.



The Huge Cost of Cable Downtime Today

Reliable performance of modern underground mining cables is essential to low-cost mining. The unscheduled interruption of production resulting from cable failures costs much more than is generally realized. Lost tonnage, interest, depreciation, overhead and labor costs associated with this kind of downtime can surpass the initial investment in cable. This emphasizes the importance of selecting cable of the highest quality.

For a true representation, ultimate cable costs must include the cost of repairs and downtime. Over a period of time, this cost can be expressed in terms of dollars per ton of coal produced. Careful cable selection, handling and maintenance can cut these costs to as low as one-half of 1%.

To accomplish this, an understanding of the design of underground cables and their optimum performance limitations is invaluable.

Design of Underground Mining Cables

The mining machine cable of the early 1900s typically consisted of a flexible copper conductor, a wall of rubber insulation and an outer covering of fibrous material.

As applications and service requirements changed, so have mining cables. Today's highly engineered complex design (Figure 1) takes advantage of modern polymeric insulating and jacketing materials, as well as stranding and shielding techniques, providing optimum safety, durability and performance.

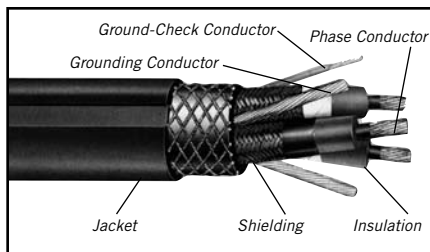


Figure 1

Here is a brief description of each of the components:

(Not all these components are included in every cable design. And there are some exceptions in choice of materials, as explained in a later section on “Applications of Underground Mining Cables”.)

Jacket

Jacketing is essential in underground mining cables and is the “first line of defense” against adverse physical and mechanical environments.

The long-time standard of neoprene as the jacketing material for Flat and MP-GC cables has been replaced by a Chlorinated Polyethylene (CPE) compound which provides improved tensile strength, high resistance to abrasion, excellent flexibility, and a wide thermal range from 90°C down to -50°C.

CPE possesses natural resistance to ozone, making it especially suitable for high-voltage applications, and it passes the Mining Safety and Health Administration (MSHA) Flame Test.

Shielding

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

- 1) To obtain symmetrical radial stress distribution within the insulation and to eliminate, for practical purposes, longitudinal stresses on the surface of the insulation or jacket
- 2) To provide a definite capacitance to ground for the insulated conductor, thereby presenting a uniform surge impedance and minimizing the reflection of voltage waves within the cable run
- 3) To reduce the hazard of shock and danger to both life and property

Reliable performance of modern underground mining cables is essential to low-cost mining.

Tests have shown that the copper/textile braid shield is mechanically superior to a full copper braid.

Shielding (cont'd)

Shielding wires have also been found to perform another function, especially important where ground continuity is essential. In constructions where grounding conductors are laid in the cable, in contact with the shield throughout the length of the cable, ground continuity is assured through the infinite number of parallel paths provided.

There has been growing interest lately in shielding low-voltage cables in order to eliminate the shock hazard that exists, although one common objection is the complexity of splicing and terminating.

There are two types of flexible shielding which have become associated with underground mining:

1. Full copper braid
2. Copper/textile braid

Tests have shown that the copper/textile braid shield is mechanically superior to a full copper braid. This is largely because the individual wires cross over threads instead of other wires. (Figure 2)

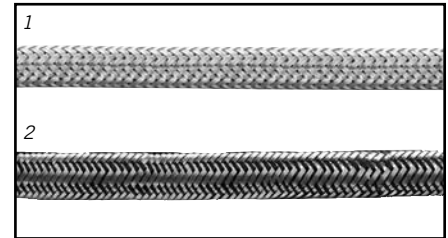


Figure 2

Grounding System

Grounding conductors and shielding wires cannot be separated from each other when considering effective ground impedance, because together they form the total grounding system.

As a result, little change occurs in the grounding system impedance after individual components have suffered extreme flex fatigue. In fact, it has been shown that the grounding system will continue to function long after phase conductor failure renders the cable inoperative.

The function of the grounding system, theoretically, is 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 for high-voltage systems and 40 volts for low-voltage systems. Where the maximum fault current is limited by a grounding resistor, it seems that the parameters for sizing the grounding conductors are thereby defined.

Even though the grounding system might be considered fail-safe in a shielded cable, continuous ground monitoring is required by Federal law to ascertain continuity through connections and to assure solid terminations.

Ground-check conductors are often included in trailing cables to facilitate this ground monitoring. Premature flex fatigue of ground-check conductors has been virtually eliminated by the application of a heavy wall of polypropylene insulation that prevents kinking. In cases where the ground-check conductor is much 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.

Insulation

Ethylene Propylene Rubber (EPR) insulation is now the standard in underground mining cables and has helped reduce insulation thickness by up to one-third, while nearly doubling typical breakdown voltage.

Ethylene Propylene Rubber has excellent mechanical properties over a temperature range of -60°C to +90°C. Within this range, EPR has high tensile strength and resistance to tear, abrasion, and compression cut. In addition, it is flexible and easy to repair, making it well suited for rugged mining environments.



Conductor Stranding

Mining cable conductors are stranded to provide flexibility and flex life. The flex life of a particular construction is the number of times it can be bent back and forth before the strands fatigue. Flex life or resistance to flex fatigue is a function of stress. The relationship is nonlinear, especially in the low-stress portion of the curve. (Figure 3) Theoretically, at some point on the curve below, you could increase the flex life by a factor of 10 simply by reducing the stress by one-half; however, operating at very low stress levels can be impractical.

Flex fatigue in any portable cable is a certainty and just a question of time. To prolong the time before it happens, the important thing is to balance the tensile load among the individual conductors as uniformly as possible.

Manufacturers' recommended minimum bending radii and maximum tensile loads are calculated with this in mind. Exceed them and you will greatly accelerate failure rates. In which case, the percent reduction in flex life exceeds the percent increase in operating limitations by a large margin.

The recommended Insulated Cable Engineers Association (ICEA) minimum bending radii are as follows:

- Braid-shielded portable cable—8 times the cable diameter
- Nonshielded portable cables—6 times the cable diameter
- Flat nonshielded cables—6 times the minor dimension
- Copper-tape-shielded cables—12 times the cable diameter

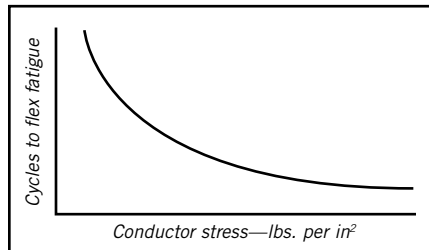


Figure 3



The control sample was flexed continuously for a specified number of cycles over a given bending radius, under specific tension, until only a few strands remained unbroken.



The second sample was flexed the same number of cycles over the same bending radius, but the tension weight was reduced by one-half. As can be seen, reduction of tension greatly reduced strand breakage.



The third sample was again flexed the same number of cycles, using the same tension as with the control sample. However, a bending radius two-and-one-half times larger was used. Increasing the bending radius practically eliminates strand damage.

Increasing the bending radius practically eliminates strand damage.

Research now underway with semi-conducting materials may result in cable designs that can provide the safety benefits of shielding without having the disadvantage of shield wire breakage.

Applications of Underground Mining Cables

As mentioned previously, not all the above components are common to every underground mining cable. In fact, there are some major differences in design dictated by the service conditions to which the cable will be subjected. These may be classified into: (1) trailing cables used on reels; (2) trailing cables for non-reeling applications; and (3) feeder cables.

1. 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 for very long. Research now underway with semi-conducting materials may result in cable designs that can provide the safety benefits of shielding without having the disadvantage of shield wire breakage.

Presently, the flat cable is preferred because its relatively small minor diameter allows a tighter bending radius. You also can wrap more cable on any given cable reel because of more efficient use of the available space. (Figure 4)

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

These operating conditions for shuttle car cables demand the toughest insulation available. They also demand a high degree of adhesion between the insulation and jacket in flat cables in order to retain the 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.

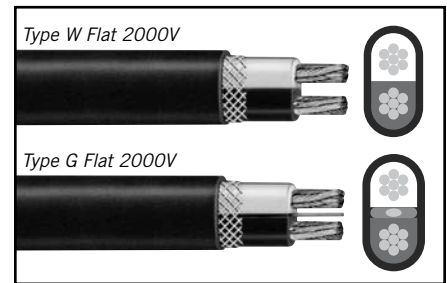


Figure 4

2. Trailing cables for non-reeling applications

Although not subject to the flexural stresses of reeling cables, these cables are often dragged along the ground by men or mining machines. This necessitates a high degree of abrasion resistance and tensile strength.

Currently, CPE jackets best meet these service conditions. In addition, conductors previously insulated with Neoprene rated at 75°C and 600 volts have given way to EPR insulation which is rated at 90°C and 2000 volts for equivalent wall thickness. EPR also provides superior resistance to moisture absorption. This design is intended for the same applications as the 600 volt cable but with increased safety margins. (Figure 5)

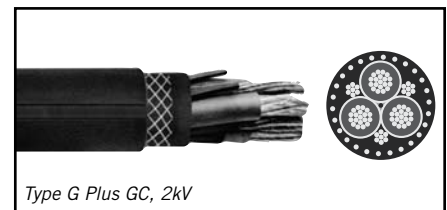


Figure 5

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.



2. Trailing cables for non-reeling applications (cont'd)

Note also the symmetrical design in Figure 5. 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 designs are designated as Type G Plus GC and SHD Plus GC.

The Type SHD Plus GC offers three features for underground mining not present in the more common Type G-GC: (1) fail-safe ground continuity; (2) no induced voltages; and (3) shock hazard protection.

3. Feeder cables

Underground distribution systems utilize high-voltage feeder cables. Mine Power Feeder (MP-GC) with Ground-Check Conductor is the cable designed for underground high-voltage distribution and is relatively stationary, i.e., relocated less than once a year. (Figure 6)

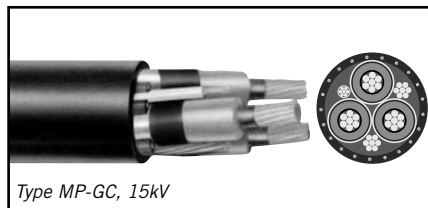


Figure 6

It consists of the following components:

1. The conductor is annealed bare copper, Compact Class B strand.
2. 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.
3. The insulation shielding system consists of an Extruded Insulation Shield (EIS) and copper tape shield.
4. A tough lead-cured Chlorinated Polyethylene (CPE) jacket provides the necessary outer protection.

If the cable is to be moved more often, or if it is to be installed in the surface area of an underground mine, then consider Type SHD-GC. (Figure 7)

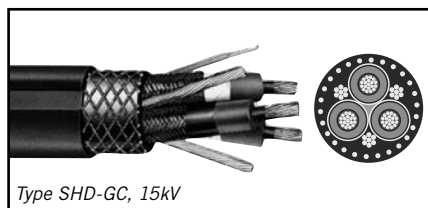


Figure 7

Type SHD-GC differs from Type MP-GC in several aspects:

1. The stranding is designed for optimum flexibility and flex life.
2. The Extruded Strand Shield (ESS) and insulation is EPR, the same as used with Type MP-GC; however, the nominal insulation thickness is 20%-30% heavier to provide additional mechanical protection.
3. A flexible copper/textile braid shield is used with Type SHD-GC to eliminate the problem of kinked copper tapes, which often occur when bending Type MP-GC.
4. The reinforced two-layered CPE jacket used for Type SHD-GC is about twice the thickness found on a comparable Type MP-GC.

General Cable's experience is that true dollar value is optimized with standard constructions, offsetting any material savings gained by using a crossbreed construction.

Today's smaller,
lighter Mine
Power Feeder
cables lend
themselves
to more
economical
methods of
suspension.

3. Feeder cables (cont'd)

Often, mine officials consider crossbreeds between Type MP-GC and Type SHD-GC. A favorite one utilizes Type SHD-GC stranding and shielding techniques with Type MP-GC insulation and jacket thickness. On the surface, there would seem to be a savings in materials with this design.

However, General Cable's experience is that true dollar value is optimized with standard constructions, offsetting any material savings gained by using a crossbreed construction. In other words, you can expect either more performance for the same costs, or the same performance for lower costs, by staying with standard cable constructions whenever possible.

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.

Longer suspensions often require additional support when the safety factor is less than seven (7) based on the following formula:

F = AT/W, where:

F = Safety factor (minimum of 7)

A = Area (in.²) of the three power conductors

T = Tensile strength of annealed copper (24,000 lbs./in.²)

W = Weight of cable to be suspended (pounds)

For example, the safety factor for 500 feet of a 4/0 AWG (0.1662 in.²), 3 conductor Type MP-GC cable weighing 4500 lbs. per 1000 feet would be calculated as follows:

$$F = \frac{.4986 \text{ in.}^2 \times 24,000 \text{ lbs./in.}^2}{2250 \text{ lbs.}} = 5.3$$

Since F is less than 7, an alternate method is needed. One such method is to attach cable grips and steel wires as support members. This can facilitate vertical suspensions up to 1000 feet.

How Underground Mining Cables Fail

Cable breakdowns are neither mysterious nor unaccountable, and almost without exception can be traced to one or more of the following causes:

1. Excessive tension
2. Mechanical damage
3. Current overload
4. Improper splicing and termination techniques

Excessive Tension

Many cable failures are the direct result of excessive tension. A cable that has been "stretched" no longer has the balanced construction that is so vital to long life. Tension on the conductors subjects the individual wires in the strand to compression and shear. These thin wires are damaged and will break more easily when bent or flexed.



Excessive Tension (cont'd)

Tension also elongates the conductor insulation. The elongated insulation is then vulnerable to compression cutting. It will rupture more easily when it is crushed against the stranded conductor during runovers. The insulation will also have a tendency to creep over the conductor at a splice.

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 tension on the cable:

- 1. Avoid backspooling, if possible.
- 2. If backspooling is unavoidable, locate the tie point as far back from the haulageway as possible.
- 3. Tram slowly when passing the tie point.
- 4. 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.

Mechanical Damage

This is one of the most prevalent sources of trailing cable failures. Factors initiating mechanical damage include cutting, compression (crushing), punctures and abrasion.

In extreme cases of mechanical damage, the failure is instant, and the cause can be assigned on the spot. Many times, however, the cable components are merely “injured” and become latent failures. At that point, it may be more difficult to pinpoint the exact cause and to take remedial action.

Current Overload

The temperature of the conductors, insulation and jacket are, of course, elevated when cables are subjected to an electrical load. The resistance of the copper is increased, voltage drop in the cable is increased, and therefore, a reduced voltage is supplied to the machine. As a result, the machine calls for more current, which adds further to cable heating.

A trailing cable’s insulation and jacket materials exhibit maximum resistance to physical abuse at the rated conductor temperature of 90°C or less. The ability of these components to withstand damage decreases as the temperature increases. Conditions which normally cause few cable failures suddenly become a problem. At elevated temperatures, the jacket has lost much of its resistance to cutting, crushing, tearing and abrasion.

The section of the cable that remains on the reel is most likely to be damaged by electrical overload. Layering on the reel hinders ventilation and heat dissipation. (Figure 9) 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

Figure 9

A trailing cable’s insulation and jacket materials exhibit maximum resistance to physical abuse at the rated conductor temperature of 90°C or less.

The best means of minimizing the occurrence of downtime is a workable cable maintenance program.

Improper Splicing and Termination Techniques

Over the years, much work has been done to improve both splicing materials and techniques. The following items have been found to be primarily responsible for unsatisfactory splice service:

1. Ending up with a grounding or ground-check conductor which is shorter than the power conductors
2. Semi-conducting residue on the insulation surface was not removed
3. Gaps, voids or soft spots in insulating tape build-up
4. Improper termination of shielding system, leaving inward-pointing projections
5. Damage to factory insulation by improper removal of shielding systems
6. Excessive slack in one or more individual conductors
7. Splice has low tensile strength and is easily pulled in two
8. Individual wires are damaged during application of connector
9. Splice is too bulky — will not pass through cable guides or over sheaves
10. Improper application of the outer covering, allowing water to enter the cable interior

By choosing a cable with an adequate current rating, avoiding excessive tension and mechanical damage, and using proper splicing techniques, it is not unreasonable to reduce cable-related downtime by 50 percent or more. This will, of course, translate into increased production and profits.

Proper Care and Maintenance Greatly Reduce Downtime

The best means of minimizing the occurrence of downtime is a workable cable maintenance program. This program should not be limited to a few “Do’s” and “Don’ts”, but must consist of a series of good cable practices that become a habit and fit naturally into the daily mining routine.

An Effective Program

There is no magic formula for cable maintenance that fits all conditions. The following basic outline suggests an approach that can be applied at any operation:

1. Choose a cable design that is consistent with voltage, safety and expected performance
2. Maintain a record of causes of cable failures
3. Educate operating personnel to recognize the limitations of a portable cable
4. Take remedial action based on records and education. Records will point to what made the cable fail. Education will help explain why the cable failed.

Effective maintenance begins with choosing the most suitable cable construction obtainable for the application. *Economic considerations alone are a poor substitute for sound engineering.*

Cable manufacturers like General Cable supply an abundance of data to serve as a guide, but the following should be emphasized in choosing a cable type and size:

1. Safety
2. Current-carrying capacity
3. Voltage drop
4. Ambient temperature—for example, extreme summer heat
5. Mechanical strength
6. Unusual conditions that might require a special cable construction



An Effective Program (cont'd)

Special consideration should be given to the recommendations of the ICEA that “where maximum safety is desired, Type SHD-GC cables are recommended.”

The second step in a good maintenance program is analysis of performance. An accurate record must be maintained and should include:

1. The date of installation
2. Record of removal for repairs
3. The cause of each failure

Information on number 3 is the most important of all.

An accurate record of causes of failure will point out those areas where maintenance is most urgently needed. This record will also indicate the effectiveness of any remedial action that might be taken. Experience is a good teacher and can be most useful in setting up a program, but experience can be greatly enhanced by an accurate record. There is too much tendency to classify practically every failure under “improper handling by operating personnel.”

There should be mutual understanding between the cable manufacturer and mining operator concerning the physical and electrical limitations of a cable. Cable manufacturers like General Cable can offer valuable assistance in training programs designed to instruct operating personnel in good cable practice.

Proper Splices

While it is true that no splice is as good as a new cable, the use of quality materials and proven techniques can dramatically improve the service life of the cable splice. A well-made splice has the following characteristics:

1. High tensile strength — the splice cannot be easily pulled in two
2. Balanced conductors — equal tension on each conductor
3. Small outside diameter — the splice can be passed easily through existing cable guides
4. Low electrical resistance
5. Adequate insulation
6. High resistance to fatigue
7. A covering that is capable of keeping moisture from entering the cable interior

Preparation of Cable for Splicing

In preparing cable ends for splicing and terminating, there are certain steps that require special attention and technique to ensure against premature failure. These are listed below:

1. Cable ends should always be cut carefully and squarely.
2. The outer jacket should be removed without damaging shield tapes or braid by the following procedures:
 - a) Ring jacket circumferentially through approximately 80 percent of the jacket thickness.
 - b) Holding knife at an angle, cut the jacket longitudinally in such a manner so that repeated traverses of these cuts will only have penetrated approximately 80 percent of the jacket thickness.
 - c) Using pliers, grip the edge of the jacket and pull in the direction of the slant cut. If the jacket does not readily tear at the cut, a knife may be used with tension applied to the jacket, still avoiding damage to the underlying shield tapes or braid.
3. Thoroughly clean jacket on both ends of the splice to obtain good adhesion between the factory jacket and the completed splice jacket.

While it is true that no splice is as good as a new cable, the use of quality materials and proven techniques can dramatically improve the service life of the cable splice.

At this stage,
the ultimate
electrical
integrity of the
cable joint will
be in direct
relationship to
the skill of
the splicer.

Making the Splice

1. Stagger the conductors so that the finished splice will have the smallest possible diameter, and so that all reconnected conductors will be of equal length. (Figure 10)
2. If the cable is shielded, cut the shield wires at the point of termination carefully. A smooth shield edge is essential in preventing premature splice failure.
3. Remove the semi-conducting insulation shield, if present, to within approximately 1/4" of the end of the metallic shield. Improper termination of shield components is one of the major causes of splice failure.
4. Pencilling of the insulation requires a 360° perpendicular cut through all but the last 1/16" of insulation, at a predetermined distance from the conductor end. This distance is directly dependent on the type of connector and type of cable insulation. Pencil and smooth the taper before removing the short section of insulation from the conductor. This buffer technique, illustrated in Figure 11, protects the conductor surface against undue abrasion and scoring.
5. Any traces of semi-conducting residue remaining on the conductor or surface of the insulation must be removed. Normally, a lintless cloth slightly dampened with cleaning solvent will suffice. (Note: Semi-conducting insulation shield materials are generally not used on mining cables rated less than 8000 volts.)
6. Reconnect the conductors, being careful not to damage the individual wires. (Figure 12)



Figure 10

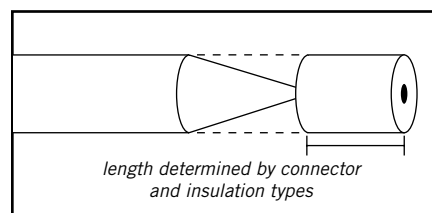


Figure 11

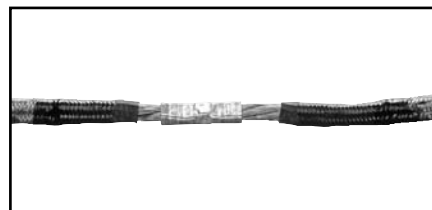


Figure 12

Re-Insulating the Joint

At this stage, the ultimate electrical integrity of the cable joint will be in direct relationship to the skill of the splicer. If the individual fails to properly address any phase of the operation, failure could result. Areas requiring strict attention to details are:

1. Application of a semi-conducting tape, when it is used, over the conductor connector must result in a smooth contour. (Figure 13) Insulation putty can assist in this, as well as seal against moisture.

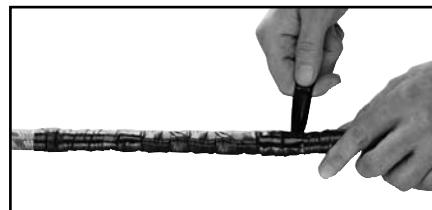


Figure 13

Re-Insulating the Joint (cont'd)

2. The insulating tape should be applied half-lapped, introducing uniform stretch as specified by the tape manufacturer. (Figure 14)
3. Frequent rolling of the work with a concave tool, screwdriver shank or other round object helps to eliminate any entrapped air which could otherwise ionize if sufficient voltage gradient is impressed across it.
4. Wrap insulating tape to approximately 1/4" from cable semi-conducting component. For proper metallic shielding, a tinned, all-copper braided tape is recommended.

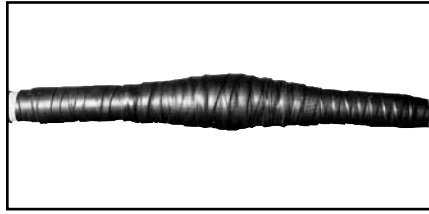


Figure 14

Re-Jacketing the Completed Splice

When a splice kit is not available, both Chlorinated Polyethylene (CPE) and Chlorosulfonated Polyethylene (CSPE) tapes have been used for re-jacketing with considerable success.

Summary of Ways to Cut Cable Downtime

Following is a summary of the steps which have proven effective in prolonging cable life:

1. Prevent twisting or kinking of cable during installation — a kinked conductor is a damaged conductor.
2. Avoid excessive tension.
3. Use the largest-size cable possible for the application. Take advantage of the extra tensile strength and current-carrying capacity of the next larger size. It is more economical in the long run.
4. Keep runovers to a minimum. Any form of crushing is a potential source of rupture in the insulation and jacket.
5. Reverse cable ends periodically. The end on the reel may be damaged by long exposure to elevated temperatures.
6. Replace damaged sheaves, guides and rollers. Make certain cable guides are large enough for splices to pass through freely.
7. Repair cut or crushed cable, even if a blowout has not occurred.
8. Provide a spare cable. Remove cable with temporary repairs and make permanent repairs. This will pay off, especially in wet sections.
9. Keep water out of cable interior.
10. Keep a record of what caused failures. It will point out where steps must be taken for more effective maintenance.

By adopting all these practices, cutting cable-related downtime by 50% isn't at all unreasonable!

By adopting all the these practices, cutting cable-related downtime by 50 percent isn't at all unreasonable!

Here's the information in tabular form:

Guide To Trailing-Cable Maintenance

Causes of Damage	Evidence of Damage	How to Avoid Damage
Excessive Tension	<ol style="list-style-type: none"> 1) Cable necked down, resembling an hourglass in shape 2) Jacket creeping back from temporary splice 3) Grounding conductor pulled in two 	<p>Install shock absorbers at tie points. (1, 2, 3)</p> <p>Keep proper tension on trailing cable reel. (1, 2, 3)</p> <p>If possible, position tie point to avoid backpooling. (1, 2, 3)</p>
Mechanical Damage	<ol style="list-style-type: none"> 1) Short sections of cable crushed or flattened to a larger diameter 2) Excessive abrasion, cable grooved or shows uneven wear 3) Gouges, cuts and punctures 	<p>Avoid runovers. (1)</p> <p>Do not pinch cable between equipment and rib, roof or mine bottom. (1)</p> <p>Observe minimum bending radius. (1)</p> <p>Replace broken sheaves or broken guides. (2, 3)</p>
Current Overload	<ol style="list-style-type: none"> 1) Blistered jacket 2) Tinned copper conductor wires turn to a blue-black color 3) Jacket on the bottom layer of cable on the cable reel hardens and cracks 	<p>Choose a cable with an adequate current rating. Consult cable manufacturer or mining machine manufacturer for recommendations. (1, 2)</p> <p>When operating only a short distance from the power source, remove cable from reel and place it where it will be well-ventilated. (1, 2)</p> <p>When cable is removed for permanent splices, reverse cable ends. (3)</p>
Temporary Splices and Terminations	<ol style="list-style-type: none"> 1) Bare conductors exposed in a temporary splice 2) Open grounding or ground-check conductor 3) Kinked cable 	<p>Carry insulating tapes back over the original conductor insulation, and replace temporary splices with permanent splices as soon as possible. (1)</p> <p>Connect these smaller conductors approximately 1/4" longer than the power conductors in all splices and terminations. (2)</p> <p>Balance the conductors in all splices and terminations so that there will be an even stress on all conductors. (3)</p>



How General Cable Helps You Cut Downtime

General Cable would be glad to work closely with you to reduce cable-related downtime in your own mining operation. To do this, we have three separate areas of competence we can bring to your situation:

1) 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!

2) Field Assistance

We've learned a lot from years of providing engineering assistance right at the mine site—experience which we're happy to share with you at your own locations. We can even train your personnel in proper cable care!

3) Mining Cable Test Lab

We believe no other supplier can offer you the services of a facility like this. Located at Marion, Indiana, USA, it has all the test equipment necessary to simulate actual conditions in a mine, with one important difference—our Portable Cable Lab can test a cable to destruction in a fraction of the time it would take under normal field conditions. Yet we can accurately extrapolate the results in terms of the type of end-use the cable is expected to receive.



Thus, the laboratory can give you fast, reliable advice on your problems with trailing cable life. It can help you with correct recommendations on which cables to select. And of course, it has helped General Cable immeasurably in the past in designing cables that are in tune with the realities of the mine site.

The following chart describes common types of failure and the lab tests we can perform to induce such damage.

Cable Damage Source	Cable Tests for Simulating Service Damage
Excessive tension and wire fatigue:	<ul style="list-style-type: none">• Tension reeler• Flexing machines• Torsion bending machine
Mechanical damage:	<ul style="list-style-type: none">• Compression cut machine• Abrader• Free-fall impact (crusher)• Pile driver (repeating impacter)
Electrical stability:	<ul style="list-style-type: none">• Current overload test• Cyclic aging• EMA• ac life endurance test• dc proof test
Flame and heat resistance:	<ul style="list-style-type: none">• Flame test• Air oven• Electrical overloads
Splices and terminations:	<ul style="list-style-type: none">• Mechanical and electrical tests
Environment:	<ul style="list-style-type: none">• Chemical- and oil-resistance• Oven aging

General Cable would be glad to work closely with you to reduce cable-related downtime in your own mining operation.



**4 Tesseneer Drive,
Highland Heights,
Kentucky 41076-9753**

GENERAL CABLE and ANACONDA
logos are trademarks of General Cable
Technologies Corporation.

©2007. General Cable Corporation.
Highland Heights, KY 41076

All rights reserved.
Printed in USA

Phone: 1.888.593.3355
Fax: 1.800.335.1270
International Tel.: +1.859.572.8000
International Fax: +1.859.572.8058

www.generalcable.com

Form No. INS-0082-0807