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# MINE MAINTENANCE MATERIAL HANDLING: VOLUME I FINAL TECHNICAL REPORT

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Canyon Research, Inc

Bureau of Mines  
United States Department of the Interior



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## FOREWORD

This report was prepared by Monterey Technologies, Inc., Carmel, California, under U.S. Bureau of Mines Contract H0113018. The contract was initiated under the Coal Mine Health and Safety program. It was administered under the technical direction of Pittsburgh Research Center with Mr. Richard Unger acting as the Technical Project Officer. This report is a summary of work recently completed as part of this contract covering the period June 1985 through present. This report is dated May 1988.

No U.S. or foreign patents have been applied for or granted for the concepts, designs, or devices discussed in this report.

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## \*\*\* 1. INTRODUCTION AND SUMMARY

### INTRODUCTION

This report summarizes work performed under U.S. Bureau of Mines Contract Number H0113018. The project was entitled: Maintenance Related Manual Material Handling In Underground Coal Mines. The objective of the project was to identify risk factors associated with underground mine and equipment maintenance materials handling tasks and to develop five prototype materials handling devices to reduce or eliminate these risks.

Manual material handling injuries represent a major source of lost time injuries in underground coal mining operations. Over the last ten years, the Bureau of Mines has funded a number of projects in an effort to identify and reduce the number of material handling injuries. Most of these projects addressed the MMH problems associated with the movement of supplies and components from the surface of the mine to the underground working sections. The focus of the current project was on the handling of materials or machine components during actual mine maintenance or equipment maintenance.

The project was organized into three phases. Phase I tasks included: an analysis of mine and equipment maintenance related manual material handling (MMH) injury reports; on-site interviews with miners and safety personnel; completion of a MMH tasks analysis and a hazard identification survey. The accident data treatment included compilation by accident type, source of injury, nature of injury, and component or material involved. The results were used to identify high risk MMH tasks and to identify components or materials involved.

Structured interviews were conducted with miners, maintenance supervisors, and mine safety personnel in an effort to identify high risk maintenance MMH tasks. A brief task analysis was then completed while miners were performing identified high risk MMH tasks. Photographic records were made where possible. A survey was also conducted to quantify materials, equipment and supplies being handled. The results were analyzed and used to develop design concepts for five underground material handling devices.

Phase II tasks included: the generation of material handling device concepts; evaluation and validation of these concepts; and the selection of five designs for detailed design and specification.

Phase III tasks included: the fabrication of the five prototype man-powered material handling devices; completion of safety evaluations; and the conduct of preliminary underground evaluations. Design improvements were identified based upon the results of the preliminary evaluations.

Volume I of the final technical report summarizes technical activities, findings, conclusions and recommendations.

Volume II includes drawings and specifications for the five selected prototype material handling devices.

#### OBJECTIVE

The objectives of this project are summarized below.

Identification of high risk mine and equipment maintenance related MMH tasks performed by miners

Definition of the materials, tool, and machine components routinely handled during mine and machine maintenance tasks

Identification of sources of MMH risks and the types of injuries associated with them

Design and construction of five inexpensive, easily fabricated, man-portable, manually operated machines or devices to reduce MMH effort and to reduce the risk of injury associated with these maintenance tasks

Completion of preliminary evaluate the prototype material handling devices in underground coal mine operating conditions

Project documentation

It is noted that particular attention was focused on the design of practical, low cost, easily fabricated materials handling devices likely to be broadly applicable in underground operations. Where possible, the designs incorporated off-the-shelf components to permit fabrication of the devices by mine site personnel.

It is also pointed out that the devices and designs discussed in this report are not intended to be final. Rather, they are working prototypes presented in the hopes of stimulating other innovative designs on the part of mine personnel and local manufacturers.

## SCOPE

This project specifically addressed handling of materials and components during actual underground mine and equipment maintenance operations. All underground coal mine seam heights were included in this study. However, emphasis was placed on lower seam coal mines (e.g., under 56" seam heights). Preliminary accident data reviews suggested that the highest risks of MMH injuries were associated with mid to lower seam mines.

Surface material handling tasks and the transporting of supplies or materials from the surface to the operating section were outside the scope of this project.

The following list includes representative mine maintenance tasks within the scope of this project.

- Installation/removal of ventilation, electrical, communications, or other mine operations support systems

- Installation of timbers, cribbing, and other materials used in roof or rib control

- Installation, repair, or retrieval of track for underground railed vehicles

- Installation of air control curtains, rock dust, sprinklers, dust, fire, or other health or safety systems

Typical machine maintenance material handling tasks falling within the scope of this project are listed below.

- Removal/replacement of belt drives, heads, pumps, drive motors, and other major machine parts on stationary equipment

- Assembly, installation and/or repair of \*monil mining equipment, including face equipment

- Routine servicing of all mining equipment

## PROJECT ORGANIZATION

The project was originally organized into four phases as identified below. Tasks within each phase were completed prior to the initiation of the next phase.

- Phase I: Investigative study and concept development

- Phase II: Material handling device concept development

Phase III: Design and fabrication of prototypes

Phase IV: Preliminary field testing

During the Phase I Review Meeting, however, it was decided that Phase III and Phase IV would be consolidated into one phase. This was to permit the sequential development and field testing of the five prototype devices, thereby eliminating unnecessary project delays.

Phase I tasks included a review of relevant research and engineering literature and an analysis of MMH handling accident data. Site visits were then conducted at six underground coal mines to complete mine and machine maintenance task analysis and to quantify materials and components handled by mine personnel. Interviews were also conducted with mine management and production personnel. During these interviews, efforts were made to solicit ideas for material handling devices.

Phase II tasks included the development and validation of candidate non-powered material handling device concepts. Preliminary design concepts were then screened with respect to safety, cost-effectiveness, practicality, and acceptability. Selected concept designs were then documented and several additional mine trips were completed in an effort to validate these designs. The five most promising designs were then selected and detailed plans prepared.

Phase III tasks included the fabrication of the selected MMH devices and the completion of preliminary underground evaluations. The prototype devices were assembled in the Bureau of Mines shops in Pittsburgh and then safety tested prior to shipment to the participating test mines. Six month underground evaluations were then initiated.

## \*\*\*2. SUMMARY OF FINDINGS

### MANUAL MATERIAL HANDLING ACCIDENT ANALYSIS

#### MMH Accidents In Industry

Manual material handling accidents have historically accounted for a significant percentage of all industrial lost time injuries. National Institute of Occupational Safety and Health (NIOSH) data indicate that material handling account for 25% or more of all industrial injuries (1). The State of California, more recently, has determined that MMH accidents account for 28.5% of the reported injuries in that state (2).

#### MMH Lost-Time Accidents In Underground Coal Mines

In underground coal mining operations, MMH accidents account

for an even larger percentage of lost-time injuries. Mine Safety And Health Administration (MSHA) data for 1980 reveals that MMH accidents in underground coal mines accounted for approximately 34% of all non-fatal lost time injuries (3)

The investigators for the current project (4) confirmed that material handling in underground mines accounted for--

34.0% of all lost-time injuries, and

32.6% of no lost-time injuries.

Another Bureau of Mines funded study (5) attempted to pinpoint where MMH accidents occur in underground coal mines. The investigators analyzed over 1,200 material handling accident reports seeking causes of the injuries and the point in the supply system where the accident occurred. The results of their analysis are summarized in table 2.1.

TABLE 2.1. - All underground material handling accidents

Handling Mode	% Of All Injuries
On-Section manual handling of equipment, supplies, and material during production shift	11.2%
Supply movement from the surface to point of use	49.5%
Section move: moving mining equipment to new section	13.0%
Non-Maintenance material handling:	73.7%
In-Mine equipment maintenance performed during maintenance shift	16.3%
Mine maintenance and mine maintenance material handling	10.0
Maintenance-Related material handling:	26.3%
Total MMH underground accidents:	100.0%

Source: MB Associates, 1980.

The above study found that--

49.5% of the MMH accidents occurred while supplies were being moved from the surface to underground storage locations,

24.2% of the injuries occurred while moving materials or parts from the underground storage places to points of use in the mine, or during production related section moves,

26.3% of the injuries occurred while the supplies or machine components were actually being used for mine or mining equipment maintenance.

### Mine And Equipment Maintenance MMH Accidents

The presently reported Bureau of Mines funded project (Contract No. H0113018) specifically addressed the problem of manual material handling injuries during actual mine maintenance or equipment maintenance operations. An accident data analysis was designed to focus on the identification of mine or equipment maintenance tasks being performed, machine components or mine supplies being handled, how they were being handled and other factors that could lead to the identification of high injury risk exposure points.

Two types of accident data analysis was completed. The first analysis sought to isolate mine and machine maintenance injuries involving material handling. The outcomes were classified on the following basis.

Accident type

Part of body injured

Source of injury

Nature of injury

The second analysis included a detailed assessment of written accident reports in order to identify factors that may be useful in the development of design recommendations as suggested below.

How the injuries were sustained

Materials or components being handled

Injury frequency patterns by type of task or materials handled

Individual maintenance MMH tasks that might be mechanized

## Accident Data Analysis

A total of 3,322 mine maintenance and 3,038 machine maintenance related material handling lost-time accidents for 1980 were analyzed. The results of these analysis are summarized below.

**Accident Type** - The results of the "Accident Type" analysis are summarized in table 2.2. As expected, "Overexertion: Lifting" accounted for the largest percentage of reported accidents. This category accounted for 34.1% of the mine maintenance and 26.1% of the equipment maintenance injuries.

The next highest category was "Falling Objects", which accounted for a surprisingly high 18.4% and 16.8% of injuries, respectively. It is noted that "Overexertion - NEC" was the next largest category accounting for 10.8% and 12.3% of the injuries respectively.

Combined, "Overexertion: Lifting", "Falling Objects", and "Overexertion - NEC" accounted for 63.3% of the mine and 55.2% of the equipment maintenance MMH accidents.

**Part Of Body Injured** - As anticipated, "Back Injuries" accounted for the largest percentage of maintenance related MMH injuries. Approximately 38.6% of the mine maintenance and 31.9% of the equipment maintenance injuries resulted in back injuries. This is a particularly significant percentage, since back injuries typically result in higher reported lost-time.

Injuries to the fingers was the next highest category of lost time injuries accounting for 21.8% and 25.9%, respectively. The next category involved injuries to feet with 5.7% and 4.6%, respectively. All other part of body categories had less than 5% each of the reported lost time injuries. Combined, injuries to the back, hands and feet accounted for 66.1% of the mine and 62.4% of the equipment related MMH lost-time injuries. These are the types of accidents normally associated with handling heavy components or materials.

**Source Of Injury** - Table 2.3 summarizes the MMH accident data by "Source Of Injury" for mine and equipment MMH accidents. Several distinct differences are noted here between mine and equipment accident percentages. For example, 53% of the reported mine maintenance injuries involved the handling of timbers, beams, posts, and caps. This is followed by cribbing which accounted for 9.0% and handling other wood items which accounted for 5.6% of the reported lost-time injuries.

Together, these roof support materials categories accounted for 67.6% of all mine maintenance MMH injuries.

TABLE 2.2. - Mine and machine maintenance  
by type of accident

Type of accident	Mine Maintenance		Machine Maintenance	
	N	% Total	N	% Total
Stationary object	185	5.6	273	8.9
Moving object	2	-	6	-
Concussion	-	-	1	-
Falling object	611	18.4	511	16.8
Flying object	62	1.9	62	2.0
Rolling object	61	1.0	18	-
Struck By: NEC	231	6.0	265	8.7
Fall: walk away	8	-	7	-
Fall on object	3	-	5	-
Caught-meshing obj	-	-	2	-
Caught-station obj	160	5.1	190	6.3
Caught-moving obj	6	-	9	-
Caught-collapse	2	-	-	-
Caught-NEC	261	7.9	292	9.6
Rub or abrade	3	-	1	-
Body reaction-NEC	2	-	2	-
Over-exert-lift	1,132	34.1	793	26.1
Over-exert-push	78	2.3	147	4.8
Over-exert-welding	112	3.4	13	-
Over-exert-NEC	360	10.8	373	12.3
Contact hot obj	3	-	26	-
Inhale nox fumes	1	-	8	-
Adsorb nox fumes	26	-	25	-
Electrical burns	2	-	6	-
NEC	1	-	2	-
Insufficient data	2	-	6	-
<b>Total by category</b>	<b>3,322</b>	<b>100</b>	<b>3,038</b>	<b>100</b>

TABLE 2.3. - Source of injury

Type of accident	Mine Maintenance		Machine Maintenance	
	N	% Total	N	% Total
Pressure vessel	12	-	77	2.5
Barrels, drums	-	-	73	2.4
Boxes, crates	-	-	47	1.5
Containers-NEC	3	-	68	2.2
Belt, conveyor	19	-	274	9.0
Motor	3	-	93	3.0
Elect conductor	10	-	146	4.8
Elect-NEC	22	-	46	1.5
Jacks	46	1.4	74	2.4
Chains, ropes	2	-	56	1.8
PWR Trans-NEC	24	-	58	1.9
Steel-rail	111	3.3	39	1.3
Metal component	34	1.0	331	10.0
Wheels	1	-	153	5.0
Metal-NEC	155	4.6	655	21.5
Broken rock	68	2.0	67	2.2
Pumps, fans	1	-	52	1.7
Mine jeep	12	-	53	1.7
Cribbing	302	9.0	17	-
Timbers, posts	1,762	53.0	67	2.2
Blocking	93	2.8	15	-
Rail ties	57	1.7	4	-
Wood items	188	5.6	20	-
Cement products	77	2.3	7	-
Totals				

Note: Only categories with 1% or greater are shown

On the other hand, 21.5% of all machine maintenance MMH injuries involved Metal-- NEC. This was followed by Metal Components with 10.9% and Conveyor Belts with 9.0%. Combined, these three categories accounted for only 41.1% of the reported lost-time injuries. The majority of the machine maintenance MMH accidents were distributed across the other 120 reporting categories. Hence, machine-related accidents were more broadly distributed across all of the machine components handled underground.

Nature Of Injury - Table 2.4 summarizes the accident data based on Nature of Injury. It is noted that the most frequently reported injuries involved "Sprains and Strains". This category accounted for 47.6% of the mine and 40.5% of the equipment MMH injuries. Other major mine maintenance injury categories included: Contusions with 14.9%; Fractures with 12.6%; and Lacerations with 8.9% of the injuries. Other major equipment related injury categories included: Lacerations with 17.6%; Fractures with 10.8%; and Contusions with 10.1% of the reported injuries.

#### Fatal Accidents

Mine or equipment related material handling fatalities were also analyzed. Only two fatalities were clearly identified as involving maintenance related MMH. These cases are summarized below.

Case 1: While trying to remove a large rock from a miner, two steel beams were placed under the rock and were being jacked up. A 50 ton hydraulic jack flew out under pressure and struck the victim.

Case 2: In the process of uprighting a mine car onto its wheels, a chain hoist was attached to the undercarriage. The bolt used to fasten the chain broke, allowing the car to slew, crushing the victim.

It is possible that a number of fall of roof fatalities reviewed could be assigned to the mine maintenance category since several involved heavy timbers and beams. The current accident reporting system, however, places these accidents in the roof control or maintenance category and not in the MMH category. Likewise, a number of fatalities attributed to equipment maintenance may have also involved the handling of heavy components, but it was not reasonable to draw that conclusion based on the information contained in the reports.

TABLE 2.4. - Mine and maintenance accidents  
by nature of injury

Type of accident	Mine Maintenance		Machine Maintenance	
	N	% Total	N	% Total
Amputation	7	-	33	1.1
Asphyxia	-	-	3	-
Heat Burn	4	-	27	1.0
Chemical Burn	25	-	23	-
Concussion	9	-	4	-
Contusion	494	14.9	307	10.1
Crushing	62	1.9	81	2.6
Lacerations	298	8.9	535	17.6
Dermatitis	-	-	1	-
Dislocation	11	-	11	-
Fracture	420	12.6	329	10.8
Hearing loss	-	-	1	-
Hernia	57	1.7	65	2.1
Inflammation	2	-	1	-
Systemic poison	3	-	6	-
Radiation-NEC	1	-	-	-
Electric burns	-	-	2	-
Sunburn	1	-	1	-
Abrasion	23	-	10	-
Dust in eye	36	1.1	35	1.2
Sprain/strain	1,583	47.6	1,231	40.5
Heart attack	-	-	1	-
Multiple injury	150	4.5	211	6.9
Other injuries	13	-	23	-
Unclassified	123	3.7	96	3.2

Note: Only percentages greater than 1% are shown

### Conclusions From Accident Data

The current investigators hypothesized that a majority of all mine maintenance MMH accidents were associated with a small number of maintenance tasks and involved a finite number of categories of materials or components. It was further hypothesized that due to the diversity of tasks performed by equipment maintainers, the tasks being performed and the components being handled at the time of the accident would vary broadly. It was also anticipated that the largest single part of body category injured during MMH tasks would be the back. Finally, it was anticipated that the largest percentages of injuries would be sprain and strain type injuries.

Table 2.5 presents a summary of the accident data analysis. The following conclusions were drawn from the preceding analysis and the data presented in table 2.5.

Back Injuries - 38.6% of all mine maintenance injuries and 31.9% of machine maintenance injuries involved the back.

Overexertion - 44.9% of all mine maintenance accidents involved overexertion, while 38.4% of machine maintenance accidents were the result of over-exertion type injuries.

Materials Handled - 67.6% of all mine maintenance accidents involved the handling of timbers, posts, caps, and cribbing materials, while 32.4% of the machine maintenance accidents were associated with the handling of metal components or metal materials.

Injury Patterns - It is noted that with the exception of Source of Injury category, the percentage distribution for mine versus machine categories was roughly equivalent. This appears to suggest that miners perhaps are being injured while performing lifting and carrying tasks, although the item being handled differed.

Source of Injury - It is observed from table 2.5 that three Source of Injury categories do, in fact, account for the majority of the mine maintenance injuries. Handling timbers alone accounted for over half of the reported lost time injuries. This table also suggests that a much larger number of machine component categories are involved with the equipment maintenance accidents. No one machine component accounted for 10% of the reported injuries. Equipment repairmen simply perform a wider variety of tasks under different conditions in different locations within the mine.

Table 2.5  
Maintenance-Related Material Handling  
Accident Summary

Analysis Type	Reporting Category	Mine Maintenance		Machine Maintenance	
		%	Total	%	Total
Part Of Body	Back Finger Foot	38.6 21.8 5.7	66.1	31.9 25.9 4.6	62.4
Accident	Overexertion Lifting Fall object Overexertion NEC	34.1 18.4 10.8	63.3	21.6 16.8 12.3	55.2
Source Of Injury	Handling Timbers Cribbing Other Wood Items Metal-NEC Metal Components Conveyors	53.0 9.0 5.6 - - - -	67.6	- - - 21.5 10.9 9.0	- 41.4
Nature Of Injury	Sprain/ Strain Contusion Fractures Lacerations	47.6 14.9 17.6 8.9	89.0	40.5 10.1 10.8 17.6	79.0

NEC - Not Elsewhere Classified

Type of Task - The majority of all mine maintenance MMH accidents involved carrying, lifting or lowering roof support timbers and beams, building cribbing and installing or removing rail sections. These tasks all involve lifting, carrying, hoisting into place, or maneuvering heavy components often in restricted workspaces. A review of the machine maintenance material handling accidents, on the other hand, indicates that no particular object or category of objects accounted for a particularly large percentage of these accidents. A majority of the back and foot injuries involved lifting or lowering components onto/off transportation or onto/off machines being repaired. The larger percentage of finger accidents involved removing or replacing components on machines being repaired. These findings were substantiated during on-site interviews with mine maintenance and mine safety personnel.

When Accidents Occur - A review of the accident records made available to the team at several of the mines visited during Phase I indicated that the majority of the back injuries occurred during transportation of the materials, while the majority of the finger and foot injuries occurred during installation. These findings were substantiated during interviews with mine personnel.

Mechanical assistance is clearly required if the number of these types of accidents are to be reduced. The design implication points to the need for tools and devices to assist in carrying and manipulating mine maintenance materials. Subsequent investigations suggested that manual, task specific tools/devices were required rather than a complex, powered multifunction material handling machine.

## MINE AND EQUIPMENT MMH HAZARD ANALYSIS

### Hazard Analysis

To identify material handling devices that would most effectively assist mine maintenance personnel, a hazard analysis was also completed during Phase I. The purpose of this analysis was to--

Define the actual tasks being performed by mine personnel during mine and equipment maintenance activities;

Identify how and where mine and equipment maintenance injuries are occurring,

Identify factors in the operational environment that would impact on the potential design of MMH aids, tools and systems,

Identify the physical activities performed by mine personnel that might be mechanized,

Define the size, weight and other characteristics of materials and components being handled during mine and equipment maintenance operations.

Two analysis were completed to identify maintenance related MMH hazards. One task involved a detailed review of published MMH accident reports while the second part involved a series of underground surveys and interviews.

Review of Accident Reports

The first part of the hazard identification task involved a review of 5,376 written accident report involving mine and equipment MMH lost time injuries during 1982. These accidents were coded using the taxonomy presented in table 2.6.

TABLE 2.6. - Hazard identification taxonomy

Activity	Item Being Handled
a. Lifting/lowering	a. Oil Drum, Grease Pail, Hydraulic Fluid In Cans
b. Carrying	b. Cover Plates/Explosion Proof Lids
c. Maneuvering	c. Hydraulic Pump, Motor, Gear case, Wheel Unit, Other Items Weighting 100 lbs Or More
d. Dropped	d. Steel Header Or Roof Beam
e. Other Activity	e. Vehicle Wheel And Tire f. Other Machine Component Or Mine Supplies Weighting 100 lbs Or Less g. Tool Box h. Rock dust or Cement In Bag i. Timber, tie, cribbing or other Wood Product j. Stopping Block (Cement) k. Rail For Track

The identified mine and machine maintenance MMH accident reports were then sorted by total number of days lost. The results are presented in table 2.7.

TABLE 2.7. - Machine related lost time injuries

Days lost	Activity	Item
3629	Lifting/lowering	Oil drums, grease cans,
2249	Lifting/lowering	Machine parts, tools
2182	Other activity	Machine parts, tools
1749	Lifting/lowering	pumps, motors, gear box,
1639	Lifting/lowering	Cover plates
1127	Lifting/lowering	Tires
1070	Lifting/lowering	Tool box
692	Maneuvering	Machine parts, tools
559	Carrying	Oil drum, grease,
537	Dropping	Machine parts, tools
490	Carrying	Pumps, motors, gear box,
434	Other activity	Tires
349	Other activity	Oil drums, grease,
334	Maneuvering	pump, motor, gear box,
314	Other activity	Cover plates
301	Carrying	Machine part, tools
289	Other activity	Pump, motor, gear box
264	Carrying	Cover plates
128	Other activity	Tool boxes
118	Other activity	Timbers, cribbing,
102	Maneuvering	Oil drums, grease,

Source: 1980 HSAC Data

For machine maintenance, as expected, a large percentage of the total number of days lost were the result of a few maintenance tasks. Ten tasks accounted for over half of the reported injuries. As is noted in table 2.7, handling oil and grease for servicing machinery was by far the most hazardous equipment maintenance MMH task. This was followed by the "Other" category which involved handling of mid-sized machine parts. Vehicle tires and equipment bay cover plates were also frequently cited as the source of injury.

Table 2.8 summarizes lost time MMH accidents for mine maintenance tasks. It is noted that lifting and lowering tasks accounted for the largest percentage of all lost time. In fact, Lifting/Lowering and Maneuvering combined accounted for 64.9% of all lost time.

### Summary Task Analysis

The second portion of the hazard identification involved the completion of a series of mine and equipment maintenance task analysis for MMH tasks. The objective of these analysis was the identification of types of materials being handled (e.g., physical size, shape, and weight), how they were handled (lifting off utility vehicle, lifting from ground, etc.), and actions taken with them (e.g.; how they were maneuvered).

Eight mine and eight equipment maintenance MMH tasks were selected based on the number of reported lost days. these tasks were examined in six different mines. All tasks involved the handling of mine supplies or construction materials or machine components. Three large mines (over one hundred miners) and three smaller mines (under one-hundred miners) were included. Seam height and location of visited mines is presented in table 2.9. Where practical, photographic records were taken of the actual task performance. Weights and dimensions of handled materials were estimated by the miners performing the task where actual measurements could not be obtained. A detailed listing of the findings was presented in the Phase I Report.

TABLE 2.8. - Mine related lost time

Days lost	Activity	Item
1828	Lifting/lowering	Track rail
1355	Lifting/lowering	Timbers, cribbing, ties
783	Lifting/lowering	Crossbars, headers
643	Other activity	Timbers, cribbing, ties
487	Maneuvering	Track rail
425	Lifting/lowering	Other
388	Other activity	Track rail
372	Other activity	Crossbar, header
327	Lifting/lowering	Stopping block
319	Dropping	Track rail
236	Carrying	Other
224	Carrying	Timber, cribbing, tie
211	Other activity	Stopping block
150	Dropping	Timber, cribbing, tie
149	Dropping	Stopping block
148	Lifting/lowering	Rock dust, cement bag
123	Carrying	Rock dust, cement bag
123	Dropping	Crossbar, header
103	Maneuvering	Timber, cribbing, tie

Source: 1980 HSAC Data

TABLE 2.9. - Mine sampling plan

Mine location	Number of mines	Seam height	Working sections
Eastern Kentucky	3	30 -48	10
Pennsylvania	2	60 - 84	14
W Kentucky/Illinois	1	60	9

Table 2.10 summarizes the types of physical and biomechanical functions performed by maintenance personnel while performing MMH related tasks. Again, it is noted that the purpose of analysis was the identification of high risk material handling tasks for which mechanical devices might be developed to reduce the miner's exposure to injury. The results of this analysis helped provided the basis for the design of the five prototype devices fabricated and tested during Phase II and Phase III of the project. The results also inspired the timber setting car which was designed and built by Bureau Of Mines inhouse engineers.

Replacement components used in equipment maintenance are typically hoisted onto a rail car or a scoop bucket on the surface. They are than transported to the section where the disabled machine is located. At this point, the components are manually lifted off the transport vehicle and hand carried to the installation location. Two or more miners "Man Handle" the component up and hold it in place while it is attached to the mining machine. Occasionally, hoists attached to roof bolts or "Come Alongs" are used to assist in this process. Failed components are than manually loaded onto the transport vehicle for shipment to the surface or the underground shop. None of the mines visited had tools or equipment available in the mine

Mine maintenance materials (e.g.; roof support timbers, steel beams, rock dust bags, stopping blocks, roof bolts, etc.) are, likewise, loaded onto the transport vehicle on the surface. Many of these items are bound up in bales, palletized, or strapped together in bundles for bulk shipment and are sometimes loaded onto the supply vehicle by forklift.

Once underground, they are broken down and manually off-loaded to storage areas or carried to the point of use. With the exception of battery powered scoops or utility vehicles which are not always available, the only other means of transporting these supplies was by hand.

TABLE 2.10. - Physical functions performed during MMH tasks

Task type	Example
<b>Lifting:</b>	
Lifting from above	Remove hydraulic pump from center area of continuous miner
Lifting from below	Lift shuttle car drive motor onto rail car
Lift and transport	Lift and carry grease drum
Lift and maneuver	Lift shuttle car drive motor into position to align and mount
<b>Lowering:</b>	
Lower to ground	Loosen and lower box cover
Maneuver and lower	Lift hydraulic pump off mounting bolts and lower to ground
<b>Carrying:</b>	
Transport	Transport rock dust bags from end of rail line to section storage area
Move to accessible area	Remove a hydraulic pump to place where it can be worked on
<b>Tossing:</b>	
Lift and toss	Lift stopping blocks and toss through man door
<b>Pushing:</b>	
Pushing material	Pushing bundled roof bolts into storage area
<b>Pulling:</b>	
Pulling	Pulling power cables to relocated junction box
<b>Maneuvering:</b>	
Lift and maneuver	Lift and maneuver shuttle car tire to align with lugs

## Survey of Components and Materials Handled

Table 2.11 summarizes the types of components and materials handled, weights or weight ranges of these items, and the frequency with which they are handled. It is noted that components used for equipment maintenance are typically handled on an aperiodic basis while mine supplies are handled on a high frequency basis.

## Conclusions From Hazard Analysis

The results of these analysis suggested the need for manually powered material handling devices that could--

Lift heavy components (or materials) from above, swing and/or maneuver it, and lower it to the ground or into position,

Lift heavy components or materials from the bottom, transport it a short distance, and maneuver it for installation (or removal),

Pick a heavy component up from within an interior body cavity on a mining machine, swing it around and lower it beside the machine or onto a utility vehicle,

Haul mortar, caps, or other supplies from storage points or shops to working sections where they were to be used,

Transport oil, grease, tools or frequently used replacement items from section to section for the performance of routine equipment maintenance.

The item descriptions presented in table 2.11 provide a functional performance specification for the above devices.

TABLE 2.11. - Material and component descriptions

Item description	Unit weight	Frequency	Tools
<b>Equipment maintenance:</b>			
Major component replacement	200-2,000 lbs	weekly	Jacks, come alongs
Minor component	2-200 lbs	daily	Handtools
Lubrication	5-90 lbs	daily	grease pails drums
Move repair tools	25-200 lbs	daily	Tool box
Welding	50-250 lbs	weekly	welding bottles
Tire change	50-200 lbs	weekly	Jack, hand tools
<b>Mine maintenance:</b>			
Set post and crossbar	100-500 lbs	1-20 per day	Saw, ax, sledge hammer
Build stopping	50-100 lbs	50 per day	Handtools
Build venting	50-300 lbs	weekly	Handtools
Build cribbing	35-100 lbs	25-50 daily	Axe, saw, sledge hammer
Install track	100-1,000lbs	monthly	Prybars, sledge hammers
Build overcast	200-500 lbs	annual	Handtools
Install electric	200-1,500lbs	monthly	Come-alongs, hand tools
Rock dust back entries	90-100 lbs	daily	None

### \*\*\*3. PHASE II: CONCEPT DEVELOPMENT

#### DESIGN CRITERIA

The intent of this project was to identify maintenance related material handling tasks presenting high risk of accident or injury and to design, fabricate and evaluate simple mechanical tools and devices in an effort to reduce these risks. A number of design criteria were used in the identification and selection of concepts and candidate devices. The criteria are listed below.

The devices had to be man powered or be designed to quickly attach to and derive power from a host vehicle. A majority of the lifting, carrying and maneuvering tasks observed did not warrant the development of an expensive complex piece of mobile equipment.

The devices had to be easy to transport within the mine. It was determined that tools were most likely to be used if they were left in the working sections or on utility vehicles and were easily hand carried to the point of use by one miner. Devices that are too awkward or too heavy to move manually had a sharply decreased likelihood of being used for a short term task such as removing a failed machine component.

The device had to be simple to use and require little or no training. Devices that required more set-up and disassemble time than the task being performed are not going to be used. Devices that required extensive training are not going to be used.

The devices had to be simple in design and easy to fabricate in mine shops. The intent was to design generic device designs that could be readily fabricated in mine shops using off-the-shelf parts and locally available materials.

The devices had to be inherently safe in design. Experience suggests that tools, aids, and devices can and will be used in unintended manners. If this unintended use renders the device unsafe in any way, the concept was discarded.

The devices had to be inexpensive to purchase or to fabricate. Although no dollar value was affixed, the intent was to develop devices that were cheap to make and which could be left in each working section or on each vehicle.

Preliminary Concepts

Material handling device concepts were solicited from the miners and supervisory personnel at the participating mine sites. A number of excellent ideas were identified as a result of this effort. Concepts were also generated by project team members and from Bureau of Mines engineers.

A total of twenty-four material handling device concepts and ideas were initially compiled. After careful evaluation by the project team using the above design criteria, this list was reduced to the twelve concepts presented in table 3.1.

TABLE 3.1. - Preliminary MMH device concepts

Item	Purpose
Roof jack mounted lift device	Installed like a roof jack at point of use and removed when task was completed
Man-powered cable hanging device	Used to lift cable while miner attached it to the roof or side wall
Quick connect lift-boom for mine scoop	Boom lifting device that could handle up to 2,000 lbs which could be attached to the front or a scoop in five minutes or less
Timber jack	A man-powered hydraulic jack that would lift roof support timbers and hold them in place until they were secured
Mud cart	A hand pulled cart to be used to transport tools and supplies by hand over relatively short distances
Mine jack	A hydraulic jack suitable for lifting tires and heavy components in a working section

Continued

TABLE 3.1. - Continued

Item	Purpose
Cable puller	A powered device mounted on the back of mining machines used to pull electrical cable
Pivot crane	A portable crane that mounts on the side of mining machines or utility vehicles that is used to lift and lower heavy components. The crane is removed and stores flat when not in use
Grease cart	A manually pulled cart for carrying lubricants which is rolled to the side of machines being serviced
Modular overhead lift device	A modular adjustable frame that could be erected over a mining machine and be used to lift and lower heavy components
Hydraulic fork lift device	A manual forklift to be used to lift or load palletized materials and wheel it short distances in the working section
Portable conveyor system	A portable conveyor belt that should be used to load materials (e.g.; rock dust, stopping blocks, etc.) through man doors or other confined spaces

#### \*\*\* 4. RESULTS

After extensive review and analysis, the following five devices were selected for detailed design, fabrication, and field testing--

Scoop Mounted Lift Boom,  
Machine Mounted Swivel Crane,  
Mine Jack,  
Mine Mud Cart, and  
Mobile Container/Workstation Vehicle.

Functions performed by, and design specifications for each of these devices are discussed in detail in Volume II of this report.

##### Scoop Mounted Lift Boom

A pressing need exists for a lifting device with the capability of lifting and maneuvering heavy machine components such as continuous miner heads. Many of these components weight up to 2,000 lbs. and represent a serious risk of injury if efforts are made to "Man Handle" them or to attempt to maneuver them with jerry-rigged lifting devices.

The concept of the scoop mounted boom was developed to serve this function. The boom quickly mounts to the front of a battery powered mine scoop using the same attachment points and pins the scoop bucket used. The tip of the boom can be lifted or lowered by means of the same hydraulic cylinders used to operate the bucket when it is attached. The cable lift capability can be provided by means of a manual crank mechanism or by means of a power wench with the power supplied by the scoop.

Figure 4.1 illustrates the scoop mounted boom lift device.

##### Machine Mounted Swivel Crane

An observed need exists for a device which can be used to pick up components weighting up to 750 lbs from a transport vehicle and swing it or position it over/near the installation point. The same device would be used to remove a failed component from the interior cavity of a mobile machine and assist in installation of its replacement. The device would have to collapse or be easily removed for storage while the machine is operating or being trammed.

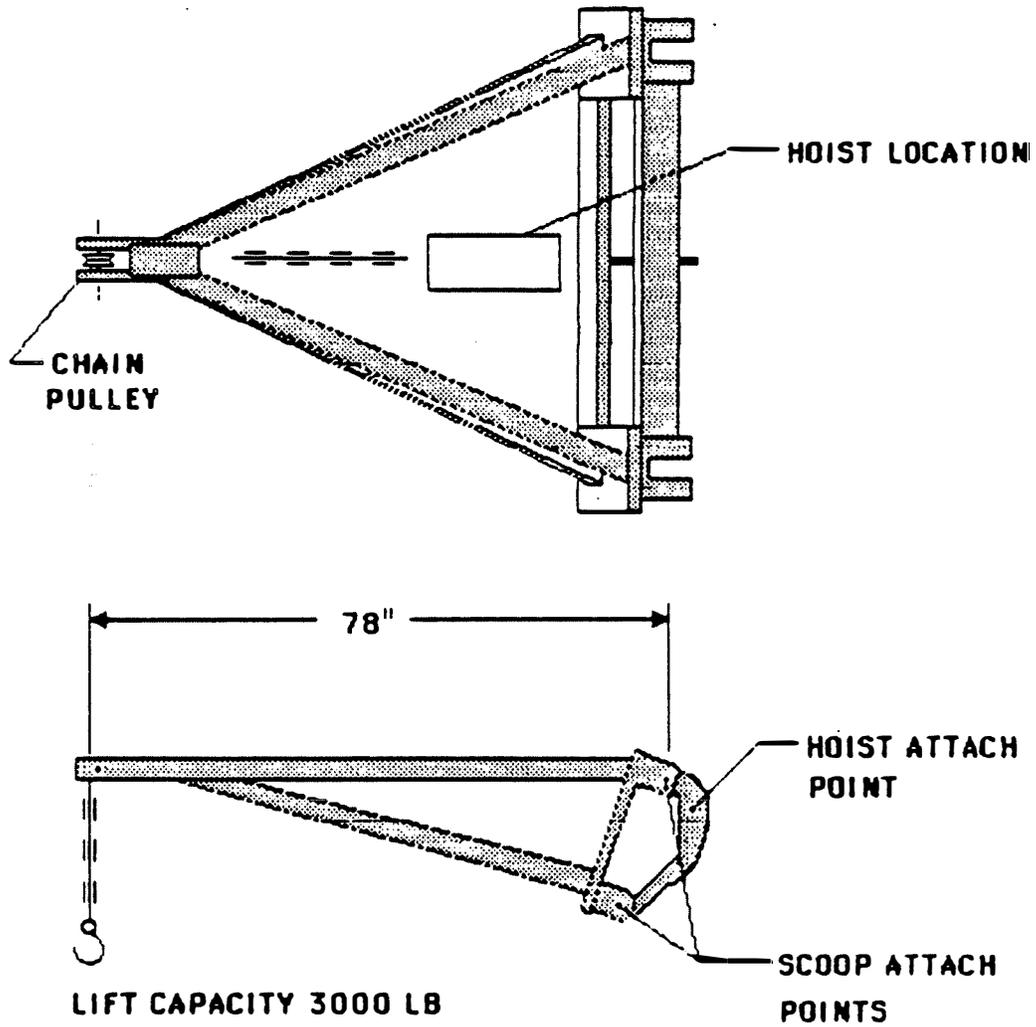


FIGURE 4.1. - Boom lift device

The machine mounted swivel crane was designed to fulfill the above requirements. It is mounted by inserting its base into mounting brackets which are welded or bolted to the side of the machine or vehicle at strategic locations. The height of the boom can be adjusted and its boom length varied as required. When the lifting task is completed, the crane is simply lifted out of the mount and laid flat to store it. A manual crank mechanism provides the lift capability.

Figure 4.2 illustrates this design concept.

### Mine Jack

A need exists for a device that can be used to lift components or materials from the bottom much as an auto shop floor jack does. This device is necessary, for example, to remove and replace heavy drive motors mounted under non-removable machine fenders. The same device could be used to lift and position tires which can weight in excess of one-hundred pounds.

The mine jack was developed to meet the above requirements. In addition to lifting up to one-thousand pounds, the load can be inched forward or backwards along the jack frame to assist in positioning the load.

Figure 4.3 illustrates this device.

### Mine Mud Cart

A need exists for a device that can be used to transport supplies, components, tools and other materials within and between operating sections or along haulways. An example is the need to haul roof bolts or stopping blocks from underground storage areas to the point of use. Another example would be to haul tools and smaller components from section to section. The device should be capable of handling loads of up to 1,000 lbs and must be capable of being pulled by a miner. It should be relatively narrow to allow it to be pulled along side of parked mining machines, along conveyor lines, and other confined areas.

Figure 4.4 illustrates the Mud Cart. This articulated dual cart rides on tandem tires (or larger balloon tires) and can be pulled by one or two miners. Each cart is designed to handle loads of up to 500 lbs. The Mud Cart can be pulled with a load in only one section.

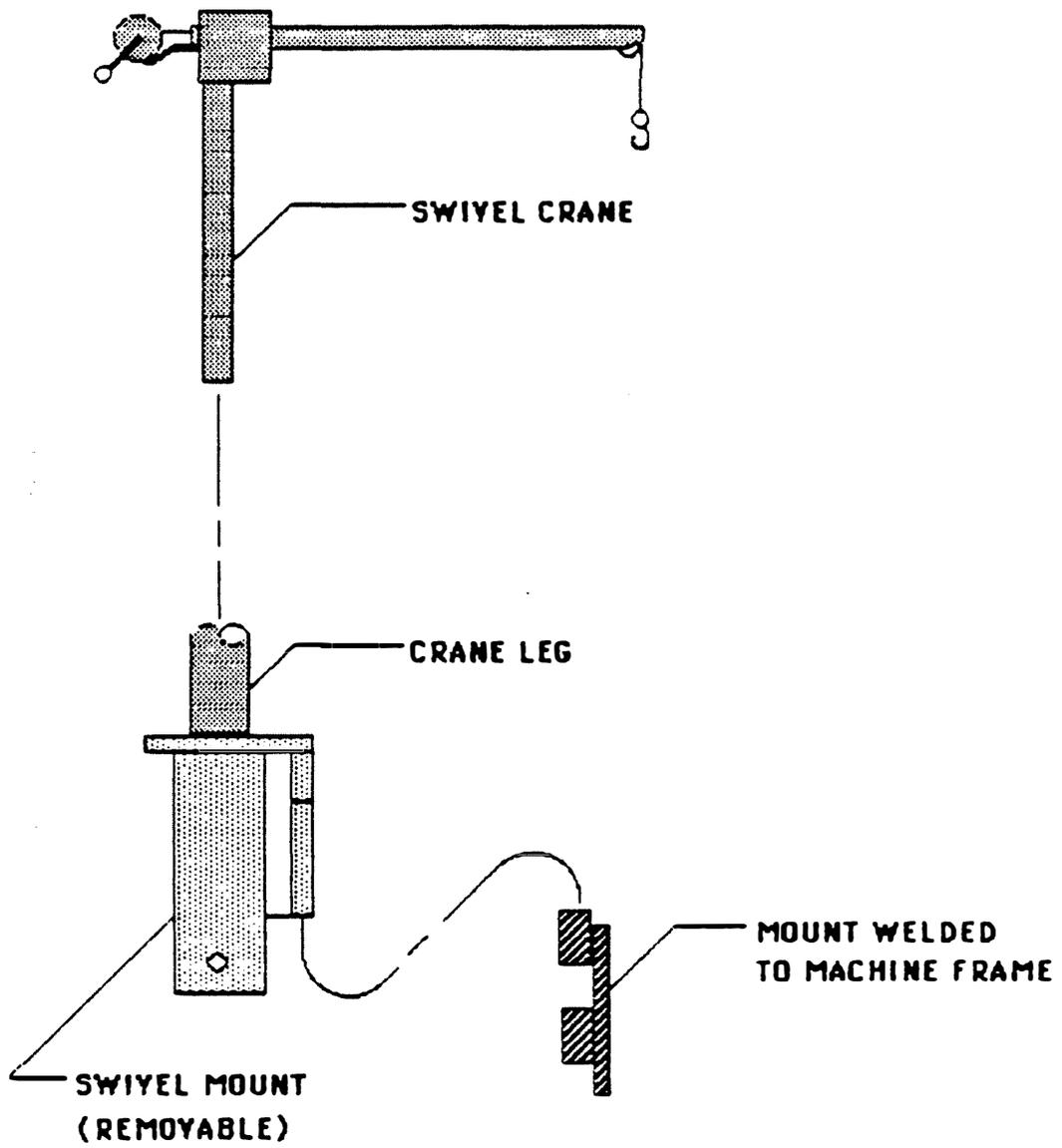


FIGURE 4.2. - Swivel crane

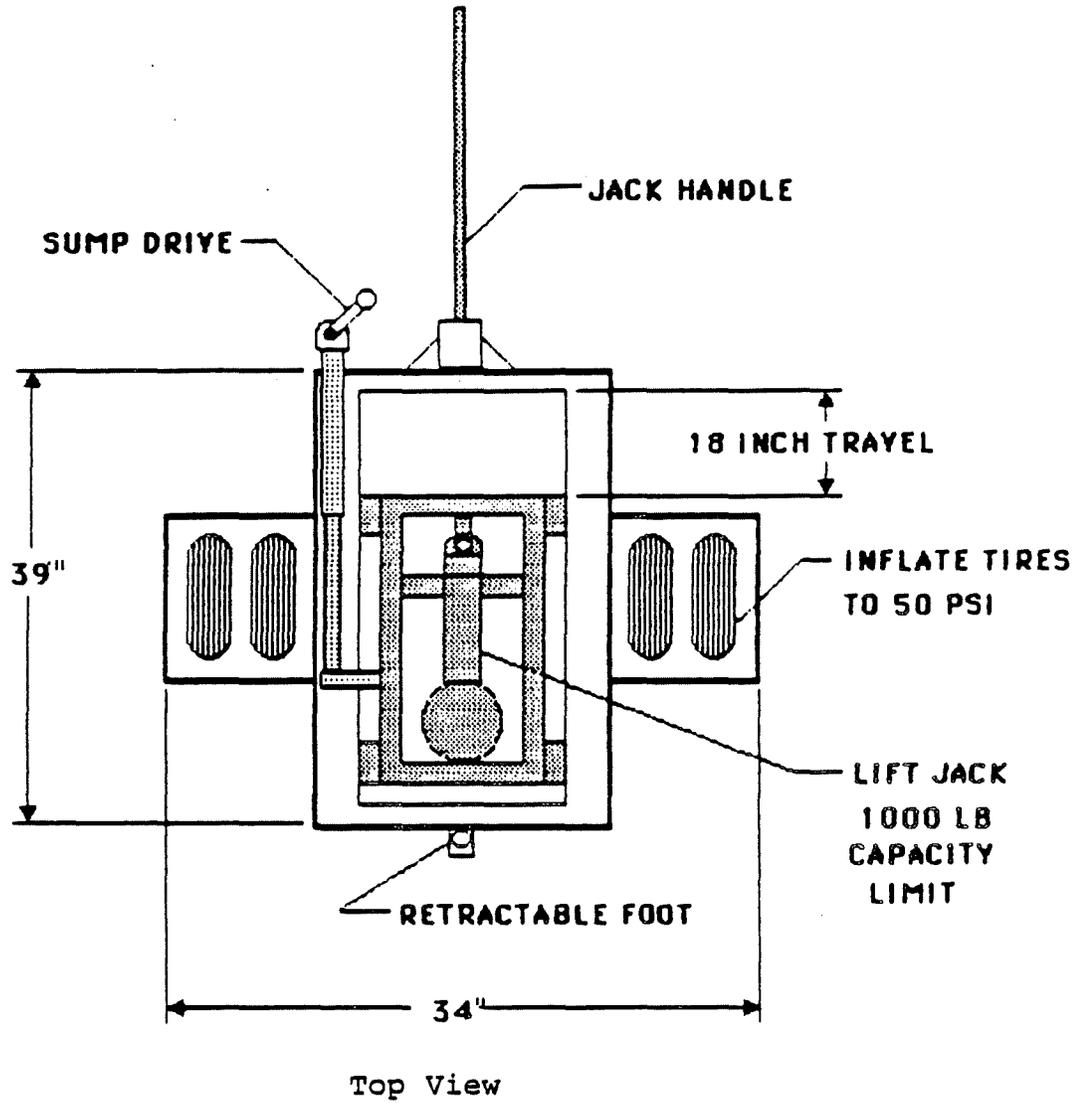
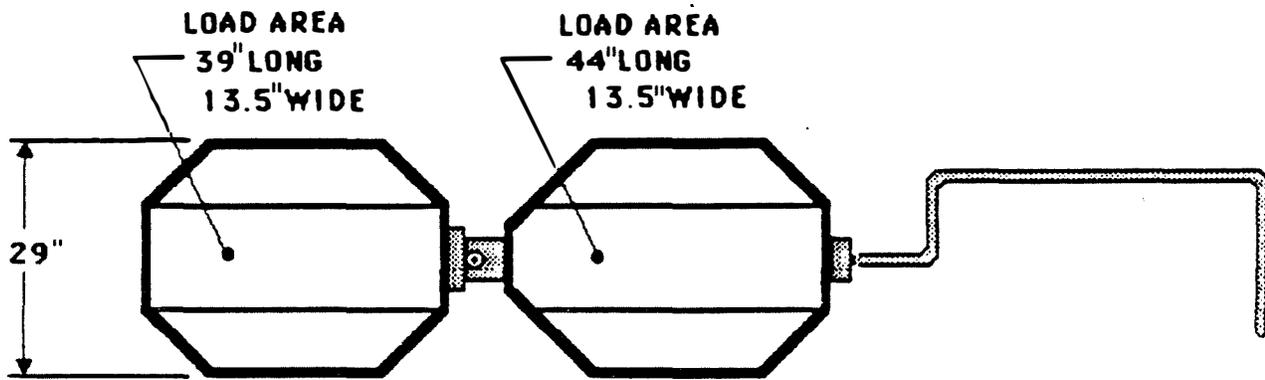
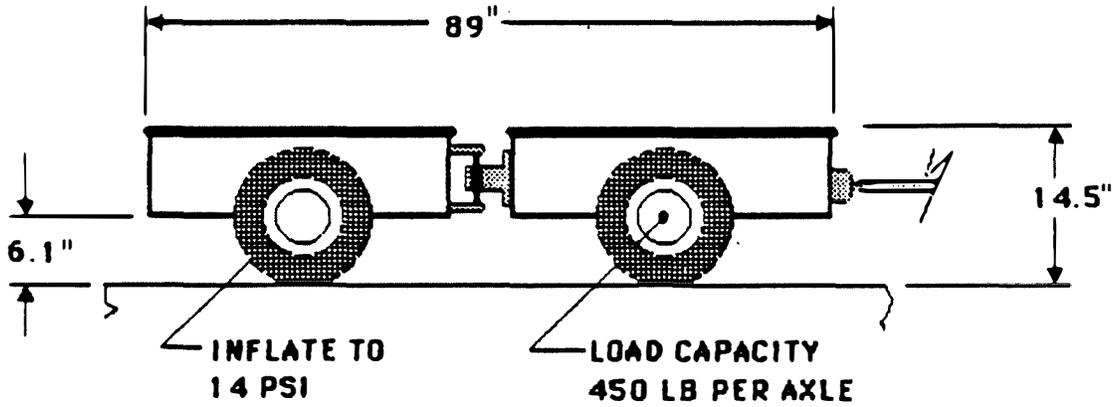


FIGURE 4.3. - Mine jack



Top View



Side View

FIGURE 4.4 - Mud cart

### Mobile Container-Workstation

A need was defined for a mobile container and workstation system that could be wheeled to a work location and dropped there. The container may be used to hold caps, cribbing, rock dust, roof bolts, mechanic tools, commonly used parts, lubricants, etc. It can be locked to improved security of items stored in them. It can be used to store emergency medical and other supplies.

The mobile lifting device is wheeled around the container which is mechanically lifted by the frame. The miner pulls the container to the next work station where it can be deposited or left on the transporter.

Figure 4.5 illustrates this design concept.

### \*\*\*5. PRELIMINARY FIELD TESTING

Three of the five prototype devices were fabricated in Pittsburgh and transported to demonstration mines in Western Kentucky for evaluation (scoop mounted boom, swivel crane, mine jack). A summary of the preliminary results are presented below.

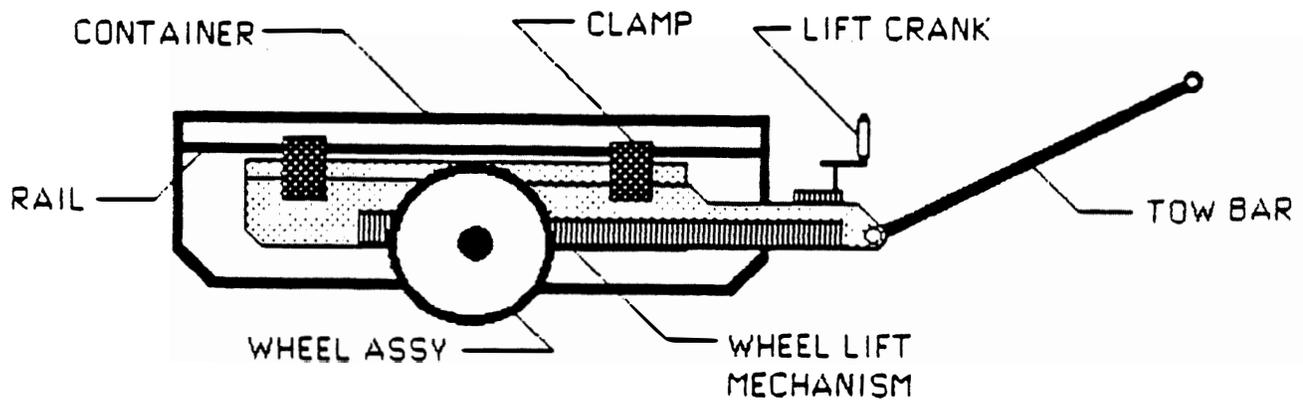
**Scoop Mounted Boom** - The boom was made available to the mine with a manual wench attached. It was used once after which the decision was made to attach a powered wench.

**Swivel Crane** - Several copies of the crane and mounting plates were supplied to the mine for evaluation. No initial modifications were required.

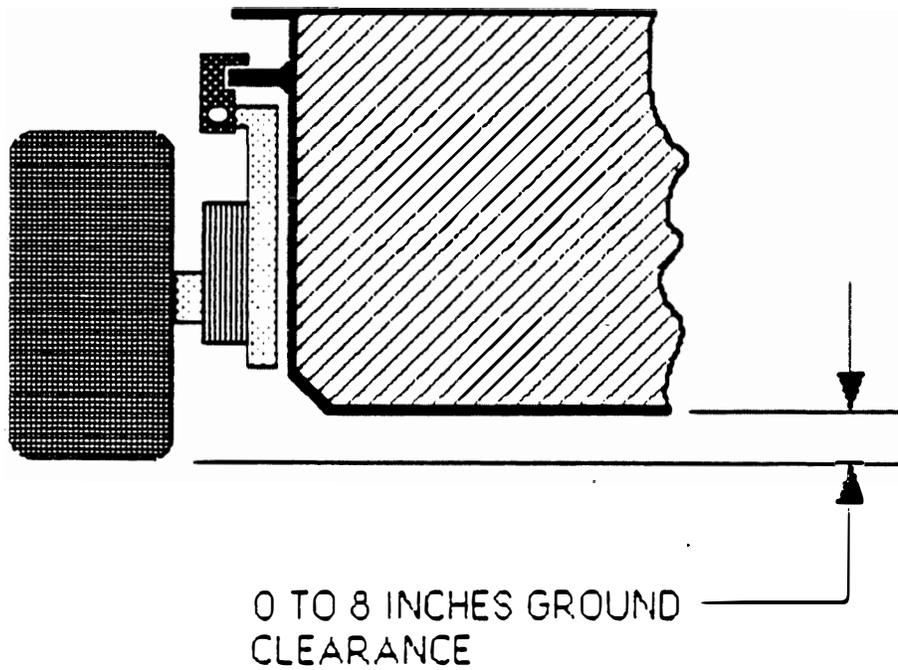
**Mine Jack** - Several copies of the mine jack were forwarded to the mine for evaluation. One jack ended up being put to use in the mine's surface shop because the shop foreman would not release it. The other was sent underground. Initial reports indicated that the tandem wheel configuration was fine on the surface, but it tended to fill with mud underground. A design change was then made to switch the jack over to two golf cart type balloon tires. This change produced positive results.

Unfortunately, the mines in which the demonstrations were being conducted suddenly cease operations. The prototype devices were left underground and could not be retrieved.

**Mud Cart** - The mud cart was tested in the Bureau Of Mines Experimental mine in Bruceton. Preliminary tests indicated that the carts appear to perform as designed. There was some

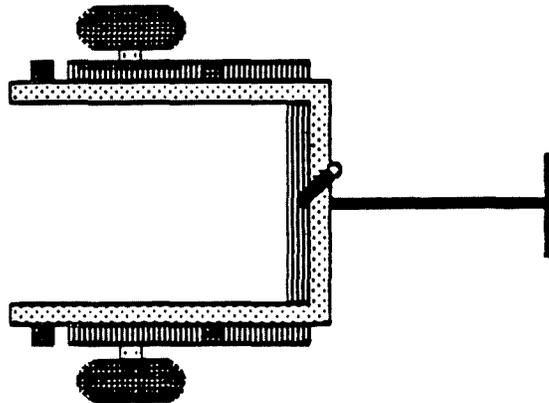


Side View



End View

FIGURE 4.5. - Container/workstation



Top View

FIGURE 4.5. - Container/workstation (continued)

How it is used:

1. Miner backs this transport unit up to container or workstation.
2. Container is positioned between arms and jacked up.
3. Transport and module is then moved to work location.
4. Transport arms are lowered and the transport is removed.

difficulty, however, with the carts in terms of turning radius.

Lift Transport Device - Unfortunately, the project period expired prior to the fabrication of the lift transport device. Delays in receiving components for the device contributed to this situation.

### \*\*\*6. CONCLUSIONS

On-site visits, task analyses, and interviews clearly suggest that the majority of the risk exposure associated with material handling in underground coal mines results from the lack of properly designed and easily accessible material handling tools, devices, and vehicles. Mine personnel traditionally rely on crowbars, a "couple of extra hands", "come along", and other make shift tools to "Manhandle" even the largest machine components underground. Similarly, lacking appropriate tools, carts, and other handling devices, mine personnel "Manhandle" timbers, posts, beams, and other heavy mine maintenance materials on a regular basis. In most instances, tools are simply not available for these heavy lifting, transporting, and positioning tasks.

These investigations also revealed that what is needed is not another complex, powered vehicle designed to perform a plethora of maintenance jobs. Rather, what is required is a series of simple, task specific tools, aids, and devices to be housed and used in the working sections and maintenance areas. Mine personnel tend not to wait 30 to 60 minutes while a special vehicle or tool is brought in from another area of the mine.

The material handling hardware should be inexpensive, easy to fabricate in mine shops and should, where possible, utilize off the-shelf components.

There is a sincere interest on the part of mine management, safety, and production personnel in reducing materials handling related injuries. There is also a need for management to be exposure to new ideas, products, and material handling mechanization concepts. Likewise, there is a need to assist miners in identifying their own unique MMH requirements and in developing solutions to these problems.

The concepts presented here were designed to stimulate the development of other mechanization concepts to address mine specific material handling problems. These concepts do not by any means solve the MMH problem.

### \*\*\*7. RECOMMENDATIONS

Three major recommendations are suggested with respect to material handling device development. These recommendations are summarized below.

#### Systems Approach to Material Handling

Many larger mines have developed "systems" for moving huge quantities of supplies and materials from surface storage areas to underground drop points or supply depots. These systems, however, have many missing elements and built-in problems.

For example, pallets are utilized to load quantities of 90 pound cement blocks or 100 pound bags of rock dust from the storage onto the supply train. Forklift or hoist may be used to unload the pallets at the drop points. Personnel must, however, manually load these supplies onto battery powered vehicles or physically lug them to the point of use.

This "systems approach" thinking has failed to account for the fact that the blocks still weigh 90 pounds and the bags 100 pounds each when they get into the mine. These loads are too heavy for personnel working in confined workspaces and on unimproved mine floors. If a systems approach is to be used, it should start with the end user/task and work backwards from there. It should start with what the miner and maintainer can safely and effectively handle during the course of an eight hour underground shift.

#### Task Specific Tools

As in any industry, the design of special tools to perform specific tasks is often overlooked. In underground mining, few if any tools or devices have been developed to cope with specific material handling tasks. Exposure to high risk tasks could be substantially reduced if appropriate task specific tools were available and work rules were implemented to encourage their use.

For example, the transporting of materials through a 3'x3' man-door requires the miner to lift a 50-100 pound or heavier object, rotate his body, and heave it through the man-door opening. Exposure to overexertion type injuries is very high. If a simple slide or material conveyor were available, the miner could simply lift the material onto one end of the system and allow gravity to pass it through the opening. Similar aids and mechanical tools are required for handling rail sections, timbers, posts, cribbing materials, etc.

## New Technologies

The search for new technologies is an ongoing process in any industry. In underground mining, however, it is even more important since so little completely new technology has been introduced to this sector within the last fifty years.

With respect to materials handling, this search could focus on new, low cost, reduced weight materials for mine maintenance and safety applications. It should address improved designs and packaging for manual handling in operational environments. It should cover improved methods of installation and maintenance of the mine and the mining equipment. It should focus on ways of reducing mine maintenance (e.g., cleaning up along belt lines) and machine maintenance. It should attempt to replace muscle power (particularly back muscles) with mechanical or hydraulic power and eliminate many of the high risk jobs currently being performed by miners.

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