

# An Alarm to Warn of Overhead Power Line Contact by Mobile Equipment

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**Abstract - As in many other industries, such as construction and agriculture, overhead electric power lines are a serious hazard at mining and mining-related operations. Even when excluding injuries that occur during electrical maintenance work, over one fourth of electrical fatalities in the mining industry are due to accidental overhead line contacts, and for each fatality nearly two serious non-fatal injuries occur due to such contacts. In incidents involving high-reaching mobile equipment, many of the victims touched the equipment after the fact, unaware that the machine frame had become energized by the line contact. MSHA data for accidents involving overhead power line contacts in the mining industry between 1980 and 1997 reveal that in 57% of the cases personnel were unaware of the accidental line contact until after one or more workers touched the equipment or a hoisted load and were injured. The situation is similar in the construction industry, where according to the National Institute for Occupational Safety and Health (NIOSH) data at least 20% of such victims are unaware of the line contact. This suggests that a device that alerts workers when a power line has been contacted could help prevent many of these injuries. Such a device would not prevent power line contacts, yet if widely employed could yield a significant reduction in the number of resulting injuries. Researchers at the NIOSH Pittsburgh Research Laboratory are attempting to develop such a device. The approach being investigated 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. Experiments thus far indicate that this approach is feasible. Ongoing research is better defining electric current flow through mobile equipment, refining techniques for measuring this current, and identifying factors that could limit the effectiveness of the proposed alarm.**

## INTRODUCTION

Common overhead electric 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 a few thousand volts to more than 10 kV. 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, as illustrated in Fig. 1. 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 vehicle, 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. Analyses of line contact incidents in the mining industry however, suggest that many of the resulting injuries could have been prevented by a device that simply alerts operators and other workers that a line has been contacted. Researchers at the National Institute for Occupational Safety and Health Pittsburgh Research Laboratory (NIOSH, PRL) are attempting to develop a reliable and practical alarm that will alert workers on or near high reaching mobile equipment when an overhead electric power line has been contacted.

## BACKGROUND

The U.S. Department of Labor's Bureau of Labor Statistics (BLS) compiles the Census of Fatal Occupational Injuries (CFOI).<sup>1</sup> BLS also compiles the Survey of Occupational Injury and Illnesses (SOII), a stratified sample of nonfatal occupational injury data in the U.S. Table 1 shows BLS electrical injury data for all industries from 1992-1998. A total of 32,309 "days lost" nonfatal electrical injuries and 2,268 electrical fatalities occurred during this period. This table also shows that 1,220 (3.8%) of the nonfatal electrical injuries, and 933 (41%) of the fatal electrical injuries involved contact with overhead power lines. This indicates that although relatively few occupational electrical injuries involve contact with overhead power lines, injuries resulting from line contacts are much more likely to be fatal than is the case for other types of electrical accidents. Three industry sectors, construction, agriculture and mining accounted for 1,323 (58%) of the 2,267 occupational electrical fatalities from 1992-1998, with 46%

<sup>1</sup> Data for the Census of Fatal Occupational Injuries are compiled from various federal, state, and local administrative sources, including death certificates, workers' compensation reports and claims, reports to various regulatory agencies, medical examiner reports, and police reports, as well as news reports.

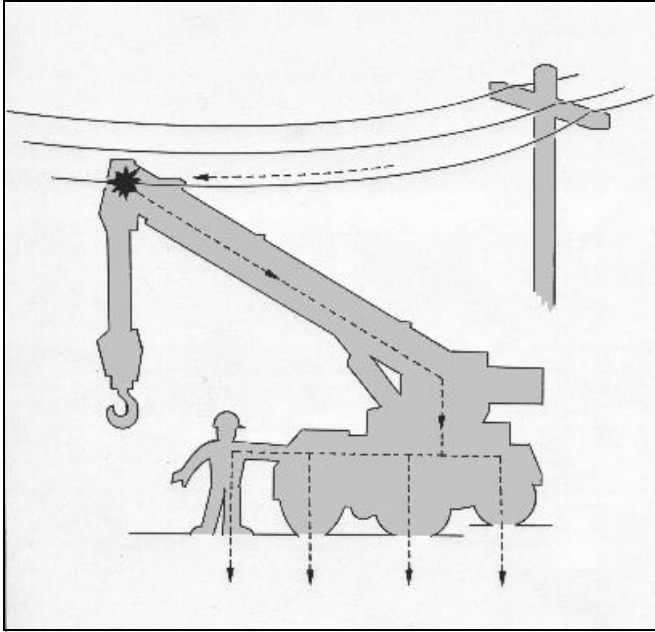


Figure 1. Typical electric current paths during an overhead power line contact incident.

of these due to contact with overhead power lines. This is an average of 87 overhead power line contact deaths per year in these three sectors.

Although most overhead line related injuries were due to direct contact or contact through a handheld object such as a ladder, a significant number involved mobile equipment. For example, 316 (33.8%) of the 933 overhead power line injury narratives in CFOI (cited above) mention a truck or crane. Similarly, data from the Mine Safety and Health Administration

(MSHA) indicate that 13 (17%) of the 75 electrical fatalities reported in the U.S. mining industry for the period 1990-1999 involved a crane, derrick, cherry-picker, or boom hoist.

CFOI data also show that 19 different job titles reported 10 or more overhead power line contact fatalities (705 of 933 reported fatalities) between 1992-1998. Based on 1998 BLS employment figures for those job titles, more than 6 million U.S. workers are exposed to overhead power line hazards.

#### EXISTING TECHNOLOGY

Most recommendations regarding safe working distances from energized overhead power lines are based on those contained in the National Electrical Safety Code (NESC). MSHA mandates several prevention techniques for the mining industry in Title 30, Code of Federal Regulations, Parts 56.12071 and 77.807-1 through 77.807-3. OSHA has similar recommendations also based on the NESC. 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, use of 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, all of these rely on the active participation and heightened awareness of the machine operator and crew.

Rossignol points out that, while training solutions are often suggested for electrical hazards, intervention efforts must shift toward engineering control solutions “to reduce the hazard at

TABLE 1

ELECTRICAL INJURY DATA, ALL INDUSTRIES (1992-1998)

	Electrical Injuries							
	1992	1993	1994	Year		1997	1998	Total
				1995	1996			
Nonfatal electrical injuries (total) <sup>1</sup> 4,806	4,995	6,018	4,744	4,126	3,710	3,910	32,309	
Overhead power line contact <sup>1</sup>	174	133	273	155	92	79	314	1,220
<b>Percent of Nonfatal Electrical Injuries</b>	<b>3.6%</b>	<b>2.7%</b>	<b>4.5%</b>	<b>3.3%</b>	<b>2.2%</b>	<b>2.1%</b>	<b>8.0%</b>	<b>3.8%</b>
Fatal electrical injuries (total)	334	325	348	348	281	298	334	2,268
Overhead power line contact	140	115	132	139	116	138	153	933
<b>Percent of Fatal Injuries</b>	<b>42%</b>	<b>35%</b>	<b>38%</b>	<b>40%</b>	<b>41%</b>	<b>46%</b>	<b>46%</b>	<b>41%</b>

1. Nonfatal injuries involving days away from work.

Source: BLS - CFOI, SOII, 1992-1998.

its source” [1]. Manuele suggests that a change in the attitude of behavioral scientists is slowly occurring, placing greater emphasis on engineering control solutions. He attributes 60% of safety problems to “facility and equipment” deficiencies [2]. While training cannot be overlooked, it should be one part of an intervention strategy that includes appropriate engineering controls. Indeed, techniques that require little or no participation by personnel often afford the greatest benefits.

At least one commercial device is currently available which is advertised to detect proximity to an energized overhead power line [3]. 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 machine 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 must fully understand the device’s operation and limitations. The manufacturer also points out that the device should not be relied upon as the primary means of power line contact prevention, but should supplement a comprehensive safety strategy. Ultimately, despite being available for decades, power line proximity warning devices have not found widespread acceptance, due to their technical and operational limitations.

Another protection technique, the use of an insulating load link in the hoisting line of a crane, is intended to prevent injury to workers in contact with a hoisted load in the event of a 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 [4]. The relatively high cost of load links also limits their acceptance by industry.

CFOI narratives for 1992 to 1998 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 truck-side mounted manual controls with a radio link remote control that electrically isolates the operator from the truck.

#### POWER LINE CONTACT ALARM CONCEPT AND APPROACH

While existing proximity warning and insulating load link technology have not found widespread acceptance for a variety of performance- and cost-related reasons, closer study of

overhead line contact incidents suggests that many line contact injuries and fatalities could be avoided simply by knowing that mobile equipment has become energized by contacting an overhead power line. A review of NIOSH Fatality Assessment Control and Evaluation (FACE) reports for overhead power line contact fatalities in the construction industry indicates that at least 20% of fatalities could have been prevented by knowing that the machine chassis had become electrically energized, allowing workers to avoid contact (about 92 fewer fatalities from 1992-1998). Similarly, an unpublished NIOSH study examined 1980-1997 MSHA data for accidents involving overhead power line contacts in the mining industry [5]. MSHA accident narratives revealed that in 57% of the cases, personnel were unaware of the accidental line contact until after one or more workers touched 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 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 employ 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 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 its 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 potentially lethal 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.

One critical issue for a line contact alarm is reliability, and an important aspect of reliability is the ability to withstand the high machine frame voltage and current flow possible during a power line contact. The current-sensing system proposed

however, is inherently resistant to damage from such conditions. Specifically, points on board mobile equipment to which alarm system components will be mounted may be at a high potential relative to ground, but there will likely be relatively little voltage difference among them. Since the proposed alarm system has no components that must be maintained at ground potential, exposure to high voltage should not pose a problem. In addition, the use of a window type CT protects downstream system circuitry from high currents, by limiting the amount of energy that can be transferred. This leaves only the proposed pivot joint shunt vulnerable to possible high currents, requiring low resistance and rugged construction.

## NIOSH RESEARCH

### *A. Initial Feasibility Study*

A 1998 NIOSH feasibility study first examined this approach [6]. 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 up to 950 Vac (a level much lower than typical overhead lines), measurable currents flowed through the tires and/or stabilizer jacks to ground. Also, some portion of the current flowing could be diverted around a pivot joint on the machine, 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 vehicle 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 earth for example, is a good conductor (i.e., 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 was required to achieve 2 amperes 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 low levels, as little as 23 milliamperes at 950 Vac.

### *B. Ongoing Experimental Program*

While initial research suggested that an equipment-mounted line contact alarm is feasible, further work is underway to study the concept in more detail. Specifically, ongoing research is better defining electric current flow through mobile equipment, refining techniques for measuring this

current, and identifying factors that could limit the effectiveness of an alarm based on detecting on-board current flow. Should results warrant, a prototype alarm will be designed and built to aid in promoting this concept for commercial development. The experimental program under this research has been designed to address several key issues.

1) In a mobile equipment-power line contact, immediate electric current flow through the machine frame to ground must be sufficient to allow detection and activate an alarm. This must be true for the types and sizes of mobile equipment most at risk for line contact, and for the types of roadways and work surface conditions likely to be encountered.

2) It must be possible to detect machine frame current flow in a simple and reliable manner. This research proposes monitoring current through a conductor shunting a pivoting joint (e.g. the pivot of a dump truck bed). The shunt must therefore, under normal operating conditions, divert sufficient current from the joint to activate an alarm.

3) The above approach must be implemented in a design and package that is reliable, inexpensive, operates with minimal attention from personnel, and can be retrofitted to a wide variety of equipment.

Another issue being examined is the possible presence of dangerous voltage drops on-board equipment during a line contact. This information is not critical to the development of the proposed line contact alarm, but does relate to worker safety under conditions where such an alarm is intended for use.

### *C. Total Machine Current Experiments*

A specialized test site has been constructed at the Pittsburgh Research Laboratory to study the total electric current flow through equipment during line contacts. The experiments are designed to measure total current while varying the specific mobile equipment involved, the roadway or work surface involved, and the voltage applied to the equipment frame. The facility and test plan are described below.

1) The test site is a remote grass-covered hilltop, several hundred feet from the nearest roadway or actively used structure. The soil has a measured resistivity of approximately 61 Ohm m (200 Ohm ft), and there are no known buried pipes, conduit, or debris in the area. Based on the soil resistivity, a driven-rod ground bed was designed and installed to supply a 5 Ohm (maximum) path to remote earth.

2) Test “pads” have been constructed at the site to replicate common roadway or work area surfaces. These are a minimum of 69 m (226 ft) from the ground bed, and include an

undisturbed grass covered surface, bare earth, compacted crushed stone, and asphalt. The pads are 9.1 m (30 ft) by 15.2 m (50 ft) and level, with the crushed stone and asphalt surfaces constructed to meet Pennsylvania Dept. of Transportation standards for road construction. The addition of a concrete pad is scheduled for early 2001.

3) Mobile equipment for these experiments will be selected based on the types and sizes most frequently cited in descriptions of past overhead line contacts. They include mobile cranes, with emphasis on rough terrain cranes and boom trucks, tandem and tractor trailer dump bed trucks, and drill rigs on truck chasses. The variety and number of machines tested will depend on time available and funding.

4) The high voltage power source for these experiments uses a 6,500 W portable generator to supply an adjustable transformer which in turn powers a custom built high voltage step up transformer. The final 60 Hz ac output is adjustable from 0 to 9,000 V. Digital multimeters and a high voltage probe are used for current and voltage measurements.<sup>2</sup>

Due to test site construction delays, this series of experiments has not yet been conducted. The test plan calls for attaching the high voltage source across the ground bed and the frame of a machine parked on one of the test pads, then gradually increasing the potential impressed across this circuit. The applied voltage and the resulting current will be documented. This procedure will be repeated for each specific piece of mobile equipment on each test pad. In the case of equipment with stabilizers, such as cranes or drill rigs, tests will be conducted both with and without stabilizers deployed.

The maximum voltage and current levels to which equipment is subjected in these tests are critical. Ideally, the proposed line contact alarm should activate if 2,300 V or less is applied to a machine frame, with this value corresponding to the line to ground voltage for a nominal 4,160 V overhead power line. Minimum required total current flow however, will be determined by the design and limitations of the contact alarm. Preliminary results so far suggest a total machine ground fault current lower limit of approximately 600 mA, based primarily on the amount of current a shunt can divert from a pivoting joint (discussed in the next section). These factors will influence the maximum voltage used for each individual test, but that level may, in many cases, be dictated by the power that can be dissipated safely across mobile equipment tires.

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<sup>2</sup> All measurement instrumentation is annually calibrated to NIST traceable standards.

#### D. Shunt Current Experiments

A series of tests has been completed examining the carried performance of shunts bridging pivoting joints on mobile equipment. Experiments measured the amount of current by such a shunt when electric current was passed through the frame of a piece of equipment. These tests were conducted as follows.

1) Mobile equipment used included a 10.9 tonne (12 short ton) tandem axle dump bed truck, a 20.9 tonne (23 short ton) tractor trailer dump bed truck shown in Fig. 2, a 20 tonne (22 short ton) rough terrain crane shown in Fig. 3, and a 31.8 tonne (35 short ton) industrial crane. All are government owned equipment available at PRL.

2) On the trucks, a shunt was placed from the dump bed to the truck frame, and on the cranes, between the base section of the boom and the main boom pivot supports on the turntable. Except as noted in results, the shunt was a 91 cm (36 in) piece of #2/0 AWG stranded copper cable, with clean, tight mechanical connections using C-clamps.



Fig. 2. 20.9 tonne (23 short ton) tractor-trailer dump truck used in experiments.



Fig. 3. 20 tonne (22 short ton) rough terrain crane used in experiments.

3) The sensor used to monitor current through the shunt was a windowtype current transformer (CT) with a ratio of 100/1, designed to measure currents as low as a few milliamperes. The CT output was terminated across a nominal 100 ohm resistor, and the voltage drop across the resistor measured with a digital multimeter. The shunt cable and CT in place on the 20 tonne (22 short ton) crane are shown in Fig. 4.

4) An adjustable 60 Hz ac power source was used to flow up to 10 A through the equipment under test. The “hot” lead was attached to the top front edge of the bed (cab protector) on the trucks, and on the tip of the boom on the cranes, while the power supply return was attached to the frame on the trucks and the outrigger support framework on the cranes. Total current was monitored directly on a digital multimeter.

5) In general, tests were conducted by passing 10 A nominal total current through each machine and measuring flowthrough the pivot joint shunt. Parameters that were varied for the boom or bed in each test included height (vertical angle), motion, and loading. Other factors tested were shunt size (resistance) and the effect of wet weather.

Results from the dump truck tests are summarized in Table 2. The test loads for the 20.9 tonne (23 short ton) and 10.9 tonne (12 short ton) trucks respectively were approximately 14.5 tonne (16 short ton) and 9 tonne (10 short ton). Bed angles ranged from horizontal to approximately 50 degrees. Beds were raised and lowered several times prior to data collection, and readings were recorded at 10 degree intervals over 3 raise/lower cycles.

Although the amount of current through the shunt varied widely with changes in truck load and bed position, the level

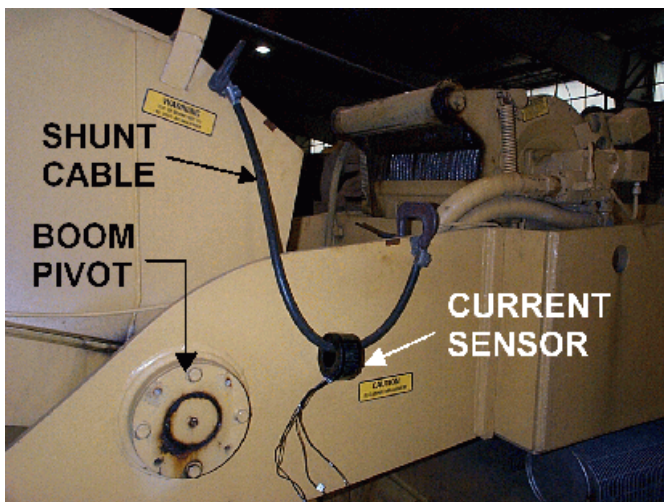


Fig. 4. Shunt cable and current sensor on boom pivot of 20 tonne (22 short ton) rough terrain crane used in experiments.

TABLE 2  
RESULTS OF DUMP TRUCK BED PIVOT SHUNT CURRENT TESTS

Truck	Percent of Total Current Flow Through Bed Pivot Shunt			
	Bed loaded		Bed empty	
	Maximum	Minimum	Maximum	Minimum
20.9 tonne tractor trailer (23 short ton)	89.3 %	9.4 %	90.0 %	51.6 %
10.9 tonne tandem (12 short ton)	88.3 %	7.8 %	87.0 %	9.7 %

for any given set of conditions during testing was generally stable, and current level changes from one test condition to the next were typically gradual and uniform. A total current of 10 A gave a voltage drop of less than 2 V for the complete test circuit.

Results from the crane tests are summarized in Table 3. The 20 tonne (22 short ton) rough terrain crane is a Grove RT-522, and for the tests done under load, was configured for lifts at 38% and 73% of maximum load chart capacity. The 31.8 tonne (35 short ton) industrial crane is a Grove IND-2535, and was tested unloaded only, due to pending hydraulic system repairs. Crane load chart limits and overhead clearance in the test building allowed 40 to 50 degrees vertical boom movement for unloaded and 38% load tests, but only 5 degrees movement for the 73 % load. Similar to the dump truck tests, booms were raised and lowered several times prior to data collection. Readings were taken at approximately 2 degree intervals for 73% load tests, and 10 degree intervals for all others, over a minimum of 2 raise/lower cycles.

The shunt current for any given set of conditions during testing was generally stable, and current level changes from one reading to the next were typically gradual and uniform. A total current of 10 A gave a voltage drop of less than 2 V for

TABLE 3  
RESULTS OF CRANE BOOM PIVOT SHUNT CURRENT TESTS

Crane	Percent of Total Current Flow Through Crane Boom Pivot Shunt			
	Under load		No load	
	Maximum	Minimum	Maximum	Minimum
RT-522	1.9 %	0.9 %	1.6 %	0.8 %
IND-2535	(no test)	(no test)	2.1 %	0.9 %

the complete test circuit. Two other experiments were conducted to assess shunt performance. One test was run on the 31.8 tonne (35 short ton) crane, where the 91 cm (36 in) #2/0 AWG shunt was replaced by three 46 cm (18 in) #4/0 AWG cables connected in parallel (10 A total current as in previous tests). This reduction in shunt resistance had no significant effect on the amount of current carried by the shunt. Another test, on the 20 tonne (22 short ton) crane, measured the effect of simulated wet weather conditions on the current diverted by the shunt. In this experiment, the boom pivot area and lift cylinders on the turntable were subjected to a heavy water spray while monitoring current through the shunt (10 A total current and #2/0 AWG shunt as in previous tests). The boom was also moved through a 20 degree elevation change during the test. No reduction in shunt current resulted from the application of water.

#### E. Shock Hazards On Board Equipment

This research has also investigated the presence of unexpected hazardous voltages on board mobile equipment during a line contact. It is generally accepted that, in the absence of a fire hazard, personnel should stay on board equipment in the event of a line contact until the line/equipment frame is de-energize. However, the possibility of personnel being injured while remaining on board equipment in contact with a power line prompted researchers on this project to investigate whether possible dangerous voltages are present on crane and truck chasses when electric current flows through them. These experiments used the 20 tonne (22 short ton) and 31.8 tonne (35 short ton) cranes and the 20.9 tonne (23 short ton) dump truck described earlier. A power source was connected to flow 10 A dc from the boom tip or top front of the dump bed to a connection on the equipment chassis. Resulting voltages were measured from the chassis connection to key points on the equipment, such as operator controls, handles, steps, and other surfaces that a worker could contact while operating or attempting to exit the machine. The results were extrapolated for a current flow of 1,000 A, and suggest that, for properly maintained equipment, it is unlikely that an operator will be exposed to a dangerous voltage during a power line contact, unless touching the machine and ground simultaneously. Table 4 summarizes the results.

One exception to these results is the possibility of high voltage between the tractor and trailer on a dump truck. Using measurements from the 10 A dc dump truck tests described above, a 1,000 A extrapolation produces approximately 24 V between accessible points on the tractor and trailer. This drop is due to the combined resistance of the trailer wiring harness connections and the fifth wheel, although the wiring harness would likely open under high current. Resistance of the fifth wheel joint however, is highly variable. In an earlier separate series of tests, up to 3,500 V ac was placed across the same

TABLE 4  
RESULTS OF MOBILE EQUIPMENT ON BOARD HAZARDOUS VOLTAGE TESTS

Values for 1,000 A dc current through crane and dump truck chasses, extrapolated from 10 A dc measurements

Mobile Equipment	Maximum Voltage Across Likely Touch and Step Points	
	Operator control area	Operator egress path
RT-522 crane	0.7 V	0.4 V
IND-2535 crane	1.2 V	0.0 V
20.9 tonne dump truck (23 short ton)	3.4 V	2.2 V

truck (including tires) producing 1 A total current flow. Under these conditions, voltage measured between the tractor and trailer varied widely, ranging from less than a volt to over 500 V, changing due to physical movement and position of the fifth wheel.

#### F. Conclusions

The following summarizes the significance of results from experiments conducted to date.

1) Under conditions where electric current flows through the framework of a dump truck or crane, a shunt bridging the dump bed pivot or crane boom pivot (a #2/0 AWG stranded conductor was used in experimentation) can divert part of this current, and provides a convenient point at which to mount a current sensor.

2) Current flowing through such a shunt is generally stable for a given boom/bed position and loading, and seems unaffected by moisture on the pivot joint (e.g. wet weather).

3) The current carried by the shunt however, can be as little as 0.8 % of the total flow on the machine frame. The current sensor and downstream electronics anticipated for the proposed power line contact alarm will likely require a minimum of 5 mA shunt current. As a result, total current flow to earth in a line contact, for the mobile equipment and conditions tested so far, would have to be over 600 mA for reliable alarm operation.

4) When a line contact occurs, hazardous voltages are unlikely to develop on board mobile equipment chasses or structures, with practically all of the voltage drop occurring

across equipment tires and in the adjacent earth. Consequently, notwithstanding an on board fire, the primary hazard is contacting the equipment and ground simultaneously, and personnel should not dismount or approach energized equipment. One exception to the absence of dangerous voltages on board equipment, is the possible hazardous voltage developed between separate structures on the equipment, such as the tractor and trailer of a semi-trailer type truck.

#### SUMMARY

Researchers at the NIOSH Pittsburgh Research Laboratory are investigating whether an overhead power line contact alarm for mobile high reaching equipment, based on current measurement, can be reliable, simple to retrofit, and relatively inexpensive. If such a device is feasible, this work will then promote its use in the workplace. Specific tasks to achieve these goals include accurately 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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