

HISTORY OF COAL MINE ELECTRICAL FATALITIES SINCE 1970

Richard L. Reynolds
Mine Safety and Health Administration
Pittsburgh, Pennsylvania

ABSTRACT

Over the past few years the Mine Electrical Systems Division of the Bruceton Safety Technology Center of the Mine Safety and Health Administration has been cataloging electrocutions which occur at coal mines. The data have been used to identify hazards resulting from inadequate safety designs and procedures used in the coal mining industry. These hazards will be pointed out to increase the industry's awareness of measures which can be taken to prevent such accidents.

INTRODUCTION

From January 1, 1970 through December 31, 1983 there were 2,025 fatalities in the nation's coal mines. Of the 2,025 fatalities 158 or approximately 8 percent were the result of electrocutions. Many of these deaths could have been avoided by using safer work procedures and in some cases safer equipment designs.

Figure 1 shows a year by year plot of the electrical fatalities. It can be seen from this figure that electrocutions have been as low as 5 in 1976 and as high as 18 in 1970. The average for the 14 year period is 11.3 or approximately 11 fatalities per year.

Table 1 tabulates the accidents as to location.

Underground	92
Above Ground	
Preparation Plants	18
Surface Areas of Underground Mines	27
Surface Mines	<u>21</u>
Total	158

Table 1. Accident Locations

ELECTRICAL FATALS

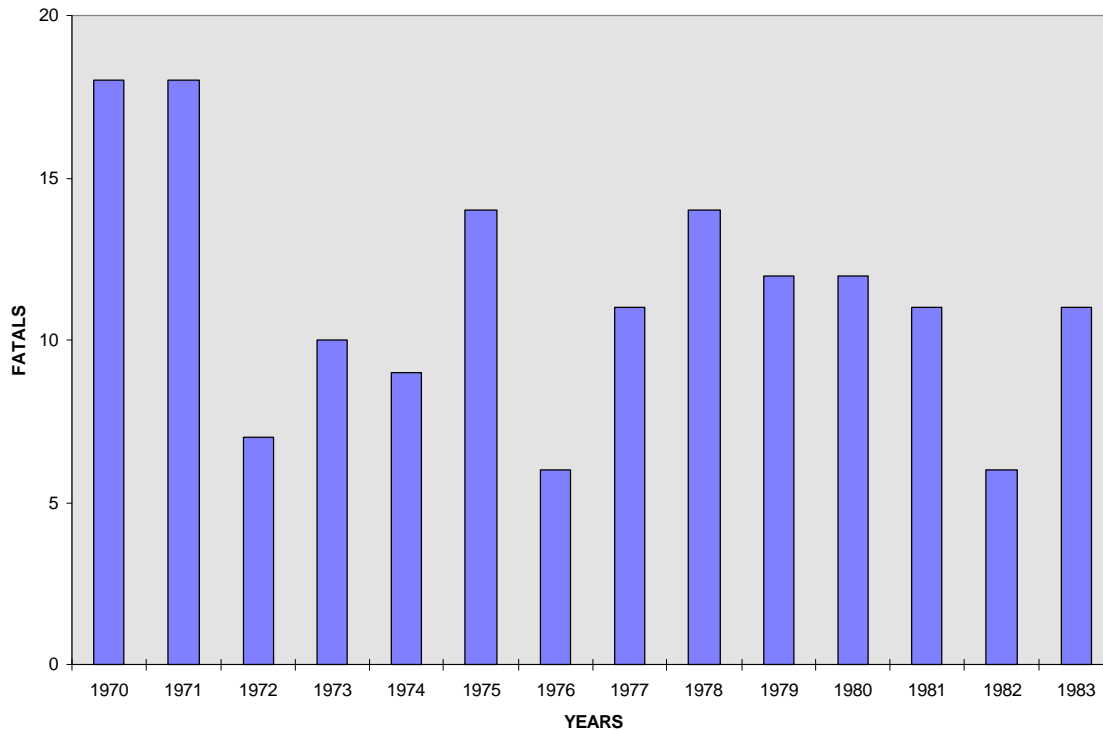


Figure 1. Electrical Fatality Distribution

This table indicates that although most electrocutions are in underground mines over 40% occur on the surface.

In an effort to emphasize which procedures and equipment are involved in most accidents, the following four categories were used to examine the fatality data.

“Equipment Involved” - If one type of equipment was repeatedly involved in accidents then possibly a new design or design change could lower the accident rate associated with the equipment.

“Victim Status” - This category reflects the experience and training of the victims. Certified, as used in these charts refers to being qualified to perform electrical work as specified in 30 CFR Part 75 and Part 77. Could it be determined from the persons experience and task being performed if new or revised procedures could be used to reduce fatalities?

“Contact Type” - This category lists how the person came in contact with the lethal shock potentials.

“System Voltage” - By grouping the fatalities within system voltage levels the full impact of the hazards involved with each voltage level could be determined.

SURFACE ACCIDENTS SUMMARY

By looking at the 66 surface fatal accidents as a separate group from the underground fatalities, emphasis can be placed on the areas within the four categories of interest which could result in the largest reduction in fatalities. Figure 2 below graphically shows the 66 surface fatalities with relation to the type of equipment involved.

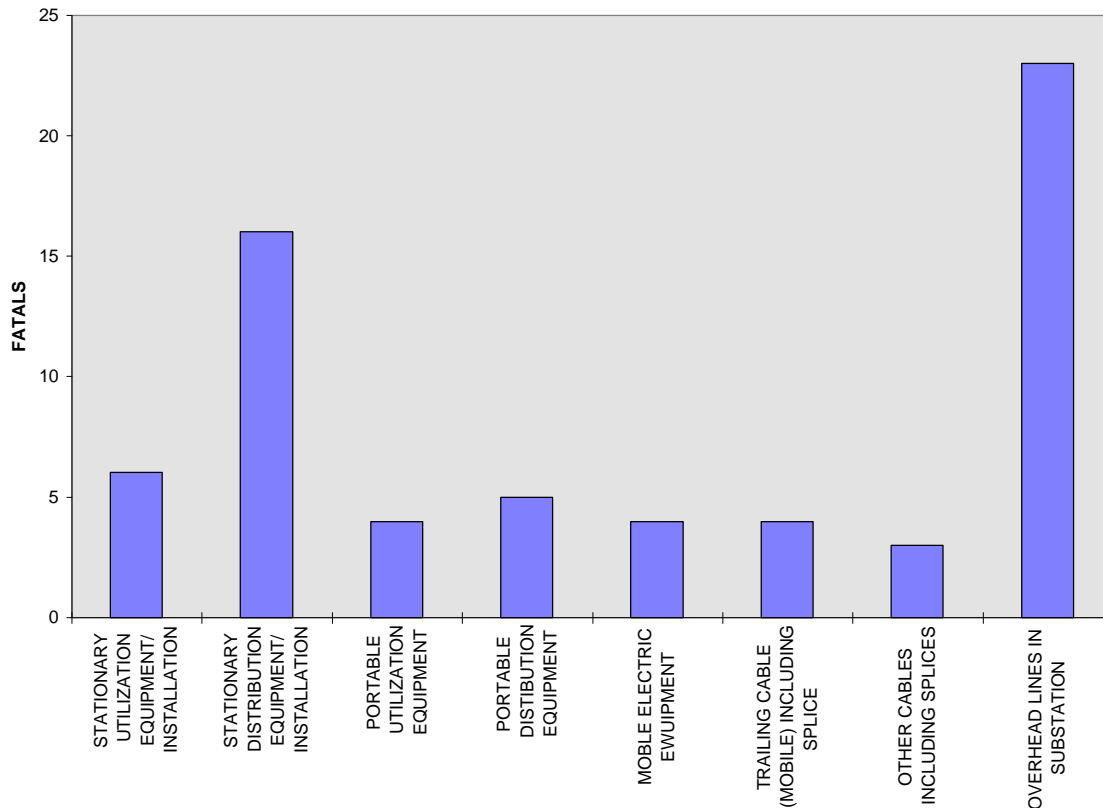


Figure 2. Equipment Involved

This figure shows that the two types of equipment involved in the most fatalities are stationary distribution equipment and overhead power lines.

The second category of interest was victim status and is shown in Figure 3.

Two groups, certified persons performing electrical work and non-certified persons performing nonelectrical work, are the victims in the majority of electrocutions.

The third category of interest was the type of contact made with the circuit and is shown in Figure 4.

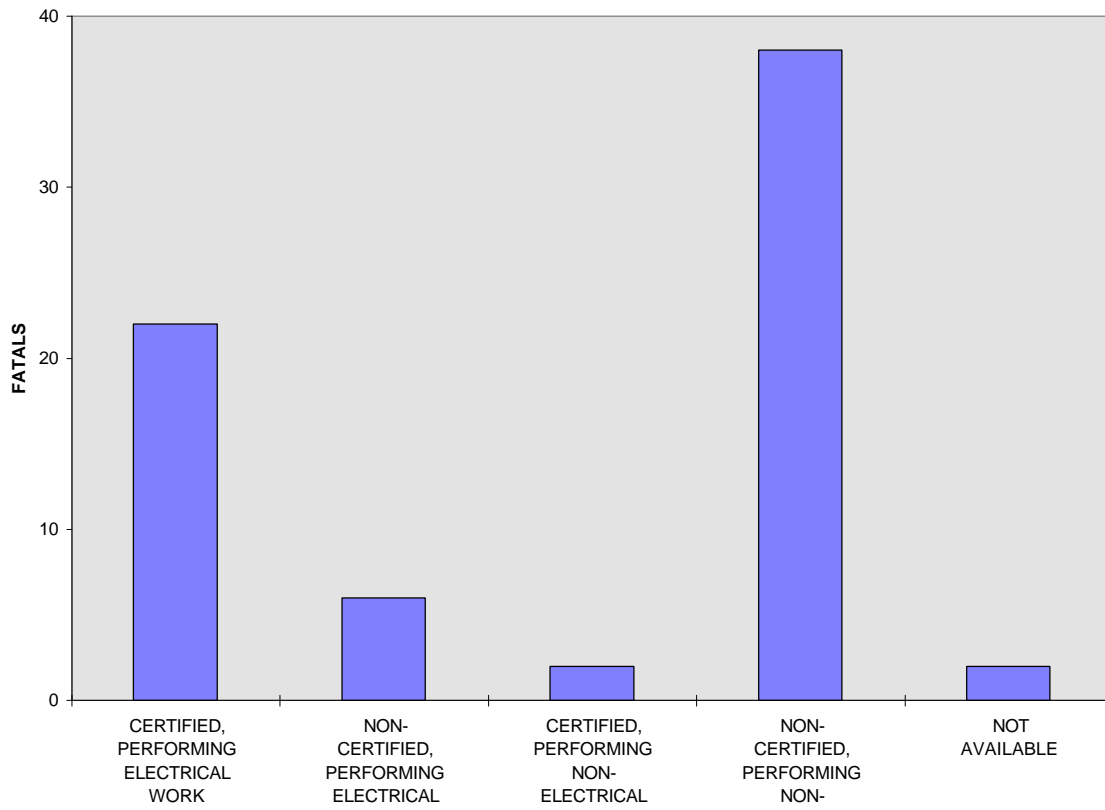


Figure 3. Victim Status

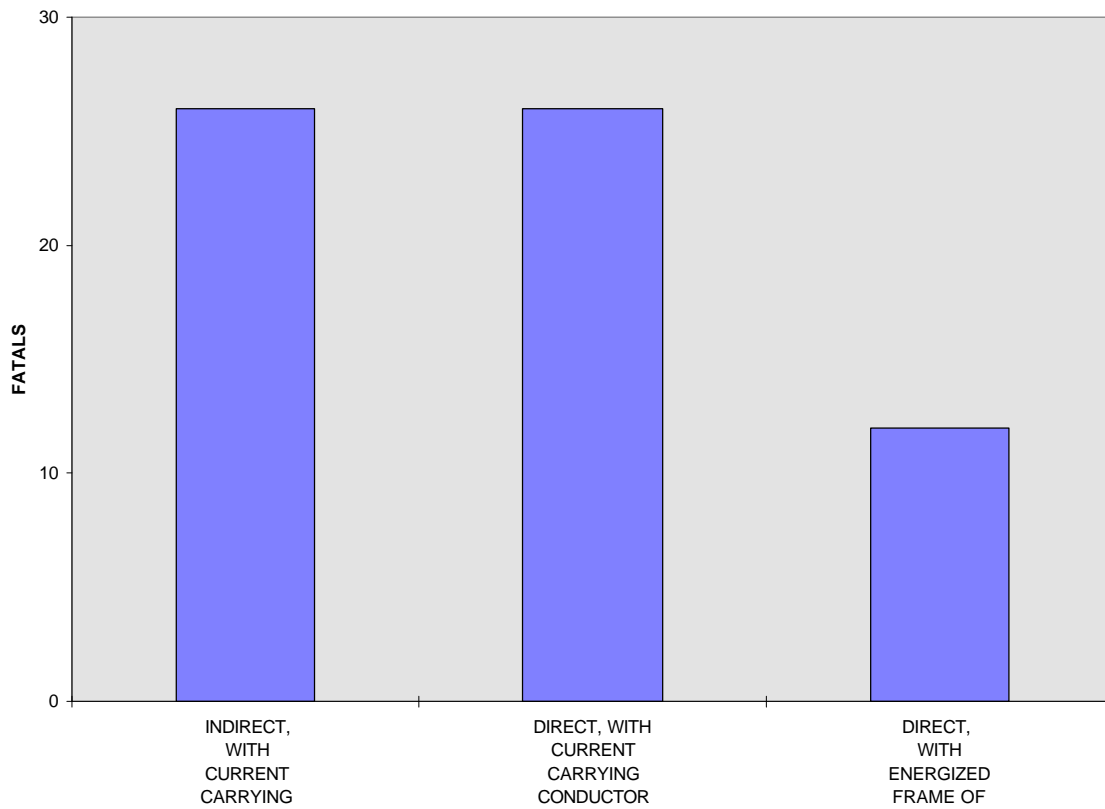


Figure 4. Contact Type

Direct contact with energized conductors implies possible problems with work procedures which expose workers to energized conductors, while indirect contact with current carrying conductors implies possible accidental contact.

The fourth category of interest was system voltage and is shown in Figure 5.

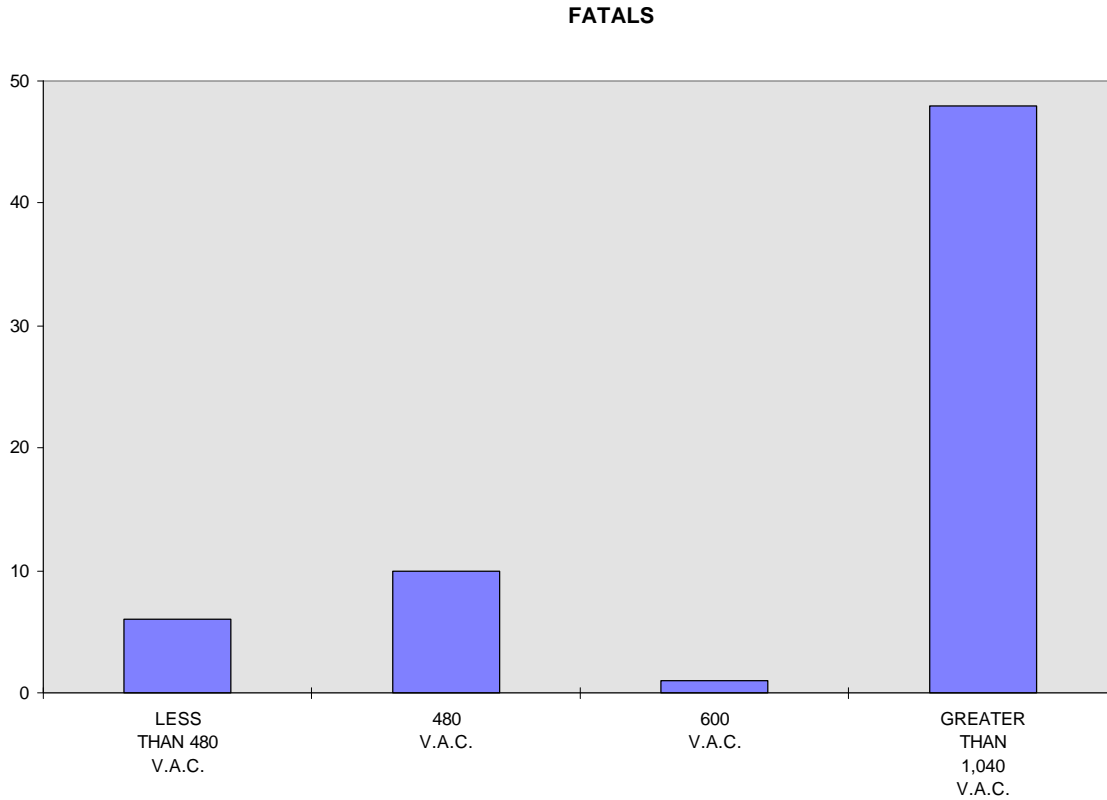


Figure 5. System Voltage

Figure 5 shows that high voltage is involved in the overwhelming majority of electrocutions on the surface. Also it is surprising that almost as many persons were killed from voltages less than 480 Vac as were killed by 480 Vac.

TYPICAL SURFACE ACCIDENTS

Since 49 of the 66 surface accidents involved high voltage, the following examples will concentrate on this area. Of this 49, 23 involved overhead lines. Nineteen of these were trucks, cranes and drill rigs contacting overhead lines.

Figure 6 shows a typical accident with trucks.

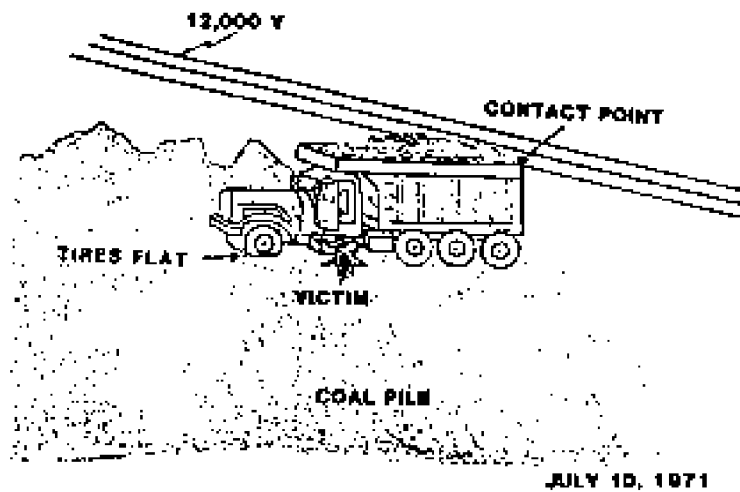


Figure 6. Truck Accidents

In most cases the trucks are in the process of dumping coal or refuse. The process usually becomes so routine that the driver never notices the overhead lines. As materials are dumped, the dumping surface moves resulting in the truck eventually being in a position where it can contact the overhead lines.

In the truck accident shown the driver had been told that the lines were present. He had positioned his truck three times before stopping the truck to check the truck's position in relation to the lines. He was electrocuted as he exited the truck to check the clearance.

Cranes usually contact overhead lines while being used to move materials from storage areas or during some type of maintenance operation. Figure 7 shows a crane in position to dredge a settling pond.

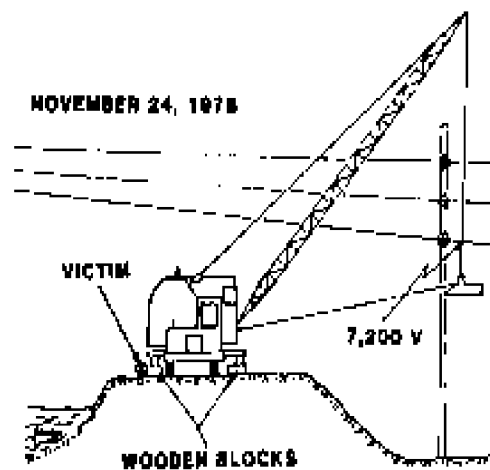


Figure 7. Crane Accidents

This accident happened while the out riggers were being set. The crane boom was positioned to lift the opposite side outrigger so it could be blocked. During this procedure the wire rope contacted the overhead line causing the person blocking the outrigger to be electrocuted. This accident happened twice at different mines.

A situation common to most of the crane accidents was that the victims were preoccupied with a task unrelated to the overhead lines and were either unaware or forgot that the lines were present.

The electrocutions associated with drill rigs usually happened when the victim raised the mast into the lines without knowing the lines were present or while the rig was being moved with the mast in the vertical position. Figure 8 illustrates the case when a drill rig was moved with the mast in the vertical position.

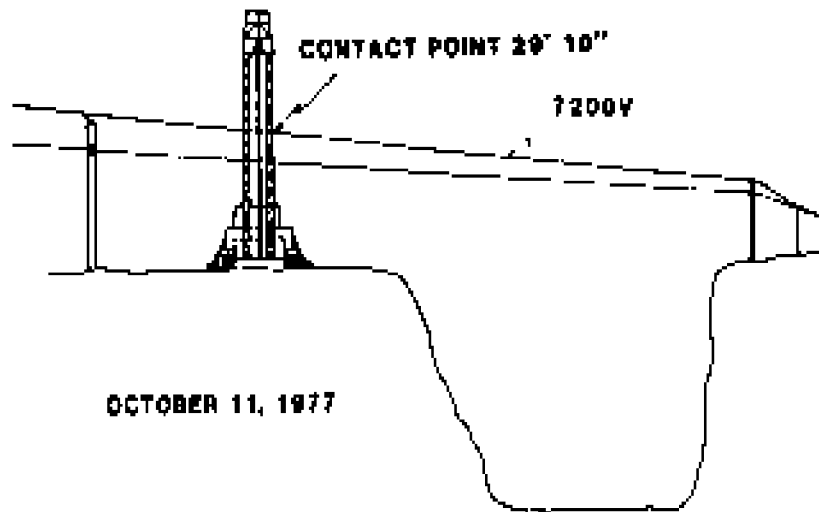


Figure 8. Drill Rig Accident

In this accident the victim had drilled three rows of blasting holes and was positioning the rig to drill the fourth row of holes. The victim was apparently unaware that the mast had contacted the lines and was electrocuted as he left the truck.

These accidents not only account for 19 of the 49 high voltage fatalities, they are responsible for a like number of the “overhead lines not in substations”, “non-certified, performing non-electrical work”, and “indirect, with current carrying conductor or part”, accidents of Figure 2, 3, and 4 respectively.

Another 20 of the 49 high voltage accidents were related to the victims working on the equipment while it was energized.

Figure 9 depicts an accident which can happen very easily if the electrician does not consider the complete circuit when performing repairs.

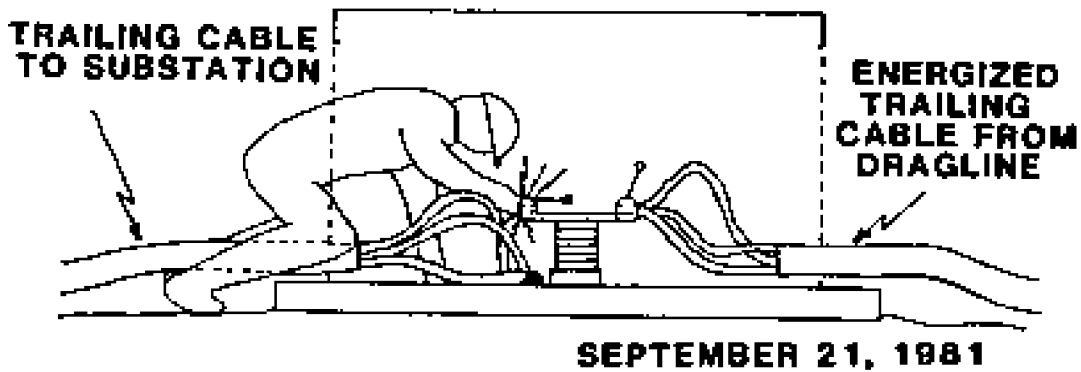


Figure 9. Back Feeding Fatality

In this particular case the trailing cable from the substation was de-energized. However a generator on board the dragline was backfeeding power to the junction box. The victim was unaware of this and received a fatal shock as he was attempting to connect the trailing cable at the junction box.

Figure 10 shows a condition which occurs in many substations.

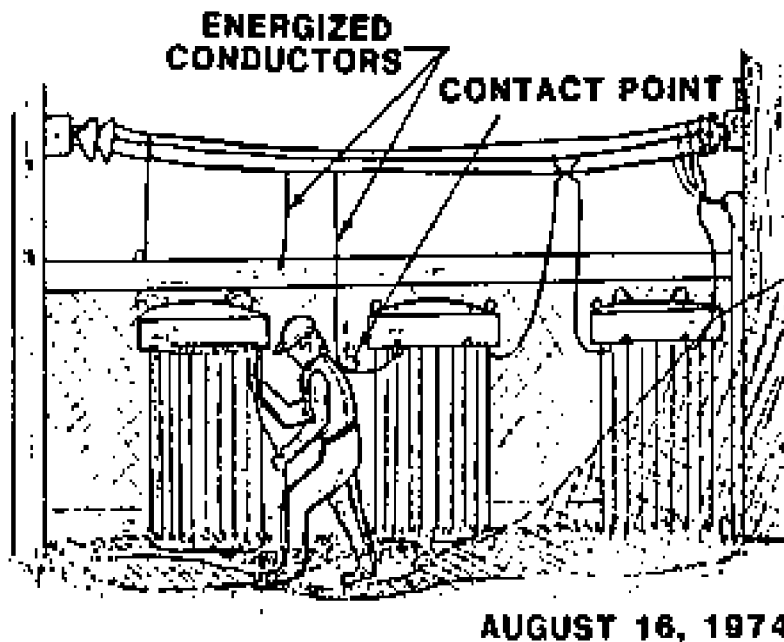


Figure 10. Exposed Energized Parts

Because substations are kept locked and posted with warning signs, poor design and installation of equipment and conductors is sometimes permitted to exist in these locations.

As can be seen in this example high-voltage conductors were so close to the working surface that a miner was electrocuted when he contacted a conductor with his back. All energized exposed live parts should be at least 8 feet 6 inches above the working surface to prevent accidental contact should a person trip, fall, or inadvertently back into them. A locked fence with warning signs prevents exposure of unauthorized personnel to the hazards but can not prevent accidental contact between competent authorized personnel and the energized parts.

Figure 11 depicts a situation where the victim was troubleshooting an energized substation when he came in contact with a fuse holder for a potential transformer.

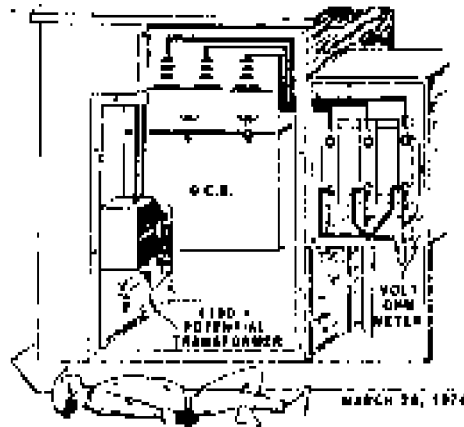


Figure 11. Troubleshooting Energized Equipment

Although testing and troubleshooting energized equipment is necessary in some cases, it must be conducted with the utmost care. A single mistake during these procedures can be fatal and therefore only the leading qualified personnel should be permitted to perform these tasks.

Figure 12 illustrates another accident which tends to occur from time to time.

The victim was taking a current reading on a transformer primary. The transformer station was mechanically well constructed with no apparent electrical shock hazards present. However, when the victim contacted the meter case which was in contact with an insulated 4160 volt conductor, he received a fatal shock from the case of the meter. During the investigation of the fatality it was discovered that a bare connector on the transformer bushing resulted in the meter case being energized to 4160 volts. It is imperative that proper care be taken when making measurements on power systems.

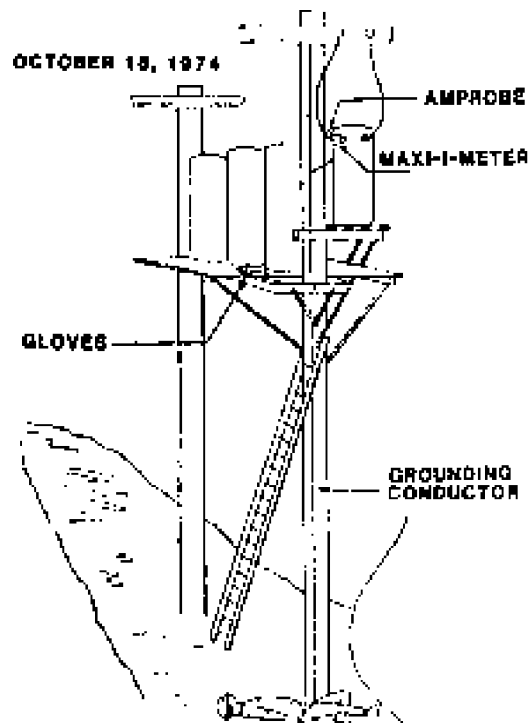


Figure 12. Reading Current

In addition to these 20 accidents accounting for a large portion of the high-voltage accidents they are also reflected in the large number of “stationary distribution equipment/installation”, “certified, performing electrical work” and “direct, with current carrying conductor or part” of Figures 2, 3 and 4 respectively.

UNDERGROUND ACCIDENTS SUMMARY

The underground accidents totaled 92 for the fourteen year period. By looking at the four categories of interest, emphasis can be placed on the areas which need attention in order to reduce fatalities.

The first category is the “Equipment Involved” and is shown in Figure 13.

It is easy to see from Figure 13 that trailing cables and splices are involved in over one third of the fatalities underground. This is without a doubt an area that needs more attention in order to reduce fatalities.

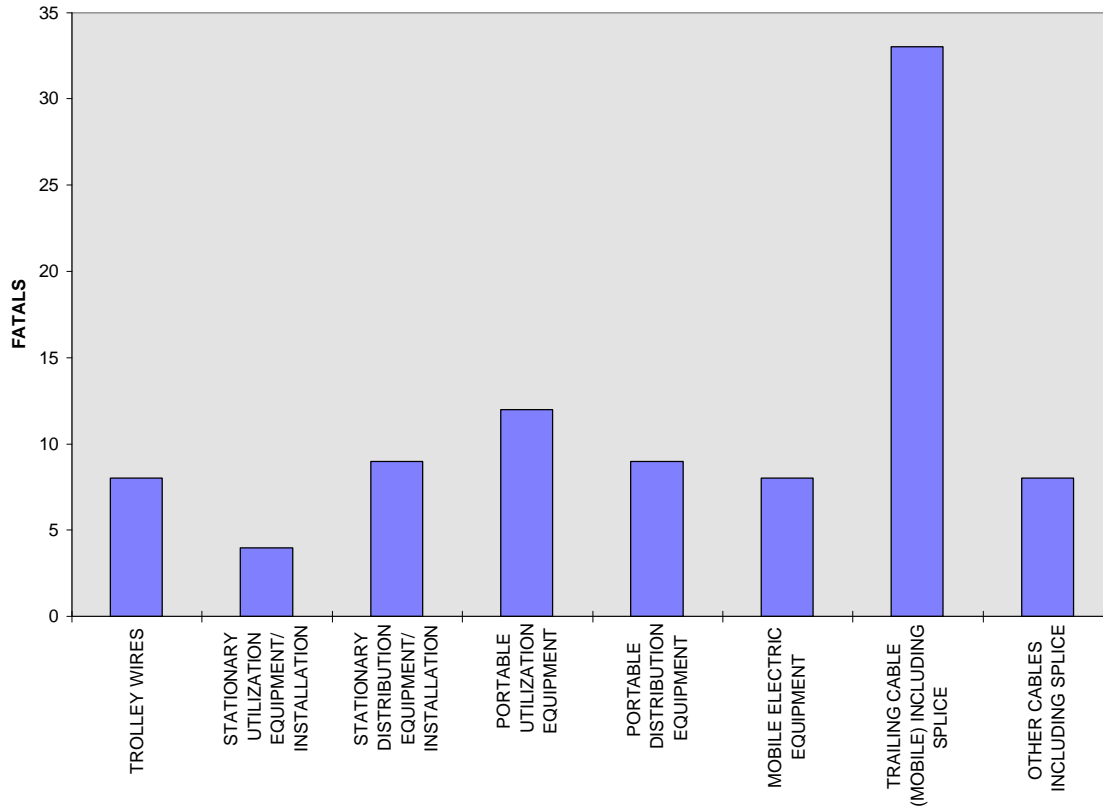


Figure 13. Equipment Involved

The second category is the “Victim Status” as shown in Figure 14.

The group “certified, performing electrical work” being high indicates inadequate work procedures or persons certified who should not be. The group of non-certified persons performing non-electrical work indicates a great deal of accidental contact possibly resulting from unnecessarily exposing persons to energized parts.

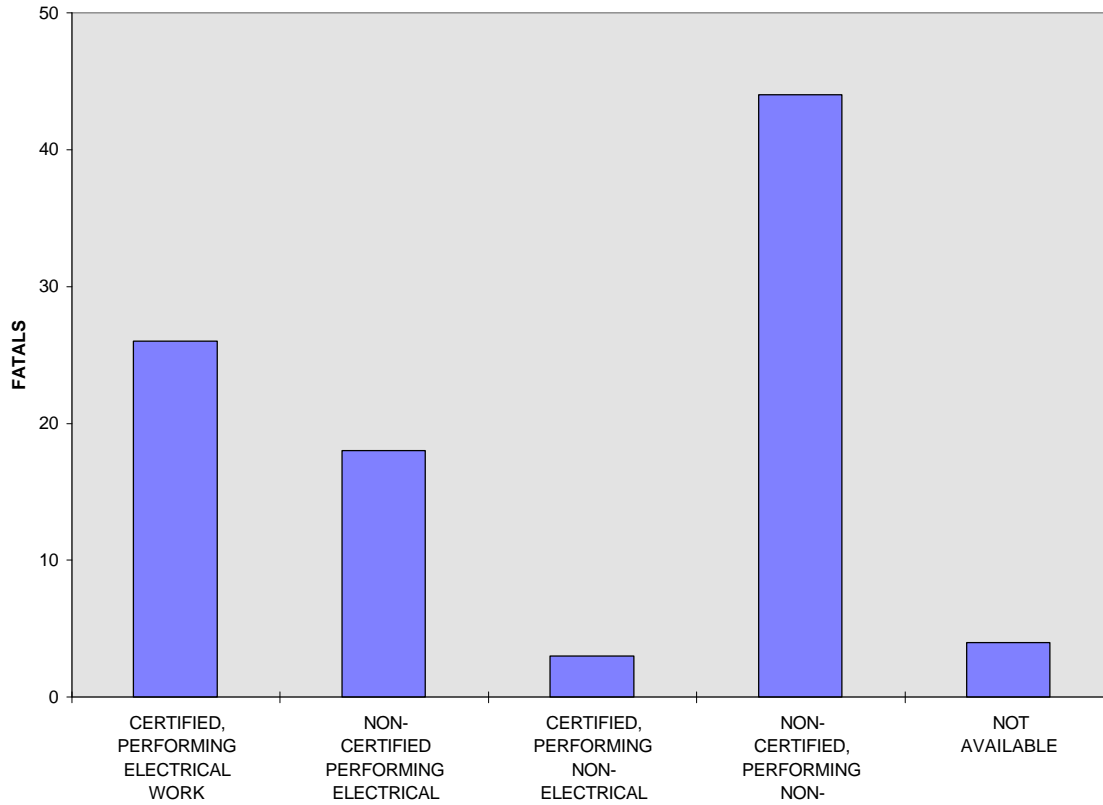


Figure 14. Victim Status

The third category separates the fatalities as to the type of contact and is displayed in Figure 15.

Direct contact with current carrying conductors points to the possible problem of unnecessary exposure to energized parts.

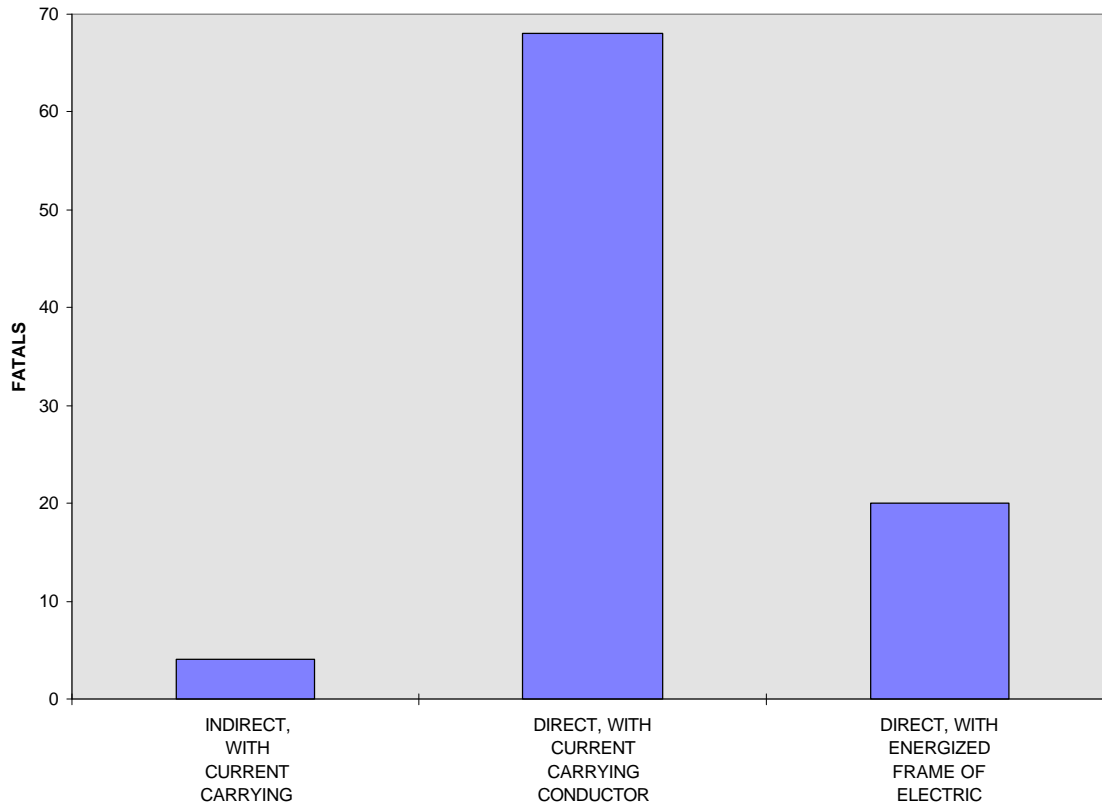


Figure 15. Contact Type

The fourth category is system voltage and is shown in Figure 16.

One revealing fact in this charts is that there have been almost as many fatalities on 300 Vdc as on high-voltage (greater than 1040 Vac) circuits and that there have been more fatalities from all direct-current systems than from high-voltage systems. The not surprising fact is that the utilization voltages of 480 Vac and 600 Vac account for more than half of the underground electrocutions.

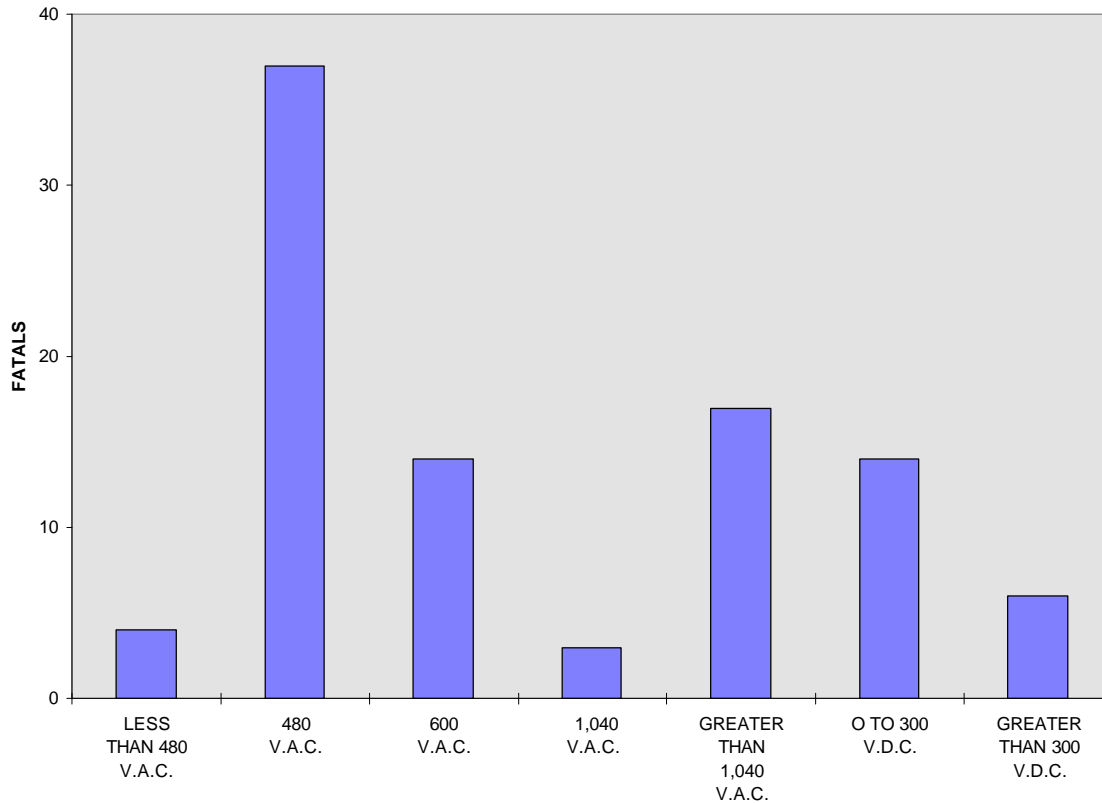


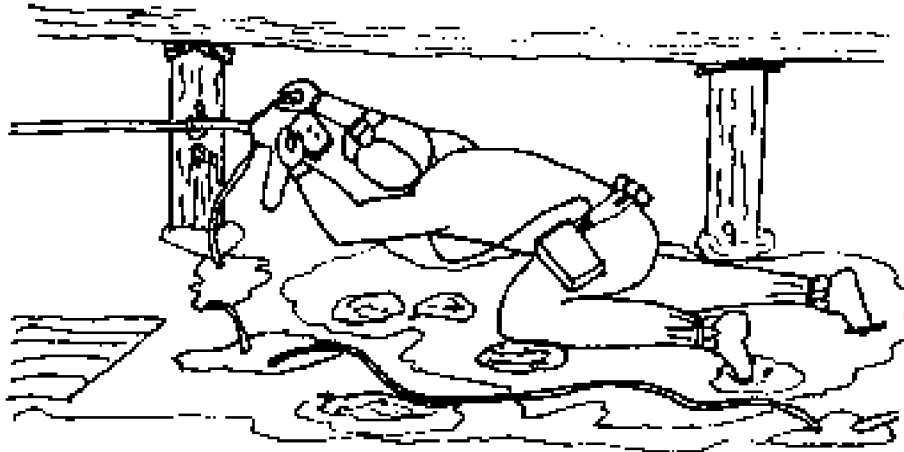
Figure 16. System Voltage

TYPICAL UNDERGROUND ACCIDENTS

Sixty-eight of 92 underground fatalities were related to the type of contact “direct, with a current carrying conductor or part” as can be seen from Figure 15. These types of accidents can occur from unintentional contact due to improper equipment and circuit design or intentional contact when repairs are being performed and the victim is not aware that it is energized.

A total of 34 of these 68 accidents were a result of working on equipment while it was energized. Figure 17 illustrates an accident where the victim was working on an energized circuit and was aware of the fact that it was energized.

This accident occurred in 1970, it is an example of some of the worst conditions in which electric circuits were being used and repaired. The victim attempted to troubleshoot an open splice with a neon circuit tester while positioned on his knees in approximately 4 inches of water with 28 inches of vertical clearance. The circuit supplied power to a 240 volt single phase pump which was running intermittently. In the process of trying to locate the problem the victim contacted a bare lead and was electrocuted.



JULY 31, 1970

Figure 17. 120 Volt Fatality

Accidents similar to the one shown in Figure 18 have been repeated many times.

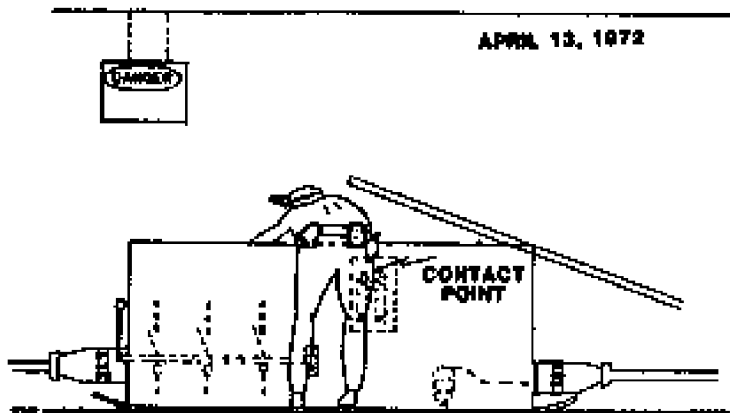


Figure 18. Unintentional Direct Contact

Many of the electrocutions are the result of the victim reaching into a compartment containing energized parts and accidentally contacting one of them. In this particular accident the victim, after being cautioned that the switchgear was energized, took the cover off the enclosure, reached in with a screwdriver in his right hand, and accidentally contacted a high-voltage fuse for a potential transformer with his sleeve.

The accident illustrated in Figure 19 is typical of the low-voltage fatalities which occur while work is being performed on energized equipment.

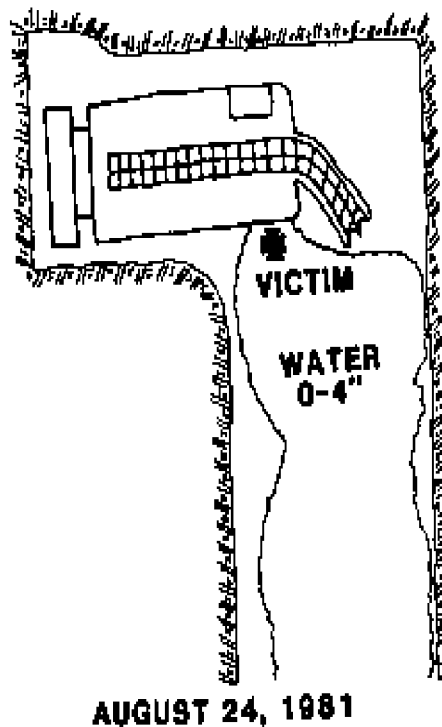


Figure 19. Low Voltage Unintentional Direct Contact

As in the previous accident the victim was reaching into a compartment containing energized parts. As he was checking for possible broken parts behind a line starter, his right hand contacted an energized 480 Vac phase conductor. He had exposed himself to a high probability for a fatal shock since he was on his knees wearing wet leather boots. He did not have knee pads or insulating gloves and the floor was covered with water up to where he was kneeling. This accident happened as recently as 1981 and these conditions are not unusual for the conditions in which electrical maintenance is performed.

In addition to the 34 fatalities due to working on energized equipment, the "Trailing cables (mobile) including splice" group of Figure 13 contributed ten fatalities to the contact type "Direct, with current carrying conductor or part" of Figure 15. Of these ten fatalities, eight were due to damaged cables and two were because of bad splices.

These ten fatalities were the result of unintentional contact with an energized conductor. The victims were not performing electrical work but were fatally shocked while handling or touching a cable or splice. Figure 20 illustrates a typical accident with the victim moving an energized trailing cable by hand.

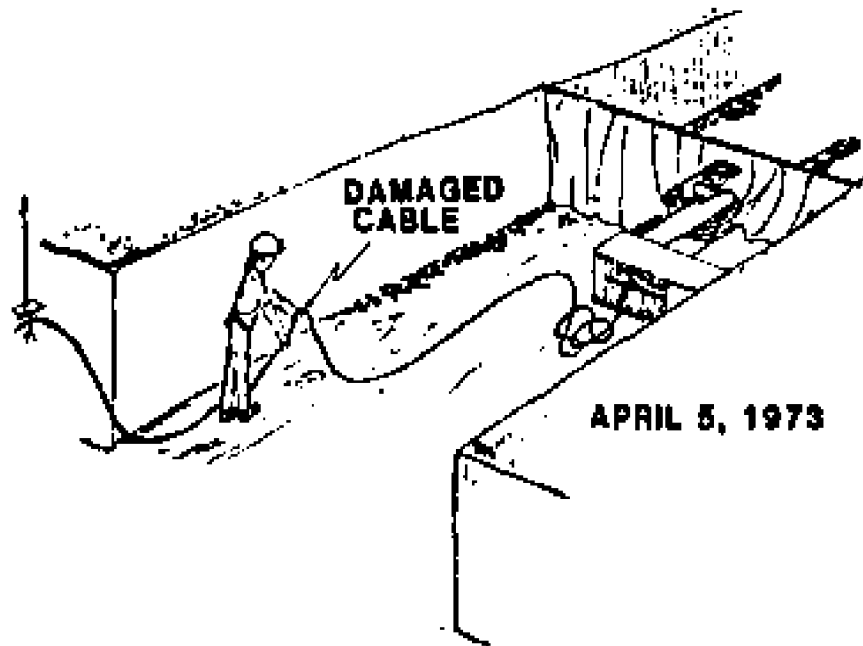


Figure 20. Handling Energized Trailing Cable

The victim was a section foreman with 12 years mining experience. He was assisting in the moving of a roof bolting machine when he contacted a damaged place in the trailing cable with his hands. He was not wearing gloves and his hands and leather shoes were wet.

Figure 21 illustrates an accident with a coal drill which was operated at 995 volts.

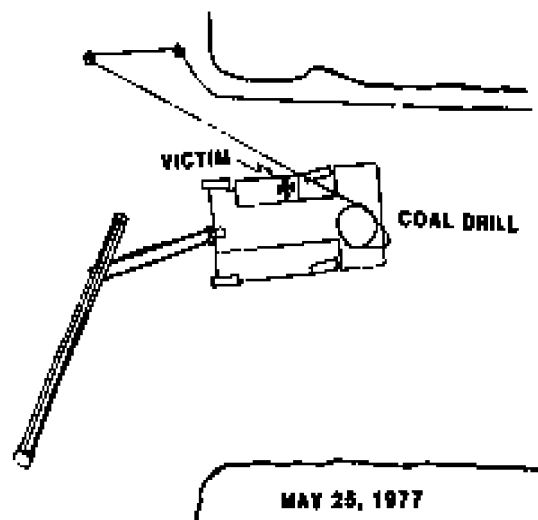


Figure 21. Exposed Conductor in Trailing Cable

In this accident the drill operator was positioning the drill in a manner which caused the trailing cable to backspool across the machine near the operator's compartment. The victim was guiding the cable with his right hand while seated in the operator's compartment. His hand came in contact with a bare place in the cable which had become exposed as a result of severe carbon tracking. The victim was electrocuted as a result of this contact.

One other area of contact type, "Direct, with a current carrying conductor or part" which accounted for ten fatalities and a like number of fatalities of Figure 16 is direct current systems.

The accident illustrated in Figure 22 is typical of the direct current trolley system fatalities.

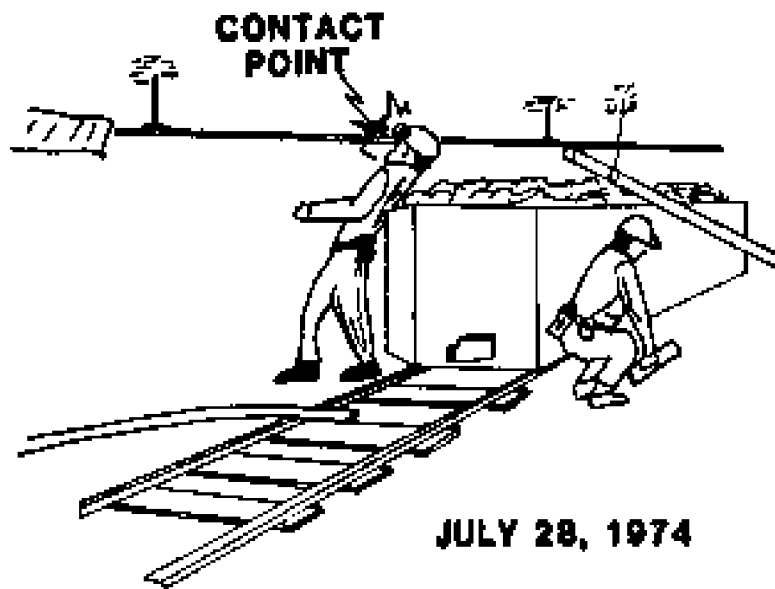


Figure 22. Trolley System Fatalities

This accident occurred while the victim was in the process of repairing a waterline which passed over an energized trolley wire. No temporary guarding was used and the circuit was not de-energized before work began. The victim's head contacted the trolley wire while he was in the process of performing the repairs. In this case as in many of the other contacts with the trolley wire, the victim knew that the circuit was energized but he felt that he could work close to the wire without contacting it.

RECOMMENDATIONS

Typical accidents which result in 59% of the surface fatalities have been discussed. These accidents can be attributed to contact of equipment with overhead high-voltage lines and persons working on energized equipment.

Contact of equipment with overhead high-voltage lines in most cases occurred because the victims were unaware of the lines or became preoccupied with performing a task unrelated to the lines.

The accidents associated with contacting overhead power lines can be significantly reduced if not eliminated by a combination of the following recommendations.

1. Design the mine plant to avoid bare high-voltage conductors around parking lots and storage areas.
2. Never store or stock pile material under overhead high-voltage lines.
3. Have the management official who is responsible for overseeing the work examine the work site before work is performed. The management official should personally observe all work when it is possible for any part of the equipment to come within 50 feet of the line.
4. Train the operators of trucks, cranes, and drill rigs to examine the work site before beginning work.

The accidents associated with working on energized equipment indicate that additional emphasis must be placed on safe work practices as well as requiring a higher competency level before a person is considered qualified to perform electrical work.

Improved designs must be implemented for substations. It is essential that all bare energized parts be maintained at a height to keep them out of reach of any person who should enter a substation. A distance of 8 feet 6 inches has become the accepted distance in almost all industries as well as the mining industry. A well designed substation must have only grounded metal frames and adequately insulated parts within reach of any person whether he is qualified, certified, registered or not. This rule should be followed since a very knowledgeable and experienced individual can accidentally fall or back into bare energized parts if they are not positioned out of reach.

Thirty-four of the 92 underground fatalities resulted from persons working on energized equipment. A closer look at these fatalities indicates at least two approaches can be used to reduce them.

The first and foremost consideration should be education. It is apparent that the victims were not aware that they were risking their lives.

The unfavorable environmental conditions under which electrical work must be conducted cannot be avoided. Limited work space with damp to wet conditions are closer to the norm than the exception. With the close working clearances, the probability of contacting energized parts is very high, and at the same time the wet conditions increase the probability of lethal shock if energized equipment, 17 of the victims were qualified under

30 CFR Part 75. The other 17 were not qualified as per 30 CFR Part 75. With 18 percent of the underground fatalities being the result of qualified persons working on energized electric equipment, it is time to examine the qualification program with an eye on upgrading the electrician who is permitted to perform electrical work. With a program that assures only well trained and knowledgeable electricians are performing electrical work, fatalities similar to the 34 where miners are working on energized electric equipment can be reduced significantly if not eliminated.

The second preventative measure which can be taken to reduce the accidents relating to working on energized equipment is improved equipment design.

Test points should be brought out to a test panel to facilitate an accessible and safe means for measuring voltage during testing and trouble-shooting when it is necessary for the equipment to be energized.

Where possible, electrical adjustments should also be mounted on a test panel. Where adjustments cannot be brought out they should be located away from energized parts and guarded to prevent accidental contact with energized parts when adjustments are being made.

High-voltage and low-voltage power circuits should be segregated from each other and from control circuits in all electric equipment such as power centers, distribution boxes, switchgear, etc.

The accidents involving handling of trailing cables and splices were responsible for eleven percent of the underground fatalities. These types of accidents could be reduced by a close inspection of trailing cables at the beginning of each shift. However, even a visual inspection of each cable, as time consuming as it would be, could not detect some of the damaged places. The use of cable handling devices and protective insulating gloves could reduce these fatalities but have not been a method which is universally practiced in the industry. Because these precautionary methods have not worked, methods which involve redesign of the system to prevent the shock exposure need to be considered. A system design method of reducing if not eliminating these accidents is the use of shielded trailing cables. This type of cable could be used to confine the shock hazard within the cable jacket and initiate the ground fault protection when the cable is damaged.

The accidents involving contact with the trolley wire accounted for eleven percent of the fatalities. Apparently, these victims became preoccupied with a task unrelated to the trolley wire and consequently forgot it was there. It is essential that all personnel become aware of the extremely serious hazard they are exposing themselves to while working around trolley wires. Procedural methods such as de-energization of the circuit and temporary guarding of the circuits have no doubt been effective but they have not been used enough to eliminate fatalities due to accidental contact.

To prevent these contact-type accidents it is necessary to provide for a trolley system design which will minimize exposure of the miners to the trolley wire. Two improvements which are indicated from the fatality data are better placement and guarding of the trolley wire. The wire should be positioned so that it will not be over any person while he is riding in a trolley vehicle.

Since the procedure of temporarily guarding trolley wire has not been effective enough to eliminate fatalities while work is being performed near the trolley wire, permanent guarding should be installed along the entire length of the trolley wire and on any uninsulated feeder wire. By installing the guarding for the entire length of the trolley wire the inclination to work near the trolley wire without guarding it is eliminated.