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Installation and Safety Practices For Cable Bolts In Underground Mines

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ILLUSTRATIONS

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

Metric units

cm	centimeter	mm	millimeter
m	meter	MPa	megapascal
m^3/min	cubic meter per minute	N • m	newton • meter
min	minute	s	second

INSTALLATION AND SAFETY PRACTICES FOR CABLE BOLTS IN UNDERGROUND MINES

By L. A. Martin,[1] J. M. Girard,[2] and J. M. Goris[3]

ABSTRACT

Flexible tendons, or cable bolts, have been recognized as an effective and efficient support system for underground mines. In the past 10 years, use of cable bolts has increased substantially. However, regardless of their increased use, little attention has been focused on the safety hazards associated with handling and installing cable bolts.

Two of the most significant safety hazards associated with cable bolts are the dissipation of stored energy in cable coils and the failure of cable anchors. The U.S. Bureau of Mines has documented these hazards, as well as other possible hazards associated with handling and installing cable bolts, and has evaluated potential solutions.

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INTRODUCTION

Around 1970, cable bolts were introduced to the mining industry as a means of reinforcing ground prior to mining. Use of cable bolts as an effective underground support system has increased in both hard-rock mines and coal mines. The popularity of cable bolts can be attributed to their flexibility and to their high tensile strength in advance of mining. As the use of flexible tendons increases, the probability of accidents related to their use becomes a concern. Safety procedures and practices for installing, drilling, and grouting flexible tendons have been studied by researchers at the U.S. Bureau of Mines (USBM).

Cable bolts consist of one or more high-strength steel cables grouted into a drill hole in the rock. The cables are usually seven-wire strands and are typically 15 mm in diameter (figure 1). The basic installation procedure is different for hard-rock mines and for coal mines. In hard-rock mines, a flexible tendon is pushed into a drill hole and held in place by an anchor at the end of the cable before the cable is grouted. In coal mines, a temporary anchor is not required. Instead, resin cartridges are placed in a drill hole, after which a cable bolt is spun into the hole using a drill fitted with a specialized bit. In hard-rock mines, the cable is bonded along the full length of the hole with a cement-based grout, which causes pullout resistance to be considerably higher than when using traditional end-anchor supports.

This report describes the installation techniques employed in both hard-rock mines and coal mines and addresses health and safety practices at each phase of the installation process.

GROUND CONTROL

When ore or coal is removed, the ground around the excavated area is not in equilibrium, and without the intervention of artificial supports, the floor, walls, and back may close (Peng, 1978). The easiest way to prevent ground control problems is to make the opening stable as quickly as possible. Cable bolts are one means of providing the needed stability. Cable bolt supports are a semirigid support system; that is, the back or roof becomes a rigid member and the pillars and floor are left as a soft system with no support (figure 2).

The application of cable bolt supports varies somewhat between hard-rock and coal mines in the United States. In hard-rock mines, the cable is grouted along its entire length using a cement-based grout. This grout commonly consists of cement-water ratios varying from 0.3 to 0.45 parts water to 1 part cement. Long cable bolt supports are installed at specific intervals in a fan-shaped configuration. The cables not only support the immediate back, but also the hanging wall, thereby preventing dilution of the ore pile.

If blocks of rock around the opening begin to move (figure 2), their weight (load) is transferred to the cable bolts and the cables become an active support system. The blocks of rock are held in place by the pullout resistance developed along the cable-grout interface.

The use of cable bolts as ground control in coal mines differs from their use in hard-rock mines on the following bases.

1. Cables are point anchored.
2. Resin grout is used instead of cement-based grout.
3. Bearing plates and anchors are used on the cable end.
4. Bolts are spun into the hole with a roof bolter.
5. The coal and rock strata being supported are not mined.

In hard-rock mines, a large number of rock bolts is necessary to keep haulageways open. Deep (20 to 25 m long) grouted cable bolts installed in stopes provide secondary support, while rock bolts provide primary support. During a mine's blasting cycle, a stope reinforced with rock bolts will be fragmented, allowing muck to be removed. Cable-reinforced sections of the stope above the blasted area are still supported. This arrangement provides a safer working environment while miners remove muck from the stope.

In coal mines, cables are also used as a secondary support system although the cables are stiffer and more deeply embedded than resin-grouted roof bolts. In addition to the extra support, the use of cable bolts increases ventilation efficiency because the space once allotted to cribbing is left open.

HARD-ROCK MINES

CABLE HANDLING AND SHIPPING

Cable is shipped to hard-rock mines in one of two forms: in precut cable lengths strapped in coils or in large spools of continuous cable (figures 3 and 4). In either case, stored spring energy may cause the cable ends to whip out as coils are unwound and presents a significant safety hazard. Each shipping method and associated hazards are described in the following sections on "Precut Cables in Coils" and "Continuous Cable Spools."

PRECUT CABLES IN COILS

One of the most common ways to ship cable to a mine site is in coils. Each wrap of the cable is secured by metal strapping or fiberglass tape that must be cut prior to cable installation. Although these coils are convenient to ship, the spring energy stored in the coil poses a significant safety hazard when the strapping is cut and the spring energy is released (figure 3). Potentially, the maximum torque from a coiled cable end whipping out could be as high as 370 N • m. To minimize the safety hazard, cables are strapped in sequence in the factory, so the straps should be released in reverse sequence when they are cut at the mine site. Cutting the straps in the proper order limits the amount of cable released and reduces the effects of stored spring energy. A quick and effective cutting device is important, e.g., an air-operated disk cutter is preferred over a hacksaw. The person cutting the straps should stand in the middle of the coil to stay out of the way as the cable end whips out from the coil.

Special precautions must be taken when coils are secured with fiberglass tape. Nicks, rubs, or accidental cuts in the tape pose a safety concern because the tape could break and allow the cable end to whip out unexpectedly.

In general, personnel should be cleared from the area when precut cable coils are being opened. This area should have a relatively smooth floor and enough space to allow the energy to be released. In small areas, the cable might bounce off the ribs and rebound toward the miner opening the coil.

Leather gloves and eye protection should be worn when opening cable coils, and a protective guard should be in place on the cutter.

CONTINUOUS CABLE SPOOLS

In this method, large spools of cable are restrained in heavy steel frames (figure 4) and uncoiled as needed. Cable is cut to the appropriate length at the installation site using a power cutter (abrasive wheel) and laid flat in the drift until needed. The advantage of large spools is that cable can be cut in various lengths to conform to changing ground support requirements. Stored spring energy is released as the cable is pulled from the spool, but the heavy metal frame stops the cable from unwinding uncontrollably. A soft rubber protective cap (indicated by an arrow in figure 4) is placed on the cable end to prevent injuries. Gloves, eye protection, and a clutter-free site make releasing the cable from a spool a safer task.

DRILLING

Drilling is the first step when installing a cable bolt. Holes are drilled from 4.5 to 18 m deep in the rock using a pneumatic ring drill and carbide button bits. Generally, holes are drilled in a fan-shaped pattern (figure 5), beginning with perpendicular holes at the center. One of the main safety concerns when drilling is that loose material may fall from the back. There may also be problems associated with adding new drill rod, water blasts at drill startup, moving drill parts, and heavy lifting when transporting the drill between drilling sequences.

INSTALLING FLEXIBLE TENDONS

In hard-rock mines, manually pushing cables into a drill hole is the most common method of installation. Pushing cables can result in back injury, especially in long upholes. The cable crew should be provided with some means of reaching the hole collar so individuals may assume an effective stance for pushing cables. A scissor lift is commonly used at many operations, and one should be dedicated to the cable bolt crew.

After pushing the cable to the end of the drill hole, the anchor is set by tugging on the cable. This is very important because laboratory tests show that 2.6 cm of downward tug is usually required before anchors set. A plastic, mushroom-shaped end cap is pushed onto the end of the exposed cable. In the event the anchor fails and the cable falls from a hole, this protective end cap provides a blunt face that reduces the chances that the cable end may cause a penetrating injury.

Several mechanized methods for pushing cables have been developed in an attempt to reduce the manual effort required and to increase productivity. Nickson (1992) noted that an air-powered inserter was commonly used in western Canadian mines, but cable bolt crews were reluctant to use it because cables could slip and the number of cables installed during production was generally lower.

ANCHORING

When placing cable bolts in hard rock, an anchor is required to hold the cable in the drill hole prior to grouting. There are three types of anchors that are typically used: single barb, double barb, and spring (figure 6). If an anchor slips or fails, the cable weight alone is sufficient to cause serious injury to a person standing beneath it. Nickson (1992) reports that anchors slipped at several operations in western Canada.

In an effort to reduce cable slip, the anchoring systems have been modified. Studies of the single-barb anchor by Hunt and Askew (1977) suggest that the radius of the bent wire should be kept small (75 mm for a 65-mm-diam hole) to maximize the frictional resistance of the anchor. Barbs of longer lengths provide less resistance to slippage because the wire bends farther as the cable is pushed into the hole. USBM studies have indicated that barb lengths should be 15 mm larger than drill hole diameter and that barb angles for the cable anchors should be between 45° and 90° to provide the maximum pullout resistance.

GROUTING

Before inserting a cable, a plastic breather tube 12.5 mm in diameter is attached to the cable with tape. The tube is placed approximately 0.5 m from the end of the cable and has a 45° cut to reduce friction when the cable is pushed into the drill hole.

After the cable and the tube are inserted into the hole, the hole is flushed with water through the breather tube. The breather tube allows air displaced by the grout to escape. A plastic 15-mm-diam grout tube is pushed approximately 1 m into the hole, and the bottom of the hole is plugged with cotton waste or expandable foam. The grout is then pumped up the grout tube until it returns down the breather tube, which indicates the hole is filled. The ends of the two tubes are folded over and tied off to prevent grout from draining out. The tubes become a permanent part of the support system (figure 7).

Batch mixing of grout is typically done with a mechanical mixer, but the water, cement, and additives are added manually. Pouring cement into the mixer produces an excessive amount of dust, and the use of masks is highly recommended. Also, because bolting is frequently located in sublevel stope developments, adequate auxiliary ventilation is necessary.

The biggest safety concern related to grouting is cement burns. Hunt and Askew (1977) commented that 80 pct of the injuries occurring during cable installation at one operation are the result of cement burns. They recommended the use of long gloves, eye goggles, and respirators. Nickson (1992) noted that the use of protective overalls and waterproof suits by operators in western Canada decreased the instances of burns. Water is generally on hand during the grouting phase, and grout should be washed off immediately upon contact with the skin.

Another safety concern is bursting of hoses or connections during grouting. Such problems were reported frequently to Nickson (1992) in western Canadian mines. Bourchier and others (1992) also report bursts resulting from back pressure at the pump hose and at grout-tube connections. It has been suggested that the pump hose outlet be coupled directly to the grouting assembly (Bourchier and others, 1992) to eliminate the hazard of bursting connections.

The use of high-pressure (1.7 MPa) tubing to reduce hose bursting is becoming standard practice in hard-rock mines. High pressures generated at the hole collar can induce ground fracturing and release loose rock. After grouting is completed, the line pressure will remain high and care must be taken when the pump hose is disconnected from the grout tube.

COAL MINES

CABLE HANDLING AND SHIPPING

Cables are shipped to coal mines in long bundles of precut lengths. This shipping method does not pose a stored spring energy hazard. However, the length of cable is limited by mine cart length, cage size, and the dimensions of mine openings. Long bundles of 50 cables are usually strapped together, loaded onto a trailer, and pulled to the installation site. Care should be taken when loading and unloading because injuries may occur while lifting.

DRILLING

In coal mines, an electric, hydraulic, double-boom jumbo with dual operators is used along with hand drills and single-boom bolters to drill holes for tendons. An automatic temporary roof support (ATRS) is set against the roof to provide initial support, and a hydraulic foot is placed against the floor when drilling. Various lengths of rod corresponding to the seam height are used, and drilling is done with winged carbide bits. After the hole is completed, the rod is removed by lowering the boom, and the driller's helper manually removes the rod. With the ATRS and foot still in place, the tendon is grouted with resin in the hole. After the resin sets, the boom is lowered and the ATRS and hydraulic foot are released (figure 8). Operators should stand under the canopy during this procedure, because debris may fall from the roof. To reduce dust during drilling, vacuum or wet head systems are used. Periodic methane checks must be made, and proper ventilation is required.

The following steps in drilling for cable bolting using resin were observed in many coal mines (McDonnell and others, 1995).

Job Step 1. Examine the machine.

Inspect panic bars. Make sure all controls are working properly. The operator must be trained in the correct operation of the roof bolting machine, roof and ventilation plans, and the use of a methane detector. Make sure the machine is blocked while being worked on. Check the following before every shift: lights; automatic emergency brake; ATRS (auxiliary temporary roof system); and guards over gears, sprockets, and chains. There must be a scaling bar and a roof sounding device on the bolting machine. Inspect dust boxes and filters to make sure they are clean before use. Check ATRS for cracks and broken welds. Check for loose or broken bands that need to be replaced.

Job Step 2. Examine work area.

Secure or pull down loose roof and rib. Always remain under supported roof. Order any special materials needed before starting to bolt. Methane checks must be made before traveling inby the last open cross-cut and every 20 min while bolting. A flow rate of 142 m^3/min must be maintained at the end of the ventilation device. The ventilation device must also be maintained to within 3 m of the operator's controls on the ventilation side of the bolter. Remove or relocate all hung cables from the installation area so that the ATRS, drill steel, or roof mat will not pinch the cable.

Job Step 3. Prepare materials.

Mark the drill steel for the length of the cable bolt plus 5 cm. Supply cable bolting resin, relocating regular resin so that the two types cannot be accidentally interchanged. If the cable bolt comes coiled, hold cable bolt securely while a second person unties the wire and slowly unwinds it. Do NOT let the cable spring open.

Job Step 4. Start machine and tram into work area.

Give a verbal alert signal "coming on" before starting machine. Make sure both booms are centered before tramming. Make sure everyone is in the clear. No one is to be beside the machine while tramming (machine can slide sideways). Always tram from place to place from inside the cab. Second operator will watch cable. Check reel to ensure there is enough cable. Be certain proper crossovers are used when tramming. ATRS controls will be under permanent supported roof. Ensure helpers stay clear when cable reel is on.

Job Step 5. Position bolter and drill hole.

Be alert to roof and rib conditions. Secure or pull down loose material. Position bolter under previously installed pan or no more than 2 m from last installed pan. If installing pan, set pan on holder and start against top from center of entry. Install cable bolts only after ATRS has been permanently set against the roof for additional support. Keep hands and feet clear of boom and drill head while bolting. Make required methane checks before tramming into place and every 20 min thereafter. When working between the boom and the ATRS, ensure the stab jack is on the floor so the boom cannot swing into the operator in case of a hydraulic failure. Wear gloves while handling materials and operating machine. Select hole locations. Drill hole to the required, previously marked, depth. Allow steel to spin in the hole, with full water pressure when appropriate, after drilling for 15 to 20 s to clear the cuttings and cool the hole.

INSTALLING CABLE BOLTS

In coal mines, a resin cartridge is inserted in the drill hole, and a cable is manually pushed into the hole until resistance makes installation difficult or until the cable stabilizer is as close as possible to the collar of the hole. The end nut on the cable is inserted into the modified bolting wrench. After securing the cable, the drill is rotated slowly and the cable is pushed into the hole until the plate nears the roof. Care should be taken to avoid contact with the spinning tendon. After the plate is close to the roof, the bolt is spun at full speed for 3 to 5 s to ensure thorough mixing of the resin. The bolt is thrust up until the plate is flush with the roof and then held for the required setting time of the resin. The drill head is slowly let down. If the bolt starts to drop, the thrust is reapplied and held for an additional 5 seconds or until the resin sets. The bolt should never be spun again.

INSTALLATION HAZARDS

Lack of standardized procedures for placing flexible tendons can lower the load-carrying capacity of the cables and could lead to failure. Grouts with higher water-cement ratios have reduced compressive and tensile strengths. Under these conditions, water bleeding and cement particle sedimentation also increase. These factors reduce the total support length of a cable bolt. Design engineers should be aware that this process occurs, and cable bolt crews should be trained to keep the water-cement ratio of the grout within design specifications.

The grout or resin interface with the cable is also very important. Holes should be flushed with water before they are grouted to remove any dirt or other debris. Also, while a small amount of rust may actually improve the grout or resin interface with the cable, the cables should not be allowed to build up a flaking rust. Load-carrying capacity of the cables is decreased when a good grout or resin interface with the cable is not achieved.

Corrosion has been a major issue in the cable bolting industry and at 6 months, a 10% decrease in effective area has been observed (Tadolini, 1993). Manufacturers now provide galvanized cable strand to minimize corrosion and extend the cable life.

The longer the embedment length, the greater the load-carrying capacity of the cable (Goris, 1990). Cable bolt crews should not make up time or increase productivity by improperly installing cables. In coal mines, the cables and resin are designed to be a self-supporting system, and improperly installed cables change ground-control conditions.

CONCLUSIONS

Cable bolts are being used more often in both coal and hard-rock mines. Lack of standardized installation procedures can lead to accidents. This paper has discussed some of the hazards associated with cable installation in an effort to help reduce accidents associated with the use of cable bolts.

ACKNOWLEDGMENTS

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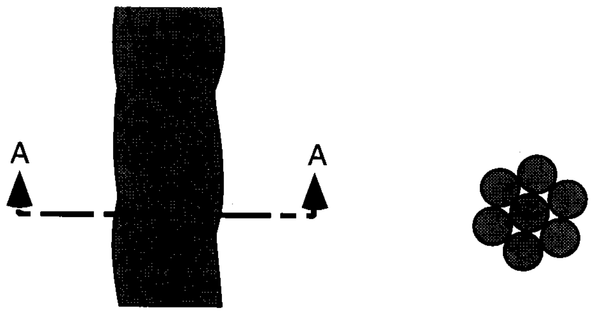
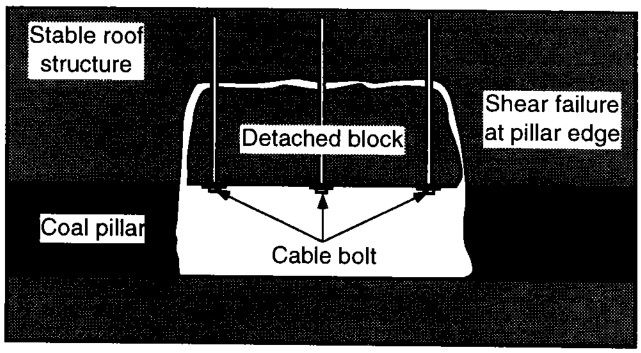
Figure 1



Seven-wire steel cable used in typical tendon.

Figure 2

A



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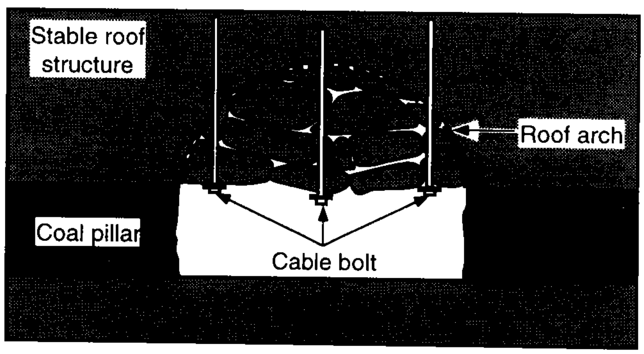


Type of failure in coal mines. A, Detached block failure; B, arch failure in roof.

Figure 3

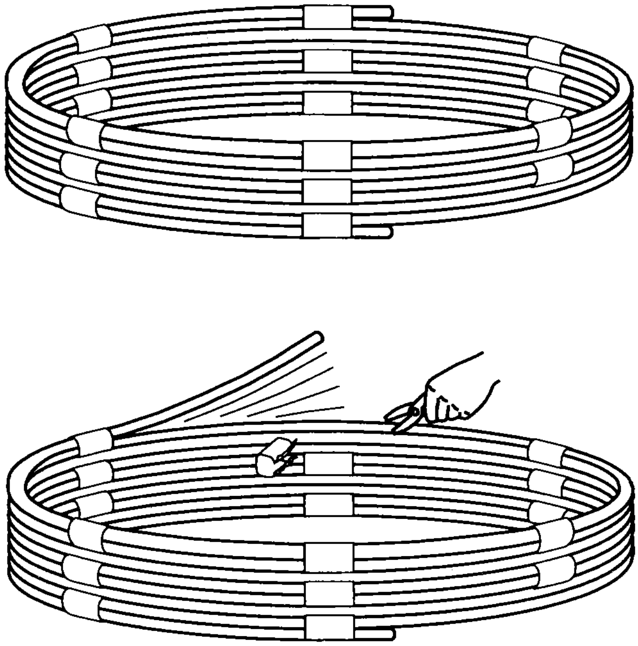
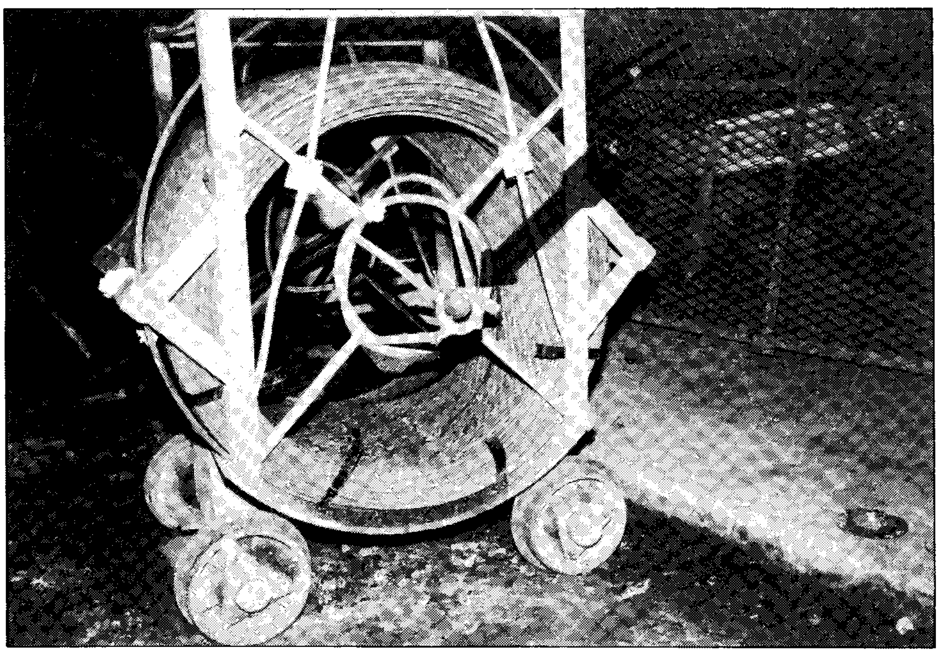


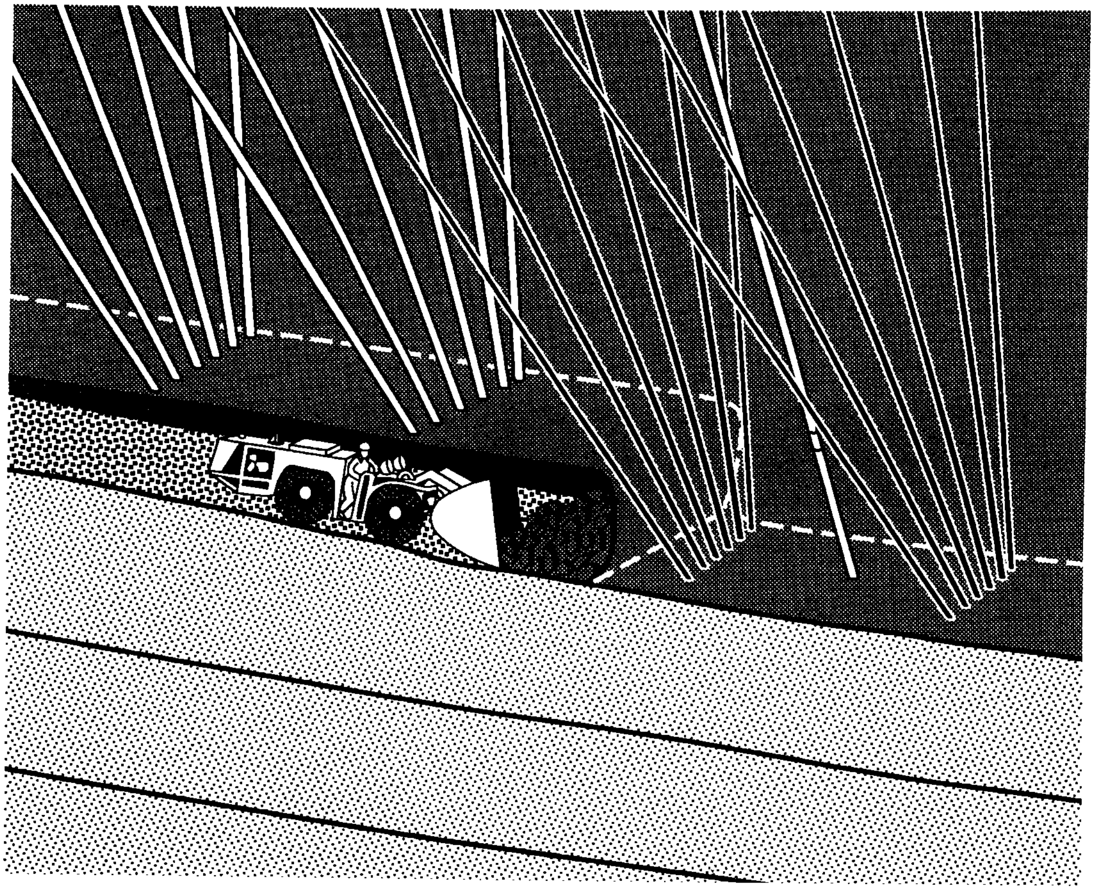
Diagram showing release of stored spring energy in cable coil after strapping is cut.

Figure 4



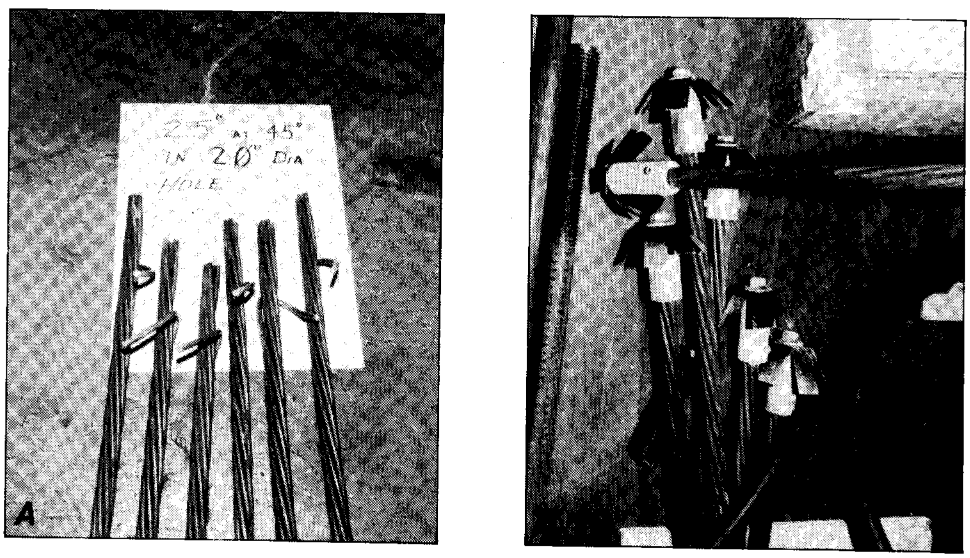
Large spool of continuous cable.

Figure 5



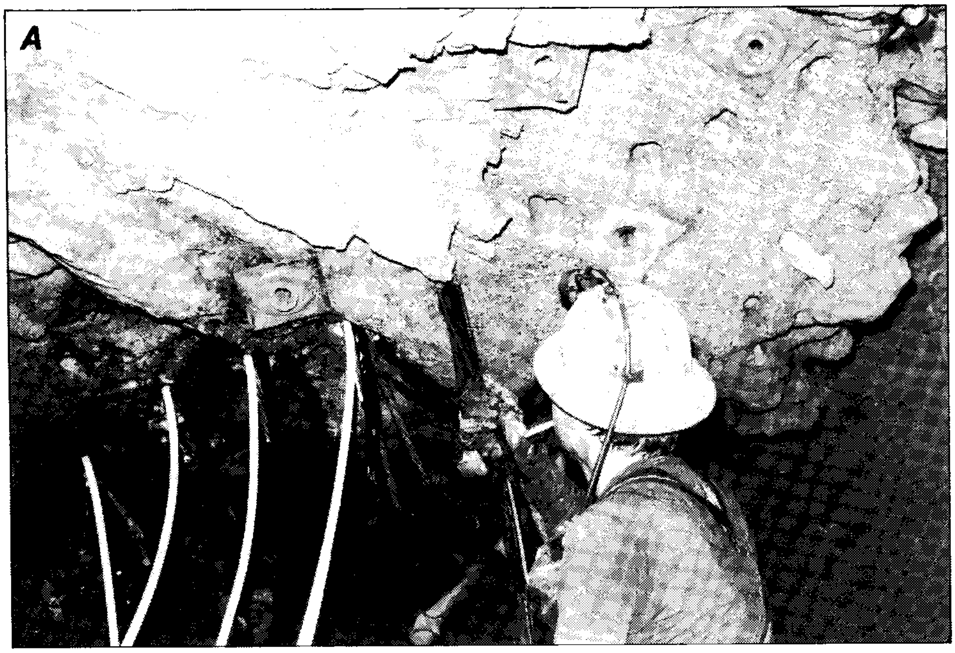
Fan-shaped installation pattern.

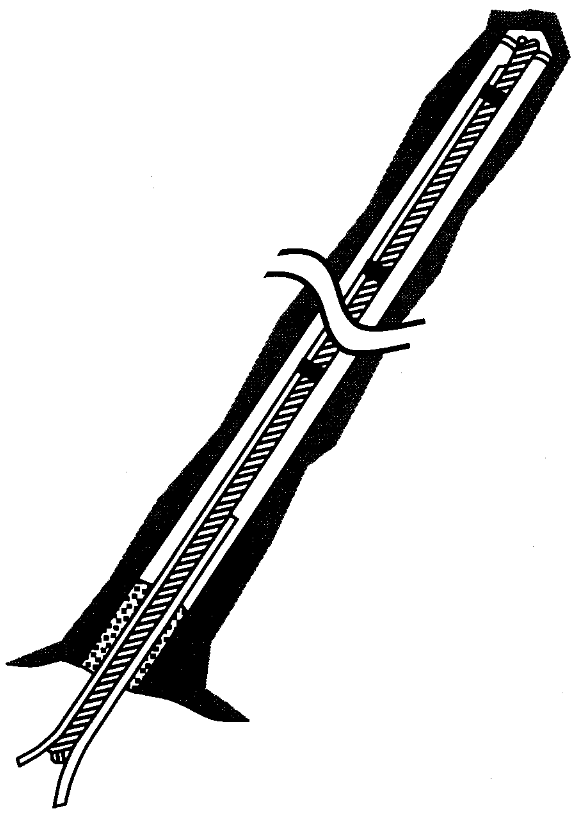
Figure 6



Types of anchors for tendons in hard rock. A, Single-barb anchor; B, spring mechanical or star anchor.

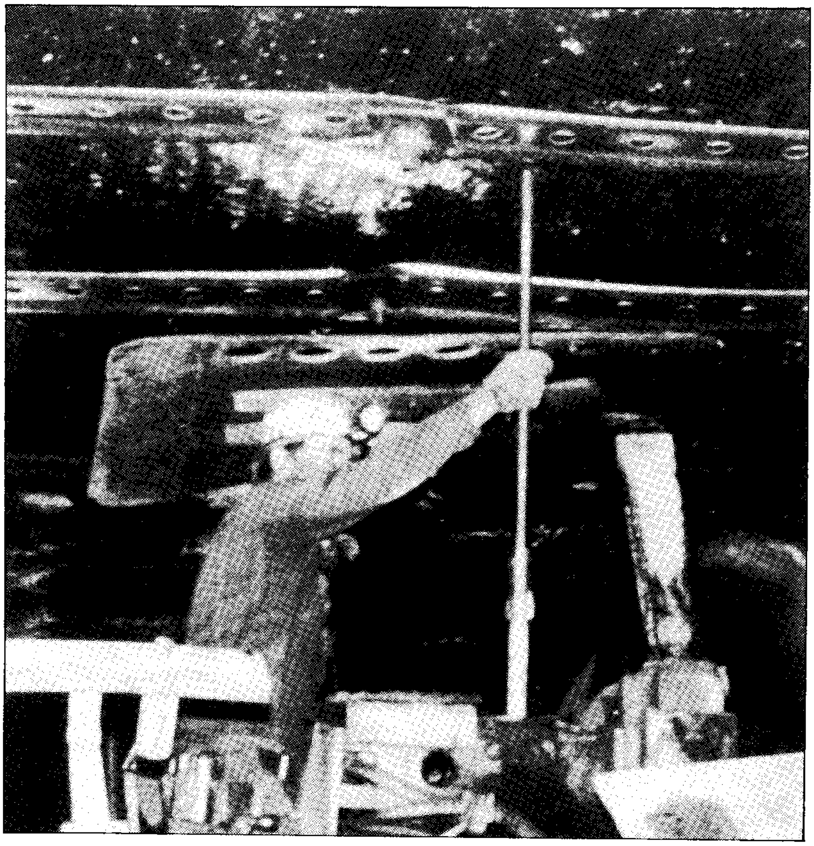
Figure 7





Cable bolt insertion at Homestake Mine. A. Miner inserting cable bolt with grout tube; B, cross section of grouted cable bolt with grout and breather tube.

Figure 8



Installing resin-grouted cable bolt with roof-bolting machine.

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