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# EVALUATION OF HEAVY EQUIPMENT OPERATORS' SAFETY BELT RESTRAINT SYSTEM

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INTERIM REPORT

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16. Abstract

This report presents the results of Phase I of an evaluation of a proposed lap belt restraint system. This system has unique features since it is intended to be issued to heavy equipment operators as personal equipment and can be snapped into various vehicles the individual may be assigned to drive. The major purpose is to increase usage and occupant protection, reducing the risk of injury in collision or jolt. Specific tasks accomplished include a limited literature review, an analysis of accidents involving drivers of heavy equipment, examination of the operators environment from human factors, physical factors, and ergonomics points of view, observation and riding in heavy vehicles in the open pit mine environment, and a subjective evaluation of the proposed restraint. Recommendations are provided for Phase II protocol for dynamic tests to provide further objective evaluation.

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# EVALUATION OF HEAVY EQUIPMENT OPERATORS' SAFETY BELT RESTRAINT SYSTEM

## PHASE I. INTERIM REPORT

Submitted to:

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1 September 1982

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# I. SUMMARY

Phase I of this study was intended to provide an objective basis for the conduct of dynamic testing in Phase II. The major conclusions are summarized as follows:

- Review of accident reports over a 5-1/3 year period from the mining operation selected indicates that the most prevalent type of injury to heavy equipment operators occurs from vertical impacts of vehicles hitting holes in the road (30 cases; 18.6%), followed closely by vehicles striking solid objects such as rocks or other vehicles (28 cases; 17.4%). Other injuries were attributed in the accident reports to rough ground (21 cases), running off a ledge or rock (17 cases), hit by shovel bucket while loading (15 cases), and the vehicle's being hit by a falling rock while loading (12 cases). These impact factors accounted for 76.4 percent of the injuries reported. Only three percent involved rollovers.
- Vertical jolt is a significant cause of the injuries reported, followed by collision impact.
- Present use of seat belts appears to be very low. In only eight of 161 accident cases reported was use or non-use reported. In only four cases (2%) were seat belts reported to be worn (although it is company policy that operators will wear belts).
- A new restraint system is warranted based upon present usage and need for increased protection.
- Site accident data do not provide sufficient detail to determine specific injuries with confidence, or to conduct further analyses of injury causation.

- Nationwide accident data available to us (SDS data from workers compensation files) do not provide sufficient detail for meaningful analysis and use as a basis for identifying injury causations.

- Seat belts (lap belts) may be expected to help prevent some injuries to heavy equipment operators under conditions of severe jolt, rollover, or impact, and to prevent ejection. The lap belt alone would not be expected to reduce severity or incidence of head impact (indicated as injury site in 11 cases (6%) of accident cases reported), or result in significant influence or prevention of chronic back problems (seldom reported to be problem in these cases, and usually associated with ride quality of the seat).

- A preliminary subjective analysis of the proposed restraint system indicates that the belt can be comfortably adjusted and is much lighter (2-1/4 - 2-1/2 lbs) than belts routinely worn in occupations such as electricians (22 lbs) and police (ca 13 lbs). An attractive feature is the concept that issued as personal equipment the belts will be kept clean, in good condition and receive more use. Some question arises relative to effect of belt angle (80-90°), which is higher than the recommended 55 ± 10° angle, and any adverse impact effects on the operator in seats where the belt is attached directly to the seat, (where a second belt is attached to the floor), rather than attached directly to floor structure.

- Over half (99 cases or 55.6%) involved vertical loadings (+Gz) on the driver, resulting from bumps, jolts, and vertical impacts. Some 15.7% (28 cases) involved a frontal (-Gx) collision, and 13.5% (24 cases) were reported in lateral (±Gy) impact. These data indicate the most prevalent directions of loading on the driver and suggest priority of test orientations.

- Based upon the foregoing findings, a Phase II dynamic test protocol is recommended as follows:

1. All tests will be conducted on the HSRI Impact Sled with an instrumented 50th percentile male anthropomorphic dummy. No surrounding cab structure will be used.
2. Three frontal impact tests will be conducted with a velocity change of 20 mph and an average deceleration of 30 G.
   a. One test will be with a fixed vehicle seat and the proposed restraint system.
   b. One test will be with a fixed vehicle seat and a conventional lap belt.
   c. One test will be with a suspension-type vehicle seat and the proposed restraint system.
3. Two lateral impact tests will be conducted with a velocity change of 10 mph and an average deceleration of 20 G.
   a. One test will be with a fixed vehicle seat and the proposed restraint system.
   b. One test will be with a fixed vehicle seat and a conventional lap belt.
4. Two vertical jolt tests will be conducted with a velocity change of 7 mph and an average deceleration of 6 G.
   a. One test will be with a fixed vehicle seat and the proposed restraint system.
   b. One test will be with a fixed vehicle seat and a conventional lap belt.

# II. INTRODUCTION

The fact that a vehicle occupant will be protected in a crash impact involving sudden deceleration (in hitting a bump or hole in the road, for example) by use of a restraint system has been well documented in the literature. However, to date, well over 100 different restraint systems have been developed, and some offer greater protection in crash environments than others. Before any system can be incorporated in a vehicle it is necessary to conduct tests to determine that the system functions as designed. Frequently dynamic tests will reveal unanticipated flaws which may be corrected prior to actual installation. In the case of operators of heavy equipment - loaders, tractors, and trucks - there are specific environmental problems which differ from that of other types of vehicles. The basic problem is that of providing the operator a simple, comfortable, but effective restraint sytem. However, this is compounded by the problem of how to ensure that the system will actually be worn by the drivers. That this is a real and universal problem is indicated by numerous studies concluding that drivers do not appear to be using the belts presently supplied with vehicles. In heavy equipment most of the belts we have observed have been left unattached on the floor, which has resulted in very dirty and almost unusable restraints.

The U.S. Steel Corporation safety department has devised a unique solution to this problem of usage. The proposed lap belt system is intended to be issued to the drivers as personal equipment. Rather than being permanently installed in the vehicle, it could be worn to and from work by the driver, and simply "plugged in" to the vehicle being used. As personal equipment it would probably be kept clean, and the intent is to encourage greater driver usage. Various aspects of this solution are addressed in the following report.

The following interim report presents the results of the Phase I background evaluation of the U.S. Steel safety belt system, fabricated by Miller Equipment Division for use by heavy equipment operators employed by U.S. Steel Corporation. The purpose of this preliminary review is to provide an objective basis to ensure that the test protocol to be conducted in Phase 2 will be most productive and that the dynamic tests will realistically address the collision environment to which drivers of heavy equipment are most commonly exposed.

To this end, the general objective has been to utilize a systems engineering approach to consider various aspects of the potential impact or vibration environment and effectiveness of the belt system proposed. In this regard, the restraint system has been evaluated from the disciplines of biomechanics, ergonomics, physical factors, and physical anthropology. Areas were not examined in depth, as a separate study, but rather from the broad point of view of experts within these areas.

Specific tasks accomplished during this phase include a limited literature review, an analysis of accidents involving drivers of heavy equipment, examination of the operator's environment from human and physical factors, ergonomics, and physical anthropology points of view, observation and riding in heavy vehicles in an operational open pit mine work environment, and consideration of potential problems and effectiveness of the proposed belt system. These considerations have been kept in mind in formulating the dynamic test protocol, proposed to be conducted in Phase II.

## III. LITERATURE SEARCH

The proposed U.S. Steel lap belt restraint system features unique design considerations as well as aspects related to the human user's comfort, fit, acceptability, and protection. The features can be evaluated to some extent on a basis of prior experience and testing. A literature search was initiated at the onset of this program to try to identify studies in which the results would be particularly pertinent to this evaluation. In this regard no attempt was made to survey the entire field of restraint systems, since there are literally thousands of publications on restraint systems. Rather, the survey was aimed at selectively locating the few studies, patents, or publications where features were similar to those of the proposed system.

A Lockheed DIALOG computer search was initiated. The Dialog program is based upon three data bases, including all publications of the National Technical Information Service (NTIS), standards and specifications, and Engineering Index. However, this resulted in only 26 references. Of these, only four were considered to be at all applicable to the unique characteristics of the proposed system. As a result, this search was supplemented by review of HSRI library files and personal files, containing over 6,000 publications on restraint systems.

As background, prior studies were reviewed which investigated the relationship between seat belts and injury reduction in heavy trucks. Although the highway environment differs in some respects from that of the open pit mine, heavy commercial trucks are the closest in size to the vehicles under study.

In the United States commercial motor carrier accident data are reported by the Bureau of Motor Carrier Safety (BMCS), and in selected cases by the National Transportation Safety Board (NTSB). An analysis and summary of 497 heavy truck accidents investigated between 1973 and 1976 was reviewed (Bureau of Motor Carrier Safety, 1977), as well as a more recent analysis of 346 heavy truck accidents during the 1977-1979 period (Bureau of Motor Carrier Safety, 1981). There were also 14 NTSB investigations during that period not included.

In the 843 heavy truck accidents investigated by BMCS between 1973 and 1979, 518 involved collisions. Of these, 141 accidents involved ejections of the non-restrained occupants, resulting in 147 fatalities and 53 injuries. During this period there were 137 head-on collisions, 226 rear-end collisions, 84 side impacts, and 17 other types of collisions. Single-vehicle accidents are separately categorized. Of 325 accidents involving only a single vehicle during this period, 211 trucks ran off the road and overturned, 24 overturned on the roadway, 38 hit a fixed object, 28 were loading/unloading accidents, and 24 were from other causes. No attempt in these statistical studies was made by BMCS to evaluate seat belt effectiveness, but it seems apparent that had these truck occupants been protected by seat belts, many less fatalities and less severe injuries would have occurred. The high fatality rate attributed to ejections, as well as roll-over and collision accidents where compartment space was not crushed in, might be areas where seat belts could have achieved injury reduction.

In Sweden heavy trucks are involved in 15 percent of the approximately 1,000 fatal accidents per year. A recent study of selected commercial truck accidents involving Volvos aimed to investigate injury location and causation as a basis for improving collision protection (Hogstrom and Svenson, 1980). Along with development of a safety steering wheel and reinforced cabs which are crash tested, it was found that the best injury reducing means was a three-point retractable safety belt. The authors of this Swedish study predicted that had this safety belt been used it could have minimized the injuries to the drivers in 74 percent of the truck accidents examined. Using the Abbreviated Injury Scale (AIS), compiled by the American Association for Automotive Medicine as a basis, they found that the six-point AIS rating in each case of injury could be reduced by at least one unit by use of the restraint system.

This finding is consistent with an earlier Department of Transport study of heavy truck accidents in England (Gratton & Hobbs, 1978). Utililzing the AIS criteria, it was reported that wearing of a seat belt would have reduced the mean overall level of injury in the accidents selected for study by one level. It was also concluded that seat belts would have reduced the severity of injury for about one-third to one-half of the fatalities.

Earlier this year a study of forklift truck overturns was completed at HSRI which is also relevant to protection in heavy vehicles (Melvin, et al., 1982). In this study a number of rollover accidents were simulated using a variety of turning manuvers and drop tests. The operator was simulated by restrained and unrestrained instrumented anthropomorphic dummies. A preceding study involving some 36 rollovers was conducted to simulate field accidents and evaluate the effects of restraint systems on the operator's motion during truck overturns (King, 1981).

Another area investigated in the literature included restraining devices similar to that proposed. The computer search resulted in only two U.S.patents with some similarities. There may be a number of others which were not accessed for some reason. A 1973 patent by Gause and Spier related to a restraint system to be used by an ergometer operator while exercising under zero gravity conditions or in a position other than upright. This restraint consists of a padded, form-fitting wide body belt, with padded suspenders over the shoulders. This equipment was developed relative to astronaut laboratory testing and training on exercise machines, and may be installed on future orbiting space stations. In 1933 a patent was applied for to restraint a child in a "chair, carriage or other similar device" (Serpico, 1935). This essentially consisted of a single belt looped around the child's body and attached to the sides, but allowing freedom of motion without abrasion through a series of slotted riders. Neither of these restraints is similar to that proposed.

# IV. ACCIDENT DATA

A second task involved review of accident files of drivers of heavy equipment to determine the nature, site, severity and frequency of injuries and identify occupant protection problems. These data were obtained from two sources and while neither source provides necessary medical information, the general accident environmental information was useful in determining major risk factors and nature of the injury.

## 1. Minnesota Ore Operations

Accident reports involving operators of heavy vehicles were provided by the sponsor through Richard Wible, and Steve Stockavich, Safety Engineer, of the Minnesota Ore operations of U.S. Steel Corporation at Eveleth and Mt. Iron, Minnesota. A copy of this form is provided in Appendix B.

These data consisted of 161 reported accidents over a 5-1/3 year period, from January, 1977 to April, 1982, in which an injury was reported involving a heavy vehicle driver at this single mining operation. Table I provides a summary of these data.

Four female drivers (2.5% of accidents reported) and 157 (97.5%) male drivers were involved during this period. Age of the female drivers ranged from 19-1/2 to 25 (mean 22-1/4 years), but unfortunately height and weight information was not available. All were injured while driving trucks, three being jolted in driving into holes on the road and one jarred while being loaded. Resulting injuries reported by the female drivers included neck sprains in two individuals, muscle strain in the lower back and neck sprain in a third, and a sore back in the fourth. The total number of female drivers is unknown to the authors.

TABLE I

SUMMARY OF ACCIDENTS REPORTED INVOLVING DRIVERS OF HEAVY EQUIPMENT
AT MINNESOTA MINING OPERATIONS, JULY 1977-APRIL 1982

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1982** | 1. | 01/06 | 18:30-20:00 | 29 | M | 5 | Sore neck, shoulder, fingers | Neck, Shoulders, Fingers | Dumping dirt and the box snapped back causing the injuries. | Pro. Truck | Jolted | +Gz |
| | 2. | 01/13 | 10:00 | 42.5 | M | 8 | Received X-rays & went back to work | Left elbow, Lower back | Engine failure which resulted in the truck running into a berm. | Pro. Truck | Collision | -Gx |
| | 3. | 02/17 | 13:15 | 40 | M | 2.5 | Sore back | Back | Seat adjustment not locked, hit bump in road, snapped back. | Pro. Truck | Jolted | ±Gx, +Gz |
| | 4. | 03/13 | 16:00 | 31 | M | 3 | Bruised back | Left side back | Plowing snow, slid down 3% hill, stopped suddenly when blade caught on rail crossing, throwing driver against steering wheel. Driver <u>didn't use seat belt</u>. | Tractor (48 Rubber Bull) | Collision | -Gx |
| | 5. | 03/18 | 13:50 | 40 | M | 2.5 | Neck & lower back sprain | Neck, Lower back | Truck hit hole, seat bottomed out. | Truck | Vertical jolt | +Gz |
| | 6. | 03/28 | 10:30 | 29 | M | 7 | Jarred neck and shoulder | Neck, Shoulder | Hit hole in road. | Pro. Truck | Vertical jolt | +Gz |
| | 7. | 04/01 | 15:20 | 38 | M | 11 | Sore back | Lower back | Hit bad spot in the road, causing pain in lower back. | Pro. Truck | Vertical jolt | +G2 |
| | 8. | 04/08 | 21:30 | 32 | M | 3 | Pain in left side and hip | Left side, Hip | While backing up a loader CAT, ran over a rock which jarred driver. | Loader Cat | Vertical jolt | +Gz |
| **1981** | 9. | 01/14 | 17:30 | 32 | M | 7 | Back (light duty for 24 hours) | Back | While loading at a shovel, a chunk fell off the teeth of the bucket & jarred the driver in the truck. | Truck | Jolted | +Gz |
| | 10. | 02/24 | 12:00 | 28.5 | M | 2 | Pain in back | Lower back | During a cleaning operation, the machine slid backwards and jarred the operator. | CAT | Jolted | +Gx |
| | 11. | 03/02 | 17:00 | 34 | M | 2 | Sore back | Back | The operator was being rocked around in a seat without footrests. | CAT Tractor | Jolted | -Gx |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1981 contd** | 12. | 03/09 | 16:40 | 33 | M | 2 | Sore Neck | Neck | The operator was involved in a cleaning operation when he struck a solid object. | CAT Loader | Collision | -Gx |
| | 13. | 03/13 | 17:15 | 25 | M | 3 | Sore back and neck | Back, Neck | Operator drove over a rough area after a dump. | Pro. Truck | Jolted | +Gz |
| | 14. | 03/15 | 14:45 | 27 | M | 5 | Bruised neck and chest | Neck, Chest | The operator struck a rock while grading & was thrown into the steering wheel. Driver didn't use seat belt. | CAT Grader | Collision | -Gx |
| | 15. | 03/22 | 6:00 | 27 | M | 5 | Pain in back | Lower back | Machine went over a tire rut. | Pro. Truck | Jolted | +Gz |
| | 16. | 03/24 | 22:45 | 32 | M | 5 | Sore neck | Neck | Hit a hole while driving. | Pro. Truck | Jolted | +Gz |
| | 17. | 03/25 | 16:00 | 27.5 | M | 2 | Strain | Lower back | Tractor backed up on a rock. When it slid off, the operator was jarred around. | Tractor | Jolted | +Gz |
| | 18. | 04/04 | 4:10 | 39 | M | 1.5 | Back and shoulder probably bruised | Back, Left shoulder | Driver drove over a rough area. Driver used seat belt. | Pro. Truck | Jolted | +Gz |
| | 19. | 04/26 | 10:00 | 29 | M | 4 | Sore back | Lower back | Operator backed over rock. When dropped off rock, he was jarred around. | Tractor | Vertical jolt | +Gz |
| | 20. | 05/29 | 18:30 | 25 | M | 2 | Pain in right hip and back | Back, Right hip | Operator backed over large rock. While tractor was stuck on rock, it tipped forward and backward, twisting the operator's back. | Tractor | Jolted | ±Gx |
| | 21. | 06/04 | 18:25 | 23.5 | M | 3 | Pain in lower back, Hit head on truck ceiling | Lower back | Operator hit hole while driving over dump area. | Pro. Truck | Vertical jolt | +Gz |
| | 22. | 06/09 | 21:30 | 41.5 | M | 3 | Sore back | Back | While operator was backing up tractor, it dropped off a rock ledge. | Tractor | Jolted | +Gz |
| | 23. | 06/14 | 19:20 | 46 | M | 3 | Bruised right side | Right side | Truck's engine died, resulting in steering lock-up. Truck veered across the road and hit ditch. | Wabco Truck | Collision | -Gx |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1981 contd** | 24. | 08/02 | 10:00 | 35 | M | 9 | Sore back, neck, and shoulders | Neck, Shoulders | Operator was grading when he struck rock and felt snap in neck. | CAT Grader | Collision | -Gx |
| | 25. | 08/05 | 10:50 | 36 | M | 8 | Hit back of head on radio | Back of head | Operator was pushing a rock when it slipped. Machine twisted to the side, causing operator to hit the radio behind his head. Driver reportedly <u>using seat belt</u>. | Bull (#58) | Jolted | +Gx, ±Gy |
| | 26. | 08/08 | 13:00 | 28 | M | 4 | Sore neck | Neck | Truck was jerked back during loading. Driver's neck was snapped back. | Pro. Truck | Jolted back | +Gx |
| | 27. | 08/08 | 8:45 | 28.5 | M | 5 | Sprained neck | Right side neck | Backing up when machine was jarred. | Rubber Bull | Jolted | -Gy |
| | 28. | 08/17 | 10:30 | 29.5 | M | 9 | Sore back, Shoulders | Upper back & shoulders | Driver backed over a 2 foot ledge. It jarred the operator's back. | CAT O-9 | Jolted | +Gz |
| | 29. | 08/20 | 9:45 | 23 | M | 2.5 | Sore muscles | Back, Chest | While driver was having truck loaded, shovel bucket struck back of truck. | Pro. Truck | Jolted | +Gz |
| | 30. | 09/26 | 17:00 | 36 | M | 4 | Strained neck and shoulder muscles | Neck, Shoulder | While grading, operator struck unexposed rock causing him to fly forward. | CAT Road Grader | Collision | -Gx |
| | 31. | 10/14 | 2:00 | 27 | M | 6 | Sore back | Lower back | Driver released dump box on truck. Box came up very fast and jarred operator. | Pro. Truck | Jolted | -Gz |
| | 32. | 10/20 | 14:30 | 39.5 | M | 2 | Back | Lower back | During loading, a rock fell from shovel bucket into truck, jarring driver. Driver said that seat had no spring action. | Pro. Truck | Jolted | +Gz |
| | 33. | 11/06 | | 33.5 | m | 2 | Sore neck | Neck | While riding in foreman's vehicle, they hit a bump. | Unknown | Jolted | +Gz |
| | 34. | 11/11 | 6:10 | 28.5 | M | 3 | Sore back | Lower right back | While operator was moving a rock pile, he hit a chuck hole. | 204 Loader | Vertical | +Gz |
| | 35. | 12/29 | 10:15 | 32.5 | M | 2.5 | Pulled muscle in right side neck | Neck | Truck operator backed into a shovel bucket during loading. | Pro. Truck | Collision (Rear) | +Gx, +Gy |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1980** | 36. | 01/01 | 18:10 | 29.5 | M | 1.5 | None | | Brakes went out on truck. When driver pulled off road to stop it, truck flipped over. | Pro. Truck | Rollover | ±Gy |
| | 37. | 01/13 | 11:00 | 21 | M | | Sore neck | Neck | Driver hit hole he didn't see. | Pro. Truck | Vertical jolt | +Gz |
| | 38. | 01/22 | 21:00 | 59 | M | 10 | Muscle strain | Lower back | While plowing frozen dirt, "the ripper let loose from the ground & the CAT slid sideways." | Intl TD-25 | Jolt | ±Gy |
| | 39. | 01/24 | 7:30 | 34 | M | .33 | Laceration | Forehead, Head, Nose | While operator was driving tractor over frozen trails, blade struck ground. | Tractor | Collision | -Gx |
| | 40. | 01/17 | 17:00 | 22 | M | .66 | Sore left lower back | Left lower back | Operator backed over large chunk and was jarred. | CAT Tractor | Jolt | +Gz |
| | 41. | 01/22 | 17:00 | 42 | M | 2 | Sore neck | Right side neck | A truck backed into shovel and jarred shovel operator. | Shovel, Bucyrus Erie | Collision | +Gx |
| | 42. | 02/05 | 19:25 | 37 | M | 6.5 | Neck and shoulder pain | Neck, Upper Back | Operator had an accident 6 mo. prior to this report. The continuous fatigue of driving caused the pain to reoccur. | Pro. Truck | Normal Operation | Unk. |
| | 43. | 02/07 | 22:00 | 26 | M | 4 | Back pain | Lower back | Driver struck unobserved bump in road. | Pro. Truck | Vertical jolt | +Gz |
| | 44. | 02/10 | 3:00 | 33 | M | .25 | Sore back | Back | Driver struck bump in road. | Pro. Truck | Vertical jolt | +Gz |
| | 45. | 02/17 | 23:30 | 47 | M | 8 | Bruised left elbow & left calf | Left elbow, Left calf | Brakes and steering failed on machine. Machine climbed a berm before stopping. Operator probably hit cab interior and door frame. | Kress Hauler | Collision | -Gx |
| | 46. | 02/17 | 14:00 | 2.5 | F | 3.5 | Sprained neck | Neck | Female operator was jarred while being loaded. | Pro. Truck | Jolted | +Gz |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1980 contd** | 47. | 02/25 | 9:45 | 27.5 | M | 2 | Fractured ribs | Fractured ribs, #4 & #5 on left side | Operator's crane tipped over while trying to lift a load. The load exceeded the crane's capacity. | Locomotive Crane | Rollover | -Gy |
| | 48. | 03/13 | 00:30 | 22 | M | 1 | Sore back and neck | Back, Neck | During loading operation, rock fell out of shovel bucket and struck rear of truck. Operator was not using seat belt. | Pro. Truck | Jolted | +Gz |
| | 49. | 03/16 | 21:00 | 22 | M | 2.5 | Sore back | Back | After loading, operator drove away from shovel, jarring his back. He said that suspension was bad. | Pro. Truck | Jolted | +Gz |
| | 50. | 03/29 | 1:30 | 38 | M | .33 | Pulled muscle | Back | While driving away from shovel, driver hit a hole. The jolt twisted driver's back. | Pro. Truck | Jolted | +Gz |
| | 51. | 03/26 | 22:00 | 31 | M | 2 | Lower back | Back | Due to muddy conditions, driver did not see deep rut in road. He was lifted off the seat. Seatbelt did not function. | Pro. Truck | Vertical jolt | +Gz |
| | 52. | 04/01 | 13:30 | 30 | M | 4 | Stiffness around neck and back | Neck, Back | Shovel bucket hit truck during loading. "The shovel just lost power." | Pro. Truck | Jolted | +Gz |
| | 53. | 04/21 | 9:30 | 30 | M | 4 | Neck strain | Neck | While looking in rearview mirror, driver struck a hole. | Pro. Truck | Jolted | +Gz |
| | 54. | 04/21 | 6:03 | 28 | M | 1.5 | Sore neck | Neck | Driver fell asleep at wheel and veered off road. | Pro. Truck | Jolted | -Gx |
| | 55. | 04/17 | 17:00 | 24 | M | | Chipped tooth | Mouth | While driving off a dump, driver hit dip at bottom which jarred him. He was not using his seatbelt. | Pro. Truck | Jolted | +Gz |
| | 56. | 05/10 | 18:00 | 42 | M | 1.66 | Head struck top of cab and chest hit steering wheel | Head, Chest | Driver hit several rough places in road. | Pro. Truck | Jolted | +Gz, -Gx |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1980 contd** | 57. | 05/11 | 12:20 | 27 | M | .75 | Sore neck | Neck | While a passenger in panel truck #617, driver struck a parked grader. | Panel Truck | Collision | -Gx |
| | 58. | 05/31 | 14:30 | 32 | M | 2 | Sore muscle | Lower back | A shovel operator thought that truck had pulled far enough away to swing shovel around. Shovel bucket hit truck. | Pro. Truck | Collision | Unk. |
| | 59. | 06/12 | 19:45 | 32 | M | 1.5 | Sore back | Lower back | While making U-turn, driver hit a rock in his blind spot. | Terey Water Wagon | Collision | -Gx |
| | 60. | 06/30 | 21:30 | 26 | M | 5 | Back | Lower back | Driver was operating tractor on rock dump and his back began to hurt him. | Tractor | Jolted | Unk. |
| | 61. | 07/19 | 2:15 | 27 | M | 2 | Sore neck | Lower neck, Upper back | While temporarily blinded by a passing truck's lights, driver hit a hole, causing the driver to be jarred. | Pro. Truck | Jolted | +Gz |
| | 62. | 07/22 | 5:06 | 30 | M | 1.5 | Pulled back | Middle back | Operator hit a hole or chunk in road. | Rubber Bull | Jolted | +Gz |
| | 63. | 07/19 | 8:30 | 31 | M | 6.5 | Back | Back | Operator drove off dump and hit a hole. | Pro. Truck | Jolted | +Gz |
| | 64. | 08/05 | 10:00 | 31 | M | 3 | Lower back pain | Lower back | Operator hit a rock and jarred his back. | CAT Loader | Collision | -Gx |
| | 65. | 08/12 | 7:30 | 27 | M | 3 | Jarring action | Back | Operator drove over a rough section in road. | Scraper | Jolted | +Gz |
| | 66. | 08/22 | 10:30 | 47 | M | 2 | Sore neck | Neck | While looking backwards, driver hit a chunk in the road. | Michigan Loader | Collision | -Gx, ±Gy |
| | 67. | 08/13 | 13:30 | 23 | M | 3 | Sore neck and back | Neck, Back | Driver hit a rough area on haul road and hit head on truck ceiling. | Pro. Truck | Jolted | +Gz |
| | 68. | 09/10 | 8:30 | 26 | M | 1 | Muscle strain | Back | Rough road conditions and some of the truck seats slid around too much. | Pro. Truck | Jolted | Unk. |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1980 contd** | 69. | 10/06 | 23:00 | 36 | M | 4 | Bruised ribs | Lower left side of rib cage | Engine slipped into safety causing operator to fall forward and hit gauge light bracket. | Locomotive Cab | Jolted | -Gx |
| | 70. | 10/21 | AM | 27 | M | 3 | Severe neck and back injury | Neck, Back | Rear of truck was hit by shovel bucket during loading. | Pro. Truck | Collision | +Gx |
| | 71. | 10/31 | 00:05 | 26 | M | 2.5 | Sore shoulder | Right shoulder blade | Operator backed into shovel bucket. After impact, bucket opened and jarred driver. | Pro. Truck | Jolted | +Gz |
| | 72. | 11/15 | 10:30 | 22 | M | 1 | Sharp pain under shoulder blade | Back | Driver hit hole while unloading. | Pro. Truck | Jolted | +Gz |
| | 73. | 11/13 | 4:30 | | M | 2 | Soreness | Lower back | Operator was bouncing around while driving over rough surface. (The tires had steel cleats.) | Loader | Jolted | +Gz |
| | 74. | 11/29 | 8:30 | 23 | M | 3 | Strain | Lower back | While ripping a rock edge, CAT fell on another rock surface. | Ripper CAT | Vertical jolt | +Gz |
| | 75. | 11/10 | 10:15 | 23 | M | 4 | Strained muscle | Lower back | While ripping rock, operator drove over some ground. | Ripper CAT | Jolted | +Gz |
| | 76. | 12/01 | 23:40 | 38 | M | 6.5 | Bruises | Back and rear of right leg | While backing up over uneven ground, truck fell on its side. Driver's leg was pinned between heater and firewall. | Pro. Truck | Rollover | +Gy |
| | 77. | 12/07 | 13:00 | 40 | M | 2 | Sore neck and arm | Neck, Arms | Operator drove over some tailings on road and hit his head on ceiling. | Pro. Truck | Vertical jolt | +Gz |
| | 78. | 12/23 | 13:30 | 23 | M | 3 | Strain to back | Upper back area | Operator hit a rock while plowing snow. | Loader | Collision | -Gx |
| | 79. | 12/30 | 8:00 | 27 | M | 5 | Jarred neck | Lower neck | Operator drove over rough area. | Pro. Truck | Jolted | +Gz |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1979** | 80. | 01/01 | 1:25 | 36 | M | 2.5 | Soreness in back and neck, Headache | Back, Neck | Shovel bucket dropped to the truck. Driver was jarred. | Pro. Truck | Jolted | +Gz |
| | 81. | 01/21 | 18:50 | 48 | M | 7 | Slight concussion, Back and neck strain | Back and possible head injury | While moving a load, suspension on truck collapsed. Driver hit head on ceiling when truck bottomed out. | Pro. Truck | Jolted | -Gz |
| | 82. | 01/26 | 21:30 | 34 | M | 2 | Sore back and neck | Back, Neck | Shovel bucket dropped into truck during loading. | Pro. Truck | Jolted | +Gz |
| | 83. | 01/26 | 19:15 | | M | .58 | back | Lower Back | During loading, shovel bucket hit back of truck. | Pro. Truck | Jolted, Collision | +Gz, +Gx |
| | 84. | 02/06 | 7:55 | 26 | M | 4.5 | Sore neck | Neck | While a passenger in a transfer vehicle (truck), he struck his head on ceiling as they drove over railroad tracks. | Crew Cab | Jolted | +Gz |
| | 85. | 02/19 | 11:00 | 30 | M | .25 | Sore lower back | Lower back | Brakes malfunctioned on truck, resulting in driver running into ditch. | Pro. Truck | Collision | -Gx |
| | 86. | 02/21 | 2 2:21 | 27 | M | .83 | Possible fracture of upper arm and shoulder | Left arm, Shoulder | Another truck backed into operator's truck. The collision smashed into safety rail which hit operator's arm. | Pro. Truck | Collision | +Gy |
| | 87. | 02/23 | 8:30 | 28 | M | 3 | Cut on elbow | Right elbow | While driving over cable jumper, cab started bouncing around. Operator fell against window brace and cut his elbow. | Loader | Jolted | -Gy, +Gz |
| | 88. | 02/23 | 00:15 | 23.5 | M | .66 | Stiffness in upper back | Upper back | Driver was trying to climb out of shovel pit and slid into left lane on second attempt. Another truck came over the hill and hit first truck. | Pro. Truck | Collision | -Gx |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1979 contd** | 89. | 03/07 | 12:30 | 22 | M | .66 | Sore muscles in neck and lower back | Neck, Lower back | A tire blew out, causing operator to be bounced around inside the cab. Among other things, he hit his head on top of cab. | Pro. Truck | Jolted | Unk. |
| | 90. | 03/09 | 21:20 | 29 | M | .66 | Bruised left leg and buttocks | Left knee, Buttocks | During loading, a chunk dropped into truck causing truck to sway from side to side. | Pro. Truck | Jolted | +Gz, ±Gy |
| | **91. | 03/17 | Unk. | | M | Unk. | Sore back | Back | Unknown | Pro. Truck | Jolted | +Gz |
| | 92. | 03/29 | 10:45 | 26 | M | 4 | Possible turn groin muscles | Groin muscles | Driver hit a dip in road which threw wheel to the left. Operator was holding steering wheel when it snapped back. It twisted and pulled his right abdominal muscles. | Pro. Truck | Twisting action | ±Gy |
| | 93. | 04/01 | 9:30 | 23 | M | .58 | Back | Lower back | Operator drove over rough section of road. | Pro. Truck | Jolt | +Gz |
| | 94. | 04/02 | 14:00 | 29 | M | .5 | Jolt to spine | Spine | Left track of CAT dropped off a large rock and operator's seat did not absorb shock. | CAT | Vertical jolt | +Gz |
| | 95. | 04/13 | 17:00 | 28 | M | 3 | Whiplash | Right side shoulder blade, Back of neck | Driver hit deep hole that was covered with mud. | Pro. Truck | Jolted | +Gz |
| | 96. | 04/20 | 11:30 | 27.5 | M | .58 | Strained neck and back muscles | Neck, Back | CAT went over edge of road fill. | CAT | Jolted | +Gz |
| | 97. | 04/22 | 23:00 | 33.5 | M | 10.5 | Lower back, Spine sore | Lower back, Spine | While being driven to his truck, the operator was bounced around in the transfer vehicle. | Panel Truck | Jolted | +Gz |
| | 98. | 05/11 | 7:1 | 40 | M | 6 | Bruises | Bruised lower back, Left side, Right hip | Truck backed into his truck. Collision resulted in operator being pinned to his seat. | Pro. Truck | Collision | Unk. |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1979 contd** | 99. | 05/07 | 3:40 | 25 | M | 3 | Bruised left knee | Left knee | Previous truck had not accelerated enough to climb ramp after leaving shovel. When it stopped and started backing down ramp, it hit injured operator's vehicle. | Pro. Truck | Collision | -Gx |
| | 100. | 05/15 | 5:20 | 24 | M | 2 | Back, Neck was hurting | Upper and middle back | After operator dumped his load, he started to pull forward. Front of truck started to come off the ground, then it came down hard. | Pro. Truck | Jolt | +Gz |
| | 101. | 06/01 | 15:30 | 26 | M | 9/52 | Neck | Neck | Operator swerved to miss hole and hit rock. Collision with rock knocked CAT into reverse and threw operator into window. | CAT | Collision | -Gx |
| | 102. | 06/17 | 2:40 | | M | 2.5 | Back | Lower back | While operating his CAT, driver ran over large rock which jarred him. | CAT | Jolted | +Gz |
| | 103. | 07/02 | 8:30 | 30 | M | 1.5 | Muscle sprain | Lower back | Operator ran over rock which bounced him around in his seat. He <u>was using his seatbelt</u>. | Loader | Jolted | +Gz |
| | 104. | 07/14 | 7:00 | 20 | M | .43 | Lower back hurting | Lower back | Operator was standing in grader, when it hit a partially buried rock. Collision threw operator forward. | Rental Grader | Collision | -Gx |
| | 105. | 07/15 | 10:45 | 29 | M | 10 | Sore neck | Neck, Back | While a pro. truck was unloading, a large rock rolled off and hit back of operator's CAT. He was tossed around in cab. | CAT | Collision | +Gx |
| | 106. | 08/12 | 17:00 | 22 | M | 2 | Bruise | Left knee | While ripping surface, CAT became hung up on rock. Suddenly the CAT freed itself. The sudden jerk forward caused operator to bang his knee into fire extinguisher. Operator <u>not using seatbelt</u>. | Ripper CAT | Collision | +Gx |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1979 contd** | 107. | 08/21 | AM | 25.5 | M | 1 | Sore lower back | Lower back | Operator riding in a seat that was not properly adjusted. | Pro. Truck | Jolted | Unk. |
| | 108. | 08/29 | 16:10 | 35 | M | .75 | Sore upper chest | Upper chest | While grading, operator struck rock. Collision threw him against steering wheel. | Grader | Collision | -Gx |
| | 109. | 08/31 | 2:00 | 23 | M | 1 | Sprain to neck | Neck | During loading, large rock fell and jarred truck. | Pro. Truck | Vertical jolt | +Gz |
| | 110. | 09/09 | 00:30 | 30 | M | .83 | Back | Back | While driving, operator hit a soft spot and truck bottomed out. | Pro. Truck | Vertical jolt | +Gz |
| | 111. | 09/18 | 11:45 | 29 | M | .5 | Pulled muscle | Upper back | Operator was back blading dump and hit a rock which jarred his back. | Tractor | Jolted | +Gx |
| | 112. | 09/15 | 17:00 | 31.5 | M | 1 | Back | Back | Driver said that bouncing around in truck during normal operation hit his back. | Pro. Truck | Jolted | ±Gz |
| | 113. | 09/24 | 19:50 | 29 | M | 6.5 | Struck head on truck ceiling | Neck | Driver hit a hole that caused him to hit ceiling of truck. | Pro. Truck | Vertical jolt | +Gz |
| | 114. | 09/28 | 12:50 | 26 | M | 6 | Back pain | Upper, middle, lower back | While backing over a pile of rocks, belt slipped off and came down hard. | CAT | Vertical jolt | +Gz |
| | 115. | 10/05 | 15:00 | 26 | M | 5 | Pulled muscle | Lower back | During a derailment clean-up operation, operator drove #50 over a large rock. | Unknown | Vertical jolt | +Gz |
| | 116. | 10/09 | 19:00 | 19.5 | F | .25 | Strained muscle | Neck, Lower back | Female driver hit dip in road and was thrown around in cab. | Pro. Truck | Vertical jolt. | +Gz |
| | 117. | 10/18 | 11:30 | 23 | M | 1.5 | Sore neck, Numbness in arms and legs | Neck | Driver hit a hole during normal operation. | Pro. Truck | Vertical jolt | +Gz |
| | 118. | 10/19 | 10:30 | 23 | M | 1.5 | Jarred back | Middle back | Driver hit a bump. | Pro. Truck | Vertical jolt | +Gz |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1979 contd** | 119. | 10/27 | 00:00 | 28.5 | M | .5 | Sore neck & shoulder | Neck, Left shoulder | Operator was cleaning up around a shovel with rubber bull. He struck a solid spot which jolted the operator. | Rubber Bull | Collision | -Gx |
| | 120. | 11/04 | 3:00 | 20 | M | 1 | Sprained back | Lower left shoulder blade | Shovel bucket not properly centered when it dropped its load. | Pro. Truck | Vertical jolt | +Gz |
| | 121. | 11/09 | 10:00 | 21.5 | M | 1 | Sore back | Back | During loading, shovel's bucket door hit truck. | Pro. Truck | Vertical jolt | +Gz |
| | 122. | 11/25 | 3:30 | 21 | M | 2.5 | Sprain to middle back | Middle back | While descending a grade, engine failed. Brakes failed to set, but dynamic and service brakes were operational. Truck crossed railroad tracks before stopping. Tracks jarred driver. | Pro. Truck | Vertical jolt | +Gz |
| | 123. | 11/04 | 15:00 | 45.5 | M | 10 | Possible lower back sprain | Lower back, Possible tailbone | Operator was cleaning up around shovel with rubber bull. Driver said that conditions were rough. | Rubber Bull | Jolted | +Gz |
| | 124. | 11/30 | 16:00 | 23 | M | .5 | Bruised left elbow, Stiff neck | Left elbow, Neck | Engine died on a curve. While trying to control truck, driver was bounced around. | Pro. Truck | Jolted | +Gz |
| | 125. | 12/04 | 17:30 | 29.5 | M | 1 | Sprain to neck and back | Neck, Back | Rock dropped into truck box during loading. | Pro. Truck | Jolted | +Gz |
| | 126. | 12/04 | 19:00 | 24.5 | M | 4 | Sore back | Lower back | Truck hit by bucket during loading. | Pro. Truck. | Jolted | +Gz |
| | 127. | 12/06 | 11:30 | 21.5 | M | .66 | Sore tailbone | Tailbone | Operator backed over a rock and came down hard. He hit a steel bar at bottom of back rest. | Tractor | Jolted | +Gz |
| | 128. | 12/10 | 18:30 | 23.5 | M | 1 | Lower back pain | Lower back | Driver hit two rough spots. He was driving too fast. | Pro. Truck | Jolted | +Gz |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1978** | 129. | 01/12 | 13:45 | 20 | M | .08 | Bruises | Left leg | Driver turned off road into shovel when steering locked. Driver failed to set brakes and hit rock. | Pro. Truck | Collision | -Gx |
| | 130. | 02/20 | 15:30 | 51 | M | 2 | Sore | Left side | As driver sat in truck seat, seat bottomed out. | Pro. Truck | Jolt | +Gz |
| | 131. | 02/27 | 15:30 | 23 | M | 1.5 | Sprain | Left leg | As driver stepped down from cab, left leg was sprained by driver's weight. Old injury, motorcycle accident. | 302 Hi Rail | Slipped Footing | +Gz |
| | 132. | 03/16 | 17:30 | 22 | M | 1 | Strain | Neck | Operator bouncing in seat while cleaning up. | Tractor | Jolt | +Gz |
| | 133. | 03/22 | 07:10 | | M | 1.17 | Back, Fracture | Back, Left leg | Driver applied brakes as rear of truck (#450) slid to left. He corrected to the right and failed to correct back to the left. Truck continued through berm and over a 20-25 ft. bank. Truck remained upright and moved ahead another 100-150 ft. Foreman shut the idled truck down. | 100 Ton Elec. Haul | Vertical drop | +Gz |
| | 134. | 03/31 | 3:00 | 27 | M | 2 | Strain | Neck | As driver made third pass to load, a rock rolled and hit side of box of truck #487. | Wabco Truck | Jolt | ±Gy |
| | 135. | 04/17 | 16:15 | 25 | M | 1.66 | Strain | Back | As driver dumped load, a large rock shifted and hit side of box. | Pro. Truck Elec. Haul | Jolt | ±Gy |
| | 136. | 04/01 | 21:45 | 24 | M | 2 | Sore | Upper back, Neck | Shovel driver hit injured's truck with shovel bucket. | Pro. Truck Shovel | Collision | Unk. |
| | 137. | 07/16 | 21:00 | 26 | M | 2 | Muscle spasms | Back | Injured was driving truck when he experienced back pain. Was worse at end of shift. | Pro. Truck | Jolt | Unk. |
| | 138. | 07/17 | 11:00 | 30.5 | M | 4 | Pulled cartilage on right side of body | Ribs | Operator was backing #334 over chunks and came down hard, jarring himself. | CAT | Jolt | +Gz |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1978 contd** | 139. | 09/15 | 12:30 | 29.5 | M | 3 | Possible back strain | Upper middle back | Operator was returning from dump in #494 truck. Half-way down hill he drove over ditch in road. | Pro. Truck | Jolt | +Gz |
| | 140. | 10/19 | 15:00 | 29 | M | 5 | Sore shoulder and neck | Left shoulder, Left side neck | Vehicle dipped into low spot in road causing driver to bounce and hit head on roof of cab. | Pro. Truck | Jolt | +Gz |
| | 141. | 11/17 | 17:00 | 25 | M | .08 | Contusion, left leg, slight bruise | Left leg | While operating #141 loader with full bucket of concrete, operator slowly raised bucket and applied brakes tipping loader forward onto bucket. Work area flat and level. | CAT Loader | Collision | -Gx |
| | 142. | 12/16 | 11:00 | 28.5 | M | .25 | Sore back ("Tailbone") | Sacrum, ("Tailbone") | Operator hit hole in road and seat hit bottom. Truck #428. | Pro. Truck | Jolt | +Gz |
| | 143. | 01/09 | 18:15 | 25 | M | 2 | Neck "Whiplash" | Neck | Operator was using bucket "to bust frost chunk." By putting pressure on chunk, chunk broke causing shovel to jar. | Shovel | Jolt | +Gz |
| | 144. | 12/16 | 14:30 | 32.5 | M | 2 | Pulled muscle in neck and shoulder | Neck, Left shoulder | Grader operator struck frozen mound on road causing grader to come to sudden stop. | CAT 78 Grader | Collision | -Gx |
| **1977** | 145. | 01/26 | 12:45 | 27 | M | 1 | Slight back pain | Back | During loading, shovel operator hit back of truck, injuring truck operator. | Truck | Jolted | +Gz |
| | 146. | 02/05 | 16:20 | 37 | M | 5 | Pain and stiffness in back & knees | Back, Knees | In backing truck over a grade, operator backed vehicle into shovel. | Truck | Collision | +Gx |
| | 147. | 03/10 | 13:45 | 48 | M | 23 | Bruise | Right side | Vehicle slid down rocky slope, throwing operator through window. | Caterpillar | Collision | -Gy |
| | 148. | 03/17 | 9:45 | 26 | M | 4 | Pain/ Stiffness | Back | Vehicle hit a dip in the road, jarring operator. | Shovel | Jolted | +Gz |
| | 149. | 03/22 | 10:45 | 26 | M | 4 | Bruise | Left ear | Vehicle slid on a snowy road, throwing operator into roll bars. | Tractor | Collision | -Gy |

TABLE 1--(Continued)

| Year | Case | Date | Time of Day | Age | Sex | Occ Exp (Years) | Injury | Body Region | Description | Vehicle | Impact | Force* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1977 contd** | 150. | 04/05 | | 23 | F | .58 | Soreness | Back | Driver was bounced around while operating truck. | Truck | Jolted | +Gz |
| | 151. | 04/21 | 13:30 | 64 | M | 31 | Whiplash | Neck | Nose of plow caught, tipping vehicle and causing it to jump truck. | Plow | Collision Rolling | -Gx |
| | 152. | 04/29 | 14:00 | 26 | M | .83 | Sprain | Back | Vehicle hit hole in road, throwing operator up. | Truck | Jolted | +Gz |
| | 153. | 05/06 | 10:00 | 22 | M | 3 | Pain | Left shoulder/ Back | Vehicle was hit from behind, jarring operator. | Truck | Collision | +Gx |
| | 154. | 05/04 | 14:30 | 25 | F | 1 | Old injury/ Sprain | Neck | Driving on alternate route (normal under construction), hit hole in road. | Truck | Jolted | +Gz |
| | 155. | 05/11 | | 61 | M | 10 | Bruised | Left Elbow | Driver hit elbow on corner of operating seat while shifting. | Truck | Collision | +Gz, -Gy |
| | 156. | 05/16 | 9:30 | 26 | M | 4 | Soreness | Back | Rock fell, striking canopy. | Truck | Jolt | +Gz |
| | 157. | 05/14 | 10:00 | 43 | M | 3 | (None given) | Lower back | Vehicle struck by rock, jarring operator. | Truck | Jolt | +Gz |
| | 158. | 07/13 | 10:00 | 24 | M | 3 | Sprain | Neck | Vehicle hit hole in road. | Truck | Jolted | +Gz |
| | 159. | 07/13 | 13:00 | 25 | M | 1.5 | Strain | Neck | Vehicle hit bump in road. | Truck | Jolted | +Gz |
| | 160. | 07/27 | 15:30 | 26 | M | 1 | Soreness | Neck | Box of truck went back to hood, jarring operator. | Truck | Jolted | +Gz |
| | 161. | 12/27 | 16:30 | 23 | M | 1.5 | Pain | Back | Driver was operating truck normally and noticed back pain. | Truck | None | +Gz |

*Estimated directions of force on body in x, y, z axis.

**Accident report not forwarded to HSRI. Case listed in U.S. Steel Summary.

Ages of the injured drivers ranged from 19.5 to 64 years, with a mean age of 29.8 years. This excluded four drivers for which age information was not given, but included four female drivers. For male drivers, 153 for which age data are given, the range was 20 to 64 years, with an average injured driver age of 30 years. No comparison of age of injured drivers compared to total driver heavy equipment population was made, since this information was also unknown. The frequency distribution of injured drivers ages showed the majority (61.5%) to be between 19 and 29 years, with 24.2% between 30-39 years of age (Table II).

TABLE II

FREQUENCY DISTRIBUTION BY AGE
OF INJURED DRIVERS

| Age in Years | Male | | Female | | Total | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| 50-64 | 4 | 2.5 | | | | |
| 40-49 | 15 | 9.3 | | | | |
| 30-39 | 39 | 24.2 | | | | |
| 19-29 | 95 | 59.0 | 4 | 2.5 | 99 | 61.5 |
| UNKNOWN | 4 | 2.5 | | | | |

Experience of the injured drivers ranged from one month to 23 years.

Review of these accident reports shows that injuries for the most part involve the spinal column (neck and back). While some injuries may be disabling and progressive to various degrees, acute life-threatening trauma was infrequently reported. No fatalities were reported during this period for heavy equipment drivers, and only two individuals reported fractures, one having a fractured back (nature and site not specified), and one driver fractured ribs four and five on the left side subsequent to rollover of a locomotive crane. In a third case "possible" fracture of the upper arm and shoulder was noted. By body region, the back was most frequently injured, with 95 injuries attributed to the back. A "sore" back was most frequently noted (39 cases), with "pain," "strain," or "sprain" backs listed in 34 cases, and in 15 cases the back was described as "jarred," "hurt," "stiff," "pulled," "bruised," "muscle spasms," or "severe back injury." In addition, in two cases a "sore tailbone" (sacrum) was noted, and in one case a fracture (undefined) was described.

The neck was injured in these accidents frequently, with some 59 injuries to the neck reported. Most commonly, the injury was described as a "sore neck" (29 cases) or a "sprained" or "strained" neck (16 cases). Various other descriptions included "stiff" neck (3 cases), or a "jarred" (2 cases), "bruised" (1 case), "pain" (1 case), "hurt" (1 case), "whiplash" (3 cases), or "severe neck injury" (1 case).

In 14 cases the shoulders were "sore," "bruised," "strained," "pain," or "sharp pain under shoulder blade." The head was involved in at least 11 cases. In five accidents the driver impacted the roof of the cab, and received a concussion in one case and a headache in another. In one case the driver hit the back of his head on the radio, in other cases a chipped tooth and lacerations to the forehead, nose, or ear were reported.

An inventory of injuries received by drivers as reported on the accident forms cited is provided in Table III. Since the medical summary for each case was not available for analysis, these data must be considered as approximate.

TABLE III
NATURE AND SITE OF INJURIES REPORTED TO DRIVERS

| Body Region | Description |
|---|---|
| Head (11 injuries) | hit head on ceiling (5) with slight concussion (1) and headache (1), chipped tooth (1), lacerated forehead, head, nose (1), bruised l. ear (1), hit back of head (1). |
| Neck (59 injuries) | neck sore (20), strained or sprained (16), whiplash (3), pulled muscle (2), stiff (3), jarred (2), pain, hurt, bruised, severe neck injury (1 each) |
| Shoulders (14 injuries) | sore (5), pain (3), strained (2), bruised, jarred, sharp pain under shoulder blade, possible fracture upper arm and shoulder (1 each) |
| Chest (10 injuries) | bruised right or left side (3), bruised, sore, pulled cartilage, pain in left side and hip. chest hit steering wheel, bruised ribs, bruised side (1 each) |
| Back (95 injuries) | sore (39), strain, sprain or pain (34), pulled muscle (6), bruised (4), stiff (2), jarred, hurt, muscle spasm, severe (1 each), pain in hip and back (2), bruised buttocks (1), sore tailbone (sacrum) (2), fractured back (1) |
| Extremities (18 injuries) | bruised l.leg (4), knees (3), sprain l.leg (1), lacerated elbow (1), bruised l.elbow (3), bruised l.calf (1), bruised r.hip (1), sore arm (1), bruised r.leg (1), fingers (1), possible torn groin muscles (1). |

Review of the accident reports indicates that the most prevalent type of injury occurred from vertical impacts of vehicles hitting holes in the road (30 cases or 18.6%), followed closely by vehicles hitting solid objects (rocks, other vehicles) (28 cases, 17.4%). Rough ground (21 cases), running off a rock or ledge (17 cases), hit by or into shovel bucket while loading (15 cases), and the vehicle being hit by a falling rock while loading (12 cases) were also frequently attributed as causes of the driver injuries. These conditions accounted for 76.4 percent of the injuries described. A further breakdown is provided in Table IV.

TABLE IV.
CAUSE OF INJURY

- Hit hole, bump, dip, ditch (30 cases)
- Collision with solild object, rock, chunk, grader, another truck (28 cases)
- Rough ground, RR tracks (21 cases)
- Ran over/off rock, ledge, chunk, embankment (17 cases)
- Loading, truck hit by or backed into shovel bucket (15 cases)
- Loading, rock or chunk fell off bucket jarring truck or CAT (12 cases)
- Slid down grade (5 cases)
- Rollover (3 cases)
- Seat bottomed out (5 cases)
- Suspension bad or collapsed (2 cases)
- Box snapped down or up while loading/ unloading (5 cases)
- Misc.: tier blew out, seat not adjusted, vered off road, continuous fatigue, descending from cab, engine slipped into safety, bounced in seat, hit elbow while shifting, loader tipped forward onto bucket (18 cases)
- Unknown (3 cases)

Impact on the driver took the form of collision or direct impact, rollover, or in the majority of accidents was reported as a vertical jolt. Each case was examined to attempt to determine the direction of the force on the driver. In some cases the driver was subjected to force from more than one direction, and in a few cases (9) information provided was not sufficient to make a judgment.

The direction of force was based upon acceleration vectors as related to the seated driver, with orientation described in relation to force in x, y, z coordinates as illustrated in Figure 1.

Determination of the nature and direction of force on the occupant is important in order to understand what occupant protection is necessary in the heavy vehicle accident environment. Over half the accidents reported (99 cases or 55.6%) involved vertical loadings (+Gz) on the driver, resulting from bumps, jolts, and vertical impacts. Some 15.7 percent (28 cases) involved a collision or front impact with the vehicle and some object in -Gx deceleration. Lateral forces (±Gy) were reported in 13.5 percent (24 cases) and are not as easily protected against by a lap belt system alone. This shows the most prevalent directions of loading on the driver, and in particular that the use of belt restraints could be effective in preventing these type of injuries in most accidents that occur.

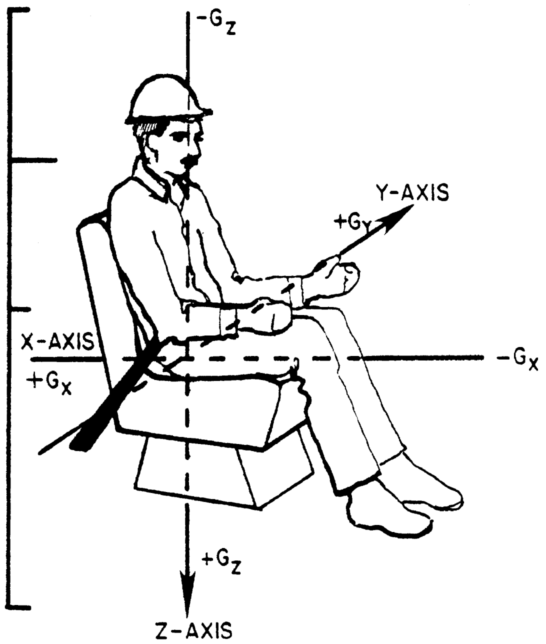


Fig. 1. Illustration of uni-axial acceleration vectors used to describe direction of force on the seated operator.

In only eight out of 161 accidents reported (5%) is it indicated whether a seat belt was installed in the vehicle and whether it was being worn. In four cases it was reported that the belt was not used. In four other cases it was reported (by the driver?) to be used; and in one of these cases it was noted that it had failed but no further information is provided. This seems to be a major shortcoming of the accident data reported, since it would be expected that usage and effectiveness data on seat belt use would be an valuable information to obtain in every case.

There are several limitations to the Minnesota Ore Operations accident data which should be noted. The form (Appendix B) upon which the accident information is recorded is fairly concise (2 pages) and description of either the accident environment or the specific injuries is very brief and provides no details. Certain information which would be of particular value in this study is not given at all. For example, the height and weight of the driver is not provided, which would be useful in judging the influence of the individual's body size and relative body form upon the particular injury. Some individuals may be outside the design specifications, and perhaps, as in the heavy trucking industry, attention should be given to updating cab driver accommodations to better protect and improve operation and safety in view of increasing body sizes through the past few decades (Sanders, 1977, Miller and Anderson 1978; Snyder, 1981).

One omission in the accident reports which would have been particularly important in this study was to specifically note whether a seat belt was available and, if available and not used, what reason(s) the driver gave for non use. Among other limitations of the form (and thus the nature of the responses) for purposes of this analysis was that the time and date that the accident report was made is often not given; in some cases this information could provide an indication of when injury symptoms were delayed, particularly in cases of neck and back injuries. Often the vehicle involved was not specified, other than "truck" or "tractor." Identification of the particular make and model involved, such as "Euclid 302HD" would have been useful to relate the specific environmental conditions (seat, etc.) to evaluation of whether certain types of injuries may be associated with certain vehicle cab environments.

The major limitation of the accident reports were that the attached medical summary for each accident were not available to us for review. This left only the gross description provided in the accident report, which usually was not as specific as desired. Probably many severe jolts and bruises go unreported. It is recommended that possible arrangements be made to statistically review (without name identification) the medical portion of the individual files without removing them from the safety office or violating privacy rights. This could be accomplished concurrent with the second phase of this study to ensure that the injury mechanisms listed are accurate.

2. <u>Nationwide Data</u>

To obtain broader information on the nationwide incidence and nature of vehicular injuries the National Institute for Occupational Safety and Health (NIOSH) was requested to provide statistical information from the worker's compensation data files relative to vehicle accidents in the iron ore industry. These data were generously provided by Roger C. Jensen, Chief, Accident and Epidemiology Branch.

The Bureau of Labor Statistics of the U.S. Department of Labor, which has been delegated responsibility for collecting data to assist the Occupational Safety and Health Administration (OSHA) in standards and compliance areas, has developed a program to supplement the Bureau's Annual Survey of Occupational Injuries and Illnesses. This is called the Supplementary Data System (SDS). The basis source document for the SDS is the first report of injury or illness submitted by employees and insurance carriers to state workers compensation agencies. This system has been described in detail by Root and McCaffrey (1978), and forms the basis for the following computer analysis.

The resultant output received was based upon several specifications. Only the iron ores industry (SIC 1011) was selected, as described in the Standard Industrial Classification Manual for 1972 (page 32). The iron ores mining group is classified as "Establishments primarily engaged in mining, beneficiating, or otherwise preparing iron ores and manganiferous ores valued chiefly for their iron content. This industry includes production of sinter and other agglomerates except those associated with blast furnace operations..." The establishments include brown ore mining; hematite mining; iron agglomerate and pellet production; iron ore, blocked; iron ore dressing (beneficiation) plants; iron ore mining; limonite mining; magnetite mining; manganiferous ore mining, values chiefly for iron content; siderite mining; sintering of iron ore at the mine, and taconite mining (Appendix C).

Data from 31 states for 1979 (Fig. 2) for five occupations were searched. These included truck driver, motormen mine, fork lift operator, and road machine operator. There were 120 cases (52%) of worker compensation claims for the category of truck driver in the iron ore mining industry for 1979, and 230 total cases for all five classifications. These statistics are shown in Table V.

Of the 31 states only seven states had claims, with 135 (58.7%) originating from Minnesota, and 55 (23.9%) from Michigan. These data, are shown in Table VI, providing the number of claims in 1979 (for each of these occupations shown in Table V.).

The NIOSH search tabulated only those cases in the iron ore industry that involved a worker in one of the five occupations listed in Table I. A frequency distribution of the type of compensation claim by occupation is given in Table VII. For truck drivers this shows that many cases of injury were not classified (27). The greatest frequency of injury was listed as striking a stationary object (13), struck by vehicle (11), involuntary motions (11) and hot objects (11). This information is not detailed enough for further comment.

The source of injury is a coding category which indicates the object, substance, exposure, or bodily motion which directly produced or inflicted the injury. Table VIII is a cross-listing of source by occupation. The frequency distribution suggests that "bodily motion," "ground," and "highway vehicle" are the three major factors.

Significantly, for truck drivers (48.3%), road machine operators (46%), mine motormen (50%) and fork lift (100%) operators the most prevalent injury reported was "sprain or strain." It was the only type of injury reported for fork lift operators. For mine operators "contusion" was the most frequent type of injury, comprising 67 percent of reported injuries. Contusions were the second most frequent injury to truck drivers as well.

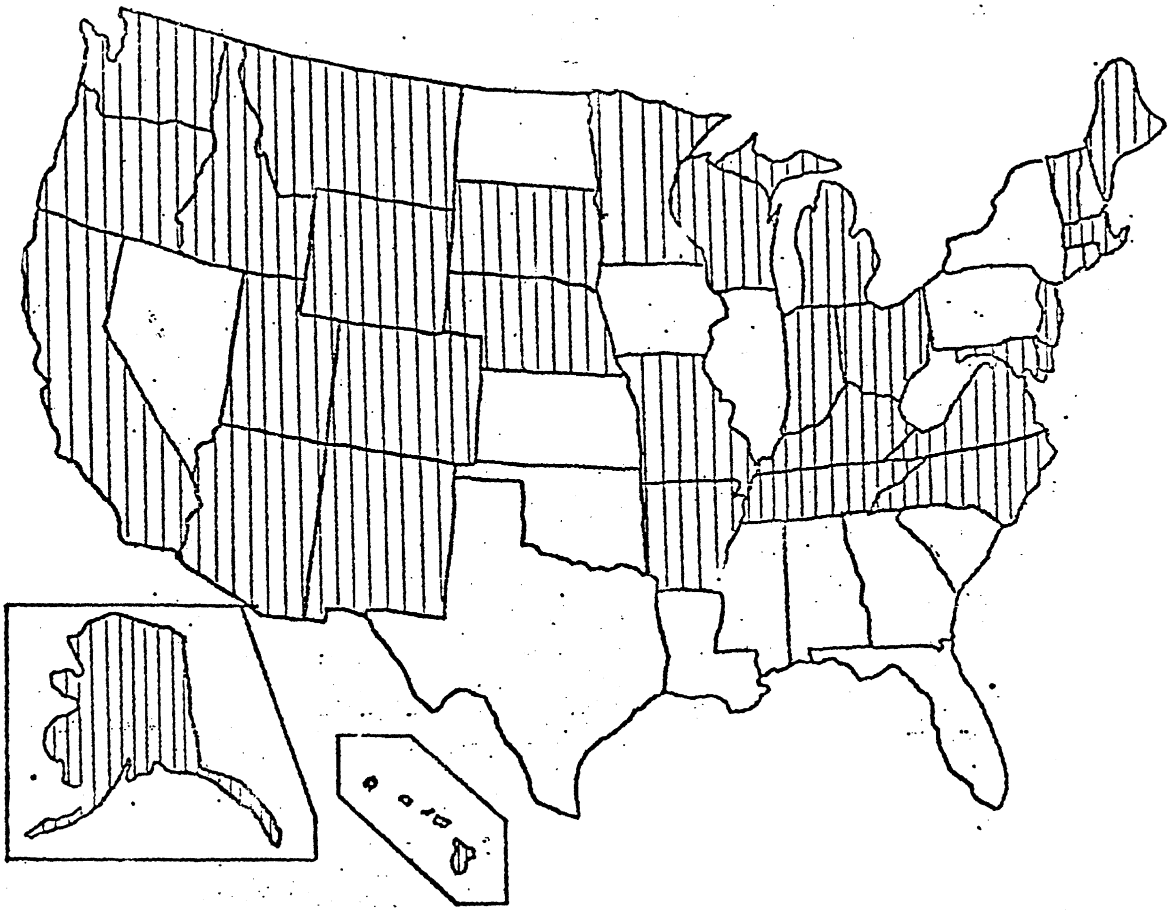

Fig. 2. States (vertical lines) that provided the data used in the 1979 SDS analysis.

TABLE V.
FREQUENCY DISTRIBUTIONS FOR 1979 SDS DATA
INDUSTRY=IRON ORES (1011) BY OCCUPATION
WEIGHTED VALUES

| OCCUPATION | FREQ. | CUM. FREQ. | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| Road Mach Oper 436* | 13 | 13 | 5.652 | 5.652 |
| Mine Oper 640 | 82 | 95 | 35.652 | 41.304 |
| Fork Lift Oper 706 | 11 | 106 | 4.783 | 46.087 |
| Motormen Mine 710 | 4 | 110 | 1.739 | 47.826 |
| Truck Driver 715 | 120 | 230 | 52.174 | 100.000 |

*Numbers refer to occupational codes listed in SDS book.

TABLE VI.
FREQUENCY DISTRIBUTIONS FOR 1979 SDS DATA
INDUSTRY=IRON ORES (1011) BY STATE
WEIGHTED VALUES

| STATE | FREQ. | CUM. FREQ. | PERCENT | CUM. PERCENT |
|---|---|---|---|---|
| Colorado | 1 | 1 | 0.435 | 0.435 |
| Michigan | 55 | 56 | 23.913 | 24.348 |
| Minnesota | 135 | 191 | 58.696 | 83.043 |
| Missouri | 28 | 219 | 12.174 | 95.217 |
| Utah | 7 | 226 | 3.043 | 98.261 |
| Virginia | 2 | 228 | 0.870 | 99.130 |
| Wisconsin | 2 | 230 | 0.870 | 100.000 |

Next, source of occupation was listed for those workmen compensation claims in which the type of injury is coded against the "struck against" category. Table X shows that all injuries listed for truck drivers were due to striking against a highway vehicle (as were the majority of injuries to mine operators).

TABLE VII.
FREQUENCY DISTRIBUTIONS FOR 1979 SDS DATA
INDUSTRY=IRON ORES (1011) BY OCCUPATION
WEIGHTED VALUES

| TYPE FREQUENCY | ROAD MACH OPER | MINE OPER | FORK LIFT OPER | MOTORMEN OPER | TRUCK DRIVER | TOTAL |
|---|---|---|---|---|---|---|
| Stationary Obj | 0 | 23 | 0 | 0 | 13 | 36 |
| Falling Obj | 0 | 7 | 0 | 1 | 1 | 9 |
| Flying Obj | 0 | 2 | 0 | 0 | 0 | 2 |
| Struck by N* | 0 | 11 | 0 | 0 | 0 | 11 |
| Ladders | 1 | 0 | 0 | 0 | 1 | 2 |
| Vehicles | 1 | 4 | 0 | 0 | 11 | 16 |
| Working Surface | 2 | 3 | 0 | 0 | 0 | 5 |
| Against Obj | 0 | 2 | 0 | 0 | 0 | 2 |
| Same Level N | 0 | 1 | 0 | 0 | 9 | 10 |
| Move & Stat Obj | 0 | 1 | 0 | 0 | 0 | 1 |
| Caught in N | 1 | 4 | 0 | 0 | 0 | 5 |
| Frgn Mat Eyes | 0 | 6 | 0 | 0 | 0 | 6 |
| Invol Motions | 1 | 2 | 0 | 0 | 11 | 14 |
| Vol Motions | 0 | 0 | 0 | 0 | 10 | 10 |
| Lifting Obj | 0 | 8 | 1 | 2 | 10 | 21 |
| Pulling Obj | 0 | 2 | 1 | 0 | 2 | 5 |
| Throw Obj | 0 | 3 | 0 | 0 | 1 | 4 |
| Overexert N | 0 | 0 | 0 | 1 | 1 | 2 |
| Hot Obj | 4 | 0 | 0 | 0 | 11 | 15 |
| By Inhalation | 0 | 1 | 0 | 0 | 0 | 1 |
| By Absorption | 0 | 1 | 0 | 0 | 0 | 1 |
| Oth N | 2 | 0 | 0 | 0 | 0 | 2 |
| Standing Veh | 0 | 0 | 0 | 0 | 1 | 1 |
| Run Into/Off Rd | 0 | 0 | 0 | 0 | 1 | 1 |
| Stop/Start | 0 | 0 | 9 | 0 | 1 | 10 |
| Oth | 0 | 1 | 0 | 0 | 1 | 2 |
| Acc Type N | 1 | 0 | 0 | 0 | 9 | 10 |
| Nonclass | 0 | 0 | 0 | 0 | 27 | 27 |
| Total | 13 | 82 | 11 | 4 | 120 | 230 |

*Not elsewhere classified.

Finally, the data were tabulated by a means of a cross-listing of source by occupation for those claims in which the type of injury is coded in the "struck by" category (Table XI). This was not very

TABLE VIII.
FREQUENCY DISTRIBUTIONS FOR 1979 SDS DATA
INDUSTRY=IRON ORES (1011) BY OCCUPATION
WEIGHTED VALUES

| SOURCE FREQUENCY | ROAD MACH OPER | MINE OPER | FORK LIFT OPER | MOTORMEN MINE | TRUCK DRIVER | TOTAL |
|---|---|---|---|---|---|---|
| Bodily Motion | 1 | 2 | 0 | 0 | 21 | 24 |
| Barrel | 0 | 2 | 0 | 0 | 9 | 11 |
| Bundle | 0 | 1 | 0 | 0 | 0 | 1 |
| Container N | 0 | 0 | 1 | 1 | 0 | 2 |
| Acid | 0 | 1 | 0 | 0 | 0 | 1 |
| Chemical N | 0 | 0 | 0 | 0 | 9 | 9 |
| Coal/Oil N | 0 | 1 | 0 | 0 | 0 | 1 |
| Powered Convey | 0 | 1 | 0 | 0 | 0 | 1 |
| Flame/Fire/Smok | 0 | 0 | 0 | 0 | 2 | 2 |
| Crowbar | 0 | 3 | 0 | 0 | 0 | 3 |
| Knife | 0 | 1 | 0 | 0 | 0 | 1 |
| Pick | 0 | 1 | 0 | 0 | 0 | 1 |
| Shovel | 0 | 1 | 0 | 0 | 0 | 1 |
| Chain Hoist | 0 | 1 | 0 | 0 | 0 | 1 |
| Const Mch N | 4 | 1 | 0 | 0 | 0 | 5 |
| Mining Mach N | 0 | 2 | 0 | 0 | 0 | 2 |
| Mach N | 0 | 2 | 0 | 1 | 0 | 3 |
| Chain/Rope | 0 | 1 | 1 | 0 | 4 | 6 |
| Beam/Bar | 0 | 5 | 0 | 1 | 0 | 6 |
| Nail/Spike | 0 | 1 | 0 | 0 | 0 | 1 |
| Metal Item N | 2 | 24 | 0 | 1 | 0 | 27 |
| Mineral (ore) | 0 | 1 | 0 | 0 | 0 | 1 |
| Sprain Strain | 6 | 19 | 11 | 2 | 58 | 96 |
| Mult Injuries | 0 | 0 | 0 | 0 | 9 | 9 |
| Mental Disorder | 0 | 0 | 0 | 0 | 9 | 9 |
| Oth Injury N | 0 | 2 | 0 | 0 | 18 | 20 |
| Total | 13 | 82 | 11 | 4 | 120 | 230 |

productive and the N of 22 was very small. It indicated that mine operators were chiefly struck by metal items.

In general, the SDS data from workers compensation files relative to vehicle accidents in the iron ore industry did not provide information in sufficient detail to be very conclusive.

TABLE IX.
FREQUENCY DISTRIBUTIONS FOR 1979 SDS DATA
INDUSTRY=IRON ORES (1011) BY OCCUPATION
TYPE=STRUCK AGAINST
WEIGHTED VALUES

| SOURCE FREQUENCY | MINE OPER | TRUCK DRIVER | TOTAL |
|---|---|---|---|
| Crowbar | 2 | 0 | 2 |
| Knife | 1 | 0 | 1 |
| Nail/Spike | 1 | 0 | 1 |
| Metal Item N | 9 | 0 | 9 |
| Highway Veh | 9 | 13 | 22 |
| Log | 1 | 0 | 1 |
| Total | 23 | 13 | 36 |

TABLE X.
FREQUENCY DISTRIBUTIONS FOR 1979 SDS DATA
INDUSTRY=IRON ORES (1011) BY OCCUPATION
TYPE=STRUCK BY
WEIGHTED VALUES

| SOURCE FREQUENCY | MINE OPER | MOTORMEN MINE | TRUCK DRIVER | TOTAL |
|---|---|---|---|---|
| Bundle | 1 | 0 | 0 | 1 |
| Mining Mach N | 2 | 0 | 0 | 2 |
| Chain/Rope | 0 | 0 | 1 | 1 |
| Metal Item N | 11 | 1 | 0 | 12 |
| Mineral (ore) | 1 | 0 | 0 | 1 |
| Mineral (dirt) | 3 | 0 | 0 | 3 |
| Misc N | 2 | 0 | 0 | 2 |
| Total | 20 | 1 | 1 | 22 |

## V. WORK SITE OBSERVATION

1. <u>General Background</u>

On 26-27 May a visit was made to the open pit Minnesota Mining Operations of U.S. Steel Corporation located at Eveleth, Minnesota, 55 miles North of Duluth. The purpose of this trip was to observe actual work conditions involved in the heavy vehicle mining operation and to provide the investigators with a better feel for the environmental problems and anticipated usage of the proposed belt restraint system.

Those making this trip included both co-investigators, Dr.'s Richard G. Snyder and John Melvin, and consultant experts Dr. Thomas Armstrong and Christopher Winkler. In addition to Richard C. Wible, U.S. Steel TCM for the study, others participating in the visit included George Dalmaso P.E., Manager, Engineering and Manufacturing, Miller Equipment Division, of Franklin, PA, developer of the restraint system being evaluated; Steve Swan of the U.S. Bureau of Mines, Minneapolis; Steve Starkovich, Safety Engineer, and R. Rantala, Engineer (Fig. 6).

Heavy vehicles in use in this mining operation include approximately "80 to 90" load hauling trucks, in addition to a variety of water trucks, large loaders, scrapers and tractors. Haulers being operated include the Euclid (Model 302HD, manufactured by Euclid Canada, Inc.),. with a 200,000 lb (100 ton) rated maximum payload and 51.33 cubic yard capacity (Fig. 3). Reportedly about six Euclids are in operation. The ones inspected were equipped with anchorlok air ride seats and two inch wide lap belts. The Wabco Haulpak (Fig. 4) is the major hauler, with reportedly 40 to 60 in operation, and 240,000 lb (120 ton) rated capacity. The models inspected utilized the Bostrom Viking T-Bar seat and were equipped with three-inch lap belts. A third hauler, of which approximately 20 were reportedly in use, was the Unit Rig Model M100, manufactured by Unit Rig and Equipment Company of Tulsa, Oklahoma.

Other vehicles inspected included the Caterpiller 992C, the Caterpiller D10 with 20 foot blade, and three-inch lap belt, and Dorf oil wagon, the Clark 46 equipped with rubber tires and used for cleanup and high mobility, and the Grove hydraulic crane model RT-751S, manufactured by the Grove Manufacturing Company of Shady Grove, PA. Graders, although inspected, were not included, since the driver primarily stands to operate.

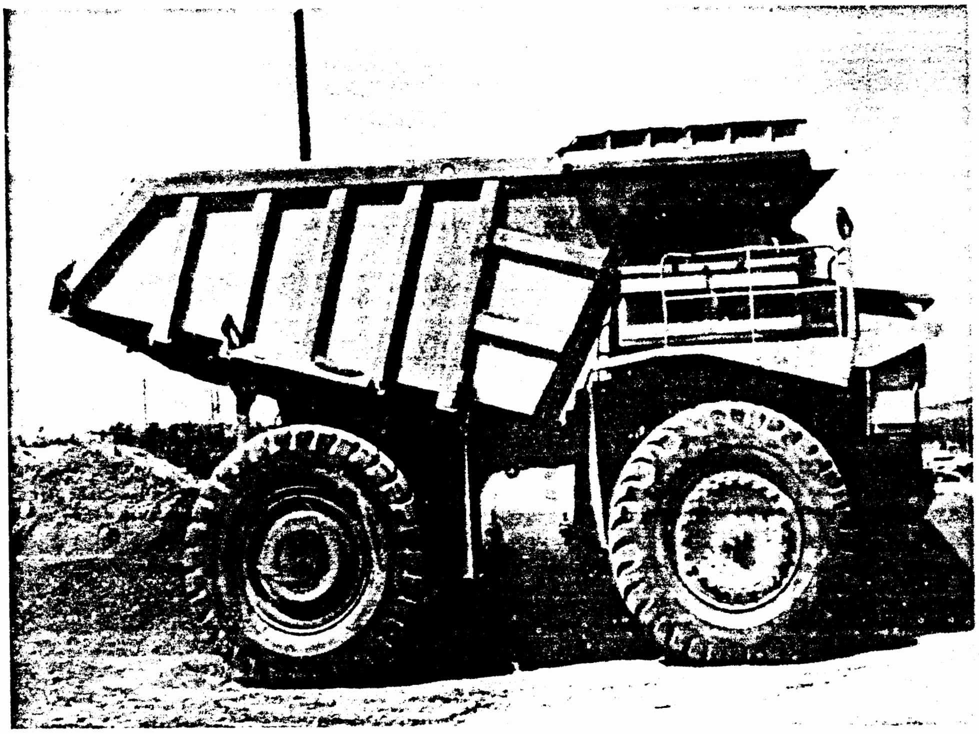

Fig. 3. Euclid load hauling truck, with 100 ton rated maximum payload.

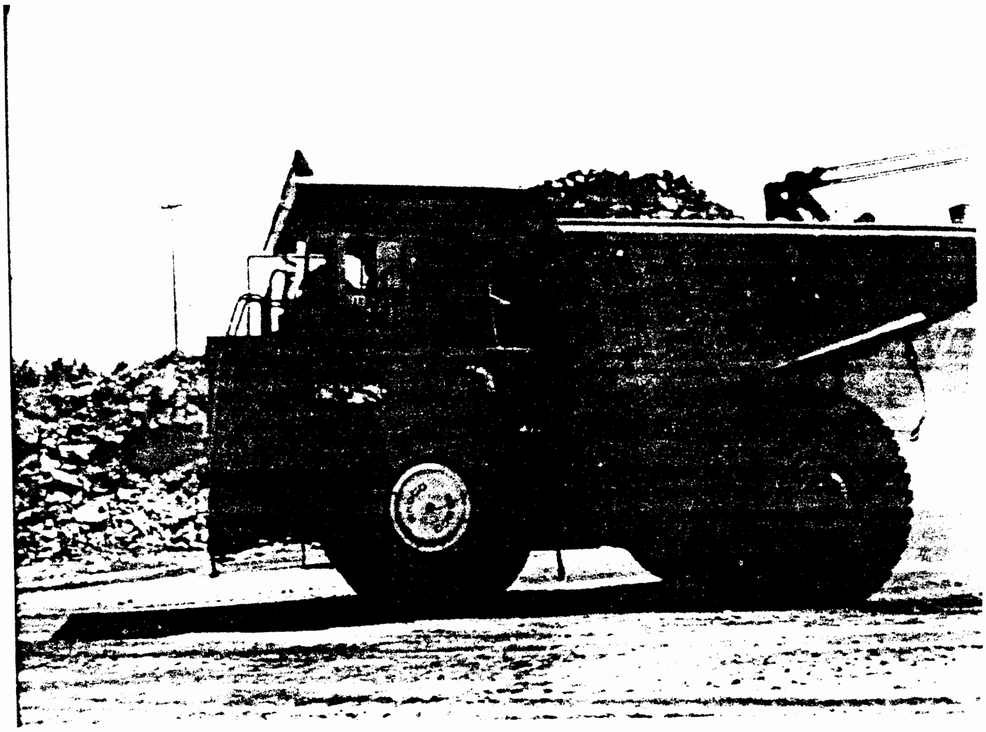

Fig. 4. Wabco Haulpak is another load hauling truck in use, with 120 ton capacity (loaded).

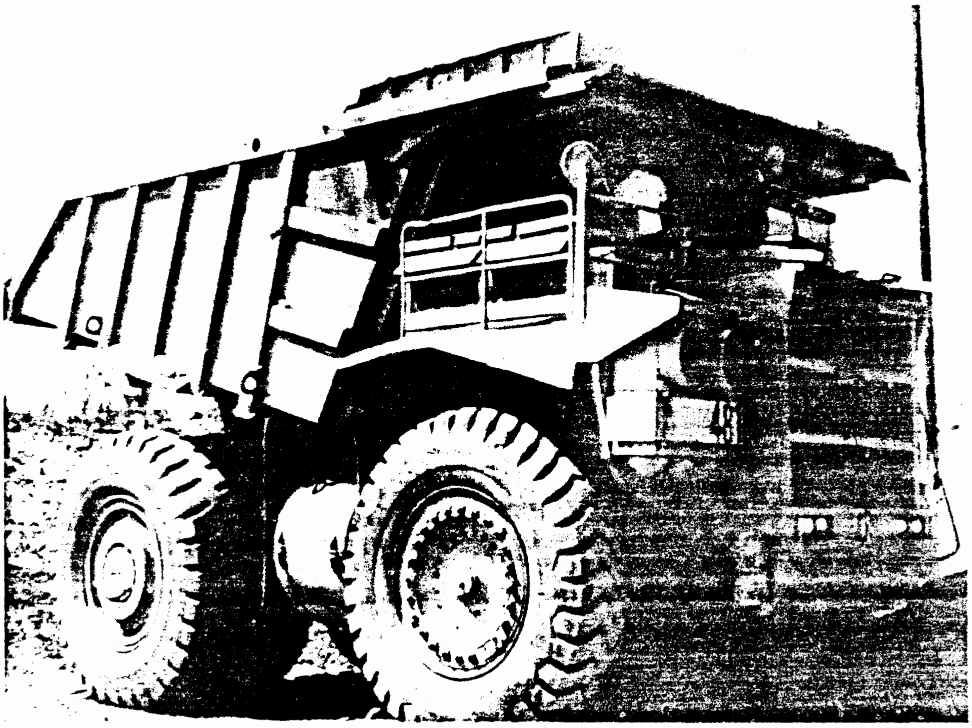

Fig. 5. Quartering view of Euclid truck.

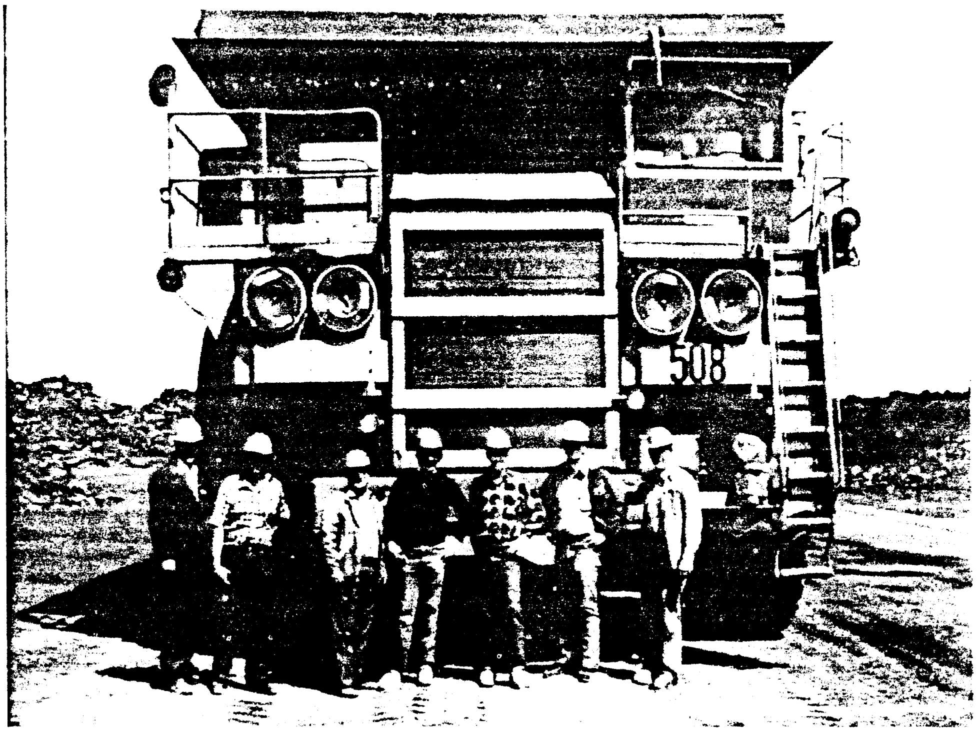


Fig. 6. Inspection team in truck frontal view to show relative size of this vehicle.

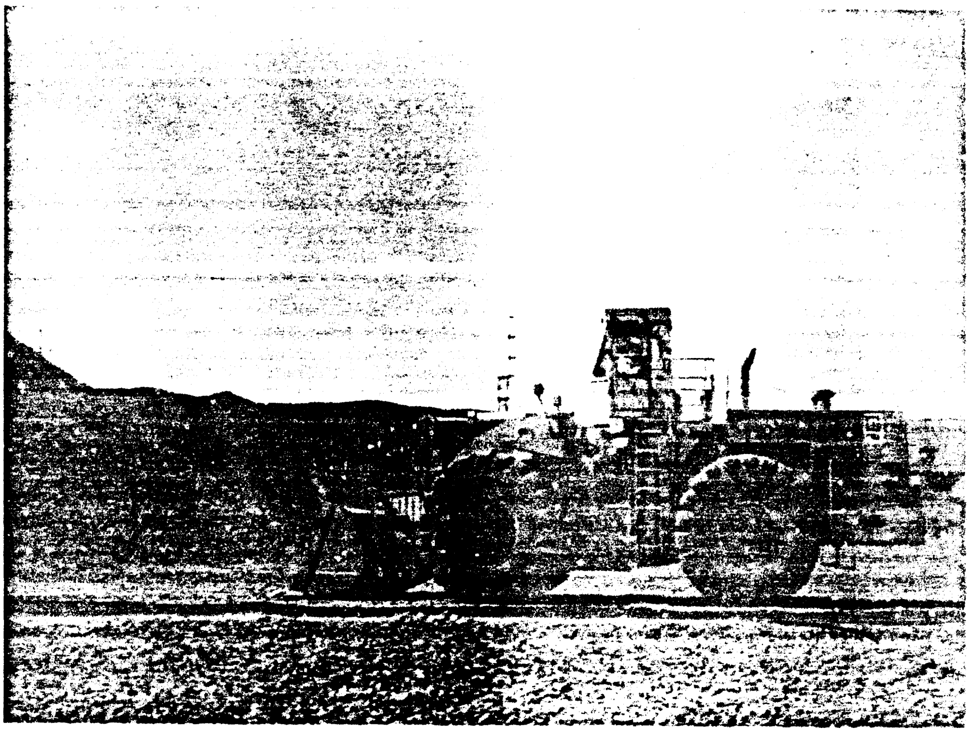

Fig. 7. CAT used to move taconite to conveyer belt for crushing and processing into concentrate (and pelletizing) and tailings.

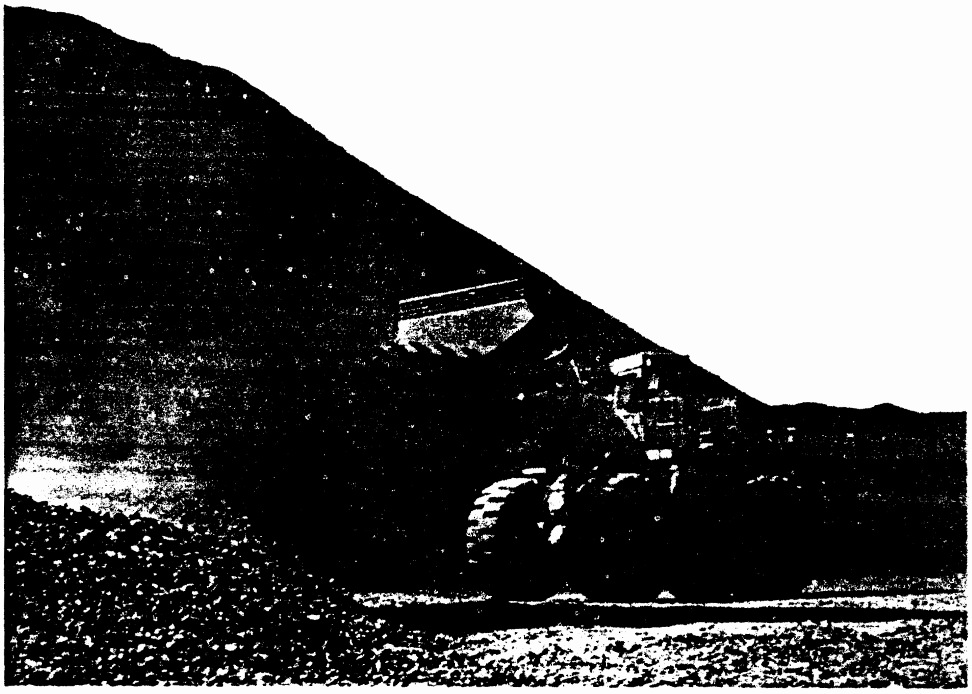

Fig. 8. CAT in action with scoop raised when loaded and raised this changes the C.G. forward.

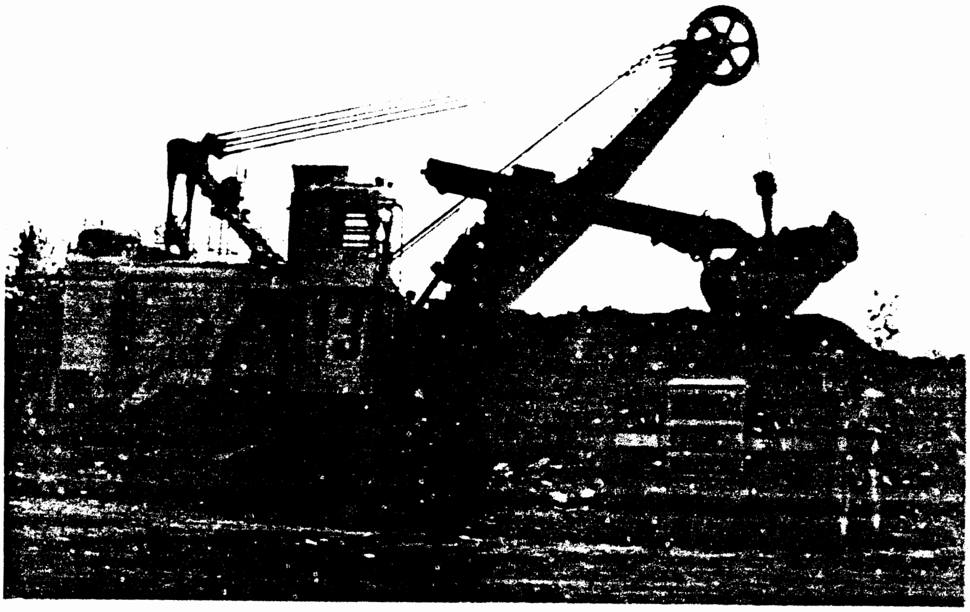

Fig. 9. Large shovel loading load hauling truck.

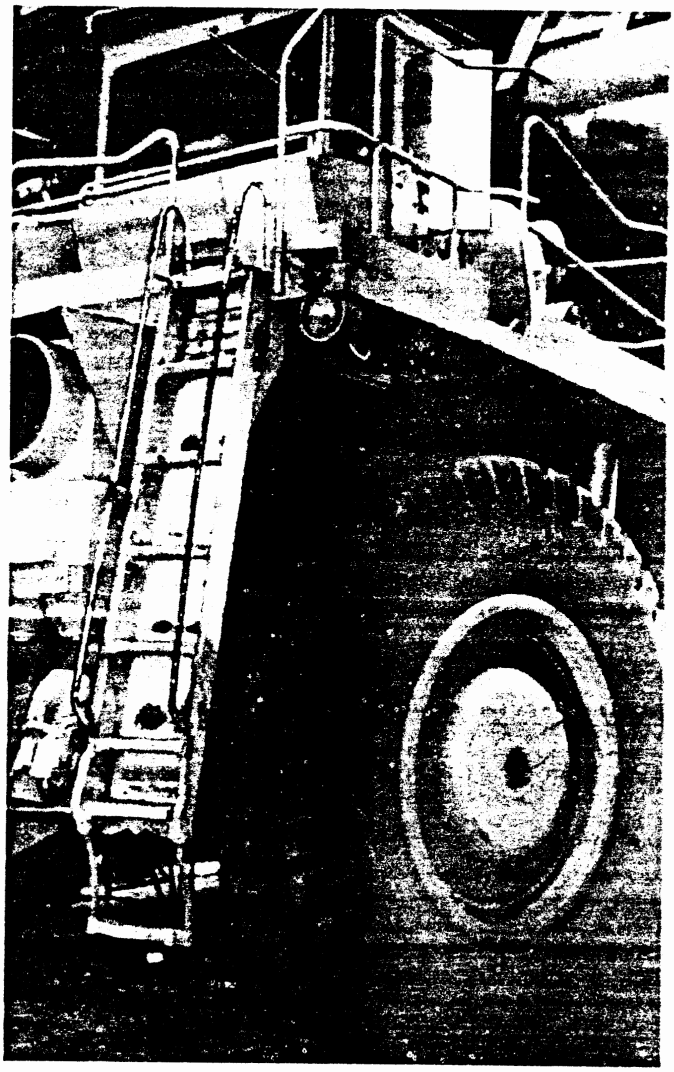

Fig. 10. Cab ingress and egress of the load hauling truck involves climbing a ladder about 10 feet to a platform before entering the cab.

During the visit to the Minnesota mine close examination of the major types of heavy vehicles was made and this presented an opportunity to observe the drivers in a work environment (Figures 2-9). In addition each investigation rode on at least two round-trips in a load hauler during loading, unloading, and travel on rough road operations. Subsequently, each rode in a CAT (Figures 7,8) during loading of the conveyer belt operation. This experience enabled collective observations related to the problems of seat belt usage both from the driver's operational view-point and that of safety management. Specific comments and discussion are outlined in the following sections.

2. Ergonomics Factors

An Ergonomics assessment of lower torso restraint by heavy equipment operators in surface mines provided by Professor Thomas J. Armstrong, both from a Human Factors and Industrial Engineering viewpoint, as follows:

CAB INGRESS AND EGRESS

Operators must climb up a ladder to a platform or catwalk, open the door and enter the cab (Figure 10). Cab floors are approximately ten feet (measured 10'8" unloaded) above ground level, so a fall could result in serious injury. The risk of a fall might be particularly high when the ladder is wet or icy. Also cold days might be expected to increase the risk of a fall because of reduced tactual sensitivity and probable use of gloves. A worker in route to the cab could be pulled off balance by snagging loose fitting clothes on a number of possible catch points. Cab entry requires use of both hands and feet, so carrying personal belongings, tools, or supplies to the cab would increase the risk of an accident.

It has been suggested that these objects might be clipped to the proposed personal restraint belt, freeing the driver's hands for climbing the ladder and entering the cab. However, such a procedure could increase the risk of an accident during ingress or egress if the bottom of the belt or the attached objects snag on a catch point. The proposed belt also could be clipped to the vertical rail of the ladder to act as a fall protection. However, this would require added worker effort and might actually interfere with climbing. These trade-offs might be assessed by experiments in which operators repeatedly climb into and out of cabs. While wearing the personal restraint system, dummy attachments could be hung from the belt to find the location that least interferes with climbing.

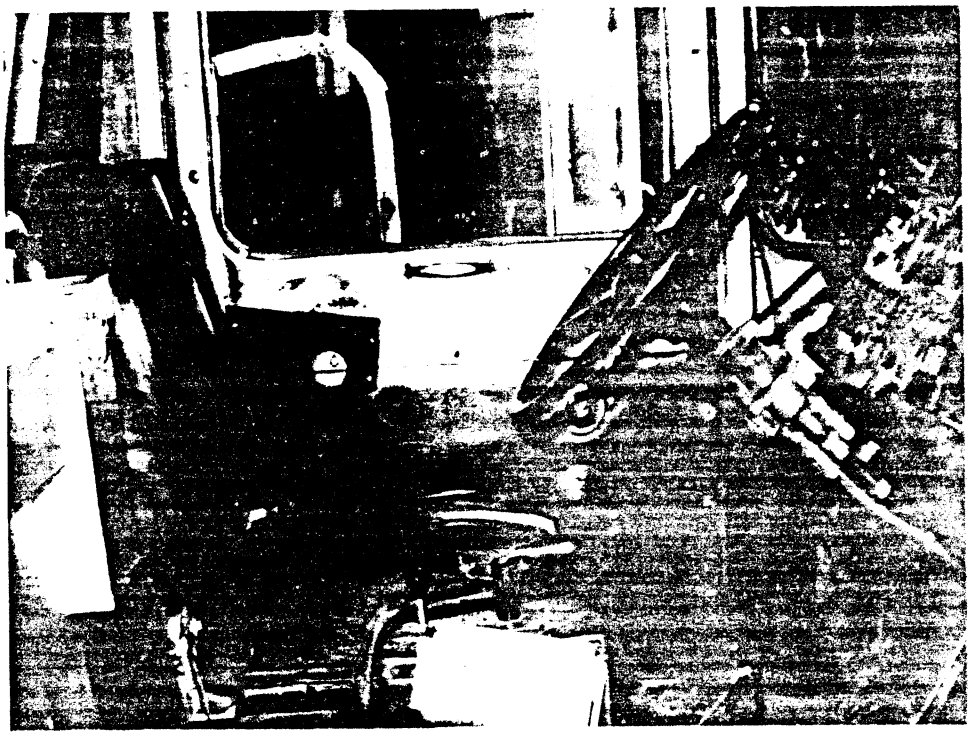

Fig. 11. The truck cab has many surfaces hostile to the driver in an impact. Note the sharp steel edges of the instrument panel, along the door, and of the steel water box to the rear of the driver.

IN THE CAB

The cab environments vary from truck to loader, truck to truck, and loader to loader. All of the cabs are built from a heavy steel frame. All have many hard sharp edges on the edges of instrument panels, steering wheel brackets, control boxes, etc. Some of these edges are associated with modifications such as water bottle boxes (Figure 11). Minor injuries could be caused by bumping these surfaces in the course of normal reach and move activities required to enter, exit, and operate the vehicle (Figure 12). Serious injuries could be produced when one of these surfaces is contacted forceably as when the vehicle goes over a bump, stops suddenly, or rolls over. Aside from the seat and armrests there is very little padding in most cabs.

Fig. 12. Example of steel projections within operator's kinematic envelope in an impact.

Operating the vehicles requires movements of the upper and lower extremities to reach and operate the controls. More movement is required to operate the scoop than the truck. The scoop is used to transport materials short distances; the scoop must be cycled once each trip and shifting may be required. Because scoops tend to be operated in the vicinity of other equipment the operators tend to move around in their seat so that they can see their wheels and bucket. Also there is probably more jarring of the scoop operator because of the way they drive into piles of material to load the bucket.

Use of the existing proposed personal restraint system could be expected to reduce risk of serious injuries due to ejection or bouncing against the ceiling. It does not restrain the upper torso and serious injuries could still be produced by contact with hostile cab surfaces in a collision.

Observations of selected operators and the condition of selected belts suggested that the existing belts are seldom used. Some workers complained that the belts were dirty, hard to fit, and in poor mechanical condition. The company apparently does not have or does not enforce regulations requiring seat belt usage. The proposed personal seat belt system in which belts are assigned to each worker should in theory overcome the problems with the belts being dirty and hard to find. They still would require action to put them on and creation and enforcement of a seat belt rule would still be required. Seat belts should be designed so that they can be quickly hooked and unhooked with gloved hands and with bare hands in a cold environment.

Both the existing and proposed designs could be expected to interfere with operator movements forward in the seat. This could reduce operator visibility and increase the risk of an accident, especially for the scoops.

AUXILIARY TASKS

Operators of trucks and scoops are responsible for auxiliary tasks such as checking the fuel level with dipsticks. These tasks should be further inventoried and studied. It appears that they require maneuvering on the vehicle outside the cab and would be subject to the same concerns discussed under CAB INGRESS AND EGRESS.

3. Vehicle Dynamics Factors. Observations by Christopher Winkler, Physical Factors Division, HSRI.

Vehicle dynamics appears to play a role in the operator injury record of this fleet (as indicated by Table 1 herein) through three general areas: (1) vehicle ride, (2) vehicle (braking and steering) control, and (3) rollover.

Beginning with the last of these, of the 161 events reported in Table 1, three (2%) involved rollovers. One of these involved a crane lifting a load in excess of rated load, and so might be attributed to operator error. The other two rollovers were of trucks operating off-road (due to brake failure) or on "uneven ground." Based on observations made on the field trip, one could venture an educated guess that the basic role stability of these vehicles would be about the same, or somewhat less, than that of the typical U.S. commercial highway vehicle. To provide a reference, then, about seven percent of accidents involving commercial vehicles include rollover of a commercial vehicle; 15 percent of single commercial vehicle accidents result in rollover; and for certain classes of commercial vehicles, the later figure ranges upward toward 50 percent. Accordingly, considering the markedly poor roadway on which mining vehicles operate, one might judge that rollover is not a highly significant safety problem for this fleet. (The generally lower operating speeds of these vehicles probably contributes strongly to their relatively low number of rollovers.) Certainly, given the uniqueness of both the vocational requirements and the specific designs of these vehicles, improving the fleet safety record through improved rollover performance would not appear to be a highly cost effective approach.

The majority of the loss of control events recorded in Table 1 appear to be characterized by system (brake or steering) failures rather than by inadequate performance of "properly" operating systems. Details of the nature of system failures are not available, and so comments on how they might be avoided are not easily made. In at least one case, however, loss of steering seemed to result from loss of hydraulic power due to a stalled engine. This suggests that reserve hydralic power, as stored in accumulators, could avoid such events.

Finally, from the information available in Table 1, ride would appear as THE vehicle dynamics phenomena most involved in the operator injury record of this fleet. This fact is rather at odds with experience and observations made on the field trip. Although my evaluation was purely subjective in nature, it can be said with no doubt at all that the ride quality of both of the two vehicles ridden in (a production truck and a large loader) was clearly superior to the ride quality of a typical line-haul highway vehicle. Given that line-haul trucking provides at least a tolerable ride environment, observations on the field trip do not provide an adequate explanation for the high number of ride-related injuries apparent from Table 1. Perhaps this is due to the nature of the road surfaces which we traversed on the field trip. Table 1 would seem to imply that much of the mining operation takes place over substantially poorer surfaces than we saw.

Personal experience aside, there appears to be real potential to improve the operator injury record through improvements in ride quality. Conceptually, at least two avenues for improving ride exist: (1) improvements in vehicle suspensions and, thus, in whole vehicle ride, (2) improvements in driver seat suspension. Practically, there is probably only one option available, i.e., improving seat suspensions. (Vehicle and/or cab suspension changes are probably feasible only at the point of original manufacture, and in any case, are probably less cost effective than improved seating).

The suspension seats installed in the vehicles seen appear to be the same models commonly used in highway trucks. Since the highway vehicle is subject to generally higher frequency but lower displacement ride vibrations than these mining vehicles experience (a subjective evaluation on my part), it is not surprising that "bottoming" of the seat suspension appears as a complaint in Table 1. One might reasonably expect that a seat suspension designed specifically for this service might serve to improve the operator ride quality appreciably.

4. Biomechanical Factors

Most of the vehicles inspected or rode in appeared to have lap belts installed, except for the graders in which the operator primarily stands. As shown in Figure 13, belts checked used nylon webbing conforming to SAE and DOT FMVSS standards wih metal-to-metal type buckles, and provided a reasonble belt angle (45-55°). The WABCO Haulpak and CATS such as the D10 and 992C inspected were equipped with

3-inch wide belts, while the other vehicles used 2-inch wide belts. Belts were generally attached to floor structure rather than to seats, providing good anchorages. Some, such as the 992 CAT, used a steel cable between the seat and floor.

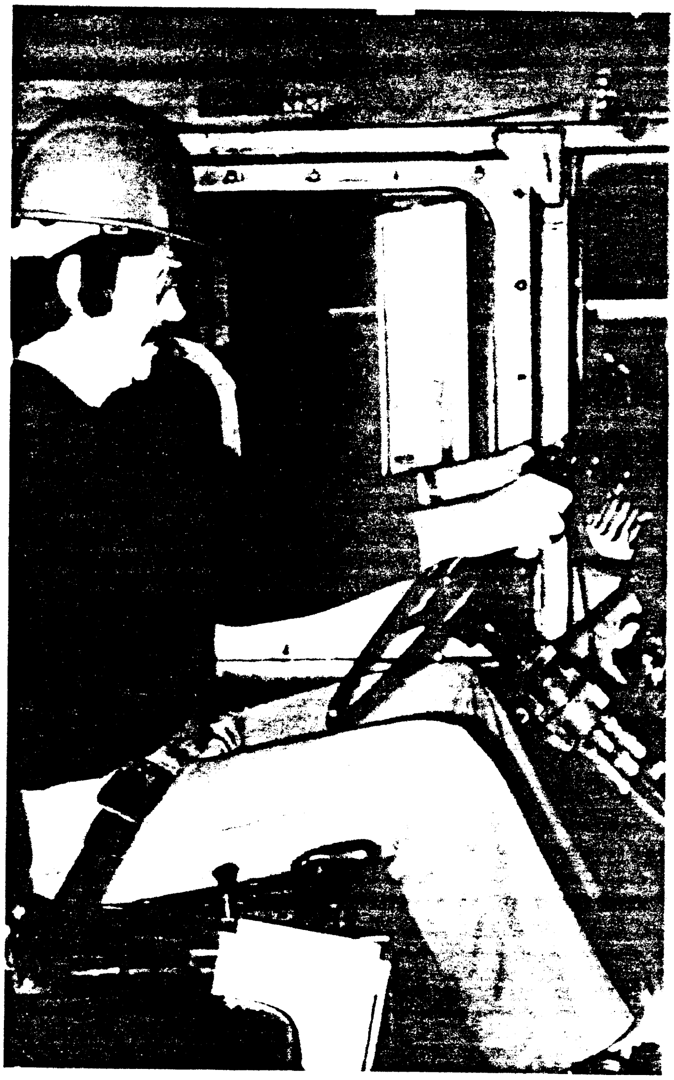

Fig. 13. The driver in position relative to the cab environment.

The main problem appears to be that drivers are not wearing belts where provided. While various reasons were given by the handful of drivers asked, the most common reason given was that the belts were dirty and greasy. And most of those examined were indeed filthy, having been left on the dirty floor, rather than being worn. It would seem that simply replacing dirty belts will not solve the problem if the driver won't wear it. One possible solution for current belts, suggested by a driver, is to provide a device (hook?) to hang up the belt ends when not in use. However this would require driver cooperation or enforcement to be effective. Another solution would be to use retractors so that when not in use the belt is protected and out of the way.

From a potential injury point of view the truck, tractor, and loader cabs present generally hazardous impact environments. The heavy non-yielding and sharp steel edges of the instrument panels present injurious contact points to the driver in a jolt or impact situation, as do the door side panels, cab roof structures, and rear of the cab. In particular the metal boxes and water containers are located where injury could result. The CAT 992, for example, has a steel box with sharp edges to the left of the rear of the head, as well as sharp metal surfaces on the right door such as the window opener. The truck cabs usually have an open metal box attached to the rear of the right side of the driver's seat (Figure 12). Some more recent models of the same make truck have improved panels, although much more could be done to provide driver protection. The latest model WABCO truck was observed to have a much better panel from an impact point of view than the previous model; sharp metal edges had been rounded and metal boxes removed.

In case of a jolt or collision the driver may be thrown into abrupt contact with sharp metal surfaces. An illustration is shown in Figures 12-14, of the positions a driver may be thrown into in the cab of a Unit Rig truck (Model M100) (Figure 15). Figure 16 shows impact points of an unrestrained driver leaning forward into the steering wheel, panel and windshield area. Figure 17 illustrates a side impact and the driver impacting the side door window frame with his head. Note that the safety helmet might not offer adequate protection in this situation.

Since it is unlikely that energy-absorption devices, crash padding, and improved cab impact design are possible without some major retrofit or redesign, the simplest and most effective driver protection for the current vehicle operation is to ensure that all drivers (even those operating from a standing position) are provided and wear a restraint system which will prevent them from contacting hazardous structures during a jolt or impact.

While there appears to be adequate headroom in the various cabs the variation in physical size of drivers is not known. Small individuals or females may have reach and accommodation problems. Heavy or large males over the 95th percentile may also have problems. Previous studies of the physical size of truck driver populations, as well as other populations such as air traffic controllers, airline stewardesses, law enforcement officers, or military pilots, have shown that such occupations may consist of individuals varying greatly in size from that of the general population. It is important to know more about the body sizes of the heavy equipment truck driver population in order to provide an objective assessment of the relationship between the drivers and the

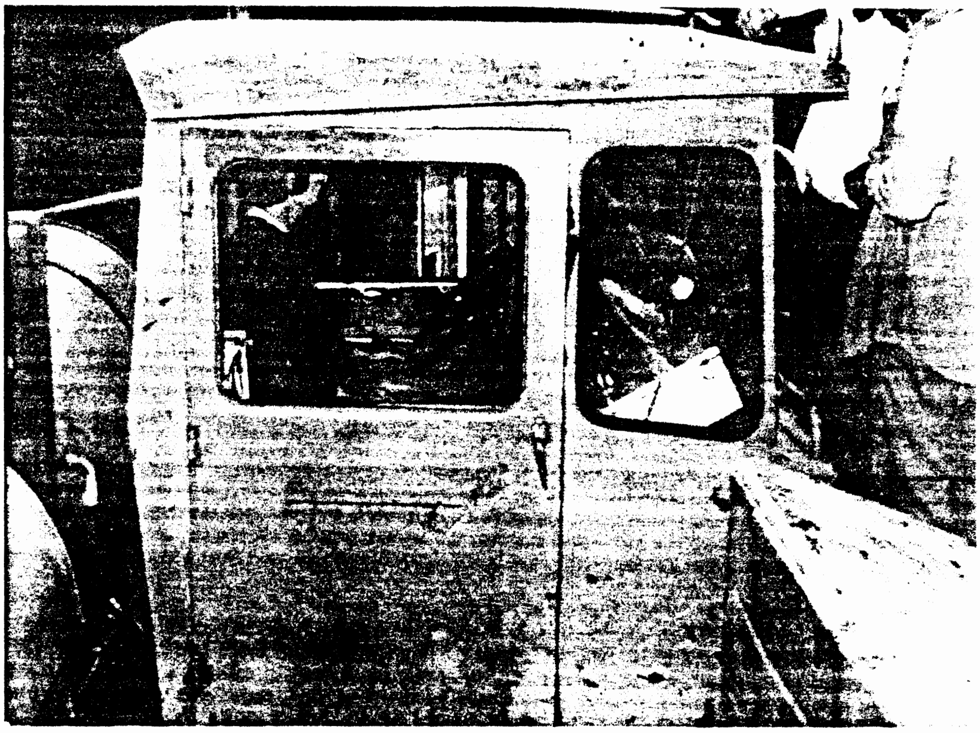

Fig. 14. View of Model M100 Unit Rig truck cab.

Fig. 15. An unrestrained driver could be thrown forward.

Fig. 16. In a side impact the driver can have his head thrown into sharp metal edges.

cab environments, and an anthropometric survey should be conducted to provide this information.

## VI. EVALUATION OF PROPOSED RESTRAINT SYSTEM

The proposed restraint system has been subjectively evaluated during this phase of the study and some observations noted in the previous sections. This restraint was developed experimentally by Miller Division of Inco Safety, Franklin, Pa. It consists of a 2-inch 6,000 lb loop strength nylon webbing belt from which shorter belts are attached to the side which attach to the existing vehicle belt tie down by steel snap hooks. In addition there is provision for two stud rings to which additional items could be attached.

The intent is to provide a personal restraint system which could be issued as personal equipment to each driver. This belt is designed to be worn all the time and can simply be snapped onto the existing restraint tie-down hardware of any truck the driver may be assigned to. An attractive feature is the notion that as personal equipment the belts will be kept clean, in good condition, and receive more use.

The idea of personal equipment works effectively in many other occupations. For example, most deep sea divers (hard hat) have their own personal diving helmet and other equipment. This is a matter of safety, preference, and tradition, since the diver maintains his own equipment as his life depends upon it daily. Sky divers and military parachutists pack their own chutes for similar reasons. Pilots and race drivers also maintain their own personal equipment. The list of occupations where personal equipment is important to the individual is extensive. There are a number of occupations including telephone linesmen, law enforcement officers, tree-climbers, and carpenters where belts are worn for carrying special equipment necessary to the job.

An example is illustrated in Figures 15-16, showing the belt worn by an electrician daily in his work. In this case two tool pouches (much heavier and bulkier than the proposed truck driver belt) fitted with various tools are worn. This particular belt weighed 22 lbs. and the electrician claimed that it was comfortable to him. Police belts examined weighed 13 lbs. In comparison, the proposed Miller restraint for truck drivers weighs only between 2-1/4 and 2-1/2 lbs. Since this would be worn by female truck drivers as well as males, weight is a factor along with comfort. This belt has been worn by the investigators, and for long periods in one case. It was subjectively found to be quite acceptable relative to comfort, and after an initial period the user forgot it was being worn.

Thus, although this concept appears to be unique for drivers, it has been effectively used and accepted by other occupational groups. The question of acceptance by the drivers may depend to a large extent on how the concept is presented to the drivers. It probably will meet less resistance once drivers experience wearing the restraint and find to what degree it is comfortable, accessible, allows individual freedom, and is convenient. The need for protection would be expected to be difficult for them to perceive, but if it can be shown that wearing the belt makes the ride more comfortable by reducing jolts and fatigue it might receive more acceptance.

The proposed Miller restraint was given a very limited field test to subjectively evaluate its potential performance and observe any major deficiencies that might not otherwise be obvious. Figs. 17 & 18 show a driver donning this belt system. One difficulty encountered in donning is that because of the way the side attachment belts attach to the main

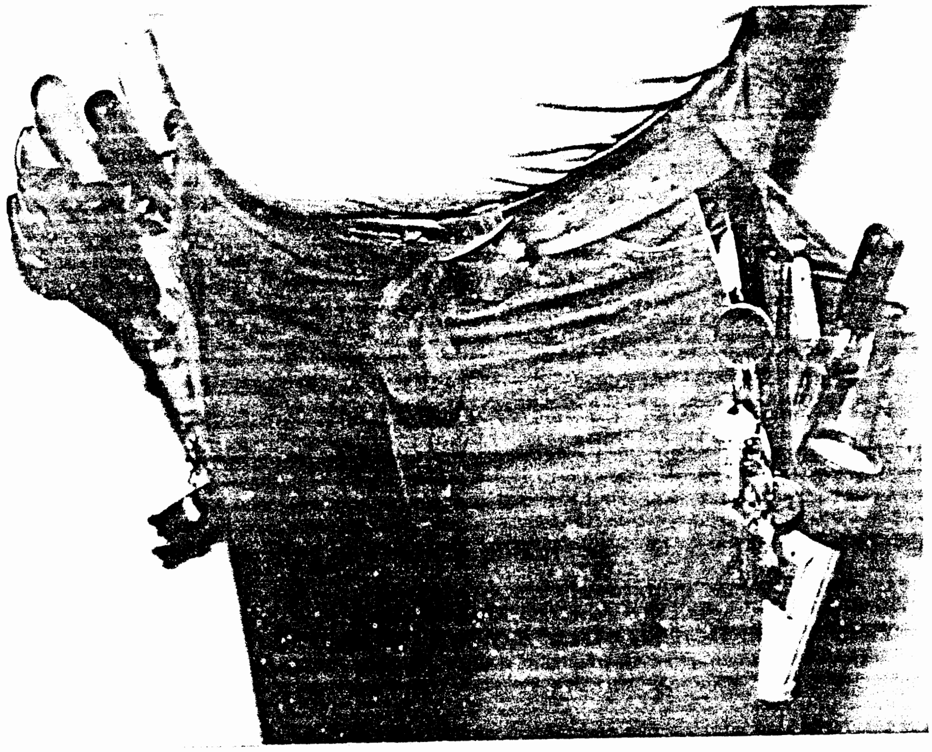

Fig. 17. Standard electrician's tool belt with equipment pouches on both sides.

Fig. 18. Rear view of electrician's belt. This weighed 22 lbs. but additional tools could be carried. In comparison the proposed truck driver restraint weighs 2-1/2 lbs.

belt, it can be put on upside down (that is, inside out). At present the side belts are loosely looped over the lap belt portion. Perhaps if a band were added about 3" below the belt top, it would keep this side harness in proper position.

The lap belt is very comfortable to wear during other than driving activities, and the attach belts can be hooked up (out of the way) on the lap belt for activities such as walking or sitting.

Figure 19 shows the truck driver illustrated above donning this restraint system (in Figs. 17 & 18) seated in his cab. This operator is 70" tall and weighs 185 lbs. The driver states he has a 34" waist. Areas were examined where improvements might be necessary. As shown in Figure 19 note the angle that the attachment belt makes in relation to the seated operator. This angle is about 90 degrees in the normal seated position, and is estimated to be 80-85 degrees when the operator is extended forward in his seat. The recommended angle is 50° ± 5°. It has been found in previous studies that too steep an angle, as well as too shallow an angle, can result in lack of adequate pelvic support and may result in abdominal injuries due to belt impingement. However, it should also be noted that previous systems have essentially involved a belt from anchorage to anchorage across the thighs. In this belt the lap belt portion is hooped around the body and this difference in configuration may also result in a different reaction under dynamic loading. The effect, if any, this extreme 90 degree angle has on restraining the operator and the potential for contributing to injury should be evaluated during the Phase II tests.

Figure 20 illustrates a second area which needs further analysis and testing. The seat belt does not plug in to the floor anchor point in all vehicles. In some vehicles the operator's belt attaches to seat anchor plate, and the anchor plate in turn has a separate belt running to the floor anchor. This creates a situation where, if the seat anchor fails, the operator may be subjected to a second jolt, as slack is taken up by the second anchor belt. While this provides an easy attachment point for the driver to reach, and also provides secondary protection should the seat fail, conventional systems attach directly to the floor anchor point. Consideration should be given in testing to this unique arrangement to determine any adverse effects on the driver during impact.

Fig. 19. Driver putting on proposed lap belt restraint.

While subjective, the preceding comments are based upon the investigators' experience in evaluating many types of restraint systems over the years and are intended to point out some features which should be considered in the testing phase.

Fig. 20. The belt can be comfortably adjusted. Note how the attach belt hangs to the side, ready to plug into the vehicle. This can be snapped up out of the way on the belt when wearing outside the vehicle.

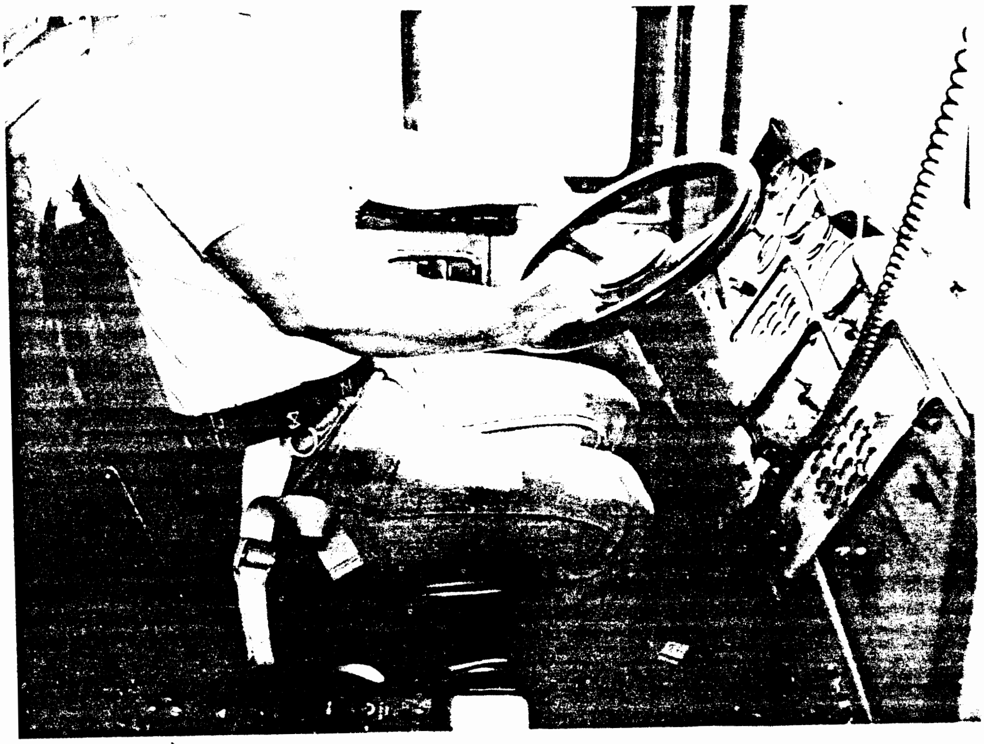

Fig. 21. Driver in truck cab wearing proposed belt. Note lap belt attachment angle.

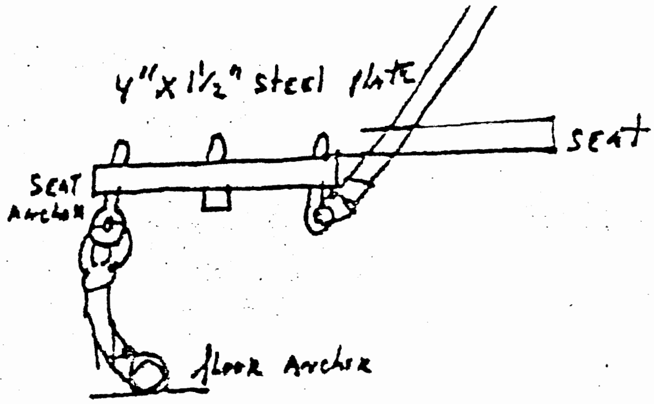


Fig. 22. Sketch of double-belt system. The driver's belt is attached to a seat anchor, which in turn is attached to a floor anchor.

# VII. DISCUSSION OF PHASE II TEST PROGRAM

The primary factors related to developing a protocol for testing the operator restraint system are:

1. Accident environment
2. Vehicle physical characteristics
3. Operator anthropometrics.

These factors have been discussed in the previous sections with regard to the extent of available information. As noted, there is a lack of definitive information in many of the areas represented by the above factors. With due consideration of this state of affairs, the following test protocol is recommended for evaluating the performance of the operator restraint system.

The accident environment data indicate that for actual collisions (as opposed to jolts and bumps) the frontal collision is slightly more common than the lateral collision. Thus, it would appear reasonable to test the occupant restraining ability of the proposed restraint system in both frontal crash simulations and in lateral crash simulations. The vehicle deceleration characteristics in such events are virtually unknown. However, a frontal crash velocity change of 20 mph with an average deceleration of 30 G would provide a test condition which reflects both the low speed of vehicle operation and the stiff nature of the vehicle structures involved. Similarly, a side crash velocity change of 10 mph with an average deceleration of 20 G would appear to be appropriate.

The vertical jolt environment, which produces over half the reported injuries, is not truly on impact in the collision sense. However, appreciable accelerations can be delivered to the occupant in the vertical direction during such events. A vertical velocity change of about 7 mph with a peak acceleration of 6 G would represent a 6-inch sinusoidal displacement at a frequency of 3 Hz.

The tests would be conducted on the HSRI Impact Sled with a 50th percentile male anthropomorphic dummy. The dummy will have head and chest accelerometers mounted and will be seated in a conventional bucket seat. The seat and dummy will be oriented on the sled to produce the desired impact condition (i.e., frontal, side or vertical). The vertical condition will require the seat and dummy to be mounted such that the dummy is on its back with its head towards the front of the sled.

Following the three tests with the proposed restraint system a second set of three tests should be run using a conventional lap belt for comparative purposes. As a final step in the evaluation a single frontal test with a suspension seat system should be run to check the total system response to the restraint system/seat structure interactions.

In none of the tests will a mock-up of surrounding cab structures be used. This is due to the great variability of such structures in the field and the arbitrariness of chosing any one structure. The tests will serve solely to evaluate the restraint capabilities of the proposed restraint system.

## ACKNOWLEDGMENTS

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# APPENDIX A.
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Form 5762 4/78

UNITED STATES STEEL CORPORATION
MINNESOTA ORE OPERATIONS

FOREMAN'S ACCIDENT REPORT

. Name ______________ 2. Check # ______________ 3. Case # ____

4. Department ______________

. Accident Date ______________ 6. __________ p.m. a.m.

. Birth Date ______________ 8. Last 4 digits of Soc. Sec. # ______________

9. Nature of Injury ______________

. Injured Body Part ______________

11. First Aid or Medical Treatment ______________

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______________

12. Occupation when injured ______________ 13. Occ. Experience ______________

. Regular occupation ______________ 15. Corp. service ______________

. Exact location of accident ______________

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. Description of incident (explain related events prior to the accident & how incident occur what was the injured miner doing, and related events after the incident.)

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18. Equipment or tool involved (list manufacturer, model no., type) ______________

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...'s actions by the miner or other miner ______

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. Steps to prevent recurrence ______

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. List names and check numbers of witnesses ______

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. Work schedule ______

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. Foreman ______ Date ______

. General Foreman ______ Date ______

. Superintendent ______ Date ______

APPENDIX C



# Major Group 10.—METAL MINING

## *The Major Group as a Whole*

This major group includes establishments primarily engaged in mining, developing mines, or exploring for metallic minerals (ores). These ores are valued chiefly for the metals contained, to be recovered for use as such or as constituents of alloys, chemicals, pigments, etc. This major group also includes all ore dressing and beneficiating operations, whether performed at mills operated in conjunction with the mines served or at mills, such as custom mills, operated separately. These include mills which crush, grind, wash, dry, sinter, or leach ore, or perform gravity separation or flotation operations. Magnesite and brucite operations are classified in Industry 1459, and crushed dolomite operations in Industry 1422. Smelters and refineries are classified in Major Group 33, Primary Metal Industries, and establishments engaged in producing primary magnesium metal in Industry 3339. The operation of brine wells or sea water plants for the production of magnesium is classified in Major Group 28.

Exploration under preliminary phases of operation should be classified according to the type of ore expected to be found, when performed by operators of the properties. Exploration performed on a contract, fee, or similar basis is classified in Industry 1081.

Group No. | Industry No.

**101** IRON ORES

**1011** Iron Ores

Establishments primarily engaged in mining, beneficiating, or otherwise preparing iron ores and manganiferous ores valued chiefly for their iron content. This industry includes production of sinter and other agglomerates except those associated with blast furnace operations. Blast furnaces primarily engaged in producing pig iron from iron ore are classified in Industry 3312.

Brown ore mining
Hematite mining
Iron agglomerate and pellet production
Iron ore, blocked
Iron ore dressing (beneficiation) plants
Iron ore mining
Limonite mining
Magnetite mining
Manganiferous ore mining, valued chiefly for iron content
Siderite mining
Sintering of iron ore at the mine
Taconite mining

**102** COPPER ORES

**1021** Copper Ores

Establishments primarily engaged in mining, milling, or otherwise preparing copper ores. This industry also includes establishments primarily engaged in the recovery of copper concentrates by precipitation and leaching of copper ore. Establishments primarily engaged in the recovery of refined copper by leaching copper concentrates are classified in Major Group 33.

Chalcocite mining
Chalcopyrite mining
Copper ore mining
Cuprite mining

**103** LEAD AND ZINC ORES

**1031** Lead and Zinc Ores

Establishments primarily engaged in mining, milling, or otherwise preparing lead ores, zinc ores, or lead-zinc ores.

Blende (zinc) mining
Calamine mining
Cerrusite mining
Galena mining
Lead ore mining
Lead-zinc ore mining
Smithsonite mining
Sphalerite mining
Willemite mining
Zinc-blende (sphalerite) mining
Zincite mining
Zinc ore mining