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ORE HANDLING EQUIPMENT OPERATIONS SAFETY STUDY IN UNDERGROUND METAL AND NONMETAL MINES

THEODORE BARRY AND ASSOCIATES

USBM CONTRACT REPORT H0230004
MODIFICATION NO. ONE

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THEODORE BARRY AND ASSOCIATES
MANAGEMENT CONSULTANTS

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON, D. C.

USBM Contract No. HO230004, MOD-1

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Theodore Barry & Associates
Los Angeles, California

FINAL REPORT
USBM Contract No. HO230004 - MOD 1

July 28, 1975

DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON D.C.

<u>Notice</u>

"The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies of the U.S. Interior Department's Bureau of Mines or of any other branch of the United States Government."

FOREWORD

This report was prepared by Theodore Barry & Associates, Los Angeles, California under USBM Contract Number HO230004-MOD(1). This contract was initiated under the Metal and Nonmetal Health and Safety Research Program. It was administered under the technical direction of Spokane Mining Research Center with Mr. David E. Nicholson acting as the technical project officer. Mr. Frank Pavlich was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period February 1, 1974 to July 28, 1975. This final report was submitted by the authors on July 28, 1975.

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*Available on library loan from USBM, Spokane Mining Research Center, Spokane, Washington.

SECTION 1

INTRODUCTION

INTRODUCTION

The low production rates associated with the underground metal mining industry have received considerable attention during the last decade. A number of significant technological advancements, in the form of new equipment, have taken place to improve the economics of ore production. Unfortunately, an extremely important factor in the equation -- the operator protection and safety -- continues to receive a low priority. The underground metal mining industry has one of the poorest industrial safety records in the United States. Equipment operators are constantly being placed in hazardous situations. Even one fatality is one too many. All of us bear the responsibility to eliminate it.

This project is one of the important steps currently being undertaken by the U.S. Bureau of Mines to improve the operational safety of seven major pieces of ore handling equipment commonly used in underground metal and non-metal mines. The objectives of this study are; (a) to identify the existing hazards associated with the operation of the specific equipment, and (b) to recommend practical solutions that will minimize these hazards and reduce operator injuries. These recommendations are to be in the areas of equipment design improvements, additional operator protection and warning devices, equipment operating procedures and any modifications to the existing safety regulations.

This study includes the following pieces of ore handling equipment:

- Load Haul Dump Machines
- Rail Haulage Systems (including loading and dumping of ore)
- Overcast Mucking Machines
- Slushers
- Skip Hoists (limited to hoists moving ore)
- Shuttle Cars
- Conveyors

SECTION 2

SUMMARY OF RESULTS AND RECOMMENDATIONS

SUMMARY OF RESULTS AND RECOMMENDATIONS

As a result of this study, a number of important recommendations have been developed. These conclusions are based on historical accident analysis, field observations of equipment operators, in-depth interviews with the various personnel in the mining industry, and an industrial engineering evaluation of equipment capabilities and limitations. Exhibit I-1 outlines the statistics of the study sample utilized in developing our recommendations. The number of accidents analyzed for each equipment type, the number of models observed, the number of actual equipment operators interviewed, etc., are all documented in Exhibit I-1.

Our recommendations to improve equipment operation and safety were developed with the following priorities in mind:

1. Equipment design changes

2. Addition of safety devices or warning systems

3. Changes in operating practices or human factors considerations (training, supervision, etc.)

In addition, changes and additions to existing federal regulations governing safety in the underground mining industry have been suggested at a number of places. These modifications either refer to the need for a new regulation, or relate to the need for improved enforcement or compliance. Exhibit II-2 summarizes our recommendations for each of the above groups.

The following sections briefly describe our findings regarding the major hazards associated with each equipment type. The recommendations to, (1) minimize or eliminate the accidents by reducing or eliminating hazards, or (2) improve operator protection, given that accidents will continue to occur, are then summarized for each equipment type. The most effective method of implementing the solution is also outlined. Details of these findings and solutions are documented in the subsequent chapters.

<u>LOAD HAUL DUMP MACHINES:</u> LHD accidents were generally found to result in high severity. Typical accidents associated with LHD's were fall of rock and collisions or run-aways. Operators were exposed to falling rock at the face and along the haulage drifts, primarily due to a failure to trim loose rock in these work areas. Collisions were generally found to result from one or a combination of: equipment malfunction, especially in brakes and steering, poor visibility, or operator inexperience.

STUDY STATISTICS

Equipment Type	Number Fatal*	Number Non-fatal**	No. of Models Observed in Study	No. of Equipment Operators Interviewed
Load-Haul-Dump Machines	12	32	10	24
Rail Haulage Systems	21	201	5-Locos 5-Cars	27
Overcast Mucking Machines	1	66	8	22
Slushers	5	65	7	19
Skip Hoists	9	12	3	12
Shuttle Cars	6	29	3	10
Conveyors	0	12	3	6

*Fatal accidents during 1971-73 that could be directly associated with equipment operation.

**Non-fatal accidents history 1969-73 for the nine mines visited during this study, associated with equipment operation.

EXHIBIT I-2

SUMMARY OF RECOMMENDATIONS

Equipment Type	Type of Recommendation: Design Changes & Research	Type of Recommendation: Operator Protection on Equipment	Type of Recommendation: Procedural	Type of Recommendation: Regulatory	Expected Reduction in Accident Frequency
Load-Haul-Dump Machines	-Emergency Brakes* -Auxiliary Steering -Operator Compartments	-Falling Object Protective Structure (FOPS)*	-Pre-shift Check and Log Book* -Operator Education & Licensing*	-Increased Enforcement 30 CFR 57.3-20 through 57.3-23	40-65%
Rail Haulage System	-New Methods to Eliminate Chute Hang-ups -Mechanical Car Positioner -Increased Use of Automatic Self-Centering Couplers		-Car Loader Station Layout Guidelines -Track Maintenance Standards* -Rerailers on Locos* -Shelter Holes Location Guidelines*	-Increased Enforcement of 30 CFR 57. 9-110	45-50%
Overcast Muckers	-Operator Step Platform* -Lower C. G. and Minimum Track Gauge*	-Protective Guards*	-Return to Neutral Controls Should Operate*	-Increased Enforcement 30 CFR 57.3-20 through 23	50-70%
Slushers	-Slusher Cable Material Research -Anchoring Devices*		-Slushers Not to Be Relocated Under Their Own Power* -Station Layout Guidelines	-Increased Enforcement of Grizzlies on Pockets	55-60%
Skip Hoists	-Improved Shaft Communication System	-Guards at Loader Station*		-Apply 30 CFR 57.19-1 Through 135 to All Skips Where Men Ride	45%
Shuttle Cars	-Emergency Brakes*	-Guards to Protect Operator from Rocks off Haulage Beds*		-Increased Enforcement 30 CFR 57.3-20 through 23	40%
Conveyors	-Use Belt Cleaners	-Overhead Rock Guards*		-Increased Enforcement 30 CFR 57.14-33 through 35	50-60%

*Implementation recommended through regulation after adequate development.

Our recommendations to improve the operation and safety of LHD's are summarized below:

- Load-Haul-Dump equipment should require Falling Object Protective Structures (FOPS) in all underground applications. These protective structures should meet specified standards like those of the Society of Automotive Engineers. The design of these FOPS should not inhibit operator visibility and his ability to get on and off the LHD's with relative ease. Implemention of this solution would be through regulations requiring new LHD units to be equipped with FOPS. Additional research to develop the best program for retrofitting existing LHD's is recommended.

- LHD units should be equipped with independent service, parking, and emergency braking systems. All of these systems should conform to a minimum performance criteria and include additional features of:

  - Protection from mud and water conditions

  - Air-over-hydraulic systems that will provide an emergency energy source in the event of a pressure component failure

  - Dual or independent operating circuits

  - Operator warning devices for component failure

  Implementing this solution would be through a retrofit program on LHD units in use and required on all new equipment. Expected reduction in LHD accident frequency would be 10-20 percent.

- In the event of failure of hydraulic-type power, or power assist steering systems, a means should be provided to continue to maintain steering control of the vehicle with normal steering effort for a reasonable distance. This emergency system should conform to a specific performance criteria and provide a malfunction warning device. This solution would be implemented through regulation. However, general agreement regarding operation standards should be reached before considering such a regulation.

- Improved maintenance of work areas and active haulage areas must be done to minimize fall of rock hazards through increased compliance and enforcement of federal regulations 30 CFR 57.3-20 through 57.3-23. Operators must be trained more effectively in hazard identification, and pre-operational inspection procedures be set up at all mines. A 10-20 percent reduction in LHD accidents can be expected with improved care of work areas.

- Each LHD should be equipped with a safety check list to be used by the operator at the start of each shift, prior to beginning haulage operations. Also, each LHD should be equipped with an equipment log book in which the driver makes entries of problems encountered. Regulations requiring safety check lists and log books, now being considered by USBM, are endorsed by Theodore Barry & Associates.

- An education program, including academic and on-the-job training, should be developed for LHD operators. Upon successful completion of this program and demonstration of operating skill, the operators should be granted a license. Only such qualified operators should be allowed to operate LHD's underground. Following development of such a program by USBM, the implementation of this recommendation is estimated to reduce all LHD accidents by 10-15 percent.

- LHD operations should meet clearly specified criteria for maximum application in grade, equipment speed, road surface, lighting, water conditions, and clearances. Such clearly-defined criteria should be used to determine the acceptability, based on operational safety, for each LHD application in the underground mining industry.

- Operator compartments should be improved in the area of comfort, control and visibility. The impact of these areas on machine safety would depend largely on the magnitude of improvement achieved, but minimum reduction in LHD accidents is expected to be about two to three percent.

<u>RAIL HAULAGE SYSTEMS:</u> Accidents associated with rail haulage were studied under three groups: car loading, ore haulage and car dumping. Typical car loading accidents were victims struck by rocks from the chute either during chute drawing or while eliminating chute hang-ups. Haulage accidents were most often caused by derailment, collisions, rerailing equipment, coupling/uncoupling cars, and pedestrian runover or pinned against the rib. Car dumping accidents were usually due to exposed ore passes or lack of guards and car tip-overs striking the operator.

Recommendations to improve the safety of rail haulage systems are briefly described below.

- The USBM should undertake a research effort to develop alternates to barring chute hang-ups, especially at the secondary levels. An expected reduction of five percent of rail accidents could be realized with these improved methods.

- Specific guidelines for loading station layouts, spelling out minimim clearances, suggested location of controls, and operator platforms, etc., should be developed and disseminated to the mining industry.

- We recommend the development of mechanical car positioning methods in which the car loader can independently control the positioning of cars without motorman's assistance.

- Track preventive maintenance programs should be required in underground metal and non-metal mines, and specific standards should be developed for acceptable and unacceptable track conditions. Improved track maintenance can be expected to reduce accidents by 10-20 percent.

- All locomotives used in underground metal and non-metal mines should carry rerailing devices. All persons involved in rerailing cars or locomotives should be trained and required to follow a specified procedure to accomplish the task in a safe manner. Expected reduction in rail accidents would be five percent.

- Increased use of automatic self-centering couplers for underground rail haulage equipment should be encouraged. Automatic couplers would reduce accident frequency by 5-7 percent.

- Specific guidelines determining (a) the minimum required distance between shelter holes, and (b) minimum clearances in rail haulage drifts need to be developed. In addition, increased enforcement of regulation CFR 57.9-110, ensuring pedestrian safety in haulage drifts is recommended. These guidelines and increased enforcement would reduce rail accidents by 5-7 percent.

- Minimum braking system performance criteria should be developed for trains or locomotives used in underground metal and non-metal mines. All trains and locomotives should be equipped with brake systems which conform to these minimum performance standards. Expected reduction in rail accidents would be 7 percent.

OVERCAST MUCKING MACHINES: Primary accidents associated with muckers (rail and rubber-tired models) were: operators pinned between machinery and the rib, fall of rock on the victim, or when the operator was struck by muck spilling from the bucket while operating the mucker. Typically, operators were pinned between the mucker and the rib wall as a result of equipment tip-over or working in extreme tight areas. Equipment tip overs often result do to (a) high C. G. of mucking machines, (b) operation on too narrow a track guage, (c) operating on unsupported rails and, (d) bucket bumping into drift walls during breakout operations. Fall of rock accidents occur primarily due to to the failure to bar down loose rock before operating the mucker. Most of the injuries due to muck spillage occur when the operator is struck by rocks off the bucket or conveyor while operating the mucker.

Recommendations to improve operations and safety of overcast mucking machines are briefly summarized below:

- The USBM should undertake a research effort to develop methods to improve stability of mucking machines. These solutions could be in the areas of: (a) modifications in mucker equipment design that will result in a lower center of gravity and, (b) minimum acceptable track gauge dimensions on which various mucker models should operate. No reliable information now exists regarding the safe width of tracks on which muckers with high C. G. should operate. The data provided by equipment manufacturers is not adequate at all times. The recommended research will provide reliable information on this point to both the mine operators and inspectors. It is estimated that when the results of this research are implemented, at least 15-20 percent of injuries related to muckers can be avoided.

- We recommend that existing step platforms on the mucking machines should be modified to improve operator protection. Some essential features for this modified platform would be (a) the ability to retract when equipment is to be transferred, (b) mucker would not operate without platform in position, (c) design characteristics that deter tip-overs and protect operator's feet. This recommendation can best be implemented through regulation immediately following the development and redesign of operator platforms. Expected reduction in mucker accidents would be 10-15 percent.

- Improved enforcement and compliance with current federal regulation 30 CFR 57.3-22 is required to minimize fall of rock hazards. Mucker operators must be trained more effectively in loose-rock-hazard identification and regular pre-operational inspection procedures be followed at all times. Accident reduction due to increased attention to loose rock can be expected in the 10-15 percent range.

- Overcast mucking machines should be equipped with adequate guards in front of the operator to protect him from rocks rolling off the loaded bucket. Though the installation of this protective guard will not eliminate the rocks thrown off the bucket, it will substantially reduce serious injuries to mucker operators 10-15 percent.

- The "return to neutral" devices on all controls should be operational at all times during mucker operation. Theodore Barry & Associates suggest that this recommendation be implemented through a specific and clear regulation. It is expected that about five percent of severe mucker accidents will be reduced after complete implementation.

SLUSHERS: Typical slusher accidents were found to be either due to the operator getting hit by a flying rock, or due to the cable snap-back, a result of cable failure. Slusher operators also get injured due to improper anchoring and tie down of slusher equipment, or while moving slushers from one location to another, under their own power. Twenty percent of all slusher accidents result from slips and falls around the slusher station.

Our solutions to minimize the above mentioned hazards are as follows:

- Steps should be taken to minimize cable failure. Research is required to develop new materials that will not fail easily under extreme conditions of fatigue and wear associated with slusher operations. Criteria needs to be developed to improve inspection of slusher cables. No rigorous criteria, such as SAE standards, currently exists that can help either the mine inspectors or supervisors to determine the adequacy of slusher cables. A research program to improve slusher cable can be expected to reduce slusher accidents by 10-15 percent.

- Slushers should not be moved under their own power, unless operated by a remote unit. In addition, an operator should not ride a slusher while it is being moved. Improved relocation methods must be targeted at slushers already in service as well as new equipment. Strict enforcement of this proposed regulation can reduce slusher accidents by 10 percent.

- Specific guidelines spelling out minimum clearances at the operator station, adequate anchoring criteria, minimum size of walkways around the ore pocket, etc., need to be developed and disseminated to the mining industry. Research on new anchoring devices is required. Increased enforcement of grizzlies on ore pockets and guards on slushers is needed.

SKIP HOISTS: Accidents associated with skip hoists repeatedly occur during skip loading, when loaders are struck with muck splash from the measuring pocket, ore pocket or the skip. Additionally, personnel riding skips were involved in the majority of fatal accidents associated with skip hoists. Flying rocks represent a major hazard during loading, maintenance, and shaft cleaning activities. Severe accidents also occur when, due to a breakdown in communication, the skip hoist is accidently started while there are personnel (maintanance, repair or clean-up crew) in the shaft.

Our recommendations to minimize the hazards associated with skip hoists are briefly discussed below.

- Manual skip loading stations should either be equipped with adequate protection from falling rocks and surge of muck, or they should be relocated so that the operator is not in the path of falling debris or muck surges from the chute. In addition, the use of measuring pockets should be encouraged. Some additional suggestions to reduce skip loading accidents are stricter control of oversize rock and chute hang-up elimination devices. Reduction of 20 percent in skip hoist accidents and increased productivity can be expected through skip loading station modifications.

- Any hoist used to transport men at any time, other than shaft inspectors, should conform to the standards as stated in 30 CFR 57.19-1 through 57.19-135. Theodore Barry & Associates feels that stricter inspection, enforcement and mine compliance to these expanded regulations would effectively reduce accident frequencies in skip hoist operations by 15 percent.

- All hoisting systems should have a continuous verbal method for signaling hoist operators from skips, cages or other conveyances, at any point in the shaft. Continuous communication systems are available in various types for application in the mining industry. Savings in information relay time, with increased accuracy and expected accident reduction of 10 percent, is likely to return much of the costs of implementing such a device.

<u>SHUTTLE CARS:</u> Recurring accidents associated with shuttle cars were either operators struck by rocks or equipment collisions. Operator injuries caused by rocks were due to rocks rolling off haulage beds and due to fall of rock from the roof. Collisions were often caused by equipment malfunction of braking systems. Operator visibility was also noted as a deficiency in most shuttle car models.

Our recommendations to minimize hazards associated with shuttle cars are:

- Screen guards or shields to protect the operator from rocks off the haulage bed should be required on all conveyor-bed-type shuttle cars.

- Improved maintenance of work areas and active haulage drifts must be done through increased compliance and enforcement of regulation 30 CFR 57.3-20 through 57.3-23.

- All diesel operated shuttle cars should be equipped with independent service, parking and emergency brakes. In addition, these braking systems should conform to a specific performance criteria. It is expected that 30 percent of shuttle car fatalities and 15 percent of non-fatal accidents can be reduced through improved braking systems.

- Each shuttle car should be equipped with a safety check list to be used by the operator at the start of each shift prior to beginning haulage operations.

  Also, each shuttle car should be equipped with an equipment log book in which the operator will make entries of problems encountered.

CONVEYOR SYSTEMS: Typical conveyor accidents occur when a maintenance man is caught in the moving conveyor and when personnel in the vicinity of overhead conveyors are hit by rocks falling off the moving belt. Hazardous exposure in most cases is the failure to stop conveyor movement while working on or around the equipment.

A brief summary of recommendations to reduce conveyor hazards are:

- Stricter inspection enforcement and mine compliance, accompanied by expanded interpretation of federal regulations 30 CFR 57.14-1,3,29,33,34,35 is required. Automatic devices to turn off the equipment when guards are removed and scheduled maintenance programs can aid in accident prevention. Expected accident reduction through these methods would be 25-30 percent.

- Belt cleaners should be used on conveyors to eliminate build-up of material and carry-back of broken ore. These devices installed on appropriate conveyor systems would minimize the need for cleaning activities and can reduce accidents by 10 percent.

- Adequate protective rock guards along conveyors should be required when uncrushed rocks are handled and when personnel need to walk near overhead conveyors. Expanded interpretation and increased enforcement of regulation 30 CFR 57.14-11 is expected to reduce accidents by 15 percent.

ADDITIONAL COMMENTS

Some additional observations, a result of this study are enumerated below:

- There is a definite need to significantly improve the accident data collection system and procedures. A number of deficiencies were observed in the existing accident reports which handicapped our analysis. Important information, like equipment models involved, operator training and experience, cause of accident, etc. were not available from the non-fatal accident reports. In addition, severity figures were often found skewed and not reported accurately. Frequently, the victim is reassigned to menial tasks in order to minimize the reported severity associated with the accident. Such deficiencies should be eliminated to improve the results from equipment safety evaluation studies.

- Many of the existing regulations governing the safety in underground mines were found to be too vague. This vagueness leads to misinterpretations and it augments the problems of mine operators during compliance, and the problems of inspectors ensuring their enforcement. Pertinent examples have been cited at various places in this report.

- There is a need to continually update equipment safety standards and procedures. We found that these safety regulations have not kept pace with the technological advancements in the mining industry. Safety guidelines on new pieces of equipment are too often written after the equipment is in operation in mines for a considerable length of time. No procedures exist by which a new piece of equipment is required to meet safety guidelines specifically meant for that machine. Old safety standards continue to be applied to new technologically sophisticated equipment. This stagnation of safety standards must be prevented.

SECTION 3

STUDY APPROACH

STUDY APPROACH

The safety of mining equipment is a concern of many interest groups. The mine management, supervisors, equipment manufacturers, union officials, USBM personnel, and the equipment operators, all have important inputs regarding the operational safety of ore handling equipment. This study was structured to include all these essential inputs.

The study approach basically consisted of; (a) an analysis of historical accident reports to identify problem areas, (b) field visits to nine selected mines and major equipment manufacturers to investigate these problem areas, and (c) the development of recommended solutions to reduce the accidents and the injuries to the victims. The study method outline is described below:

1. <u>Selection of mines:</u> Nine mines were selected to observe equipment operations and interview equipment operators, mine management and other pertinent personnel. Specific criteria utilized in this mine selection process were:

    - Management's willingness to permit observations by the study team.
    - Availability of current and complete accident history.
    - Typical mine in the underground metal and non-metal industry from the standpoint of size, mining method and operating practices.
    - Opportunity to observe more than one category (model as well as type) of the pieces of equipment included in this study.

2. <u>Analysis of past accident reports:</u> A thorough review of all the available fatality reports associated with the study equipment (1971-73) was conducted. In addition, all the non-fatal lost time accident reports available from HSAC records and the individual records at each of the nine mines in the study sample for a five year period (1969-73) were also analyzed. Common factors were selected to describe each accident (Appendix A)* and specific factors were also selected to describe accidents associated with each of the seven pieces of equipment (Appendices B-H)*. All of these factors were oriented towards man-machine interaction problems, environmental effects and work procedures to provide statistics consistent with the goals of this study. Each report was read and coded

*These Appendices have been bound under separate cover.

on an 80-column card image coding sheet. The SPSS (Software Package for Social Sciences) was used to run frequency distributions and cross tabulations of the accident factors on the computer. Appendices B through H document the important results of this analysis.*

3. Mine Visits: Detailed observations of the operation of the equipment were conducted at the nine mines. These observations included equipment maintenance practices, available operator protection, exposure to hazards, work area and the existing environment, etc. Equipment operators and mine operators were extensively interviewed during these visits. Data was collected in the following areas:

   - Operator training procedures
   - Experience on machine
   - Location of controls
   - Operator comfort (visibility, fatigue, etc.)
   - Likes and dislikes regarding various safety features

4. Interviews with major equipment manufacturers: Concurrent with these mine visits, interviews with leading equipment manufacturers were also conducted to assess the state of the art in equipment design. In addition, we solicited their ideas regarding the following topics:

   - Major design problems
   - Difficulties in coupling with USBM requirements
   - Operator acceptance problems
   - Future steps to improve operator safety
   - Operator and maintenance training programs

5. Interface with MESA inspectors: Interviews were conducted with a number of MESA inspectors across the country. The objective was to solicite their ideas regarding the enforecment and compliance problems of federal regulations and the required modifications to the regulations.

6. Data Analysis and Results: Our findings and recommendations, based on the analysis of the collected data, are presented in the following sections of this report. Theodore Barry & Associates feels that the results of this study will contribute significantly towards the reduction of hazards in underground metal and nonmetal mines in the United States.

*Bound under separate cover and available on library loan from Bureau of Mines, Spokane Mining Research Center, Spokane, Washington.

SECTION 4

STUDY RESULTS

STUDY RESULTS

This section of the report documents the details of the information gathered, the identified hazards, the conclusions reached and the solutions recommended to improve the operations and safety of each type of equipment studied. Each project has been written in the following general format to insure easy reading and comprehension:

- Problem: This section identifies and discusses the major safety problems associated with the equipment. The discussion includes a description of the typical accident(s) occurring, the personnel generally involved, the percentage of fatal and non-fatal accidents it represents and other cogent facts.

- Hazards and Causes: Using the results of the field visits, the accident analysis, etc., the hazards present and the probable causal factors of the accident are discussed. These hazards and causes are the potential areas for improvement.

- Recommendations: The solutions presented are those that Theodore Barry & Associates feels can result in improving operations and safety of the equipment. Each recommendation is a one or two sentence statement which is numbered and underlined. This statement is followed by a complete discussion of the recommendation, noting alternatives considered, data collected, field observations made, relevant regulations and statements of opinion. At the end of each solution, items such as industry impact, cost, methods of implementation and impact on accident frequency are discussed.

- Summary: A brief chart summarizing the recommended solutions is given. The chart shows the recommendations, the accident frequency reduction, estimated costs and suggested implementation procedure. Additional thoughts or comments which may prove helpful to the Bureau are also included here.

The details of the accident analysis for each equipment type are documented in the Appendix which is bound under separate cover.* Various pertinent accident frequency, table by accident location, victim activity, causal agency,

*Bound under separate cover and available on library loan from Bureau of Mines, Spokane Mining Research Center, Spokane, Washington.

etc., are documented for each equipment type, under a separate Appendix. In addition, useful cross-tabulation (e.g. victim activity vs. causal agency, etc.) are also presented. Pertinent references to these tables are made in the report text.

Theodore Barry & Associates feels that the results of this project will provide the Bureau of Mines with information and direction it is seeking to initiate a full-scale effort to improve safety in underground metal and nonmetal mines in the United States.

LOAD-HAUL-DUMP MACHINES

The use of Load-Haul-Dump equipment is gaining popularity in the underground metal and nonmetal industry. Much of this popularity can be attributed to the LHD's flexibility and independence in its use for production as well as development operations. The physical size of the LHD equipment has increased significantly over the past few years, but, it appears, that the safety aspects of this equipment have not kept pace with its increase in popularity and size.

PROBLEM STATEMENT

The majority of lost-time accidents (fatal and non-fatal) associated with LHD equipment are typically caused by (a) Fall of rocks and (b) Equipment collisions and runaways. An average of 50 man-days are lost for every non-fatal LHD accident.*

"Fall of Rocks" result in frequent injuries to the LHD operator because of: (a) The absence of any substantial overhead protection provided on the equipment and (b) The failure to adequately trim or bar down the working areas. Contrary to the common belief, the bulk of the injuries due to "fall of rock" occurred in the haulage drifts rather than at the loading face.

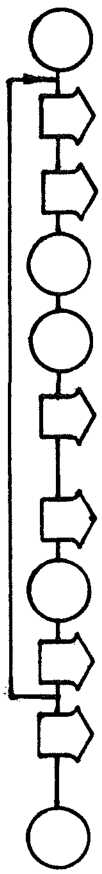
"Equipment Collisions and Runaways" were found to occur due to a combination of a number of causes, such as brake/steering failures, haulage drift, road bed conditions and grade, inadequate operator visibility and lack of proper operator training. Most of the injuries due to equipment failures were found to result from inadequate maintenance practices as well as from a lack of adequate back-up brake/steering systems.

HAZARDS AND CAUSES

Exhibit II-1, on the next page, shows the relationship between the percentage time spent on various tasks and the percentage frequency of accidents associated with those tasks. It is evident that an LHD operator spends about 60 percent of his time on haulage activities (empty or loaded), while haulage is associated with about one-half of the LHD accidents. In addition, about 20 percent of the work time is spent at the face, during loading activities, and results in about ten percent of the accidents. The accident analysis showed that most of the injuries at the face were due to fall of rock, while those during tramming were due to collision or runaway.

*Based on the severity data of LHD non-fatal accidents for the study mine sample (1969-73).

Typical LHD Operation Breakdown



Tasks	Analyzed Accident* Frequency	Estimated % of Total Work Time of LHD Operator	Estimated Hazardous Exposure Duration Task
1. Start Equipment	2.3	3%	5%
2. Tram to Muck Pile	11.4	30%	100%
3. Approach Face		5%	
4. Lower Bucket		2%	
5. Load Bucket	6.8	10%	100%
6. Reverse LHD and Raise Bucket	4.5	5%	80%
7. Tram to Dump Location	36.4	30%	100%
8. Dump Bucket	2.3	4%	5%
9. Reverse		2%	
10. Tram to Parking Location	6.8	7%	30%
11. Park and Shut Down	2.3	1%	5%
Total	70.5%	100%	100%
Other Tasks			
On and Off	6.8%		
Repair	11.4%		
Unknown	11.3%		
	100.0%		

*Indicates proportion of LHD accidents associated with the task -- from past accident reports. Appendix B-4.

Exhibit II-2 summarizes the relationship between the type of LHD accidents and the probable cause(s) of those accidents. Although the existing non-fatal accident reports make it impossible to accurately identify causes of operator injury in over 50 percent of the cases, we feel that important insight is provided by the limited information in Exhibit II-2. Our own observations and extensive interviews with the LHD operators, maintenance personnel, supervisors and equipment manufacturers, not only confirmed the accident causes outlined in Exhibit II-2, but also revealed additional hazards associated with LHD equipment. Our findings are discussed below for the two major accident types.

1. Fall of Rock: At least 25 percent of all LHD lost-time accidents can be attributed to fall of rock. Operators are being continuously exposed to the hazard of falling rock, primarily at the face and along the haulage drifts. Our observations, and interviews with inspectors and operators indicate a frequent failure to trim loose rock at all work areas and along the haulage drifts, as required by Federal regulations 30 CFR 57 3-20 thru 57 3-23. Many operators stated that "it is not my job" to bar down loose rock along their work areas. The problem is compounded in the case of contract miners who are paid by the ton produced. These miners tend to shorten their job cycle times by eliminating the barring procedure, or trim during cleanup. In some instances, even large slabs or faults can go undetected over a long period of time, and then fall on an unsuspecting operator, resulting in severe injuries.

   By and large, no substantial protection is available to LHD operators from falling objects in the underground metal mining industry today. Present requirements of protective devices to minimize the effects of rock falls and other operator injuries are stated in the Federal Register under 30 CFR 57 14-13, where "substantial canopies be provided when necessary to protect the operator." Our field observations revealed that almost all LHD units are operating underground with no canopies or any protective structures at all, as documented in Exhibit II-3. Only in a few instances during the accident analysis, we discovered the use of some overhead protection on LHD, but in those cases, the protection structure was not designed with adequate strength and integrity and therefore was unsuccessful in preventing injuries to the operator.

2. Collisions: Again, at least 25 percent of all lost-time LHD accidents resulted from collisions. Collisions were generally found to result from one or a combination of the following causes:

SUMMARY OF LHD ACCIDENT ANALYSIS

Accident Type	% of Accidents	Accident Causing Agency (% LHD accidents by agency for each accident type)				
		Lack of Operator Protection	Brake/ Steering Failure	Operator Visibility	Operator Training	Unknown*
Collisions	25.0	2.3	13.6	2.3	✓	4.5
Fall of Rock	25.0	20.5			✓	4.5
Struck by moving part	9.1	2.2			✓	6.8
Struck by moving equipment	4.5			2.2	✓	2.3
Others/unknown*	36.4		2.3		✓	38.3
Totals	100.0	25.0	15.9	4.5	--	56.4

Source: Appendix B-5,B-9 (Bound under separate cover)

*Existing accident reports were unable to provide reliable information in these cases

EXHIBIT II-2

Exhibit II-3

No Falling Object Protection for LHD Operator

Exhibit II-4

Example of Steep Grade

- Equipment malfunction, especially brakes and steering
- Poor visibility
- Operator inexperience and unfamiliarity with LHD equipment.

We will discuss each of these in detail.

- <u>Equipment Malfunction</u>: Equipment failure was the principal cause in over 50 percent of all LHD collisions. Typically the failure of braking systems, steering and hydraulic systems were found to result in collision-type accidents. In many instances, brakes and steering systems were found to be inadequate for the conditions under which the LHD's were being used in the underground mines. For example, the existing mud and water conditions in many haulage drifts underground have a deteriorative effect on braking systems. Upon failure of these systems, while tramming, an operator is generally confronted with an out-of-control situation. Adverse circumstances encountered in the haulage drifts, such as high grades (see Exhibit II-4), poor road surface, mud and water in the drift and restrictuve clearances usually add to the hazards associated with "loss of control" situations. Additionally, adequate back-up systems for critical functional requirements like brakes, steering and hydraulic systems are neither required nor available in the majority of the LHD's underground.

  The problem of equipment malfunction is not due to design considerations only, but also extends from the generally poor maintenance practices on the LHD's. Availability of LHD's, during our field observations, ranged from 50-75 percent - a factor that should be of concern to the mining industry. Adequate LHD maintenance programs are scarce in the mining industry. Evidence of fighting crises and incidences of "patch work" in LHD's were frequently encountered during our study. Many operators and maintenance personnel acknowledged that, occassionaly, the repair of some LHD units was cut short because of production priorities. Typically, the repair items are brakes, hydraulic hoses, steering systems, tires and engines. Since the failure of these items can put the LHD operator in a dangerous situation, we have strong reason to believe that lack of regular attention to the maintenance of LHDs is responsible for many accidents.

- <u>Poor Visibility</u>: The accident analysis revealed visibility to be usually a contributing factor to an accident rather than the major cause of the accident. About ten percent of the collisions can be partially attributed to poor visibility. The problem with the LHD's is one of obstructed vision. This occurs when the operator's vision is restricted or blocked by a part of the machinery causing a "blind" area. LHD operators in many cases cannot see within 50 feet in the direction of travel and extremely small areas are visible on the opposite side of the vehicle from the usual operating compartment. Exhibit II-5 shows a typical LHD visual area analysis. It appears that these blind areas developed by LHD equipment design result in potential hazards, especially to an inexperienced LHD operator, because he has to steer the vehicle by feel only.

- Operator Inexperience with LHD Equipment: Although not readily evident from the available non-fatal accident reports, the field visits and interviews revealed the correlation of frequency of accidents and the LHD operator's experience and training on the equipment. This fact was confirmed from the information gathered from the analysis LHD's fatality reports across the U.S. for the period 1971 thru 1973. The bar graph documented as Exhibit II-6 shows that in about one-half of all fatal accidents associated with LHD's, the operator's experience was six months or less.

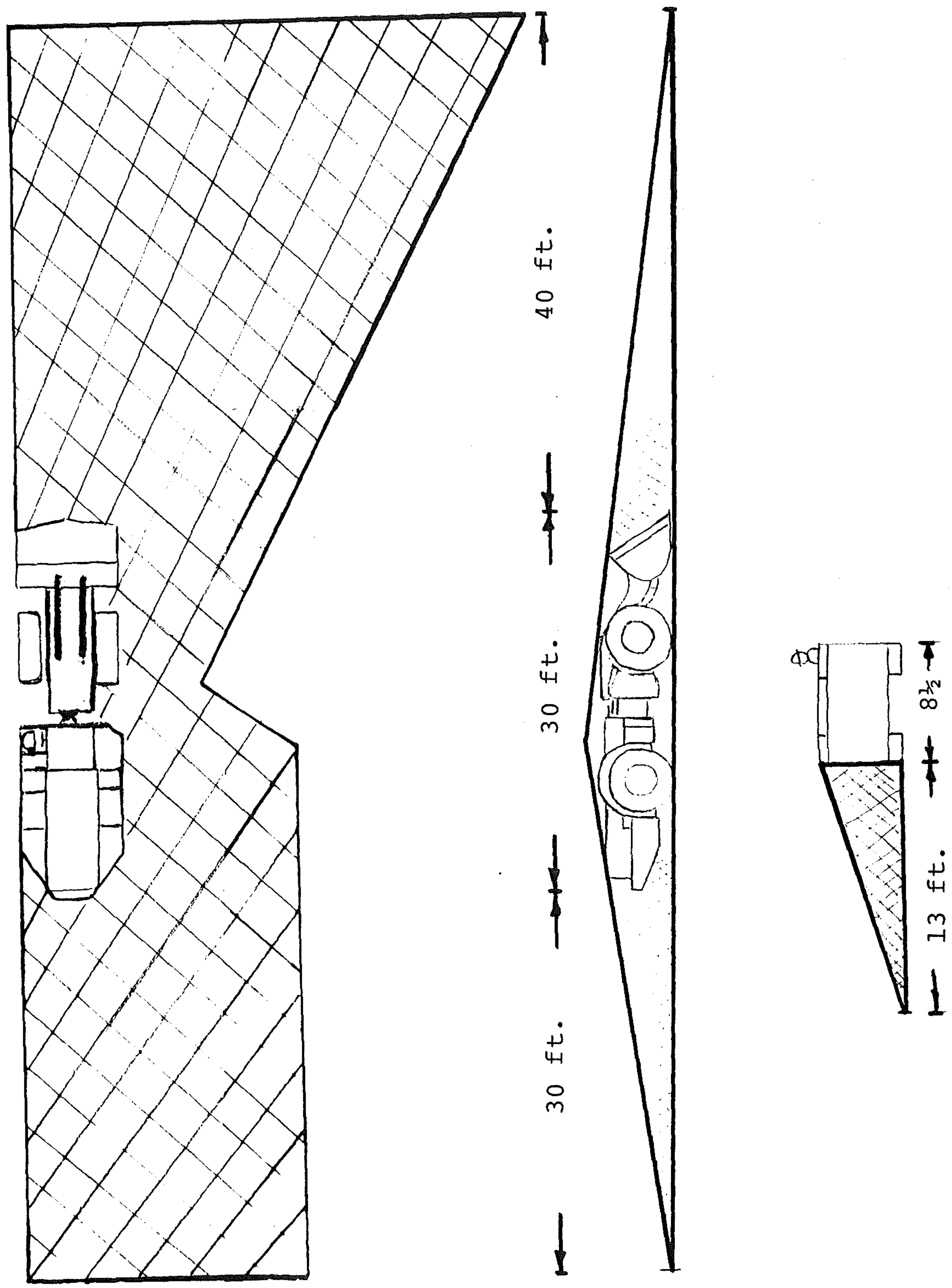
  The increasing size, complexity and sophistication of the LHD equipment demands more and more qualified operators. The mining industry, in general, has not responded adequately, as yet. Most of the LHD operators in the field were generally found to be exposed to no formal training programs. Most of them learned about the equipment from being around another operator, and acquiring the feel of the equipment by trial. Requirements of minimum qualifications and a certification program for LHD operators was encountered at only one of the nine mines visited during the study.

3. Additional Hazards: Our field visits and interviews revealed that the performance and safety of the LHD equipment might be adversely affected by the existing designs of operator compartments. Many manufacturers of LHD equipment acknowledged that the placement and features of the operator's compartment were usually the last items considered in the design of the vehicle. A number of deficiencies were observed in the existing designs of operator compartments. These will be discussed in detail in the recommendations section below.

In summary, the major hazards and causes associated with LHD equipment are as follows:

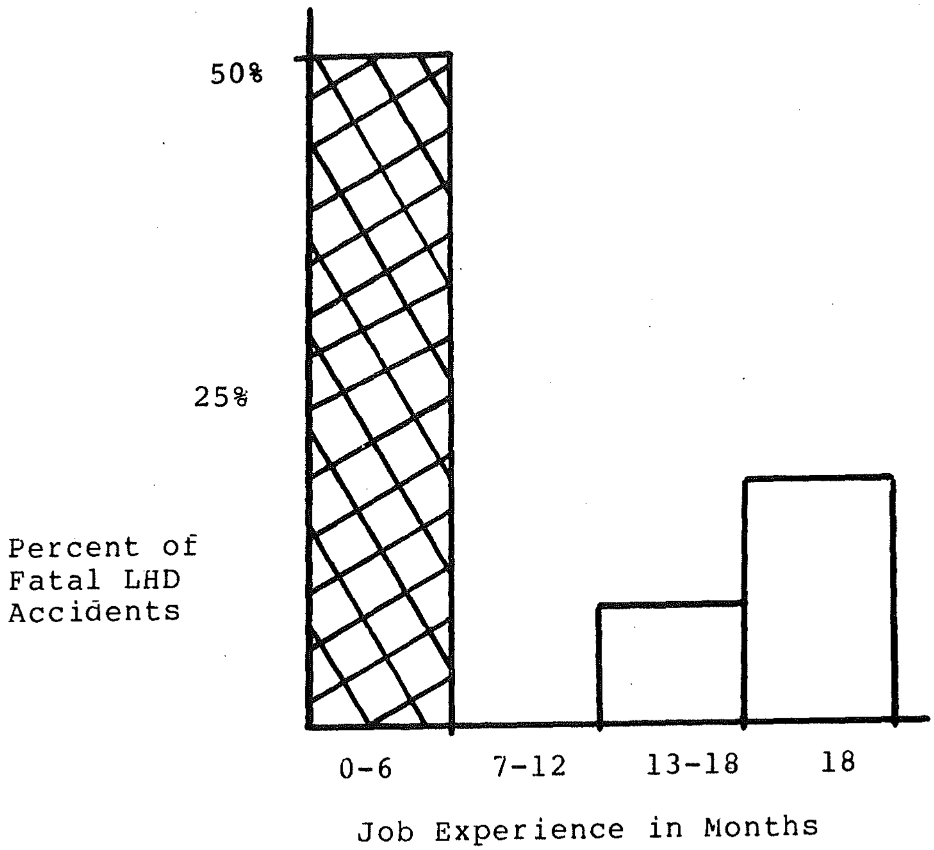
- Lack of adequate operator protection from falling objects

- Inadequate maintenance of work areas



Typical blind areas associated with LHD equipment.
(Not to Scale)

Correlation of LHD Fatal Accidents and Operator Experience



- Equipment malfunction and back up systems, especially for brakes and steering

- Equipment maintenance programs

- Operator experience and training

- Poor road bed and excessive grades

- Design of operator compartments

RECOMMENDATIONS

Our solutions to improve the operation and safety of LHD equipment are presented in this section. These cover certain equipment modifications, additional safety devices, and improved procedures and regulations. These solutions attempt not only to minimize the cause of the accident, but also address themselves to minimize the injury to the victim, once the accident occurs.

1. Falling Object Protective Structures (FOPS): Load-Haul-Dump equipment should require Falling Object Protective Structures in all underground applications. These protective structures should meet specified standards like those of the Society of Automotive Engineers, and also incorporate the features discussed below.

   The existing regulation covering protective structures is 30 CFR 57.14-13, Mandatory Safety Standards for Surface and Underground Metal and Nonmetal Mines. It states that "Fork-lift trucks, front-end loaders, and bulldozers shall be provided with substantial canopies when necessary to protect the operator." Theodore Barry & Associates suggests this regulation be modified to require protective structures in all LHD underground applications.

   Though the installation will not eliminate the incidents of falling objects, they can substantially reduce the chance of serious injuries given that a fall does occur. Little can be done with protective hardware to ensure safety during a massive roof fall, but the action of a protective structure will minimize the effects to the greatest extent possible. We feel that the changes proposed here would be more readily acceptable to the mining industry if it is demonstrated that the FOPS can withstand the loads they will be subjected to. During our mining observations, it was questioned whether or not structures would be a workable solution. We feel that successful application of FOPS systems must incorporate the following features:

   - Visibility restrictions by FOPS must be minimized.

- Ingress and egress from operator station must be made easily.

- Performance criteria for FOPS as stated in SAE J231 must be met.

The question of retrofitting FOPS on existing LHD's also deserves consideration. Due to the long life of LHD's, we feel that eventually all existing LHD's should be fitted with FOPS. The dimensions and available clearances, however, in existing haulage drifts may preclude the use of FOPS in many instances. Therefore, we suggest that USBM carefully conduct further investigation as to the economics and feasibility of retrofitting LHD's with FOPS. Many equipment manufacturers offer FOPS as an optional accessory but almost no mine operators exercise this option today. The retrofitting of FOPS on these existing units should, therefore, present no major mechanical problems. It is estimated that retrofit costs will be approximately $300-$500 per unit, and additional costs for new equipment would be comparable. This would affect an increase in base price of approximately .005 percent. Theodore Barry & Associates feels that the best method of implementing this solution would be through regulations requiring all LHD units operated in underground metal and nonmetal mines to be equipped with FOPS conforming to SAE J231 standards.

2. <u>Braking Systems: All LHD units in underground metal and non-metal mines should be equipped with independent service, parking, and emergency braking systems. All of these systems should conform to a "Minimum Performance Criteria" of the type specified by SAE J237 for Braking Systems for Off-Highway Rubber-Tired, Front End Loaders and Dozers. Additional features outlined below should also be incorporated to improve the LHD braking systems.</u>

   At the present time, brake systems which comply with the above mentioned SAE standards are required by Department of Labor, Occupational Safety and Health Administration (OSHA)* on all surface construction front-end loaders manufactured after January 1, 1972. No such requirement exists in Part 57 of Mandatory Safety Standards for Underground and Surface Metal and Nonmetal Mines. As a result of OSHA regulations, these systems are now standard on equipment of most makes on surface front-end loaders. The adaptation of these braking system requirements for underground use, in most cases, would mean only the addition of an independent emergency system. The existing LHD's frequently have combined parking and the emergency brake systems. Inadequate braking systems are mentioned as a common contributing factor in LHD

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*Section 1926-607 a(4) of Safety and Health Regulations for Construction.

accidents, as shown in Exhibit II-2. Theodore Barry & Associates feels that an independent emergency brake system, in addition to parking brakes, will go a long way in minimizing hazards involved with brake failures. We also recommend that each of the three independent braking systems mentioned above must perform to a minimum criterion of the type specified by SAE standards. We recognize that SAE performance criterion for Front End Loaders is available for speeds in excess of 20 M.P.H. LHD in underground operations generally travel at much lower speeds. Relevant performance criterion for LHD applications must be developed and supplied to the mining industry, and enforced by regulation.

In addition, Theodore Barry & Associates suggests that the following features be also incorporated to improve the performance and reliability of LHD braking systems:

- Brake units should be better protected from muck and water conditions in the haulage drifts. Various types of splash shields and backing plates have been used with very limited success to protect the brake disc or drum from muck. One leading manufacturer of surface front end loaders and agricultural equipment is currently using a sealed brake unit to protect brakes from muck and water. Research needs to be done to extend the applicability of the similar concepts in the underground mining industry.

- All vehicles equipped with air or air-over-hydraulic braking systems should be provided with an additional air supply, or emergency source of energy so that in the event of a failure in an air hose, tank, or similar pressure component, the additional source would be capable of stopping and holding the vehicle on any operating grade. This stopping and holding system should conform to the minimum standards of brake performance (SAE J237).

- LHD vehicles equipped with hydraulic braking systems should have dual or independent operating circuits so that in the event of a single brake unit failure, the remaining system will perform to minimum standards. This is similar to a current required regulation, 265 of Mines Regulation Act of British Columbia.

- In all braking safeguard systems warning devices should be incorporated to inform the operator of component failure.

- Temporary repairs or "patch work" on braking systems such as blocking out a defective wheel unit should be discouraged.

Implementing these recommendations for maximum effectiveness would be through a retrofit program of emergency systems on all LHD units currently in use. Since many of the above features are already in use, or available as options for the existing LHD's, mine operators should have little difficulty in complying with a regulated retrofit program.

3. Auxiliary Steering Systems: In the event of failure of hydraulic type power, or power assist steering systems, a means should be provided to continue to maintain steering control of the vehicle with normal steering effort for a reasonable distance. An audible and/or visual device should be provided to alert the operator that a failure of the primary steering power source has occured.

Currently, an Ad Hoc Committee of Sub-Committee XIX--"Remote and Automatic Controls"--of the Society of Automotive Engineers' Construction and Industrial Machinery Technical Committee is working on the final stages of a performance criteria for emergency steering of off-highway, wheeled construction machines, SAE XJ53. Once these standards are finalized, they will represent a general industry consensus on the requirements of such a system. Presently, several different auxiliary steering systems are either available as options, or are in the research stage.

An "electrically powered system" is now available from many manufacturers of surface type front-end loaders. Research and further development is also being done on "ground driven pump systems" and "accumulator systems," for LHD's and related equipment groups. Currently, Canadian Department of Mines and Petroleum Resources also requires auxiliary steering systems for LHD units operated in that country.*

We feel that the addition of an auxiliary steering system as outlined by the SAE and Canadian requirements would significantly reduce the chances of an out-of-control situation on LHD units. Loss of steering control has been identified as a contributing factor on LHD accidents. Dependency on hydraulic pressure is one of the major difficulties in steering control. In the event that an engine dies or if a hydraulic component fails, loss of steering is immediate. Continued control is also necessary with the combination of emergency braking systems, since vehicles continue to travel for a limited distance after activation. The benefit of reduced accident frequencies would then have no effect on the productivity of LHD's.

* Province of British Columbia, Mines Regulation Act, Chapter 25--Rule 266 (b).

It has been estimated that the cost of such a unit will range anywhere between $1,000 and $1,500, or approximately two-thirds of one percent to one percent of the total cost of the machine.

The best method of implementing such a solution would be through regulation. However, before considering such a regulation, general agreement should be reached regarding the performance standard and operation standards for service, as well as auxiliary steering systems.

4. Trimming Procedures: Improved maintenance of work areas and active haulage areas must be done through increased compliance with and enforcement of federal regulations 30 CFR 57.3-20 through 57.3-23.

   Inadequate maintenance of work areas and haulage drifts have been an important contributing factor in LHD accidents. Almost all of these accidents were the result of unbarred loose rocks or slabs which fell during the operation of the equipment. Throughout our field work, we observed LHD operations in areas where less than adequate attention had been given to loose rocks left on the rib or back after the blasting cycle. Theodore Barry & Associates feels that operators must be trained more effectively in hazard identification, and regular pre-operational inspection procedures be set up at all mines. Increased compliance by mine operators to regulation 30CFR 57.3-20 through 57.3-23, and increased enforcement of the same is definitely required in the LHD work areas.

5. Pre-Shift Check List and Equipment Log Book: Each LHD should be equipped with a safety check list to be used by the operator at the start of each shift, prior to beginning haulage operations. Also, each LHD should be equipped with an equipment log book in which the driver is to make entries of problems encountered during the shift, including equipment malfunctions and items which require maintenance attention.

   The pre-shift safety check list should be developed by the mine personnel, with the assistance of LHD manufacturers. A good guideline for development of the check list is SAE Recommended Practice J153, "Safety Considerations for the Operator." The check list may differ as to specific items from one LHD model to another, but generally should include:

   - Check log book for problems which may have occurred on previous shift,
   - Required safety equipment on machine,
   - Seat adjusted and latch secure,

- All guage readings correct,
- Steering systems operating properly,
    - Service system and emergency system
- Braking system working properly,
    - Service system
    - Parking brake
- Air pressure in operating range,
    - No air system leaks
- Fluid levels correct and no system leaks,
    - Hydraulic
    - Engine oil
    - Coolant

The equipment log book would be used by the LHD operator to communicate to the next driver any problems encountered during his shift and to notify maintenance personnel that a problem exists. In addition, the driver should notify his foreman as soon as practical of any problem which has arisen during the shift, to determine if immediate repairs are necessary to maintain a safe operation. This equipment log book should always remain with the particular LHD unit. Exhibit II-7 shows how one mine keeps their equipment log books.

There should be sufficient space provided in the log book for a mechanic to enter all work done on the vehicle and to "sign off" problems when repaired. The master mechanic or his designee should be required to review the log book periodically and initial and date each page. It must also be available for inspection by MESA personnel.

The impetus for recommending safety check lists and equipment log books is subjective information resulting from discussions with mine operators, and equipment manufacturers. These people comment that oftentimes, minor mechanical defects, or a group of defects, may compound to become a contributing factor in a haulage accident. Employees complain that management is lax in expediting repairs. Management states that employees are in too much of a hurry to leave the job site to report to the proper authorities. We see check lists and log books as a viable solution to these problems.

Development of the safety check list, purchase of equipment log books, and placing them in the vehicle is estimated to be a one-time cost of from $500-$1,000 per operation. It is estimated that 15 minutes per shift

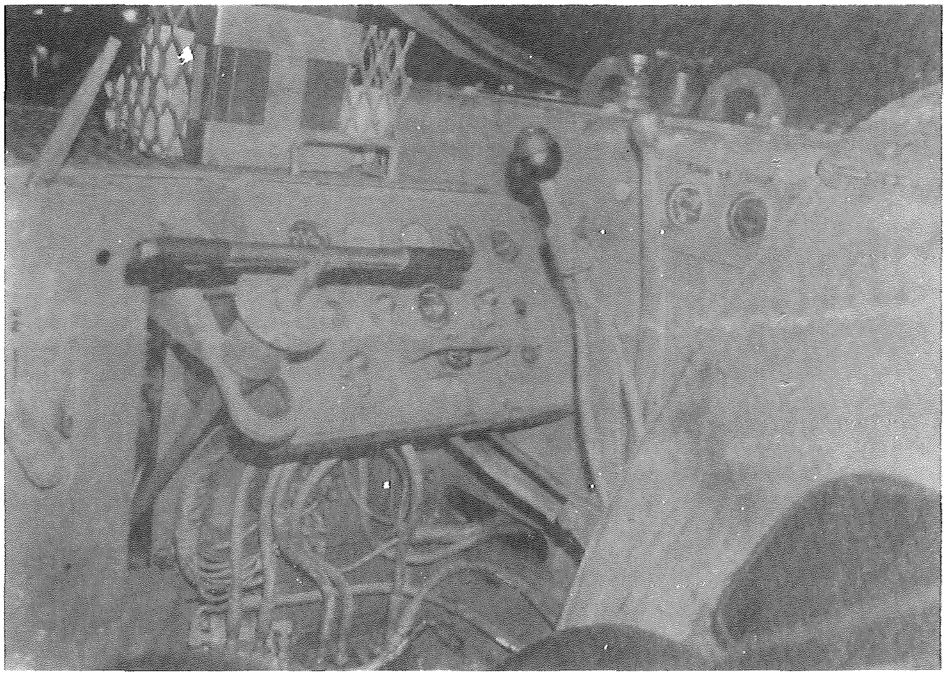

Exhibit II-7

Equipment Log Book on LHD

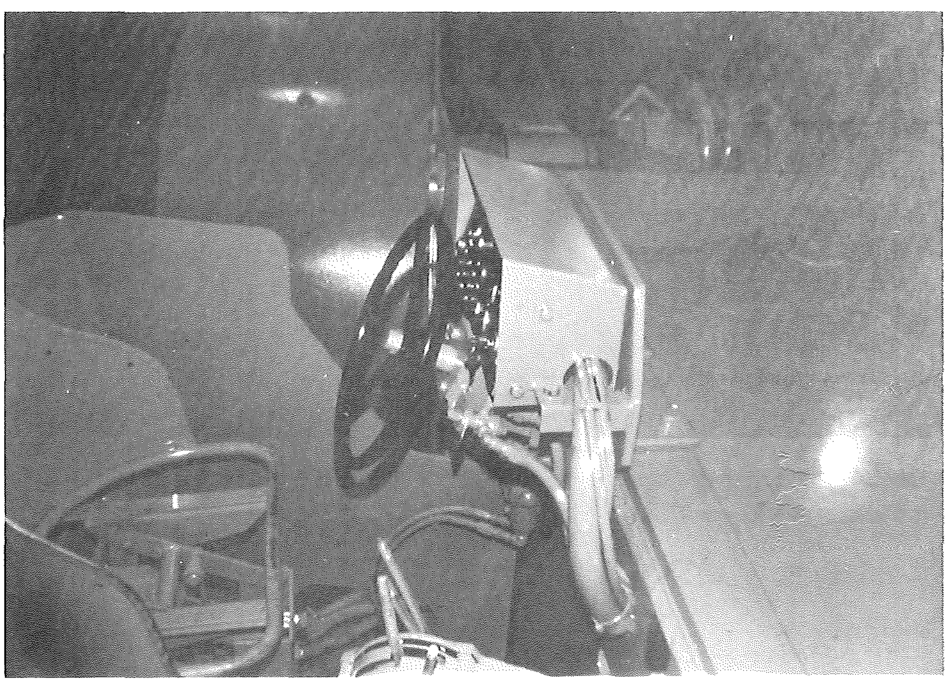

Exhibit II-8

Tight Clearance Between Guages and Steering Wheel would be required for pre-shift inspection and making log book entries. This would reduce available productivity time by less than one-half of one percent (0.5%).

Regulations requiring the development and use of the safety check list, the furnishing of equipment log books, and indoctrination of employees regarding their use is the suggested way of implementing this recommendation.

6. Driver Education and Licensing: An education program, including academic and on-the-job training, should be developed. The operation of an LHD should require a license which would be granted upon successful completion of the education program and demonstration of operating skill.

The reasoning behind this recommendation is that the driver is a critical part of a safe LHD operation. The best way to reduce perception and judgemental errors is through training and experience. Time on the job is required to develop experience, but a training program could be used to assure that a driver meet a required level of skill and knowledge before being allowed to operate a LHD by himself. Information from the industry indicates that a two-part training program is desireable.

The first phase of the educational program would be academic and should include the following:

- Familiarization with LHD's used at this mine,
- Safety devices on the vehicle and their use,
- Emergency procedures,
- Proper safe operating techniques,
- Information on what type of LHD accidents normally occur, and the fact that the best chance of preventing serious injury is to stay with the vehicle,
- How to avoid hazardous situations,

The second phase would be on-the-job training which would follow, or be given concurrently with the first phase. In the second phase, the new driver would ride with, and under the supervision of an experienced operator. The on-the-job training would include:

- Familiarization with LHD,
- Familiarization with LHD travel drifts,
- Develop operating experience,

Following the phases of the training program, the operator would be required to successfully complete a written and field examination prior to receiving his license. Implementation of the program could best be accomplished by the Bureau of Mines undertaking research to develop such a training program. The program(s) should then be furnished to the mine operators to present to employees. After the training program is developed, a regulation should be included in the Federal Register requiring that:

- Employers offer the program to new employees,
- No one may operate a LHD, except as a trainee, until he has successfully completed both phases of the program,
- Periodic refresher courses should be administered,
- All employees engaged in LHD operation must attend the training sessions.

The full impact of such a program is difficult to appraise. There would be no cost to the mine operators for the development of the training program; there would, however, be a cost to administer the program, and this would vary depdening on the length of time required and the size of the program.

The implementation of this recommendation is estimated to substantially contribute to a reduction in fatal and nonfatal LHD accidents. The magnitude of this reduction is estimated to be 20-30 percent of all LHD accidents.

7. <u>Operation Limitations: All LHD operations should meet clearly pre-specified criteria for maximum application in grade, equipment speed, road surface, lighting, water conditions, and clearances.</u>

Mine operators were seldom found to fit a piece of equipment to their own situation without encountering modification requirements, or an unsafe operation due to adverse environmental conditions. Existing safety inspection criteria is very vague, and it is difficult to ascertain situations where LHD application becomes unsuitable and unsafe.

Interviews with mine operators and mine inspectors of the Mining Enforcement and Safety Administration confirmed the need for explicit guidelines to identify unsafe situations associated with LHD operations. Arbitrary assessment of either acceptable or unacceptable conditions is not enough to minimize accident frequencies. It is therefore our recommendation that guidelines be developed by USBM, in cooperation with equipment manufacturers and mine operators, for acceptable levels of grade, road surface, lighting, water, and clearances.

Such clearly-defined criteria can then be used by the mine operators and MESA inspectors to determine the acceptability, based on operational safety, for each LHD application in the underground mining industry.

8. Operator Compartments: Operator compartments should be improved in the areas of comfort, control, and visibility.

Many manufacturers of LHD equipment acknowledged that the placement and features of the operator's compartment were usually the last items considered in the design of the vehicle. After all the drive train, hydraulic systems and size of the unit, etc., are established, the operator compartment is usually located in the remaining space. The result is that the operator compartments in the existing LHD's have a number of deficiencies. In addition to the drawback of a substantial "blind" area, outlined under Hazards and Causes, the following deficiencies with LHD operator compartments were also observed:

- Distance between steering wheel and control panels were restricted so that operator knuckles frequently hit edges and guages, as shown in Exhibit II-8.

- Scrubber tanks are often located almost next to the operator seat, as shown in Exhibit II-9. These tanks radiate substantial heat as their temperature gets in excess of 180 degrees F.

- Operator's controls are not located in the best location. Exhibit II-9 shows a brake valve unit placed where the operator's ankle should be to push the brake pedal.

- Seats are not designed to allow for adequate space required by cap-light batteries and self-rescuers on operator's belt (Exhibit II-10). This results in substantial discomfort to the LHD operator.

It is very difficult to assess the impact of greater comfort, controls, and peripheral vision on machine safety, since the results would depend largely on the magnitude of improvement achieved. However, we recommend increased use of human factors, or ergonomics, in the design of operator compartments. The result will be improved visibility and less fatigue to the LHD operator.

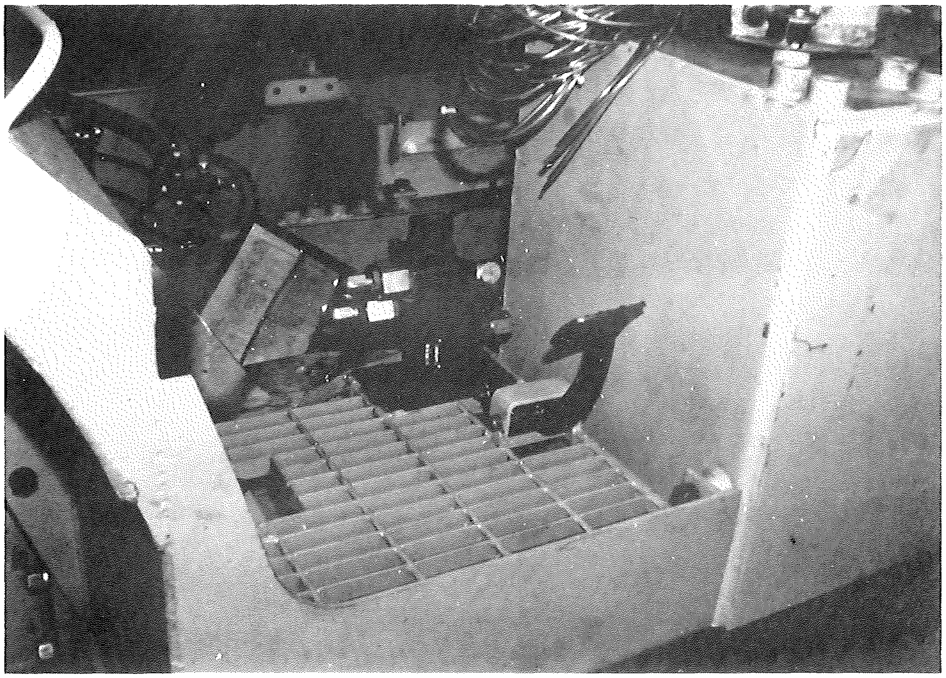

Exhibit II-9

Scrubber Tank Next to Operator's Seat
Poor Location of Brake Valve

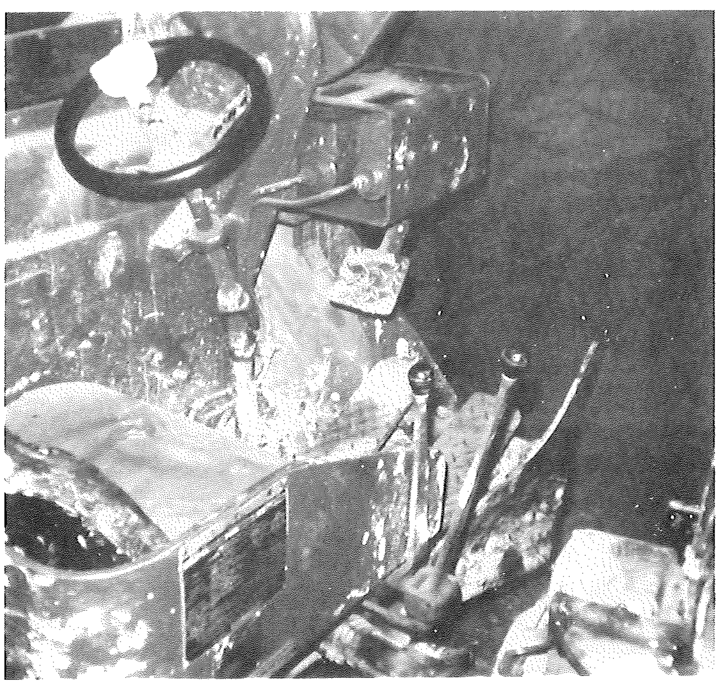

Exhibit II-10

Restricted Space Around LHD Operator's Seat

SUMMARY OF RECOMMENDATIONS

Given below is a summary of our recommendations with their probable impact on LHD accident frequency, and their estimated cost in terms of loss or gain in productivity, actual dollar amount, and precent of the total cost of equipment.

Recommendations	Expected Reduction in LHD Accidents	Estimated Costs: Productivity	Estimated Costs: Estimated $ Amount	Estimated Costs: % of Machine Cost	Implementation
1.Falling object protection FOPS	*	--	$300-500	.005%	Regulation
2.Improved braking systems	10-20%	Slight Increase	$1000	.01%	Regulation Research
3.Auxiliary steering systems	5-10%	--	$1500	.02%	Regulation
4.Improved Inspection of work areas	10-20%	--	--	--	Increased Enforcement & Compliance
5.Pre-shift check list and equipment log book	--	-0.5%	$500-1000		Regulation
6.Operator education and licensing	10-15%				Research Leading to Regulation
7.LHD operating criteria	10-15%	--	--	--	Research Leading to Regulation
8.Improved operator compartments	2-5%	--	--	-	Research

*Would not reduce the frequency of fall of rock, but will minimize severity of injury in 25-35 percent of all LHD accidents.

The above recommendations, when fully implemented, are likely to reduce LHD accident frequency by 45 to 75 percent.

RAIL HAULAGE SYSTEMS

Rail haulage is extensively used to transport broken ore in underground metal and non-metal mines. The rail transport method normally involves the loading of broken ore into mine cars via a chute. The cars are then hauled to a dump site by means of an electric, diesel, or battery locomotive, and dumped into an ore pass. The empty train is then hauled back to the chute and the cycle is repeated. Rail accidents form the single largest number of ore-handling-equipment related accidents (fatal and non-fatal) in the underground metal mining industry today.

Based on the analysis of past accident reports, we feel that the safety aspects of the Rail Haulage Systems can best be discussed under three groups. These groups are a) car loading activities, b) rail haulage and associated activities, and, c) car dumping activities.

PROBLEM STATEMENT

Activities associated with rail haulage accounted for over 75 percent of all rail accidents. The typical accidents resulting in victim injury occurred during collisions, derailments, being crushed against haulage drift walls, or while coupling/uncoupling haulage equipment. Poor track conditions, inadequate clearances in the drift and inadequate rerailing procedures were the most significant safety problems associated with rail haulage.

Barring of chute hang-ups while loading cars was found to be associated with the majority of lost-time accidents. The layout of the entire car loading station and the existing car positioning procedures were observed to be very deficient.

Car loading operations and activities associated with rail haulage operations accounted for the majority of rail accidents while car dumping was found to be relatively accident free.

HAZARDS AND CAUSES

We will discuss the hazards and causes associated with rail system accidents in the same three groups; a) car loading, b) activities associated with haulage, and, c) car dumping. Exhibit III-1 on the next page summarizes the correlation between the victim activity and the injury contributing agency. It is evident that in about one-third of the historical accidents, the injury contributing agency could not be determined from the available data from the accident reports.

RAIL HAULAGE SYSTEM - ACCIDENT SUMMARY
Total Sample = 222 Accidents

Activity		% of Accident Frequency		Accident Causing Agency (% of rail accidents by agency for each accident type): Collision	Derailment	Hit by Rocks	Run Over	Pinned at Rib	Link & Pin Coupling	Others/ Unknown*
Loading	Positioning Train	2.7						1.0		1.7
	Operating Chute	4.5				4.1				.4
	Barring Hang-ups	8.6				5.0				3.6
	Total		15.8							
Haulage	Operating Locomotive	14.9		4.5	4.5	1.0				4.9
	Riding Train	7.2		1.8	2.7	1.0				2.7
	Rerailing Equipment	7.7			7.2					0.5
	Coupling/Uncoupling	10.8							10.8	
	Throwing Switches	4.1								4.1
	On & Off Motor	8.6					1.4			7.2
	Track Repair	7.7					3.2	2.3		2.2
	Others	16.0		4.5	0.9	1.5	4.0	2.1		2.0
	Total		77.0							
Dumping	Dump Ore Cars	7.2			0.5	0.5				6.2
	Total		7.2							
TOTAL			100.0	10.8	15.8	13.1	8.6	5.4	10.8	35.5

*Accident reports were not detailed enough to provide specific information in these cases.

Source: Appendix C-4, C-8 (bound under separate cover).

EXHIBIT III-1

Car Loading

Exhibit III-1 shows that three major tasks accounted for all the accidents occurring during car loading operations. These are: a)barring chute hang-ups, b) operating chute, and, c) car positioning at the loading station. The hazards associated with each of these activities have already been described in detail in another report.* Therefore, we will only mention the important hazards in the following section:

- Barring chute hang-ups: Typical accident occurs when the car loader, standing on the platform across the chute (Exhibit III-2), uses a steel bar or a blow pipe to pry the jammed ore in the chute. The loader is occasionally hit by rocks once the hang-up is cleared. The lack of operator protection, primitive methods of eliminating hang-ups, low clearances around the platform and poor footing are some of the hazards associated with this activity.

- Operating chute: This activity accounted for about one-third of accidents associated with car loading group. A typical accident occurs when a large surge of muck through the chute results in small pieces of rock hitting the unprotected operator. The operator platform was normally found to be directly in front of the chute opening, as shown in Exhibit III-2.

- Car positioning: Typical accident occurs due to errors in communication between the car loader and the motorman during car positioning activities. Signaling with cap light is the most common method by which the car loader directs the motorman when to stop or start the train. Limited clearances around the operator platform result in severe injuries.

Rail Haulage Activities

Exhibit III-1 indicates that 30 percent of the haulage type accidents occur while the train is in motion. Victims suffer injuries due to derailments, collisions, being run over or pinned against rib by a moving train. Another 11 percent of the rail accidents occur during the coupling/uncoupling of cars, while 7.7 percent of the accidents occur while the derailed equipment is put back on the tracks. The prime causal agency in about 30 percent of haulage accidents could not be identified from the past accident reports.

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*Final Report on Parent Contract HO230004--Chapter VI, Car Loading Operation, Page VI-8; July 1974.

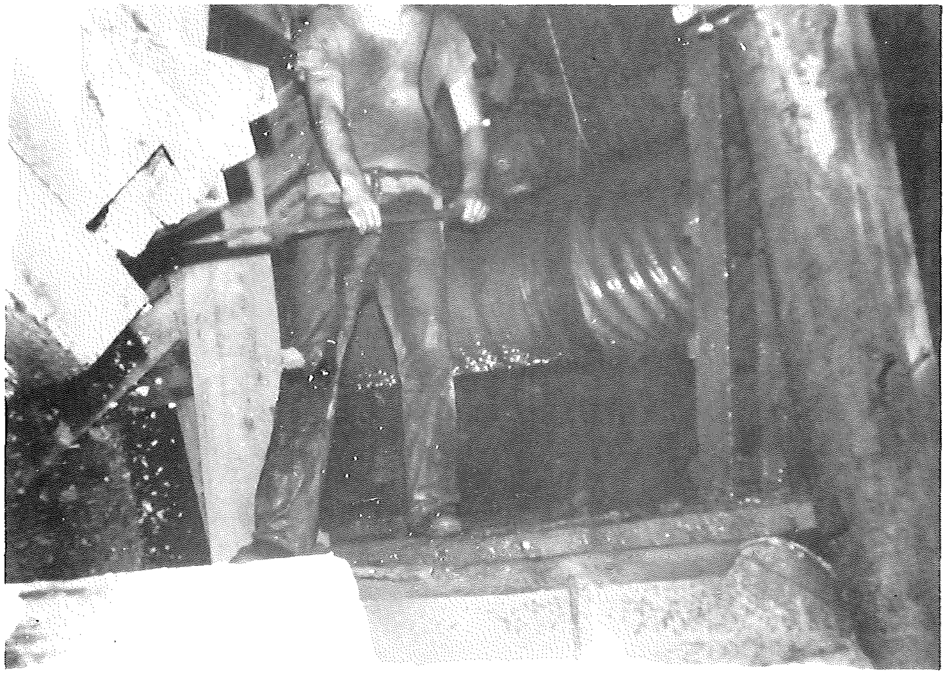

Exhibit III-2

Car Loading Platform Located in Front of Chute

Exhibit III-3
Poor Track
Conditions

- <u>Derailment:</u> accounted for 16 percent of the rail system accidents. A derailment is often caused by a combination of items. Some of the main causal agencies are worn wheels, mis-matched switch blocks, and poor track conditions. Inadequate track conditions are often found to result from loose track ties and rails. Gauge variations, sharp corners, and muck spills can also cause a bad track condition, as shown in Exhibit III-3. Our field observations and interviews revealed that after a derailment occurs, the rails can be twisted and loosened even more. Seldom are adequate repairs done to sections of bad track. Field visits also revealed that not enough attention is paid to track maintenance throughout the underground mining industry. Although most of the mines visited did have full-time workers on track maintenance, the activities of the crews were usually spent on main line tracks and, occasionally, cleaning the muck off secondary tracks. Preventive maintenance of tracks, especially at secondary levels, is lacking.

- <u>Collisions:</u> accounted for 11 percent of rail system accidents. They are generally caused by equipment failure to stop in time and/or due to procedural violations or poor visibility. Locomotives were often found to have inadequate braking power to stop a loaded muck train in the required distance. Most of the locomotives did not have a service brake system, they used parking brakes to stop the trains. "Plugging" of motor -- a practice by which the wheels of moving locomotives are put in reverse -- is common in underground mines. This practice results in additional hazards created by reverse skids. Procedural violations often caused collisions also. Equipment was found left abandoned on a track section or equipment parked on a grade without adequate parking brakes. Many times, section signal lights installed to permit one train in a track section are not activated by motormen, and therefore result in a collision. Visibility is usually limited to a small area illuminated by the head light. Poor and wet track conditions also reduce the efficiency of brakes and contribute to collisions.

- <u>Rerailing equipment:</u> These activities resulted in about eight percent of rail accidents. Accidents are caused due to the use of primitive, unsafe and crude means of putting derailed equipment back on track. Commonly-used methods of jacking, spragging, and dragging to rerail ore cars or locomotives expose the operators and observers to hazardous situations. Rerailing activities are not done by any particular crew or crew size, but usually the motorman and whatever help is available do the job. In some cases where jacks are available, the equipment is propped up on blocks high enough so it can be pushed off and fall on the track. Sometimes, the ore car or locomotive falls the wrong way, thus crushing personnel.

Spragging methods are also used in some cases to pry a car or motor back on the track. A timber or steel bar is wedged between the equipment and a track tie, or a locomotive to a car. The objective is to force the equipment up and over so that it will engage the rails. In some instances, derailed cars or motors force the ones pushing the sprag or bar off the track, crushing observers against a rib.

Dragging ore cars or locomotives through a frog or switch block is only feasible when these devices are close by, and if the wheels are close enough to the rails for the switch or frog to catch the flange. Personnel watching or signaling a motorman are crushed by derailed equipment when it fails to catch the rails and is instead forced out to the rib.

- Coupling/uncoupling cars: These injuries resulted from about 11 percent of the rail accidents and were primarily hands crushed between couplings of link and pin type. Occasionally, victim's feet were also crushed under the moving cars or locomotives during these activities. Typically, the worker was found to be exposed to these hazards when he reached in to pull or place the pin in the coupling, and at the the same time, he must guide the link into the coupling to be set. The worker was also exposed to the hazard of working in between moving cars.

- Runover or pinned against rib: These type of accidents accounted for about 14 percent of the rail accidents. Exhibit III-1 shows that about half of these accidents were associated with the track repair activity. Victims are typically not properly warned by horns, or lights, or by other warning devices on the on-coming trains. Additionally, the tight clearances in most haulage drifts (Exhibit III-4) add to the hazard and result in victims being crushed between the equipment and the rib. Most mines provide shelter holes to ensure the safety of personnel along haulage ways from moving trains, according to regulation CFR 57.91-110. However, inadequate distance between shelter holes was often found. For example, at one mine, these shelter holes were found to be 350 feet apart, and not at regular intervals. A man travelling at two miles per hour (typical in mine conditions) will require 1.10 minutes to walk 175 feet, for the worst case, when he is in the middle of two shelter holes. In the meantime, a

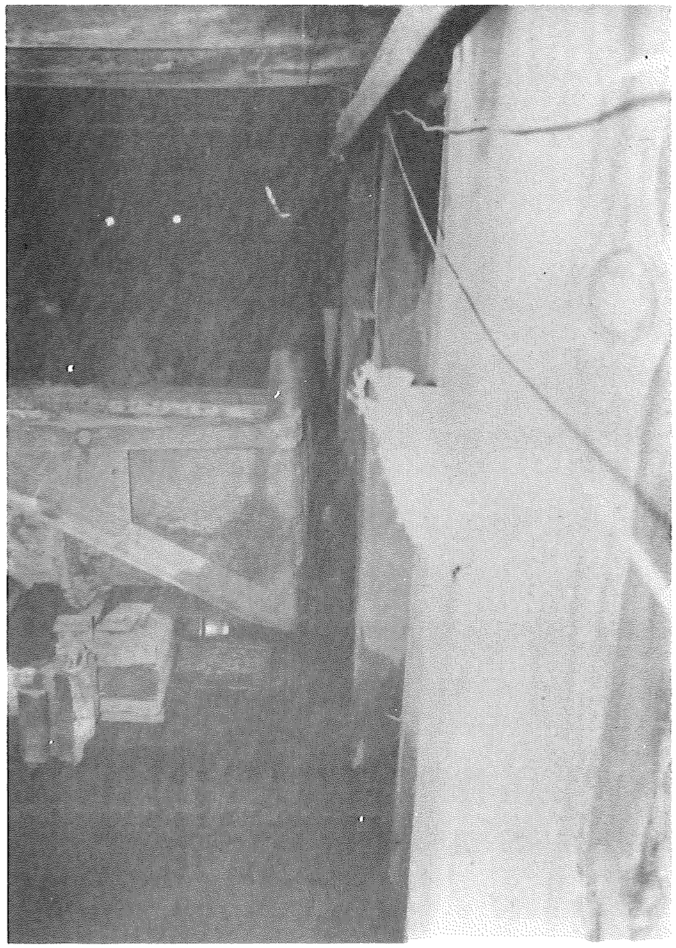

Exhibit III-4
Tight Clearance in Haulage Drift

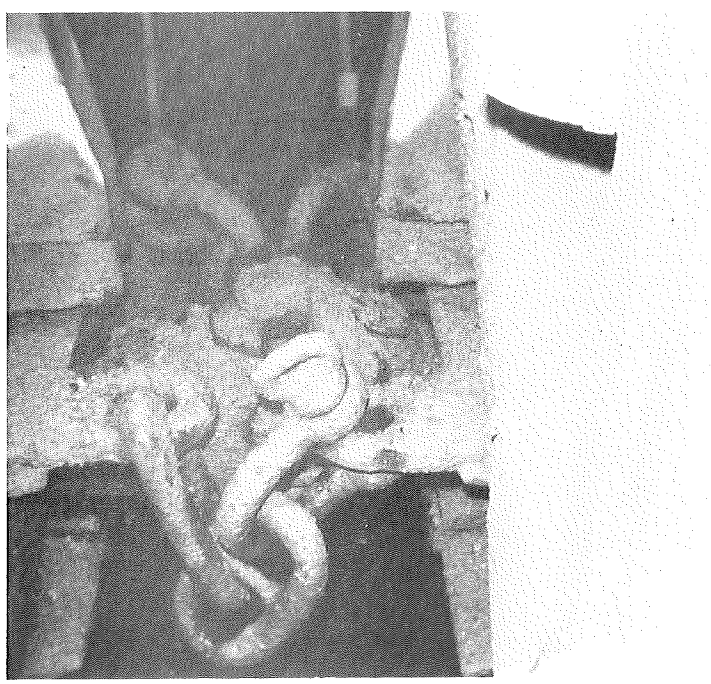

Exhibit III-5

Automatic Coupler and Safety Chain

train travelling at eight miles per hour will travel 775 feet in 1.10 minutes. This means the worker must realize the train's presence when it is a minimum of 600 feet away for him to reach the shelter hole for safety. Train headlights do not warn an individual at that distance. In these cases long distances between shelter holes presents a hazard.

Car Dumping Activities

These accounted for a relatively small amount (7.2 percent) of rail accidents. Accident reports were not specific enough to pinpoint causes of these accidents. A small portion of haulage crew's time is spent in actual dumping of ore (measured about eight percent of a crew's time at one mine). Field observations and interviews revealed two hazards normally associated with ore dumping. These were, (a) exposed ore passes or lack of proper guards, (b) car tip-over, endangering the dumper who normally stands in close proximity to the dumped car. The camel-back type of dumping facility was found to be associated with the least number of accidents.

Summarizing, the major hazards associated with rail systems are as follows:

- Barring chute hang-ups
- Flying rocks during chute drawing operation
- Car positioning methods
- Poor track conditions
- Collisions due to inadequate brakes on locomotives
- Rerailing methods
- Coupling/uncoupling of cars
- Tight clearances in haulage drifts
- Inadequate guards at dump sites

RECOMMENDATIONS

Our solutions to significantly improve the safety of rail haulage systems are described in this section. Recommendations one through three deal with car loading hazards, while the solutions, four through eight, deal with the rail haulage activites. No major recommendation is made to improve ore dumping operations. The car loading recommendations have already been described in the previous report on this contract, and are only mentioned here for completeness.*

1. Chute Hang-ups: The U.S.B.M. should undertake a research effort to develop new methods of removing chute hang-ups, especially at the secondary levels.

   Improved methods to remove hang-ups should ideally be installed on the chute itself, should be remote-controlled and should be capable of being transferred to a new chute after the life of the original chute is over. In the interim period before new methods are researched, increased operating training in safe practices while barring chute hang-ups will help reduce car loading accidents.

2. Guidelines for Loading Station Layouts: Specific guidelines spelling out minimum clearances, suggested location of controls, and operator platforms, etc. need to be developed and disseminated in the mining industry.

   The use of existing operator platforms directly in front of the chute openings should be discouraged, especially without adequate protection to the car loader. The revised layouts should call for relocation of the car loader station to a widened section of the drift at the track level on the opposite side of the chute, as shown in Exhibit III-6.

3. Car Positioning Methods: Research is recommended to develop mechanical car positioning methods in which the car loader can independently control the positioning of cars without motorman's assistance.

   The existing technology is limited to two methods described below:

   - An electrically-powered remote control system is now available and has been sparsely observed in our field work. Though an easily operated system, it is constrained by frequent malfunctions and the possibility of a runaway. The remote unit often bypasses the deadman control switch and, if for some reason, it does not release, the hazard of the muck train moving down the track without an operator exists.

   - Air-powered tugger hoists have been used in some mines for positioning muck trains. The use of a hoist requires a worker to feed out the cable line every time, and attach the line to the muck train.

*See Final Report on Parent Contract HO230004 -- Chapter VI, Car Loading/Chute Drawing Operation. July 1974.

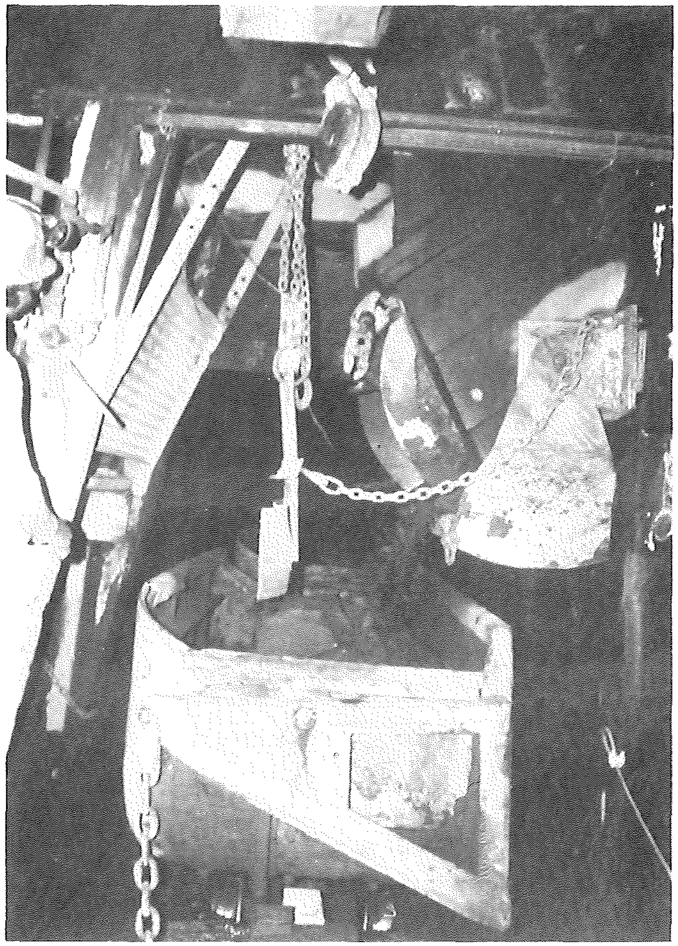

Exhibit III-6
Relocated Car Loading Station

Exhibit II1-7

Rerailers Carried on Locomotives

Accident reports show that personnel are often injured by the cable whenever this method is used. Moveover, these are cumbersome and inefficient systems.

Theodore Barry & Associates feels that mechanical devices that can move the muck train a pre-specified amount will minimize hazards associated with the above methods. Conceptually, an air-operated chain link mover, similar to the type used in car washes, or an air cylinder mover, already in use on rail in surface coal mines, can be a starting point. Anyway, the crude methods currently used by the majority of operations involving hit and miss car positioning with cap light communications should be discouraged.

4. Track Maintenance: Track preventive maintenance programs should be required in underground metal and nonmetal mines, and standards should be developed for acceptable and unacceptable track conditions.

Poor track conditions have been identified as the largest factor contributing to derailments. Secondary level tracks, in particular, at many mines were found to be covered with muck, had excessive gauge variations, had loose ties and rails, and had sharp corners. Interviews revealed that it was not uncommon to have one derailment per shift at a number of operations.

Track maintanance is generally given low priority in the mines. Usually, new hires are assigned this job as part of their training. Examples of patch work in track repairs are not too uncommon in the mining industry. No specific criteria exists by which an inspector or a mine operator can determine whether a piece of track meets safety standards or not. The existing regulation, 30 CFR 57.9-16 only calls for rails, joints, switches, frogs, etc., to be designed, installed and maintained in a safe manner. Interviews with MESA inspectors and mine operators confirmed the vague nature of this rule, as there is no clear-cut guidelines as to what is safe and what is not.

Theodore Barry & Associates feels that specific guidelines that spell the acceptable variations in gauge variation, strength of railroad beds, etc., will help the mining industry. Inspectors and mine operators can then enforce and comply with these specific regulations governing acceptable and unacceptable track. Such guidelines are available for surface railroad operations.*

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*For example, Bethelem Steel Rail Haualage Track Guidelines.

The implementation of this recommendation will greatly minimize derailments, and therefore, many of the injuries resulting from re-railing equipment, also. Our conservative estimate is that 10-20 percent of all rail haulage accidents can be averted, if track were acceptably maintained.

5. Rerailing Ore Cars and Locomotives: All locomotives used in underground metal and non-metal mines should carry rerailing devices. All persons involved in rerailing cars or locomotives should be trained and required to follow a specified procedure to accomplish the task in a safe manner.

Our field visits revealed that over 90 percent of the derailed equipment is put back on tracks through a combination of jacking, spragging or dragging methods. These unsafe methods result in frequent accidents.

Rerailers are available but rarely used in the mining industry, in general. Two prominent reasons account for this; (a) rerailers are often not available at the site of derailment, and, (b) personnel are not adequately trained in their use. Theodore Barry & Associates, therefore, recommends that all locomotives should carry rerailers on them as a standard practice, as shown in Exhibit III-7. Some mines also have welded brackets in the locomotives to carry the rerailers, and this practice should be encouraged. We also suggest that adequate training in rerailing equipment should also become part of a pre-requisite training program for each motorman and car loader.

It is estimated that the cost of these rerailers would run between $90 and $120. This would be approximately .05 percent additional cost to a locomotive purchase price. The best method for implementing the solution to rerailing accidents would be through regulation. However, before considering such a regulation, further research should be done to evaluate the effectiveness of rerailing devices available, and possibilities in new designs.

6. Automatic Couplings: Increased use of automatic self-centering couplers for underground rail haulage equipment should be encouraged.

The existing link and pin type couplers on the majority of ore cars in the mining industry have already been identified as prone to accidents. About 11 percent of all rail accidents are associated with this activity.

Theodore Barry & Associates feels the automatic self-centering couplers (Exhibit III-5) eliminate many of the hazards associated with the link and pin type. Many mines are increasingly using these new couplings, especially on larger equipment, and we endorse this practice. We suggest that the mining industry should seriously consider replacing the worn link and pin type coupling with the automatic couplers. The additional cost of $175 per coupler will pay for itself in reduced accident frequency, and shorter time for the activity. A 5-7 percent reduction in rail haulage accidents can be expected.

7. <u>Shelter Holes Location: Specific guidelines determining the minimum required distance between shelter holes needs to be developed. In addition, increased enforcement of regulation CFR 57.9-110, ensuring pedestrian safety in haulage drifts is recommended.</u>

   The sample analysis under Hazards and Causes clearly shows the inadequacy of shelter hole locations in underground mines today. Many haulage drifts that had less than 30" <u>effective</u> clearance on either side of the track were observed, but the shelter holes in those cases were not provided, or were spaced too far from each other for them to serve a useful purpose. Theodore Barry & Associates feels that the mandatory regulation, CFR 57.9-110 is not being complied with or enforced effectively. The 30" minimum clearance requirement should clearly spell out 30" continuous clearance from the track level to the top of a worker's head. Too often, extraneous material like pipes, cables, etc., on the top side and piles of muck, ore spillage, abandoned equipment, etc., on the track level do not provide effective 30" clearance required for pedestrian safety.

   For cases where 30" clearance is not available, Theodore Barry & Associates recommends that clear criteria specifying minimum distances between shelter holes be developed. Such criteria should take into account the existing conditions like average speed of train, track level conditions, etc. We feel that 5-7 percent of all rail accidents can be reduced when this criteria is stringently enforced.

8. <u>Train Braking Systems: Minimum braking system performance criteria should be developed for trains or locomotives used in underground metal and nonmetal mines. All trains and locomotives should then be equipped with brake systems which conform to these minimum performance standards.</u>

Trains were too often found to have inadequate braking power. As mentioned earlier, "plugging" the motor is a common practice that ought to be discouraged. Locomotives do not, as a rule, have independent service brake systems -- parking brakes are normally used to stop them. No specific criteria exists by which the adequacy of a braking system for underground locomotives can be determined. The result is that locomotives with subnormal braking power continue to be used in ore haulage. The development of criteria such as specific minimum stoping distance for varying conditions and loads will greatly assist in enforcement of and compliance with safe equipment usage. Enforcement of minimum performance criteria is expected to minimize collisions in rail haulage and reduce overall rail haulage accidents by about seven percent.

Additionally, roadbeds should be well maintained to minimize the adverse braking effects of bad track (refer to recommendation 4).

SUMMARY OF RECOMMENDATIONS

The table below summarizes our recommendations to improve operational safety of Rail Haulage Systems. The expected impact of each recommendation on accident frequency associated with Rail Haulage Systems is also documented. In addition, the estimated cost of each recommendation in terms of loss or gain in productivity, actual dollar amount to the mine operator, percent cost, and the best implementation methods are also presented.

Recommendation	Expected Reduction in Rail Accidents	Expected Costs			Implementation
		Productivity	Estimated $ Amount	% of Equip. Cost	
1. Improved methods to remove chute hang-ups and improved chute design	5%	Increase			Research
2. Guidelines for loading station layout	4%	Increase			Regulation and Research
3. Improved car positioning methods	2%	Increase			Research
4. Improved track maintenance	10-20%	Increase			Regulation
5. Rerailing device	5%	Increase	$90-120	.05%	Regulation
6. Automatic couplers and safety chains	5-7%	--	$300	5-6%	
7. Minimum clearance guidelines for haulage drifts	5-7%	--			Regulation
8. Braking systems for locomotives	7%	--			Regulation

The above recommendations, when fully implemented, are expected to reduce the Rail Haulage Accident Frequency by 45-50 percent.

OVERCAST MUCKING MACHINES

Overcast mucking machines have a long history of involvement throughout the underground metal/nonmetal mining industry. Size and model variations make muckers suitable for development, production, and cleanup operations. These variations are mainly in method of movement; rubber-tired, rail type, and crawler are available for various applications. Rubber-tired units are commonly used for driving drifts or mucking out narrow headings such as rich vein. Rail mounted muckers are often used for track clean-up as well as driving new drifts for rail haulage. Crawler type muckers often serve in shaft-sinking operations. This discussion will be limited to rubber-tired and rail-mounted mucking machines.

PROBLEM STATEMENT

The bulk of the lost-time accident associated with muckers result from equipment tip overs or when the operator gets pinned between equipment and wall while working in tight clearances. Equipment tip overs for track mounted muckers are caused by a number of factors that include high center of gravity, operating muckers on too narrow track gages and by the deflection of slide rails.

Operator injuries also result from fall of rocks due to inadequate trimming and maintenance of working areas. In addition, operators are struck by muck spillage especially while dumping the loaded bucket into the mucker bed or the ore car.

HAZARDS AND CAUSES

Exhibit IV-1 summarizes the correlation of the victim activity with the type of accident. The major hazards and causes associated with each of the four major accident types will be discussed in this section.

Pinned between equipment and wall: About 85 percent of this type of accidents occur when the operator is either mucking or tramming to and from the face. Typically, as a result of of equipment tip over or working in extreme tight areas, the operator is pinned between the mucker and the rib wall. These accidents generally result in severe injuries to the victim.

Overcast mucking machines typically have a high center of gravity in relationship to their wheelbase width. This high C.G. is further raised when the bucket is in the air, especially in a loaded condition. The C.G./wheelbase relationship is a result of the overall equipment design. However, the likelihood of equipment tip over is increased by other contributing factors such as:

EXHIBIT IV-1

OVERCAST MUCKER ACCIDENT SUMMARY

Activity	% of Accident	% of Estimated Task Duration	Injury Causing Agency: Pinned Between Equipment & Wall	Fall of Rock	Hit by Muck Spillage	Derail-ment	Run Over	Others/Unknown
1. Operating Mucker	53.7	55.0	13.4	14.9	16.4		1.5	9.5
2. Moving/Tramming	23.9	38.0	11.9	1.5			4.5	6.0
4. Rerailing	6.0	3.0	3.0			3.0		
5. Repair	6.0	3.0	--	1.5				4.5
7. Stepping on/off	1.5	1.0	--					1.5
6. Pedestrian in Vicinity	4.5	--	--		1.5	1.5	1.5	
Others	4.5	--	1.5					3.0
Totals	100.0	100.0	29.8	17.9	17.9	4.5	7.5	22.5

Source: Appendix D-4, D-8 (Bound under separate cover)

- Narrow Track Gauge: Mucking machines are used on a wide range of gauge widths for each model. Examples of two popular models are (a) Track Gauge Operating -18" to 44", and (b) Track Gauge Operating --21-3/4" to 56-1/2". None of the mucker specification sheets reviewed by TB&A had any recommended safety considerations in terms of gauge variation. Nevertheless the probability of equipment tip over is increased when operating on the narrower gauge tracks.

- Unsupported Rails: Mucking machines are commonly operated on unsupported rails and unlevel track. Additionally, loose rocks on the track or "tramp" rock between loading and dump points contribute to mucker instability.

- Breakout Operation: An additional hazard results when the moving bucket (during breakout portion of the loading cycle) catches a fixed object (timber, drift wall, etc.) thus resulting in a mucker tip over.

Working in areas with tight clearances also contributes to the "pinned" type accidents. The locations of these minimal clearances are frequently at turns, and at places where additional ground support is used at the expense of effective drift size, as shown in Exhibit IV-2. Contract miners are particularly prone to drive narrow service drifts, in order to maximize their return. Existing incentive pay systems often do not adequately compensate workers for additional ground support operations since these systems are primarily based on drift advance. Since the workers' pay is, in this way, directly proportional to the linear advance, (or the amount of ore removed), they tend to take short cuts. The resulting situation is that often the drift is less than adequate in effective clearance and ground control. Additionally, a poorly constructed drift exposes many future mining systems to the hazards described above. For example, rail haulage personnel will be continually exposed to tight clearances and faulty ground.

The fall of rock accidents occur primarily due to the failure to bar down loose rock before the operation of mucking. As shown in Exhibit IV-1, 83 percent of the injuries to operators from fall of rock happen at the face. Safety precautions as outlined in current regulations, expecially 30 CFR 57.3-22 of the Federal Code for Metal and Nonmetal mines, are often not fully complied with. Miners are supposed to frequently examine the back, face and ribs of working places for loose rock, but accident reports and field visits point to occasional violations of these regulations. These violations, again, are more prevalent in the case of contract miners who are paid

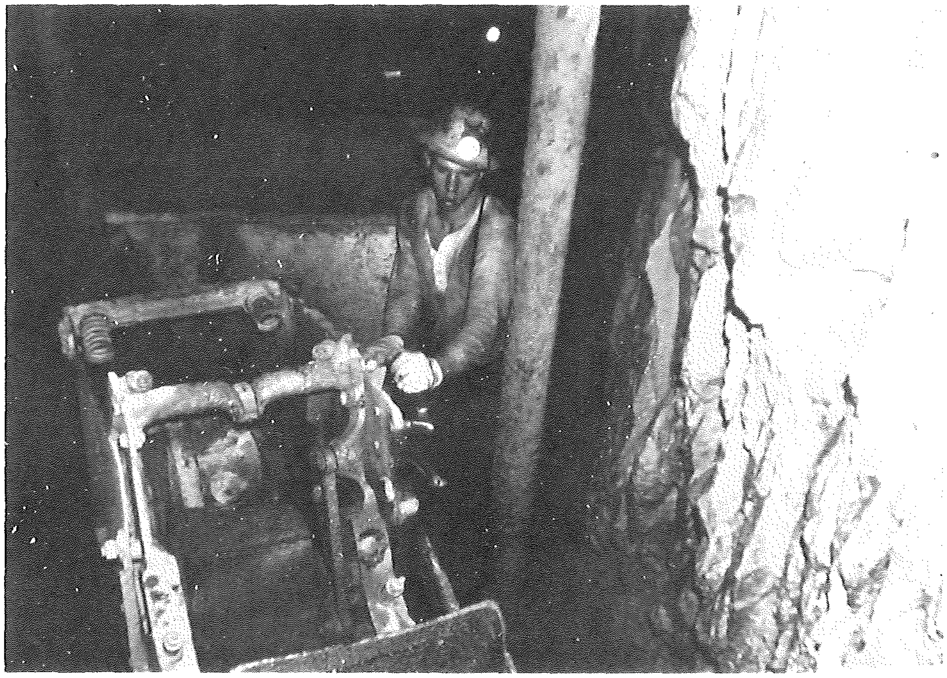


Exhibit IV-2

Mucker Operator Working in Tight Clearances

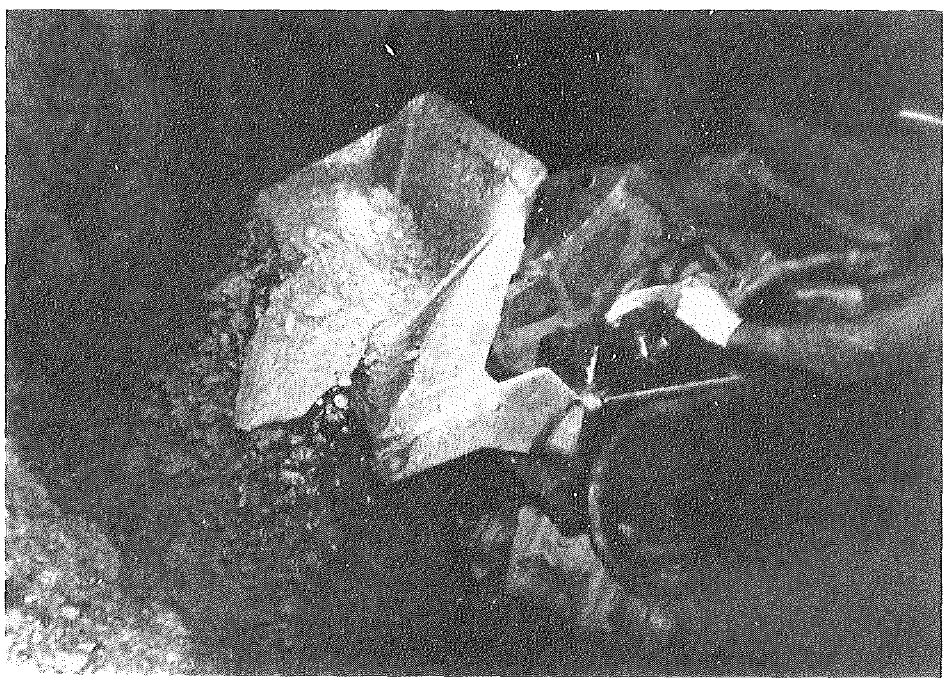


Exhibit IV-3

Operator Exposed to Rocks Rolling Off the Bucket solely based on the amount of ore they move. During interviews, many contract miners acknowledged taking short-cuts and being lax on trimming and barring procedures. No overhead protection to the operator is normally available on the mucking machines in the study.

Most of the injuries due to muck spillage occur when the operator is struck by rocks off the bucket or conveyor while operating the mucker. The equipment design is such that the overhead trajectory of the loaded bucket, in most cases, is as close as six inches from the operator's head. Operators tend to overload the bucket, with the result that oversize boulders roll off and small rocks tend to fly off when the bucket is emptied into the mucker bed or rail car. Most of these rocks fall onto the operator's hands and upper body. An example of this hazard is shown in Exhibit IV-3.

Some additional hazards associated with mucker operations were uncovered during our field observations and interviews. The most important is the practice of removing the devices (commonly springs) that automatically bring controls back to neutral position. Controls that move muckers back and forth and raise and lower the bucket are occasionally tampered with in this fashion. Operators remove these devices in order to minimize the return tension on these controls so that they can keep these controls in operational mode with minimal effort. However, the accidental release of pressure on these controls does not render the equipment inoperative because of the absence of return tension. The inherent instability of muckers coupled with poor floor conditions that are full of broken muck, results in very bumpy operation. As a result, the operator occasionally loses his balance, thereby accidently releasing pressure on the controls. Accidents such as run-over or pinned-against-wall can occur because the mucker continues to move without the operator in control.

Muckers were occassionaly observed where the operators had removed the step plates (which are normally part of the mucking machine), as shown in Exhibit IV-4. These step plates are removed especially while working in tight working areas. This contributes to run-over type accidents, and possibly more equipment tipovers. The step plate, when in position, can act as a deterrent to the equipment tipping completely over. Additionally, high noise levels were encountered at most mucking machine operations. The contribution of these high noise levels to the occurrence of accidents was not measurable from accident reports.

A motion analyses of the mucker operation and its controls revealed an illogical action/control situation in a majority of the equipment observed. For example, manipulation of the bucket control lever in one direction, sets the bucket motion in the opposite direction relative to the lever. Compatibility of movement relationships usually aids in operator training and response times.

Exhibit IV-4

Mucker Operating with Step Plate Removed

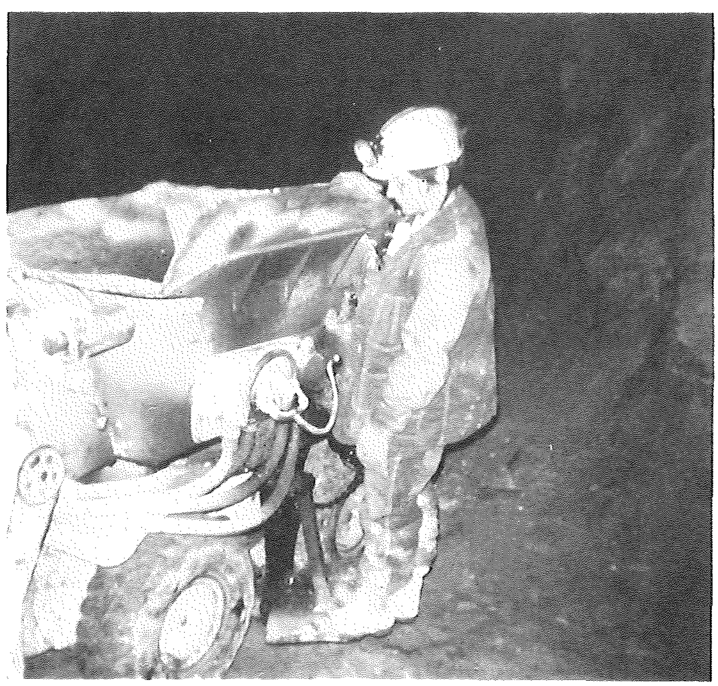


Exhibit IV-5

Example of Inadequate Step Plate

Interviews with equipment manufacturers revealed that controls of many foreign mucking machines of the same models operate in a compatible mode. Imported muckers are modified to operate similar to those manufactured in the United States. We could not conclusively develop a correlation between mucker accidents and control levers in an incompatible mode from the available accident reports and our field observations. However, we suggest that MESA should investigate the feasibility of control lever compatibility on muckers.

Summarizing, the major hazards and causes of overcast mucker accidents are as follows:

- Equipment tip overs and rib pins
  - High center of gravity
  - Narrow operating gauge
  - Bucket forced tip overs during breakout
  - Tight operating clearances
- Operator exposure to hazard of "fall of rocks"
- Lack of operator protection from muck spillage
- Removal of devices (springs) to bring controls back to neutral
- Working with step plates removed.

RECOMMENDATIONS

Interviews with mine operators and equipment manufacturers revealed that overcast mucking machines have a fairly long life. A vast majority of these muckers, still operational in underground mines, were manufactured over a decade ago. Very few new muckers are sold every year. This important criteria has been borne in mind while developing recommendations to improve the operational safety of overcast mucking machines. If any significant impact is to be made on the overall safety of muckers, most of the solutions should be capable of being implemented on the existing old muckers. Recommendations (1) through (5) emphasize this concept.

1. The USBM should undertake a research effort to develop methods to improve stability of mucking machines. These solutions could be in the areas of: (a) modifications in mucker equipment design that will result in a lower Center of Gravity and (b) minimum acceptable track gauge dimensions on which the various mucker models should operate.

As mentioned earlier, existing muckers have a high center of gravity as compared to its wheel base width, and therefore they have a tendency for tip overs. This high C.G. is inherent with the existing equipment design. We feel that there is a need to change the equipment design in order to lower the C.G. These modifications in equipment design can be done only for new muckers and a USBM study is recommended to identify those needed equipment design changes.

We envision the same study to ascertain the range of track gauge on which the overcast muckers ought to be operated. This acceptable track gauge range should be dependant upon the weight of the mucker (fully loaded), overall dimensions, and the height of the center of gravity for the existing machine. Additionally, we feel that full consideration should be given to rubber-tired muckers to fully benefit the industry and encompass all aspects of overcast mucker instability problems.

Theodore Barry & Associates suggests that this recommendation can best be implemented through a carefully designed research project targeted at existing equipment models as well as future muckers to be used in the underground metal and non-metal mines.

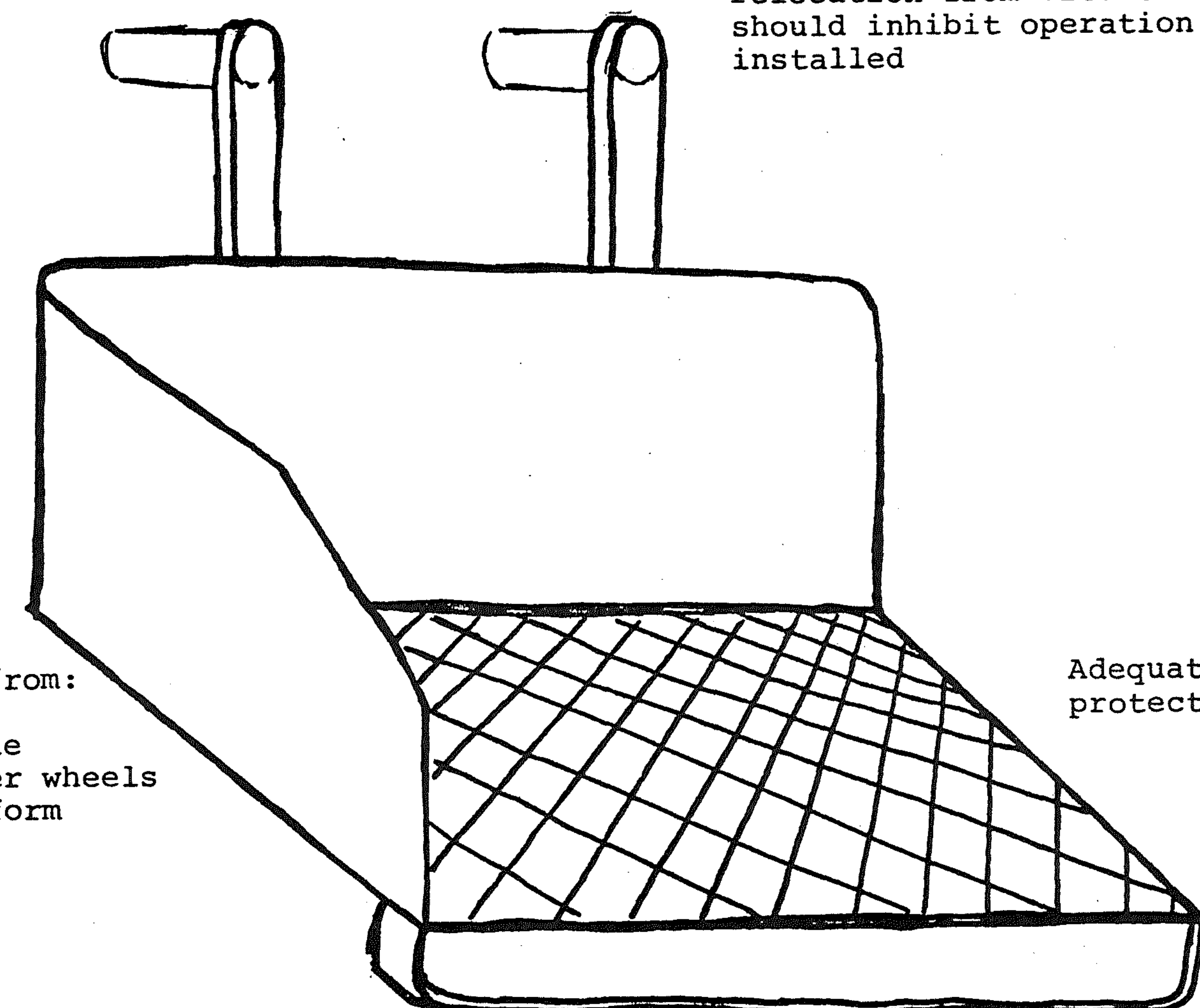
2. <u>Operator Step Platform:</u> <u>We recommend that existing step platforms on the mucking machines should be modified to improve operator protection. This type of platform, with the features discussed below, should be in position at all times while operating the muckers.</u>

Step platforms on most of the muckers in operation today need to be improved. They are either inadequate in size (Exhibit IV-5), or are not rigidly installed. In addition, the practice of operating the mucker without a step platform should be discouraged. Sixty percent of all mucker accidents were due to equipment tip-over, and another seven percent were caused when the operator was run over by a mucker.

Mucker operators obviously need some protection from being pinned against a wall during a tip-over accident. In our opinion, neither the standard rollover protection, nor a protective tubing behind the operator is the answer. Since the mucker operators have to constantly get on and off the mucker step, a protective structure behind them will be in the way. Mining companies and the equipment operators will also have a significant acceptance problem since muckers' operational productivity will be adversely affected.

Theodore Barry & Associates, therefore, feels that a properly-designed step platform that can act as a deterrant to equipment tip-over through the leverage of an outrigger type step, and can help to minimize operator injury. A conceptional sketch of such a step platform is shown in Exhibit IV-6. Some essential features of this kind of step platform and their respective advantages are as follows:

Mount acts to retract step during relocation from site to site but should inhibit operation if not installed



Shield protects feet from:

- Rocks off muck pile
- Being crushed under wheels
- Slipping off platform

Adequate width to protect from rib pins

Outrigger deterrent to tip-overs

Conceptional Sketch of Mucker Step Platform

EXHIBIT IV-6

- Step platforms should be designed to retract when equipment needs to be transported to a new work site. However, the controls should be such that muckers should not operate without the platform in position.

- Platforms should extend outward at least to the outermost part of the operator's body. This feature would also limit the extreme minimum clearances under which the equipment will operate.

- When the platforms are set in place, they should be located as close to the ground as possible and rigid to act as a brace or deterrent for tipping characteristics of mucking machines.

- These platforms should have a footrail feature to minimize feet slipping off and parts of feet hanging off.

Theodore Barry & Associates suggests a careful redesign of mucker step platforms. The incorporation of the above features, and a rigid compliance with the constant use of the step platform will result in substantial reduction in injuries to mucker operators. The additional cost to the equipment is estimated not to exceed two percent of the total price of a mucker.

We feel that this recommendation can best be implemented through regulation immediately following the development and redesign of operator platforms.

3. <u>Inspection of Work Areas: Improved enforcement and compliance with current federal regulation 30CFR 57.3-22 is required to minimize fall of rock hazards.</u>

   As mentioned earlier, about 18 percent of all mucker accidents were caused by "fall of rock" on the operator. Inadequate maintenance of mucker work areas was repeatedly observed during field visits. Mucker operations were observed to take place in areas where less-than-adequate attention had been given to loose rocks left on the rib or back after the blasting cycle.

   Theodore Barry & Associates strongly feels that mucker operators must be trained more effectively in loose rock hazard identification and regular pre-operational inspection procedures be followed at all times. The front line supervisors must play the key role in administering these pre-operational inspection procedures more effectively than in the past, especially in the case of contract miners. The USBM needs to ensure improved enforcement and an increased compliance of the federal regulation 30 CFR 57.3-22.

4. Operator Protection: All overcast mucking machines should be equipped with adequate guards in front of the operator to protect him from rocks rolling off the loaded bucket.

Approximately 18 percent of all accidents associated with overcast muckers resulted from rocks rolling or flying off the loaded buckets. About 90 percent of these accidents result when rocks roll off the loaded bucket and hit the mucker operator either on his hands, fingers, head and front part of his body. The location of controls on almost all muckers is such that rocks rolling off the bucket hit the very fingers that are operating the controls of the machine. The problem is further compounded if the device that brings the controls to neutral is inoperative because it has either been removed or is completely worn out. In those cases, the machine continues to operate in an uncontrolled fashion, in spite of the natural reaction of the operator to move his hand out of the way, after being struck by a rock.

Theodore Barry & Associates recommends that appropriate protection to the operator from the hazard of flying rocks off the bucket is essential. The redesign of the buckets that minimizes the rolling of such rocks was considered, only as a marginal answer, and rejected as an unacceptable solution because of retrofit problems. Many manufacturers are providing guards to protect operators' hands, fingers, and front parts of his body, as optional equipment on new muckers, as shown in Exhibit IV-7. However, most of the mine operators do not buy this option, with the result that the majority of muckers in the underground mines today do not provide adequate operator protection of this kind.

Theodore Barry & Associates suggests that, as a minimum, the following features should be incorporated in these operator protection guards:

- They should be so designed that operators' visibility is not inhibited. A screen material shield of adequate strength installed between the bucket trajectory and the operator controls, as shown in Exhibit IV-7, is a good example.

- These guards should be so constructed that they can be retracted to facilitate transfer of muckers from one work site to another in the mine. However, some kind of a lockout procedure should be incorporated that ensures that the machine will only operate when these guards are in position.

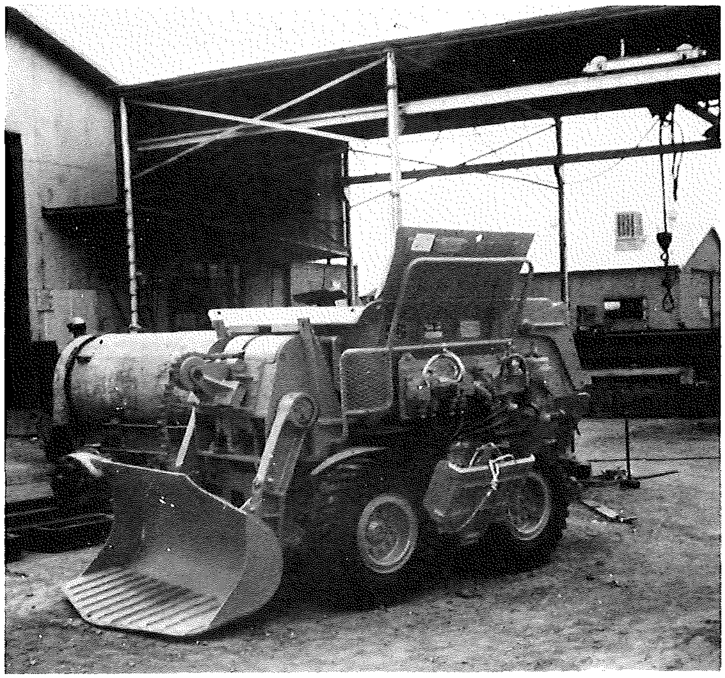


Exhibit IV-7

Example of Operator Protective Guards

We feel that though the installation of this protective guard will not eliminate the rocks thrown off the bucket, it will substantially reduce the probability of serious injury to the operator. We recommend that such devices be required on all new overcast muckers and that all the existing ones be retrofitted with such operator protection. This recommendation should be implemented through regulation and research on acceptable guards on overcast muckers.

5. Return to Neutral Devices: The "return to nuetral" devices on all controls of overcast mucking machines should be operational at all times during mucker operation.

As mentioned under "Hazards and Causes," the return to neutral device (normally springs) were found to be either removed altogether or are worn out so as to render them inoperational in a number of overcast mucker operations visited during this study. Although the limited information provided by the available accident reports does not cite the absence of operational "return to neutral" devices as a cause of accidents, Theodore Barry & Associates feels that this practice is a definite contributing factor to many mucker accidents.

The existing regulations that are supposed to discourage tampering with such devices are too vague to be enforced specifically in this case. Federal regulation 30 CFR 57.14-25 states that, "Machinery and equipment should be maintained properly," and CFR 57.14-26 states that, "Unsafe equipment or machinery shall be removed from service immediately." These two regulations in themselves have not succeeded in the elimination of the said unsafe practice. Theodore Barry & Associates, therefore, suggests that, through a specific and clear regulations, the recommendation to have an operational "return to neutral device" on the critical controls on overcast muckers be implemented.

SUMMARY OF RECOMMENDATIONS

Exhibit IV-8 below is a summary table of Theodore Barry & Associates' recommendations to improve operations and safety of overcast mucking machines. The probable impact on accident frequency and the estimated affect on mucker productivity for each of the recommendations is also presented. Our suggested method of implementation of these solutions is also summarized in this table.

EXHIBIT IV-8

Recommendation	Expected Reduction of Mucker Accidents	Productivity	$ Cost of Change	% Mucker Cost	Implementation
1. Study to Modify Equipment Design to Lower C.G. and Determine Minimum Track Width	15-20%	None	---	--	Research and Regulation
2. Redesign of Operator Step Platform	10-15%	None	Negligible	1%	Research and Regulation
3. Improved Inspection of Work Areas	10-15%	Negligible	None	None	Training & Improved Enforcement
4. Operator Protective Guards	10-15%	None	Negligible	1%	Regulation
5. Operational Return to Neutral Controls	5%	None	None		Regulation

The complete implementation of all the above recommendations will reduce a conservative 50-70 percent of all accidents associated with overcast mucking machines.

SLUSHERS

Slushers, like much of the ore handling equipment, are not new to the mining industry. They have been in use in much the same manner for over 50 years. They are commonly used for scrapping ore from a supply point or points along a path and into an ore chute or draw hole. They are available in various sizes ranging from 5 to 150 horsepower. The two major power sources used are electric and compressed air. Air-driven slushers are rarely found larger than 20 horespower. One, two, or three-drum slushers are normally available to consumers, but we found the two-drum type to be most popular in the U.S. metal mining industry.

PROBLEM STATEMENT

A typical lost-time accident at a slusher operator station is either due to the operator being hit by flying pieces of rock and debris or due to the cable snap-back when the slusher cable breaks. Slusher operators also get hurt at their work stations due to improper anchoring and tie-down of the slusher equipment, or while moving slushers from one location to another, under their own power.

Slips and falls account for 20% of all slusher accidents. Slusher operators have to constantly cross the ore pass in front of the slusher hoist in order to perform a number of tasks, such as broken cable repairs, moving the shieve block, breaking oversized ore, etc. Inadequate layouts and low clearances around the slusher station and cluttered work areas significantly contribute to slusher accidents. Activities performed in the slusher drift such as cable repair, moving shieve blocks, etc. are associated with many "fall-of rock" type lost-time accidents.

HAZARDS AND CAUSES

Exhibit V-1 clearly indicates the slusher related activities associated with high accident frequency. Operating slushers (27%), moving slushers (16%), repairing slushers and broken cable (17%), and moving slusher sheave (10%), account for the majority of slusher accidents. The remaining (30%) slusher accidents result from hits by rocks while barring hangups or slips and falls due to poor footing.

The hazards associated with <u>operating the slusher</u> are many times the result of equipment failure and poor slusher station layouts. Two prime areas of equipment failure are in slusher tie downs and cables. In both of these cases, few mines have standards or guidelines regarding adequate securing of slushers and cable care.

SLUSHER ACCIDENT SUMMARY

Activity	% of Accidents	% of Estimated Task Duration	Major Contributing Causal Factors (% of all slusher accidents)					
			Operator Protection	Equipment Failure	Inadequate Anchoring	Bad Roof Conditions	Accum. of Ore	Poor Station Layout
Operating Slusher	27.1	50	4.3	8.6	2.9	1.4	2.9	✓
Repair Slusher	7.1	3		2.9				✓
Repair Cable	10.0	10		7.1		1.4		
Move Shieve	10.0	5				4.3		
Move Slusher	15.7	3		5.7	2.9			
Bar Hangups/ Oversize Ore	10.0	15					8.5	✓
Unknown/Others	20.0	14	7.1		1.4	1.4	2.9	
Totals			11.4	24.3	7.1	8.5	14.3	

Source - Appendix E-4, E-6 (bound under separate cover).

EXHIBIT V-1

During the equipment observation and interviews of slushing operations, we found a number of installations where a slusher hoist was tightly fastened to a surrounding framework or to rock. In many cases, the slushers were held by wedging into a narrow section, by a hold-back chain (as shown in Exhibit V-2), or propped timbers. In each of these instances, the large strain generated on the cables, during slusher operation, results in enormous vibrations of the entire slusher hoist and the operator platform. During these vibrations and subsequent breaking and jumping of the slusher hoist, the operator, standing in close vicinity, is exposed to hazards. Very minimal clearances exist between the operator and the vibrating hoist, especially when the slusher tie downs give in. This fact is borne out by numerous accident reports that show recurring injuries to operators when their hands or feet get pinned under the hoist. Our field visits also reported instances when entire slusher units fell into ore chutes in front, as a result of improper tie downs.

Cable breakage is another leading cause of slusher accidents. The frequency of cable breakage depends upon the cable material being used, on the size of the cable in relation to the slusher horsepower, on the experience of the slusher operator in minimizing jerks to the cable during the slusher operation, on the initial condition of the slusher cable and lastly, on the nature of wear and tear on the cable. Field visits revealed that plow steel was the most frequently used cable material and that slusher cables were generally in poor condition. Plow steel is normally high in tensile strength, but is highly brittle. The constant fatigue on brittle cable during slusher operation, therefore, results in frequent cable breakage.

Injuries result when the broken cable snaps back on the slusher operator either directly or through the slusher drums. The drum guards on these slushers were normally found to reduce operator injury, but not completely eliminate it. Accident reports identified the number of instances where cast iron plates serving as drum guards were broken and sent into the legs of the slusher operator. The protective screens in front of the slusher operator were frequently found to be improperly tied, loose, worn out or even completely removed by the slusher operator.

Repairing of broken cable resulted in 10 percent of all slusher accidents. Cable repairing is a cumbersome manual process that involves unwinding and untangling of cable fibres before joining them together. Stiff cable ends, which are very sharp, often snap back at the operator, resulting in cuts and abrasions. In addition, cable repair activities done in the slusher drifts often expose the operator to hazards of loose rock and poor ground conditions.

As part of his normal routine, a slusher operator has to maintain the flow of ore into the ore pocket. Barring of

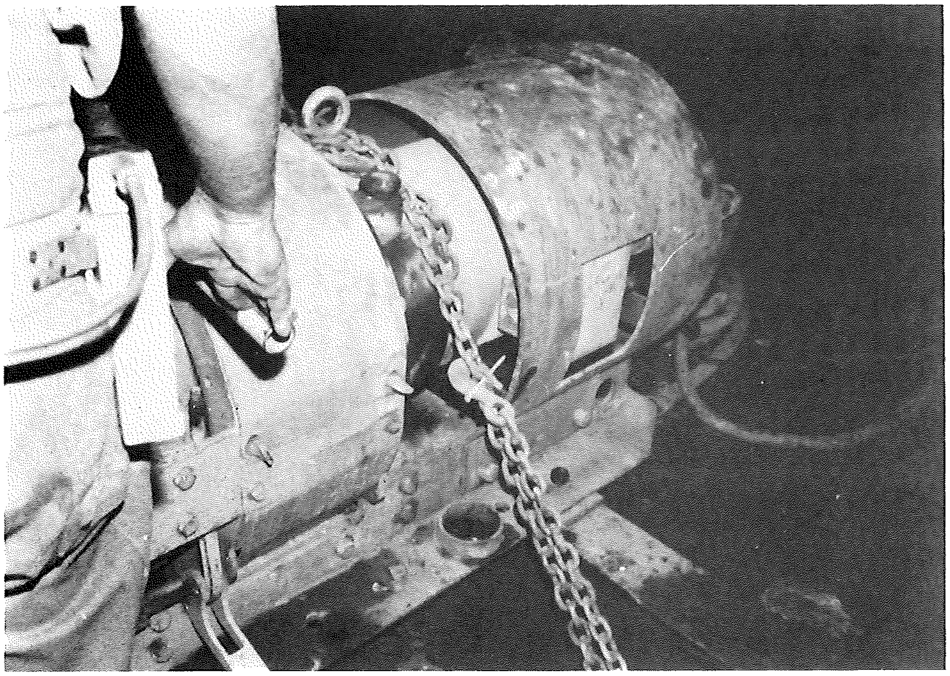


Exhibit V-2

Slusher Tied by Chain

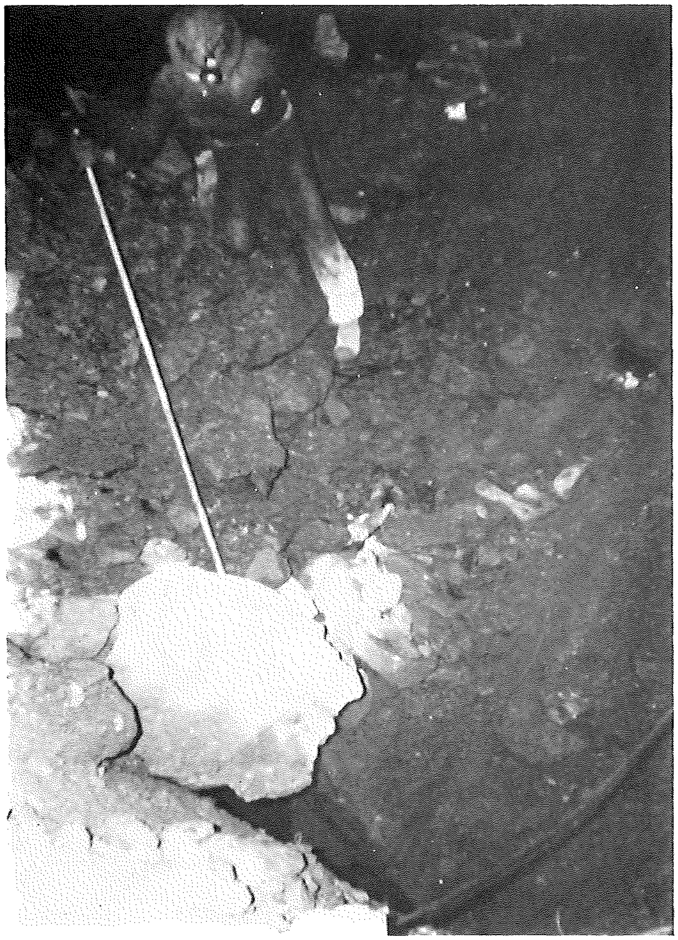


Exhibit V-3
Barring Oversize
Into Unprotected
Ore Pocket

hangups or loose rocks and secondary breaking and/or blasting of oversized rocks are constantly performed by the operator. Exposure to bad roof and ground conditions make the above activities hazardous. This hazard is magnified in the proximity of the ore pocket into which the ore is being slushed (Exhibit V-3). Ore pockets were frequently found to be unprotected and grizzlies removed by the slusher operator (in violation of Regulation 30 CFR 57. 11-12) in order to minimize tedious secondary breaking. This practice of removing grizzlies atop the ore pocket is not only dangerous, but also detrimental to the overall production rate, because large chunks of rocks allowed to pass can block the chute down below and choke off the ore flow. Removal of hangups in chutes are often more dangerous and time consuming than secondary breaking at the initial source.*

Relocating Slushers resulted in about 15 percent accidents. No set procedures are currently followed while relocating slushers in the stopes. Frequently, the slusher motor is used to pull the slusher assembly to the desired location. Interviews with operators revealed that operators occasionally ride these slusher platforms during the relocating activity. Slushers are fairly bulky assemblies and can generate considerable momentum. The result is a "pinned against" type of injury to the victim.

Summarizing, the major hazards and causes associated with slusher accidents are:

- Equipment failures, especially the snap-back action associated with broken slusher cables (24% accidents)
- Inadequate anchoring of slusher hoists (7% accidents)
- Improper methods of moving slushers (15% accidents)
- Inadequate slusher station layouts, especially in the area of working clearances and unprotected ore pockets.

RECOMMENDATIONS

Our solutions to minimize the above mentioned hazards are as follows:

1. Cable Wear: Steps should be taken to minimize cable failures. Research is required to develop new materials that will not fail easily under extreme conditions of fatigue

*See Final Report on "Analysis of Ore Handling Systems" Contract HO230004.

and wear associated with slusher operations. Criteria needs to be developed to improve inspection of slusher cables.

As mentioned earlier, plow steel is the most commonly used material for slusher cables. The wear characteristics of this material are not completely suitable for many of the slusher applications. This is especially true in light of the fact slushing serves as the entry-level jobs in many mines. This relative inexperience of slusher operators, coupled with minimal on-the-job training, results in "bumpy" slusher operation and therefore additional strain on the slusher cable. We recommend that additional research be undertaken to develop improved slusher cable material. Field visits revealed that very little attention was generally paid by the front level supervisors as to the condition of slusher cable. It is often considered as an area of relative unimportance and something that the operator needs to worry about. Quite frequently, cables discarded from other areas in the mine (hoists, tuggers, etc.) are used as slusher cables. No rigorous criteria currently exists that can help either the mine inspectors or supervisors to determine the adequacy of slusher cables. Theodore Barry & Associates recommends that the development and dissemination of such criteria will help minimize slusher cable breakages and therefore reduce slusher accidents. These inspection standards should be developed on the general guidelines specified by "The Society of Automotive Engineers' Recommended Practices for Lifting Crane, Wire Rope Strength Factors - SAE J959."

2. Relocating Slushers: Slushers should never be moved under their own power unless operated by a remote unit. In addition, no operators should ever ride a slusher while it is being moved.

We have already described the unsafe practice of relocating slushers under their own power. About 15 percent of all slusher accidents result from this activity. Theodore Barry & Associates feels that strong steps need to be taken by USBM and the mining supervision to discourage this unsafe practice. It can be argued that this practice is already a violation of the existing regulation 30 CFR 57 14-36, which states that all equipment will be used for its designed usage. We feel that this regulation is too vague to discourage the unsafe practice under review.

Theodore Barry & Associates suggests that the improved relocation methods be targeted at slushers already in service. All of these existing slushers should be retrofitted with adequate hooks, eye bolts, or structures for the purpose of lifting. Regular inspections ought to be carried out to ensure the adequacy of these items. In addition, USBM should ensure that slushers are never lifted or dragged under their own power to another location. As an alternative, a separate slusher could be properly rigged and secured for this task. Theodore Barry and Associates appreciates the difficulty of enforcing this proposed regulation, but we strongly feel the need for it.

3. Slusher Station Layout Guidelines: Specific guidelines spelling out minimum clearances at the operator station, adequate anchoring criteria, minimum size of walkways around the ore pocket, etc., need to be researched, developed and enforced at all slusher applications.

   As described under Hazards and Causes, a large number of slusher accidents resulted from inadequate anchoring of slusher hoists. Primitive and temporary anchoring devices often fail to withstand the constant vibrations of the hoist unit. No criteria currently exists that specifically determines the adequacy of slusher anchoring devices. Current anchoring methods are obviously inadequate and need to be replaced by new methods. Research in this area is recommended.

   In addition, increased enforcement of regulations requiring grizzlies over all slusher ore pockets is needed. Adequacy criteria for protected walkways across the ore pocket (in front of the slushers) needs to be specified and enforced. The walkways encountered during our field observations were found unsafe and unprotected at a number of operations. The enforcement of protected walkways will minimize the hazard of slips and falls around the ore pocket.

SUMMARY OF RECOMMENDATIONS

Exhibit V-5 on (the following page) is a summary table of our recommendations to improve slusher operations and safety. The probable impact on accident frequency and their estimated cost in terms of loss or gain in productivity for each of the recommendations is also presented. Our suggested method of implementation of these solutions is also indicated.

EXHIBIT V-5

Recommendations	Expected Reduction of Slusher Accidents	Cost Analysis: Operation Productivity	Cost Analysis: Cost of Change	Cost Analysis: % of Slusher Cost	Implementation
1. Minimization of Cable Wear	10-15%	Increase	Negligible		Research
2. Procedures for Moving Slushers	10%	None	Negligible		Regulation
3. Slusher Station Layouts	20%	Slight Increase	Negligible		Regulation
4. Anchoring Devices	10%	None	Negligible		Research & Regulation
5. Use of Grizzlies	5%	Slight Increase	Negligible		Increased Enforcement

The efficient implementation of our recommendations is expected to reduce the overall slusher accidents by 55 to 60 percent.

SKIP HOISTS

Hoisting of men, materials and ore from one level to another is commonly done throughout the underground metal mining industry. Skip hoists that are normally used for the movement of ore will be the topic of the following discussion. Two basic types of skip hoists were included in this study; drum style and friction hoists. The drum hoists have one end of the rope(s) anchored to the drum while the entire drum is used for rope storage, while the friction hoists drive the rope by friction. Common variations of hoists are based on number of drums, ropes, and whether the hoist application is along vertical or sloped shafts. Most of these variations were observed during our field visits.

PROBLEM STATEMENT

Approximately one-third of all skip hoist accidents occurred at the skip loading station. Skip loaders stationed at these service levels were occasionally struck by muck splash from the chute or by rocks and debris falling down the shaft.

Another type of skip hoist accident, often assoicated with high severity, we found to accur when the personnel cleaning the shaft are hit by falling rocks, or when personnel hit protruding objects while riding the skip hoist buckets. Severe accidents also occur when, due to a breakdown in communication, the skip hoist is accidently started while there are personnel (maintenance, repair or clean-up crew) in the shaft.

HAZARDS AND CAUSES

Exhibit VI-1 on the next page summarizes the results of the skip hoist accident analysis. The major activities being performed at the time the accident occurred, and the major hazards and causes associated with each of them are documented. Loading skips accounts for 33 percent of the accidents, repair and clean-up activities result in another one-third of the accidents. Riding skips primarily meant for carrying ore result in another 20 percent of all the skip hoist accidents.

A major hazard associated with the skip hoisting operation is the loader's exposure to flying rocks or to an unexpected surge of muck through the measuring gate or chute gate. Fast moving ore, whether into a measuring pocket or directly into a skip, sends bits of rock flying in all directions. Groundwater accumulation, drill tailings, and highly saturated ore bins pose additional hazards to skip loaders. The sudden rush of water and mud through the measuring pocket gate, or chute gate can often wash the skip loader out of his operating position. Measuring pockets restrict damage to the main shaft from rock splash and sudden surges of ore. However, the

EXHIBIT VI-1

SKIP HOIST ACCIDENT SUMMARY

Activity	% of Accidents	% of Estimated Task Duration	Major Contributing Causal Factors (% of Skip Hoist Accidents) Flying Rock or Surge of Muck	Brake System	Protrusions in Shaft	Equip. Failure	Missing Guards	Hoist operated While Man in Shaft
Loading Skips	33.3	50	23.8				4.8	
Riding Skips	19.0	5		4.8	9.5			
Cleaning Shaft Pocket	14.3	10						9.5
Repair Work	19.0	10	4.8			4.8	4.8	4.8
Others/Unknown	14.3	25						
Totals	100.0	100.0	28.6	4.8	9.5	4.8	9.6	14.3

Source - Appendix F-4,8 (bound under separate cover).

skip loader's operating position, with respect to the first ore bin gate (measuring pocket or direct system) is the critical factor when considering lost-time accidents. In most cases, skip loader stations were found to be very near this first ore bin gate. Very few of these stations were protected from rock splash or a sudden surge of ore. Exhibits VI-2 through VI-4, show skip loader stations placed very close to, and between the ore bin gates (direct loading and measuring pocket types respectively). Similar hazards of rock splash and sudden surges of ore are also present during the barring of an occasional chute hang-up caused by jamming of rocks in the chute. In this situation again, the skip loaders' nearness to the moving rock accentuates the problem. Often, a loaders' station is located close to, or actually in the shaft. Groundwater, skip overflow (common when measuring pockets are not used), and debris all can contribute to frequent fall of objects down the shaft. The result is an injury to the skip loader. The sketch in Exhibit VI-2 illustrates a frequently occurring skip loaders' position relative to the ore bin chutes and placed in the shaft. The lack of overhead protection available to the loader is evident from the sketch. Accident analyses in Exhibit VI-1 indicates that falling rock accounted for 28.6 percent of the skip hoist accidents.

Hazards associated with riding skips or buckets are both mechanical and procedural in nature. In some cases, safeguarding devices which were supposed to be used by personnel operating or riding buckets were not used. An assumption often made while riding skip hoists usually used for ore hoisting is that if a hoist is safe enough to hoist ore, it is safe enough to hoist men. Quite often, such skip hoists do not rigorously meet the safety criteria required for normal hoists used to transport men. Failure to use crossheads or guards which act as guides and safety braking devices are some of the examples of misuse of equipment. Unconscious ignorance of procedures and inattention often accentuate the probabilities of injury. Examples of procedural breakdowns when riding skips are accidents involving hoistman inattention, or riding skips with machinery. About ten percent of the accidents occurred when personnel riding skips were hit by protrusions in the shaft.

A breakdown in communication between the hoistman and the repair or clean up personnel in the shaft was also found to be a frequent hazard with the skip hoisting operation. About 14 percent of skip hoist accidents occurred due to this loss of communication. A <u>direct</u> and <u>continuous</u> communication system between the two parties in cases such as above is almost non-existant in the underground metal mining industry today. The mining industry appears to have traditionally relied on the commonly-used practice of the bell and cord system. In this system, the skip operator is given the appropriate instructions in a signal code by pulling on the buzzer cord in the shaft.

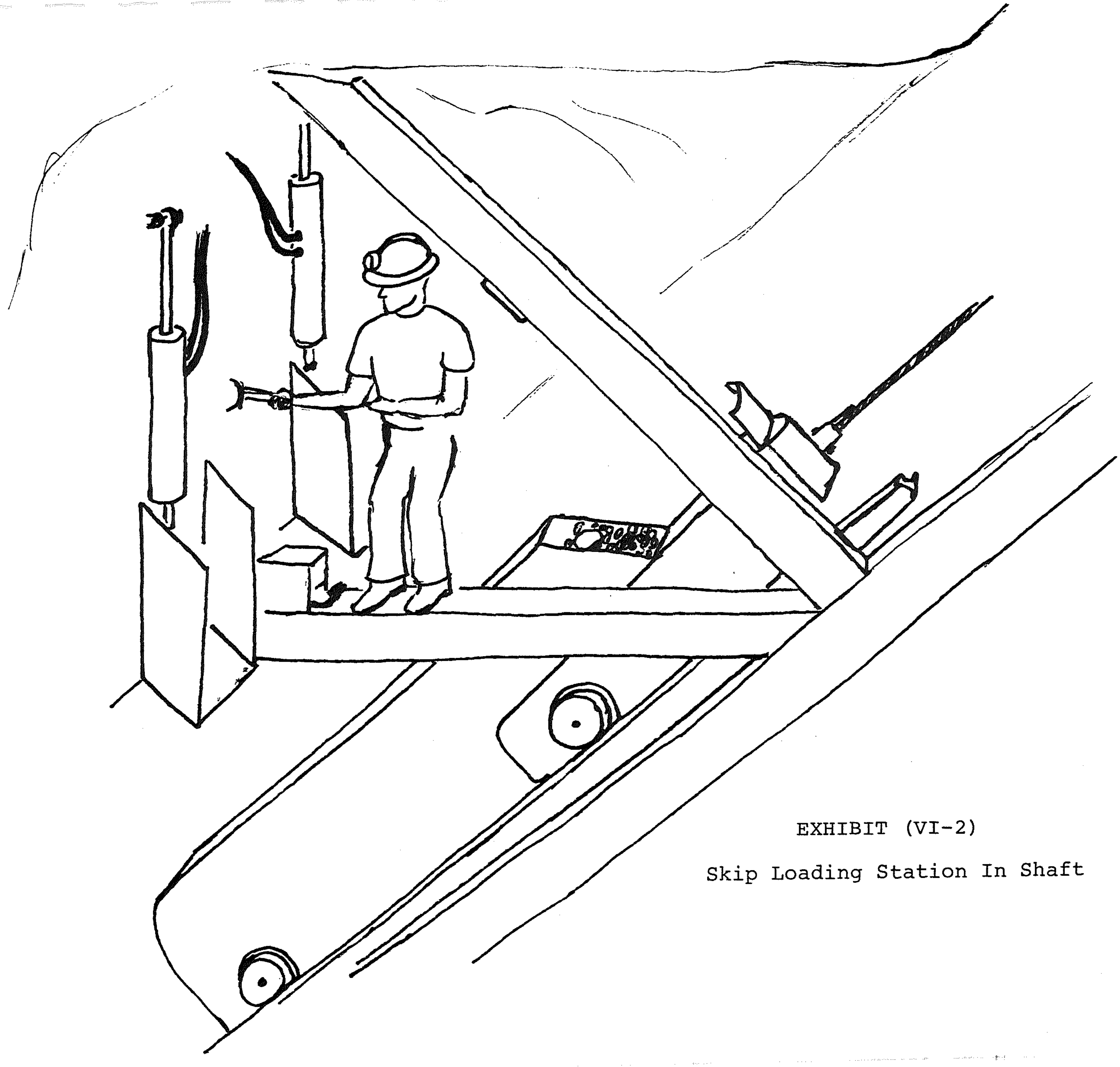


EXHIBIT (VI-2)

Skip Loading Station In Shaft

A neglection of the lock out procedure, or a misinterpretation of the buzzer code, or just plain inattention on the part of the hoistman can lead to severe injuries to personnel in the shaft.

Summarizing, the following major hazards and causes are associated with skip hoist accidents:

- Fall of rock or debris on the loader operator or maintenance personnel (28.6% accidents).
- Improper use of some skip hoists to transport men (18.3% accidents).
- Lack of constant and direct communication between the loader operator and repair or clean up personnel in the shaft (14.3% accidents).

RECOMMENDATIONS

Our recommendations to minimize the hazards associated with skip hoists are discussed as follows:

1. Operator Protection at the Skip Loading Station: Manual skip loading stations should either be equipped with adequate protection from falling rocks and surge of muck or they should be relocated so that the operator is not in the path of falling debris or muck surges from the chute. In addition, the use of measuring pockets should be encouraged.

   Our field visits and accident analysis point out the need for improved protection for the skip loader in many cases. Of course, automating the skip loading operation will eliminate such hazards completely, but, we recognize that it may not always be an economically feasible alternative.

   We feel that more thought needs to be given while designing skip loading work stations. No criteria currently exists that specifically addresses this problem. Historically, it appears that the skip loader work station is located wherever it is closest to the chutes, without much regard to existing clearances and operator protection from flying rocks. We recommend that operator stations be located so that they are reset from the shaft, and therefore out of the way from the path of falling debris. This will minimize the opportunities of operators getting hurt, even if the fall of rocks occurs.

   However, in many cases (Exhibit VI-3), relocation of the skip loader station may not be feasible or economical. In those cases, adequate operator protection (example

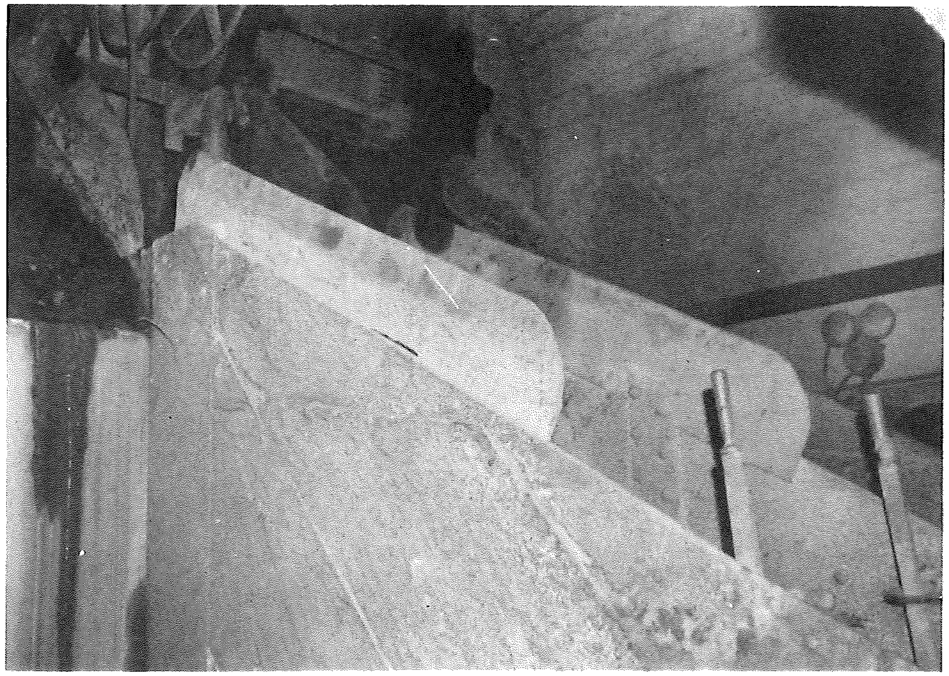


Exhibit VI-3

Skip Loader Station Without Overhead Protection

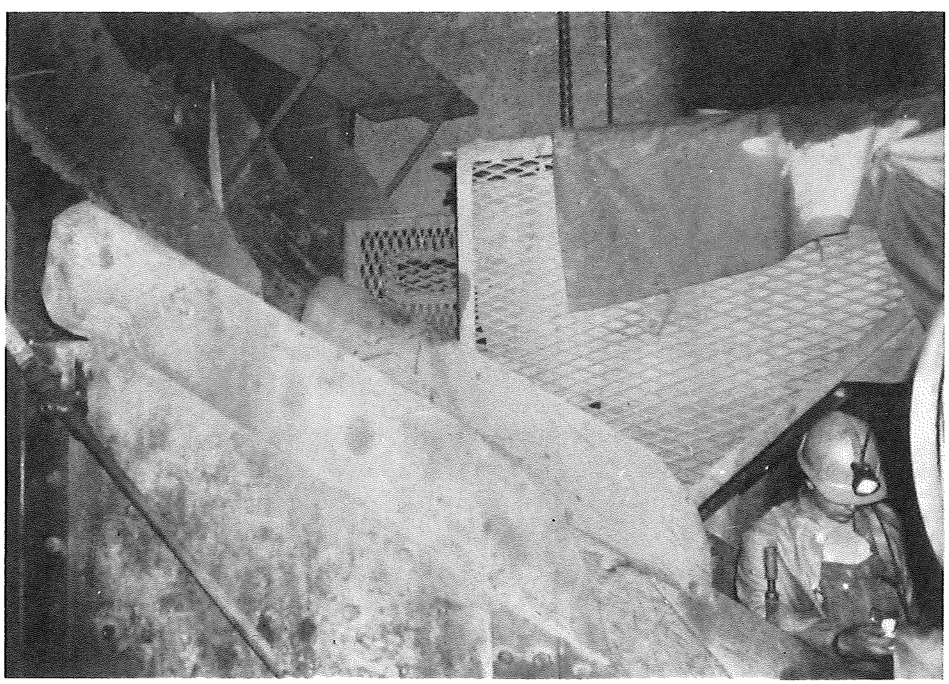


Exhibit VI-4

Skip Loader Station With Overhead Protection shown in Exhibit VI-4) should be provided to minimize injuries to the operators. It should be borne in mind that this should not hamper operator's visibility.

Some additional suggestions that will help reduce skip loader injuries are (a) centralized control of chute gates from the work station, and (b) improved devices to eliminate chute hang-ups (some mines were found to use compressed air, water spray, or vibrators), (c) stricter control of the entry of oversize rock into the system, due to the fact that oversize rock not only leads to unsafe situations, but it hurts the overall mine productivity.* This stricter control of oversize rock can be accomplished through improved awareness of supervision. Theodore Barry & Associates feels that skip loading stations, once modified with these features will yield substantial returns in increased productivity to pay back additional costs. It is estimated that about twenty-five percent (25%) of skip hoisting accidents may be eliminated due to improved design of loading stations.

2. <u>Restriction of Personnel Transport on Skip Hoist System: Any hoist used to transport men at any time, other than shaft inspectors, should conform to the standards as stated in 30 CFR 57.19-1 through 57.19-135.</u>

Throughout our field work and accident analysis of skip hoist operations, we have found a reluctance to implement all the safe practices as required in federal regulations. Primarily, this is true when hoists are used most for muck and materials, but occasionally for the transport of persons. For example, in some situations, the skip loader rides a skip from level to level when pulling muck from more than one station. Shaft sinking equipment, such as buckets, can be even less suited for personnel transportation than an established skip system.

It is our recommendation that hoists used for even occasional transport of men be required to conform to each of the regulations as stated in the federal register (30 CFR 57.19-1 through 57.19-135). Theodore Barry & Associates feels that stricter inspection, enforcement and mine compliance to these expanded regulations would effectively reduce accident frequencies by 15 percent in skip hoist operations.

3. <u>Communication Systems</u>: <u>All hoisting systems should have a continuous verbal method for signaling hoist operators from skips, cages or other conveyances, at any point in the shaft.</u>

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*See Final Report of Parent Contract HO230004, Chapter II, July 1974.

Many of the accidents which occured in repair, cleaning, inspection activities and when personnel were riding skips or buckets, could have been eliminated with increased communication between hoist operators and personnel in the shaft. Situations where hoists were used inadvertantly while shaft work was being done, or used improperly as a result of misdirected signals are cases in point. The existing signal cord method is obviously not fool proof, and often leads to misinterpretations. It is our recommendation that some other positive means of communication be required between skip operators and personnel in the shaft.

Investigation of the availability of continuous communication systems revealed a wide variety of telephone and radio-type systems for increased advantages in underground operations. Some of the alternatives are:

- Two-Way Telephones
- Loudspeaking Telephone
- Radio System

- Two-Way Telephones: A few underground hoisting operations employ telephone communication at various station levels. In-shaft communication consists of phones in several locations and installation of a complete conductor system through the full length of the shaft. Performance of telephone systems are often adversely affected by the dust, humidity and temperature conditions found underground.

- Loudspeaking Telephones: A few of the mine operations observed used systems similar to telephones on rail haulage, except that initial communication is established by paging over various loudspeakers. Additional advantages of this system are that the operators intentions can be announced over the entire system, and that a message can be conveyed to any point desired.

- Radio Systems: Radio communication systems were also observed in both shaft inspection activities, as well as personnel hoisting operations (Exhibit VI-5). Fixed units at hoisting controls on conveyances, or carried units, provided an information link whenever needed.

  Theodore Barry & Associates feels that, of the existing technology alternatives, the radio communication has the most potential. However, new communication methods ought to be continually researched for special applications in the underground metal mining industry. The cost of each system would vary, but savings in information relay time, with increased accuracy and accident reductions, is likely to return much of the costs of implementing such a device.

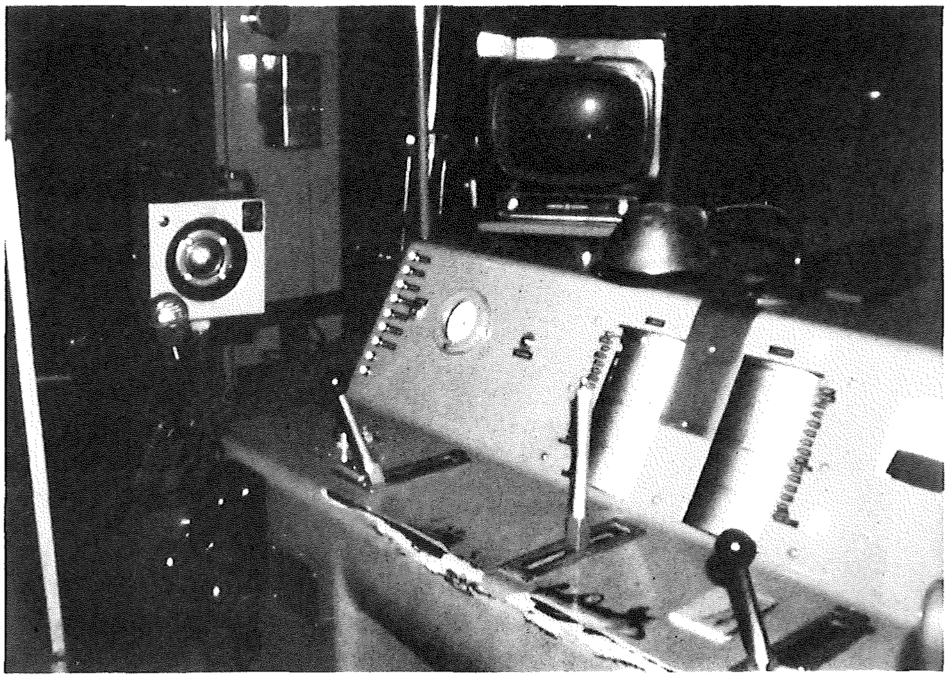

Exhibit VI-5

Hoistroom With Radio Communication

SUMMARY OF RECOMMENDATIONS

Exhibit VI-6 below is a summary table of our recommendations to enhance safety of skip hoists.

Recommendations	Expected Reduction in Skip Hoist Accidents	Cost Analysis: Productivity	Cost Analysis: Estimated Dollar Amount	Cost Analysis: % of Equip. Cost	Implementation
1. Relocating of skip loading stn. plus operator protection	20%	Slight Increase	Negligible	--	Regulation
2. Restriction of personnel riding skips	15%	None	None	None	Regulation
3. Shaft communication system	10%	Slight Increase	Variable	Variable	Research & Regulation

EXHIBIT VI-6

Implementation of the above recommendations is expected to reduce overall skip hoist accidents by a conservative 45 percent.

SHUTTLE CARS

Shuttle cars, also commonly known as ore trucks, are used to transport broken ore from the face to the ore bin, or onto a conveyor system. These are loaded at the face and discharge this broken ore by means of bed conveyors or telescoping haulage trucks. Shuttle cars come in varied models and configurations. Only three different types were observed during the field observations. Our findings regarding the shuttle car operation and safety are, therefore, based on limited observations and data.

PROBLEM STATEMENT

Recurring lost-time accidents associated with shuttle cars were either due to operator being struck by rocks or due to equipment collision. Shuttle car operators are exposed to the hazard of rocks rolling off the haulage beds or are hit by fall of loose rocks off the roof.

Shuttle car collisions or runaways are caused primarily by brake failures or the use of inadequate brakes. The lack of adequate visability to the shuttle car operator was also found to be a prime contributor to the collision type accidents where the equipment runs into the rib.

HAZARDS AND CAUSES

This section will describe the causes of major accidents associated with shuttle cars, as summarized in Exhibit VII-1, on the next page.

1. Collision or run-aways: The failure of brakes was the prime cause of at least one-third of the fatalities and about 10 percent of all lost-time accidents associated with shuttle cars. In many cases, available brakes were found to be inadequate for the conditions under which the shuttle car was operating. For example, the bad road conditions and steep grades on which this equipment (especially diesel shuttle cars) is used taxes the brakes beyond their capacities. In addition, the mud and water conditions in many haulage drifts deteriorate most braking systems. Independent emergency, service and parking brakes are not available on the diesel units.

   The failure of brakes generally renders the equipment in an "out-of-control" situation during tramming activities. Typically, the operator panics and jumps out of the equipment and suffers severe injuries. These injuries are the result of him being run over or him

EXHIBIT VIII-1

SUMMARY OF SHUTTLE CAR ACCIDENT TYPES

Activity	% of Accidents	Accident Causing Agency (% accidents by agency for each type)				
		Fall of Rock	Struck by Moving Equipment Part	Brake Failure	Rocks off Haulage Bed	Others/Unknown*
1. Tramming Shuttle Car	60.0	8.6	2.9	8.6	25.7	5.7
2. Repairing	11.4		5.7	2.9		2.8
4. Pedestrian in Vicinity	8.6		2.9		2.9	2.8
6. Dumping Load	5.7					5.7
7. Stepping On/Off	8.6					8.6
Others	5.7					5.7
Totals	100.0	8.6	11.4	11.5	28.6	31.3

Source: Appendix G-4, G-8 (bound under separate cover).

*Existing accident reports were unable to provide reliable information in these cases colliding with the rib. Lack of adequate maintenance of shuttle car equipment was also cited as one of the reasons of brake failures. In any case, no real back-up systems for critical functional requirements like brakes, steering and hydraulic systems are either required or generally available in the case of diesel shuttle cars.

2. Rock roll over from haulage beds: This problem typically occurs with the electric type shuttle cars, and accounts for a relatively large number of lost-time accidents. Exhibit VII-2 is an example showing the relative location of the operator to the haulage bed. Over loading of the truck and bed type shuttle cars, coupled with rough road conditions, result in rocks rolling off the bed onto the operator. No protection is available to the operator from this hazard. The rock type accidents resulted in about one-third of all shuttle car accident data base.

3. Fall of rock: Although not accounting for a significant amount of shuttle car accidents, fall of rocks do result in severe injuries to shuttle car operators. These workers are constantly exposed to the hazard of loose rocks both at the face and along the haulage drifts. No protection from falling objects is currently available to most of the shuttle car operators.

4. Poor visibility: Poor visibility is another prime cause of the shuttle car running into the rib and into other equipment. This lack of visibility is significant in the case of low-profile conveyor bed type shuttle cars. Two locations of operator compartments are generally found for this equipment. Exhibit VII-4 shows the situation when operators are positioned in a corner of the equipment. Visibility in the forward direction is relatively good, but in the rear and far side areas, visibility is at a minimum. In this location, little protection is available for the operator if the equipment smashes into a rib or collides with other equipment. Exhibit VII-5 shows the center/side placement of an operator. Visibility is somewhat restricted in both tramming directions, as the driver must look over the tires or around the side. Operator protection in the event of a collision is, however, better in the latter arrangement.

In summary, the major hazards associated with shuttle cars are as follows:

- Equipment malfunctions, especially failure of brakes
- Lack of operator protection from rock rolling off haulage beds
- Hazard of fall of rock

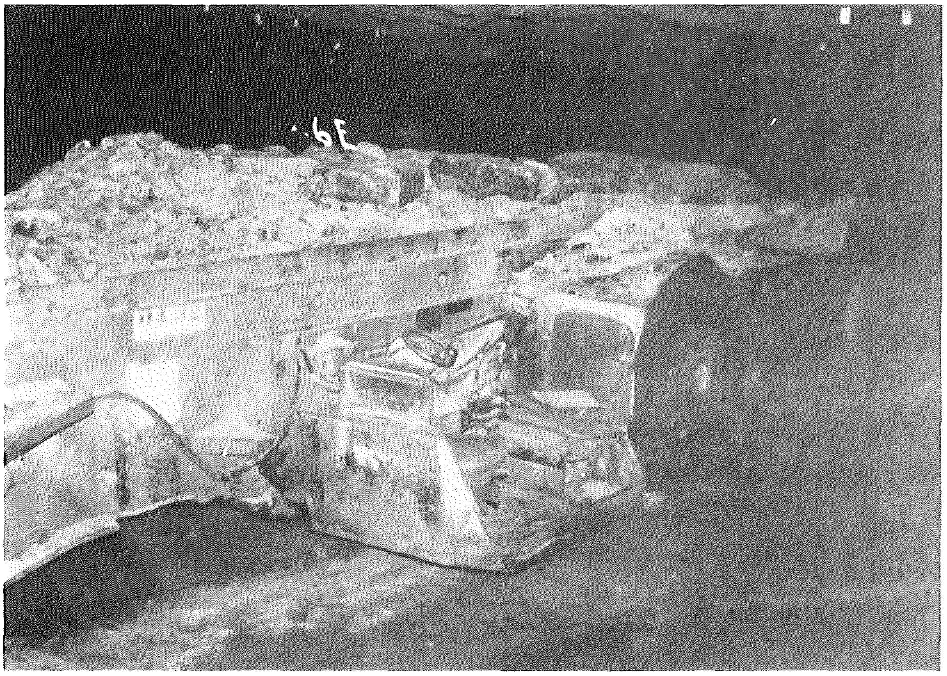

Exhibit VII-2

<u>Operator Exposed to Rocks Off Haulage Bed and Falling Objects</u>

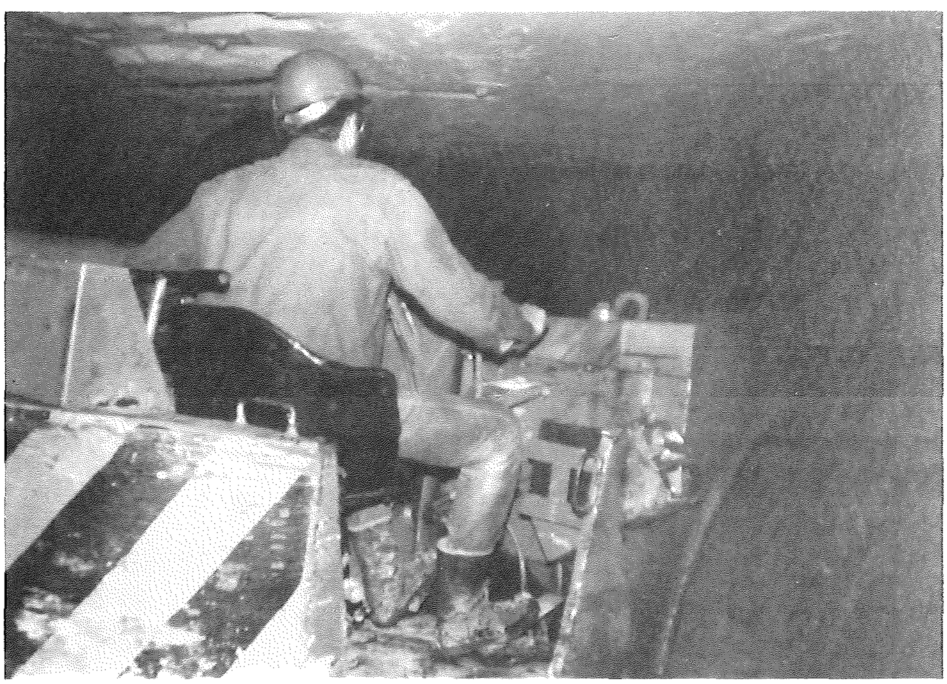

Exhibit VII-3

<u>Low Head Clearance for Shuttle Car Operator</u>

Exhibit VII-4

Corner Located Operator Compartment: Minimal Operator Protection

Exhibit VII-5

Center Placed Operator Compartment: Limited Visibility But Improved Operator Protection

- Inadequate visibility in some models

RECOMMENDATIONS

Many of the hazards and causes of accidents relating to shuttle cars were found to be similar to those of Load-Haul-Dump Machines. Some of the recommendations to improve equipment safety, by minimizing brake and other system failures are similar to those already described under the LHD section. Those common solutions will only be mentioned here and the reader is directed to the pertinent portions of the LHD sections.

Our recommendations to improve operational safety of shuttle cars are as follows:

1. Operator Protection: Adequate guards or shields to protect the operator from rocks off the haulage bed should be required on all conveyor bed type of shuttle cars.

   As mentioned earlier, about 28 percent of all shuttle car accidents are caused by rocks rolling off the haulage beds. We recommend that guards or a screen shield properly installed be required to minimize operator injuries. A screen appears to be the best choice, as it will not impair visibility which is already a problem on these low bed type of shuttle cars. The best way to implement this recommendation is through regulation. Although the screen will not prevent rocks rolling off from the bed, it is expected to eliminate injuries to the operator from this cause.

2. Inspection of Work Areas: Improved maintenance of work areas and active haulage drifts must be done through increased compliance and enforcement of regulation 30 CFR 57.3-20 through 57.3-23.

   Fall of rocks account for about eight percent of accidents. These can be minimized through an improved compliance of the above regulations. No operator protection is available to the operator in case a loose slab or rock falls. Careful consideration was given to the idea of requiring FOPS on shuttle cars, but we feel that with the given accident history of shuttle cars and our field observations, the cost of FOPS on shuttle cars can not be economically justified at this time. Improving the trimming procedures will considerably reduce the injuries from from fall of rock.

3. Braking System: All diesel operated shuttle cars in underground metal and non-metal mines should be equipped with independent service, parking and emergency brakes.

Braking systems on all shuttle cars should conform to a specific performance criteria.

This solution is basically the same as recommendation number two of the LHD section. It follows basically the same rationale. It is expected that about 30 percent of fatalities and 10-15 percent of all lost-time shuttle car accidents can be prevented by complying with this recommendation through research and subsequent regulation.

4. Pre-Shift Check List and Equipment Log Book: Each shuttle car should be equipped with a safety check list to be used by the operator at the start of each shift, prior to beginning haulage operations. Also, each shuttle car should be equipped with an equipment log book in which the operator will make entries of problems encountered.

Many of the shuttle car accidents can be attributed to inadequate maintenance of the equipment, as in the case of LHD machines. The details of this recommendation are similar to those documented in the pertinent sections of LHD equipment recommendations (recommendation number five on page 30 of this report).

SUMMARY OF RECOMMENDATIONS

Exhibit VII-6 below is a summary table of our recommendations to minimize shuttle car accident frequency. In addition to documenting the expected impact on accident frequency, the estimated cost for each recommendation is also presented. Our suggested method of implementation of these solutions is also indicated below.

Recommendations	Expected Reduction of Shuttle Car Accidents	Cost Analysis			Implementation
		Productivity	Cost of Change	% of Shuttle Car Cost	
1. Operator protection from rocks off bed	25%	Slight Increase	Negligible		Regulation
2. Inspection of work areas	5%	Slight Increase	-		Increased Enforcement
3. Braking system improvements	10-15%	--	$1000	.05%	Research and Regulation
4. Pre-shift check and equipment log book	--	-.5%	$500-%1000*		Regulation

*One time cost for all shuttle cars in the mine.

The above recommendations, when fully implemented, are likely to reduce shuttle car accident frequency by 40-45 percent.

CONVEYOR SYSTEMS

Conveyor systems in underground metal and nonmetal mines are often used to transport ore from a breaker crusher to a skip hoist or to the surface. In some instances conveyors are used for ore haulage to a crusher, but usually the characteristic of uncrushed ore inhibits this kind of application. The popularity of conveyor systems in ore handling operations is steadily growing, especially in operations requiring long haulage distances.

Conveyor systems account for a relatively small number of accidents in underground metal and non metal mines in the U.S. Two possible reasons for this fact are (a) the small number of conveyor systems utilized by the metal mining industry today, and (b) personnel are not transported via conveyors, and therefore are not directly exposed to the equipment.

PROBLEM STATEMENT

A typical conveyor accident occurs when a maintenance man is caught in the moving conveyor while inspecting, servicing or cleaning it. Usually, a part of the victim's body or his clothes become caught on the conveyor drive head, take-up pulleys, or the idlers. Once caught, he is drawn into the machinery and seriously injured. Approximately 66 percent of all conveyor accidents analyzed occurred at these conveyor pinch-points.

HAZARDS AND CAUSES

The two primary types of conveyor accidents occurring are:

1. Inspecting or cleaning moving conveyors
2. Hit by rock off the moving conveyors.

The causes and hazards involved with each of these problem areas are discussed below in detail:

Inspecting, cleaning conveyors: As mentioned earlier, most of the accidents occur when a maintenance man is caught in the moving parts while inspecting or servicing the equipment. Approximately 75% of all conveyor accidents occcurred in this fashion.

A primary factor involved in most conveyor accidents is the priority of a continuous operation. Shutting down one conveyor to inspect or work on it may usually mean shutting down the entire operation. Production pressure to get material out of the mine creates a situation where repair or adjustment takes place while the system is operating whenever possible. In this way, the hazardous situation leading to accidents is created.

Interviews with mine operators indicated that some maintenance work was done during operations but most was scheduled during idle periods. Equipment designers and manufacturers mentioned that the equipment was not designed to be maintained during operation, and that nearly all maintenance accidents could be avoided if the conveyor had been stopped.

Equipment guards are required on all moving machine parts which may be contacted by persons. At some mines, adequate guards were not provided, as shown in Exhibit VIII-1. These guards only serve the purpose of protecting a person from accidently contacting the moving part but cannot protect the worker who deliberately bypasses the protection.

Rocks off moving conveyors: Another type of conveyor accident occurs when maintenance personnel or cleanup crews are walking close to or under a moving conveyor. Rocks are knocked off and roll off conveyors, striking persons in the vicinity. This problem is intensified when conveyors are used to haul uncrushed rock. Exhibit VIII-2 illustrates the accumulation of large rocks along the side of a conveyor system. These rocks rolled off of the conveyor, thus representing a potential hazard. The use of inadequate guards and other protective devices results in many of the accidents of this type.

Our observations of conveyor operations and interviews with operators identified additional hazards which were not revealed through the past accident analysis. Belt materials are required to be constructed of fire-resistant material, but many items which are part of the equipment system do not have this quality. Cleaning devices, wooden supports, and timbering are examples of flammable items in the vicinity. Exhibit VIII-3 shows a conveyor belt wearing its way through an idler hanger bracket. This same tendency will cut completely through braces and supports if not checked. Unchecked belt wear such as the tendency shown above can easily create a hazardous situation due to fire and equipment failure.

RECOMMENDATIONS

Investigations of the problem areas revealed that nearly all solution ideas are covered by an existing regulation designed to reduce hazards and accidents. Our recommendations, therefore, are presented below to highlight areas of increased enforcement and to augment the current regulations.

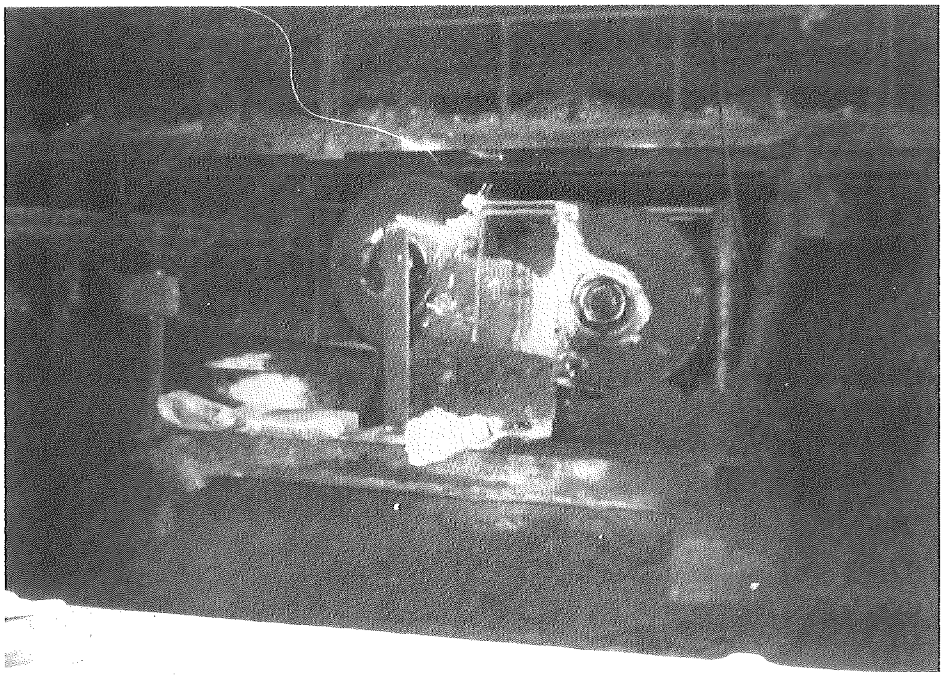

Exhibit VIII-1

Inadequate Conveyor Guards

Exhibit VIII-2

Example of Rocks Off Moving Conveyors

Exhibit VIII-3

Conveyor Wearing Out the Idler Hanger Bracket

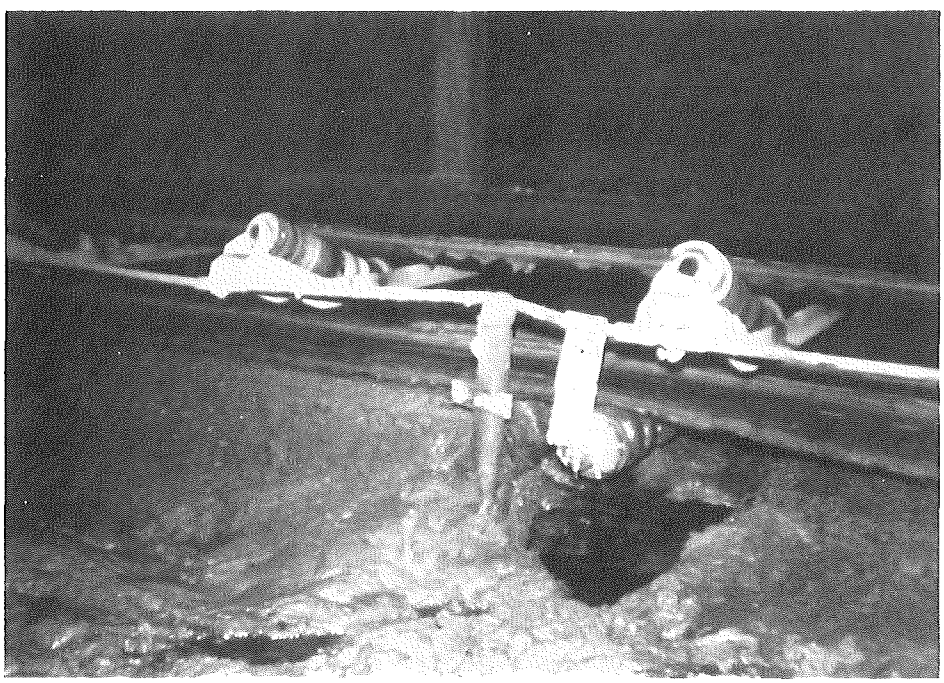

Exhibit VIII-4

Muck Buildup Under Conveyor

1. Stricter inspection enforcement and mine compliance accompanied by expanded interpretation of certain rules and regulations is required.

Most of the accidents associated with conveyor systems were directly due to personnel caught in pinch-points of operating belts. Theodore Barry & Associates feels that better mine compliance and stricter enforcement of the following regulations will aid in reducing hazardous situations. Comments concerning expanded interpretations of these rules are also included.

Federal Regulations 30 CFR 57.14-1 and 57 14-3 require the mandatory use of guards at the drive, head, tail and take-up pulleys of the conveyor systems. Further, sections 57.14-29,33,34 and 35 require that the conveyor systems (and the machinery) should not be cleaned, dressed or lubricated while in motion. Compliance is generally good, though the operators continue to defeat its intent and get caught in the machinery while working on it. A possible solution is the mandatory use of interlocking devices which would turn off the equipment automatically when the guards are removed. Again, the practice of designed, scheduled maintenance programs during equipment idle time should be encouraged. Such efforts will minimize the need for conveyor maintenance when the equipment is operating.

2. Belt Cleaners: Belt cleaners should be used on conveyors to minimize buildup of material and carry-back of broken ore.

Exhibit VIII-4 illustrates a case where belt cleaners were not in use. The pile up of muck under the conveyor is clearly shown. The clean up operation of this muck build-up is carried out frequently while the belt is operating. This hazardous situation can be minimized by the use of better belt cleaning equipment. Such belt cleaners are gaining popularity in the mining industry, although substantial research needs to be performed to develop reliable belt cleaners. Theodore Barry & Associates encourages more research in this area and also suggests that these devices be installed at all the appropriate conveyor systems to minimize the need for cleaning activities.

3. Rock Guards: Adequate protective guards along conveyors should be required when uncrushed rocks are handled and when personnel need to walk under overhead conveyors.

Exhibit VIII-2 indicates the hazards created by uncrushed rocks that fly off conveyors. Although Federal Regulation

30 CFR 57.14-11 essentially states the spirit of this recommendation, Theodore Barry & Associates feels that modifying that rule to emphasize the additional dangers of undercrushed rocks will be helpful. Increased enforcement of this expanded regulation 30 CFR 57.14-11 will help to reduce conveyor-associated accidents by about 15 percent.

SUMMARY OF RECOMMENDATIONS

The table below summarizes our recommendations to improve the operations and safety of conveyor systems.

Recommendation	Expected Reduction In Conveyor Accidents	Estimated Costs		Implementation
		Productivity	Actual $ Amount	
Enforcement and Compliance	25-30%	--	Negligible	Enforcement
Belt Cleaners	10%	--	Negligible	Research and Regulation
Rock Guards	15%	--	Negligible	Regulation

The complete implementation of all the above recommendations will result in reducing conveyor accidents by 50-55 percent.