HEAVY EQUIPMENT NEAR OVERHEAD POWER LINES?
New Safety Research May Save Your Life

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Accidents occur when least expected, from sources that we rarely anticipate and with outcomes that can vary greatly. Anyone who has ever been involved in an automobile accident knows, the transition from driving comfortably and safely down a highway to being involved in a potentially life-threatening situation can occur in a heartbeat. Accidents on the job are no different.

The mining industry has a relatively small number of electrical injuries, compared to industries such as construction or agriculture, due to the small total employment in mining. Mining does, however, have one of the highest occupational electrocution rates of any U.S. industry, at 2.8 for every 100,000 workers per year. This is approximately four times the average for all industries. Data from the Mine Safety and Health Administration (MSHA) shows that 75 electrical fatalities occurred in the mining industry between 1990 and 1999. Of these, at least 17% involved high-reaching mobile equipment that contacted overhead power lines.

The U.S. Department of Labor's Bureau of Labor Statistics (BLS) compiles the Census of Fatal Occupational Injuries (CFOI). BLS also compiles the Survey of Occupational Illnesses and Injuries (SOII), which provides a statistical sample of the more than 5 million, U.S. nonfatal, occupational illnesses and injuries that occur annually.

These databases were used to compare the number of fatal and nonfatal electrical injuries involving overhead power lines in all industries. More than 2,260 fatal and 32,300 nonfatal days arising from electrical injuries were reported in all industries from 1992 to 1998 in the United States. While only 3.8% of nonfatal electrical injuries involved contact with overhead power lines; such contact caused 41% of all electrical fatalities. So, contact with overhead power lines is much more likely to be fatal than many other types of electrical accidents.

Common overhead power-line contact incidents involve operators and nearby workers around cranes, dump trucks, drill rigs, and other high-reaching mobile equipment. In typical cases, workers lifting and placing aerial loads with cranes, maneuvering trucks with raised beds, and placing drilling equipment into position fail to recognize their proximity to power lines of which they may or may not be aware.

When a machine contacts a bare, overhead power-line conductor, the frame becomes energized to approximately line-to-ground voltage, often ranging from several thousand to more than 10,000 volts. Three possible scenarios can lead to injury under this circumstance. In one, workers guiding a suspended load, or otherwise in direct contact with both the machine and ground, immediately become a path for electric current. In another, equipment operators are not aware of the line contact, or may perceive themselves to be in immediate danger and attempt to dismount the equipment, simultaneously bridging the high voltage between the equipment and ground. Finally, nearby workers who may not realize a serious electrical hazard exists, try to help those involved in the incident, and in doing so contact energized equipment or victims.

Existing Protection Technology

MSHA mandates procedures for preventing accidental line contacts in the mining industry in Title 30, Code of Federal Regulations, parts 56.12071 and 77.807-1 through 77.807-3. These are based on recommendations in the National Electrical Safety Code (NESC) and include maintaining a minimum 10-ft clearance from energized overhead power lines. A NIOSH alert, Preventing Electrocutions of Crane Operators and Crew Members Working Near Overhead Power Lines, suggests techniques to use when working near overhead power lines. These include de-energizing lines, maintaining appropriate distances from energized lines, using an observer to warn the operator of impending contact, and barriers to prevent physical contact with an energized line. Like most overhead power-line contact-prevention techniques, however, all of these rely on the active participation and heightened awareness of the machine operator and crew.

Earlier studies point out that while training solutions are often suggested for electrical hazards, the intervention effort must shift toward engineering control solutions “to reduce the hazard at its source.” Subsequent studies suggest that a change in the attitude of behavioral scientists is slowly occurring, placing greater emphasis on engineering control solutions. They attribute 60% of safety problems to “facility and equipment” deficiencies. While training is certainly important, engineering control interventions should not be overlooked.

At least one commercial device is currently available that is advertised to detect proximity to an energized overhead power line. Using electric field sensors mounted on the protected machine, the device is designed to sense electric fields that surround an overhead power line, and to warn when protected equipment projections are less than a preset distance from the power line. It is reported to be effective in many applications, but the manufacturer stresses that personnel using these units must fully understand their operation and limitations. Furthermore, the device should not be relied upon as the primary means of line-contact prevention, but should supplement a comprehensive safety strategy. Ultimately, despite being available for many years, these devices have found limited acceptance, due to their technical and operational limitations.

Another protection technique is the use of an insulating load link in the hoisting line of a crane, providing electrical insulation between the load and the crane, including the hoist rope. They are intended to prevent injury to workers in contact with a hoisted load in the event of line contact. Analysis of past line contacts suggests that widespread use of such links could reduce injuries. However, surface contamination and moisture can reduce a load link's insulation resistance. In addition, workers in contact with parts of the crane other than the isolated load would be unprotected by a load link. The relatively high cost of load links also limits their acceptance by the industry.

CFOI narratives for 1992 to 1998 electrical fatalities indicate that 83 boom truck (a small crane or hoisting device mounted on a flatbed truck) operators or support personnel were involved in fatal overhead power-line accidents. For this type of equipment, operators often stand on the ground next to the bed and manually operate the boom controls. Should a power line be contacted, the flow of current through the operator at the controls can be immediate. One effective solution sometimes employed on this type of equipment is replacing side-mounted manual controls with a radio-link remote control that electrically isolates the operator from the truck.

A Novel Approach for Preventing Line-Contact Injuries

Existing proximity warnings and insulating load-link technologies have found limited acceptance for a variety of performance- and cost-related reasons. Many overhead power-line contact injuries and fatalities could be avoided, however, simply by knowing that an overhead power line has energized a high-reaching vehicle. MSHA accident data for overhead line contacts in the mining industry from 1980 to 1997 reveal that in 57% of the cases, personnel were unaware of the line contact until after one or more workers touched either the equipment or a hoisted load and were injured. Based on these findings, NIOSH researchers are attempting to develop an alarm that warns mobile-equipment operators and nearby workers when a power line has been contacted.

For a line-contact alarm to be effective and reliable, it should be suitable for use on the types of mobile equipment most frequently involved in such incidents, work reliably under a wide range of conditions, function with minimal attention from personnel, be relatively inexpensive, and be easily retrofitted to existing equipment. Focusing on these characteristics, the approach being investigated at NIOSH is based on measuring electric-current flow to ground through a machine during a line contact. The specific technique being tested involves the diversion of some part of this current through a shunt cable mounted on board the machine, to provide a point at which to install a current sensor.

Most high-reaching mobile equipment employs at least one weight-bearing joint that rotates in a single plane, such as the pivot on a dump-truck bed or the base of a crane boom. Such a joint can be bridged with a shunt cable (a heavy, flexible, electrical conductor), monitored by a specially constructed current-sensing transformer (CT). Current passing through a machine from an overhead power-line contact will flow to ground through the bed or boom, frame, tires, and/or stabilizer jacks. Since the pivot joint has some finite resistance, part of this current flows through the shunt cable and is sensed by the CT. The signal from the CT is processed by electronics in the alarm device to trigger an audible and visual alarm, warning both the equipment operator and nearby workers of the electrical hazard presented by simultaneously touching the machine frame and ground. U.S. and Canadian patent applications have been filed for the current-sensing, overhead power-line contact alarm.

Ongoing Research

A 1998 NIOSH feasibility study first examined this approach. This work looked at electric-current flow to ground through a small crane and dump truck parked on grass, a gravel road, and a limestone quarry floor and produced two important findings. When these pieces of mobile equipment were energized at voltages of up to 950 volts-AC (vac; a level much lower than the line-to-ground voltage of most overhead lines), measurable currents flowed to ground through the tires and/or stabilizer jacks. Also, some portion of the current flowing could be diverted around a pivot joint on the machine by using a shunt cable. In general, test results suggest that the concept and approach are feasible, but experiments also pointed out that the road-surface conductivity (the contact resistance between the equipment and the road surface) and the bulk resistivity of the earth as a return path for electric current are all critical parameters that need to be better understood. Grass-covered ground, for example, is a good conductor (has low resistivity), and equipment parked on grass had the highest current flow to earth. In the case of the test crane parked on grass, only 105 volts were required to achieve 2 amps of current flow to ground. A gravel road and a quarry floor (a massive horizontal limestone formation) had progressively higher resistivities, and therefore, limited currents to successively lower magnitudes. A limiting case was observed with the crane parked on the quarry floor with its stabilizer jacks deployed. The small contact area of the jack pads on the hard, high-resistivity limestone surface reduced the current flow to levels as low as 23 milliamperes at 950 vac.

This work is continuing under a current NIOSH research project. Ongoing tests are being conducted to better define electric-current flow through mobile equipment, refine techniques for measuring this current, and identify factors that may limit the effectiveness of the proposed alarms. Experiments will focus on two issues, measuring total current flow through equipment energized to high voltages (up to 8 kilovolts (kv)) under diverse conditions and determining the effectiveness of bridging a pivot joint with a shunt cable for current detection. The work will use several types of cranes, dump trucks, boom trucks, and drill rigs. Test surfaces will include grass-covered and bare earth, as well as crushed stone, asphalt, and concrete road surfaces built to recognized roadway specifications. Should results warrant, a prototype alarm will be designed and built to aid in promoting this concept for commercial development.

Researchers at the NIOSH Pittsburgh Research Laboratory are developing an overhead electric power-line-contact alarm for mobile equipment. This work will determine whether an alarm based on current measurement can be reliable, simple to retrofit, relatively inexpensive, and, if feasible, promote its use in the workplace. Specific tasks to achieve these goals include: better defining the electrical characteristics of cranes, dump trucks, boom trucks, drill rigs, and other high-reaching equipment that can contact overhead power lines; construction and testing of a prototype overhead power-line contact alarm; promoting the commercialization of such a device; and conducting technology transfer to the private sector through labor organizations, equipment manufacturers, and publications.

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