TECHNICAL SESSION - I

SAFETY: INSTALLATION OF CABS AND CANOPIES ON UNDERGROUND ELECTRIC FACE EQUIPMENT

"Cabs and Canopies for Underground Electric Face Equipment"

by

Richard B. Farrar [1]

I. Introduction

This paper describes protective canopy development work performed by Bendix for the U. S. Bureau of Mines, Pittsburgh Mining and Safety Research Center, over the past two years. Work is continuing under recently awarded contracts, one of which covers the canopies for very low coal (<36") machinery. The following summarizes the contracts under which this work has been performed:

CONTRACT	TITLE	STATUS
H0220031	"Design and Development of Protective Canopies for Underground Low Coal Electric Face Equipment, Including Shuttle Cars"	Complete
H0242020	"Survey on Protective Canopy Design"	Complete
H0242028	"Design and Development of Protective Canopies for a Shuttle Car, Loader, and Roof Drill"	September 1974 Completion
H0346102	"Study of Low Coal Canopy Concepts"	February 1975 Completion
H0242065	"Refined Design of Protective Canopies for Shuttle Cars, Loaders, and Cutters"	January 1975 Completion

[1] Project Manager, Bendix Navigation and Control Division, 2796 S. Federal Bldg., Denver, Colorado.

The initial contract covered the design, fabrication, and in-mine evaluation of protective canopies for low coal (<48") conventional electric face equipment. Canopies were fabricated and installed in the Jewell Ridge Coal Company's No. 12 Mine on a Joy 21SC shuttle car, 14BU10 loader, and 16RB cutting machine and a Galis 300 roof bolter and 460S face drill. In-mine evaluation of these canopies revealed desired improvement areas. This work was undertaken in contract H0242028. Concurrently, a canopy survey was made wherein visits were made to all equipment manufacturers and a number of mines to determine canopy status, operational problems, and to develop recommendations concerning canopy dimensions, required mining heights for canopy equipped machines, and canopy design improvements to solve certain operational problems.

Two recently awarded contracts cover additional canopy design refinements and design alternatives for the shuttle car, loader and cutting machine involved in the initial contract and the generation of canopy designs for the low coal Wilcox Auger Miner and Roof Bolter, the Elkhorn AR-4 Scoop, and the LEE-NORSE 245 CM Miner.

The details of work performed under each of the five contracts are described in subsequent sections.

II. Detailed Description of Canopy Development and Evaluation Programs

A. "Design and Development of Protective Canopies for Underground Low Coal (<48") Electric Face Equipment Including Shuttle Cars," Contract H0220031.

This program was directed toward equipment used in a low coal conventional mining section in order to cover a wide range of machine types and to address the mining heights considered likely to pose greater difficulties with respect to canopy design. Program participants in addition to Bendix and the Bureau of Mines, were the Jewell Ridge Coal Company, Joy Manufacturing Company, Galis Manufacturing Company (now Mining Equipment Division of FMC Corporation), and George Judy Associates, Consultant.

Equipment and Mine Selection: The Machines were specifically selected as highly representative of equipment in operation in low coal conventional sections. The mine was chosen on the basis of having an average mining height of 48 inches or less, having the desired equipment makes and models in use, and of course, being willing and able to participate in and support the in-mine installations and evaluation.

The machines selected for canopy development were the Galis 460S face drill, Galis 300 roof drill, Joy 14BU10 loader, Joy 21SC shuttle car, and Joy 16RB-3AH cutter. The mine sites selected were the No. 12 and the Big Creek Tiller Mine of the Jewell Ridge Coal Company.

Design Constraints: A major overall requirement that governed canopy design was that the canopies had to be installable on existing machines with minimum machine changes and that the installation be accomplished underground with little or no equipment down time.

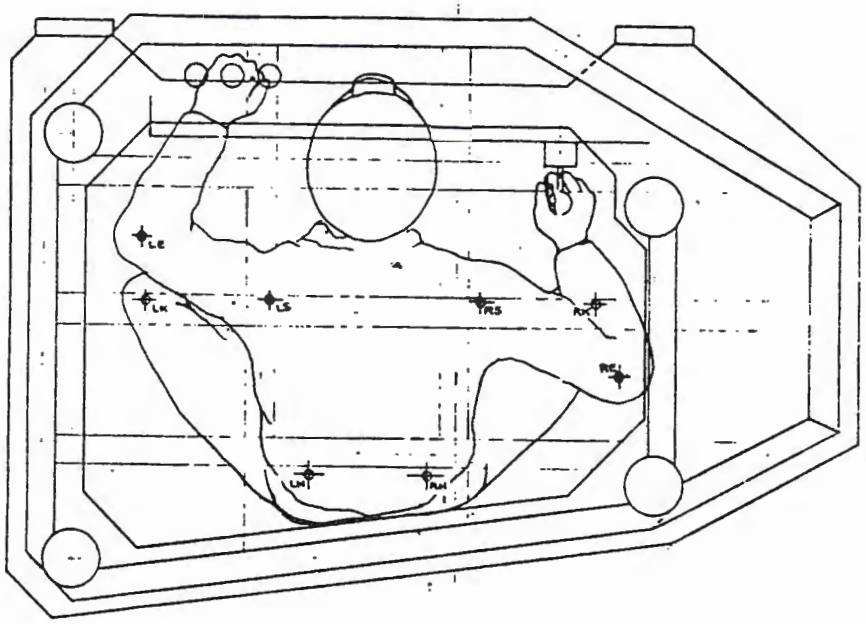


Figure 1. Plan View of Workspace
Joy 14BU10 Loader
(5th Percentile Miner)

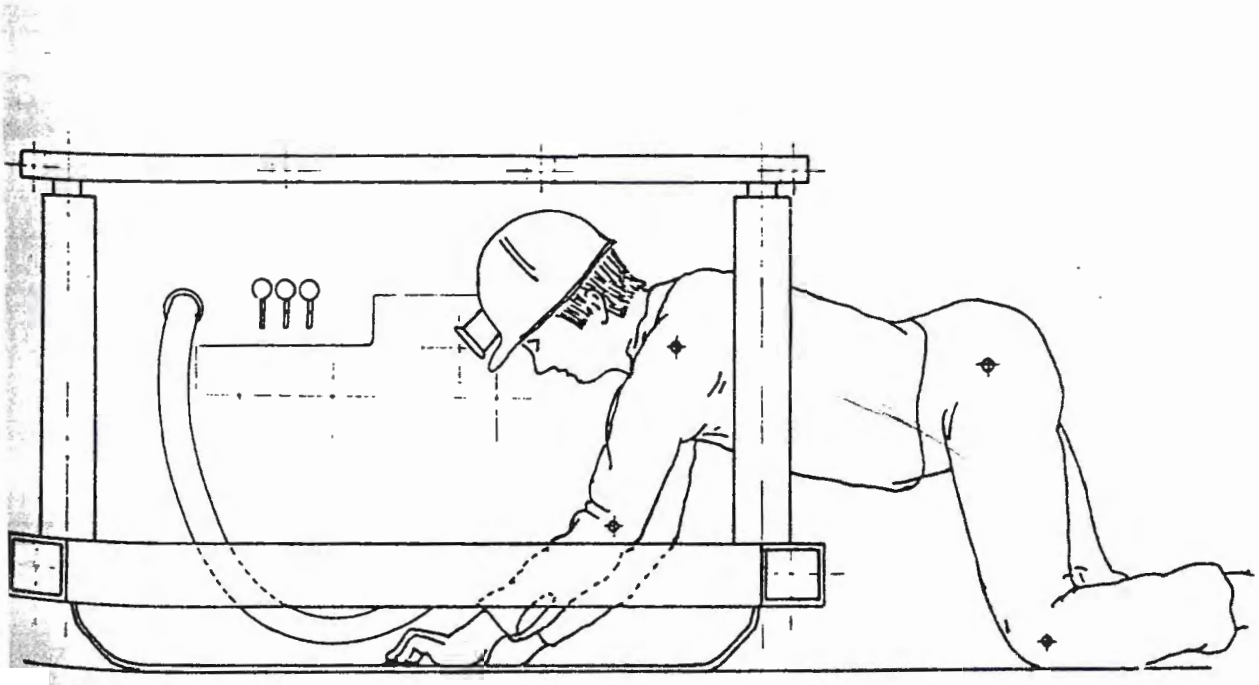


Figure 2. Miner Ingress/Egress (Side Elevation)
Joy 14BU10 Loader
(95th Percentile Miner)

Design Approach and Procedures: Canopy configurations were established based on human engineering studies, full scale canopy mockups, and in-mine observation and consultation with mine and equipment manufacturing personnel.

1) Human Engineering Studies: Investigations were made to determine if canopy installations on the machines would degrade normal operator performance or create new hazardous conditions. Comparison studies were made of machines operating with a canopy and without a canopy. Major study variables included visibility, reach envelopes, ingress, egress, work physiology, and safety. These studies were conducted by examining the machine operator's tasks, considering operator anthropometry, and by simulating operator tasks. Numerous anthropometric sketches were generated and widely used in the establishment of canopy dimensions and in the evaluation of all human factors aspects of placing a protective canopy over and around the machine operator. Examples of these sketches are shown in figures 1 and 2.

2) Full Scale Mockups: Inexpensive full scale wood mockups of each canopy were built and used in task simulation and evaluation of operator anthropometry. Tests were run under simulated low coal conditions using a mine entry mockup constructed of plywood sheets. Use of mockups in the design providing a low cost method of achieving realism and increasing the validity of evaluating such items as: "Can the man get in and out?", "Can he reach certain areas?", "Can he see?", "Is he comfortable?", "Can a big man be accommodated?"

The following photographs illustrate the typical mockup work that was performed in this program. Figures 3 and 4 show a test subject in canopy mockups for the Joy 21SC shuttle car and the Joy 14BU10 loading machine.

Figures 5 and 6 show canopy mockup work for the Galis 300 roof drill. In figure 5, the test subject is simulating roof bolting tasks in order to evaluate human factors safety of the proposed canopy. In figure 6, the roof drill canopy mockup is shown in front of a plywood mockup of a low coal entry.

3) IN-MINE Observations of Machine and Operator Operations: Each of the five machines involved in the canopy program were observed in operation in several low seam coal mines of the Jewell Ridge Coal Company. The objective was to record all tasks performed by the operator during machine operation and to translate this, if applicable, into requirements for the canopy. Machine behavior, mine conditions, etc. were also noted with respect to effect on canopy design.

4) Consultations with Equipment Manufacturers: The manufacturers of the machines for which canopies were being designed were consulted throughout the program. This commenced with discussions of the proposed canopy concepts, identification of satisfactory canopy/machine interface structure, and continued through detail design, including an on-site review of the canopy mockups.

5) Machine Operator and Mine Management Recommendations: Particular emphasis was placed on securing comments and recommendations from machine operators and mine operators throughout the program. On three different occasio mine personnel, including several operators of the specific machines designated to receive the trial canopies, visited the Bendix Denver Facility for review of the canopy mockups, detail drawings and fabricated hardware.

Figure 3. Canopy Mockup - 21SC Shuttle Car

Figure 4. Canopy Mockup - 14 BU10 Loader

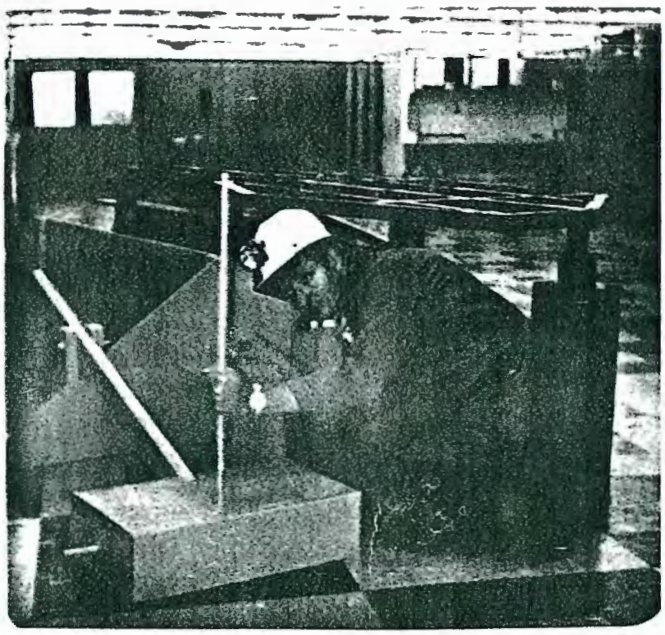


Figure 5. Canopy Mockup - Galis 300 Roof Drill

Figure 6. Low Coal Entry Mockup

Major Human Factors Considerations: In this canopy development program, a major effort was made to be responsive to human factors considerations. This was accomplished by conducting formalized human engineering studies on each machine and proposed canopy as outlined previously under design procedures. These efforts were initiated at the outset of the program and the results guided concept formulations and evaluations.

In all of the work the large man (95th percentile) and small man (5th percentile) were considered. Below are listed the major human factors that were addressed:

1) Operator Visibility: It was recognized from the start that any substantial structure placed around and over the operator would inevitably detract from existing vision capability; such structure placement was held to a minimum. Only small structure was used consistent with the load requirement and the ability to withstand the underground environment. In this regard, high strength steels were used in order to minimize certain structural member sizes. Open bar tops were used to permit visual contact with the mine roof. Structure posts were placed at positions to offer least visual blockage.

2) Reach Envelope: To a large extent, extensive analysis of reach capability was not required because canopies were placed over the existing operator's work station and controls were not changed. However, his ability to reach controls and work areas was considered to assure control accessibility after canopy installation. This analysis was performed for both large and small men (particularly the small men) using the canopy mockup.

3) Ingress/Egress: The ability to get into and out of the canopies was examined in considerable depth. This was done both analytically (taking into account the dimensions of the human body) and experimentally through use of a large and small man dressed in typical miner work clothes entering and exiting the canopy mockup. This information provided guidance in sizing the openings, making them large enough to get in and out with ease, yet not so large as to exceed canopy envelope constraints or expose the operator to sizeable unprotected areas.

4) Safety: The principal requirement was to sustain a vertical load of 18,000 pounds or 15 psi over the canopy top area, whichever was lesser. Operator protection from rib contact, leaning out of the machine to see, or impacting other machines, was incorporated in the canopy design. Over-hanging brows on the canopies, substantial side structures, and swing down side bars provided a degree of lateral protection. Additional efforts were directed toward shaping the design to avoid introducing potential operation danger points.

5) Work Physiology: The work functions and processes were examined by analysis of tasks performed by the operator of each of the machines involved and every attempt was made to be responsive to these data in the course of establishing the canopy configuration and details of the design.

6) Operator Comfort: The comfort of the operator was considered. The canopies were made as large as machine envelope constraints would permit. Also, handholds and body rests and supports were considered in order to gain comfort. All canopy envelope sizing included restraints imposed by typical miner work

clothes, e.g., loose fitting clothes, hard hat and lamp, battery, self-rescue cannister, etc.

Installations and Tests at the Machine Manufacturer's Facilities: All canopies were trial installed and load tested at the respective machine manufacturer's facility. The two primary reasons for doing this were to increase the chances for a smooth and efficient underground installation and to effect a better controlled load test on a complete machine/canopy installation. The photographs in figures 7 and 8 were taken at Joy and Galis and show the canopy installation on the cutting machine and the roof drill respectively.

The practice acquired in installing the canopy, the correction of problems, the routing and makeup of all required hydraulic hoses and fittings, the identification and solution of numerous installation details, and the collection of required hardware all contributed to an orderly and rapid underground installation effort. This "trial run" at the factory in an above ground environment was found to be of considerable benefit to the program.

Above ground load testing of the canopy installed on a machine was considered to be more convenient and to allow for better instrumentation. This approach also yielded more extensive evaluation of the machine/canopy interface. The photographs in figures 9 and 10 show factory load test setups on two canopy installations. In figure 9, the canopy undergoing the load test is on a Joy 14BU10 loading machine.

A hydraulic jack was used to apply the 18,000 pound load. In order that this single point load be distributed evenly over the canopy top, a 3-inch steel pressure plate and a sand box was used.

In figure 10, the canopy installation on the Galis 300 roof drill is being loaded to 18,000 pounds with a concrete block and a sand box arrangement.

In summary, trial installations and load tests at the machine factory were for the purpose of:

a) Insuring canopy fit
b) Certifying load requirements
c) Debugging and acquiring installation experience
d) Minimization of underground installation time

The objective of underground installation on existing machinery, on off-shifts was accomplished (average installation was completed in two maintenance shifts). The installation design was aimed at minimum machine changes and this, of course, made it possible to install the canopies underground with no interference with production.

Canopy Features: Each canopy configuration covers the existing platform area or the operator work station of each machine involved. In addition to overhead protection, a certain degree of side protection is incorporated into each configuration. A horizontal canopy top (four corner post arrangement) configuration is used to maximize working volume and to benefit operator visual capability.

Figure 7. Canopy Trial Installation on Joy 16RB Cutter

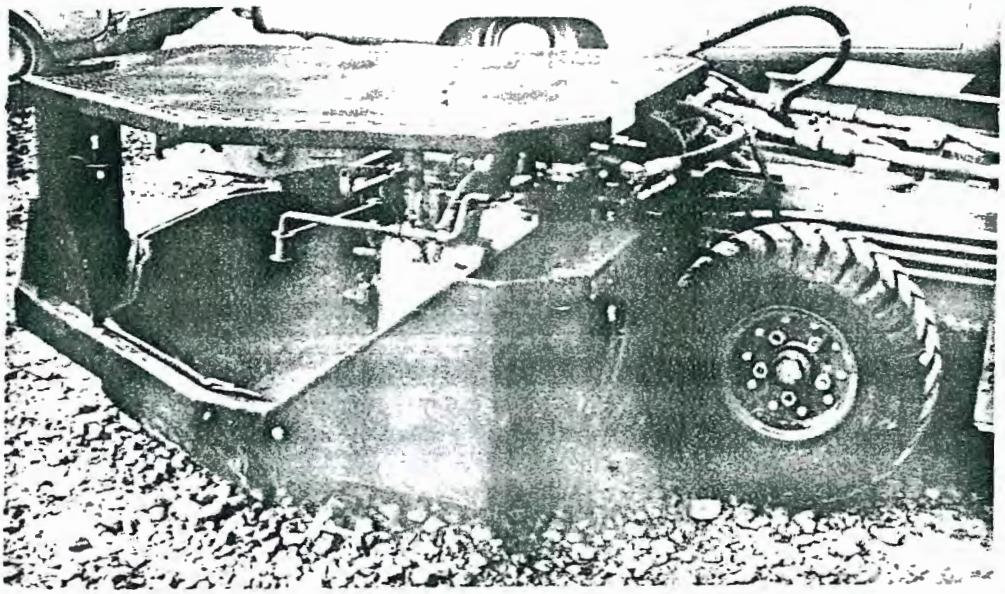


Figure 8. Canopy Trial Installation on Galis 300 Roof Drill

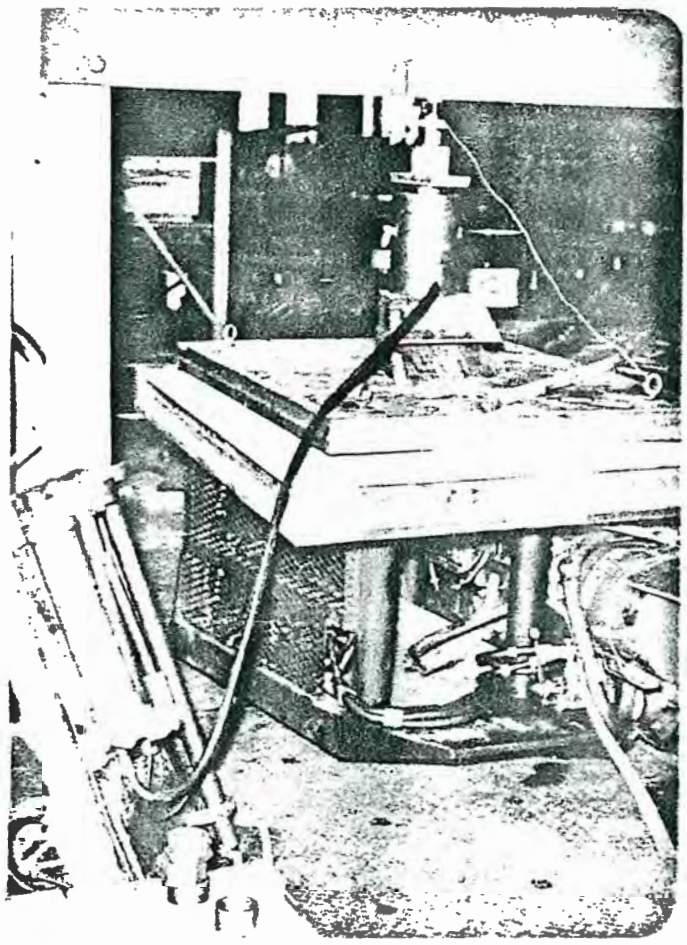


Figure 9. Test Setup for Loader Protective Canopy Load Test

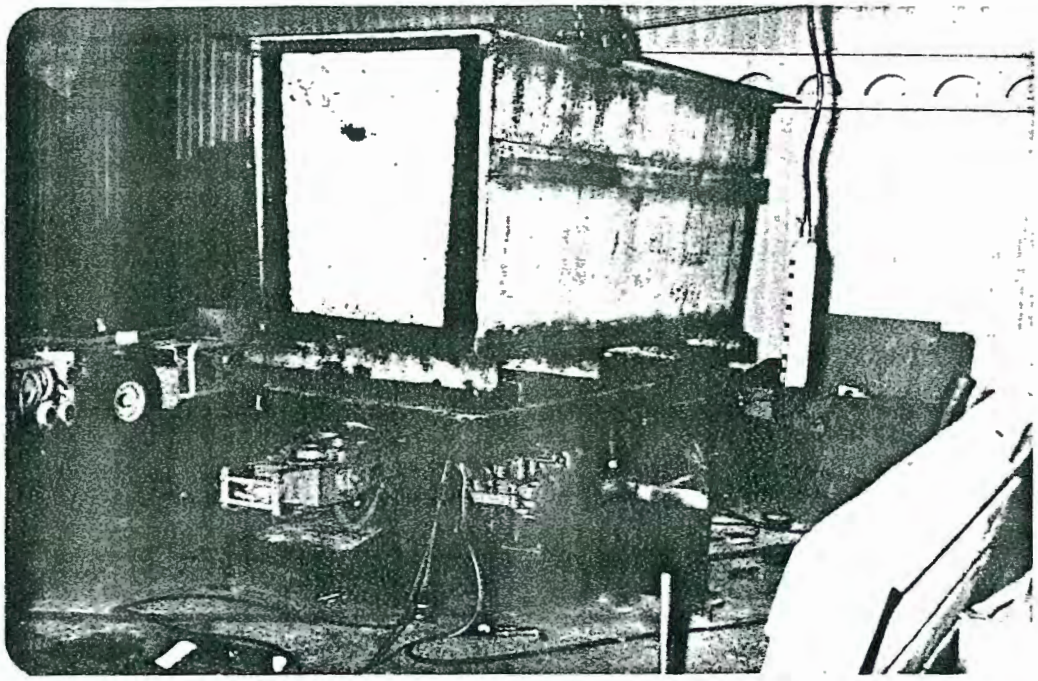


Figure 10. Test Setup for Roof Drill Protective Canopy Load Test

Figure 11 illustrates the general configuration approach used.

The canopy top will support a uniformly distributed load of 18,000 pounds. The load is reacted through the support structure to the machine frame. In the case of the roof drill the structure is expected to deflect to the ground for support. The following summarizes features of the canopy designs:

1) Hydraulic Height Adjustment: The overall height of each canopy top is hydraulically adjustable between a value of 32 inches and 40 inches. This is accomplished with four actuators, one located at each corner of the canopy structure. The hydraulic system is designed to support the entire vertical load requirement of 18,000 pounds. An incrementally adjustable mechanical stop is also provided as a backup in case of hydraulic failure.

2) Open Framework Canopy Top and High Strength Steel Usage: An open bar canopy top, as shown in Figure 11, was used in order to maintain some visual path capability through the top, and to keep the structure as light as possible consistent with the load carrying requirement. An open mesh material covers the entire top to prevent small objects from coming through the basic open framework. Frame members are square and higher strength materials such as A500B and 4130N steel are used in order to keep canopy tops thin and maximize head room.

3) Bolt-On Canopy/Machine Interface: In the interest of simplicity and ease of attaching the canopy to the machine, an attempt was made to use a "bolt-on" approach throughout. Weldments were used on only two machines; the existing platform was cut off and a new one, with canopy, was welded on. Figure 11 illustrates the simplified installation wherein four mounting pads are welded to the loader frame and the entire canopy is supported by eight bolts.

4) Rib Protection: Some degree of rib and side protection as well as vertical protection was provided in each design. Illustrative of this is the fixed side protection shown in figure 11. In this case, the loading machine canopy, the operator normally enters from the open aft end. Figure 12 shows the swing down side bar on the cutting machine canopy which the operator can depress when leaving the canopy.

Figure 13 shows the shuttle car canopy. A substantial contoured structure is attached to the operator pit at the lower edge to give some bumper action. The canopy overhangs at each end to give the operator some lean-out protection. A swing down side bar, as shown in figure 12, is also incorporated to give further side protection.

The above described features are the principal ones that applied in general to all of the canopies designed in the program. Other features were tried on individual canopy installations. Among these are:

a) Floating Floor Pans on the loading machine, wherein the operator rides on the mine bottom in a pan that floats within the canopy structure.

b) Flexible belt flooring in the roof drill canopy which moves the operator with the machine while still permitting him to sit essentially on the mine bottom.

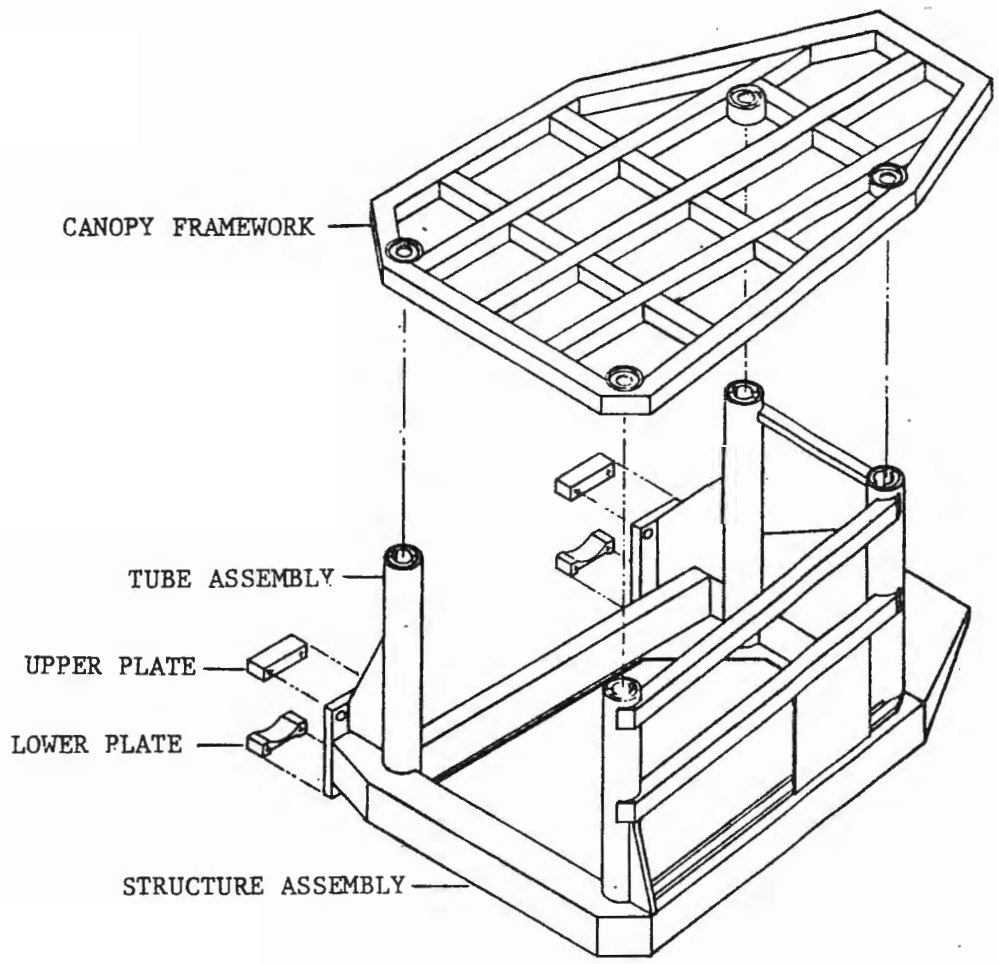


Figure 11. Skeleton Exploded View of Loader Protective Canopy

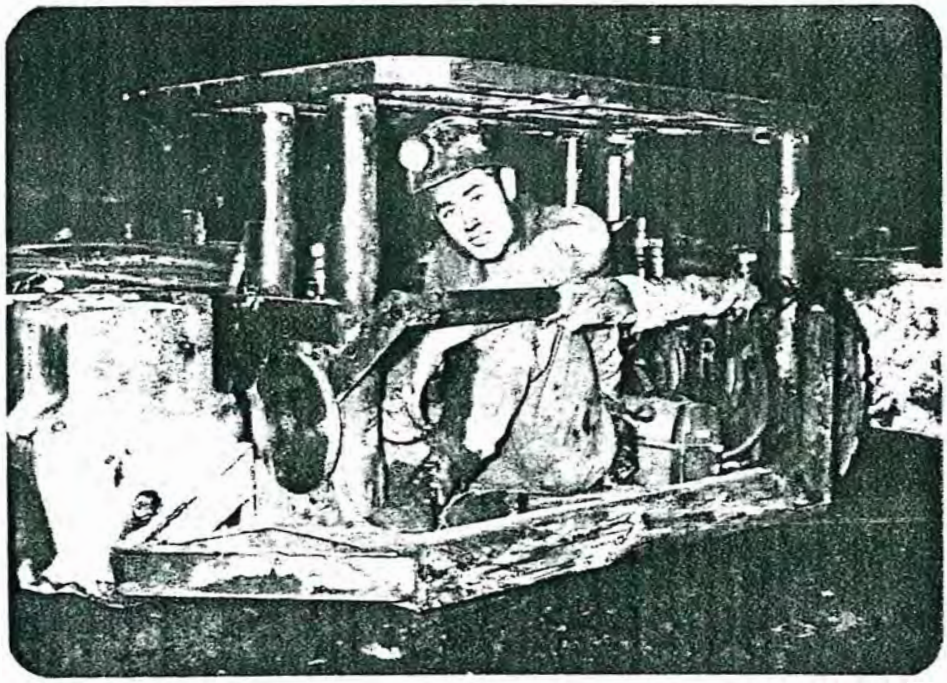


Figure 12. Cutter Canopy Assembly with Top and Swing Down Bumper Installed

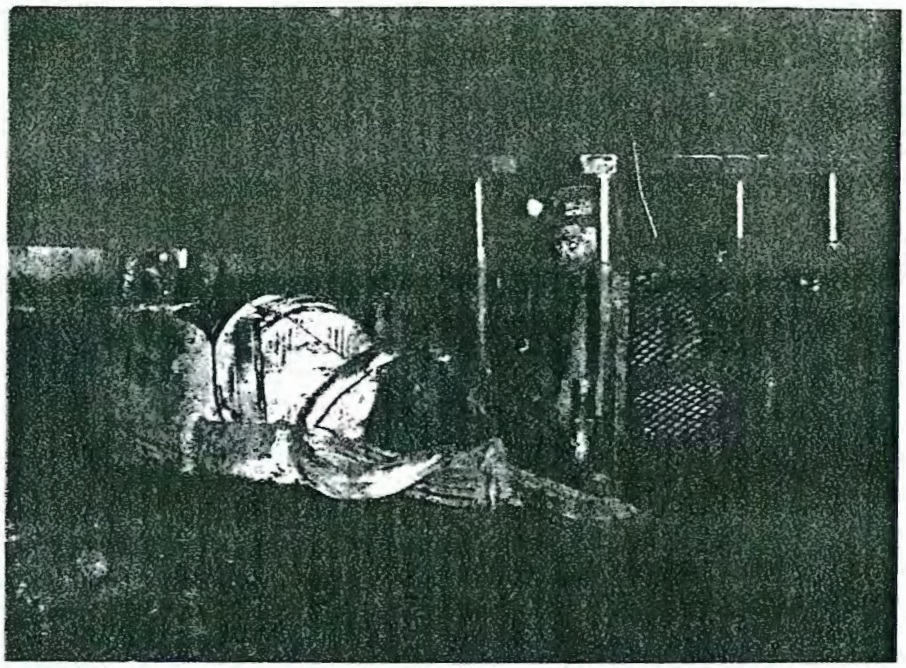


Figure 12A. Loader Canopy In-Mine Installation

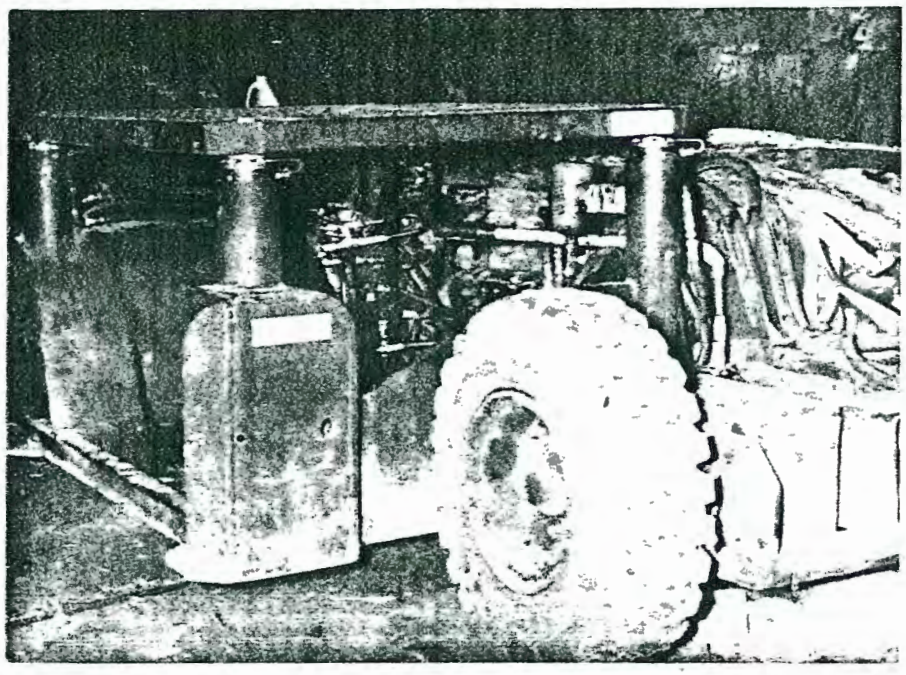


Figure 12B. Face Drill Canopy In-Mine Installation

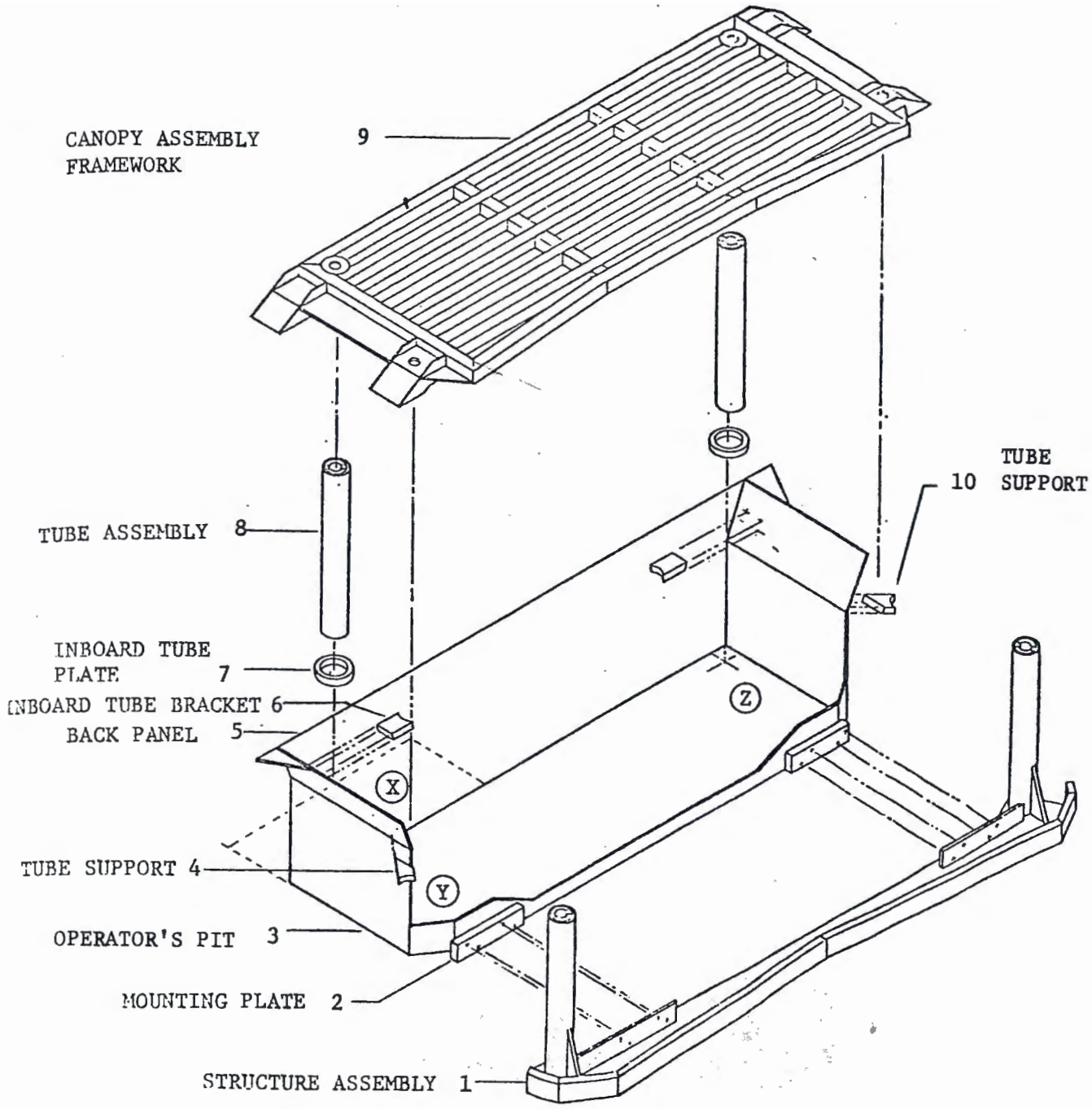


Figure 13. Skeleton Exploded View of Shuttle Car Protective Canopy

c) Roof sensor on the cutter canopy installation which automatically stops the canopy height adjust at a predetermined distance from the mine roof.

d) Hydraulically adjustable seat heights in the shuttle car canopy installation.

In-Mine Evaluation Highlights: The loader, face drill, and cutter canopies have been in operation in the Jewell Ridge Coal Company's No. 12 mine for over a year. These installations are shown in figures 12, 12A, and 12B. The mining height during this time has been in the 50"-52" area and the canopies have generally been operated in the near full-up (38"-49") position. The loader canopy is well liked by the operator and it is believed that the safety protection afforded the operator has enabled him to devote more attention to the loading operation. The loader canopy contacts the rib frequently and has sustained damage to the height adjust hydraulic cylinder piston rods and the mechanical stops.

Hydraulically powered canopy height adjustment was not found to be mandatory for the loader, face drill, and cutter in the particular installations demonstrated. It should be noted that the higher mining heights and good bottom conditions prevailing in the No. 12 mine did not provide the opportunity for a full assessment of the worth of the hydraulic adjust system.

The standard and off-standard shuttle car canopies and the roof bolter canopy were installed in the Jewell Ridge Coal Company's Big Creek Tiller Mine. These installations are shown in figures 14 and 15.

Shuttle car operators found visibility to be adversely affected, particularly in the off-standard car. The standard shuttle car canopy installation was also tested in No. 12 mine and the observation was common to machine operators as well as mine management personnel. The same feeling existed even with with canopies in the full 40-inch up position. Apparently, the tunnel effect of the long canopy top overhead caused a real visual obstruction as well as perhaps a psychological one. As a result of this objection, testing was terminated after approximately one week of accumulated test time.

The roof drill canopy installation seriously affected the tramming capability of the machine. This resulted from the sizeable amount of added weight (750 lbs) necessary for the canopy flexible flooring and the support structure. The floor material selected for good durability was found to be so inflexible that the floor tended to "plow" the mine bottom rather than float over it. Because of this, testing was terminated after about a week of evaluation. The concept of a flooring that the operator can ride on at the front of the machine was received favorably by the roof drill operator.

The principal documentation of this program is contained in a USBM contract Final Report (Contract No. H0220031) which contains drawings as well as photos and narration covering the entire program work. Another information and detailed document that was generated is the Installation and Maintenance Manual for each of the five canopy installations.

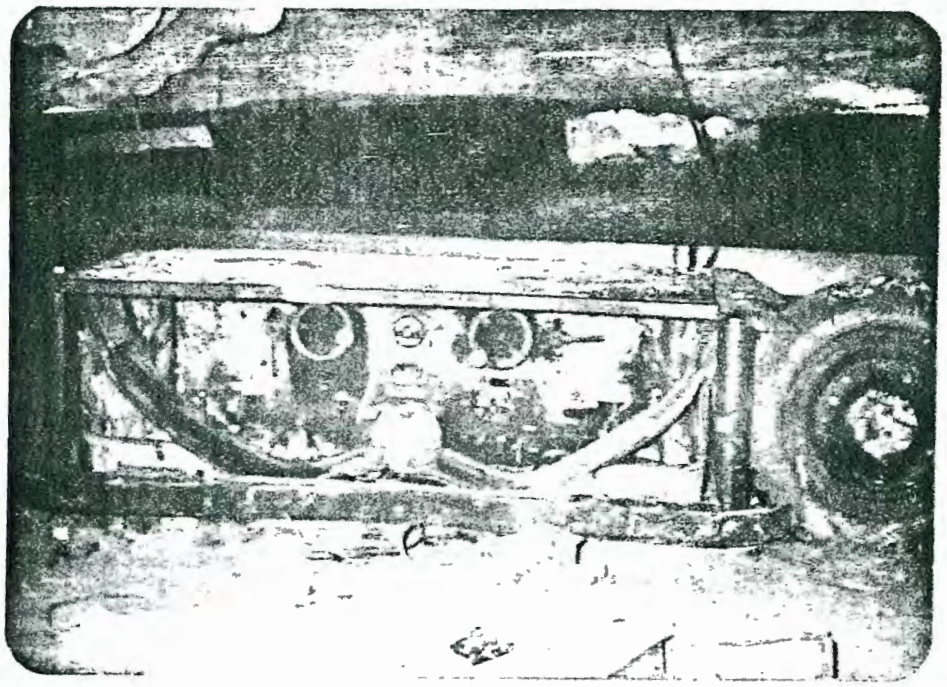


Figure 14. Shuttle Car Canopy Installation (32-Inch Height Position)

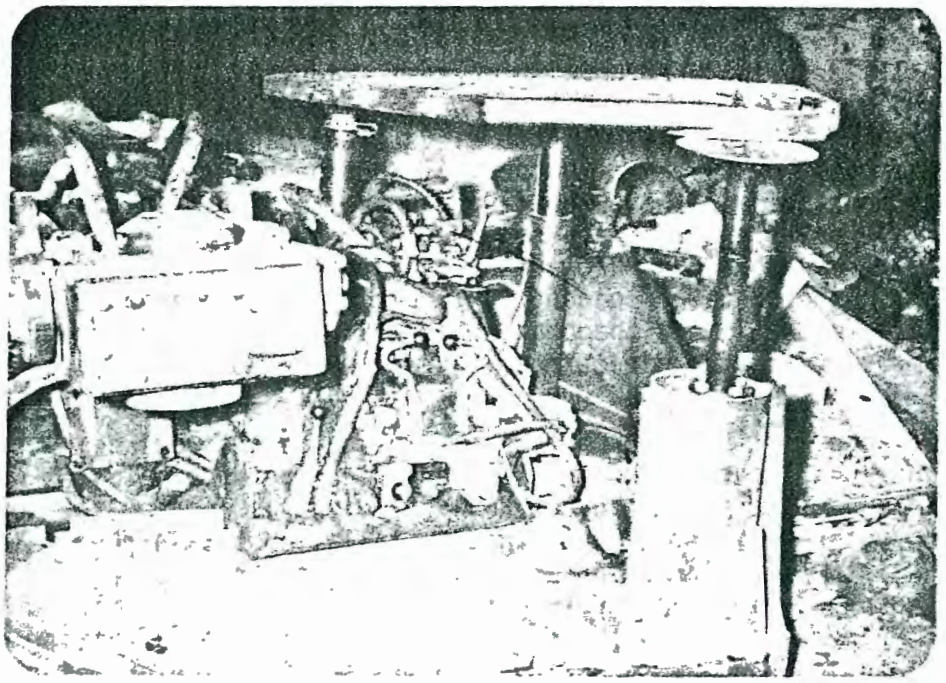


Figure 15. Flexible Floor Pan Installed on Roof Drill

B. "Follow-On Canopy Modifications," Contract H0242028.

The in-mine evaluations pointed out areas that needed improvement. In principal these were: 1) improve visibility for the shuttle car operator, 2) make loader canopy top supports stronger, 3) reduce the canopy effect on roof drill tramming, and 4) seat concept evaluation.

The following canopy design changes were proposed:

Shuttle Car Canopy: The shuttle car operator objected to visual limitations even when the canopy was raised to 40 inches on this 28" basic frame height car. The following refinements were proposed:

1) Contouring the canopy top to lower the center section below the operator's line-of-sight.
2) Contour canopy structure around the operator's head and shoulder areas and place structure openings close to operator's eyes, so as to improve field of vision.
3) Incorporate independent height adjust system on each end of the canopy to permit the unoccupied canopy half to be lowered out of operator's line-of-sight.

A wood mockup of the new canopy configuration was fabricated and taken to a mine for evaluation. The photograph in figure 16 shows the mockups installed on the shuttle car. This was a static test and the operator sat in the pit and judged the degree of visual improvement obtained, suggested further changes, and indicated whether or not he thought sufficient promise existed to warrant going ahead with fabrication. The result of this mockup evaluation was favorable and the hardware has just been completed and subjected to laboratory load testing. As noted in figure 16, the canopy is cantilevered over the operator's head from two support posts behind the operator's back. These posts are attached to the pit and wheel fender structure. The center portion of the canopy is a fixed plate mounted just above the operator's legs. Each end of the canopy is hydraulically adjustable between an overall height of 32" and 47". The support posts are nominally 4" square tubes that telescope. A hydraulic actuator is mounted within each post assembly to elevate the canopy. Side loads are taken by the posts and not by the actuator. It is expected that for maximum visibility the operator will have the canopy opposite of him in the lowest position and will reverse this situation when he reverses position within the pit. Figure 17 shows the actual hardware undergoing a vertical load test of 9,000 lbs, which is the required loading for a canopy of this area. The top structure is A36 plate welded into a "pagoda" shape which adds to the strength and also helps to protect against direct roof contact.

Roof Drill Canopy: The major proposed revision to the roof drill canopy installation was a lighter and more flexible flooring material. It was believed that this would tend to ride over the mine bottom as opposed to the "bulldozing" action encountered with the more rigid installation obtained with the heavy 15/16" belting material. In order to verify that the flooring was the major factor causing "dozing" and tram degradation, a test was run in No. 12 mine with the canopy installed without the flooring material. Tramming was observed to be satisfactory and work continued to install the lighter weight flooring material along with a revised floor attachment arrangement calculated to avoid

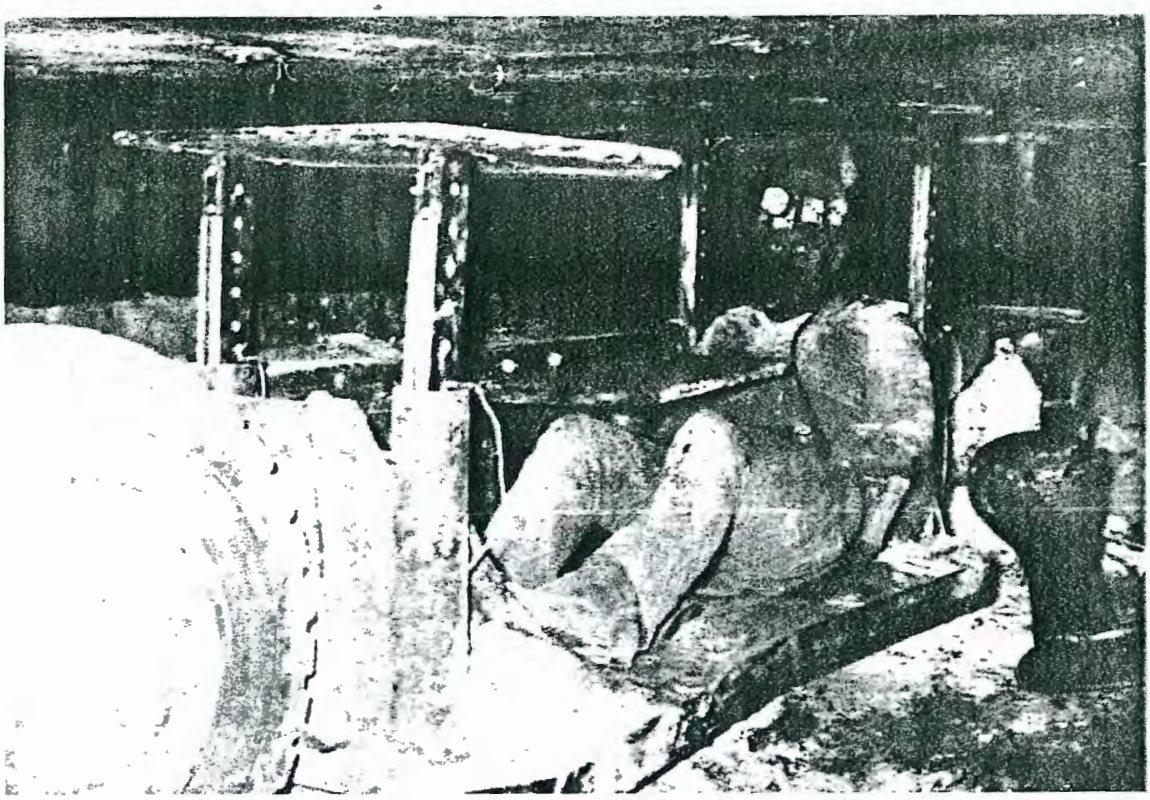


Figure 16. Shuttle Car Canopy Mockup In-Mine Evaluation

Figure 17. Load Test - Shuttle Car Canopy

sharp corners and minimize any rigidizing effect due to fitting the floor within the support frame.

The new floor arrangement was placed in operation in the latter part of March 1974 without the canopy top. The operator has continued to use the machine, riding in the flooring as shown in figure 18.

The mine reports that this is working well and that the operator is satisfied with both machine tramming and the capability to ride on the machine. The complete canopy is being reinstalled with several modifications. The two aft cylinders are being removed and replaced with telescoping tubing that can be pinned at various heights ranging from 38" to 48".

The hydraulic safety jack at the front of the machine is being retained. This installation has been revised with a spacer arrangement to give the jack added reach in the No. 12 mine where the mining height exceeds the stroke capability of the original design.

Loader Canopy: The loader canopy top was supported only by the piston rods of the four hydraulic actuators that raised and lowered the overall height. These rods, while of substantial diameter, would not withstand the impact loads resulting from impacts with the rib. It was proposed to replace the hydraulic adjust arrangement with a telescoping and pinned tube assembly, manually adjustable to heights between 38" and 48".

The manual system is considered to be all that is required in the No. 12 mine and the necessity of the hydraulic system does not appear to be evident. This modification is currently being made in the mine.

Seat Evaluation: In addition to the canopy modification discussed above, the USBM requested an evaluation of an operator's seat concept developed for the USBM by another contractor. Seat mockups furnished by the USBM were taken to the mine along with the wood canopy mockup discussed previously. Machine Operator's commente favorably and work was authorized to modify the seat design slightly in accordance with operator comments and to acquire seats and mounting brackets for trial installation and evaluation in the 21SC shuttle car. Figure 19 shows this seat in the 21SC mockup at Bendix. These seats are currently being installed in the mine for evaluation.

C. "Refined Design of Protective Canopies for Shuttle Cars, Loaders, and Cutters," Contract H0242065

In the course of the canopy work done to date, a number of further refinement areas have been identified for consideration. A number of these suggestions have been approved and effort has just been initiated on the program. The refined design effort is directed toward the shuttle car, loader, and cutter canopies and involves the following:

Shuttle Car:

1) Develop a concept and construct a breadboard of an easily adjustable stop for canopy height which will enable the operator to readily return the canopy to an optimized height (just clearing the lowest

Figure 18. Preparing to Drill with Flex Floor in Place

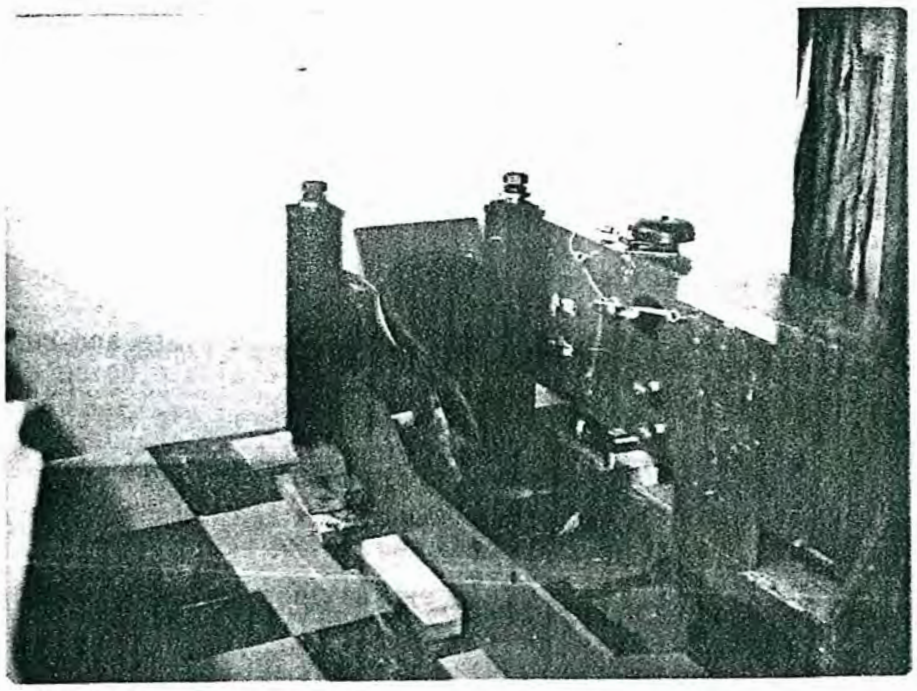


Figure 19. Standardized Operator Seat in 21SC Shuttle Car Mockup

point in the tram path) after having adjusted the canopy to maximum height at the loading and discharge ends of the path.

2) Equip the second (off-standard) shuttle car in the test mine section with the revised canopy design.

3) Revise the swing down protection bars and the rock guards to be compatible with this new canopy design.

Loading Machine:

1) Install a small cable take-up reel to handle the trailing cable when the loading machine is loading. The canopy installation makes it more difficult for the operator to tend the cable himself.

2) Evaluate the flexible belt flooring in the loader canopy.

3) Revise current canopy top to partial solid plate and remove expanded metal mesh. Install soundproofing and evaluate noise control in solid plate area.

4) Redesign rock guards to be compatible with new canopy design.

Cutting Machine:

1) Extend canopy height to gain evaluation of roof sensor in No. 12 mine.

2) Modify canopy top to solid plate.

3) Remove right hand canopy.

D. "Survey on Protective Canopy Design," Contract H0242020

Survey Objectives: As underground coal mining electric face equipment with canopies began to be used underground in compliance with Federal Regulations, operational problems were encountered which adversely affected acceptance of canopies in the mines. The general objective of the survey was to find out what kind of canopies were being used, what the operational problems were, and what could be done to secure improvements. More specifically, survey objectives were to:

1) Survey state-of-the-art in canopy design.

2) Establish minimum canopy dimensions (length, width, and height) for safe operation.

3) Identify new canopy designs and concepts.

4) Secure inventory of existing coal mine electric face equipment.

In the course of carrying out the survey the following work was performed:

a) All electric face equipment manufacturers (eighteen) were personally visited.

b) Eleven coal mines (seam height 60 inches and greater) were visited.

c) Current production canopy configurations and minimum mine entry dimensions for each model and type of electric face equipment were identified.

d) In-mine operation and usage problems encountered with canopies developed by manufacturers and/or coal companies were examined.

e) Recommendations for optimal canopy configuration and minimum mine entry dimensions for each type and model of electric face equipment were established.

Factors to be Considered in Canopy Design:

The survey did identify many of the problems and objections being encountered in canopy usage and a number of factors to be considered in canopy design were defined. Listed below are several of the major factors identified and a number of design guidelines suggested to improve the problem areas.

1) Operator Vision: This must receive careful attention and be improved with design approaches such as:

a) Use minimum number of support posts; consider cantilever suspension of canopy top, consider tapered posts.

b) Minimize structural members (tops and posts) dimensions through use of high strength materials.

c) Optimize support post placement to favor required visual paths.

d) Arrange canopy top members to give maximum height above operator's head.

e) Eliminate unnecessary canopy overhang and minimize need for operator to look long distances underneath a canopy, i.e., the shuttle car operator has to look under an unused portion of the canopy at the opposite end of the pit.

2) Entrapment by Canopy: The possibility of trapping the operator in the canopy must be avoided. Use design guidelines such as:

a) Avoid design that will trap operator by reason of machine location within entry, e.g., against rib.

b) Provide two ways out of canopy.

c) Consider rapid egress.

d) Consider hand holds and aids for getting in and out.

e) Consider partial dismantling of structure to get out.

3) Operator Comfort: The comfort of the operator must be considered. Design guidelines such as the following are suggested:

a) Prevent coal dust, etc., from falling through canopy top onto operator's neck.

b) Eliminate interior reflections from cap lamp.

c) Consider sound proofing interior.

d) Consider insulation and padding on structure that comes in contact with operator's body.

e) Minimize chance for operator bumping his hard hat against canopy top.

1) Maximum head clearance

2) Space canopy structural beams to clear head.

3) Consider use of shock mounted seat.

4) New Canopy Concepts Suggested by Survey Results: In response to the many suggestions, comments, and complaints received about canopy installations during the course of the survey, a number of canopy concepts have been generated which are believed to give improvement in the problem areas. Shown below are several which address the visual problem on a shuttle car canopy installation.

In figure 20 is shown a typical canopy installation on a shuttle car. The chief complaint was vision, particularly while at the face and loading with the off-standard car. Figure 21 shows a three post suspended flat plate canopy. Placement of the single inboard post as shown eliminates the two inboard corner posts and removes items that obstruct operator vision in this normal field-of-view. Figures 22 and 23 show two versions of a cantilevered canopy concept which eliminates two support posts in what are believed to be the more important view fields. In figure 22, posts have been eliminated such that visual obstruction is minimized when the operator is going to the face. When hauling out, it is believed that the operator, being on the front end of the car, can tolerate some canopy support structure, thus the support structure location was selected as shown. In figure 23, the two inboard support posts have been eliminated and the canopy is cantilevered off the outboard structure of the pit.

In figure 24, a more complicated concept is shown wherein an attempt was made to remove as much structure as possible from the operator field of view. Each end of the canopy is adjusted hydraulically and is independently controlle The portion of the canopy in front of the operator's eyes can be lowered still providing protection for the leg area.

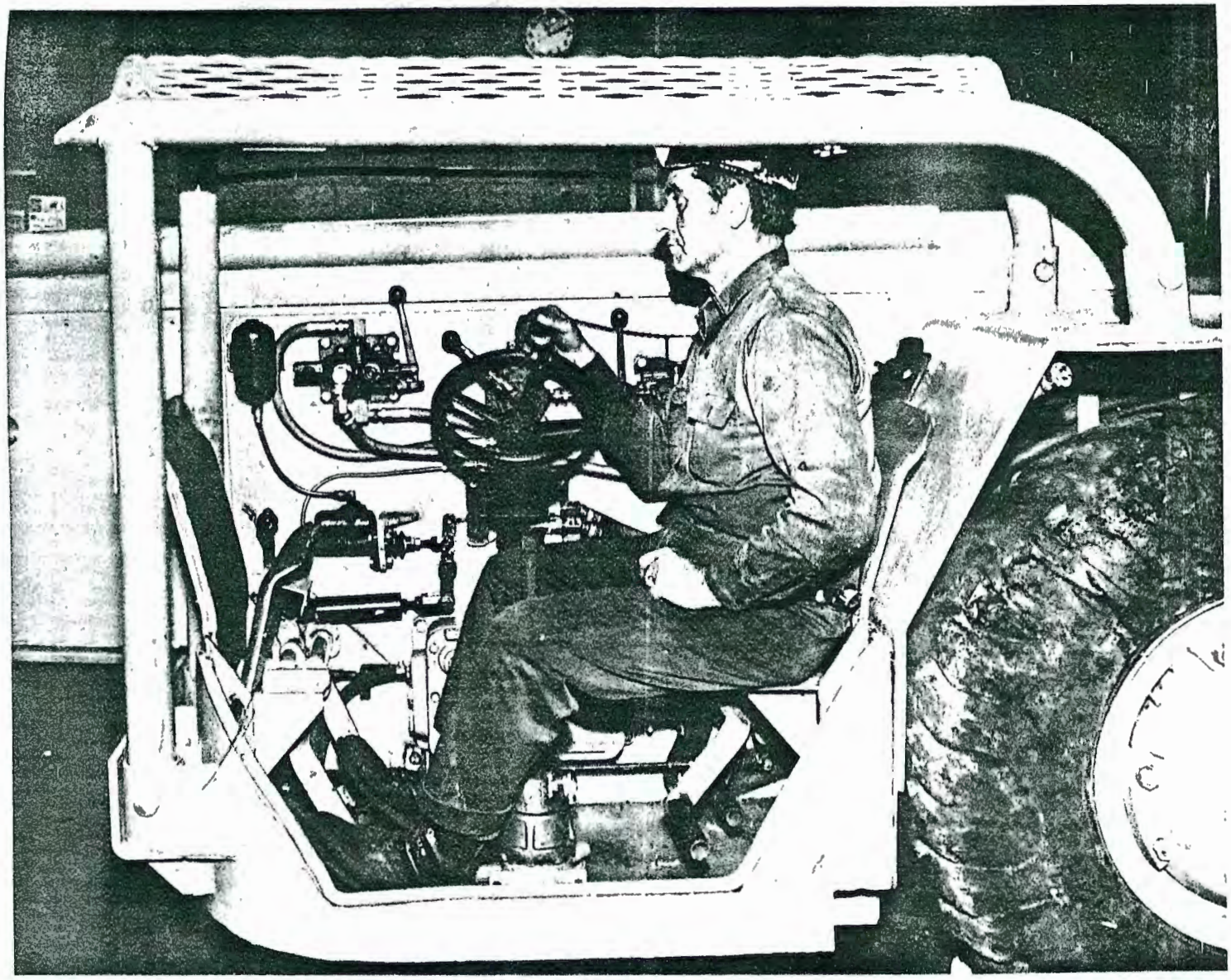


Figure 20. Typical Canopy Installation on Shuttle Car

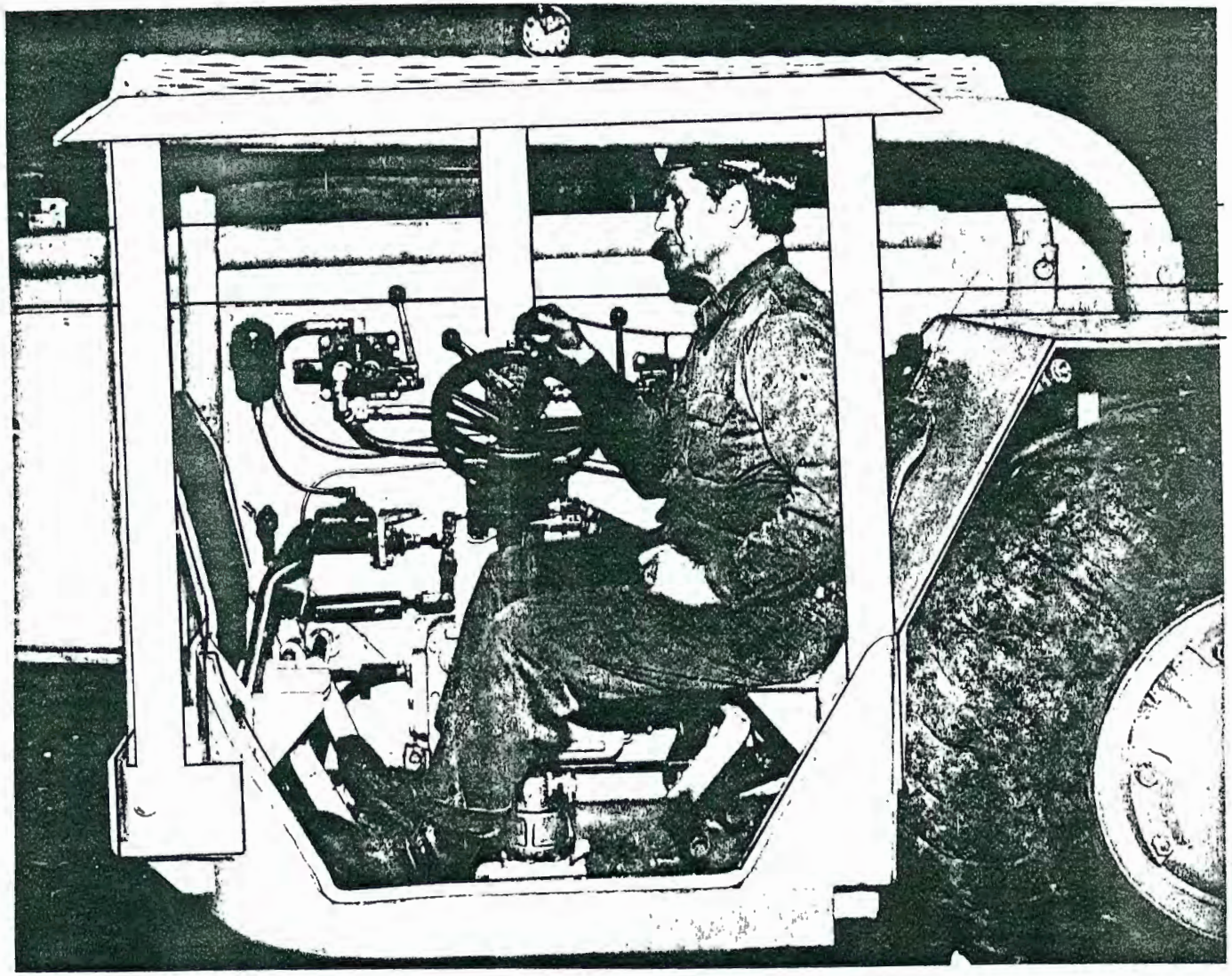


Figure 21. Vision Improvement Using Three-Post Suspension of Canopy

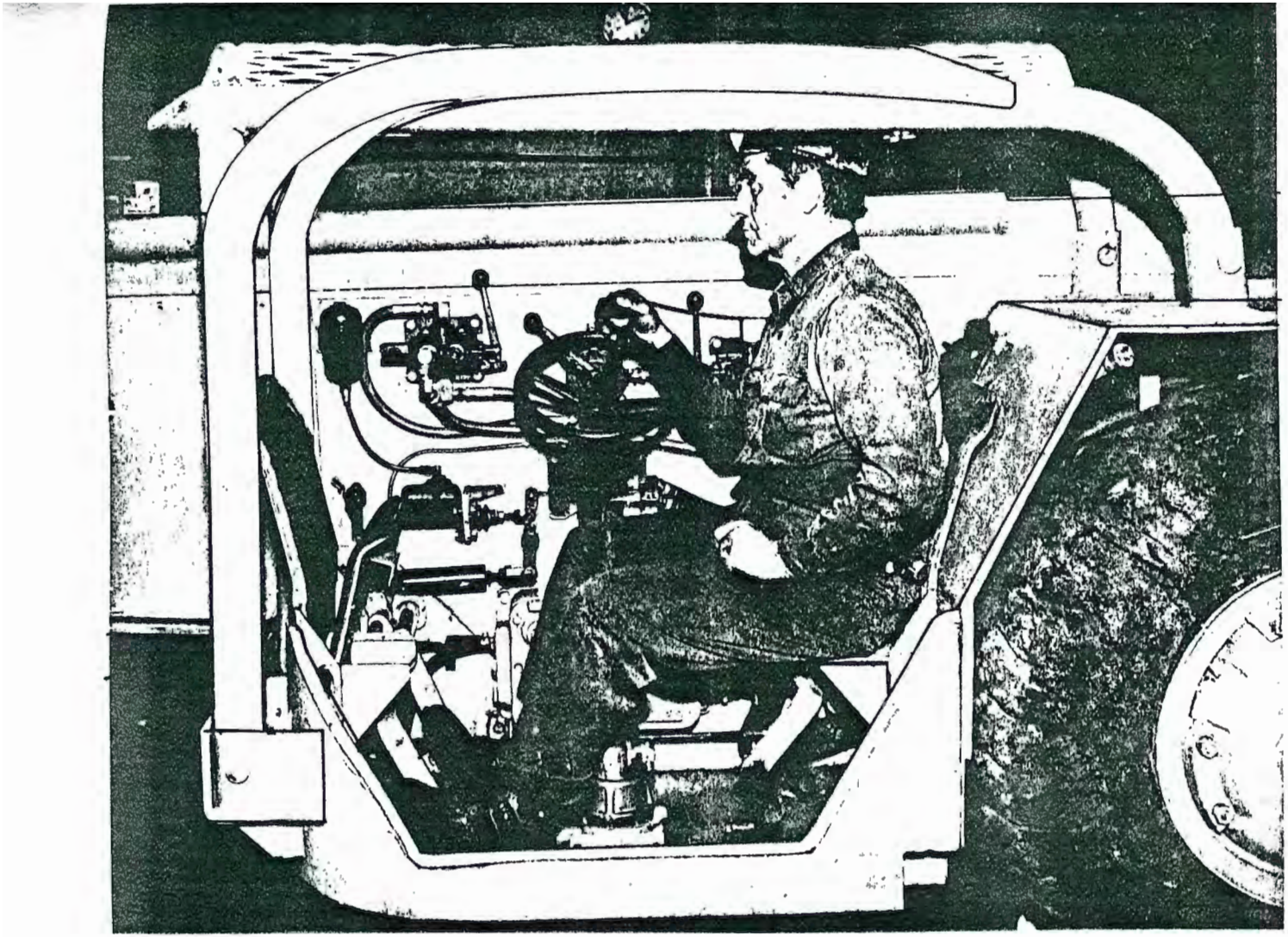


Figure 22. Cantilevered Canopy for Shuttle Car

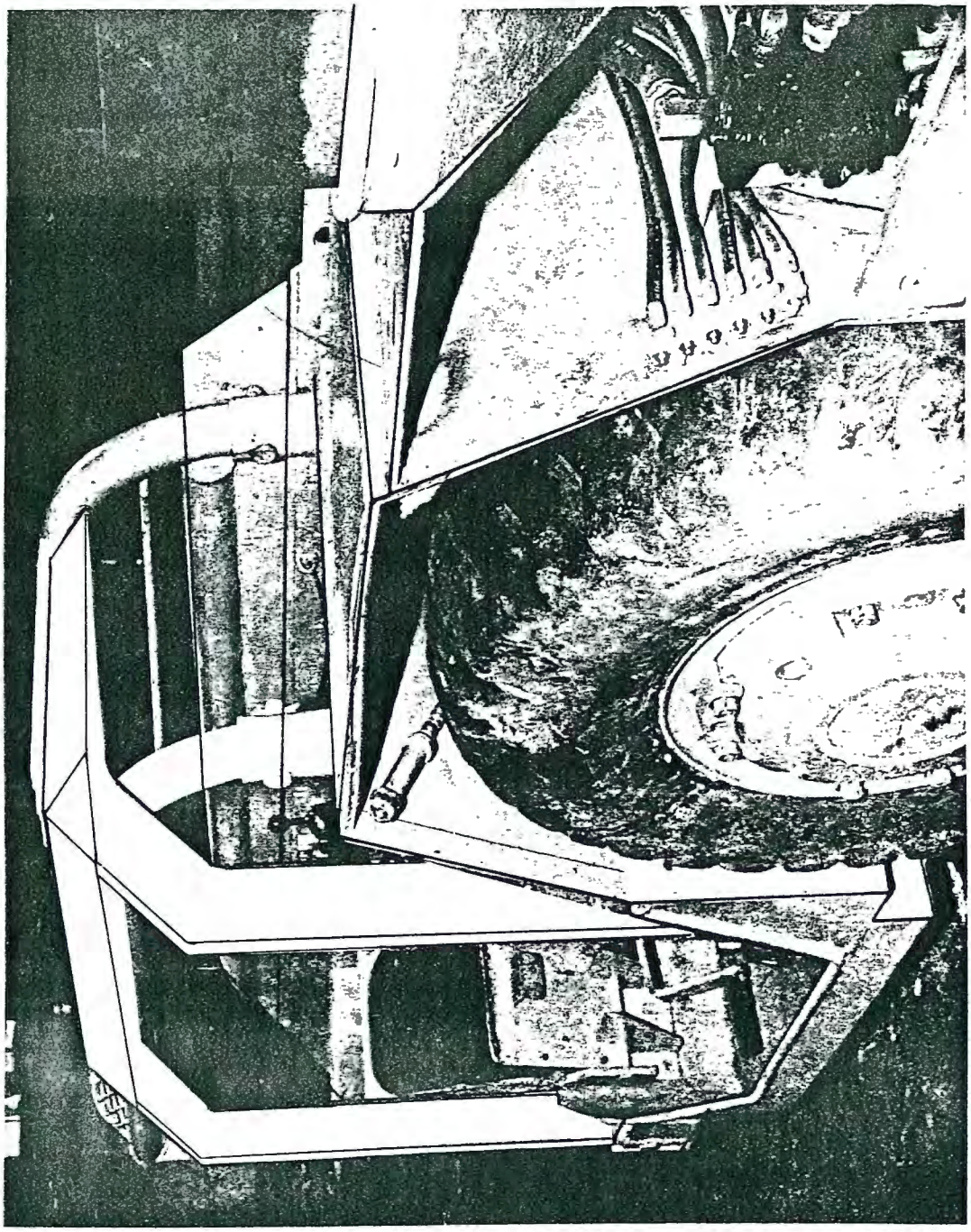


Figure 23. Typical Canopy Installation on Shuttle Car

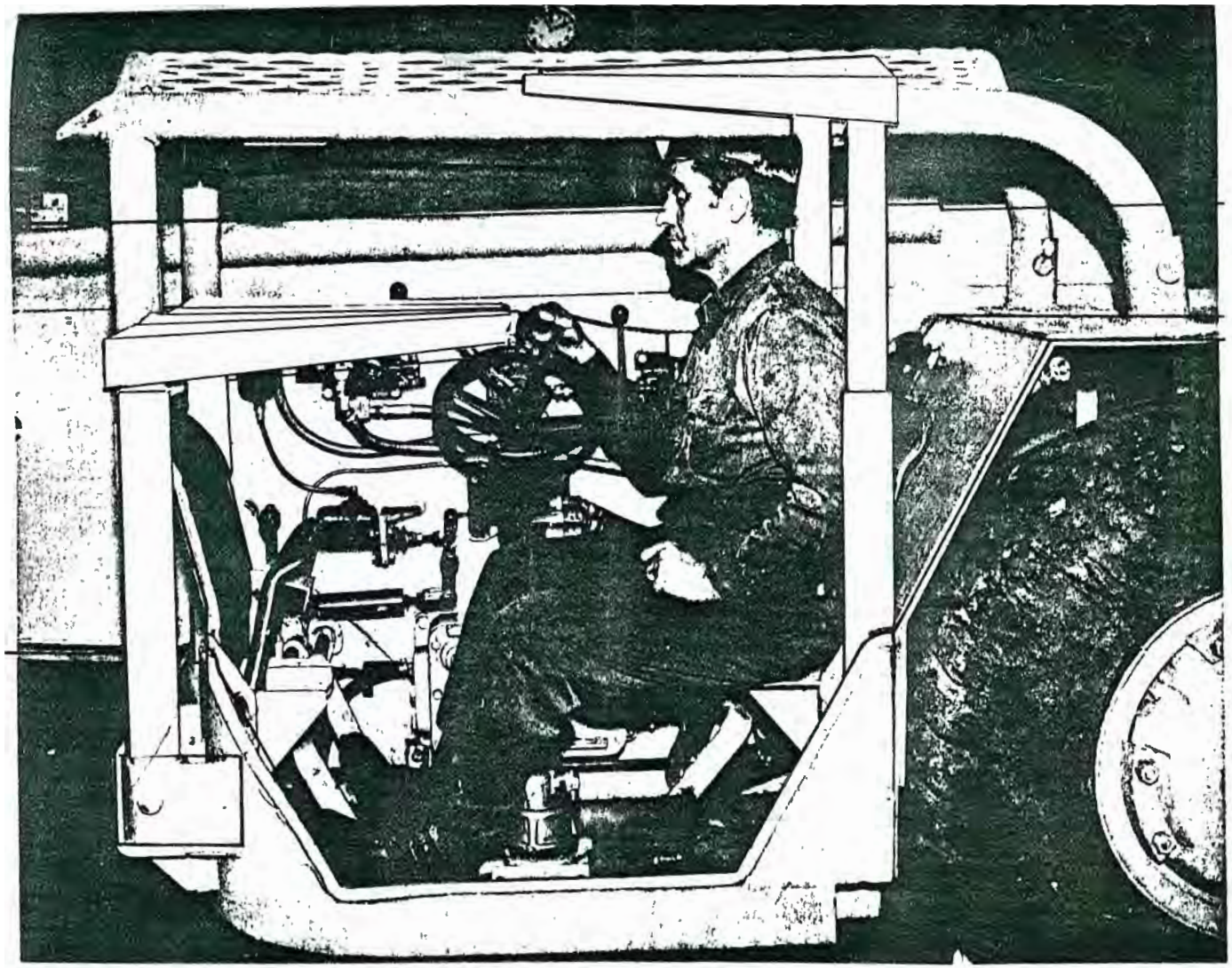


Figure 24. Shuttle Car Two-Piece Canopy (Hydraulically Operated)

In the course of conducting the survey, a number of canopy design innovations were noted which the equipment manufacturers and the mine operators have employed in an effort to improve installations. Among these are:

1) Cutouts and hinged shuttle car sideboards.

2) Thinned structure, better post placement, and canopy top cutouts.

3) Tailoring and shaping of canopy tops in order to minimize collision and damage potential.

4) Hydraulic height adjust of entire operator compartment.

5) Canopy shock absorbing mount.

6) Damped spring seat system.

7) Hinged operator compartment.

E. "Study of Low Coal Canopy Concepts," Contract H0346102

A canopy research and development program has just been initiated which is directed toward face equipment operating in seam heights ≤36". The Bureau of of Mines has undertaken this program in order to provide the mine operator with the technology necessary to implement canopies in this height coal and to help them meet the January 1976 incorporation deadline for equipment working in this seam height range. Canopy designs will be developed for four machines, 1) Wilcox Auger Miner Mark 20 PJ, 2) Wilcox Compact Roof Bolter, 3) Elkhorn AR-4 scoop, and 4) Lee-Norse 245L Continuous Miner. Wood mockups of the canopies will be constructed and they will be taken to a number of mines and placed on the machines for a static human factors evaluation by the machine operator. The designs will then be refined as required in accordance with comments and suggestions received. This particular contract will end with completion of the canopy drawings.

Canopy concepts for the four machines were proposed in the course of establishing the development contract. These concepts are depicted in Figure 25. A brief description of each follows:

Wilcox Mark 20PJ Auger Miner: The baseline canopy concept, shown in greater detail in figure 26 is mounted on a pallet surrounding the operator's compartment. The pallet is in the shape of a "J" which surrounds the pivot jack and runs along the outside of the operator's platform. Roof fall loads are reacted from the canopy through the three vertically adjustable support posts to the pallet and finally onto the mine floor. The substantial area of the pallet insures floor loading will be kept to low pressure values. Additionally, the center of gravity of the canopy top is within the pallet projected outline and insures the canopy will not tip.

During machine maneuvers, the pallet is dragged along the floor by the machine. The pallet is attached, at its forward end, to the machine by a multi-degree of freedom joint. The joint accommodates relative vertical and pitching motions between the machine and the pallet. In use, the canopy would be raised to be in close proximity with the roof. The presence of the canopy would only slightly reduce the operator's head clearance.

Wilcox Roof Bolter: The baseline canopy concept shown in figure 27 provides operator protection during the bolting operation and during tramming. To meet both requirements and keep the size of the canopy small and compatible with the machine size, the canopy is designed as a two- or three-position assembly. The canopy is pivoted to swing in the horizontal plane and is cantilevered from a second roof support jack located at the pivot axis of the canopy. In addition to offering additional roof support, the jack also moves the canopy vertically. In its extended position, in contact with the roof and floor, the canopy is at a position to provide the maximum operator work height. At a retracted position, operator work height is slightly reduced for tramming. In its extended position, the jack absorbs roof fall loads which are transmitted to the mine floor rather than the machine. In the event a roof fall occurs during tramming, it is likely the light weight machine will tip or the tires will blow. In either case, the canopy will experience limited downward motion.

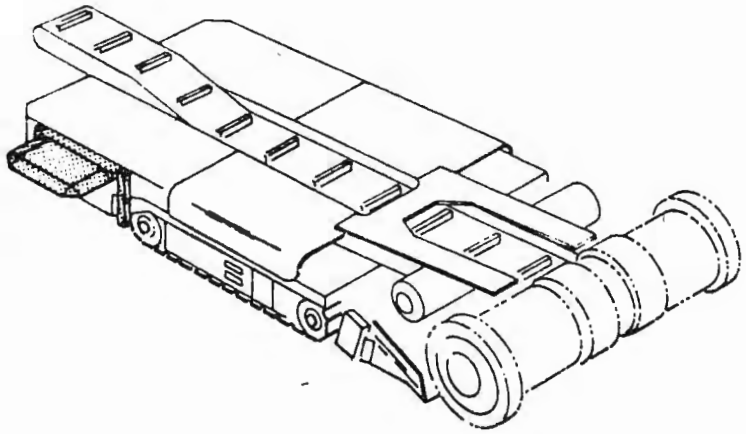
Lee-Norse 245L Miner: The Lee-Norse Miner is a remotely operated machine. It is equipped, however, with secondary frame mounted controls to the rear and on the side of the machine. Inasmuch as the machine can be operated from this position alongside of the frame, a canopy is proposed to protect this area.

Since the machine is designed to be remotely operated from a position to the rear of the machine, it is desirable that the canopy not impair the vision of the operator. To meet this end. the baseline canopy design is hinged to rise vertically. In its down position, the canopy is flat against the side of the machine and covers the controls of the operator's station. The effect on operator's vision is negligible when the machine is remotely operated. To utilize the controls of the secondary station, the operator must raise the canopy to its proper position. The operator is therefore insured of protection when he gains access to the controls.

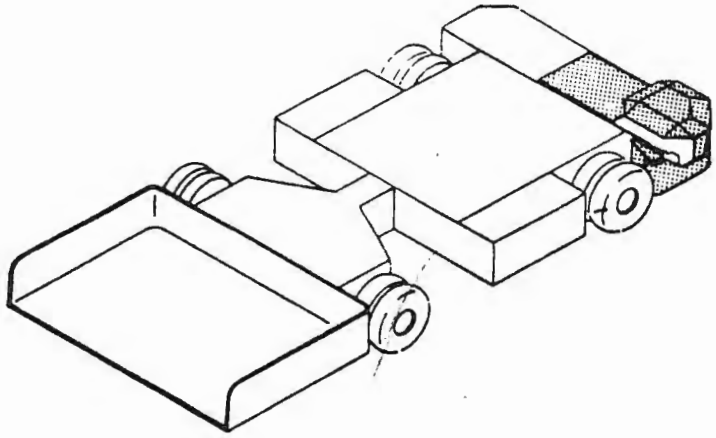
The configuration of the baseline concept is shown in figure 28. The canopy is basically rectangular and is adequate to afford the operator protection. In its stowed position, the canopy lies below the height outline of the machine. In its deployed position, the canopy would be above machine height to offer the operator the maximum envelope for the seam thickness. A multi-bar linkage is employed to achieve the height increase. Further study will indicate whether it is feasible to achieve an adjustable height or a fixed height somewhat above the machine for the deployed position.

In the baseline concept, the canopy is supported in its deployed position by a two member support linkage. In operation, the canopy is raised and the linkage automatically locks. To stow the canopy, the support linkage is manually unlocked by depressing a buttom or lever to release the canopy. Since the canopy will be relatively massive and therefore heavy, the canopy will be counterbalanced to facilitate deployment and stowage.

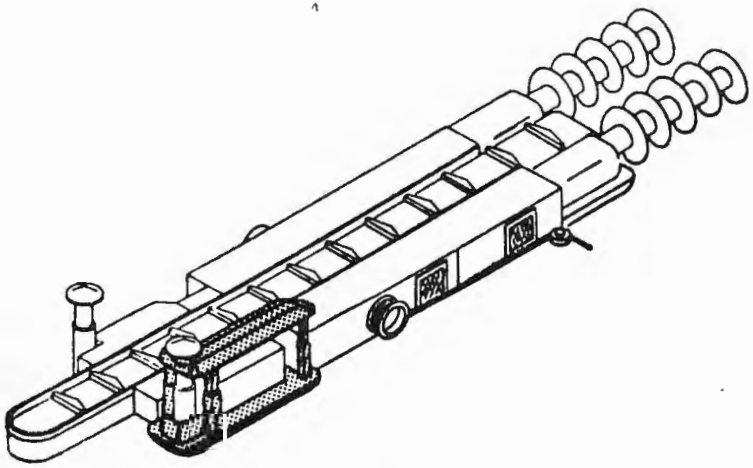
Elkhorn AR-4 Scoop: The baseline concept, figure 29, consists of two separate canopy sections: a moveable section and a fixed section. The moveable section is vertically adjustable and has swing out capability. The fixed section remains stationary and, for the baseline concept, has no vertical adjustment. With the moveable section in its lowest vertical position neither canopy extends above the machine. In the lowest position operator visibility is obviously impaired and operator entry into the compartment is difficult. The baseline canopy is configured with overhang to protect the operator when he leans out. To afford easier entry into the compartment, the moveable canopy section is a hinged structure. This canopy section and supporting structure moves as a unit to provide



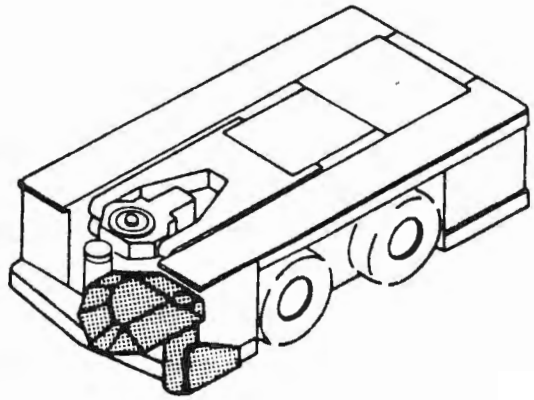
PROPOSED CANOPY FOR LEE-NORSE
CM 245 CONTINUOUS MINER



PROPOSED CANOPY FOR
ELKHORN AR-4 SCOOP



PROPOSED CANOPY FOR
WILCOX MARK 20PJ AUGER MACHINE



PROPOSED CANOPY FOR
WILCOX ROOF BOLTER

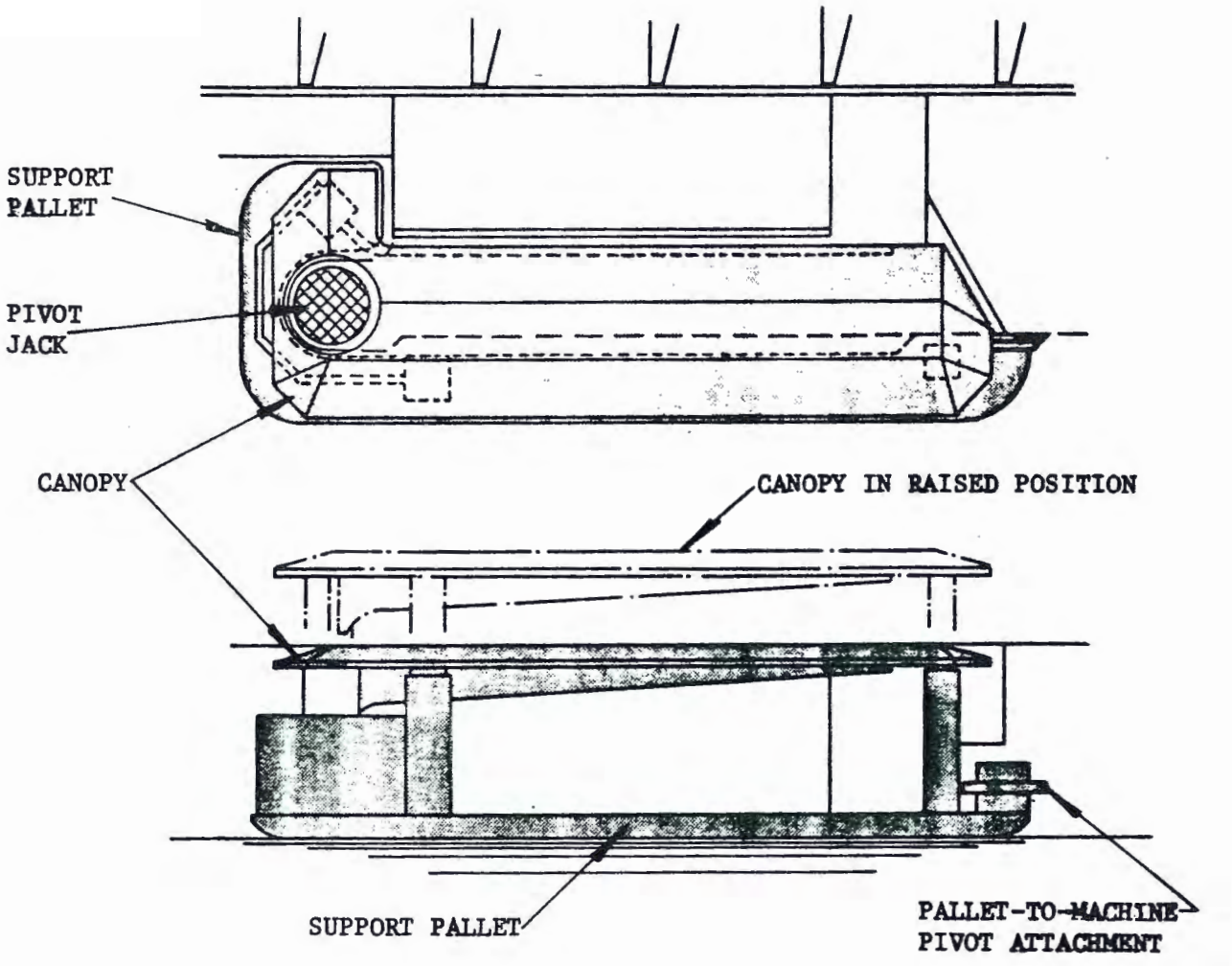


Figure 26. Canopy Concept for Wilcox Mark 20PJ Auger Miner

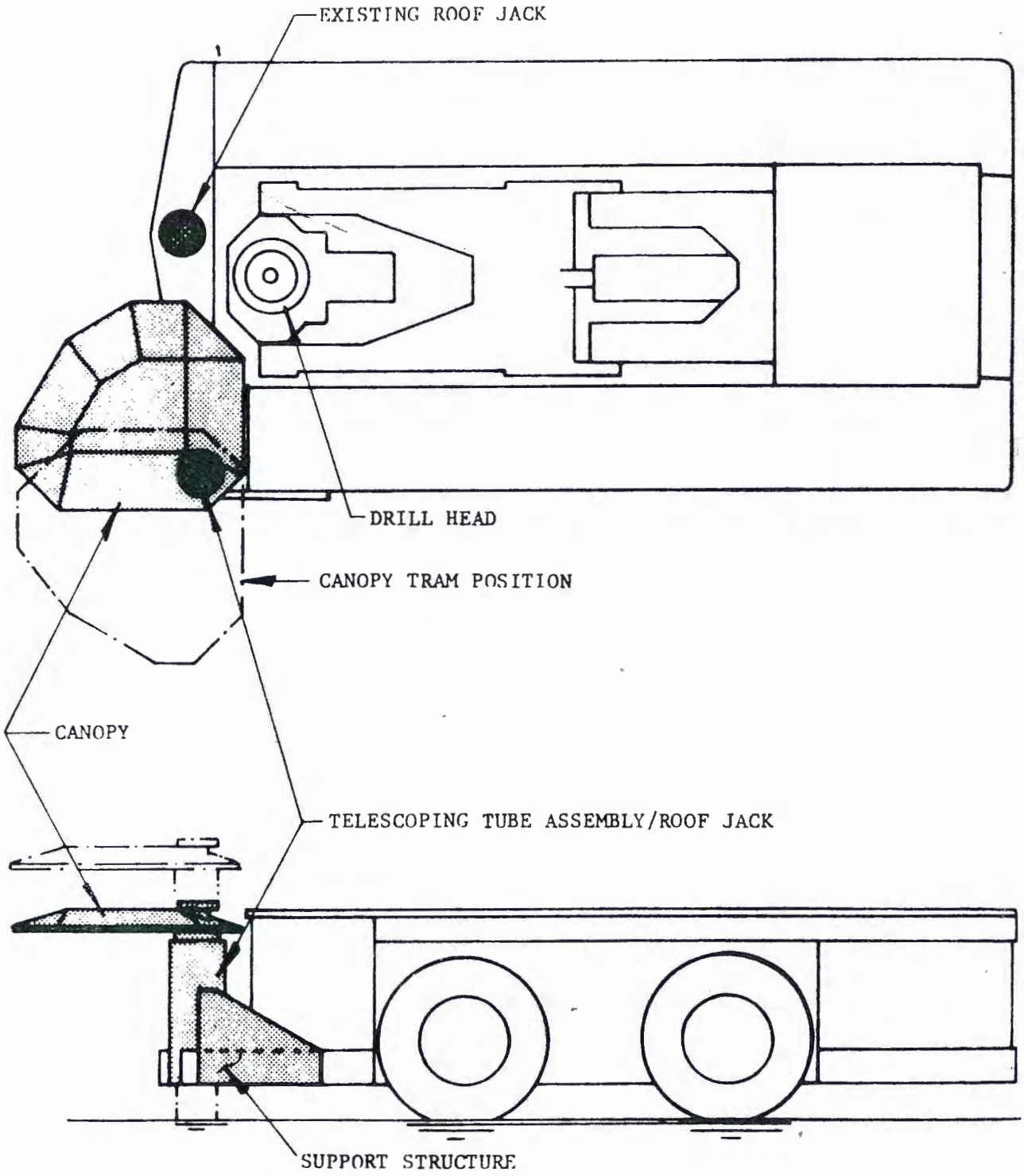


Figure 27. Canopy Concept for Wilcox Roof Bolter

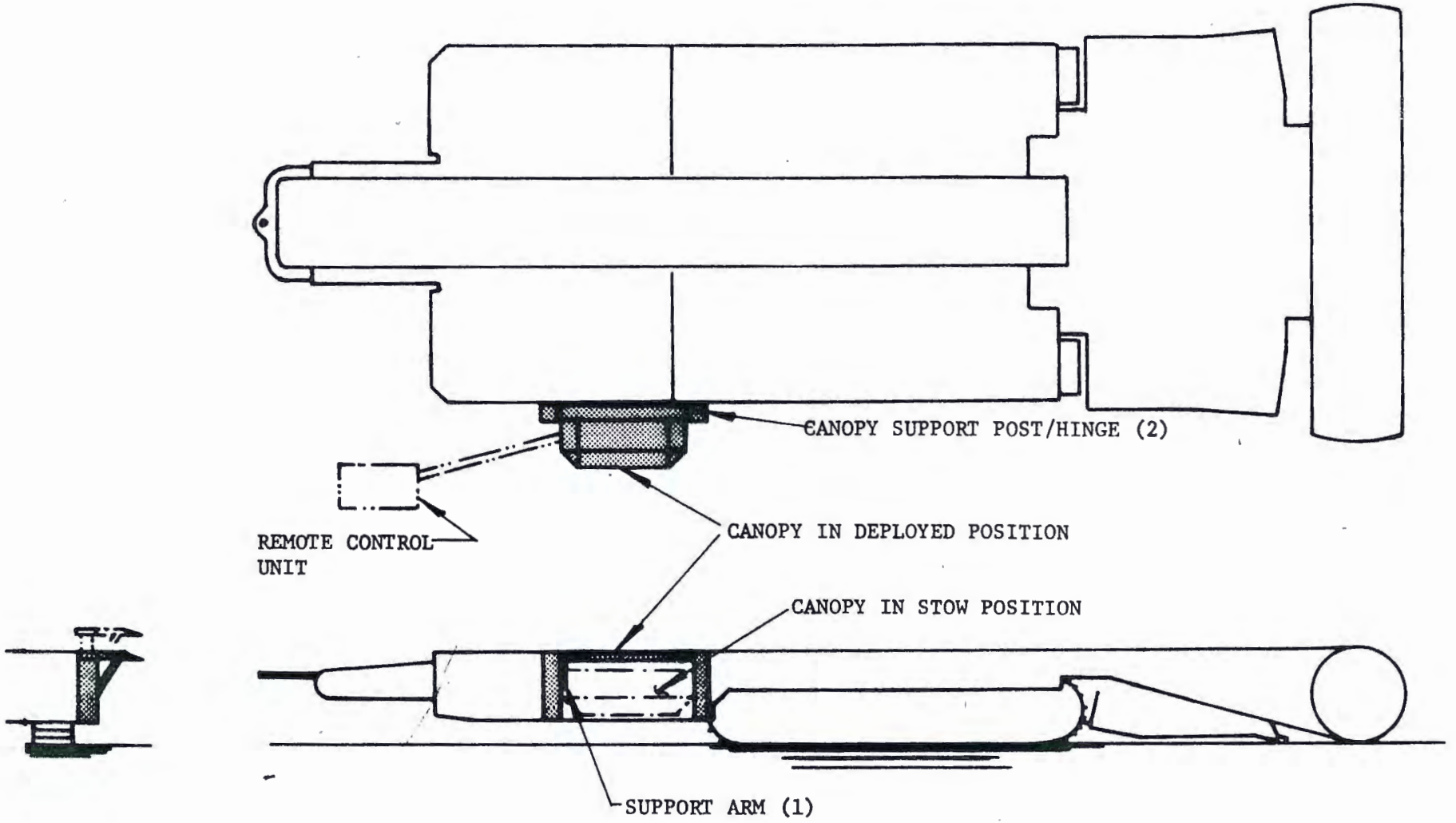


Figure 28. Canopy Concept for Lee-Norse Miner

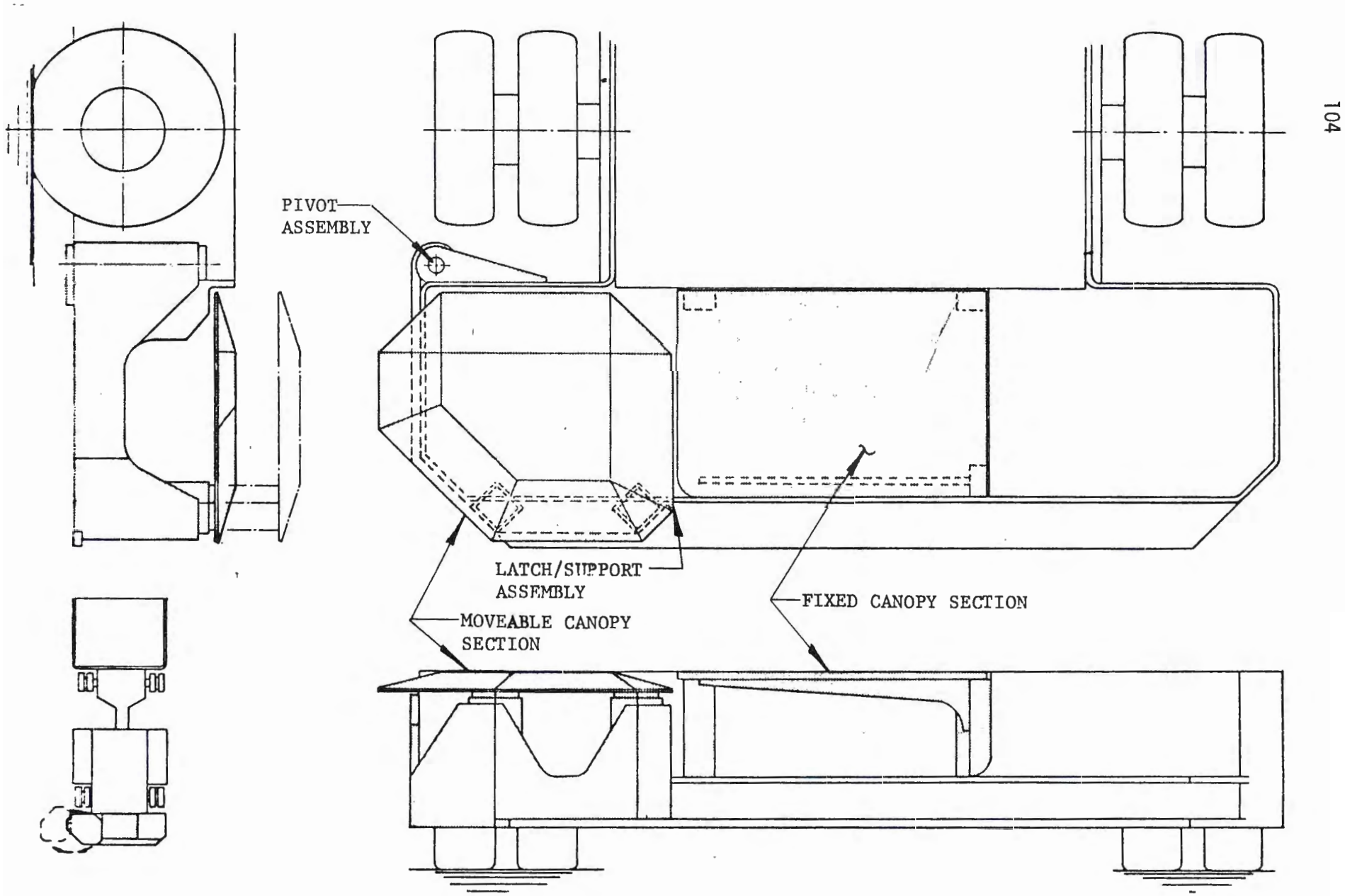


Figure 29. Canopy Concept for Elkhorn Scoop

an adequate opening for entry. The supporting structure also is used to afford the operator protection against rear and side collisions. The moveable canopy section and the adjacent rear and side areas are completely open to provide adequate entry space for the operator's head and upper body. A fixed canopy section provides an adequate opening for the operator to swing in his legs and lower body.

PROCEEDINGS
OF
THE FIFTH ANNUAL INSTITUTE
ON
COAL MINING HEALTH, SAFETY AND RESEARCH

Center for Continuing Education
Virginia Polytechnic Institute & State University
Blacksburg, Virginia 24061

August 27-29, 1974

Co-Sponsored By:

Minerals Engineering Division
Virginia Polytechnic Institute & State University

and

Coal Mine Health and Safety
Mining Enforcement and Safety Administration
U. S. Department of the Interior
Washington, D. C. 20240

Compiled By:

T. Carl Shelton, Jr.
Associate Professor of Mining Engineering and
Director of Office of Occupational Health and Safety
Virginia Polytechnic Institute & State University
Blacksburg, Virginia 24061