CANOPY PROTECTION FOR OPERATORS OF CONTINUOUS HAULAGE SYSTEMS IN LOW-SEAM-HEIGHT COAL

By R. J. Gunderman[1] and A. J. Kwitowski[2]

ABSTRACT

Placing an operator of a mobile continuous haulage conveying system under a protective canopy was investigated using the latest technology for both canopies and floating compartments. Investigations first considered how to position the operator in the low compartments and included unobtrusive observation of human subjects repositioning themselves when confined to the compartment. Locations for such a compartment on the crawler-mounted machine were considered using both small-scale and full-scale mockups.

A floating operator compartment was designed in conjunction with the new design for an improved machine. Evaluation of the compartment for human factors was made at the manufacturer's facility prior to installing the machine in an underground coal mine. Subjects representing the male 5th, 50th, and 95th percentile sizes were used along with photographic techniques for recording data.

Operation of the new machine with operator compartment in a coal mine with seam heights typically between 40 and 46 in was monitored for 10 months. The practical feasibility of this operator protection was adequately demonstrated for coal seams as low as 40 in.

INTRODUCTION

This program was one of several initiated by the Bureau of Mines to investigate the applicability of canopies and cabs to coal mining machines operating in seam heights below 48 in. A study contract was awarded to the Jeffrey Mining Machinery Division, Dresser Industries, Inc., to investigate the feasibility of placing the operator of a model 506C-5 double-bridge carrier, shown in figure 1, under a protective canopy. This crawler-mounted carrier supports a bridge conveyor on the inby end (seen to the left of the operator), which is linked to the discharge boom of the continuous mining machine. A similar bridge conveyor links between the carrier and the pan line. If there are more than three entries, a second bridge carrier and an additional bridge conveyor may be added to lengthen the reach. The operator of the double-bridge carrier maneuvers the machine to follow movements of the mining machine and controls operation of the conveyor. This machine is used in seam heights as low as 28 in.

The inby bridge conveyor is supported on a carriage or dolly that rides on the receiving conveyor of the double-bridge carrier. This carriage, which is free to move approximately 6 1/2 ft, provides flexibility for small movements of the continuous miner. The operator of the double-bridge carrier must move the carrier to assure that the carriage is adequately positioned to allow movement of the continuous miner in either direction.

Using technology and ideas applied in previous Bureau of Mines contracts as well as concepts developed by manufacturers and coal companies, the feasibility of a protective operator compartment was investigated. As shown in figure 1, the controls on the 506C-5 are on the side (or fender), and the operator usually squats or kneels next to the machine.

[1]Consultant; formerly project manager, Jeffrey Mining Machinery Division, Dresser Industries, Inc., Columbus, OH.

[2]Civil engineer, Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.

FIGURE 1. - Operator at controls of 506C-5 double-bridge carrier.

This gives the operator good visibility and mobility. However, this position is vulnerable in the event of a roof fall or if the bridge carrier is inadvertently pushed by the mining machine, which could possibly pinch the operator against a rib.

ACKNOWLEDGMENT

The work described in this paper was performed under Bureau of Mines contract H0387027[3] to the Jeffrey Mining Machinery Division, Dresser Industries, Inc., Columbus, OH. The in-mine evaluation was performed under a cooperative agreement between the Solar Fuel Co., Somerset, PA and the Jeffrey Mining Machinery Division.

PRELIMINARY DESIGN

All possible operating positions for the human body were considered because of the severe space restrictions in low seams. Studies were conducted on six subjects to evaluate each one's response to postures within the confines of a compartment 30 in high, 24 in wide, and 70 in long. A video camera recorded their positions and movements on tape for later analysis. Each subject was told to position himself in the compartment and to go through simulated functions of operating controls and observing both inby and outby operation for periods of 1 h. These subjects tried lying down, squatting, sitting cross legged, sitting in a very reclined position, etc., and needed frequent postural relief. The consensus favored the reclined seat position.

[3]Gunderman, R. J. Canopy Technology for Low Seam Continuous Haulage. Final Report USBM Contract No. H0387027, Feb. 1980, 72 pp.; for inf., contact A. J. Kwitowski, TPO, Pittsburgh Research Center, BuMines, Pittsburgh, PA.

Required dimensions for an operator compartment were thus determined to be approximately 5-1/2 ft long and at least 2 ft wide in the shoulder area. A detailed consideration of the 506C-5 bridge carrier showed that there was no possibility of locating such an operator compartment on that machine. However, Jeffrey was starting design of a new bridge carrier with increased haulage capacity and greater tram speed. Effort was then directed at locating an operator compartment on the new machine so that the resulting design would allow adding the compartment, if desired. Fender-mounted controls would be retained in the standard design because of mine operator preference, especially in seam heights less than 36 in.

Many potential locations for the compartment on the machine were examined using a small-scale model. Because of the requirement for frequent ingress and egress, along with maintaining a properly located machine center of gravity, the side-rear compartment position was preferred.

A full-scale mockup was constructed from cardboard and wood (fig. 2). Only significant portions of the bridge carrier were included in the mockup since it was used primarily to determine operator fit, functional movement, and visibility. The canopy on the mockup and the items inside the operator compartment were moved until satisfactory locations were established empirically. Figure 3 shows a 50th percentile operator in the mockup.

Results from the mockup evaluation showed feasibility with canopy heights adjustable between 30 to 42 in above the floor. Depending upon seam conditions and undulations, a bridge carrier of this type could operate in seams from 48 to 36 in high. Jeffrey agreed to constrain the design of the new machine to allow for this compartment as an option.

OPERATOR COMPARTMENT DESIGN

Considerable effort went into the design of the operator compartment and attachment to the bridge carrier. Also, the controls of the new bridge carrier were relocated to the right side of the machine instead of the left side because the operator of the continuous mining machine is on the right side. The resulting design is shown in figure 4.

The newly designed machine is 9 in wider and almost 4 ft longer than the 506C-5 in order to accommodate the compartment and the fact that the outby conveyor must swing as much as ±90°. This also required longer crawler tracks. Therefore, the compartment has to float on the floor in order not to impede mobility.

The operator compartment is attached to the main frame by two pivots with horizontal axes. Figure 5 is a closeup of this attachment taken during tests for mobility. The compartment side of the pivots consists of steel collars that slide vertically on the two front canopy support posts. This slide travel is limited to 8 in by the support members at the bottom and fixed collars on top. Angular movement of the compartment is limited with respect to the discharge conveyor in the upward direction by a stop on the conveyor and in the downward direction by a link chain.

Selection of an operator seat was limited by the practical factor of availbility. In this case a seat was selected that has a seat unit separate from the back rest. A new adjustable seat mount was designed using data from the functional mockup evaluation. A single lever on the seat back retracts dual pins that engage in holes in the seat mount. This provides positions reclining from the vertical of 25°, 34°, 43°, 51°, or 60°. A similar arrangement allows separate adjustment of the seat cushion to angles from the horizontal of 10°, 20°, or

FIGURE 2. - Looking down on the mockup from the receiving end.

FIGURE 3. - Operator seated in the mockup.

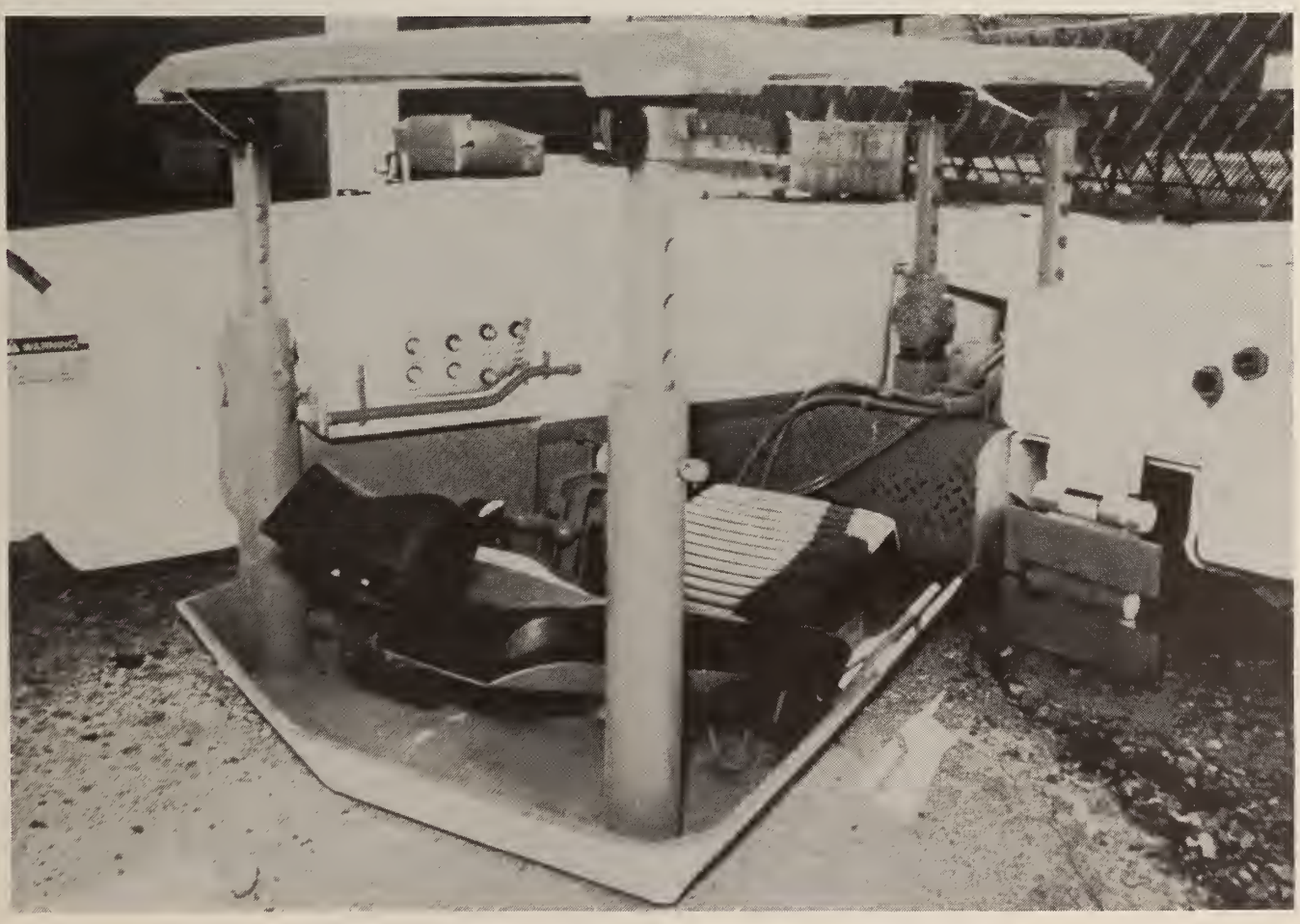


FIGURE 4. - Completed operator compartment on new machine.

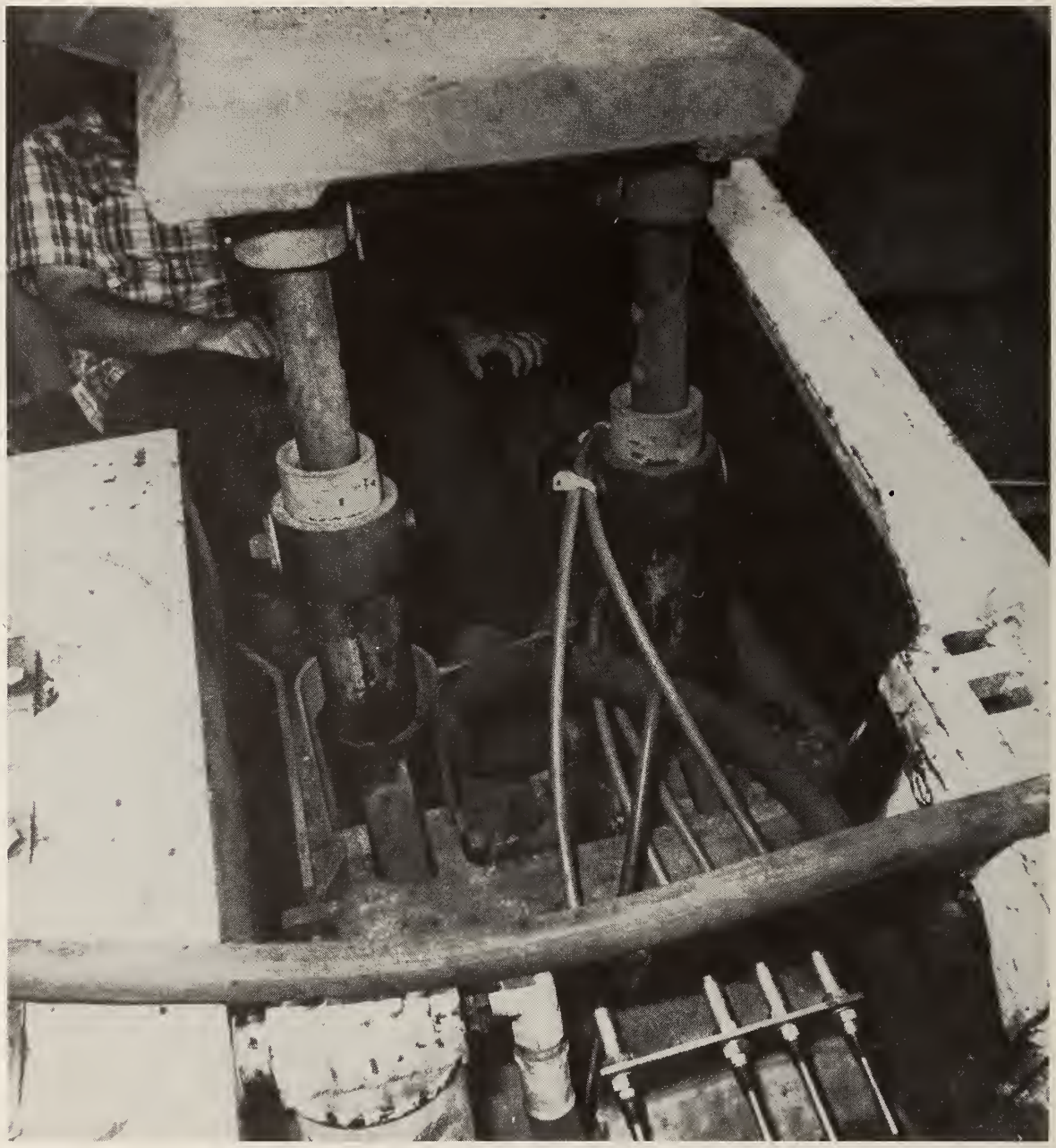


FIGURE 5. - Attachment of compartment to mainframe.

30°. The adjustment holes are indicated by arrows in figure 6. The mount with the seat slides forward and back on the track bar shown in figure 7. A clevis pin through holes in the seat mount allows nine fore and aft position selections in 1-in increments.

Arm rests that tilt back for ingress and egress were provided. However, the left arm rest was deleted when it was found to interfere with both arm movement and other items in the compartment.

As noted in figure 1, the operator kneeling and facing the machine only has to turn 90° to see either inby or outby operation. Unfortunately, there is not enough room in the entries to place a compartment so that the operator faces the machine the same as with the 506C-6. The compromise in the new design is to

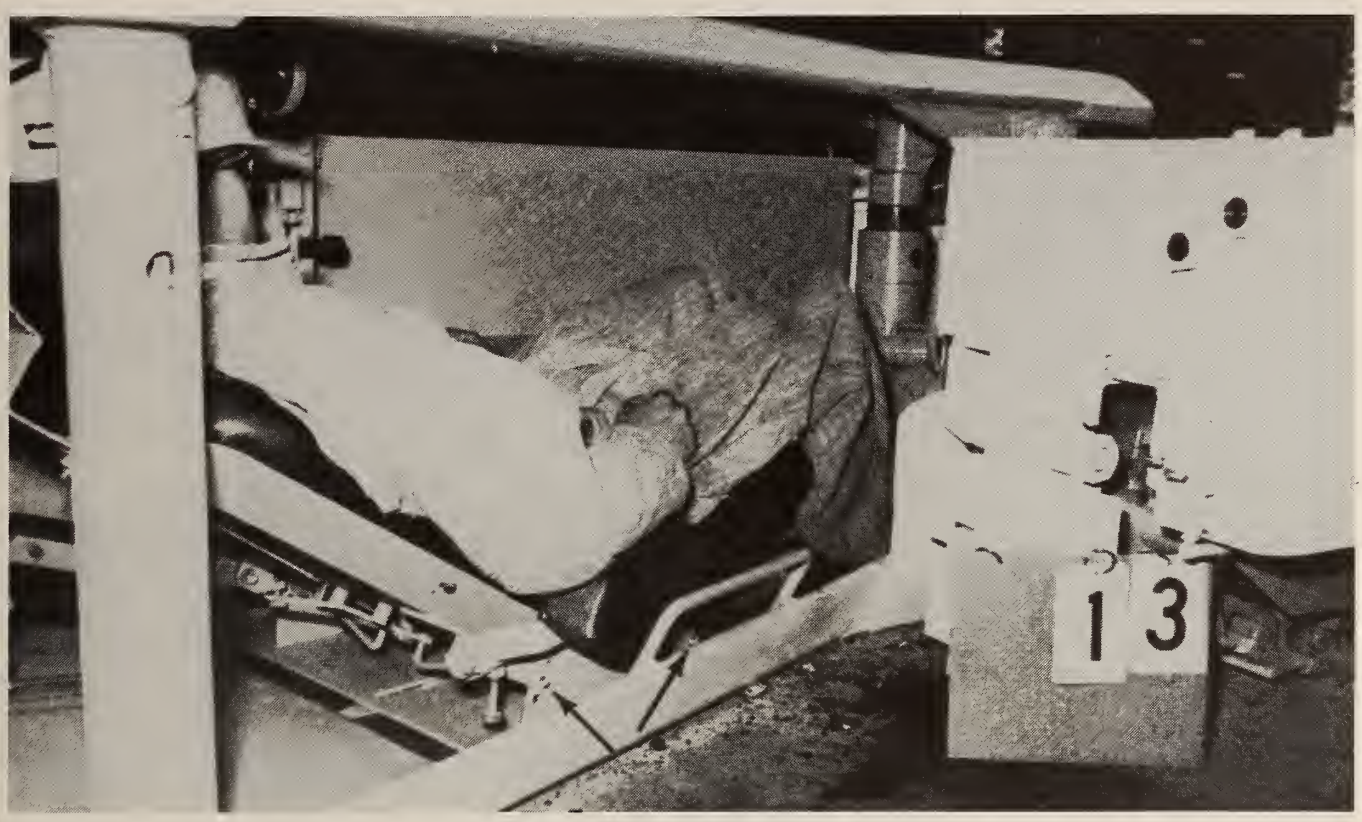


FIGURE 6. - Seat adjustment.

FIGURE 7. - Seat fore-aft adjustment track.

place the operator at a small angle (19°) with respect to the longitudinal axis of the machine. This angle helps considerably when turning the head to see the outby transfer point. Most operators, sitting in the reclining position, roll the body slightly off the seat when turning to see outby.

Four posts are used to support the canopy because of the size and loads. The posts telescope, and each is adjustable with a pin for canopy heights from 30 to 42.5 in in 2.5-in steps. During the compartment design phase, the Solar Fuel Co. became interested in this program and agreed to an in-mine evaluation of the machine at its mine No. 9. Because the seam heights there have considerable variation, as well as undulations, they desired a method to change canopy height without the need for extra equipment, such as a jack. Two hydraulic lift cylinders were added, one at the left rear as shown in figure 8 and the other at the opposite corner. A small pump with oil reservoir and a reversing valve comprise the rest of the canopy raise system. The pump is operated by stroking the handle, and the flow direction is set by the valve. The first step in adjusting the canopy height is to pump up the circuit to lift the weight of the canopy off the four pins so that they may be removed. The four adjustment pins must all be replaced for the desired height setting before the operator enters the compartment. Figure 9 shows, left to right, the support post, raise cylinder, flow direction valve, and hydraulic pump.

FIGURE 8. - Operating the canopy adjusting pump and flow valve.

Both the electrical and hydraulic controls are located to the left of the operator so as not to impede ingress and egress. Figure 10 is a side view of the operator compartment taken during the in-mine evaluation. Note that the arm rest is tilted back. The handhold on the compartment floor adjacent to the seat aids the operator during ingress and egress.

Operator visibility in order to safely and comfortably accomplish all functions was a major concern. This was investigated using the full-scale mockup shown in figure 2. Markers indicating the height above the floor were placed at four locations--the inby end of the bridge conveyor loading boom, the inby ends of both the right and left crawlers, and the outby end of the conveyor discharge boom. Data were collected for each size operator in the mockup with canopy heights of 30, 32, 34, and 36 in, and at each key direction from his eye location. Higher canopy settings were considered to be no problem, so data were not collected for these. Visibility at the loading boom, discharge boom, and near-side (left) crawler positions for the minimum canopy height was 17, 25, and 25 in respectively. The minimum visible height across from the operator and in front of the right crawler ranged from 24 to 35 in. As the canopy was raised, so also was the operator's head, which gave a lower minimum visible height.

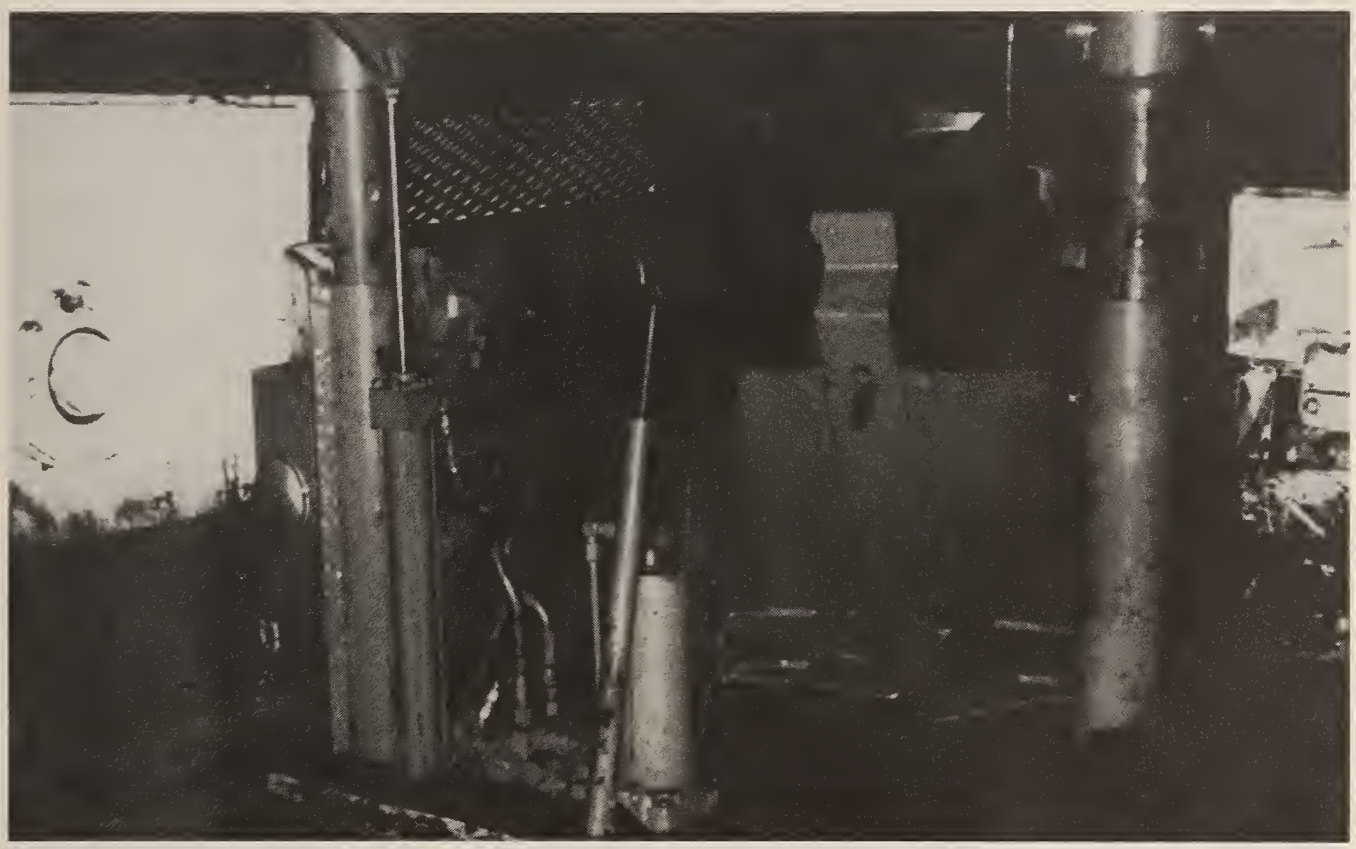


FIGURE 9. - Canopy adjusting system.

FIGURE 10. - Side view of operator compartment.

Variations in the highest visible height were relatively small. These variations were dependent upon how the operator positioned the seat, both in angle and in fore-aft direction. The highest visible measurements ranged from 38 to 50 in at the four aforementioned positions.

EVALUATION PRIOR TO SHIPMENT

These visibility measurements were repeated for the actual machine before shipment to the mine. As shown in figure 11, the operator compartment was located on the right rather than the left side (fig. 2) of the machine. A camera was positioned at the operator eye location, and pictures were taken of the visibility of the inby loading boom position. With the canopy set at 30 in above the floor (fig. 12), the limits of visibility were 34 to 47 in. When the canopy was raised to 35 in (fig. 13), the visibility range was 23 to 56 in; at a canopy height of 40 in (fig. 14), the visibility range was 22 to 75 in.

When the operator looks back at the bridge carrier outby transfer point, the angles are limited. However, the operator does not have to see over a large vertical angle, as long as the coal flowing across the transfer point is within the visible angle. In figure 15 the limits are 14 to 34 in with the canopy at 30 in. In this case the discharge end boom was lowered to the floor. The boom can be raised 7° or lowered 6° with respect to the mainframe, but if the seam height requires the canopy at 30 in, it is not likely that the boom would be raised more than 12 in from the conditions shown in figure 15.

Another visibility consideration is toward the general outby direction when tramming the system outby. In this case, the operator will usually turn in the opposite direction, as when observing the outby conveyor transfer. There is very little visibility obscuration in that direction. However, as shown in figure 16, the operator has to strain somewhat even with the canopy at 35 in.

In general, the visibility is reasonable at most canopy heights, except for 30 in. If the operator size is not much over the 50th percentile rank and the mine conditions are good, then operation with the canopy at 30 in should be possible. Table 1 summarizes the visibility data collected with subjects in the machine before shipment to the mine.

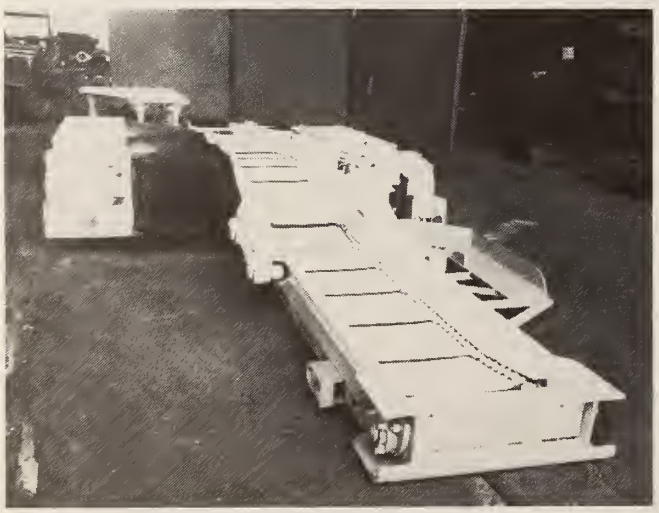


FIGURE 11. - New machine ready for human factors evaluation.

FIGURE 12. - Looking forward under 30-in canopy height.

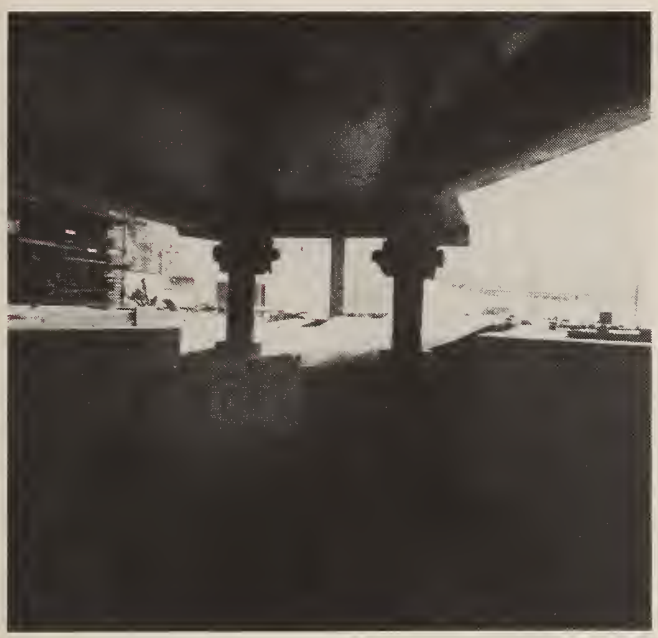


FIGURE 13. - Looking forward under 35-in canopy height.

FIGURE 14. - Looking forward under 40-in canopy height.

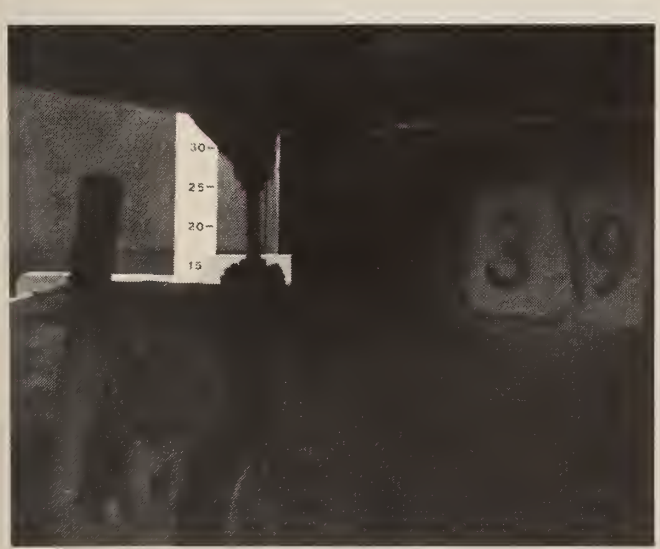


FIGURE 15. - Looking at outby transfer point under 30-in canopy height.

FIGURE 16. - Operator under 35-in canopy tramming outby.

TABLE 1. - Summary of collected visibility data

Operator size, percentile	Canopy height, in	Seat back angle from vertical, deg	Seat cushion angle from horizontal, deg	Visibility range, inches above floor, measured at noted location[1]				Seat cushion to bottom edge of foot rest distance, in	Legs and knee position
				1	2	3	4		
5th.....	30	43	30	NM	34-47	NM	NM	15.5	Knees bent, feet on floor.
	32.5	34	30	NM	25-46	NM	NM	15.5	Do.
	35	34	30					18.5	Do.
	40	25	30					18.5	Knees bent, feet on rest.
50th....	30	60	30	30-41	28-38	26-34	14-34	18.5	Do.
	35	51	30	NM	23-56	NM	NM	21.5	Do.
	40	34	30	24-56	22-75	24-57	16-56	23.5	Do.
95th....	30	60	20	NM	27-35	NM	NM	18.5	Feet crossed on floor under thighs.
	32.5	60	20	NM	22-42	NM	NM	18.5	Knees bent, feet on floor.
	35	51	20	NM	21-50	NM	NM	19.5	Do.
	40	34	10	NM	16-64	NM	NM	23.5	Feet crossed on floor under thighs.

NM No measurement.

[1]Visibility locations:

1 - Inby left crawler (opposite operator).

2 - Inby end of loading boom.

3 - Inby right crawler.

4 - Outby end of discharge boom.

Paired numbers indicate the height range, in inches above the mine floor, visible to the operator at each location.

Canopy heights at 35 in or more appear reasonable on this particular mobile bridge carrier. The effective window is large enough for good visibility angles. A perspective on this window may be obtained from figure 17, which is a photograph looking at the 5th percentile operator in the compartment with the canopy set at 35 in.

A large operator finds the compartment a tight fit, as shown in figure 18. This subject's favorite position for his legs was crossed and on the floor. In this scene, the canopy height is 40 in and the backrest angle is 34° from the vertical. Another view of this operator position is shown in figure 19. Note that he uses the headrest to support his shoulders rather than his head.

Control operation is primarily with the left hand. As shown in figure 20, there are four levers located in a console on

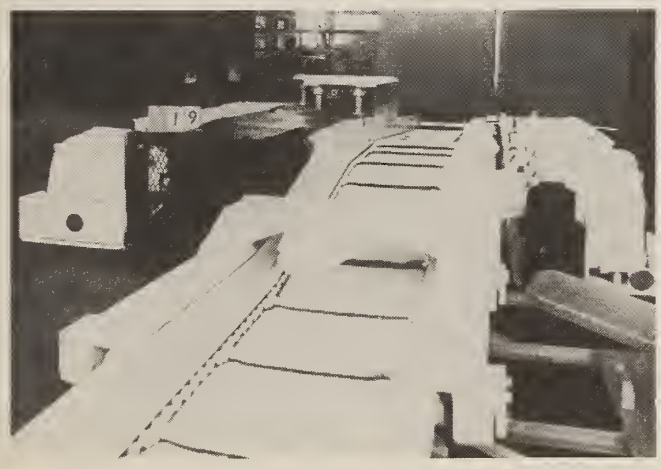


FIGURE 17. - Looking at operator under 35-in canopy from inby end of loading boom.

FIGURE 18. - Large-size operator with legs crossed.

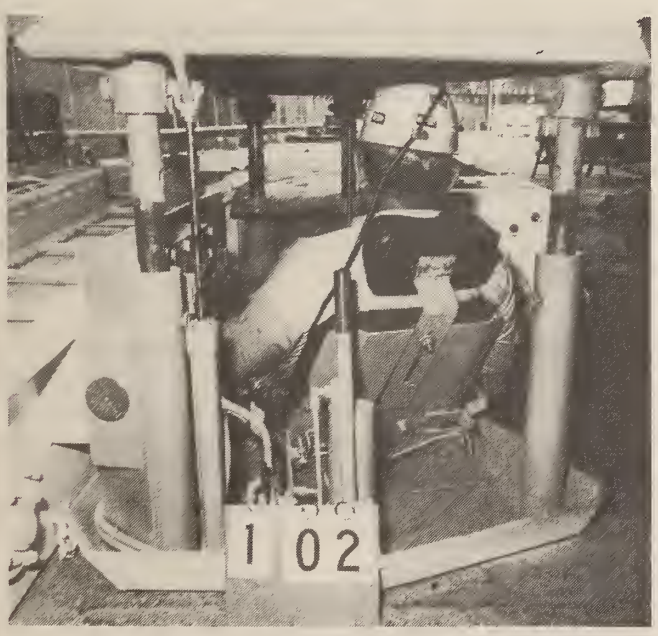


FIGURE 19. - Large-size operator supporting shoulders with headrest.

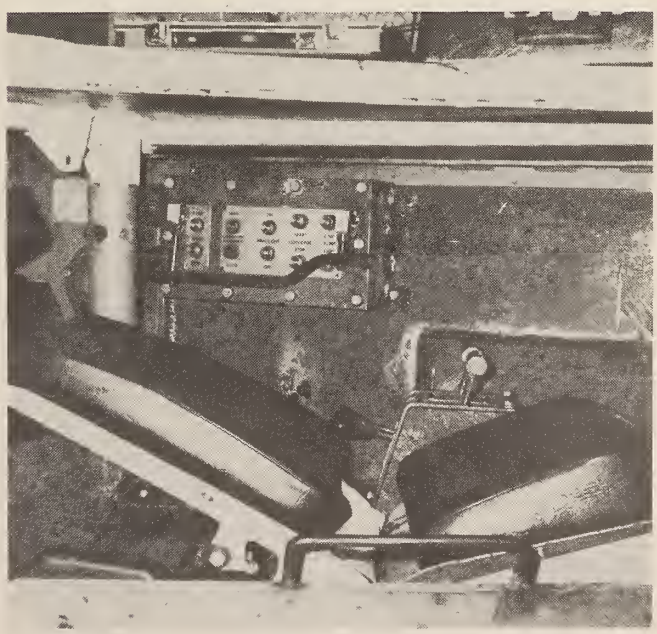


FIGURE 20. - Closeup of controls in compartment.

the floor of the compartment to the left of the operator. These levers work hydraulic levers on the mainframe in front of the operator through cables. The two upper levers are for the left and right tram. Pushing them forward moves the machine inby, and pushing them rearward reverses the tram.

There are two lower controls on this console that work the receiving and the discharge conveyor booms. The left control raises the discharge conveyor when it is pushed up and lowers it when pushed down. The receiving conveyor works similarly with the right control lever.

The electrical controls, also shown in figure 20, are all located within the enclosure mounted high on the left wall of the operator compartment. This was an existing control box used on another machine which had already been approved by MSHA. The fire extinguisher is located below the electrical control case, and the actuator knob is visible just above the backrest. Note that the panic bar must be operated either with the left shoulder or a hand.

IN-MINE EVALUATION

The in-mine evaluation was conducted through the cooperation of the Solar Fuel Co. at its mine No. 9 near Somerset, PA. Seam height at this mine generally ranges from 40 to 46 in but frequently pinches down much lower. Entries and crosscuts are 20 ft wide. Moisture, roof, and floor conditions were fair.

The new bridge carrier (Jeffrey model 5010) with operator compartment was substituted on an operating section for a Jeffrey model 506C-5 bridge carrier. The new machine was installed early in October 1981, and the evaluation was planned to last 3 months. This time was extended for various reasons, including unrelated interruptions to the mining operation. The bridge carrier with operator compartment was removed from the mine in October 1982 and was delivered to the Bureau's Pittsburgh Research Center.

In the section area, the mine operator first tried the 35-in canopy setting but settled on 37.5 in soon afterwards. As can be seen in figure 21, there was little clearance between the canopy and the roof when the height was set at 37.5 in. During the in-mine operation, the compartment floated well on the floor through the action of the slides and pivots. As a result, the canopy-to-roof clearance could be nominally as low as 6 in.

Visibility for the operator was fairly good with the canopy at 37.5 in. A protective metal mesh, angled inward, was added to the top of the compartment wall to assure that the operator did not reach beyond that wall and become pinched by the relative movements between the compartment and the discharge conveyor. This mesh did not significantly block visibility toward the opposite side of the machine.

As stated earlier, the discharge conveyor may be raised several inches. Figure 22 is a view from the left front of the machine with the conveyor raised to the roof. While this conveyor would obscure vision directly across the machine, it does not otherwise affect operation. The conveyor would normally be lower when tramming the machine, and the operator would be able to see through the mesh and across the machine.

Four different operators of the double-bridge carrier were observed during the in-mine evaluation. One male operator was in the 50th percentile size range, and two other males were somewhat smaller. The other operator was female and was slightly larger than a 50th percentile female.

Operator indoctrination occurred quickly, although it took the operators some

FIGURE 21. - Clearance under roof with canopy at 37.5 in.

time to get over the restless reaction that resulted from confinement within the compartment. Inability to directly see the inby conveyor carriage was the biggest problem. The movement between stops on the new machine is only 5 ft, which means that the operator must be even more skillful in moving the bridge carrier to avoid banging the carriage against the stops as a result of continuous miner movement. The operator seated in the compartment can only see the top of this carriage.

Each operator had different preferences on positions within the compartment. Repositioning was frequent in order to retain reasonable comfort. There was a tendency toward operator inattention since the workload within the compartment was small. Operator personnel were encouraged to get out of the compartment frequently when not running coal and to do spillage cleanup, machine inspection, etc., in order to overcome boredom.

The attitude of the operators varied as they became more familiar with the new compartment. At first, they did not like the concept and were very uneasy because they could not move around as they did before and because visibility was now restricted. After familiarization for a few weeks, the operators expressed satisfaction with the compartment. However, the satisfaction did not last long as boredom set in and their personal performance tended to deteriorate. The operator workload was subsequently adjusted by having the operators leave the compartment when not running coal and perform duties including spillage cleanup and machine lubrication. Ultimately, the operators accepted the operator compartment as a compromise from the older machine with fender-mounted controls.

Difficult mining conditions, due to incursions of stone into the coal seam, precluded a good measure of the effect that the addition of an operator

FIGURE 22. - Looking at compartment from left side with conveyor raised.

compartment on the double-bridge carrier had on coal production. It appears from data collected that the production rate is unchanged.

CONCLUSIONS

The program objective of investigating the feasibility of providing operator protection on crawler-mounted continuous haulage systems was achieved. These findings are summarized as follows:

1. Adding operator protection requires considerable compromise.

2. An operator compartment is reasonable for seam heights as low as 40 in.

3. Operation in seam heights as low as 36 in is questionable and should be evaluated in-mine.

4. Adding an operator compartment required redesign of the machine.

5. The floating concept using slides and pivots works well.

6. A reclining seat provides the best operating position.

7. Operator repositioning within the compartment occurs frequently.

8. The operators always set the canopy to the highest tolerable setting.

9. Line of sight to the continuous mining machine operator is more frequently obscured.

10. Operators react mostly on the basis of familiarity with running conditions and seldom use signals.

11. Noted shortcomings with the compartment include--

Inattention due to minimal activity.

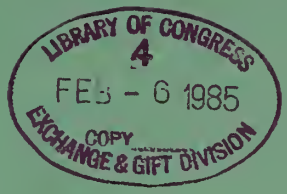
Limited visibility requires extra care when tramming.

Large operators are not practical at lowest canopy setting.

It is recommended that the double-bridge carrier with operator compartment be further evaluated under in-mine conditions where the mining height is typically 36 in.

IC 8996

Bureau of Mines Information Circular/1985



Cabs and Canopies for Underground Coal Mining Equipment

Proceedings: Bureau of Mines Technology Transfer Symposium, Charleston, WV, June 22, 1983

Compiled by William W. Aljoe

UNITED STATES DEPARTMENT OF THE INTERIOR

Information Circular 8996

Cabs and Canopies for Underground Coal Mining Equipment

Proceedings: Bureau of Mines Technology Transfer Symposium, Charleston, WV, June 22, 1983

Compiled by William W. Aljoe

UNITED STATES DEPARTMENT OF THE INTERIOR
William P. Clark, Secretary

BUREAU OF MINES
Robert C. Horton, Director

Library of Congress Cataloging in Publication Data:

Bureau of Mines Technology Transfer Symposium (1983 : Charleston, WV)

Cabs and canopies for underground coal mining equipment.

(Information circular ; 8996)

Includes bibliographical references.

Supt. of Docs. no.: I 28.27:8996.

1. Mining machinery—Safety measures—Congresses. 2. Mine railroads—Cars—Safety measures—Congresses. I. Aljoe, William W. II. Title. III. Series: Information circular (United States. Bureau of Mines) ; 8996.

~~TN295.U4~~ [TN345] 622s [622'.2] 84-600210