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IMPROVED VISIBILITY SYSTEMS FOR LARGE HAULAGE VEHICLES

VOLUME II

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16. Abstract (Limit: 200 words)

The objective of this project was to improve a driver's field of view for large trucks used in the mining industry. Rearward viewing was enhanced by improving the rear-view mirror designs. Rear vision was accomplished using a closed circuit television system. Views ahead, to the right, and downward were obtained with a blind area viewer (BAV). The BAV is a unique combination of fresnel lenses housed in a shielded, environmentally protected enclosure that produces an image of the area in front of and downward 70° and to either side of the BAV 30°. The improved visibility devices were evaluated by long-term, in-mine testing. The right side mirror (RSM) and BAV provide the greatest improvements for the least cost and are commercially available. Application of the RSM and BAV should achieve a reduction in accident potential and greater vehicle productivity by enlarging and improving the equipment operator's visibility and making priviously blind areas and hazardous situations detectable.

17. Document Analysis a. Descriptors

Mining

Haulage trucks	Open pit	Mirrors
Wheel loaders	Surface mints	Fresnel lens
Front-end loaders	Quarries	Closed circuit television system

b. Identifiers/Open-Ended Terms

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Visibility	Productivity
Blind area	Safety
Field of view	Accident avoidance

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FOREWORD

This report was prepared by Tracor MBA (formerly MBAssociates) of California, under USBM Contract H0262022. The contract was initiated under the Federal Coal Mines Health & Safety Program. It was administered under the technical direction of Twin Cities Mining Research Center with Mr. Guy A. Johnson as Technical Project Officer. Mr. R. J. Simonich was the contract administrator for the Bureau of Mines. This report, Volume II, is a summary of the work recently completed as a part of this contract during the period May 1978 to January 1981 and was submitted by the authors on 29 January, 1982.

Volume I of this report was submitted on April 30, 1978 and covered the period of this system's development and initial in-mine, on-vehicle testing, June 1976 to April 1978.

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EXECUTIVE SUMMARY

Large rear dump haulage trucks used in surface mining operations have a severe problem with restricted driver visibility (or field-of-view). The driver cannot directly see large areas adjacent to his haulage truck. These blind areas can conceal from the driver large utility vehicles, pickup trucks, cars, personnel, structures and road hazards, resulting in dangerous situations. Analysis of blind areas, haulage truck operation, usage, traffic situations, accident history and environmental factors reveals that present visibility aids (mirrors) are inadequate and that the visibility problem is greatest in the right front and rear areas around the typical haulage truck. The problem becomes acute in shovel, dump and utility areas in the typical surface mine. The benefit of improved visibility is a reduction in the accident potential and substantially less property damage.

Based on visibility needs, an improved visibility system was developed during Phases I through IV of this program. The first generation hardware was demonstrated on an actual production haulage truck to evaluate its effectiveness, prove the design concepts and investigate design improvement. The system consisted of a larger left rear-view mirror assembly, a rectangular convex right mirror, a unique blind area viewer and a ruggedized CCTV system. The Blind Area Viewer is the first application of the fresnel lens concept to the problem of mine haulage truck blind areas. The investigation carried out in Phases I through IV of this project was reported in Final Report, Volume I, which can be obtained from U.S.Department of Commerce, National Technical Information Service, Publication No. PB 286063, "Improved Visibility Systems for Large Haulage Vehicles" MBAssociates, San Ramon, California, 30 April, 1978.

The left mirror is a nine-inch wide by twenty-seven-inch high mirror, with a small convex mirror attached. It was designed for ease of maintenance (glass replacement) and provided an optimum view of the left side rear area including orientation features such as the

ground at the rear tire and the top edge of the load bed. Both of these features are needed for efficient operation of the vehicle.

The right mirror assembly is a rugged 12 by 16-inch rectangular convex (spherical) mirror with a 20-inch radius of curvature. The rectangular shape gives the optimum view configuration with a compact shape for mirror protection.

The Blind Area Viewer (BAV) is used to view the blind areas forward and to the right of the driver. Two units can be used for adequate coverage, front and right side. They are mounted on the engine head and on the right deck. Each BAV increases the driver's downward angle of view by 70 degrees. This gives the driver a view of objects within five feet of his truck as opposed to the driver's usual 60 feet to 70 feet wide blind area. The Blind Area Viewer consists of a three-element fresnel lens which provides a downward oriented 70 degree vertical and 60 degrees horizontal field of view.

The CCTV system was designed to give the driver a view to the rear similar to an automobile rear view mirror. It consists of a ruggedized camera enclosure with a semi-automatic lens window cleaning system. The CCTV camera is a tubeless CCD charge-coupled type which uses only five watts of power at 12 volts. It has a wide angle, automatic iris lens for extended light range, and blooming is eliminated by the CCD device. The monitor is a standard CCTV type with the picture reversed right to left for rear view orientation.

The visibility system eliminated 85 percent of the forward and right blind area and 95 percent of the rear blind areas. This is near total coverage of the areas that have an identifiable history of accidents. The total visibility system (two BAVs, two improved mirrors and CCTV system based on a total cost of about $7000) is cost effective for trucks of 170 tons or larger. Without the CCTV, one BAV ($650.00) and one right-side mirror ($425.00) are cost effective for trucks larger than 85 tons.

During Phase IV of the program the system was shown to be effective in a short term demonstration on a 150-ton production haulage truck. It was then subjected to long term in-mine testing in four different mines located in Southern California, Wyoming, Montana and Minnesota. This long term in-mine testing (Phase V) resulted in the design improvement of more ruggedized units to withstanding the rigors of the mining environment and a lower profile BAV to eliminate objectionable glare and sun reflection. These improved models were also subjected to long-term in-mine testing (Phase VI).

The improved mirrors were very well received by the drivers who clearly preferred them over the available commercial models. The Blind Area Viewers were found useful by the drivers, especially the one mounted on the extreme right. The front mounted BAVs, although helpful to many drivers, were not judged to be as necessary as the right side BAVs. The drivers were usually aware of the possible hazards directly in front of the truck since they have been proceeding or traveling in a forward direction.

The general response by drivers was that they felt much more confident while operating their trucks when they personally could see where they were going, and that the area was clear, rather than having to rely on others to direct them or trusting that no one would get in their blind area. Thus, the overall effectiveness of the system developed is excellent. The most beneficial effect of the improved visibility is the achievable increased productivity in truck haulage. A few seconds saved per cycle by a more confident driver, experiencing less tension fatigue during the maneuvering of his vehicle in and around the load and dump areas, can readily result in an increased monthly tonage hauled. The increased safety of operation aspect (reduced accident potential and cut tires) is a plus that should also be considered.

As a result of the favorable acceptance by industry of the Blind Area Viewer and the right side mirror, Tracor MBA is currently offering these units as commercial products.

1.0 INTRODUCTION PHASE V

1.1 Background

In Phases I through IV of this project an analysis was made of large haulage trucks used in open pit mining evaluating the driver's visibility, the truck's operation, traffic situations, accident histories and environmental systems in order to design, fabricate and in-mine test a prototype improved visibility system.

This previous work was covered in Final Report Volume I which can be obtained from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161, title "Improved Visibility Systems for Large Haulage Vehicles". Publication No. PB 286065A, author, MBAssociates.

1.2 Purpose

The purpose of this Phase V work was to evaluate the visibility aids developed during the previous four phases and, where feasible, perform some redesign to effect acceptance by industry. Previous work indicated that the improved visibility system could be very beneficial to industry by helping to reduce accidents and improve efficiency of operation. This would result from providing the operators with greater visibility and thus knowledge of hazards as they developed. Many accidents occur because the driver or operator is unaware of the development of the hazard that produces the accident.

By field testing over a relatively long period in actual mining environmental conditions and during normal mining operations, the visibility aids could be fully evaluated as to their functioning, durability and acceptability by drivers, mine managers and maintenance personnel.

1.3 Objective

The main objective of the Phase V was to prove or disprove the performance, durability and acceptability of the visibility aids developed in previous phases by conducting actual in-mine tests of a reasonably long duration.

1.4 Scope

To provide adequate data for a reliable evaluation of the visibility aids, ten complete improved visibility systems, three with CCTV systems, were fabricated and installed on three trucks in three mines for long term testing. One system was retained as a spare. The three mines selected were chosen for their extreme weather conditions. One was chosen in the desert area of Southern California for its relatively high temperatures and dust conditions. One was selected in the iron ore district of Minnesota for its relatively low temperatures and frequent rain and snow conditions. A third mine was selected in the Wyoming/Montana region which would exhibit both relatively high and low temperatures and frequent rain and snow conditions. A third mine was selected in the Wyoming/Montana region which would exhibit both relatively high and low temperature extremes and rapidly changing conditions of mud and dust.

The tests took place over a twelve (12) month period in order to give time to the truck drivers, management and maintenance personnel to get used to the novelty of these new visibility aids. It also allowed for a full range of seasonal environmental conditions, and to determine maintenance and replacement requirements.

Monitoring of the tests was achieved by personal visits of Tracor MBA engineers who inspected the visibility systems and questioned the equipment operators. This information was supplemented by telephone inquiries to the safety directors, mine managers and various maintenance personnel involved at the test mines.

At the end of the test the units were removed from the test vehicles and inspected for defects or deterioration. All were returned to USBM Twin Cities Research Center, Minneapolis, Minnesota.

1.5 Mines Selected for On-Site Testing

The mines utilized for long term field testing of the improved visibility system were as follows:

California - Eagle Mountain Iron Ore Mine
Kaiser Steel Corporation
P.O. Box 158
Eagle Mountain, CA 92241
Mine Manager: John O. Englund
Safety Director: Wm. A. Eastgate

Minnesota - Erie Mining Company
Pickands Mather & Company
P.O. Box 847
Hoyt Lakes, Mn. 55750
Mine Manager: George Lerick
Safety Director: Robert L. Giuliani

Wyoming - Belle Ayr Mine
AMAX Coal Company
P.O. Box 3005
Gillette, Wyo. 82716
Mine Manager: Ed. Calahan
Safety Director: Don Haney

Montana - Decker Coal Company
P.O. Box 12
Decker, Montana 59025
Mine Manager: John Gable
Safety Supervisor: Gary Webb

1.6 Truck Models and Sizes

The visibility systems were installed in 1979 on haulage trucks in the four test mines as follows:

May 1979 - Erie

Truck 7404	85 ton Unit Rig	2 BAV's, R&L Mirrors
Truck 7411	100 ton Unit Rig	3 BAV's, R&L Mirrors
Truck 7423	170 ton Euclid	3 BAV's, R&L Mirrors
Truck 7430	150 ton Unit Rig	1 BAV, R&L Mirrors

May 1979 - Belle Ayre

Truck	185	120 ton Wabco	3 BAV's, R&L Mirrors
Truck	227	120 ton Wabco	3 BAV's, R&L Mirrors
Truck	234	120 ton Unit Rig	3 BAV's, R&L Mirrors, CCTV

Removed BAV's - August 1979

Removed mirrors - January 1981

August 1979 - Eagle Mountain

Truck	474	100 ton Rim Pull	3 BAV's, R&L Mirrors
Truck	607	150 ton Terex	3 BAV's, R&L Mirrors
Truck	615	150 ton Terex	3 BAV's, R&L Mirrors, CCTV

August 1979 - Decker Coal

Truck	24	170 ton Euclid	3 BAV's
Truck	29	170 ton Euclid	3 BAV's
Truck	33	170 ton Euclid	3 BAV's

1.7 Technical Description of Blind Area Viewer (BAV) Including Installation and Maintenance Procedures

1.7.1 Blind Area Viewer Development

Although the development of the BAV was covered in Vol. I it is being repeated because it is the most novel and important aspect of the improved visibility systems.

The Blind Area Viewer is an entirely new concept in its application to mine truck haulage. The Blind Area Viewer was developed to help the truck driver see into the blind areas to the front and right of the truck. It is basically a fresnel lens (or flat lens) which has a well oriented, wide angle view producing an image of the scene below the driver's unaided line of sight. A first generation Blind Area Viewer is shown mounted on an engine hood in Figure 1.7-1.

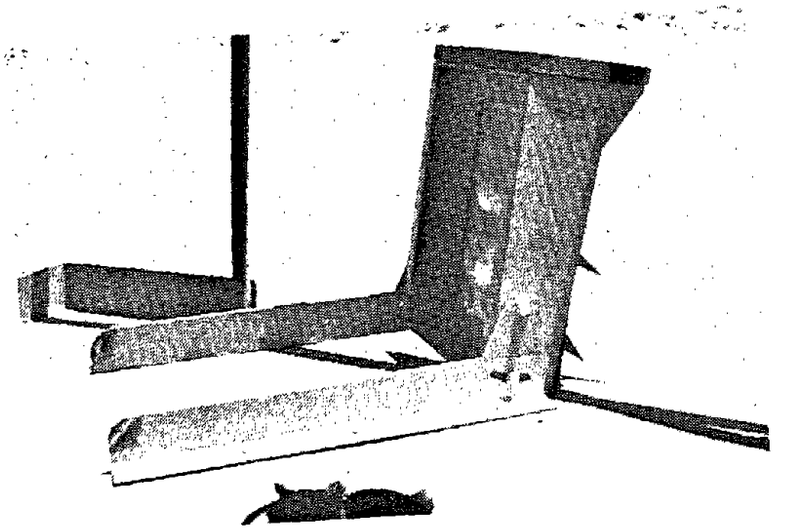

FIGURE 1.7-1
BLIND AREA VIEWER – FIRST GENERATION

The main feature of the Blind Area Viewer is a downward angle of view of 70 degrees combined with a wide horizontal view of 60 degrees. This allows objects to be seen to within five feet of the truck.

This particular fresnel optical capability is unique in the fresnel lens industry and the Blind Area Viewer is the first known application of this particular fresnel concept. This fresnel unit consists of two elements and is the equivalent of three lenses.

A commercially available single element fresnel lens for this type of application was evaluated; however, only a 30 degree downward angle of view could be obtained. The two elements of the Blind Area Viewer fresnel lens are one-eighth inch thick and are sandwiched between two panes of safety glass in a lens assembly. This protects the finely grooved lens from fouling due to dust and moisture. The lens is mounted in a rugged enclosure to protect it from rock spills and to prevent glare (see Figure 1.7-2). The Blind Area Viewer is mounted perpendicular to the driver's line of sight and can be tilted away from the driver to optimize the optical qualities. This tilt of the lens improves the view by reducing light losses and is most effective in a range from 15 to 25 degrees downward tilt.

The fresnel lens system has the following features and specifications:

- The fresnel lenses are pressed into plastic plates composed of cellulose acetate butyrate and have a design life of five years. Each fresnel lens unit is 12-inch by 14-inch by 1/8-inch.
- The two elements of the fresnel lens contain three linear echelon analogs of cylinder lenses.
- The field of view is 70 degrees downward from the observer's line of sight. The horizontal field of view is 60 degrees. This is a rectangular wide angle field of view with the downward angle of view

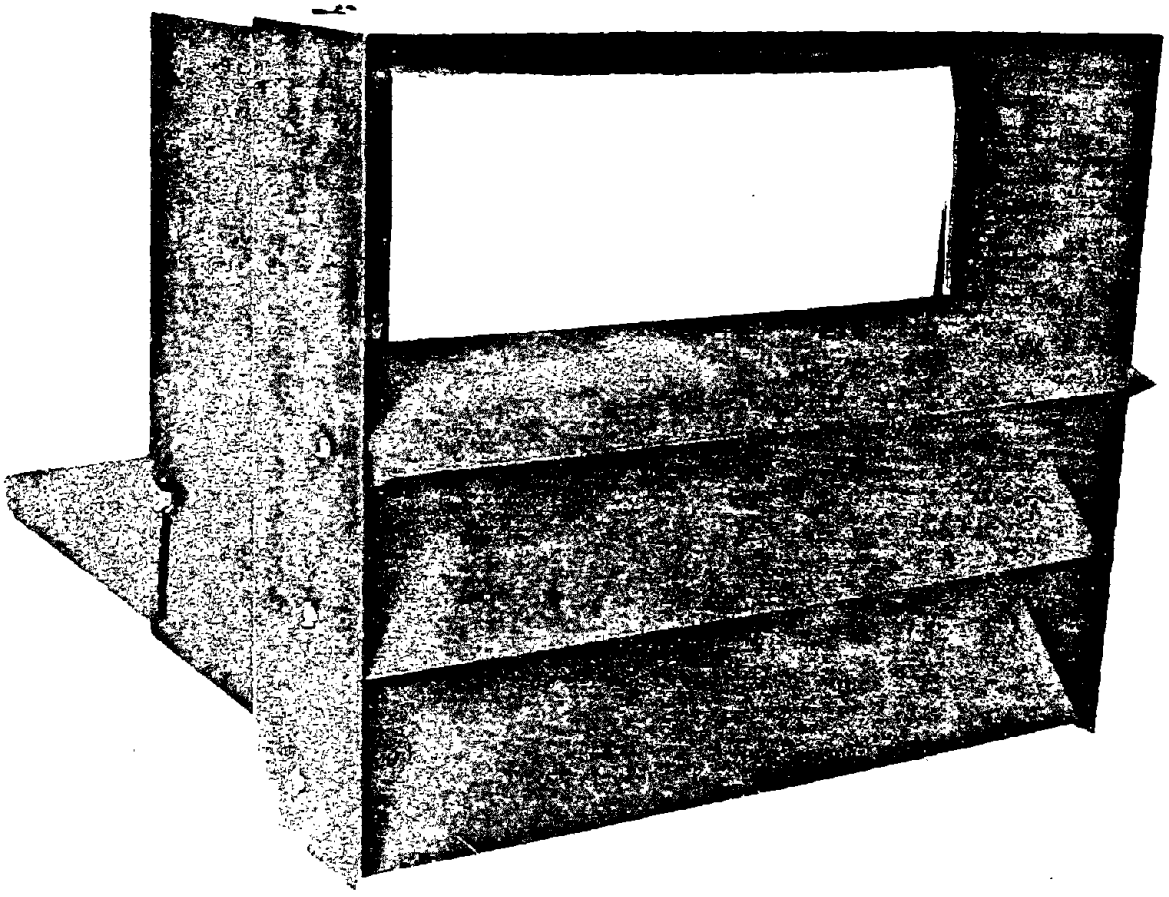

FIGURE 1.7-2
BLIND AREA VIEWER – LOW PROFILE MODEL

emphasized. The downward angle of view of 70 degrees approaches the practical limit of the lens configuration. The lens is designed to emphasize the portion of the view between 20 and 50 degrees downward.

- The lens assembly has an estimated light loss of between 15 and 20 percent. This light loss increases in the view range from 50 to 70 degrees downward. The effect of this light loss is a loss in image contrast and increased sensitivity to glare. Below a downward angle of 50 degrees high contrast items such as helmets and painted vehicles can be seen and recognized.

- Glare must be controlled for effective utilization of the fresnel lens assembly. The best approach which does not increase light losses is to prevent direct sunlight or direct lighting from contacting the lens assembly. This requires glare control louvers on the front of the lens. On the driver's side of the lens, the truck load bed and the lens enclosure provide glare control.

- At night, object recognition is limited to well illuminated objects (within truck headlight beams, area flood lights, shop lights, etc.) and illumination sources (other headlights, taillights, or flashlights). This is not adequate for all hazardous situations. However, most operating vehicles and mine personnel utilize lights continuously for personal safety at night. Auxiliary lighting on board each truck may be needed.

1.7.2 Installation and Maintenance of BAV

The installation of a BAV on a truck is a very simple procedure of welding four bolt heads to the deck or top of a cabinet using the BAV as a template to which the bolts are temporarily attached until the bolt heads are tack-welded to the structure. Some truck models may require additional brackets on which to weld the bolt heads but these brackets are not complicated. They are usually necessary only to bridge an opening between an accessory already mounted on the truck deck and the deck edge and to provide a flat, level surface.

The recommended maintenance is simply to keep the lens clean by washing when needed with normal window washing liquids and procedures. There are no moving parts to malfunction. Damage can occur from load spills or other accidents; however, the housing and louvers can be readily straightened and repainted as they are made of sheet metal.

Illustrations, Figures 1.7-3 and 1.7-4 are reprints of two pages of the "Information and Installation Data Sheet" prepared to be included with each BAV for the customer's information. A complete pamphlet is included in the appendix.

1.8 Technical Description of Mirrors Including Installation and Maintenance Manual and Mirror Handbook

1.8.1 Left Side Rear-View Mirror

Background study of the left side rear view mirror revealed this mirror is used to mainly position the truck when backing to the loading position or to the dump berm. Thus it should give good orientation to the driver. He should simultaneously be able to see the horizon, the top of the load bed and the rear wheel's ground contact. For safety of

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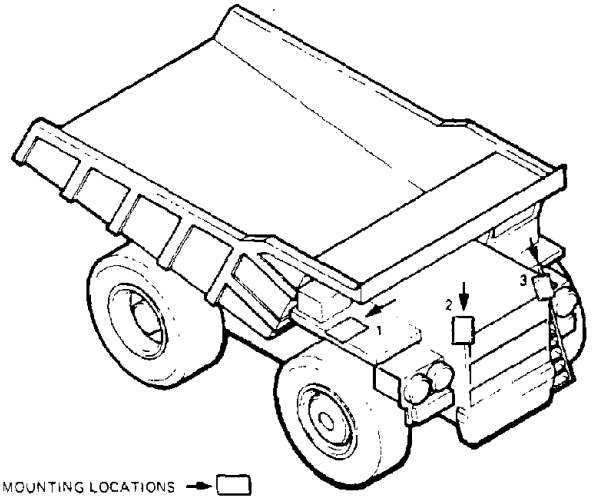
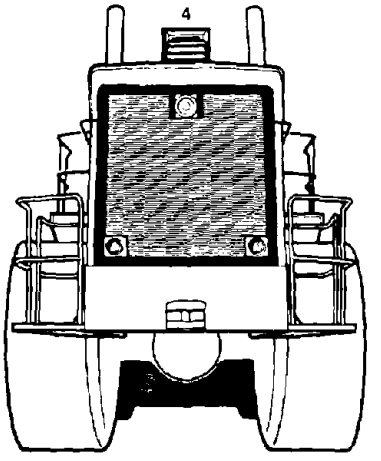
BLIND AREA VIEWER INSTALLATION AND MAINTENANCE INSTRUCTIONS



MOUNTING LOCATIONS →

1. Viewed through right door window (Primary)
2. Viewed through right corner window (Optional – For large trucks)
3. Viewed through windshield (Optional – For very large trucks)
4. Viewed through window (Wheel Loaders)



LIST OF CONTENTS:

- One Blind Area Viewer (assembled)
- One Mounting Bracket (attached to Blind Area Viewer)
- One Mounting Hardware Kit

MOUNTING LOCATION: Mount 3 Blind Area Viewers on a haulage truck in the following locations.

- Left corner of the engine hood (viewed through front windshield of cab)
- Right corner of the engine hood (viewed through right forward window of cab)
- Right side of truck on the deck, fan housing, etc. (viewed through right door window)

WARNING	*Do not carry Blind Area Viewers up the truck ladder. Use a safe method approved by OSHA or MSHA to lift them onto the truck deck.*

INSTALLATION PROCEDURE:

Position the mounting bracket at each location according to these guidelines:

- Have the driver sit in the driver's seat to guide placement of the mounting bracket
- Aim the long dimension of the bracket at the driver's normal position
- Make sure the front edge of the mounting bracket is entirely overhanging the truck edge
- Align and mark 4 (2 on each side) widely spaced mounting holes in good locations for mounting bolts
- The mounting bracket is designed to be mounted level on a flat surface. If the location is not level, it is up to the owner to fabricate hardware to position the shock mounts level

Weld mounting bolts to the flat surface using the detached mounting bracket as a template (welding fixture) to hold the bolt heads in position, as previously marked (see Fastener Assembly Detail); recheck alignment

Assemble the Blind Area Viewer and mounting bracket (see Fastener Assembly Detail)

Mount the assembled Blind Area Viewer on the mounting bolts according to the shock mount assembly detail.

WARNING:	*The Blind Area Viewer is not balanced and will fall off its mounting bolts if not held on or fastened down. For safety, have a 3/8" nut ready to spin on one of the rear mounting bolts when lifting the Blind Area Viewer into its mounting bolts.*

FIGURE 1.7-3
BLIND AREA VIEWER INSTALLATION
AND MAINTENANCE INSTRUCTIONS

ADJUSTMENTS FOR VIEWING:

The rear hood and louvers are designed to reduce glare and reflections on the lens. The glare and reflection cannot be eliminated completely; however, adjustments can help considerably.

TILT: With the driver in the driver's seat to guide the adjustment, tilt the Blind Area Viewer forward until reflections are minimized and the view through the bottom half of the lens is clearest. The lens glass can reflect the deck, cab, hand rails, or the bottom of the load bed overhang and the tilt adjustment can reduce its effect. The operator should make sure that the lens tilt adjustment is optimum for his truck and the lighting conditions at the mine.

LOUVERS: With the driver in the driver's seat to guide adjustment, rotate the louvers by hand until they appear to the driver as a thin line.

CLEANING: Clean the lens glass with window washing solution and wipe with a paper towel.

To clean between the louvers, apply excess cleaning solution and allow it to run and drip off, then wipe between the louvers starting at the top.

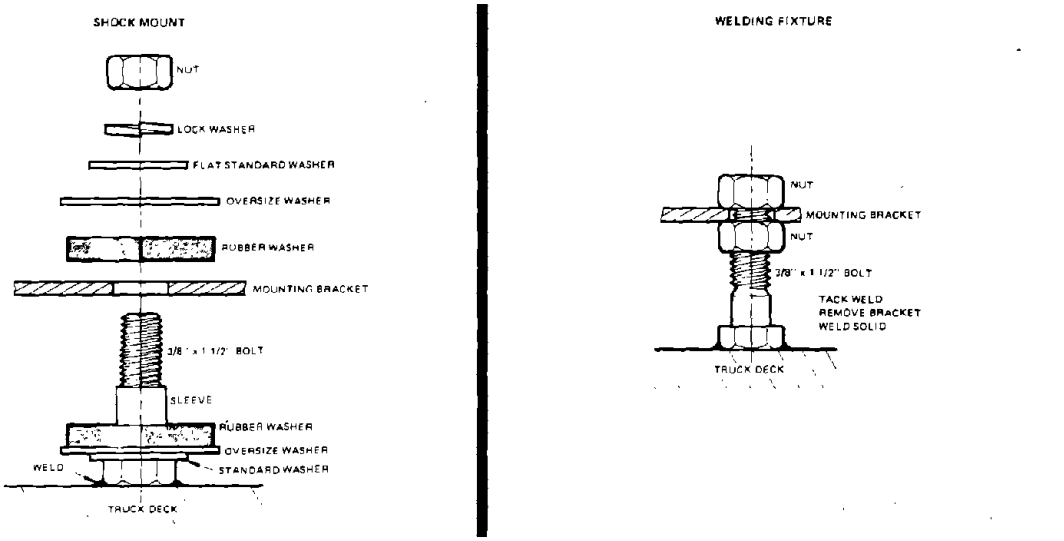
WARNING: *Be aware of the danger of falling. Clean lens in a safe manner.*

MAINTENANCE: Replace damaged parts by disassembly. Bent or dented sheet metal parts can be straightened in the welding shop.

Touch up finish with Rustoleum #412 flat black paint.

Note: The lens assembly consists of 2 plastic lenses sealed between 2 sheets of automotive safety plate glass. The sealant used is a hot melt butyl.

FASTENER ASSEMBLY DETAIL



BLIND AREA VIEWER ASSEMBLY

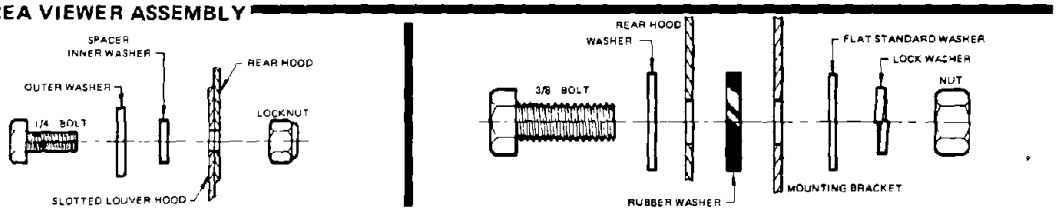


FIGURE 1.7-4
BLIND AREA VIEWER INSTALLATION
AND MAINTENANCE INSTRUCTIONS

1631-17346

operation he should not have to move from his normal straight ahead driving position, thus keeping his hands and feet on the operating mechanisms at all times. It was also found that the use of two or more mirrors on the left side (a fairly common practice to achieve a large field of view) was not desirable. Thus it was decided that a large flat mirror properly spaced from the driver would be the most efficient.

The left mirror system developed is shown in Figures 1.8-1, -2, -3, -4. It is a 9"x27" plane mirror with a 3"x5" rectangular convex mirror attached for a wide angle view. The mirror is framed in a rugged enclosure designed to withstand minor rock spills and to facilitate quick replacement of the mirror element. Although simple in appearance, this mirror contains a composite of concepts and features which are not in evidence or effectively utilized in existing left mirrors.

The left mirror system as developed and demonstrated has the following specifications and features:

- The field of view contains a view of the left side of the truck, including the top edge of the load bed and the bottom of the rear tire. No head movements are required to see this vertical field of view. The horizontal field of view of the plane mirror is sensitive to its distance from the driver; however, a small rectangular convex mirror is attachable to expand this view to greater than 40 degrees if the driver so desires.

- The view orientation can be maintained when glancing from the top to the bottom of the mirror because of the left side position of the convex mirror which does not interrupt the orientation features in the plane mirror. The convex mirror is field mounted in a position selected to prevent it from masking any significant view features in the flat mirror.

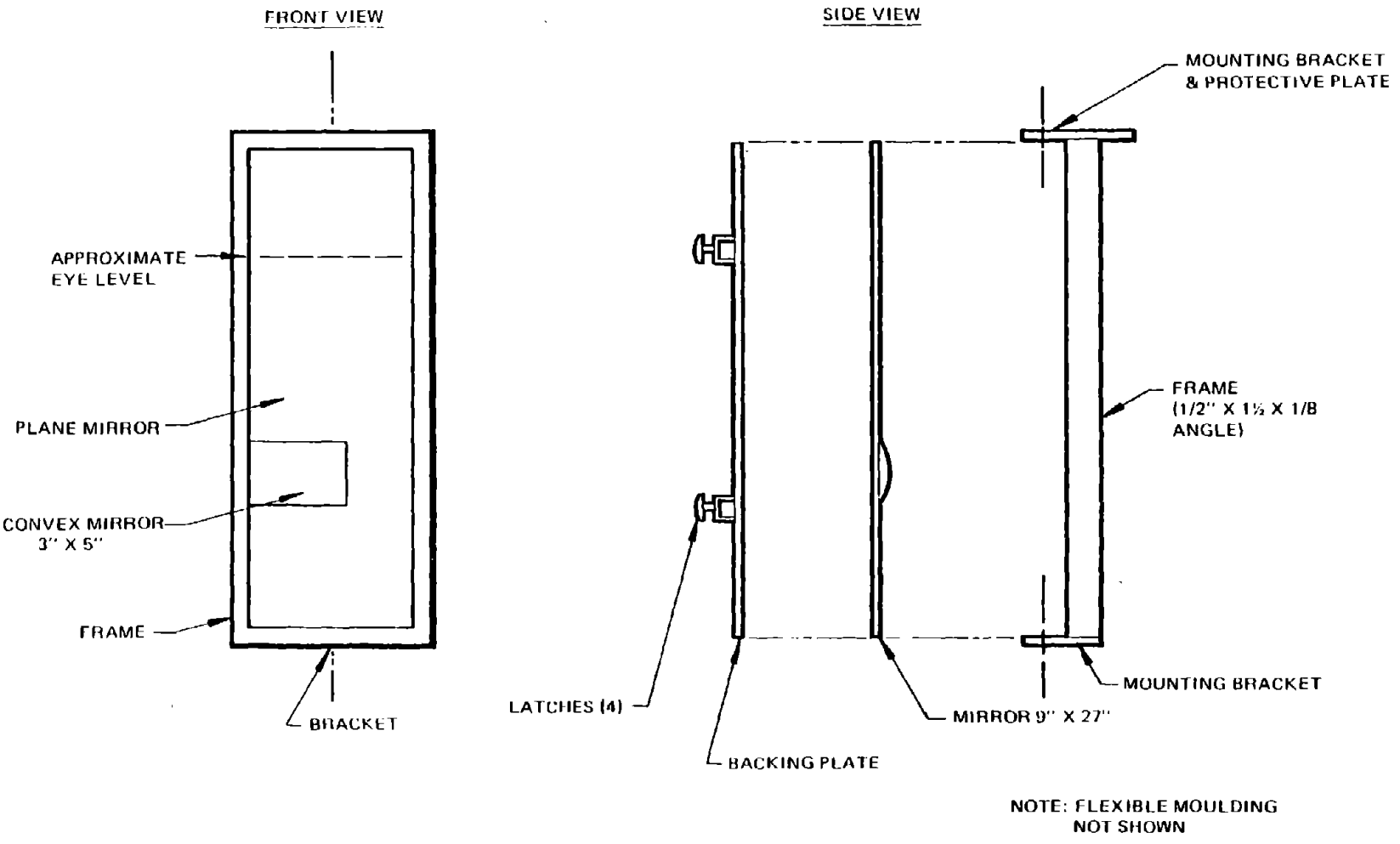
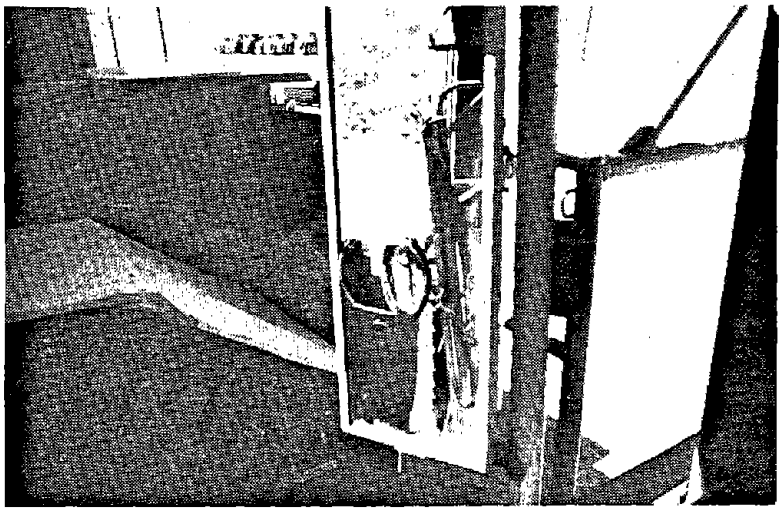


FIGURE 1.8-1
LEFT MIRROR LESS MOUNTING STRUCTURE



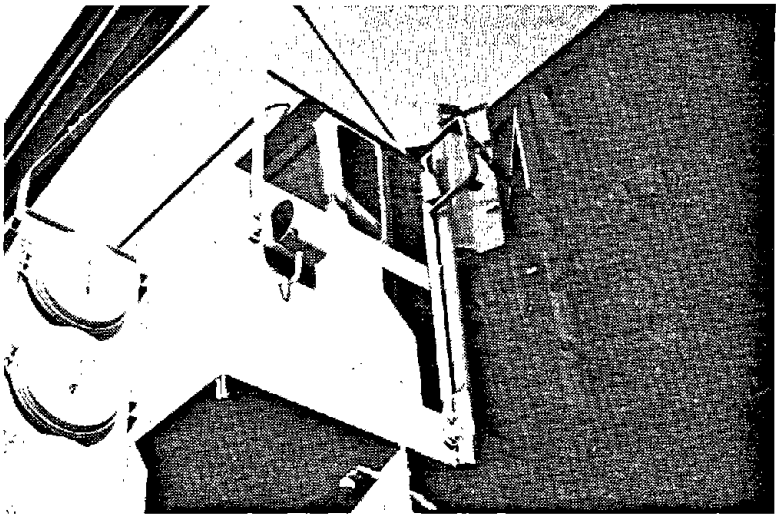


FIGURE 1.8-2
LEFT MIRROR SYSTEM ON HAULAGE TRUCK

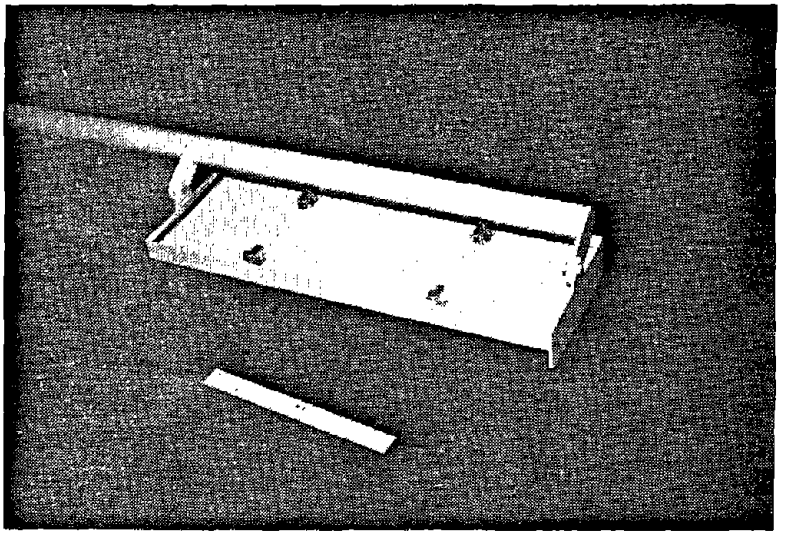


FIGURE 1.8-3
LEFT MIRROR HOUSING AND MOUNTING POST

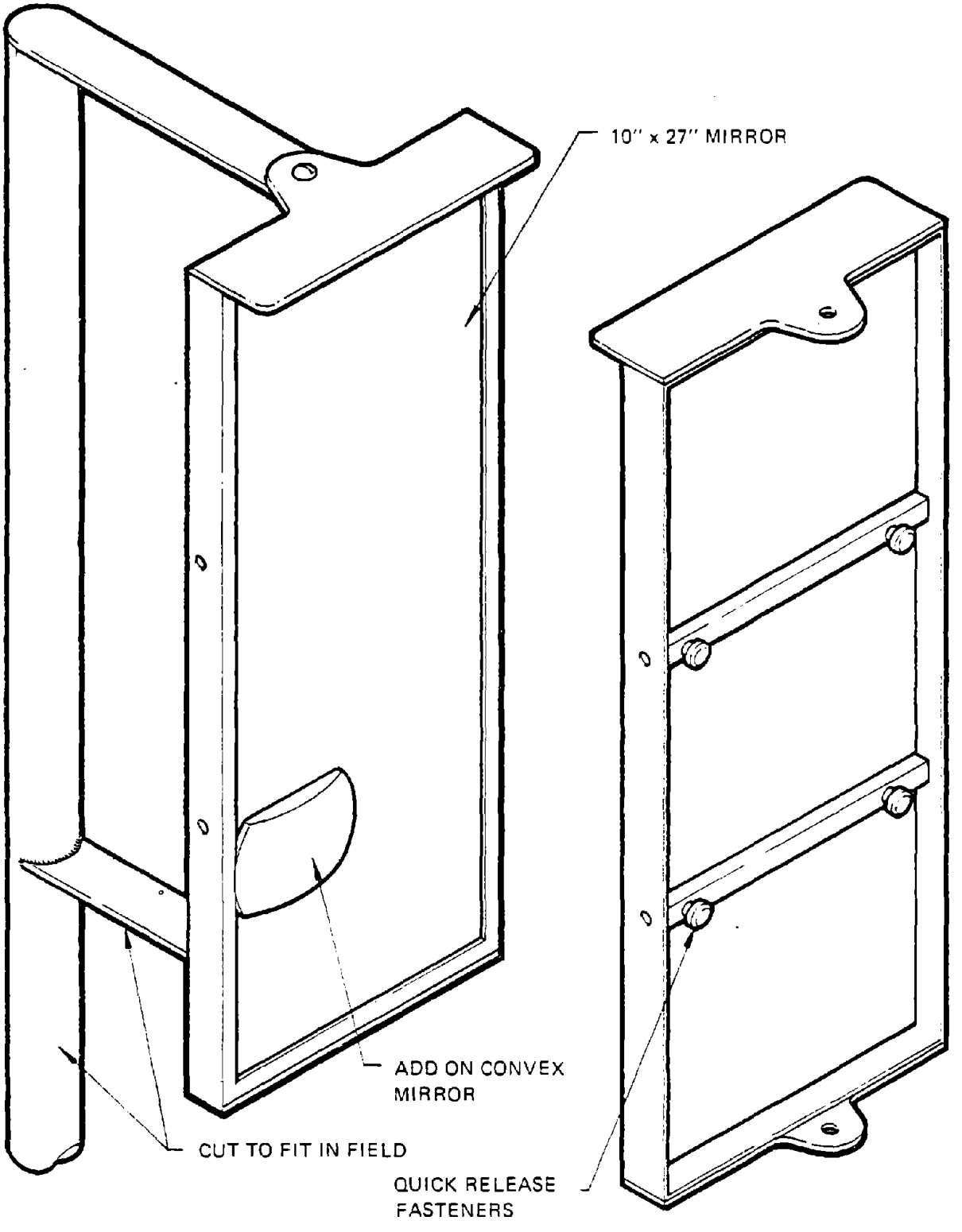


FIGURE 1.8-4
IMPROVED LEFT TRUCK MIRROR

2658-16438

- The flat mirror element is a standard glass mirror. The mirror assembly will accept glass mirror elements from 1/8" to 3/8" thick, including tempered and safety-mesh-backed mirror glass. The rectangular convex mirror is a standard hardware item mounted with silicone based sealant.
- The frame is of rugged construction and is topped with a 3/16" steel plate to prevent damage from minor rock spills.
- The left mirror is mounted with its right edge in line with the load bed for best view orientation.
- The mirror assembly is attached to the mounting structure using 3/8" bolts with rubber washers for positive alignment.
- The mounting structure can be attached to deck side and hand rail or to the cab door - when door opens forward and hand rail does not interfere.
- The rear plate of the mirror can be removed by hand by releasing four latches for quick mirror element replacement. The mirror element can be replaced in the field without tools in less than a minute. All material and components are common off-the-shelf items.

1.8.2 Right Side Rear-View Mirror

Since the right side mirrors are so far from the drivers, (15-24 ft), the curved convex mirrors were the most popular because they provided the larger field of view. The larger the convex radius angle, the larger the image, but the smaller the field of view. The available convex mirrors were round which produced some distortion, particularly around the edges, and thus distraction for the viewer. The mirror developed and tested is a 20" radius convex mirror with a rectangular shape of 12"x16".

This provided a more recognizable, better oriented view, with a sufficient field of view to include the top of the load bed and the back wheel ground contact. It provides a field of view of 40° in the vertical and 46° in the horizontal.

Since it is necessary for side mounted rear-view mirrors to protrude past the edge of the truck, possible impact with external objects must be considered. Thus the improved mirror for long term testing was designed with a friction clutch mounting to allow it to swing away on impact. It was also protected from falling rocks by a top steel plate and a steel backed housing. In addition, the mirror was set on a sponge rubber pad to absorb vibration and shocks.

The right mirror system as developed and demonstrated had the following specifications and features:

- The image size was above average for the mirrors in common use. Image recognition was improved by the improved orientation features in the view.
- The mirror element was a 12-inch by 16-inch rectangular section of a spherical mirror. The mirror radius of curvature was uniform with a radius of 20 inches.
- The mirror element was constructed of tempered glass and mounted on foam rubber.
- The mirror enclosure was fabricated from heavy gage sheet steel and capped with a 3/16" steel plate to prevent the common minor rock spills from causing damage.
- The mounting bracket with friction assembly was designed for universal application without right handrail modification.

- The mirror face was mounted with the left edge in line with the load bed. It was also aligned 60 degrees out from the side of the truck and 15 degrees down from the vertical. The alignment will vary slightly for different trucks; however, no adjustment is needed for individual drivers, so that adjustment after installation is not required.

A drawing in Figure 1.8-5 shows the assembly of the right mirror system used in the long term test.

Evaluation of the right mirror system in the laboratory and in the field shows that the rectangular convex shape gives considerably more effective field of view with a consistent view orientation which does not vary significantly from truck to truck. The field of view is greater than 100 percent wider than with a standard 12 inch polished steel circular convex mirror such as sometimes used on haulage trucks.

More definitive information on the friction assembly, mounting bracket, mounting and installation procedure, can be obtained from the Installation and Maintenance Manual in the Appendix.

1.8.3 Mirror Technology

During the investigation of mirrors available to industry that were being used in the surface mines, it was found that straightforward information on basic mirror usage was not readily available. Thus, the mirror information developed during this project was compiled into a handbook. The intention of the "Mirror Technology Handbook for Large Haulage Trucks" was to provide practical information to personnel of the surface mining industry. A photo-copy is included in the appendix of this report.

EXPLODED VIEW

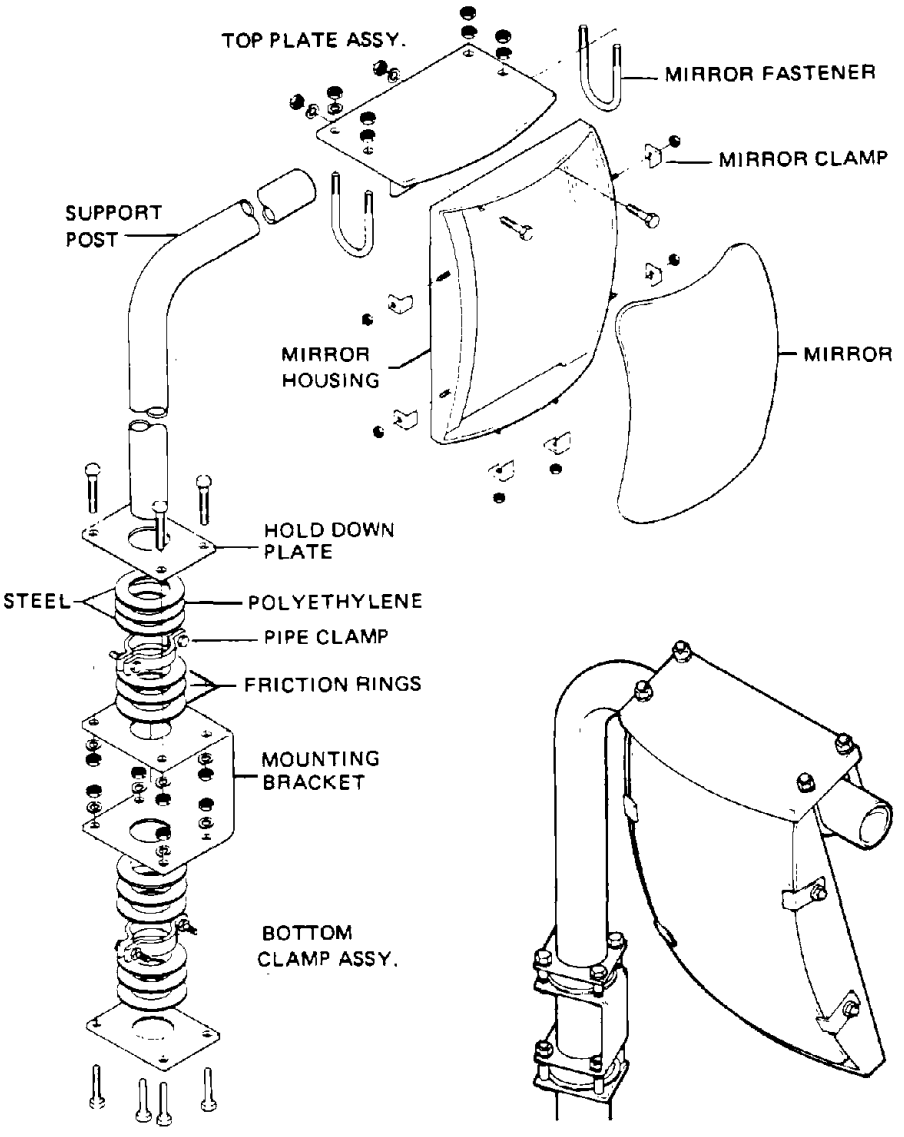


FIGURE 1.8-5
RIGHT SIDE REAR VIEW MIRROR

1.9 Technical Description of Closed Circuit Television System (CCTV)

1.9.1 Improved CCTV System

The improved CCTV system was developed for application to the rear blind area on the larger haulage vehicles. This CCTV System was designed to demonstrate a combination of unique features which will improve the utilization of CCTV Systems in the mine haulage environment. The CCTV System is shown installed on a 150-ton haulage truck in Figure 1.9-1. It consists of an improved CCTV camera with a lens cleaning system and a 6-inch CCTV monitor with systems controls. Details of the camera enclosure are shown in Figure 1.9-2 and the monitor assembly in Figure 1.9-3. This CCTV System has the following features:

- The system was designed to operate under all lighting levels including night time conditions with automatic adjustment to light changes.
- The monitor is a standard CCTV model which cannot receive broadcast television channels.
- The camera is a charge coupled solid state silicone imaging device. The camera enclosure is designed to adapt to other vidicon tube type cameras. The camera system is a fixed mount system. A wide-angle camera lens with an auto-iris was used.
- On demand, the lens cleaning system will wash and wipe the camera-lens window. The cleaning cycle is automatically timed and is initiated by a single actuation of a push button contactor mounted on the CCTV monitor.

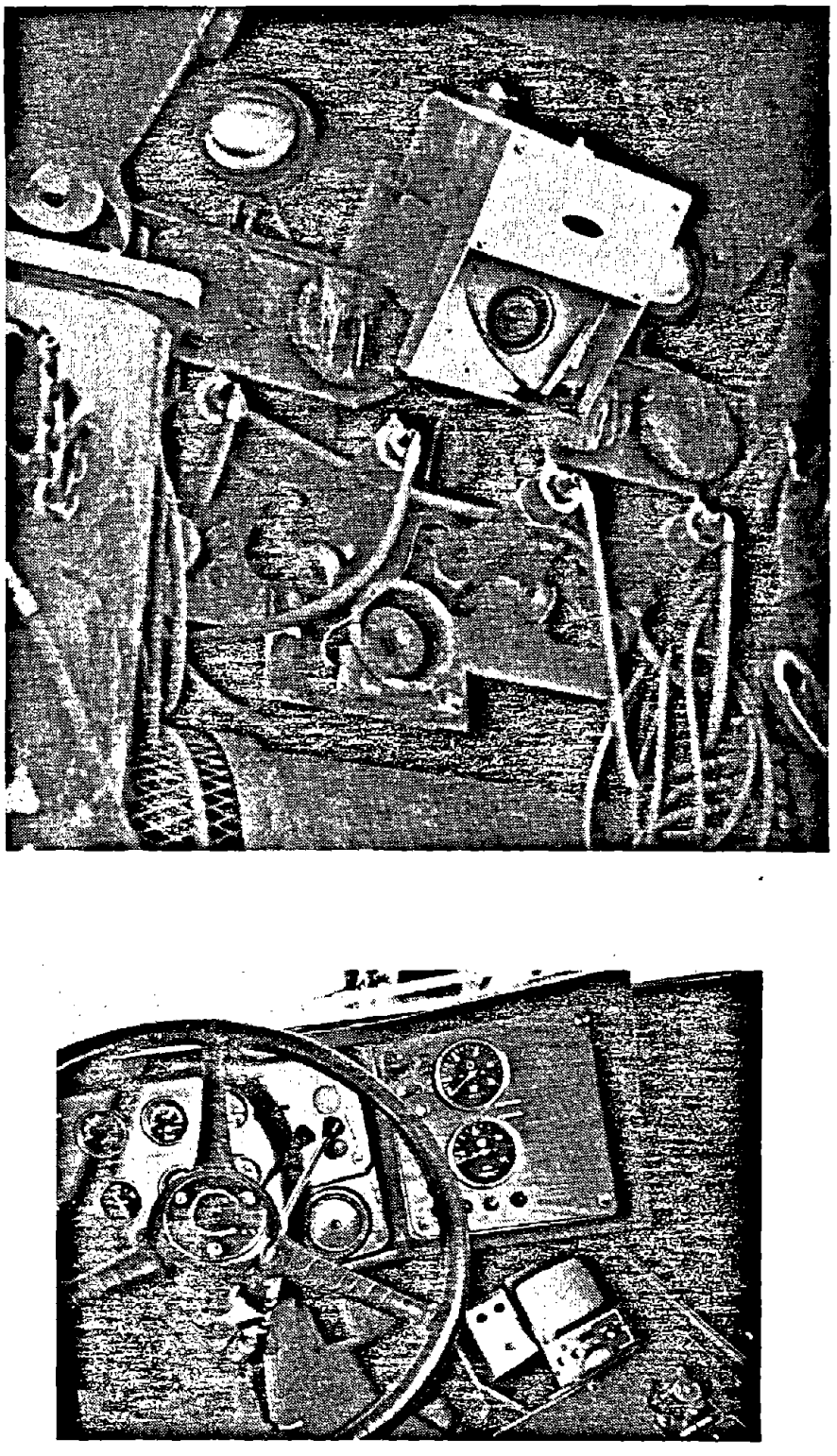


FIGURE 1.9-1
CCTV SYSTEM ON HAULAGE TRUCK

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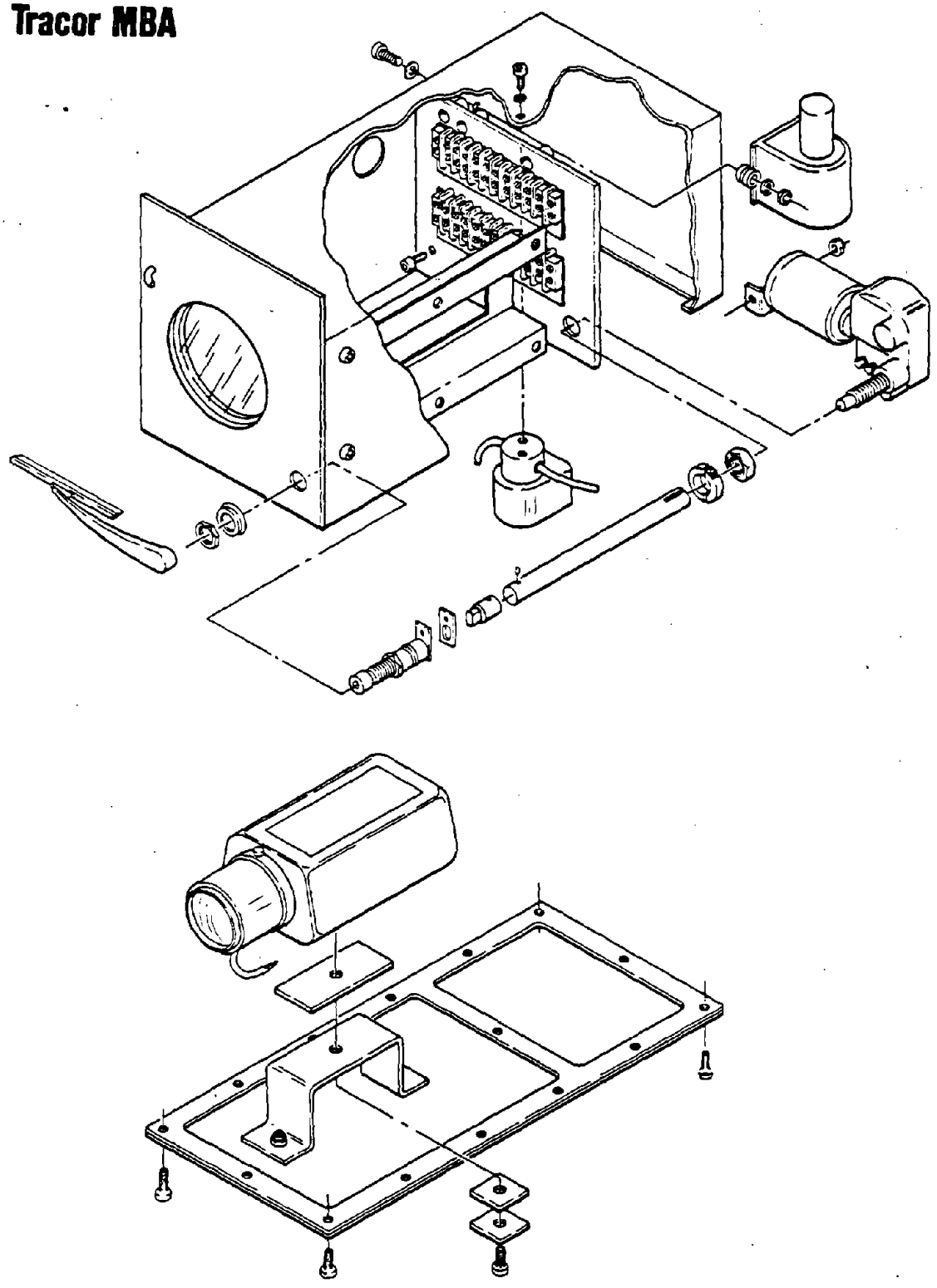


FIGURE 1.9-2
REVISED CCTV CAMERA AND ENCLOSURE ASSEMBLY

Tracor MBA

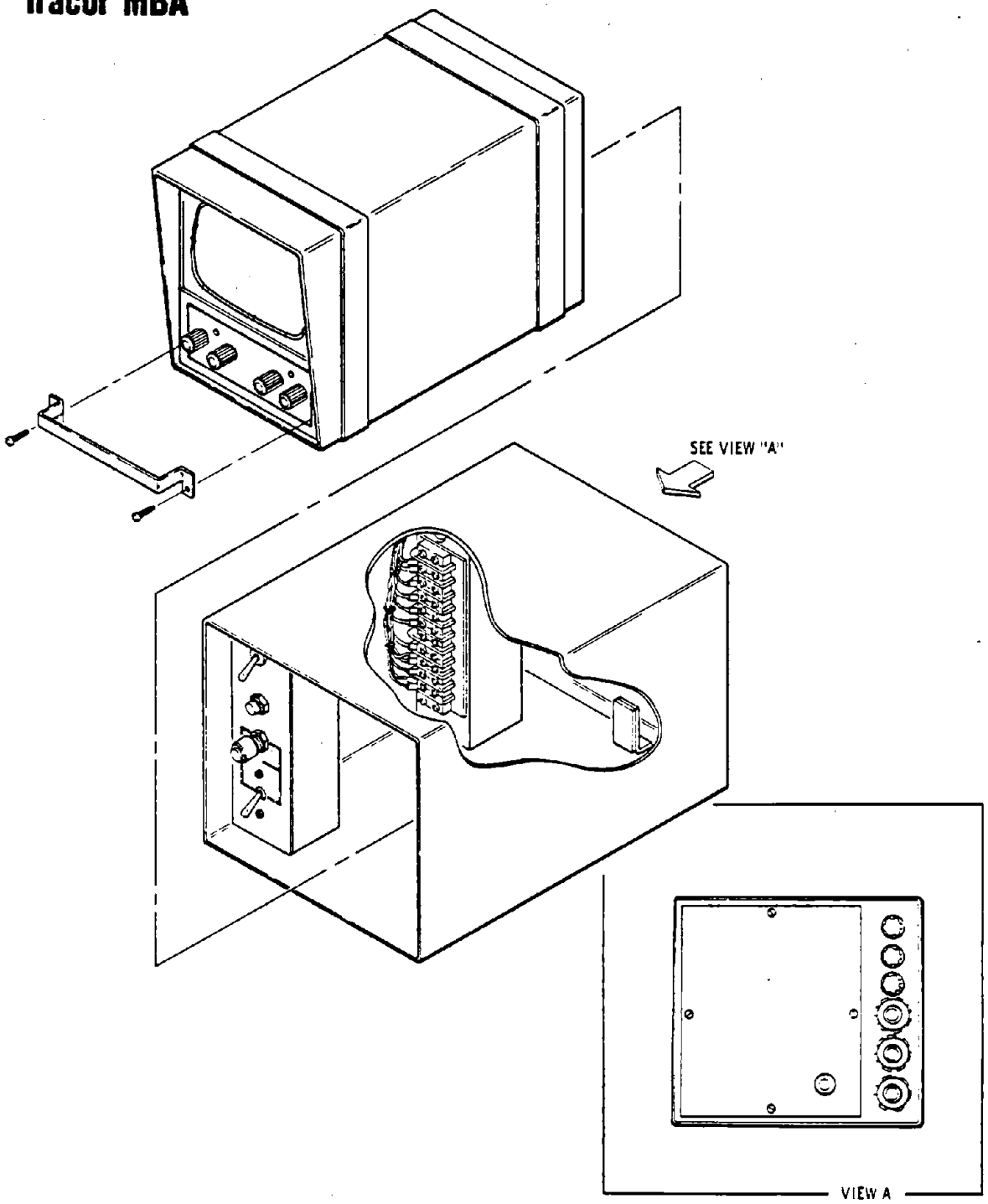


FIGURE 1.9-3
CCTV MONITOR ASSEMBLY

- The camera enclosure can be sealed from the outside environment. Provisions for the use of dry nitrogen purging, or dessicants, were included in the design. The lens cleaning system is external to the camera enclosure. Functionally the washer reservoir can be removed from the camera location to create a lower profile system.
- A four-inch diameter glass window is used to effectively protect the camera lens from damage. The glass is mounted flush with the cover plate for effective use of standard wiper systems. The lens wiper is a compact windshield wiper with an 85 degrees stroke. Both the lens wiper and washer are standard automotive products.
- The system is powered by 12-volt and 24-volt DC sources. Automotive type batteries were used for the demonstration.

The camera and lens selected for use in this CCTV system had the following features:

- The charge coupled camera operates on 12-volts DC and consumes only five watts of power (less auto-iris lens), eliminating heat problems.
- The camera with an auto-iris lens operates at normal and very low light levels without manual adjustments. The silicone imaging device has an anti-bloom feature which prevents lights, reflections and the sun from obscuring the video picture.
- The CCTV camera with its lens is 8-inches long, 4-1/2-inches wide and 3-inches high. Its weight is less than four pounds.

- The CCTV camera is mounted on a rubber pad and is ruggedized internally for protection from shock and vibration. For low temperature operation, a thermostatically controlled tape heater is attached to the camera. No provisions for cooling are needed.
- The CCTV camera uses a high cost silicone imaging device. This is an advanced application of integrated circuit technology. This technology has the potential of becoming the low cost standard in the near future.

The CCTV camera is an RCA[1] TC1160 with a grade B silicone imaging device (SID 52501). The 5½" x 5½" x 17" enclosure can be adapted to other vidicon type cameras, however, there is no alternate camera that is a direct replacement. With a significant difference in performance, a RCA 1025/S05 camera could be used. The monitor is a Setchell Carlson Model 6M917 modified to operate on 24 volts DC.

1.10 Test Results

1.10.1 Blind Area Viewers (BAV)

Three (3) BAVs were installed on each test truck to provide maximum coverage. In all test mines, except the Eagle Mountain Iron Ore Mine, the drivers complained that the units on the front of the vehicle interfered with their direct vision and were not of much use. At Belle Ayr Coal Mine in Wyoming the complaints were so universal and continuing, even in some instances including the viewer mounted on the right side, that the test was terminated the second month. The BAVs were removed and installed on test vehicles at Decker Coal Company in Montana.

In almost all reports the drivers liked, and found useful, the BAV mounted on the right which permitted them to see alongside the right front side of their truck. Some of the first criticisms were of the sunlight being pulled into the top part of the lens and shining into the driver's eyes when the sun was low on the horizon. This effect was minimized by masking off the top two inches of the lens which has an upward

1 Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines.

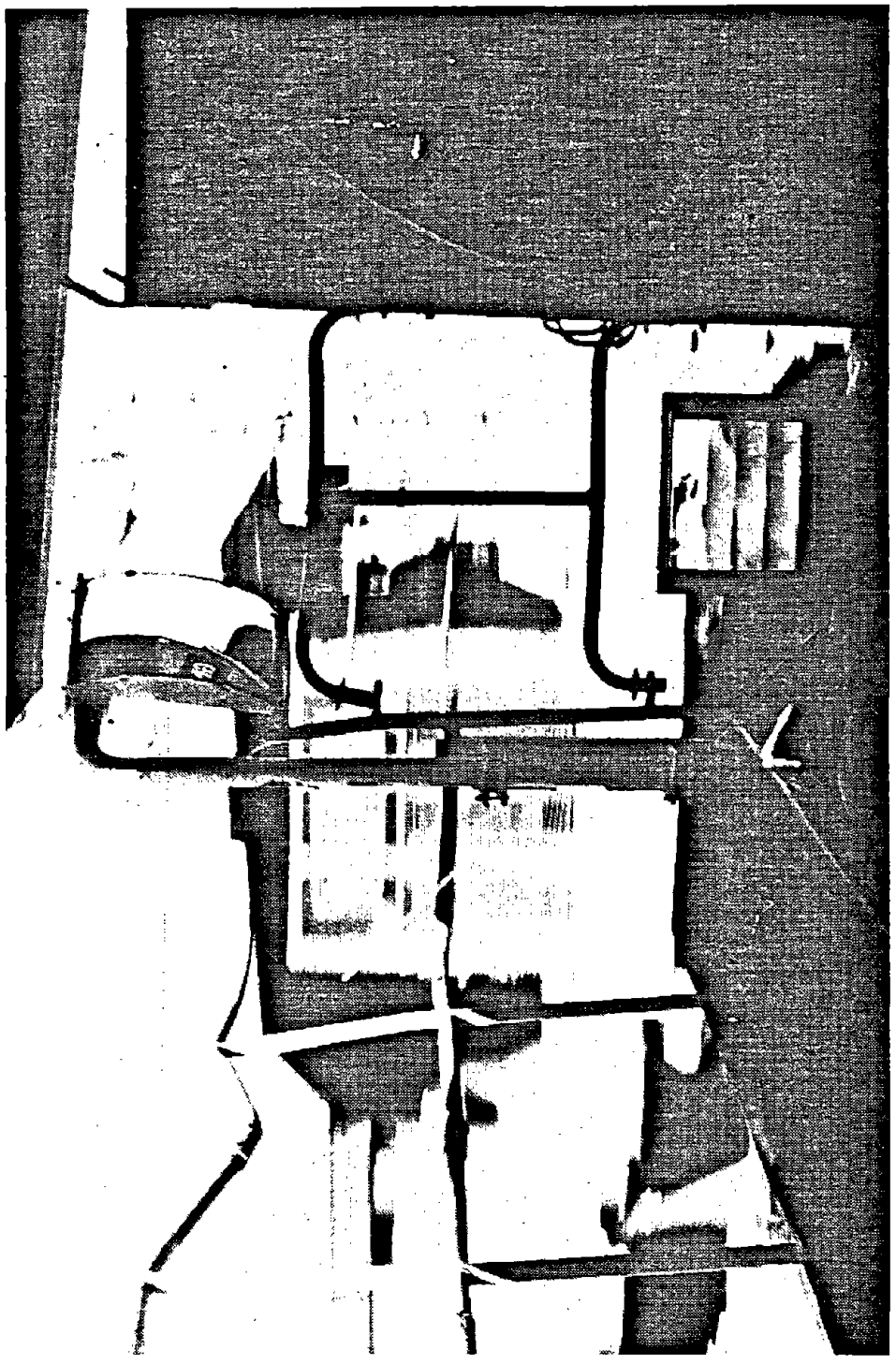
angle of 15^{o} and is not needed in this application. Another complaint was reflections in the lens under certain light conditions. This usually happened when the truck cab was well lighted and the area in front of the BAV in shadow. This situation was not considered too detrimental as it occurred only occasionally and was far less than the time the BAVs were producing clear views.

In one instance a driver said the viewer mounted directly in front did not work. He was somewhat amazed to see that it did function when a target was deliberately moved into the area covered by the BAV. It is usually rare that anyone will move into the front area of the large trucks. Also, most of the time the trucks are moving in a forward direction and the driver is well aware of any hazards that might exist.

When the BAVs were first installed at Decker Coal, the drivers complained about those BAVs on the front of their vehicles and these were removed, leaving the ones on the right. Most of the drivers at Decker said they checked the area to the right of their vehicle by using the BAV before making a right turn.

It was not intended that the BAV be used while the vehicle is in motion but it was found feasible and at times useful. The expanded area shown in the viewer contains object images that move in relatively slower motion than the truck. An example is shown in Figure 1.10-1. The truck passing in the opposite direction is blurred because of the relatively slow speed setting of the camera shutter. However, the image of the right front wheel of the passing truck, displayed in the lens of the viewer, is distinct.

During the year-long (12 month) test period, only 6 of the 27 BAVs on test were damaged. Two were damaged in the first month of the test period. One was cracked by a rock spill (misloading of the shovel) and the other had the lens cracked by a rolling rock that fell off the body canopy. By the end of the one year test period, two others were destroyed at another mine. One in a truck accident where another truck backed into the viewer. The other vibrated loose, fell off the truck and was run over by a following truck.



Tracor MBA

FIGURE 1.10-1
RELATIVE MOTION AND BAV

Two other units each had a cracked lens caused by rolling rocks that fell off body canopies..

Extended use of the remaining units for another 12 months resulted in four more units with broken lenses and damaged hoods, due to rock falls. All but one were front mounted BAVs which were not protected by the body canopy. At all test sites the drivers complained that the lenses were difficult to clean especially on the louver side. However, even though the lenses appeared not as clean as would be desired for a windshield, a color contrast image such as a hard hat or a vehicle could be seen without difficulty.

1.10.2 Rear-View Mirrors

1.10.2.1 Left Mirrors

The left side mounted rear-view mirror was well liked by the majority of drivers. Only two complained that it was so large it interfered with their direct view.

Vibration loosening at the mounting was a problem at first. This was corrected by the installation of non-metallic washers in the pivot connections. The very first versions suffered some glass damage by falling rocks. This was improved by installing heavier top plates to ward off falling rocks. One unit was damaged beyond further use in an accident involving an obstacle, which destroyed the mirror backing. Except for periodic glass replacement, the remaining left mirrors survived the regular and extended test periods.

1.10.2.2 Right Mirrors

The right side mirror performed remarkably well with a good survival rate. Only four breakages of the glass occurred during the 12-month test period. The actual cause of the breakages was not reported. One mirror was missing with no record of what happened.

The drivers all reported they liked the mirror and the view it provided.

The drivers at Belle Ayr reported that their 12" round convex mirror (30" radius of curvature) produced a better image in low light and low color contrast conditions. A larger radius convex mirror is known to have less reduction of image size and less light loss. The drivers at this mine preferred to use both mirrors. The round mirror was mounted on the load bed canopy and used for spotting. The rectangular mirror was then used when the load bed was up to observe the area around the right rear of the truck. The drivers were unhappy when the mirrors were removed at the end of the testing. Mine management had decided not to extend the test period and the mirrors were taken to Decker Coal Company for additional testing.

1.10.3 Closed Circuit Television

The closed circuit television system was installed at two of the test mines, Belle Ayr and Eagle Mountain. Installation at Belle Ayr was on May 14 1978. The camera was inoperative and replaced August 28, 1979. The monitor was replaced September 25, 1979. The camera was replaced again January 21, 1980 (at this time the improved housing was also installed). The system was reported not functioning in May 1980. The test was terminated and the system removed. Installation at Eagle Mountain was on June 4, 1979. The monitor was repaired (capacitor wire broken) on July 12, 1979. Camera and enclosure was removed September 14, 1979 as it had been flooded. The housing was redesigned to separate the electronics from the lens cleaning system and the covers ruggedized. The improved housing with camera was reinstalled on October 10, 1979. Camera was replaced one month later on November 7, 1979 because of a defective automatic iris and again on April 24, 1980 for the same reason. It reportedly was operating in June when the mine shut down operations but inoperative in November 1980 when the mine resumed operations.

The main problems with the CCTV system, after the camera enclosure was improved, was mechanical failure of the monitor control knobs, broken wires in the monitor and automatic iris lens failures.

Good, clear pictures were obtained and the system was well liked by the operators. However, it was found to require regular preventative maintenance of the type not readily available at the mines.

1.11 Summary, Phase V

Improved visibility systems for large off-highway haulage trucks consisting of rear-view mirrors, blind area viewers and closed circuit television were tested for 12 months in operating open pit mines. The mines were selected to provide the weather extremes possible in the United States. They were: Kaiser Steel Corp's iron ore mine at Eagle Mountain, California; AMAX Coal Company's Belle Ayr mine in Gillette, Wyoming; Decker Coal Company in Decker, Montana and Pickands Mather & Company's Erie Iron Ore Mine in Hoyt Lakes, Minnesota.

Right-side and Left-side rear-view mirrors and blind area viewers were tested at all four mines. The closed circuit television was tested at Eagle Mountain Mine and Belle Ayr.

1.11.1 Right-Side Mirror

The right-side rear-view mirror was a rectangular 12x16" convex, with a 20" radius of curvature enshrouded in a protective metal housing mounted on a swing-away friction-controlled post. It was well received by all test drivers and much preferred over all other mirrors except a 12" round convex mirror with a 30" radius of curvature. At one test site the drivers wanted to use the rectangular mirror in conjunction with the 30" radius convex mirror. The breakage or failure rate for this rectangular convex mirror was less than for the normally used right side mirrors.

1.11.2 Left-Side Mirror

The left-side rear-view mirrors were off-the-shelf mirrors but of maximum size presently in use. The mirror frame or housing was designed to facilitate glass removal and replacement and to help protect from falling rocks of small load spills. This mirror was also well received and

appreciated at all test sites. Even though it is larger, the survival rate was no different than for the smaller available mirrors.

The view produced by the mirror which included the top of the load bed and the rear wheel ground contact was much more desired than the view obtained with one or more smaller mirrors. The add-on small convex mirror which provided an expanded area view was also an advantage and appreciated in most cases.

1.11.3 Blind Area Viewers

The blind area viewer, using the fresnel lens system permitting a driver to see down in front and on the side of his vehicle, performed well and was appreciated by most all drivers, particularly for the right side position. The front mounted BAVs did not come into play very often because very rarely does anything move into the area in front of the large trucks. Also, because the trucks were for the greatest portion of operation moving forward, the drivers were very much aware of any possible hazards in the frontal area. Therefore, the front mounted BAVs were not considered useful or desirable by the drivers. The complaints having justification were that glare and reflections were caused by special light conditions and that it was difficult to clean the lens between the louvers on the front of the unit. The right side mounted BAVs exhibited good survival because they were protected by the load bed canopy. Even those mounted on the truck's front hood were damaged only when struck by another truck with a careless driver or by rock spills caused by an inexperienced shovel operator or a mispositioning of the truck. Weather extremes had no detrimental effect on the lens assemblies.

1.12 Recommendations

Results of the long term in-mine testing prompted the following recommendations:

1.12.1 Mirrors

- That nothing further be done with the left hand mirror since similar size mirrors were already available to the mining industry.
- That right-side rear-view 30" radius of curvature, convex mirrors of rectangular shape, 12" x 20", be fabricated and in-mine tested for industry acceptance and evaluation. Also, that a simpler, less expensive mounting be investigated and tested.

1.12.2 Blind Area Viewers

- That blind area viewers be redesigned to incorporate readily removable louvers to facilitate cleaning with a shorter lens (minus the two inch top portion) lowering the overall profile to minimize glare and reflections.
- That a special anti reflection coating be investigated for the BAV fresnel lens to minimize reflections.

1.12.3 Closed Circuit Television

- That no further work be done on the CCTV system until a more durable, longer lasting automatic iris lens is available and overall component costs are reduced.

2.0 PHASE VI IMPROVED BAV AND RIGHT-SIDE MIRROR DESIGNS

2.1 Statement of Requirement

Following the recommendations in Phase V, the Improved Visibility Systems for Large Haulage Vehicles contract was expanded to test a revised model of the BAV and a larger rectangular convex right side mirror of 30" radius. It was also decided to investigate the possible application of the BAV to large front-end wheel loaders which have large blind areas to the rear of the vehicle. They have been known to have backed over smaller vehicles causing considerable damage and serious injuries. In addition, lighting to make the BAVs useful at night was also investigated.

2.2 Phase VI Objectives

The Phase VI objectives were:

- To investigate by in-mine testing the degree of improvement in the rectangular convex mirror with a 30" radius of curvature over the previously tested 20" mirrors. The tests were also to determine if the increased size 12" x 20" vs 12" x 16" were objectionable.
- To test the new low profile (LP) Blind Area Viewers (BAVs) by in-mine testing at the same mines used in Phase V to obtain driver comments on the degree of improvement made in relation to glare, reflection and ease of cleaning.
- To fabricate and test a light for the BAV.
- To make an anti reflection treated lens for the LP BAV and test it at the most likely test site (the one with the greatest amount of reflection complaints).
- To test BAVs on large front-end wheel loaders (FEL) and other equipment exhibiting blind areas under actual mine and quarry operations.
- To continue with the Phase V long term testing.

2.3 Scope

To keep within available funding and obtain as much test data as possible, the scope was limited to the fabrication and testing of two anti reflection coated fresnel BAV lenses; two rectangular 12" x 20", convex, 30" radius of curvature mirrors, eight LP BAVs (two on FELs and six on trucks at the Phase V test mines) and a light for night time use of a BAV. Four previous model BAVs were also to be tested on FELs.

2.4 Mine Sites Selected for On-Site Tests

The Phase V test mines of Eagle Mountain Iron Ore Mine, Decker Coal Company and Erie Mining Company agreed to continue the Phase V tests and add the new right-hand 30" convex mirror and the LP BAVs.

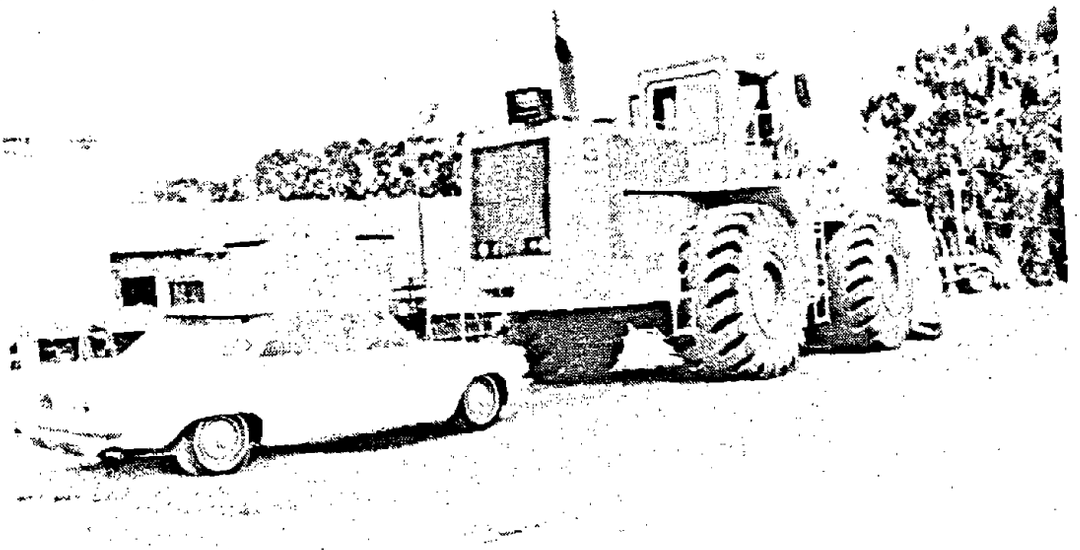
Washington Irrigation and Development Company in Centralia, Washington, Syar Industries' rock quarry in Vallejo, California and the test proving grounds of Fiat-Allis were selected as test sites to test the BAVs on front-end loader application. The test of the night light for the BAV was to be done at Hanna Mining Co's National Steel Pellet Plant in Keewatin, Minnesota.

2.5 Vehicle Model and Sizes

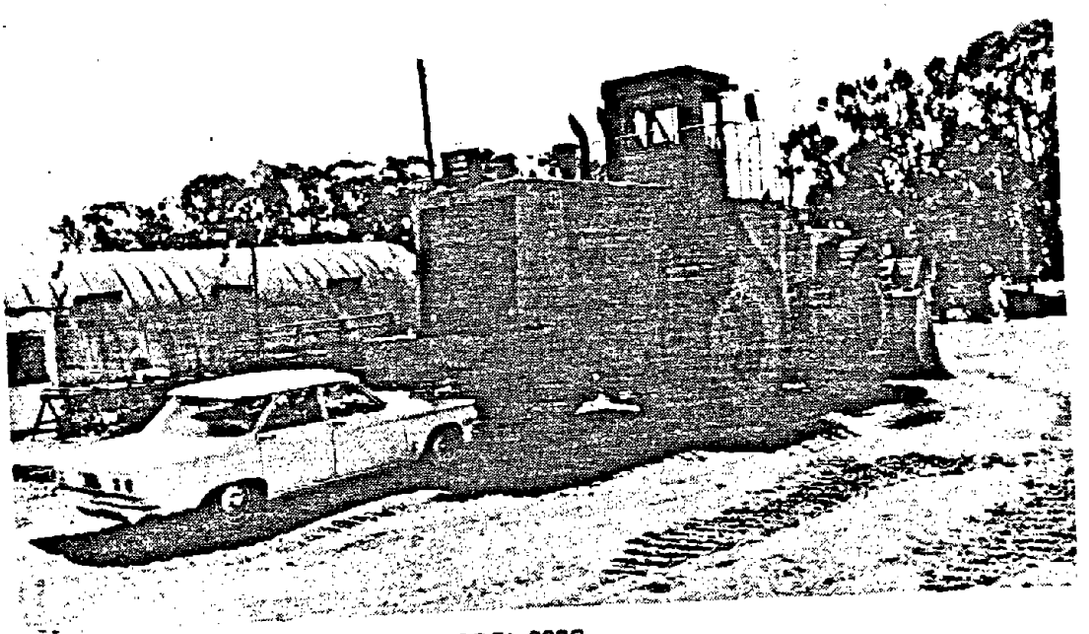
The vehicles selected for the front-end wheel loader application tests were a 988 and a 992 Caterpillar, Dart 600C and a Fiat-Allis 945B. The Caterpillar loaders were located at Syar Industries. The LP was installed on the 988 and the HP BAV on the 992. Photographs of these installations are shown in Figure 2.5-1. The Dart 600C loaders used in the field test were located at Washington Irrigation and Development Co. in Centralia, Washington. Two high profile and one low profile BAVs were installed. Photograph in Figure 2.5-2 shows the LP BAV installed on a Dart 600C wheel loader. The Fiat-Allis 945B was located at the Fiat-Allis test proving grounds in Illinois.

2.5.1 Critical Dimensions

The critical dimensions of each loader in respect to the BAV application are shown in Table 2.5-1. These data were taken from sales literature. The graphically plotted blind areas of each loader,



MODEL 988B



MODEL 992C

FIGURE 2.5-1
BAV ON CAT LOADERS

1741-17363

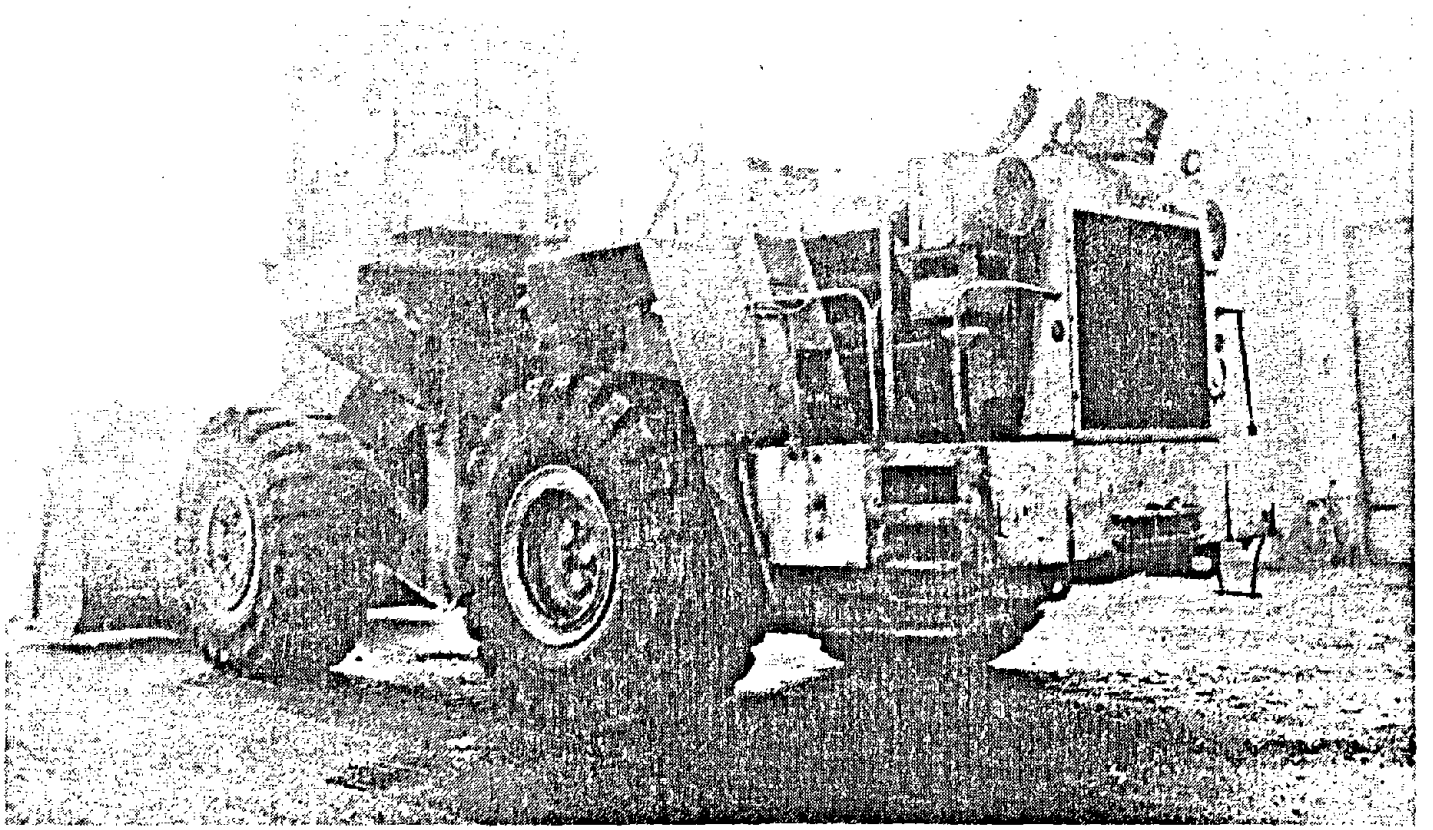


FIGURE 2.5-2
BAV ON DART 600C LOADER

MODEL	UNITS	A	B	C	D
CAT	FT	8' 8"	9' 9"	13' 6"	15' 1"
988B	mm	2640	2970	4130	4600
CAT	FT	10' 7"	11' 6"	18' 0"	19' 2"
992C	mm	3226	3505	5487	5842
CLARK	FT	12' 0"	14' 8"	20' 6"	21' 9"
675	mm	3657	4470	6248	6629
DART	FT	10' 0"	12' 6"	17' 0"	18' 5"
600C	mm	3048	3810	5181	5918

A = WIDTH OF BODY AT REAR
B = CAB HEIGHT
C = HEIGHT OF BODY AT REAR
D = DISTANCE OF DRIVER FROM BAV

Dimensions are approximate and were obtained from sales literature.

TABLE 2.5-1
CRITICAL DIMENSIONS – WHEEL LOADERS

on which the blind area viewers were field tested, and the improved visibility obtained are shown in Figures 2.5-3, -4, -5 and -6. The areas were plotted using the data in Table 2.5-1.

2.5.2 Vehicles Selected for Test Units

The trucks selected for the 30" radius of curvature rectangular convex mirror were:

Truck 7420 Euclid 170 ton at Erie

Truck 613 Terex 150 ton at Eagle Mountain

Figure 2.5-7 is a photograph of the installation at Eagle Mountain Iron Ore Mine.

The trucks selected for the new LP blind area viewers were:

Truck 7423 Euclid 170 ton at Erie (one on the front and one on the right side)

Truck 615 Terex 150 ton at Eagle Mountain (one on the right front corner and one on the right side)

Truck 48 Terex 170 ton at Decker Coal (one on the right front corner)

Truck 23 Euclid 170 ton at Decker Coal (one on the right side)

Figure 2.5-8 contains two photographs showing the installation at Eagle Mountain and Decker coal.

2.5.3 Night Light Installation

Figure 2.5-9 is two photographs showing the night light installation at National Steel Pellet Company in Keewatin, Minnesota. The BAV was a test unit supplied by USBM's Twin Cities Research Center in Minneapolis, Minnesota.

2.6 Technical Discussion of BAV Improvements

The changes or improvements to the BAV were to facilitate cleaning the lens, to reduce objectionable glare and to investigate night lighting.

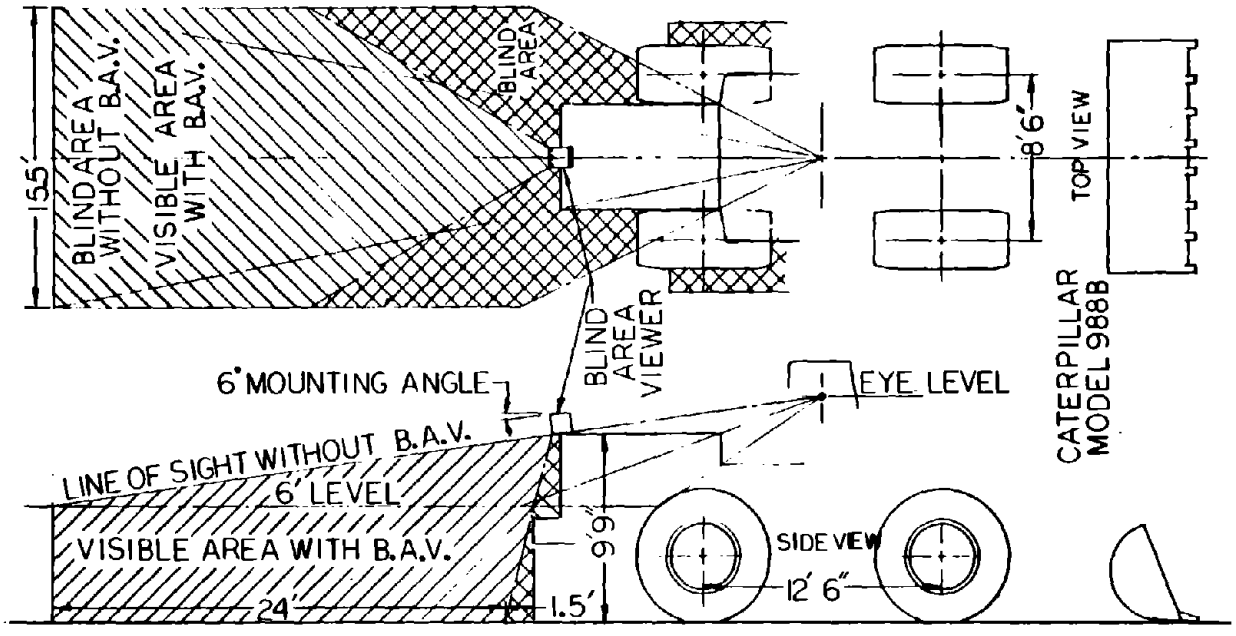


FIGURE 2.5-3
CATERPILLAR 988B LOADER
BLIND AREAS AND BAV IMPROVEMENTS

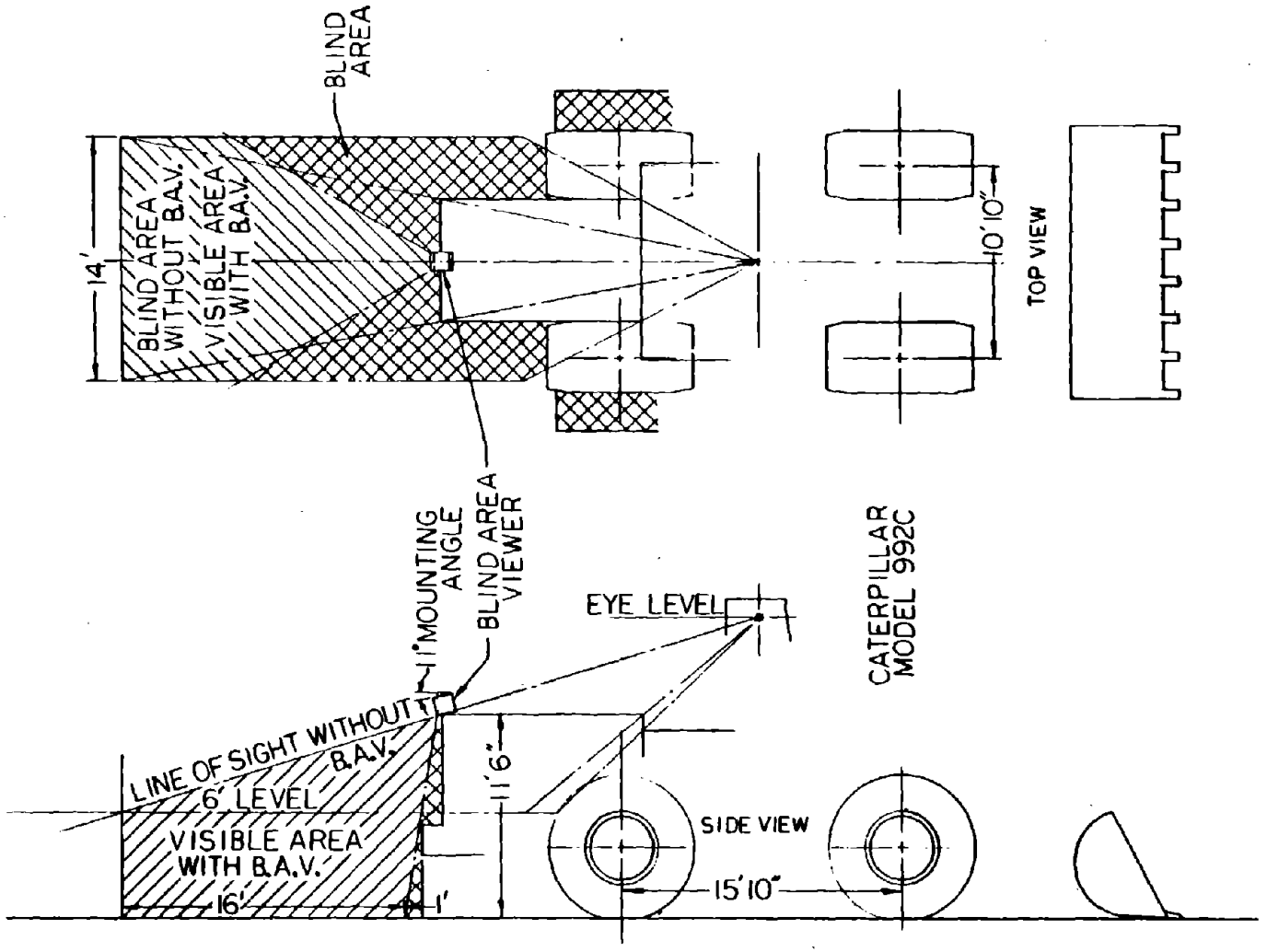


FIGURE 2.5-4
CATERPILLAR 992C LOADER
BLIND AREAS AND BAV IMPROVEMENTS

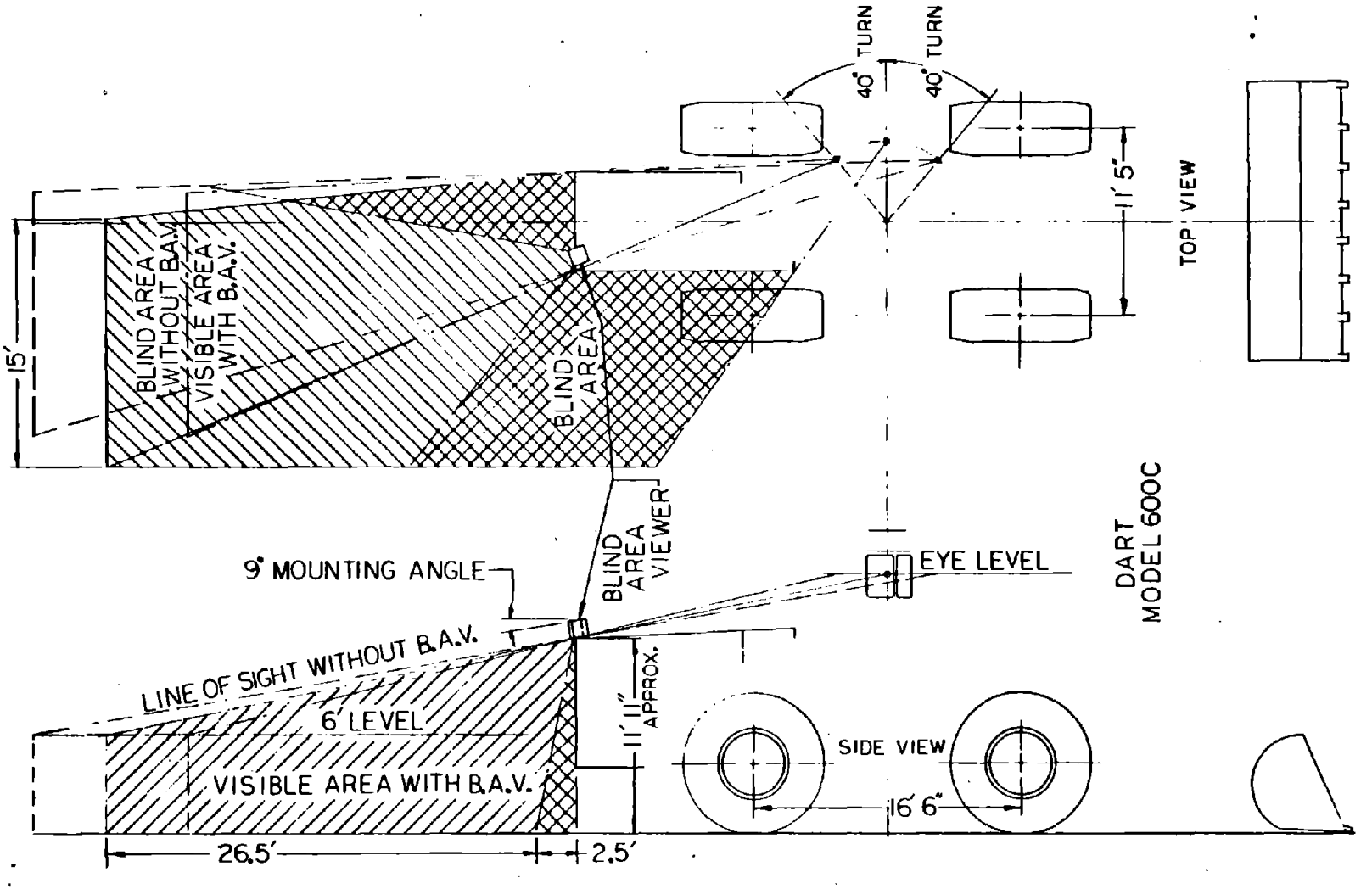


FIGURE 2.5-5
DART 600C LOADER
BLIND AREAS AND BAV IMPROVEMENTS

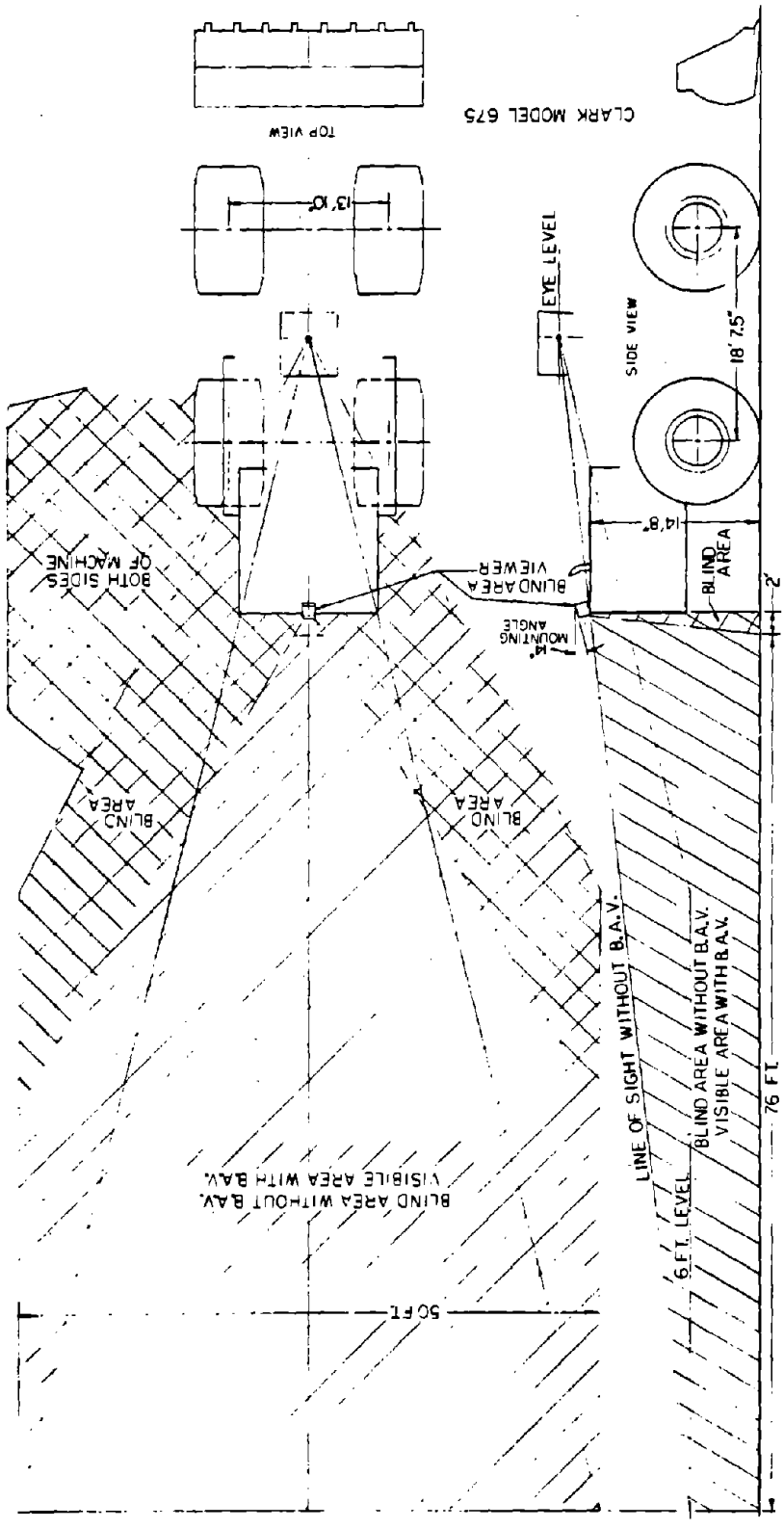
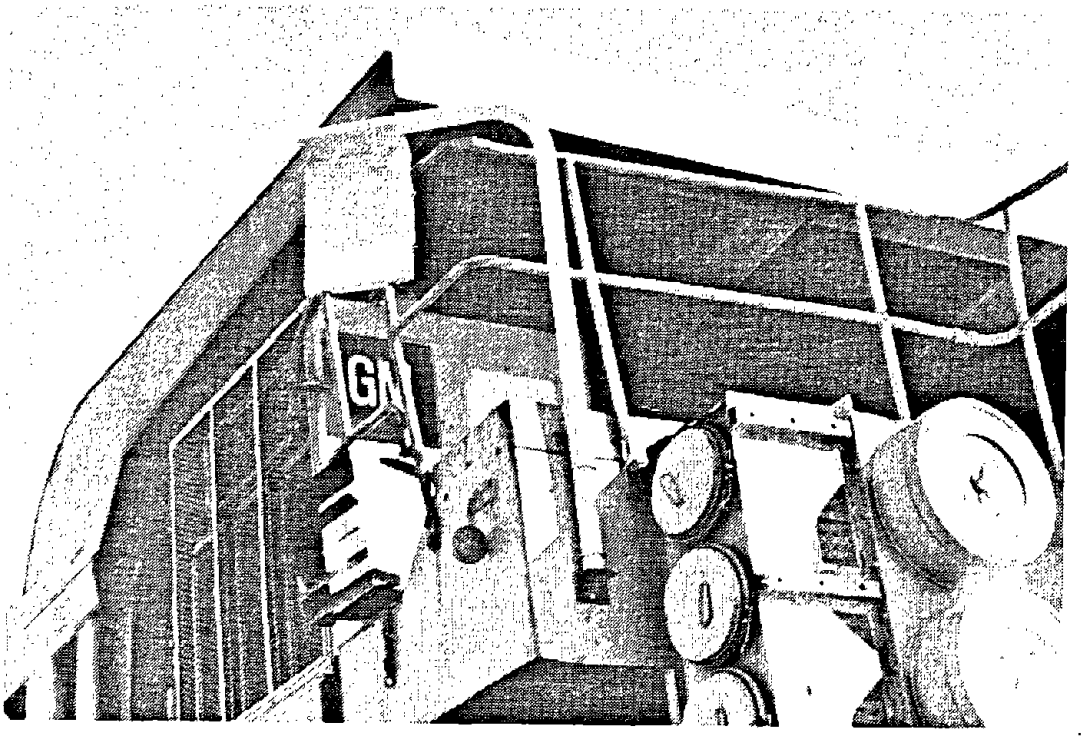


FIGURE 2.5-6
CLARK 675 LOADER
BLIND AREAS AND BAV IMPROVEMENTS



HIGH PROFILE BAV AND 30" CONVEX - RECTANGULAR MIRROR

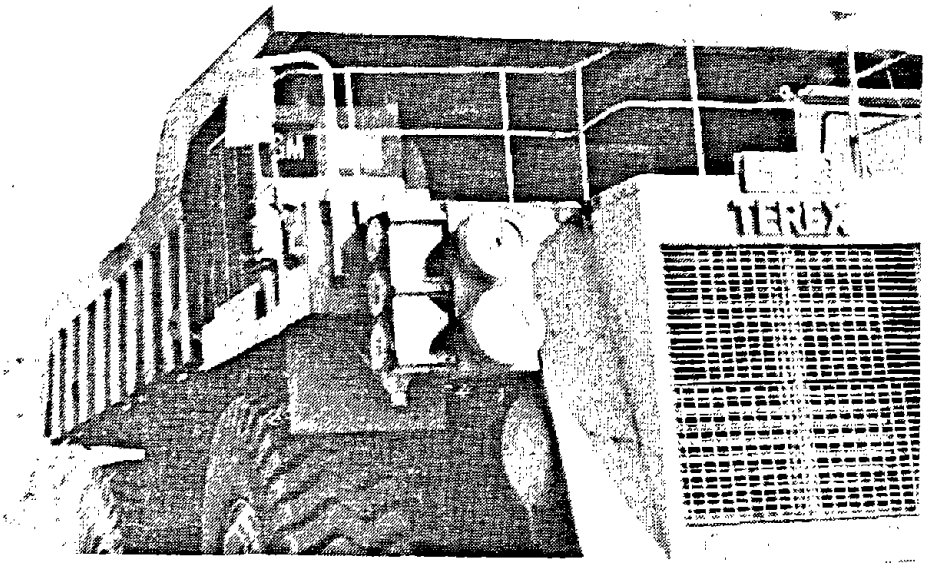
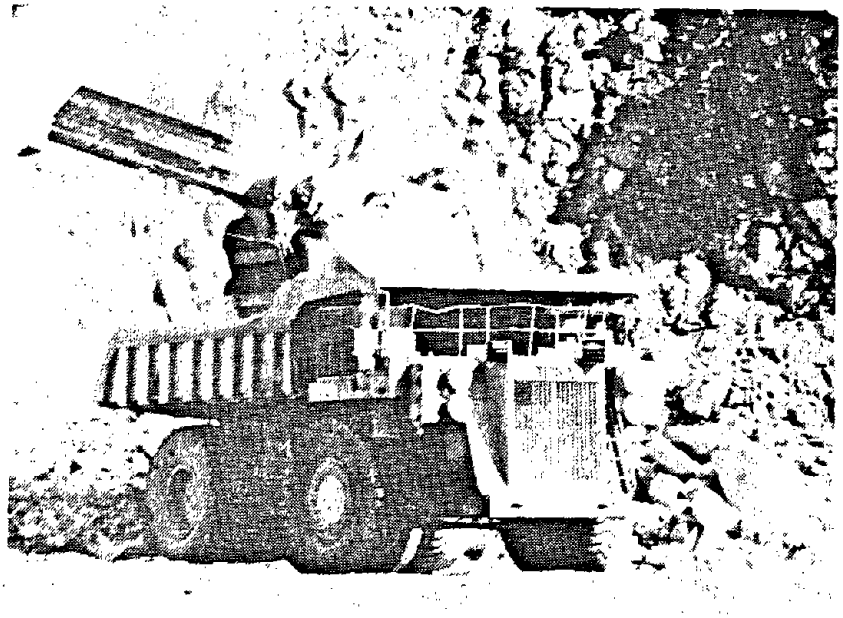


FIGURE 2.5-7
MIRROR INSTALLATION – 30" CONVEX - RECTANGULAR
EAGLE MOUNTAIN IRON ORE MINE

1741-17369

Tracor MBA



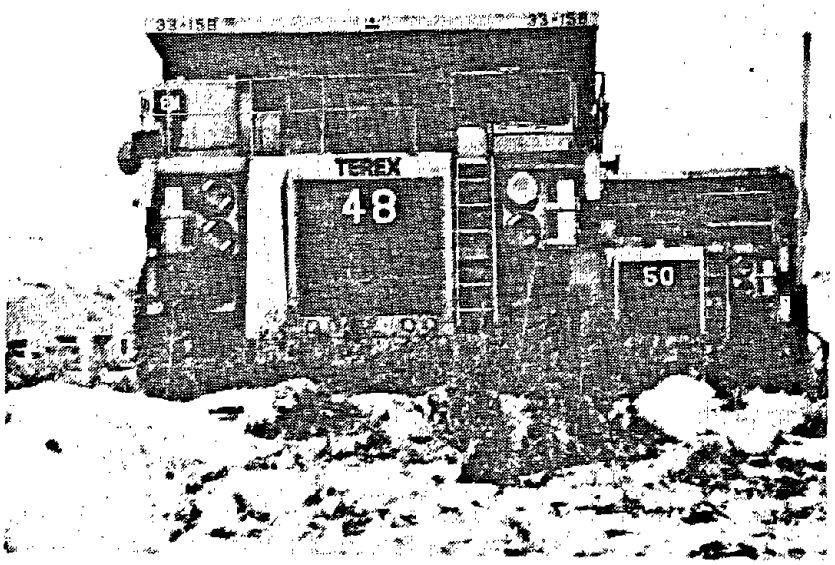
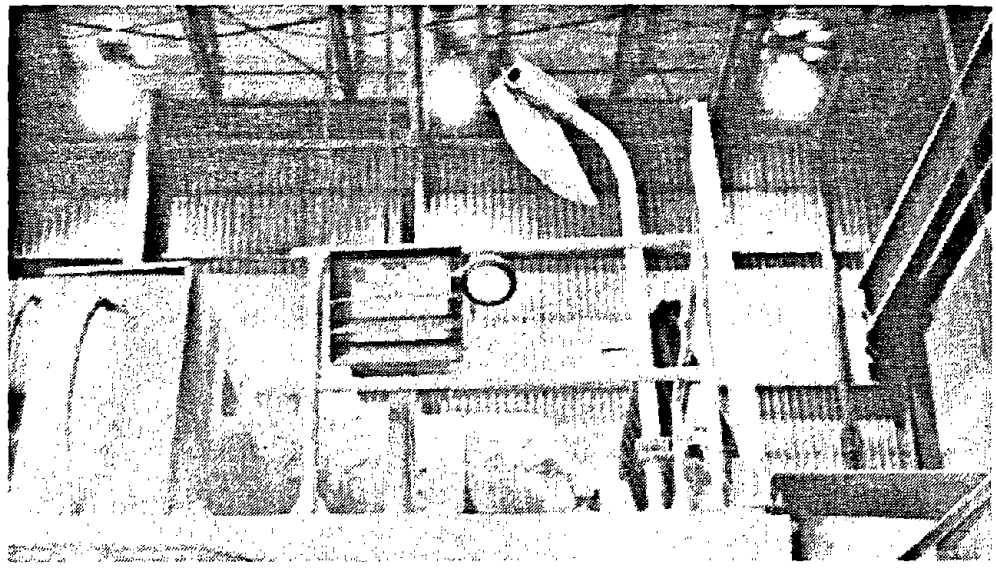


FIGURE 2.5-8
BAV INSTALLATIONS AT TWO TEST MINES

1741-17370



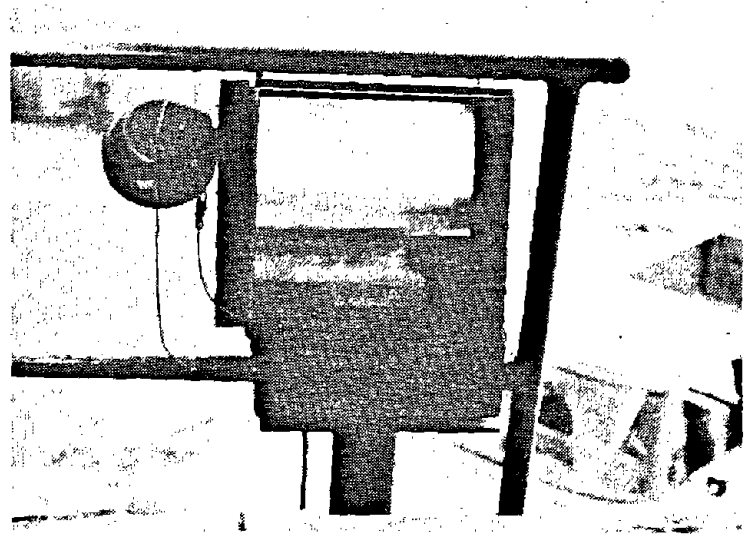
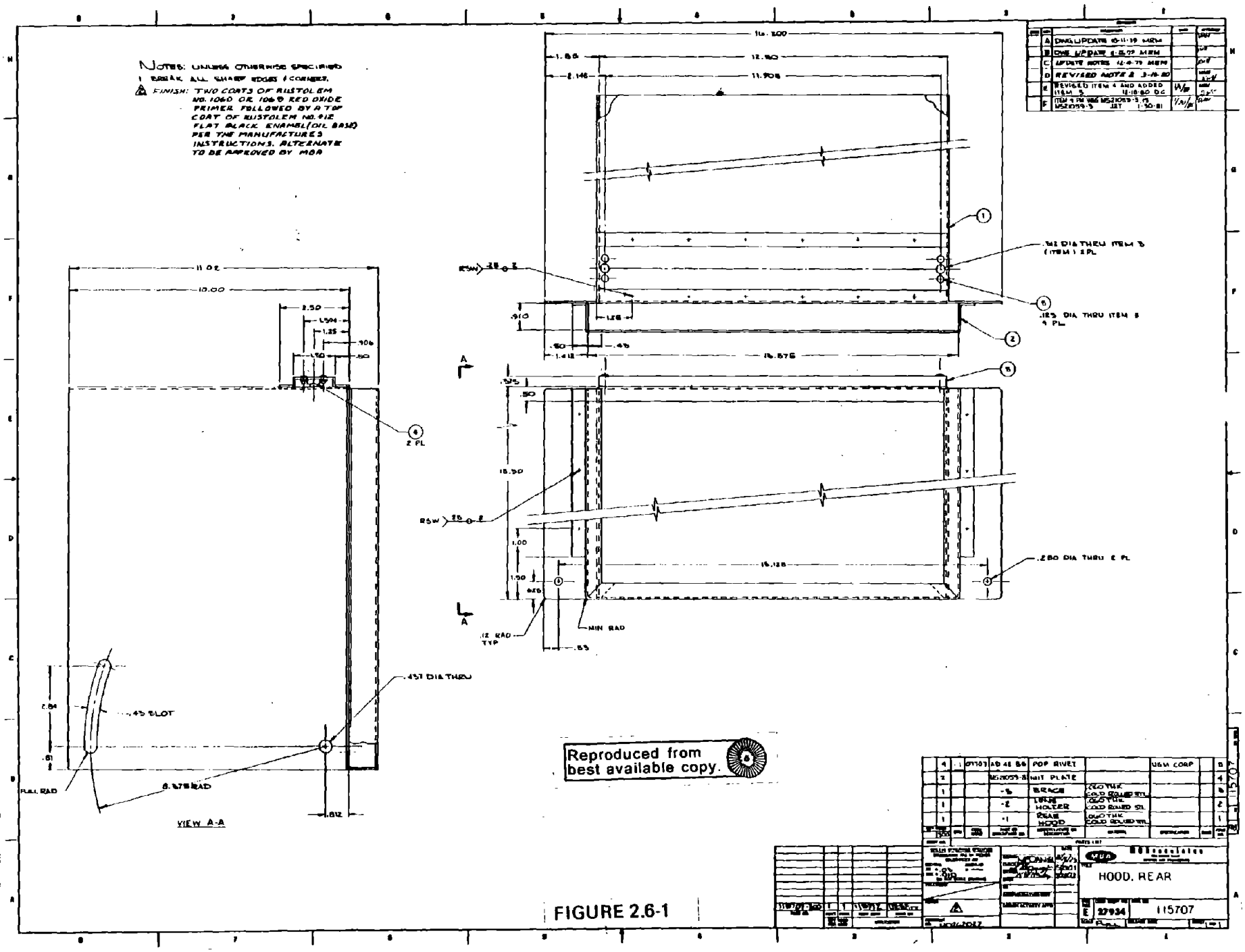


FIGURE 2.5-9
LAMP MOUNTED ON BAV FOR ILLUMINATION AT NIGHT


NOTES: UNLESS OTHERWISE SPECIFIED
1 BREAK ALL SHARP EDGES & CORNERS.
4 FINISH: TWO COATS OF RUSTOLEM NO. 1060 OR 1069 RED OXIDE PRIMER, FOLLOWED BY A TOP COAT OF RUSTOLEM NO. 912 FLAT BLACK ENAMEL (OIL BASE) PER THE MANUFACTURER'S INSTRUCTIONS. ALTERNATE TO BE APPROVED BY MOA
11.200
12.150
11.905
.375 DIA THRU ITEM 5 (ITEM 1 2 PL)
.125 DIA THRU ITEM 5 4 PL
15.875
15.125
.280 DIA THRU 2 PL
.12 RAD TYP
.MIN RAD
11.02
10.00
2.50
1.504
1.25
.906
1.50
.50
2 PL
.451 DIA THRU
.45 SLOT
2.84
.81
FULL RAD
8.375 RAD
.812
VIEW A-A
Reproduced from best available copy.
DWG UPDATE 10-11-79 MRM
DWG UPDATE 5-8-79 MRM
UPDATE NOTES 12-6-79 MRM
REVISED NOTE 4 3-18-80
REVISED ITEM 4 AND ADDED ITEM 5 10-10-80 DC
ITEM 3 PN WAS MS21059-3 (3) MS21059-5 JET 1-30-81
AD 48 S6 POP RIVET
MS21059-8 NUT PLATE
-5 BRACE
-2 LEAN HOTEER
-1 REAR HOOD
CRES THK COLD ROLLED STL
USM CORP
HOOD, REAR
115707
27934
FIGURE 2.6-1

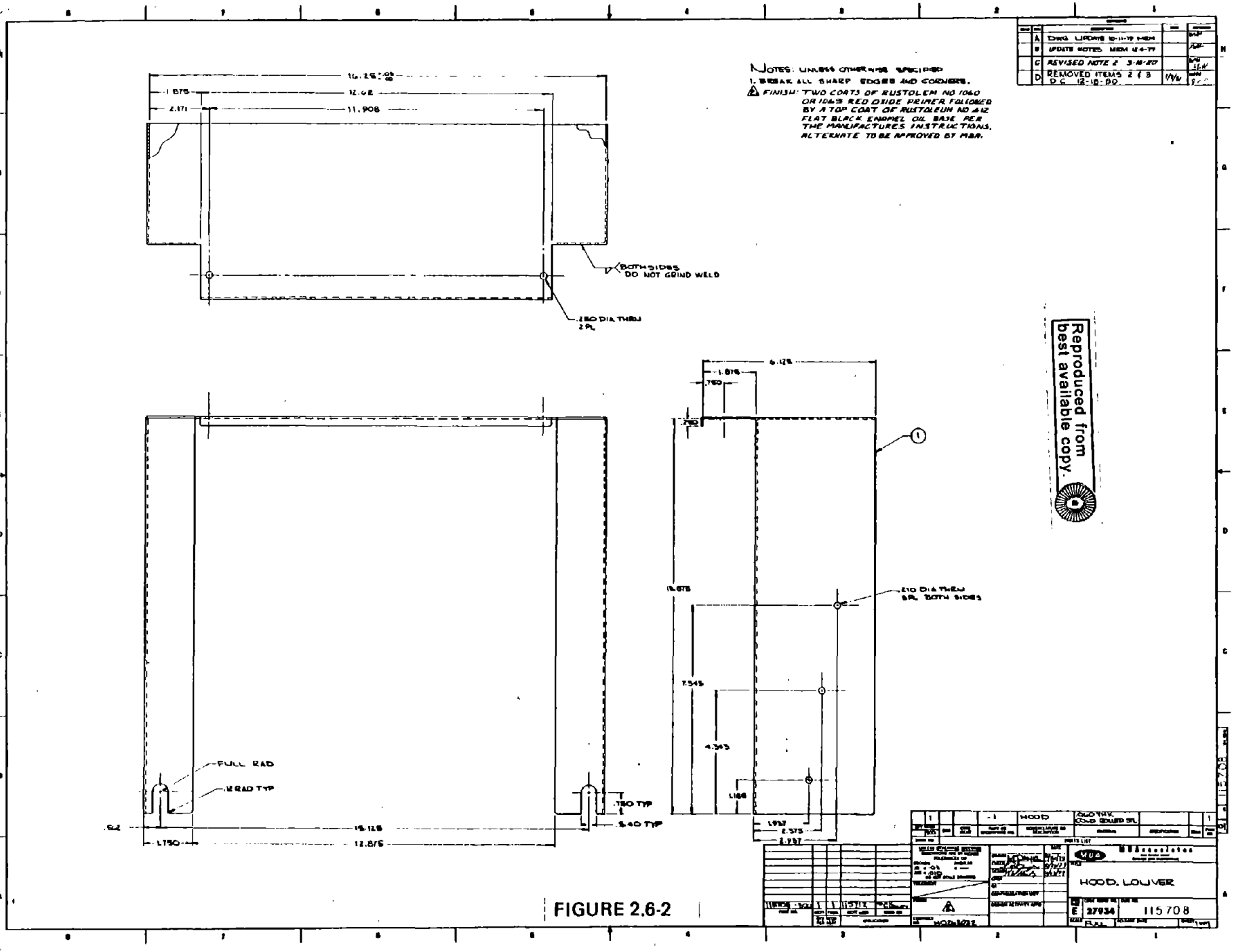


FIGURE 2.6-2

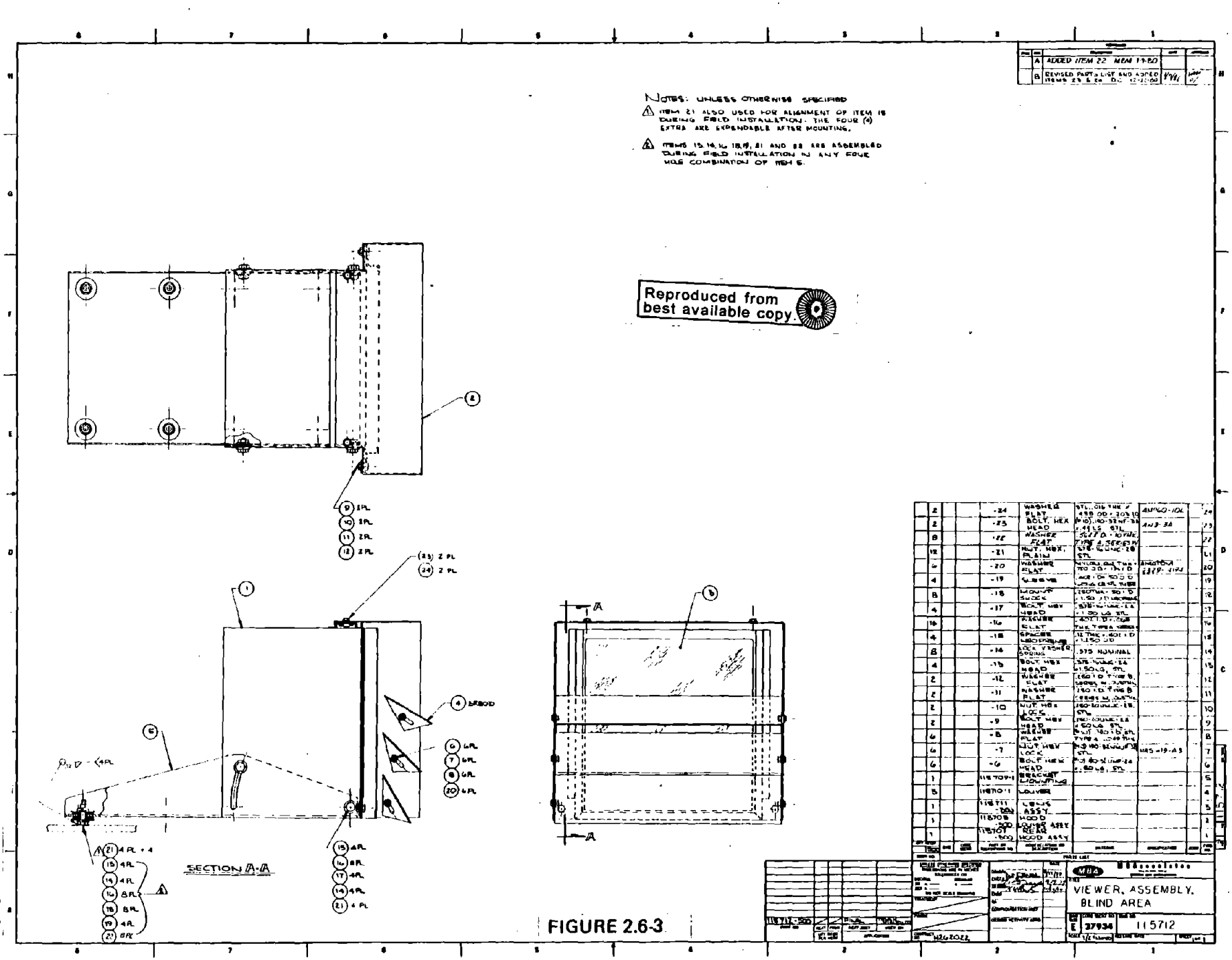


FIGURE 2.6-3

2.6.1 Facilitating Cleaning

To facilitate cleaning, the lens housing was redesigned for quick and easy removal of the louver hood to expose the outer surface of the lens. Figures 2.6-1, -2 and -3 are drawings of the rear hood #115707, louver hood #115708 and viewer assembly #115712, respectively.

The lens holder, item 2 of drawing 115707, is an integral part of the rear hood. The louver hood was attached to the rear hood with six bolts and nuts. The redesign provides for the attachment by means of slotted slide connections at the bottom corners and held in place by two fasteners at the top. Figure 2.6-4 is an exploded view of the blind area viewer which illustrates the simplicity of assembly and disassembly.

2.6.2 Reduction of Glare

To reduce the amount of glare and reflections from direct sunlight, the top two inches of the lens were removed and the height of the hoods reduced the same amount producing a lower profile structure.

The top two inches of the lens contained the upward 15^{o} deflection portion of the lens which tended to pull the low angle sunlight rays into the lens. Taping over this section in earlier tests disclosed this portion of the 12" x 14" lens was not needed.

In addition, various other means were investigated to reduce reflection by the use of add-on cover films, non-reflection picture glass and coatings. The most promising was an optical coating produced and marketed by Optical Coating Laboratory Inc. OCLI's specification for this coating, "HEA 11-002C Multi-layer Antireflection Coating for Contrast Enhancement Products No. 6020020", is included in the appendix. Two lens assemblies were fabricated using safety glass made from glass treated with this coating and compared with a normal lens in a mockup demonstration.

The lenses were fabricated by first treating both sides of the glass plates from which the safety glass was formed with OCLI - HEA 11-002C coating. This treated safety glass was then used to sandwich the fresnel lens in the regular manner.

EXPLODED VIEW

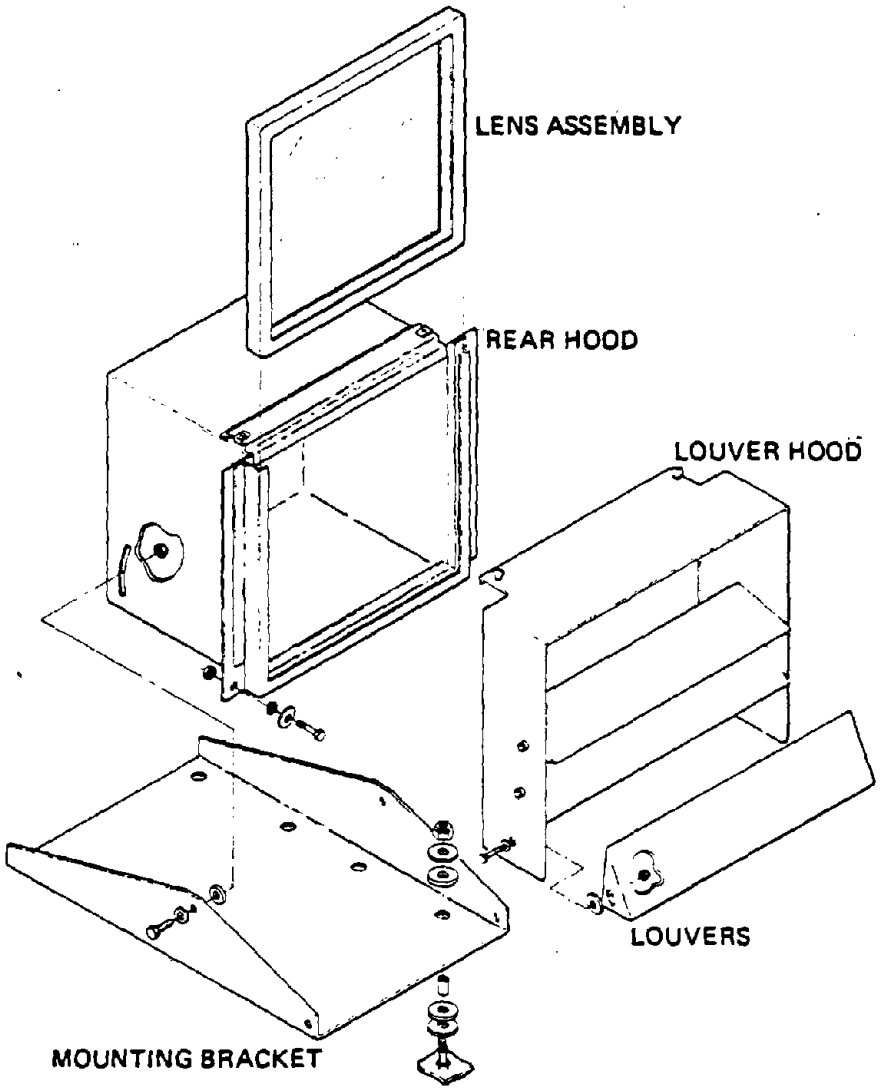


FIGURE 2.6-4
LOW PROFILE BLIND AREA VIEWER

The cost of producing such a lens in safety glass was approximately $200.00. The plan was to demonstrate these on the mine test site where the reflection complaints were the greatest. However, there were no complaints regarding the reflection after the low profile BAVs were installed.

2.6.3 Night Lighting

A Hobbs heavy duty shock mounted tractor head lamp was installed on a BAV that had been provided to National Steel Pellet Company by U.S. Bureau of Mines. To facilitate installation, the light was mounted on a spare louver hood which was then used to replace the original louver hood in the field. The model lamp chosen was M-2095 with a 4578 Par 46, 28 Volt sealed beam bulb having the flood characteristics of 55° x 25°. The electrical connection was made using a pushbutton switch with contact made, turning the light on, while the button was being held down. This light was off when the driver was not using the viewer.

2.7 Technical Discussion of BAV Application to Front End Loaders

Front end or wheel loaders (FEL) have continued to become larger as have the haulage trucks and other mining equipment used in open pit mining. They have become so large that an area of considerable size directly behind the loader cannot be seen by the driver even with rear-view mirrors. These blind areas were shown in Figure 2.5-3, -4, -5 and -6. The blind areas for some of the largest loaders were large enough to hide a pickup truck or normal size car. Figure 2.7-1 is a series of photographs depicting a hidden car behind a Caterpillar 992C loader. There have been several accidents in which FELs have backed over automobiles. One accident resulted in legal action taken against an original equipment manufacturer.

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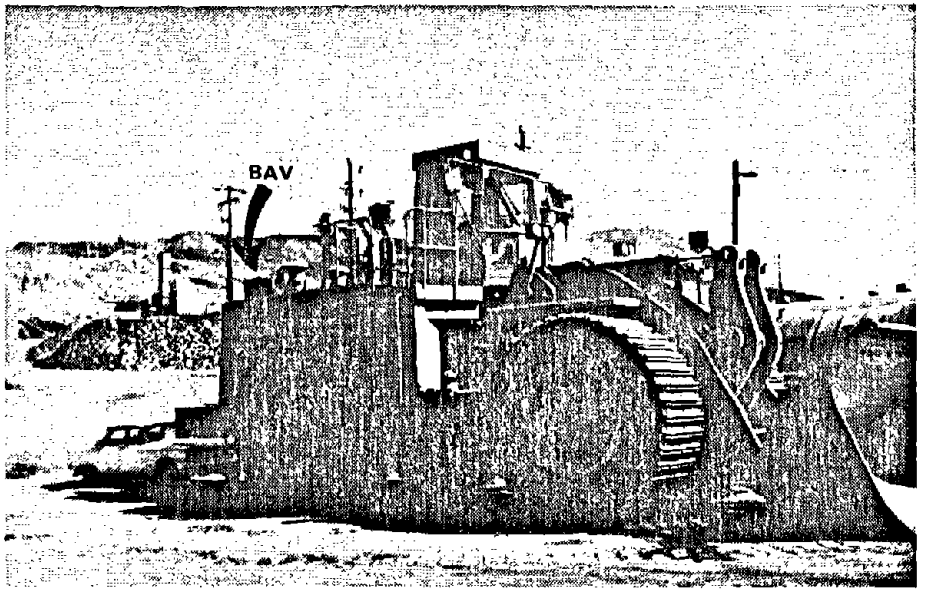

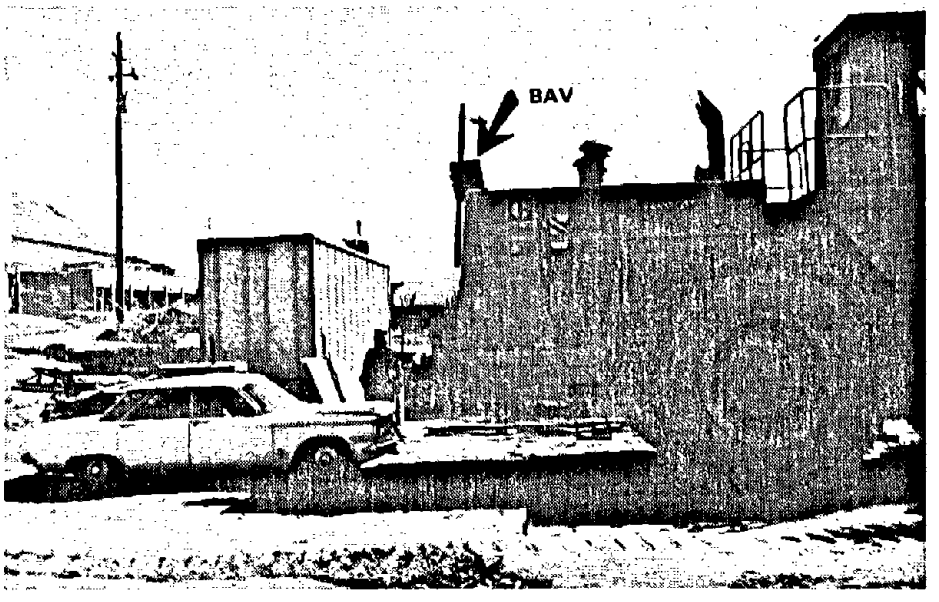

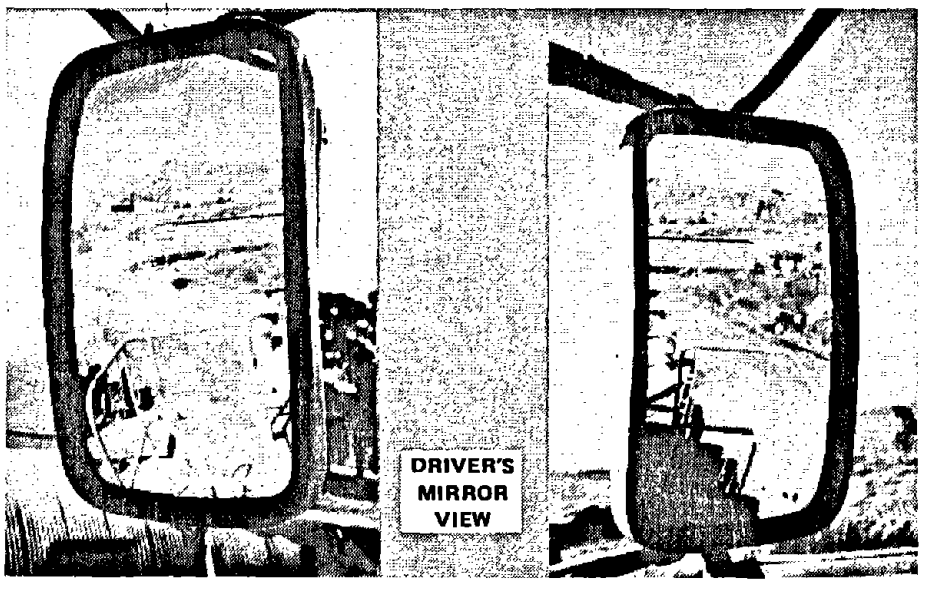

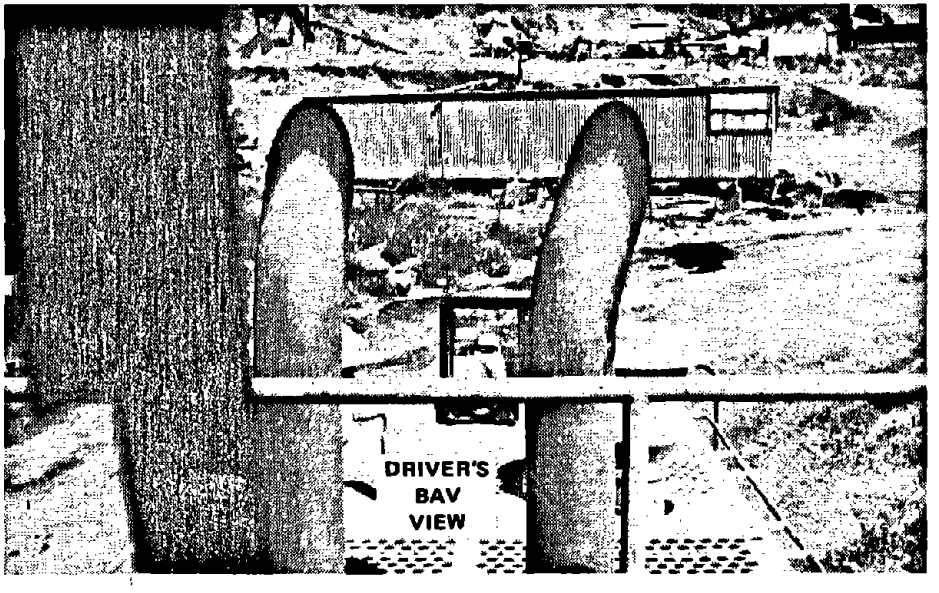

FIGURE 2.7-1
BLIND AREA VIEWER ON "CAT" 992C LOADER

2.7.1 Caterpillar Loader Installations

There was no difficulty installing the viewers on the loaders. The Caterpillar loaders were used in a rock quarry operation and the BAVs were not bothered by vibration or dust. A viewer was installed on a Cat 988B loader. However, this loader was not large enough to actually require a viewer. It was reported that the drivers did find the BAV useful to watch the connection of a trailer or more accurately gauge his position when backing up to an object.

2.7.2 Fiat-Allis Loader Installation

Fiat-Allis was first interested in the possible application of a BAV to a crawler tractor pulling a ripper in order to watch the ripper blade during operations. However, this did not prove practical as the support structure for the ripper was in the line of sight. The BAV was then tried on a loader. It was reported that it did function as intended and was not affected by the vibrations or the dust to any objectionable extent. A letter and sketch from Fiat-Allis describing the applications and test results are included in the appendix. The loader was a 945B model and not large enough to benefit greatly from the BAV.

2.7.3 Clark Loader Installation

Clark Equipment Company, Construction Machinery Division, was supplied three BAVs by the USBM which they installed on their Model 675 tractor shovel, front-end wheel-loader. They installed the three BAVs, one on each side and one on the rear in an attempt to obtain complete coverage. However, these were perhaps a little overwhelming to the operator who requested that they be removed. Possibly the operator may not have been properly prepared or fully informed about the viewers. This same reaction was received from some truck operators when three (3) BAVs were installed and the drivers not adequately informed of the BAV's capabilities and purpose.

On most all mining properties the large equipment is given the right-of-way because of the blind areas. The operators, of course, do not want to give up that right-of-way and rightfully so. The operators should not be led to believe they will be held responsible for all accidents after the BAVs are installed. The BAVs should be added for the convenience and assistance to the driver in order to make his job easier to avoid hazards.

The non-acceptance by the truck drivers occurred on one of the test mines when three BAVs were installed on each of the trucks. However, at the other two test mines the complete installations were accepted by the drivers. Some even preferred to keep the BAVs mounted on the front of the vehicle, particularly the low profile model. However, some did ask to have those on the front removed as they were seldom required.

2.7.4 Dart Loader Installation

Two high profile and one low profile BAVs were installed on three DART 600C wheel loaders at Washington Irrigation and Development Co. in Centralia, Washington. The 600C is an articulated loader with the cab moving in the opposite direction of the bucket swing. The movement of the cab in relation to the rear of the vehicle where the BAV had to be mounted was at first thought to be a problem. However, with the cab offset to the right when the bucket is straight forward, it was possible to offset the BAV on the hood cover, positioning it where the driver could see it at all times.

Using an automobile as a target (located in the normally blind area) the loader operator swung the bucket to both left and right positions and found he could still see the BAV's lens. The target could be seen in the BAV from all positions. See Figure 2.7-2.

The low exhausts did pose a problem in causing the lens to soot rapidly. To minimize this problem, the hood of the BAV could be extended four to six inches and the exhausts lengthened twelve to eighteen inches.

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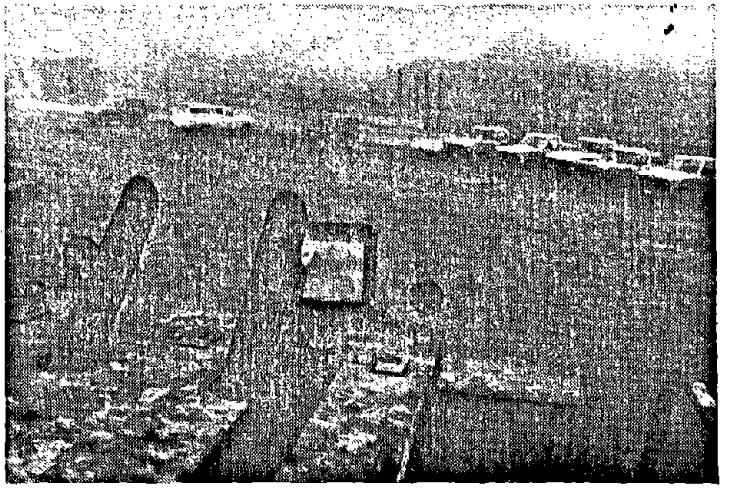
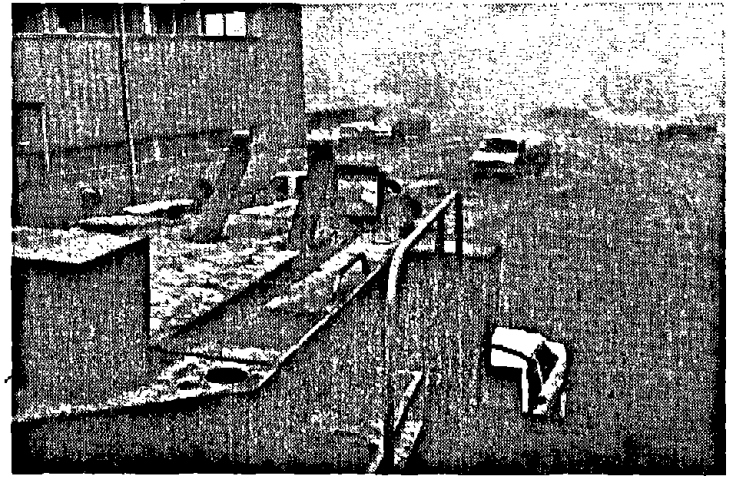
AUTO IN BLIND AREA



OPERATOR'S VIEW
BUCKET POSITION – LEFT

OPERATOR'S VIEW
BUCKET POSITION – STRAIGHT AHEAD



OPERATOR'S VIEW
BUCKET POSITION – RIGHT

FIGURE 2.7-2
DART 600C LOADER WITH BLIND AREA VIEWER

2.8 Technical Discussion of Right Side Mirror

2.8.1 Size

The rectangular, 12" x 20", convex 30" radius of curvature mirror used for a right-side rear-view mirror was tested to determine if the extra length of four inches would be detrimental to obstructing the operator's view. It provides a larger image than the 20" radius which is preferred. The extra length is necessary to provide the same field of view in the vertical direction as obtained with the 20" radius mirror which includes both the top of the truck body and the bottom of the rear wheel. Since it does produce a larger image it consequently has a smaller field of view. Image size in a convex mirror is inversely proportional to the distance to the object and to the number of degrees between the light rays from observer to object. See Figure 2.8-1.

2.8.2 Mounting

The method of mirror mounting was tested using simple U bolts. The test unit at Eagle Mountain was bolted to the front edge of the truck deck with a small angle-iron stop at the bottom. The mounting installation is shown in Figure 2.5-7, page 53.

Controlling the tightness of the U bolts produced a swing-away friction mount which is less costly and easier to adjust than the slip ring arrangement of the first design.

2.9 Test Results

Personal inspection trips to the test site mines were limited to the installation and removal of the LP BAV and the 30" radius of curvature rectangular mirrors. Test results were obtained by telephone contact with safety departments and maintenance supervisors plus a final report from the safety and mine managers. Thus, the results reported are not as detailed or as precise as might have been obtained through direct personal contact with all drivers during the test period.

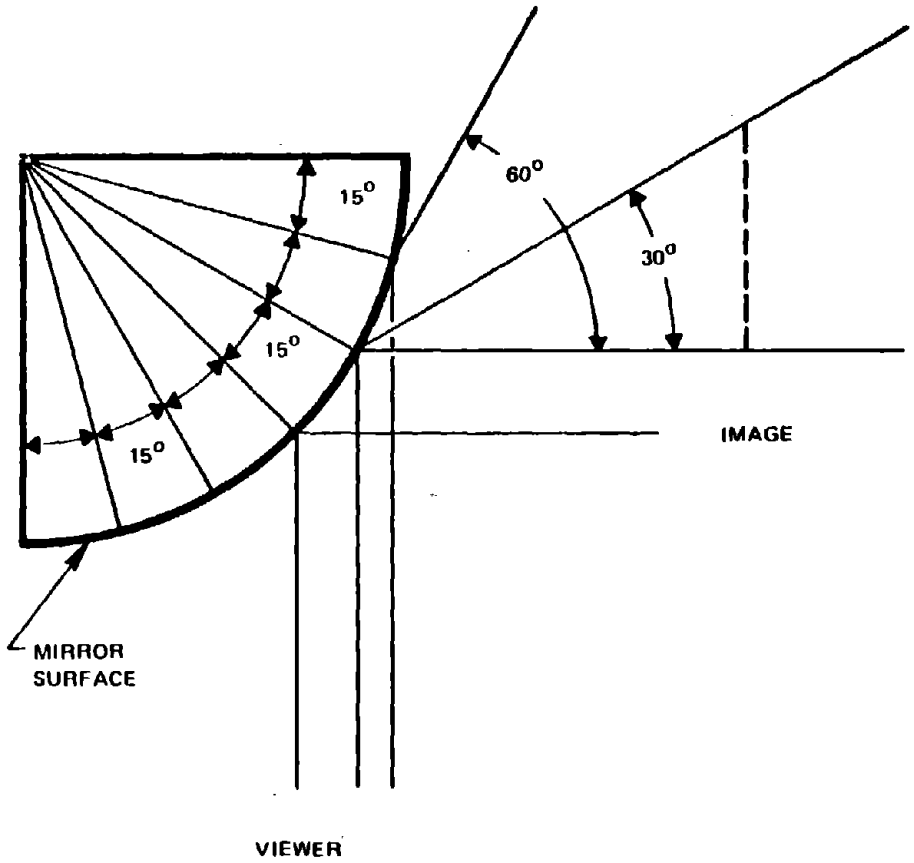


FIGURE 2.8-1
RELATIONSHIP OF IMAGE SIZE TO ANGLE AND DISTANCE

2.9.1 Blind Area Viewers

The reports and comments received on the low profile Blind Area Viewer (LP BAV) were such that the attempt to provide improved visibility was considered successful. Driver acceptance of the BAV mounted on the right was universal at all three test mines.

There were no more complaints on reflections or light glare with the low profile BAV. Comments received regarding cleaning mentioned that it was now easier to clean the lens with the readily removable louver hood on the new LP model.

Specific inquiries were made concerning objectionable reflections in order to locate a test site to demonstrate the new experimental lens that had been treated with the anti reflection coating material. However, no such comments were obtained from either of the three test mines.

2.9.2 Anti Reflection Treated Lens

The BAV lens with anti reflection coating was tested by comparing it with a non-treated lens in mockup demonstrations. The two BAVs were mounted on a table with casters so it could readily be moved to different positions. A colored object was placed on the ground and photographs were taken of the images produced in the BAVs under varying sunlight conditions. A series of photographs taken of this test demonstration are shown in Figures 2.9-1, -2 and -3. Note the degree of reflection of the photographer in the BAV lens.

Under the most adverse conditions (that producing the greatest reflection) the treated lens reflected approximately 75% less than the non-treated lens. This condition existed with the viewer well illuminated and the object in deep shadow.

Some difference, but not as large, was observed and recorded under other light conditions, such as direct sunlight in the lens from front, back and side lighting.

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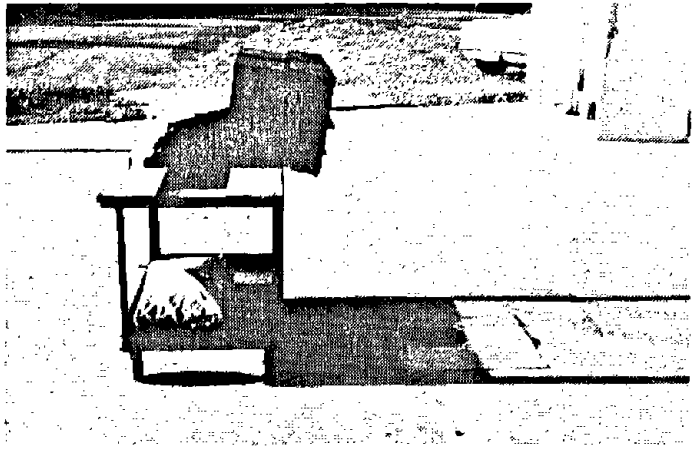
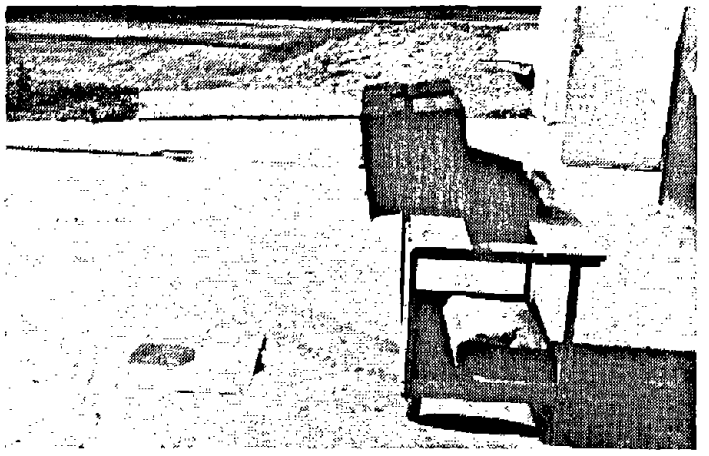
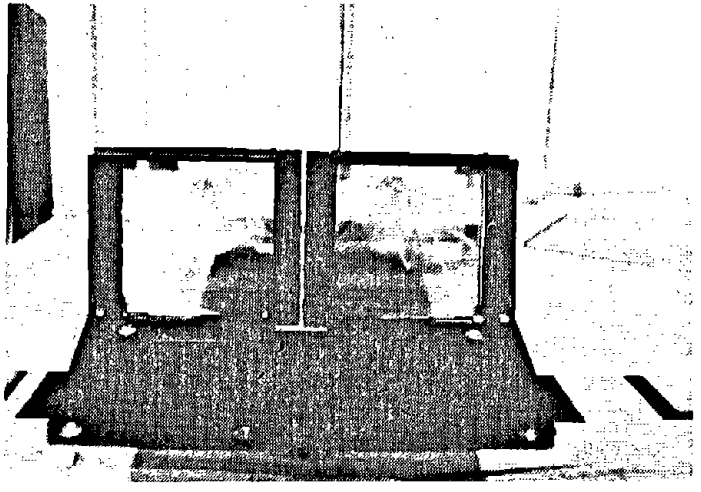
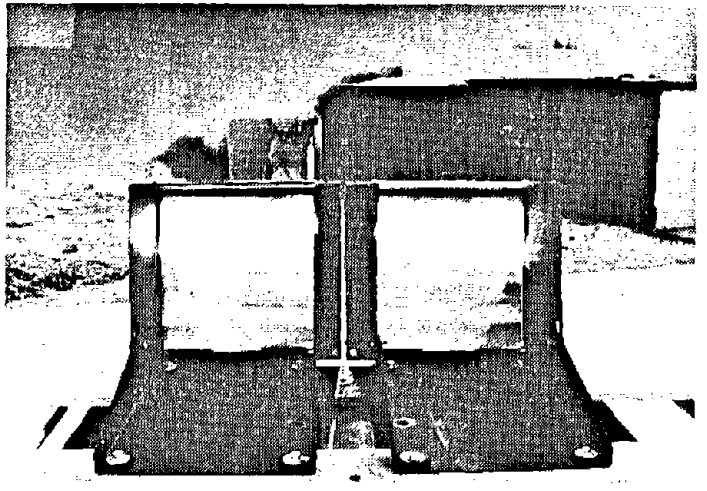




LOW LEVEL SUNLIGHT





SUN REFLECTION (TREATED LENS ON RIGHT) SUN GLARE

FIGURE 2.9-1
LABORATORY TEST ANTI-REFLECTION TREATED LENS

Tracor MBA

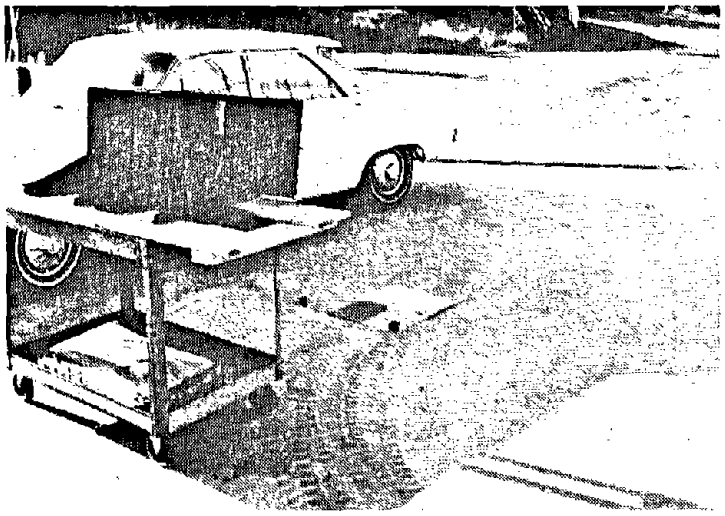
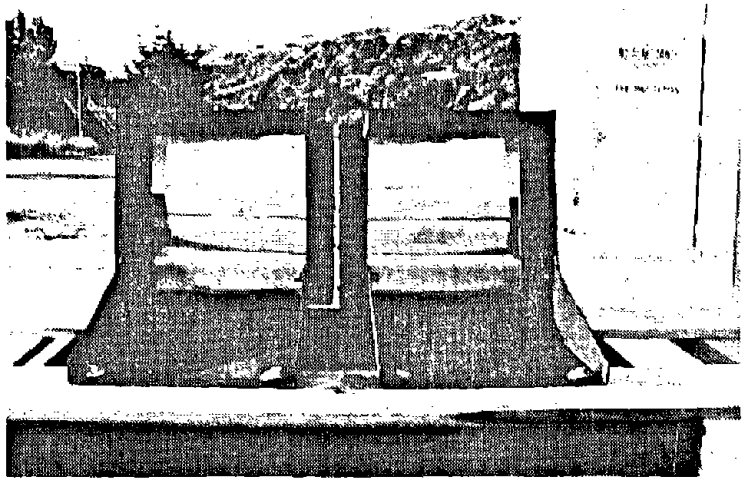
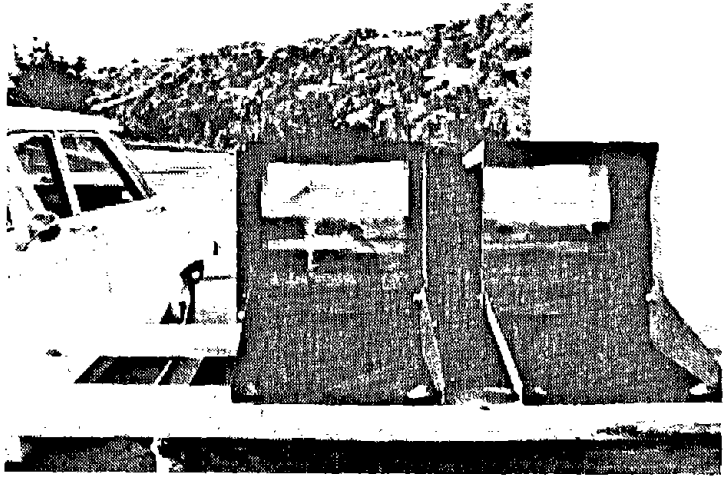
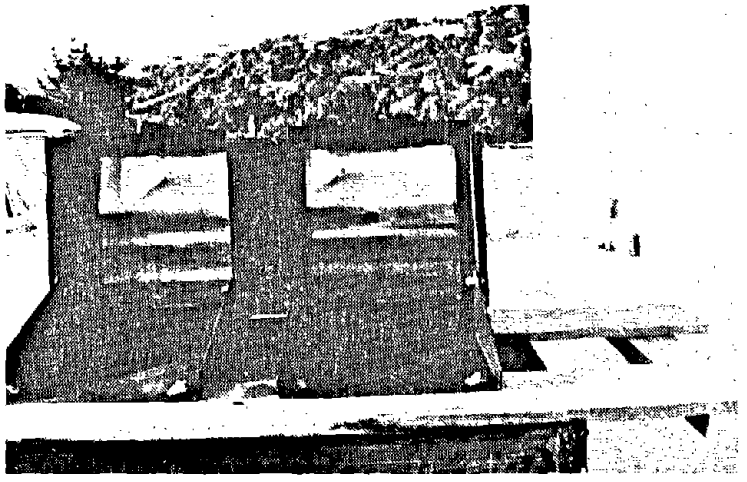


IMAGE IN SHADOW



NO SHADOW – DIRECT SUNLIGHT





TREATED LENS ON RIGHT

FIGURE 2.9-2
LABORATORY TEST ANTI-REFLECTION TREATED LENS

Tracor MBA

OPTIMUM LIGHT CONDITIONS FOR MAXIMUM REFLECTION
TREATED LENS ON RIGHT

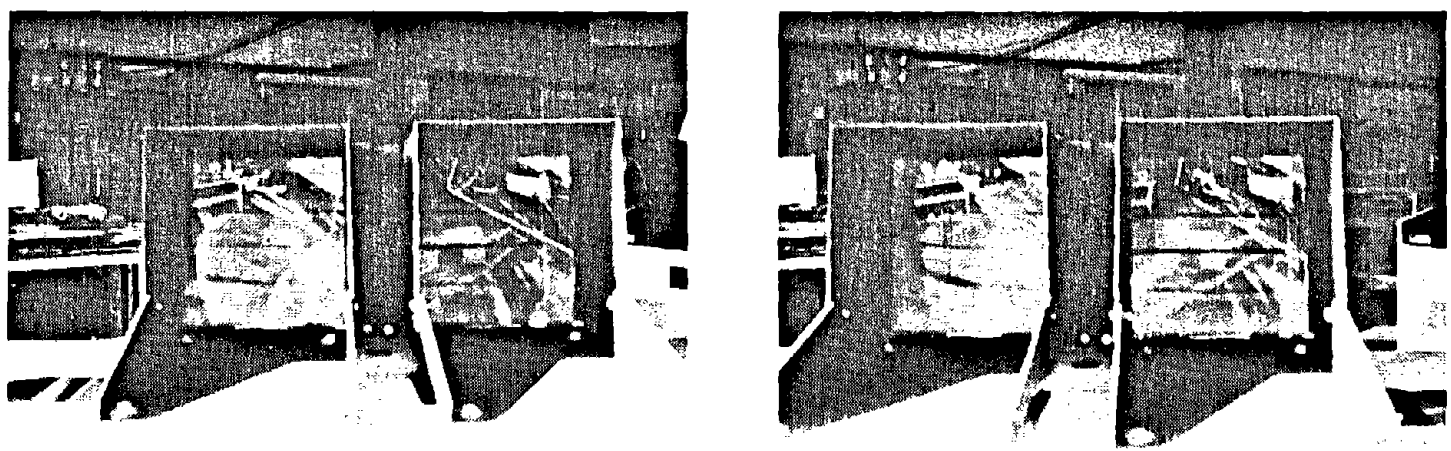


FIGURE 2.9-3
LABORATORY TEST ANTI-REFLECTION TREATED LENS

The treated lens did have greater light absorption as the images were not as bright as in the untreated lens under most all light conditions. However, the image did appear to be more distinct under the optimum reflection condition since it did not exhibit the strong reflections to interfere with the image.

2.9.3 Night Light

The illumination produced by the lamp was very bright in the center portion of the BAV's lens (vertical). The lamp had been positioned with the 55° portion of the beam in the vertical direction. Since the horizontal field of the BAV's lens is an overall 60°, the 25° spread of the light was concentrated in the center portion of the lens.

One driver said he would like to have the light stay on all the time as he used the BAV to determine how close he was to the berm (right side of the road traffic). Thus the light was evidently bright enough to make this distinction possible.

Even though the side portions of the BAV's field-of-view were less illuminated, it appeared to be sufficient illumination to discern objects of contrasting colors to the ground. The sealed beam lens will be rotated 90° to change the illumination spread 55° horizontal and 25° vertical which is expected to provide more uniform illumination over the critical area of the BAV's field-of-view.

2.9.4 Right-Hand Mirror

The right-hand rear-view mirror (the experimental rectangular, 12" x 20", 30" convex) mounted with simple U bolts on a 2" pipe support performed very well during the test demonstration. The mountings held firm throughout the full test. There was no reported accidental striking of the mirror housing which would have tested the swing-away feature of the friction between the U bolts and the support pipe. This condition was tested manually at installation and before removal from the truck and found that the mirror supports would twist in the mountings.

All drivers interviewed who had used the large 30" radius mirror preferred it to the other smaller mirrors with 20" radius. They did not feel the size interfered with their direct vision.

2.10 Summary of Phase VI

2.10.1 Blind Area Viewer

The improved design of the BAV to facilitate lens cleaning and to reduce glare and reflection by removing the top two inches of the lens and lowering the height of the housing respectively was proven to be effective in actual field tests. There were no complaints from the drivers regarding glare and reflections and there was mention that the lenses were easier to clean now that the louver hood could readily be removed.

2.10.2 Right-Side Rear-View Mirrors

The new experimental 30" radius convex rectangular 12" x 20" mirror with a simplified mounting performed well during the in-mine tests. All drivers preferred its larger image and the mounting survived well under the rigors of the open pit iron ore mining operations in southern California and in northern Minnesota. The 30" radius convex mirror was preferred over the smaller mirror by all drivers having the opportunity to use both.

2.10.3 BAV Application to Wheel Loaders

Blind Area Viewers were tested on Caterpillar 988B and 992C loaders. The 988B proved to be too small to benefit from the BAV since its blind area was small enough to pose no problem. The blind area was covered sufficiently with the rear-view mirrors. The 992C loader was of sufficient size that the viewer did prove useful to the driver and it survived and performed well in a rock quarry operation.

The Fiat-Allis loader also was too small for the beneficial application of the BAV, but testing indicated that dirt and vibration would not be a problem when the BAV is used on wheel loaders.

The DART 600C articulated loader had a changing blind area depending upon the bucket position. However, the BAV appeared to be applicable since the driver could see the BAV's lens which covered the blind area for any particular bucket position. When the bucket's horizontal position changed, the rear of the vehicle and consequently the BAV coverage also changed to a small extent. The operators on the property where these tests were run were not pleased with the BAV but they had also not been fully informed of the BAV's principle of operation. The photography in Figure 2.7-3 illustrates how well the BAV does cover the blind area. The drivers suggested they would like to have something they could use to see into the blind area without turning their head to look.

2.10.4 Anti Reflecting Lens BAV

The anti reflecting lens made by coating both sides of the glass used to make the safety glass (coating HEA 11-002X multilayer anti reflection coating for Contrast Enhancement Products) demonstrated in laboratory mockup tests a considerable reduction in reflection compared to a non-treated lens under maximum reflection lighting conditions. The amount of reflection reduction was estimated at 75%. Under normal lighting conditions the amount of reflection or glare produced by the LP BAV was not enough to warrant the extra cost of the anti reflection treatment. However, in special circumstances it may prove to be cost effective.

2.10.5 Night Light

The night light was successful to the extent that it can be recommended as an add-on kit for those installations where it is desired. For permanent mounting, a Universal bracket should be used for mounting the lamp in the upper corner of the rear hood on the side of the BAV where it would be most desirable for that particular installation. The Universal bracket is attached with two 1/4" bolts. It is estimated at this time that the lighting kit would cost approximately $100 FOB factory.

3.0 FINAL ANALYSIS PHASES IV, V AND VI

3.1 Safety Aspects

The amount of safety improvement obtained with the improved visibility system could not be ascertained by using only three operating trucks. The number of accidents were not reported as being less with these trucks than with the other trucks over the test period. If all trucks of a mine had been equipped with the visibility systems for a year and that year's truck accidents compared with other years, a definite percentage could have been obtained.

The test trucks at each mine were reported as not having any accidents during the test period. Also, during this period, no other trucks were reported having had any accidents that might have been prevented if the operator had had better visibility.

However, it can reasonably be assumed that an alert and confident driver will be a safer driver than one who is tired or under tension. Fatigue can be increased by the tension of not knowing if any hazards might be in the blind area into which the truck is about to travel. Thus, if the driver knows the area is clear by the use of a CCTV, a good rear-view side mirror or BAV, he should suffer less fatigue caused by anticipation of the unknown and be a more alert, efficient and safer driver.

3.1.1 Collision Avoidance

Even with the improved visibility aids a driver may become sleepy, or inattentive and not see or be aware of a hazard before it is too late to avoid a collision. To overcome this problem, Tracor MBA is engaged in other U.S. Bureau of Mines R&D projects to help prevent accidents. They are:

- Driver Alertness Monitoring
- Radar Transponder Anti-Collision Systems for Large Mine Haulage Trucks

In the driver alertness monitoring program, Contract No. H0282006, the driver is monitored by electronic means to determine his degree of attentiveness and warned by appropriate devices, lights or voice messages when his response indicates he is not alert.

In the Radar-Transponder Anti-Collision System, Contract No. H0202004, the radar transponder technology will be used for detecting moving or far-out objects, warning the driver when he is on a collision course and also when he is in imminent danger of an accident. For those objects close to the truck, ultrasonic devices are being investigated for use in detecting the hazardous object and in warning the driver by appropriate signals to look for the object.

For more information on these on-going Research and Development Programs, write to Guy A. Johnson, U.S. Bureau of Mines, Twin Cities Research Center, 5629 Minnehaha Ave. So. Minneapolis, MN 55417.

3.2 Productivity Effect

Time and motion data were not taken and thus no quantitative measurement made in the productivity of the test trucks equipped with the visibility systems over those trucks not equipped. No truck downtime caused by an accident that might have been prevented with better driver visibility was reported for any of the trucks in the test mines during the test period.

However, if a downtime accident can be prevented by the use of the improved visibility devices, then the availability of that particular truck is greater, which could result in increased truck haulage productivity.

Open pit mine productivity is measured by shovel and loader output which is greatly affected by truck availability. The shovel and loader have their maximum production when there is no waiting for trucks. Also, if a truck is equipped with good visibility aids, there is less chance for the truck to be side-lined because of an accident. Good visibility can minimize tire problems (driver can avoid hazards that cut tires if he can see the hazard).

It is reasonable to expect that a more confident driver, able to see all around his vehicle, can perform the maneuvers necessary in and around the load and dump areas more quickly than if he has to rely on guess work that the area is clear. By performing these maneuvers more quickly the increased productive or haulage time has been estimated at approximately 8 hours per month, assuming the driver can save 20 seconds per cycle during the maneuvering and final positioning of his truck at the load and dump areas (based on 21 minutes average cycle time and 525 operating hours per month). The eight hours gained per truck-month would approximate 24 extra truck loads of ore hauled per month per truck in operation.

3.3 Cost Effectiveness

Cost effectiveness is an evaluation of the initial cost plus maintenance versus the amount of savings that can be attributed to the device being evaluated.

The cost of the visibility aids were readily determined for those units on the test. The maintenance cost was derived as an average per unit based on possible expected usage (using test results) such as a lost unit, broken lens or damaged housing caused by rock falls, etc. These are shown in Table 3.3-1.

For a cost effectiveness ratio, the value of a visibility system in terms of reduced percentage of injuries and property damage would be needed along with an estimate of increased productivity and employee morale. These factors were not possible to obtain during the in-mine testing.

The concepts of "cost benefit" and "cost effectiveness" have come into increasing usage in recent years in an effort to justify (or attack) an existing or proposed safety program. As O'Neil and Kelley[1] point out in their informative paper, both of these concepts are often misunderstood and misused. Appendix A contains a discussion of this complex issue.

(1) O'Neil, B. and Kelley, A.B. "Costs, Benefits, Effectivenss and Safety: Setting the Record Straight", Society of Automotive Engineers reprint - No. 740988, 1974.

UNIT	COSTS $			
	Purchase	(xx) Installation	(xx) Maintenance Yearly	TOTAL
LEFT MIRROR	(xx) 250	40	60	350
RIGHT MIRROR	(x) 400	20	100	520
BAV	(x) 650	20	175	945
CCTV	(xx) 3000	160	1000	4160

(x) Present commercial prices

(xx) Estimated

TABLE 3.3 1
COSTS OF VISIBILITY SYSTEMS

The benefits of improved visibility would vary considerably at different surface mines due to the individual character of the mine. Each particular mine operator can best make an assessment of potential benefit based on a first-hand knowledge of injury accidents, property damage and tire maintenance costs. Improved visibility for haulage truck operators could result in potential benefits by reducing or eliminating:

- Disasbling injuries and fatalities
- Lost time injuries
- Haulage truck damage or loss
- Small vehicle losses
- Damage to shovels and structures
- Tire damage
- Low employee morale
- Production loss from accidents
- Production loss from poor visibility

These potential benefits, which can be realized in specific situations, are common in surface mining operations. The size and power of large haulage vehicles are such that even a minor accident can cause significant costly damage. Examples of situations where the benefit of improved visibility can be realized are as follows:

- Small vehicles parked or passing close to a stopped haulage truck can be detected by the driver before moving his haulage truck forward, backward, or to the right. A safe path certainly would result.
- When backing to the shovel, spotting, position and shovel body clearance can be judged with more certainty which results in improved vehicle control. Tire damaging rocks can also be avoided.

- When backing to a dump berm, the location of the berm and its alignment can be judged more accurately while positive vehicle control is maintained.
- When maneuvering, road hazards such as rocks, holes and ditches can be avoided preventing tire damage and driver injury.
- In shop and utility areas, structures, equipment, vehicles and personnel can be detected and tight clearance maneuvers can be accomplished more safety.
- More certainty of a safe path would result in less stress to drivers and maneuvering around observable hazards would be expeditious for better time efficiency.
- Collisions with other haulage vehicles and embankments can be avoided if observed with an improved view.

Overall, it appears that the relatively low costs of improved visibility devices[1] would be offset many times over by the benefits. However, it is difficult to document those accidents that never happened because the driver saw the hazard through his visibility aid. Over a period of time, the benefits would eventually show themselves if detailed and accurate records were kept of minor as well as major accidents; however, such is not the usual case nor was it possible to obtain such records during the test period.

When taking the cost of the large haulage trucks into consideration, $250,000 and more, the costs to add on visibility improvement devices is very small. If they help increase production or just to keep the truck producing and help prevent damage or loss of such an expensive and difficult to replace vehicle, then the add-on costs can definitely be considered as cost effective and worthwhile.

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[1] Tracor MBA Factory List Prices for:

Blind Area Viewers - $650.00 each (lot quantities of 20)

Right Side Rear-View Mirrors 12"x20" with 30" Radius of Curvature - $425.00 each (lot quantities of 20)

3.4 Acceptance by Drivers and Management

In all cases where the individual driver was shown that the BAV was installed to help him without adding to his responsibility or eliminating any right-of-way for the vehicle, the driver accepted the BAVs and liked them, particularly those installed on the right side of the vehicle. They also liked the CCTV and greatly preferred the mirrors over the ones they had been using.

Management generally did not express an opinion of the visibility aids except for the safety officers who were very much in favor of all the visibility improvement devices tested.

3.5 Life and Durability of Visibility Aids

At the end of the long term field test program, the visibility aids were removed from the test vehicles, inspected and returned to the U.S. Bureau of Mines, Twin Cities Research Center.

3.5.1 Close Circuit Television Unit

One of the earlier models (even before the test was complete) had the camera enclosure completely flooded with water which destroyed the camera. This unit had not been sufficiently protected from the environment. Two other (improved/ruggedized) CCTV units stood up well to the environment with no noticeable abnormal deterioration. However, on both these units, the automatic iris of the camera's lens had vibrated apart as had happened in earlier tests.

3.5.2 Left-Side Rear-View Mirrors

One of each of the left-side rear-view mirrors at each test site suffered frame structure damage from being struck by extremities of other vehicles or fixed structures. The actual damage or accidents were not reported by the drivers in sufficient detail to determine if the design could be improved to provide greater life or durability. Only 30% loss in over 24 months of testing was not considered objectionable. Several mirror glass replacements were required for broken mirror glass caused by rock spills, collision, etc., (approximately 50%) but this also was not considered objectionable, or abnormal in an open-pit mine environment.

3.6 Industry Acceptance Results of Marketing Effort

Since the BAVs and right-hand mirrors were so well received by the test mines and appeared to be beneficial to industry, steps were taken to make them commercially available.

Tracor MBA manufactured a trial lot of BAVs and displayed one at the 198th International Coal Show in Chicago. The BAVs were offered at a low-discount-introductory price which a few companies and potential distributors took advantage of. As of this writing, eight mines have purchased trial units and many others have requested information for further consideration.

The right-hand or right-side (rectangular-convex) rearview mirror was also offered to industry.

The left-hand flat mirror will also be offered to industry if the market study indicates the mines will be willing to pay the cost of an improved version over those that are presently available.

The CCTV system will not be offered at this time, but may be considered at a later date when more durable and less costly components are available.

As of this date, mine management has been reluctant to invest the dollars needed to equip all their large haulage trucks with the BAVs and improved mirrors mainly due to the slump in business as a whole and lower demand for minerals. When business and the mineral demand improves, mine management may start including the available improved visibility aids in the specifications for all their new haulage trucks and loaders. In this way the haulage vehicles would be delivered to the mines with the increased visibility aids included in the approved capital investment for haulage units and no additional capital expenditure requests would be needed.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

- The closed circuit television system needs less costly, more rugged, longer lasting components to be cost effective and reliable, but that the system developed performs the functions well for which it was designed, i.e., to allow the truck driver to see directly behind the truck.
- The improved left-side rear-view mirror was superior and preferred by the truck drivers over those presently available in industry.
- The rectangular-convex mirrors for rearward viewing to the right-side of the truck were superior to the circular convex mirrors.
- The 30" radius of curvature mirror is preferred for its larger image. The two inches of extra length in the rectangular version was not detrimental to the driver's direct view.
- The fresnel lens Blind Area Viewer was the greatest innovation in visibility improvement.
- Standard off-the-shelf lamps can be added to the BAVs to provide illumination for their use at night.

4.2 Recommendation

- Continued publicity should be given the new improved visibility aids to inform the mining industry of their availability and of the possible benefits to be derived from their use.

5.0 APPENDIX

5.1 Appendix A

DISCUSSIONS OF COST VS BENEFITS

APPENDIX A

DISCUSSION OF COST VS BENEFITS

The concepts of "cost-benefit" and "cost-effectiveness" have come into increasing usage in recent years in an effort to justify (or attack) an existing or proposed safety program. As O'Neill and Kelley[1] point out in their informative paper, both of these concepts are often misunderstood and misused.

There is much room for discussion as to what is the appropriate criterion of statistical significance to apply in interpreting the results of such a program as visibility aids. In attempting to plan for a "before vs after" type of evaluation of accident occurrences, there is no pre-established significance level that automatically can be used. It is most appropriate that a study present the essential raw data as well as the level of statistical significance that was found. Then, arguments can be made in support of the particular acceptance level the authors choose to use. Some authors of scientific papers don't choose any level, but instead merely report the results and let the reader reach his own conclusions regarding the risks and trade-offs associated with accepting or rejecting the null hypothesis.

This is sometimes difficult to do, because one can only attempt to consider all the consequences and then decide whether or not there is enough likelihood for a real difference to have occurred to warrant making a decision. For example, the reader must decide whether a 5% or a 10% or a 20% chance of being wrong is worth the risk. However, there are two ways of being wrong, namely falsely accepting as being real a difference in accident experience that is actually only apparent, but not real. (This type of error is called "Type I"); and the risk of falsely rejecting a real difference ("Type II" error).

This hard fact of life for researchers is rather cumbersome. It is more clearly stated by the following diagram to show the various decision alternatives and possible errors in assessing the effectiveness of a visibility aid.

		True State of Affairs	
		The Aid is Effective	The Aid is Not Effective
Researcher's Decision	The Aid is Effective	Correct	False Alarm Type I error
	The aid is Not Effective	Miss Type II error	Correct

Usually it is not feasible to protect against both kinds of errors simultaneously. The decision-maker must, therefore, decide which kind of error would be the most severe and obtain greater protection against that particular kind of error. As related to the question of visibility aids, a Type I (false alarm) error would be to conclude that the aids are effective when they really are not. A Type II (miss) error would be to decide that the aids are not effective when they really are. Which ever error would hurt the most, that is the error for which one should make the greatest attempt to avoid.

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(1) O'Neill, B. and Kelley, A. B., "Costs, Benefits, Effectiveness and Safety: Setting the Record Straight, "Society of Automotive Engineers Reprint No. 740988, 1974

A related and very important point is that the researcher actually never has the option of saying "There was no difference." He can only state, "I found no evidence of a difference." There is a great and important difference between these two statements. For example, if one chooses to be 95% confident that he is not falsely accepting a "no difference" result (Type I), he might well be taking a very high (80 - 90%) risk of rejecting a real difference that would be of benefit (Type II, due to the small change in accident experience necessary to show a real benefit when an individual accident can cost several hundred thousand dollars.

This again brings us to a consideration of the appropriateness of the cost-benefit approach in evaluating visibility aids. In an excelelnt paper recently published on the topic, O'Neill and Kelley[1] agree with several other researchers who state that where the saving of lives and injuries is concerned, there is no adequate way to express "benefits" in dollars. Since comparable unit designation is a prime requirement for conducting a cost-benefit analysis, such analysis may not be valid. Actually, O'Neill and Kelley argue that it is not even necessary to perform a cost-benefit analysis, because it is more appropriate to perform a COST-EFFECTIVENESS evaluation, wherein the criteria do not have to be stated in terms of dollars. This argument is stated by O'Neill and Kelley as follows:

> "Cost-effectiveness analysis compares the cost of alternative means for effectively achieving an agreed upon goal. The means may be programs, technologies, devices, or combinations of approaches. The goals are often expressed in public policy as laws and standards.
>
> Much of the philosophy and methodology of cost-effectiveness analysis was derived from cost-benefit analyses. As a result, there are many similarities in the techniques and many people confuse the two." (pp. 3-4)

The authors go on to point out that in order to perform a valid comparison between two (or more) alternate means for attaining a goal (i.e., accident reduction), the capability of measuring the cost and effectiveness of each alternative must exist. However, while in the cost-benefit approach, both costs and benefits must be measured and compared in monetary units, the cost-effectiveness method requires that the systems being compared have common goals or purposes, which do not have to be expressed in monetary units.

In the case of visibility aids, their costs would be the basis for estimating how many accidents would have to be prevented by other alternative uses of the same amount of money. Apparently this type of evaluation has not yet been attempted for visibility aids and, indeed, O'Neill and Kelley condlue that it is not being used very much in general in high safety.

Since most, if not all, of the alternative methods for expending mine safety funds also cannot show "proof" of the number of accidents they would prevent, a cost-effectiveness evaluation of visibility aids cannot properly be accomplished, and it is possible that a decision to use them could therefore be based solely on the of the amount of increased visibility and consequent human factors advantages.

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(1) op cit

In any event, writers on the topic of cost-benefit analysis are in agreement that this analysis must take into account all of the costs, all of the benefits and all of the alternatives. For example, Pagano and Sauerlender,[2] in their most thorough discourse state:

> "Probably the most conceptually difficult aspect of benefit-cost analysis is the measure of the benefits of each alternative project or system. When the terminology "cost-effectiveness" is used, the measure is referred to as a measure of effectiveness. The analyst would have a comparatively easy task if all the benefits were known and could be quantified. This is not the usual case. Most benefits are subject to a great deal of uncertainty, and the analyst may not be able to estimate even the likelihood that a benefit may be at any given level. Some benefits and costs are not even subject to quantification. How does the analyst measure the increased security and well-being of society? He cannot even measure, let alone place a value on these benefits." (p. 160)

Even assuming that it were possible to list all of the benefits to be derived from the use of visibility aids, it would still be very difficult to perform a comprehensive cost-benefit analysis. We could never be sure that our information on the benefits was as accurate and complete as that on the costs, and it is highly unlikely that we would be able to apply a uniform quantification system to all the factors involved.

Pagano and Sauerlender cite opinions by many other authors, and the consensus seems to be that because of its limitations, benefit-cost analysis should be only one of the tools used by the decision-maker in determining the best course of action. If it is properly done, it can be the best tool the decision-maker has at his disposal; but it should seldom, if ever, be the sole basis for a decision.

When the listing of benefits is incomplete, as in the analyses performed in this study where we have concentrated largely on accident reduction, the results of the analysis are even less to be trusted. The analyses that have been conducted in this fashion are victims of the "sole criterion fallacy," described by Pagano and Sauerlender, which states that it is a fallacy to assume that a single criterion, such as accident reduction, can be used to evaluate all alternative safety programs. This is because of differences in complexity and other aspects among the various programs.

An additional problem that arises when using accident reduction in benefit-cost analysis is that it is very difficult to determine dollar costs for fatalities. O'Neill and Kelley[1] say it can't be done and recommend a cost-effectiveness approach to get away from the need to quantify benefits in monetary terms. The present authors agree, for it would make possible inclusion in the analysis such factors as driver comfort or stress, increased alertness, more efficient maneuvering, etc.

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(2) Pagano, A. M. andSauerlender, O. H., "Benefit-Cost Analysis", Appendix E in Roadway Delineation Systems, Washington, D.C.: Highway Research Board, National Cooperative Highway Research Program Report 130, 1972

(1) op cit

It is likely that one benefit of visibility aids would be a reduction in driver stress (increase in driver comfort) due to the increased visibility and resultant decrease in uncertainty. Pagano and Sauerlender[2] also discuss this under the heading of "Strain and Discomfort of Nonuniform Driving," and go on to say that such strain and discomfort is a road user cost that can be reduced through highway improvement. The present authors feel this cost could also be reduced by vehicle improvement, such as improved headlights, taillights and passive aids to vehicle visibility such as reflectorization and improved reflex reflectors (larger and less directional). Pagano and Sauerlender quote the following from an AASHO report:

> "There is value in the convenience of being able to go to one's destination without interference. There is a comfort value, over and above the saving in vehicle operating cost, in being able to drive without frequent brake applications, stops and starts, or unexpected interferences to travel. There is value in the conservation of health through driving in a relaxed manner without the tension necessary where roadside interference is imminent."

and they go on to say that:

> "There are two problems involved in the evaluation of the strain and discomfort factor. One is the enumeration of the factors that affect strain and discomfort; the second, the placing of some dollar value on this cost." (p. 184)

Again, however, it should be stressed that inability to quantify certain benefits and/or costs should not automatically be used by the decision-maker as an excuse for excluding them from consideration. There is too much at stake.

One further point bears discussion before leaving the general topic of cost-benefit or cost-effectiveness analysis, and this has to do with the use of accident records to derive accident reduction estimates.

As the reports by Arthur D. Little, Inc.[3] and T. W. Forbes[4] point out, there are a number of methodological difficulties involved in any attempt to use accident records to prove or disprove a traffic safety benefit. Particularly is this true when one is dealing with the prevention of crashes, rather than the reduction of injuries or fatalities. Any accident records approach is fraught with problems that arise in the accident reporting process, in which a relatively small amount of information normally is reported about the accident circumstances. Particularly meager is information describing the driver's capabilities and the nature of the roadway and environment leading up to and surrounding the crash location.

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(2) op cit

(3) "The State of the Art of Traffic Safety," Cambridge, Mass.: Arthur D. Little, Inc., June 1966.

(4) Forbes, T. W., "General Approach and Methods," Chapter 2 in Human Factors in Highway Traffic Safety Research (T. W. Forbes, Ed.), New York, N.Y.: Wiley-Interscience, 1972.

There are many combinations of accident-producing circumstances. Any attempt to prove a safety benefit must take account of these many circumstances in the research plan, and the researcher can deal with this in two ways:

1) Select for study only those accidents that are matched on all variables except for the one(s) under study, or

2) Study a random selection of accidents from among two or more groups of drivers that differ only in the experimental variables.

Neither of these methods is easy to accomplish, since they require large sample sizes plus detailed information on accidents and/or drivers. It is for these reasons that studies often employ the "before-after" approach. As pointed out earlier, however, the difficulty with this approach is that one must be preapred to deal with any and all of the many other changes that may occur during the periods under study.

Selection of the two populations of drivers to be studied is critical when the simultaneous approach is used, and selection of the type of accidents to be studied is also critical. As stated earlier, there are so many factors known to relate to accident causation that a matched sample approach will require study of hundreds of accidents to produce meaningful results to be able to study daytime collisions with parked vehicles. This is the type of accident in which visibility aids would be expected to be of most value to an approaching driver in detecting a vehicle. However, a large number of total accidents is necessary in order to provide a sufficient number of this type of accident for adequate statistical analysis, and while this approach would isolate a single, accident-related circumstance, there are many more.

Regardlless of this issue, however, when it is not possible to isolate satisfactorily a particular set of accident circumstances and the study must compare groups of drivers or vehicles, it is definitely not appropriate to concentrate on a few types or accidents solely for drawing conclusions. All accidents incurred by both groups must be looked at collectively, as well as in their separate categories, in an effort to ascertain whether the two groups of drivers (or vehicles) are truly comparable in all aspects except visibility aids.

The following list presents some of the factors that should be considered in any study of the effectiveness of visibility aids in terms of accident occurrences:

1. Exposure to risk - -

   The groups of drivers to be studied should be matched, to the extent possible, as to the mine layout and type of driving rules that are in force.

2. Driver age and driving experience - -

   The groups should be matched at least in coarse groupings that differentiate on these variables.

3. The "novelty effect" - -

   It is desirable to allow at least one year to elapse after introduction of visibility aids to allow for the novelty effect to wear off before collecting "after" data, and also to permit any "learning effect" that might occur to take place. That is, "after" measurements should be made only when the new relationship has stabilized.

4. Driver vision - -

   Because of the wide range of visual abilities found in the driving population, and the demonstrated relationship between vision and accidents, as much information on visual performance (particularly night vision) of the drivers as possible should be obtained.

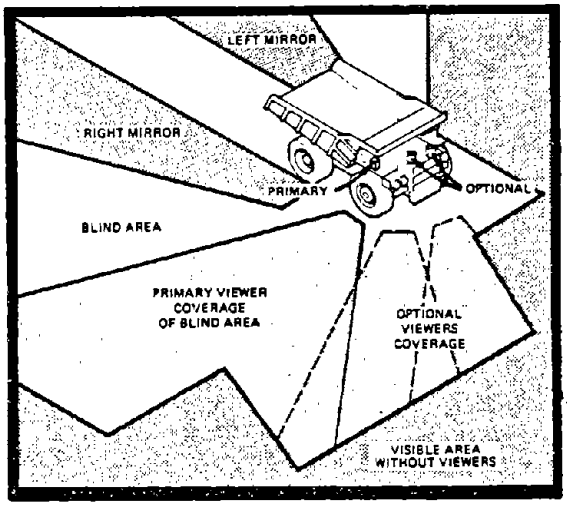
5.2 Appendix B

BLIND AREA VIEWER AND RIGHT-SIDE MIRROR

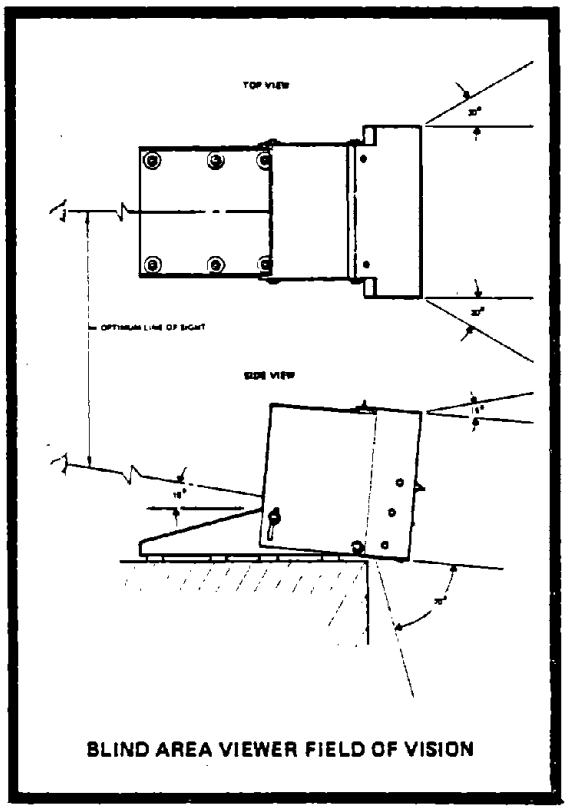
INFORMATION AND INSTALLATION DATA SHEETS

5.2.1 Blind Area Viewer

Tracor MBA
Blind Area Viewers



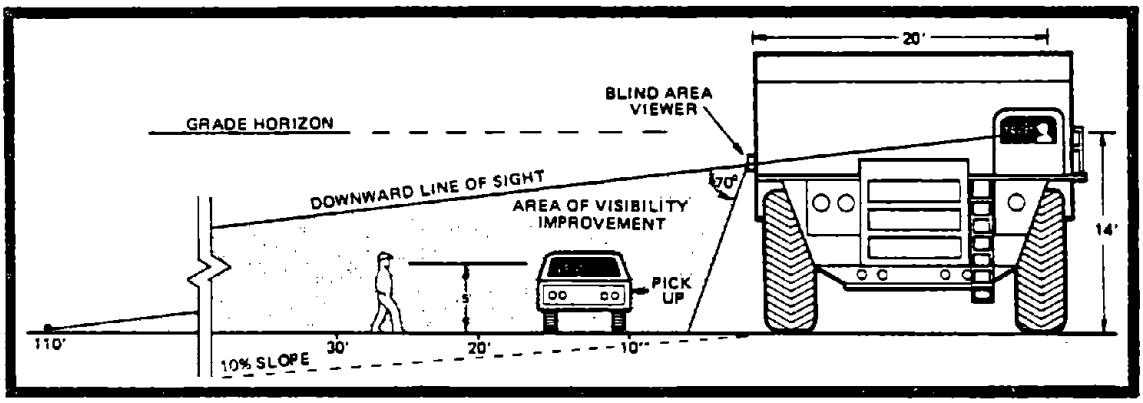
Provides a 60 degree wide angle view of blind areas to approximately 70 degrees below the line of sight.



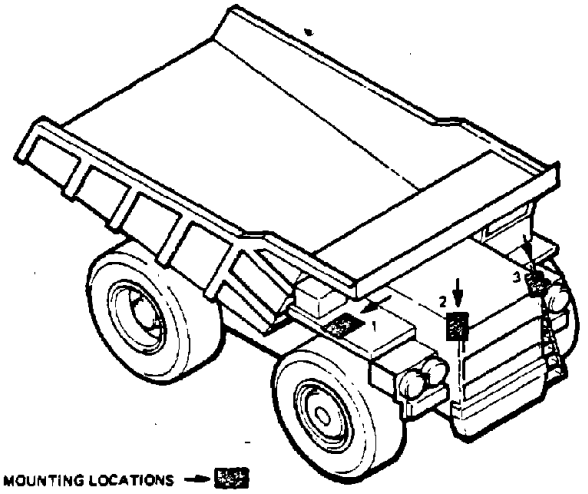
BLIND AREA VIEWER FIELD OF VISION

Information and Installation Data Sheet

The truck driver can use Blind Area Viewers to check his blind area when he is STARTING OUT or MOVING SLOWLY. The Driver can also use Blind Area Viewers to keep track of people and equipment near his truck when it is stopped. One to three units per truck recommended depending on truck size, configuration and requirements. One unit per large wheel loader.

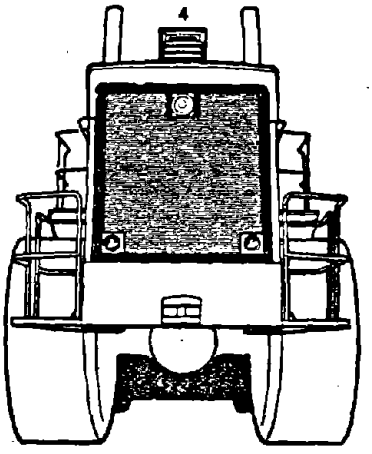


BLIND AREA VIEWER INSTALLATION AND MAINTENANCE INSTRUCTIONS



MOUNTING LOCATIONS →

1. Viewed through right door window (Primary)
2. Viewed through right corner window (Optional – For large trucks)
3. Viewed through windshield (Optional – For very large trucks)
4. Viewed through window (Wheel Loaders)



LIST OF CONTENTS:
- One Blind Area Viewer (assembled)
- One Mounting Bracket (attached to Blind Area Viewer)
- One Mounting Hardware Kit

MOUNTING LOCATION: Mount 3 Blind Area Viewers on a haulage truck in the following locations:
- Left corner of the engine hood (viewed through front windshield of cab)
- Right corner of the engine hood (viewed through right forward window of cab)
- Right side of truck on the deck, fan housing, etc. (viewed through right door window)

WARNING	*Do not carry Blind Area Viewers up the truck ladder. Use a safe method approved by OSHA or MSHA to lift them onto the truck deck.*

INSTALLATION PROCEDURE:

Position the mounting bracket at each location according to these guidelines:
- Have the driver sit in the driver's seat to guide placement of the mounting bracket
- Aim the long dimension of the bracket at the driver's normal position
- Make sure the front edge of the mounting bracket is entirely overhanging the truck edge
- Align and mark 4 (2 on each side) widely spaced mounting holes in good locations for mounting bolts
- The mounting bracket is designed to be mounted level on a flat surface. If the location is not level, it is up to the owner to fabricate hardware to position the shock mounts level

Weld mounting bolts to the flat surface using the detached mounting bracket as a template (welding fixture) to hold the bolt heads in position, as previously marked (see Fastener Assembly Detail); recheck alignment

Assemble the Blind Area Viewer and mounting bracket (see Fastener Assembly Detail)

Mount the assembled Blind Area Viewer on the mounting bolts according to the shock mount assembly detail.

WARNING:	*The Blind Area Viewer is not balanced and will fall off its mounting bolts if not held on or fastened down. For safety, have a 3/8" nut ready to spin on one of the rear mounting bolts when lifting the Blind Area Viewer into its mounting bolts.*

ADJUSTMENTS FOR VIEWING:

The rear hood and louvers are designed to reduce glare and reflections on the lens. The glare and reflection cannot be eliminated completely; however, adjustments can help considerably.

TILT: With the driver in the driver's seat to guide the adjustment, tilt the Blind Area Viewer forward until reflections are minimized and the view through the bottom half of the lens is clearest. The lens glass can reflect the deck, cab, hand rails, or the bottom of the load bed overhang and the tilt adjustment can reduce its effect. The operator should make sure that the lens tilt adjustment is optimum for his truck and the lighting conditions at the mine.

LOUVERS: With the driver in the driver's seat to guide adjustment, rotate the louvers by hand until they appear to the driver as a thin line.

CLEANING: Clean the lens glass with window washing solution and wipe with a paper towel.

To clean between the louvers, apply excess cleaning solution and allow it to run and drip off; then wipe between the louvers starting at the top.

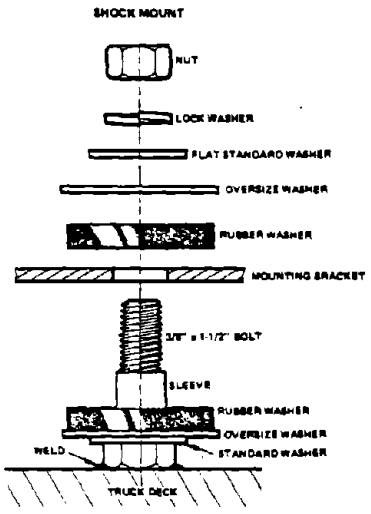
WARNING: *Be aware of the danger of falling. Clean lens in a safe manner.*

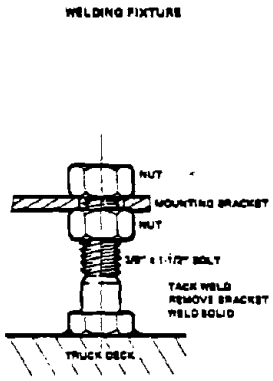
MAINTENANCE: Replace damaged parts by disassembly. Bent or dented sheet metal parts can be straightened in the welding shop.

Touch up finish with Rustoleum #412 flat black paint.

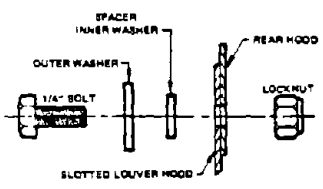
Note: The lens assembly consists of 2 plastic lenses sealed between 2 sheets of automotive safety plate glass. The sealant used is a hot melt butyl.

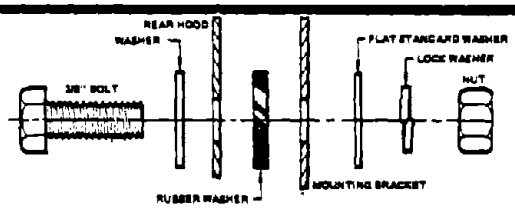
FASTENER ASSEMBLY DETAIL



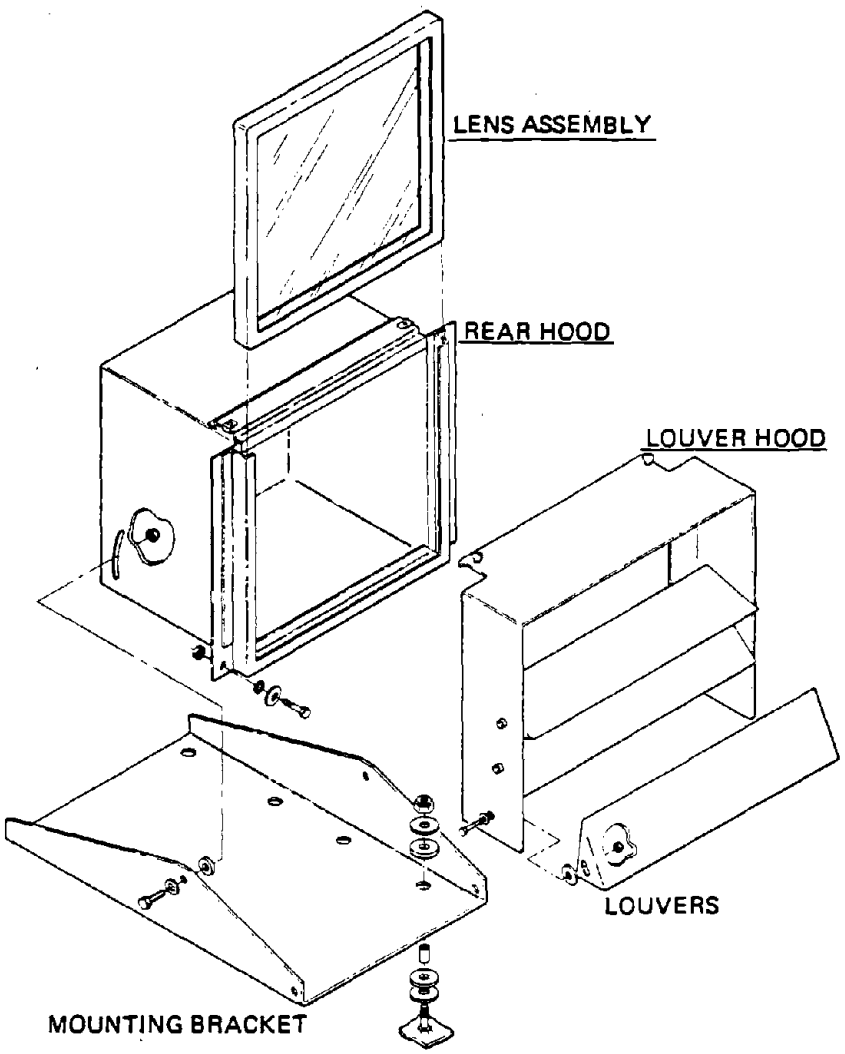


BLIND AREA VIEWER ASSEMBLY





EXPLODED VIEW

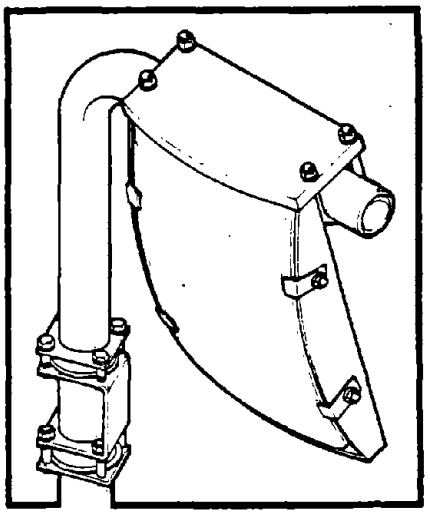


Tracor MBA

MBAssociates Post Office Box 196 Bollinger Canyon Road San Ramon, California 94583 Telephone 415: 837 7201

Tracor MBA

Right Hand Mirror For Large Haulage Trucks

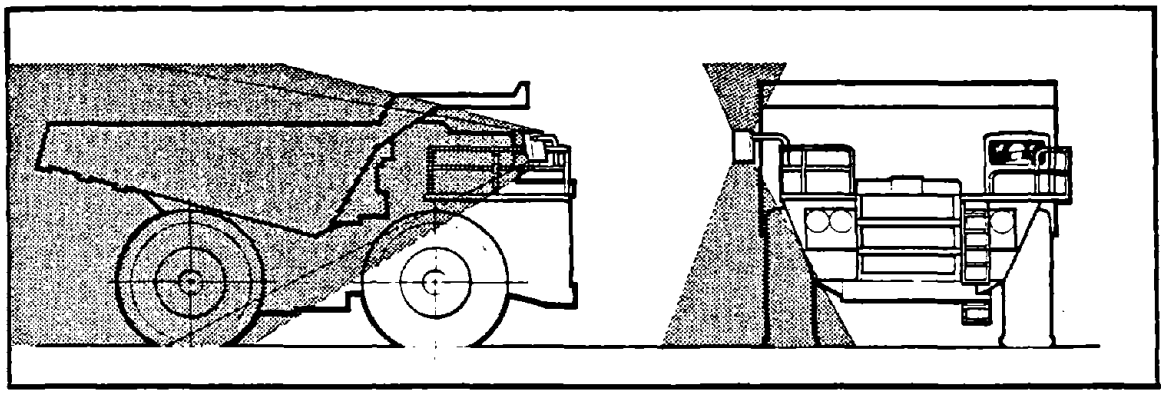


Provides a well shaped rectangular field of view of the right rear side of truck. View scene includes top edge of load bed and rear tire ground contact. The angles of view approximate 70° vertical and 48° horizontal.

The mirror is convex with a spherical radius of 20° and is rectangular — 16" long by 12" wide. Its support and mounting system provides protection from load spills and damage when being scraped by garage door frames or other structures. It has a protective top cover and readily swings aside if pushed by another object.

Information and Installation Data Sheet

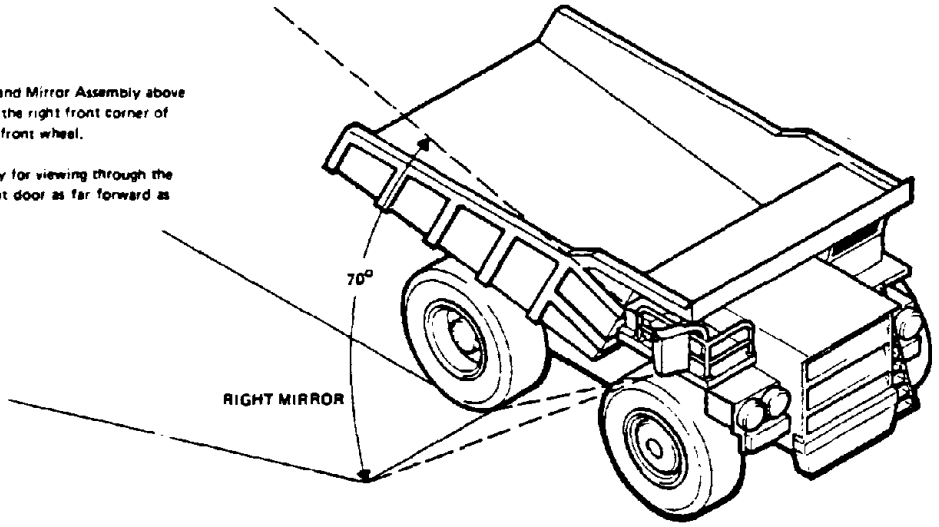
The driver can use the Right Hand Mirror to check his rear blind area when BACKING UP or MOVING SLOWLY to see if people, equipment or other obstacles are in a dangerous position for his operation.



RIGHT HAND MIRROR INSTALLATION AND MAINTENANCE INSTRUCTIONS

MOUNTING LOCATION:

- Mount the Right Hand Mirror Assembly above and outboard from the right front corner of the deck above the front wheel.
- Locate the assembly for viewing through the window of the right door as far forward as possible.



RIGHT HAND MIRROR FIELD OF VISION

WARNING: *Do not carry the heavy pieces up the truck ladder. Use a safe method approved by OSHA or MSHA to lift them onto the truck deck.*

ADJUSTMENTS FOR VIEWING:

- The two subassemblies consisting of Hold Down Plates, Clamps, Friction Rings and Fasteners are designed to perform two functions. The first function is to allow easily and accurately adjusted angle positioning of the tubular support with the fasteners tightened sufficiently to hold the arm in trial positions. The second function is to prevent damage to the Mirror by destructive forces such as caused by the truck's encounter with an obstruction. This requires additional tightening of the fasteners as described below. The U-bolt fasteners which attach the Mirror to the Support arm are not intended to slip during use and are loosened only for tilt and reach adjustments of the Mirror and Support arm.

PAN, TILT AND REACH ADJUSTMENTS:

- With the driver giving instructions while seated in his normal position and posture, and the Post Clamp friction assemblies and the U-bolts loosened enough for easy movement but tight enough to prevent undesired change of position during adjustment, move the Mirror up and down (rotate around support arm) for vertical tilt angle adjustment; slide mirror housing inboard and outboard on the support arm for REACH distance adjustment; and swing the support post for horizontal PAN angle adjustment. The best possible mirror adjustment will produce a view scene including the top rear of the load bed and the bottom of the rear tire, and, without losing too much of the bed and tire, as large an area as possible to the right of the truck. This must be accomplished with the REACH adjustment locating the mirror as near to the truck as possible. At this point, it may be found that the Adapter Bracket should be in a slightly different location. This is accomplished by cutting the tack welds with a grinder or chisel and re-welding in the more suitable location. After confirmation of proper adapter position, the welds should be made high-strength with deep penetration and larger beads.

FASTENER TIGHTENING:

- With the pipe clamps fully tightened, tighten the four fasteners on the top friction assembly so that when pressing at the outboard end of the support arm pipe, maximum possible thumb-only pressure will swing the arm. Loosen these four fasteners exactly two turns. Repeat the above procedure with the bottom friction assembly, except in this case, after thumb pressure test, leave as adjusted and retighten the top friction assembly exactly two turns of each fastener. Check final adjustment with two thumbs. If support arm extends more than two inches outboard from the mirror, cut off the excess.

MAINTENANCE:

- Replace damaged parts when necessary; keep mirror glass surface clean by using window washing solution and wiping with paper towel. If paint needs touching up, use Rustoleum # 659.

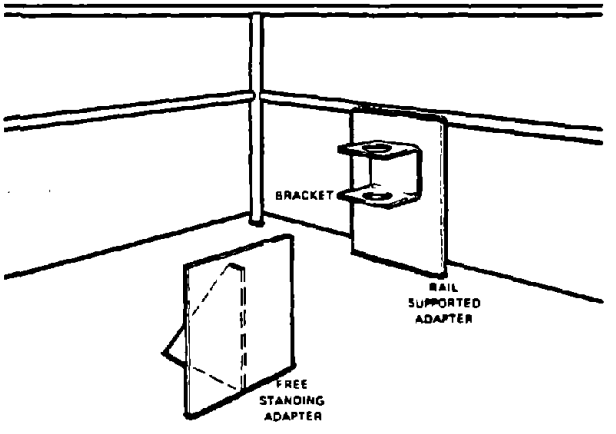
INSTALLATION PROCEDURE: (Refer to Exploded View)

- Position the vertical center of the Mounting Bracket as far forward as possible and spaced inboard from the right edge of the deck to leave allowance for the thickness of the user-furnished Adapter Bracket. Mark deck for Adapter Bracket location.
- Make the Adapter Bracket (see suggestions) and temporarily tack-weld the Adapter to the deck and/or other truck structure with small, minimum strength welds. This will allow easy change of location, if found to be necessary.
- Permanently weld the Mounting Bracket to the center line of the Adapter with its bottom 4 - 6 inches above the deck. This has proven most satisfactory during field tests.
- Loosely fasten the two Post Clamp Assemblies to the Mounting Bracket, one above and one below. (Note the correct arrangement in Exploded View.)
- Keeping in mind the required swing of the mirror and support post when it is accidentally struck, measure the height above the deck which is desired for the top of the mirror. Cut the longer leg of the support post to this length.
- Insert this shortened leg of the post through the mounting bracket and clamp pieces, temporarily tightening the eight fasteners enough to prevent slippage.
- Fasten the mirror assembly to the horizontal leg of the support post with the U-bolts.
- Adjust the tightness of mounting bracket, pipe clamp and mirror fasteners to allow swing and tilt adjustment of the mirror without extreme manual force, and yet insure that final tightening in the desired position does not cause slipping out of current adjustment.

SUGGESTIONS: Adapter Bracket

- The adapter bracket should be made of strip or plate steel and mounted in a vertical position. It can be either free standing (attached to truck deck plate only) or attached to both the deck plate and hand rail structure. The mounting bracket is attached to the adapter bracket. Attachments can be either by screw fasteners or by welding. Welding is recommended.

TYPICAL ADAPTER BRACKETS

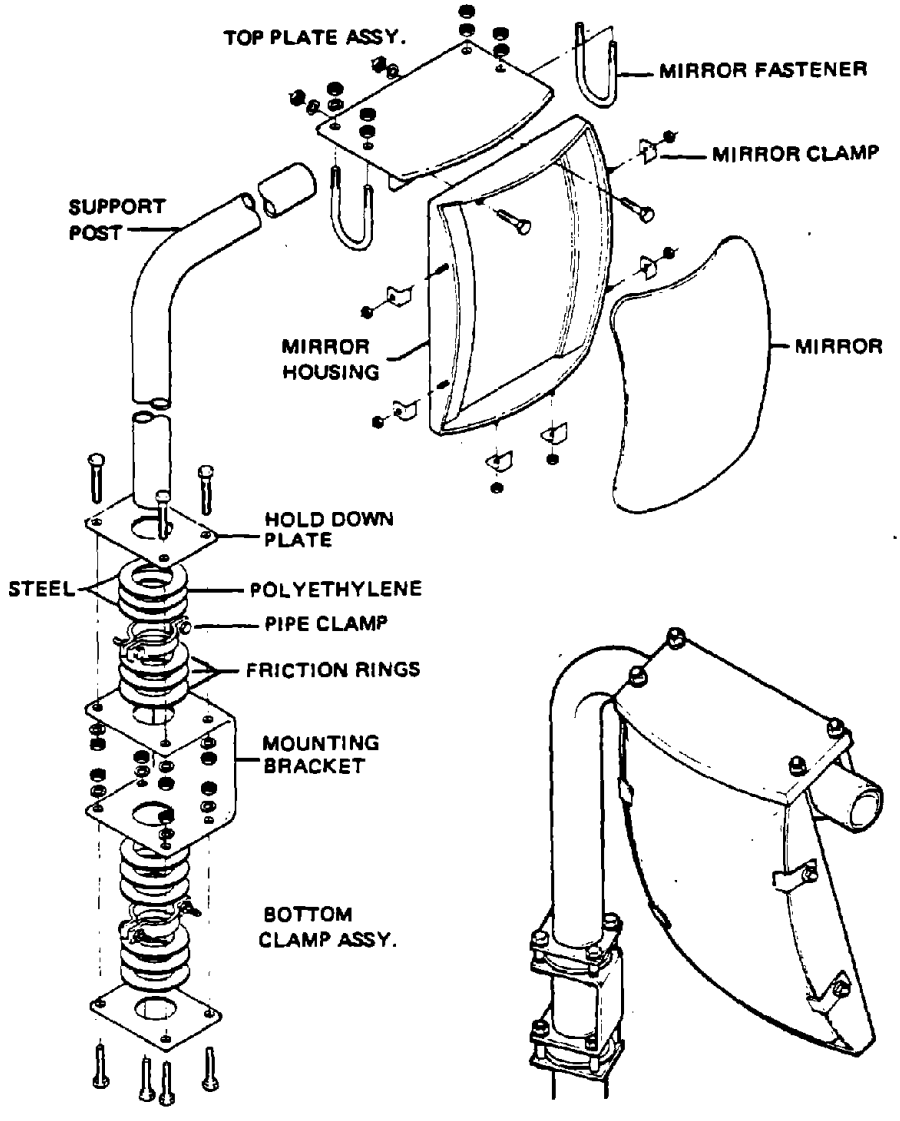


MIRROR INSTALLATION COMPONENTS

Item No.	Description	Part No.	Qty.
1	Mirror Assembly, Right Hand	115732-500	1
	Mirror - 12" x 20" - 30"R Convex	115732-9	1
	Housing Mirror	116098-300	1
	Bolt 3/8" - 16 unc. 1¼" Lg. Hex. Hd.	115732-20	2
	Lock Washer - 3/8"	115732-21	2
	Washer - 3/8" medium	115732-27	2
	Nut - 3/8" - 16 unc. Reg. Hex.	115732-22	2
	Clamp, mirror	115751-1	6
	Locknut, Mirror Clamp 10-32HH	115732-18	6
	Top Plate Assembly	115734-300	1
	U-bolt with nuts	115732-5	2

Item No.	Description	Part No.	Qty.
2	Support, Mirror Housing	115738-1	1
3	Mounting Assembly	116362-500	1 set
	Mounting Bracket	115737-1	1
	Plate, hold down	115738-1	2
	Ring, Friction - Steel	115739-1	8
	Ring, Friction - Polyethylene	115739-2	4
	Clamp, Support Post	115362-5	2
	Washer, Flat ¼"	116362-7	8
	Bolt, ¼" - 20 unc. 2-¾" Lg. Hex. Hd.	116362-6	8
	Lockwasher, ¼" Med.	116362-9	8
	Nut, ¼" - 20 unc. Reg. Hex.	116362-8	8

EXPLODED VIEW



Tracor MBA
MBAssociates Post Office Box 196 Bollinger Canyon Road San Ramon, California 94583 Telephone 415 837 7201

5.3 Appendix C

OCLI HEA MULTILAYER COATING SPECIFICATION

OCLI OPTICAL COATING LABORATORY, INC.

PRODUCT
(TYPE)

SPECIFICATION

HEA 11-002C MULTILAYER ANTIREFLECTION COATING FOR
(TITLE)
CONTRAST ENHANCEMENT PRODUCTS

6020020
(NUMBER)

REV. LTR.	DATE	DESCRIPTION	WRITTEN BY
	5/31/79	Original	Jim Ford

LATEST REVISION WRITTEN BY	AUTHORIZED FOR RELEASE BY	RELEASE DATE
6/15/79	Leonard P. Mott	8/15/79

6020020

OCLI OPTICAL COATING LABORATORY, INC.

1.0 SCOPE

This specification defines the minimum requirements for a multilayer high efficiency antireflection coating for contrast enhancement products having refractive indicies within the range of 1.450 to 1.550.

2.0 APPLICABLE REFERENCE DOCUMENTS

The following documents form a part of this specification to the extent specified herein.

MIL-C-675A	Coatings of Glass Optical Elements (Antireflection)
MIL-C-14806A	Coating, Reflection Reducing for Instrument Cover Glasses and Lighting Wedges
MIL-M-13508	Mirror Coating Process, Front Surface Aluminized for Optical Elements
MIL-STD-105D	Sampling Procedures and Tables for Inspection by Attributes

3.0 REQUIREMENTS

3.1 Spectral Performance

3.1.1 The specular reflectance from a coated front surface measured at an angle between 0^{o} and 15^{o} shall be:

Location	Max. Reflectance	Wavelength
Center	0.3% Average	Between 0.6% Reflectance Intercepts
Center	Upper 0.6%	650nm (min.)
	Lower 0.6%	430nm (max.)

The maximum allowable wavelength shift from center to the corners of the part shall be no more than 10% lower than the upper 0.6% reflectance intercept, and no more than 2% greater than the lower 0.6% reflectance intercept.

3.2 Environmental/Durability Characteristics

3.2.1. Product acceptance.

3.2.1.1 Adhesion (snap tape) - The coating shall show no evidence of damage after Scotch Brand #610 cellulose tape is pressed firmly against the coated surface and removed quickly with a snap of the wrist (reference MIL-M-13508B, paragraph 4.4.6).

6020020

DOCUMENT TITLE	DOC. REV.	DOC. NO.
Mulilayer Antireflection Coating for Contrast Enchancement Products		6020020

OCLI OPTICAL COATING LABORATORY, INC.

3.2.1.2 Abrasion Resistance (200 Eraser Rub)-The coating shall withstand being subjected to the 200 rub eraser abrasion resistance test, prior to humidity test (reference MIL-C-14806A, paragraph 4.4.7).

3.2.1.3 Humidity - The coating shall be capable of withstanding continuous exposure for 24 hours in an atmosphere of 120°F ± 4°F and 98% ± 2% relative humidity without evidence of deterioration (reference MIL-C-675A, paragraph 4.6.9).

3.2.2 Product certification.

3.2.2.1 Solubility - The coating shall show no evidence of deterioriation after being immersed for 24 hours in water containing six ounces of sodium chloride per gallon (reference MIL-C-675A, paragraph 4.6.8).

3.2.2.2 Temperature - The coating shall show no evidence of deterioration after exposure to ambient temperature of -80°F and +160°F for a period of five hours at each specified temperature (reference MIL-M-13508B, paragraph 4.4.4).

3.3 Surface Quality

3.3.1 Inspection conditions - Normal room light, matt white background, 60 watt Tungsten or 2-30 watt fluorescent lamp, approx. 20" from the light at a 30° incident angle. Transmission and reflection.

3.3.2 Scratch -

Visible	
> .005" Wide	None allowed
.002-.005" Wide	Max. accumulated Length 2"
< .002" Wide	Disregard

3.3.3 Digs (opaque round defects -

Visible	
> .030	None allowed
.020-.030	3 max. per 4" circle
< .020	Disregard

3.3.4 Stain - Visible by transmission, none allowed.

6020020

OCLI OPTICAL COATING LABORATORY, INC.

3.3.5 Tooling Marks - For parts that are coated in the exact finished product size, the maximum tooling mark along the periphery will be 1/4".

3.3.6 Edge Chips - .040" plus 0.010" for each additional inch (diameter or diagonal) over 2" up to max. of 1/8".

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Spectral and Environmental Acceptance Tests

4.1.1 Acceptance test and measurements will be made using polished glass witness pieces that have been coated in the same batch as the substrate being evaluated.

4.1.2 Spectral measurements will be performed on a witness piece with a refractive index within ± 0.01 of the substrate's refractive index.

4.1.3 All environmental and durability tests will be performed on 1.52 nominal index witnesses.

Witnesses from each batch shall be tested in accordance with Table I. Failure to meet one or more requirements shall be cause for rejection of parts processed in that batch.

Table I Acceptance Testing

Test	Requirement Paragraph	Witness 1 2 3 4	Test Paragraph
Spectral	3.1	x	3.1
Adhesion	3.2.1.1	x	MIL-M-13508B, Para. 4.4.6
Abrasion	3.2.1.2	x	MIL-C-14806A, Para. 4.4.7
Humidity	3.2.1.3	x	MIL-C-675A, Para. 4.6.4
Solubility	3.2.2.1	*	MIL-C-675A, Para. 4.6.8
Temperature	3.2.2.2	*	3.2.2.2

*OCLI will certify to this requirement without testing each batch.

4.2 Surface Quality Acceptance

6020020

OCLI OPTICAL COATING LABORATORY, INC.

4.2.1 Surface quality of the shipping lots are warranted to meet a 2.5% AQL. (Reference MIL-STD-105D)

5.0 PREPARATION FOR DELIVERY

5.1 The coated parts shall be clean and packaged in a manner to ensure adequate protection against breakage or damage during reasonable handling and transportation.

5.2 The parts will be shipped in protective containers provided by OCLI or in reusable containers provided by the customer if the containers lend adequate protection to the coated parts.

5.3 OCLI certifies that each shipping lot meets each requirement of this specification. A spectrophotometric scan will be supplied showing spectral conformance to 3.1 upon request only. All supportive data will be retained for inspection purposes for a period of three years from the date of shipment.

5.4 All shipping packages shall have contained or affixed in a manner to permit convenient access, a packing slip containing the quantity of parts, description, and date shipped.

6.0 CLEANING

6.1 Coating is impervious to dust and dirt in normal environments. Dusting with a dry, soft, clean cloth is sufficient. Heavier soils may be removed with:

Detergent and Water - Joy, Sparkle, Alconox, Liquinox

Ammonia-Based Window Cleaners - OCLI TFC Cleaner, Windex, Glass X

Solvents - Acetone, trichoroethylene, benezene, xylene, methyl ethyl ketone (MEK)

6.2 Scouring pads, abrasive cleaners, acid solutions, and chlorinated cleaners will affect the coating and should not be used.

6020020

DOCUMENT TITLE	DOC. REV.	DOC. NO.
Multilayer Antireflection Coating for Contrast Enchancement Products		6020020

5.4 Appendix D

BAV INSTALLATION ON 945B WHEEL LOADER

FIAT-ALLIS
CONSTRUCTION MACHINERY, INC.
3000 South Sixth Street, Springfield, Illinois 62710 (217) 789-3000

03 December, 1980

M. B. Associates
Bollinger Canyon Road
San Ramon, CA 94583

Attention: Mr. Jim Eirles
Project Engineer

Dear Mr. Eirles:

Thank you for allowing Fiat-Allis to use your blind area viewer for a test installation on our 945B Wheel Loader. The viewer has been removed and returned to M. B. Associates, Attention: Mr. Jim Eirles.

An attached sketch shows the location of the viewer on the 945B.

Operator comments were neutral. This may be due to the following reasons.

1. The machine was operating in a large open area so it was not necessary to have good close up visibility to the rear of the machine.

2. The 945B is narrow compared to proximity of objects near the machine during normal operation at our Proving Grounds.

3. The operators seldom look back so the viewer was not an obstruction to vision.

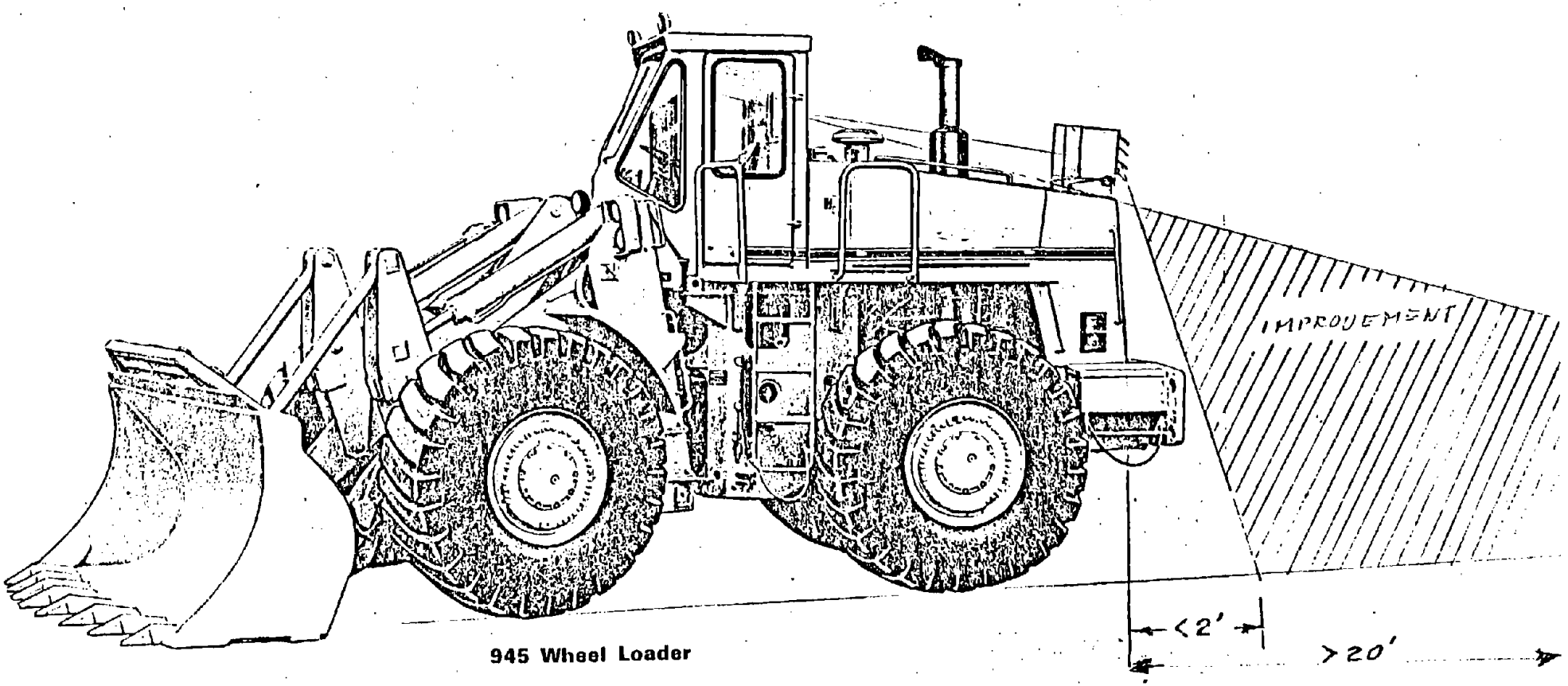
A Proving Grounds supervisor commented that dust accumulation and vibration were not a problem and that if the machine was larger, or used in a congested area, the viewer may have been used more.

Sincerely,

Myron L. Vigesaa

Myron L. Vigesaa
Project Engineer
Crawler Tractor Engineering

ca
Attachment

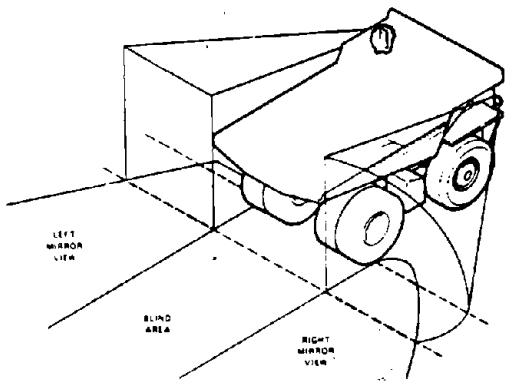


945 Wheel Loader

5.5 Appendix E

HANDBOOK OF MIRROR TECHNOLOGY FOR LARGE HAULAGE TRUCKS

Handbook of Mirror Technology for Large Haulage Trucks



Guidelines for Selecting and Using Mirrors on Large Haulage Trucks

February 1980

Supplement to Final Report
To
U. S. Bureau of Mines/MBAssociates

Contract H0262022

"Improved Visibility Systems
For
Large Haulage Vehicles"

Preface

This handbook is the result of an effort to develop and test Improved Visibility Systems (USBM/MBA Contract H0262022) for use of the drivers of mine haulage trucks. This development effort includes an ongoing study of truck mirrors and the visibility needs of truck drivers.

The need for a mirror technology handbook became apparent because of a lack of straightforward information on basic mirror usage. Some of the information presented here was developed from ongoing, long-term testing of improved mirrors and other visibility aids on large mine haulage trucks.

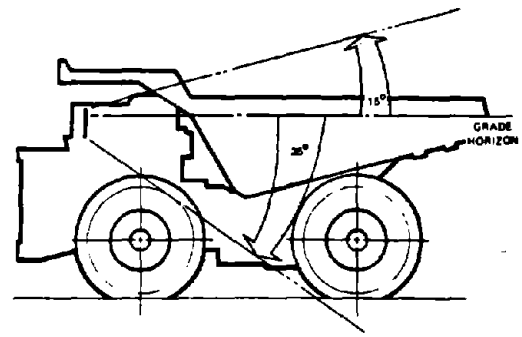
This handbook provides practical information to personnel in the surface mining industry for applying modern mirror technology to the safety needs of large haulage vehicles. An attempt has been made to make this handbook useful to both administrative and supervisory personnel involved with the selection, installation and maintenance of mirrors.

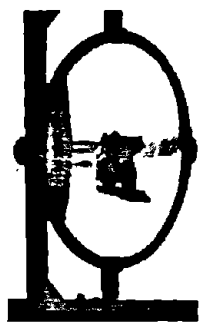
MBAssociates

Bollinger Canyon Road, San Ramon, California 94583
(415) 837-7201/837-8181 · TWX No. 910-389-6390

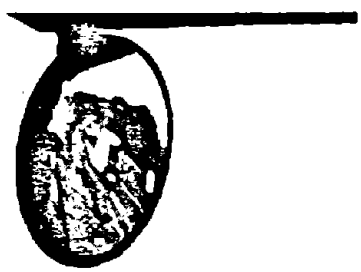
Introduction

10" x 30"
PLANE
MIRROR





ROUND
CONVEX
18" DIAMETER
30" RADIUS



ROUND
CONVEX
18" DIAMETER
30" RADIUS

RECTANGULAR
CONVEX
12" x 16"
20" RADIUS

INTRODUCTION

The shape of large haulage trucks creates the need for a wide angle mirror view. For example, the required vertical field of view shown above is more than double that which is used on highway trucks, yet many haulage trucks use highway type mirrors.

This handbook provides information on the size, shape, features, location and mounting of haulage truck mirrors to provide the driver with a better view so that he can drive and maneuver safely.

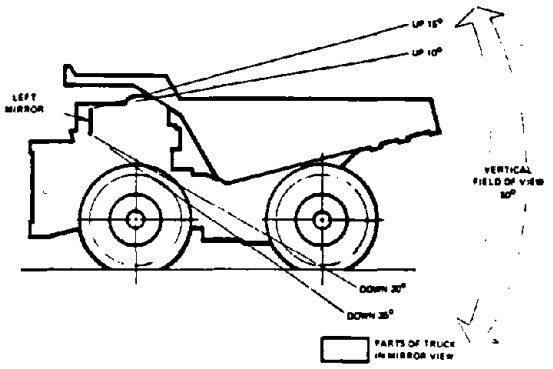
MIRROR SELECTION

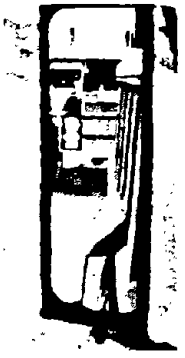
Haulage trucks are usually equipped with mirrors that are readily available from convenient suppliers. Mirrors which are better suited to the needs of large haulage trucks generally are marketed by small specialty manufacturers or can be special ordered. The sources of haulage truck mirrors are:

- Safety equipment distributors (catalog orders)
- Haulage truck manufacturers
- Specialty products manufacturers
- Special order fabrication

Left Mirrors

8" x 16" PLANE MIRROR





6" x 18" PLANE MIRROR

LEFT MIRRORS

Left mirrors are used to observe traffic and for guidance while backing. When backing, a high quality, well-oriented left mirror view allows the driver to remain seated with his hands and feet placed properly on the controls of the truck. Without a left mirror the driver would have to lean out the left door window or even open the left door to see when backing. In either of these positions, loss of control of the truck is a potential safety hazard.

10" x 30" PLANE MIRROR

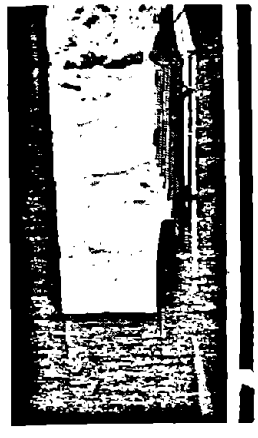
FIELD OF VIEW REQUIREMENTS

When backing to a berm a truck driver can best judge when to stop if he can observe his rear tire as it approaches the berm. He can also judge if he is lined up perpendicular to the berm. This requires a downward angle of view of 30° - 35° degrees, as shown above. When spotting at a shovel the driver can judge his position if he observes the rear tire as it approaches the bank and follows previous tire tracks. The driver also needs to observe the teeth on the shovel bucket when spotting at a waiting shovel. This requires an upward view of 10° - 15° degrees.

For normal driving a wide angle view is desirable for observing traffic.

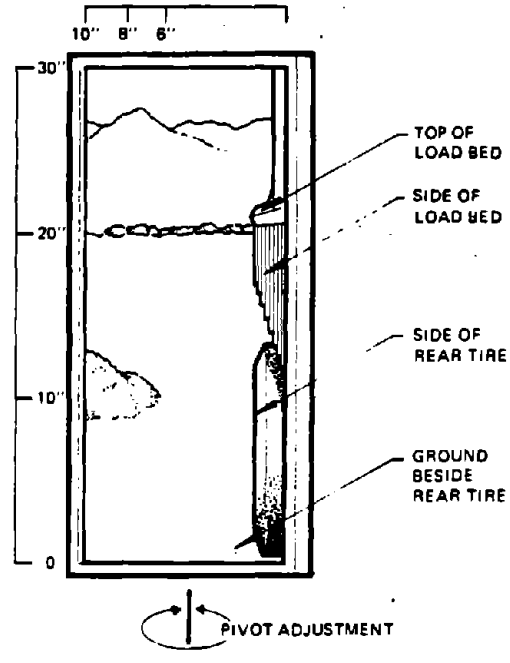
Left Mirrors (cont.)

10" x 30"
PLANE
MIRROR



10" x 30"
PLANE
MIRROR

6" x 18"
COMBINATION
MIRROR



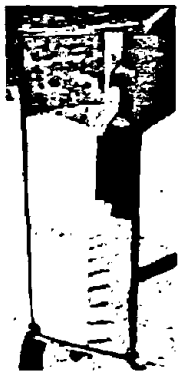
MIRROR SCENE REQUIREMENTS

As shown above, the driver needs to see the following features in his rear view scene to judge his position or situation with confidence:

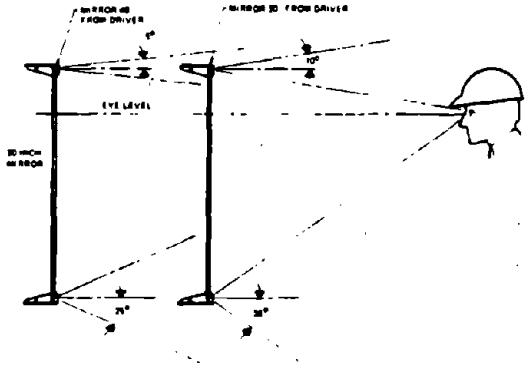
- The ground behind the truck
- The ground beside the rear tire
- The side of the rear tire
- The side of the load bed
- The top edge of the load bed
- The space above the load bed
- The clearance from other equipment or objects

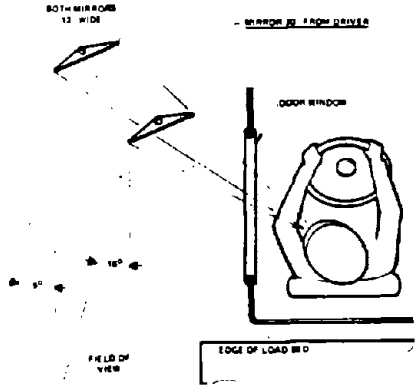
These view scene features can be used best when observed in a single, adequately sized mirror. With the mirror shown above, as the driver's concentration shifts from feature to feature, only eye movement is needed. With a smaller mirror the driver must move his head to see what he needs. With two or more small mirrors, as shown at left, the driver's eyes and mind have to adjust to a new orientation when the driver switches his gaze from mirror to mirror. Mirrors larger than 12" wide block too much of the driver's direct view; however, mirrors 30" to 45" high can be mounted easily on haulage trucks.

Left Mirrors (cont.)



6" x 18"
PLANE MIRROR
40" FROM DRIVER





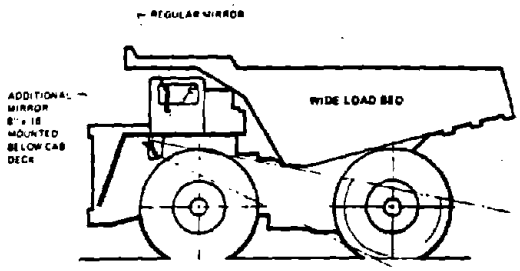
MIRROR POSITION

The distance between the left mirror and the driver is very important. The field of view of a flat (plane) mirror gets smaller as the mirror is moved away from the driver. The figures shown above and left show what field of view can be expected from a 12" x 30" flat mirror at different distances from the driver. The mirror shown at 30" is approximately an arm's reach from the driver. Any flat mirror view can be evaluated this way by using simple geometry and the optical law of reflection.

6" x 18"
PLANE MIRROR
30" FROM DRIVER

Left Mirrors (cont.)

9" x 30" PLANE MIRROR WITH ADD-ON CONVEX MIRROR DISRUPTING THE VIEW



ROUND CONVEX MIRROR 6" DIAMETER

AUXILIARY LEFT MIRRORS.

On wide-bed trucks an additional flat mirror may be needed to see the side of the rear tire, as shown above.

When view requirements place the mirror over 40" from the driver a small (6" diameter or less) convex mirror mounted above or outboard the regular mirror can provide a greater field of view for use while driving. NOTE: Do not mount any added mirrors on the flat mirror because this will interrupt the vertical scene and cause problems in judging distance, location and clearance.

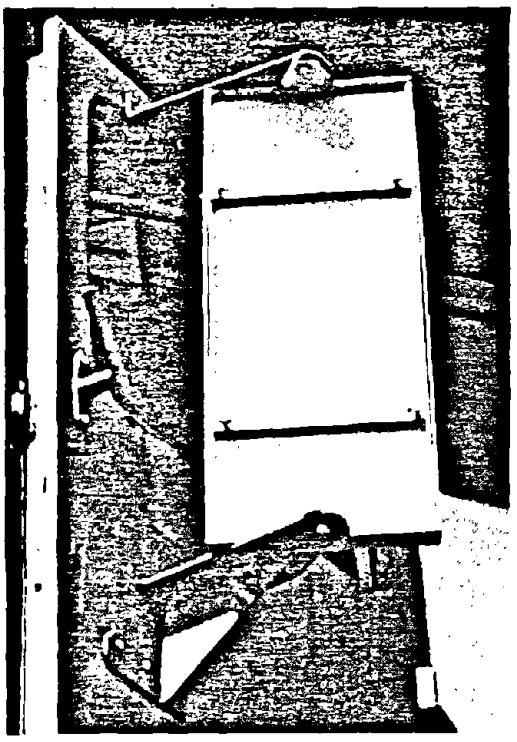
OTHER FEATURES

Other left mirror features which can aid the driver's usage and view are:

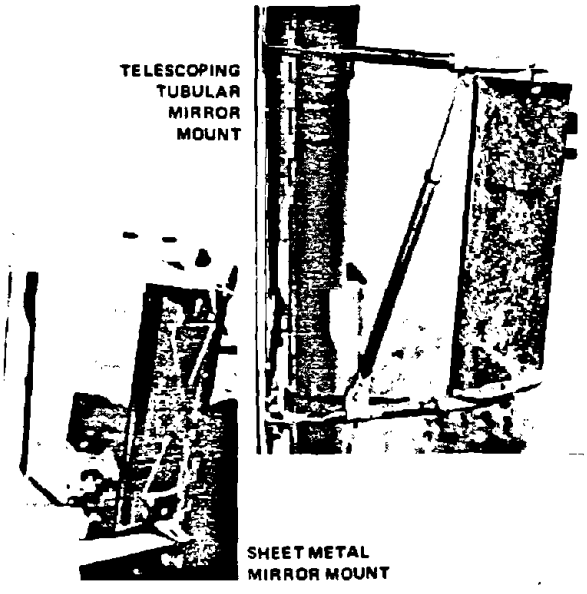
- Safety-backing for shatter resistance
- Quick-change glass for fast repair
- Remote control pivot adjustment for wide angle glance
- Additional convex mirror for wide angle view (6" diameter or less)
- Tilt adjustment for tall or short drivers

ROUND CONVEX MIRROR 6" DIAMETER

Left Mirrors (cont.)

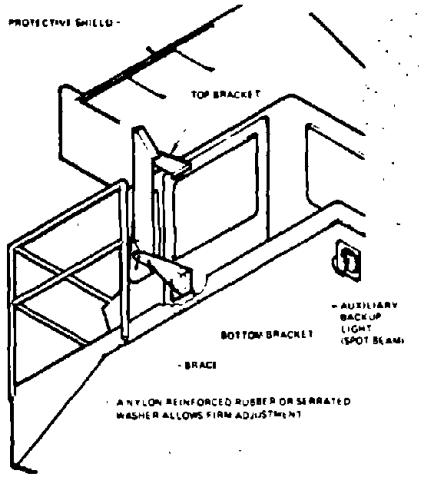


DOOR MOUNTED 10" x 30" MIRROR
WITH REMOVABLE
BACK PLATE



TELESCOPING
TUBULAR
MIRROR
MOUNT

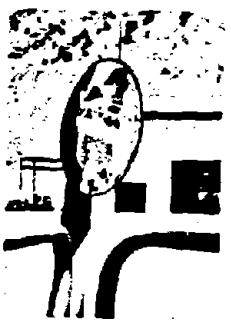
SHEET METAL
MIRROR MOUNT



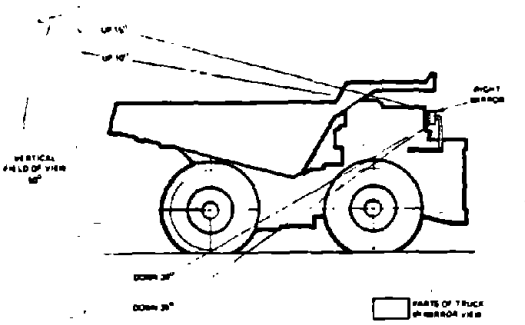
MOUNTING GUIDELINES (Large Left Mirrors)

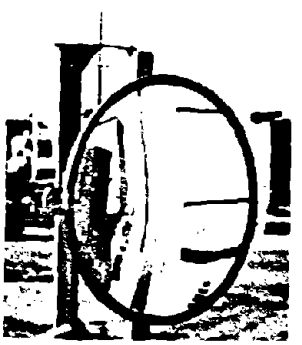
- The left mirror is viewed through the left door window of the cab.
- The left mirror is forward of the driver.
- The left mirror is mounted slightly outboard of the load bed so the side of the load bed can be viewed. If mounted too close, the driver cannot see the side of his truck or his tires on the ground. Therefore, he cannot judge where objects are. If mounted too far outboard, the field of view is reduced, the mirror is vulnerable to damage and it becomes more difficult for the driver to move his head far enough to view around the mirror.
- The left mirror is mounted so that the eye level (horizon) is approximately 1/3 of the way down from the top of the mirror.
- If needed, a shield mounted on the load bed overhang will prevent damage from load bed spills.
- The mirror mount must be strong enough to prevent vibration from interfering with the view and to hold its adjustment. (Nylon, reinforced "rubber" or serrated washers can be used between the mirror and its mounting bracket to allow and hold hand pivot adjustments.
- The mirror and its mounts must not hinder access to and from the cab.
- Left mirror can also be mounted to deck posts, on the hand rails or from the top of the cab. If the cab is more than 18" inboard of the load bed, mounting to the door is not recommended.

Right Mirrors



ROUND CONVEX
12" DIAMETER
15" RADIUS





ROUND CONVEX
18" DIAMETER
30" RADIUS

RIGHT MIRRORS

Right mirrors, like left mirrors, are used to avoid hazards while driving, but they cannot be used as effectively for guidance when backing. Right mirrors are typically 15 to 24' from the driver; therefore, a curved convex mirror is needed to provide a large enough field of view. While providing a large field of view, the size of images (views of objects) in a curved mirror is much smaller than those in a flat mirror. This makes it difficult to judge distances or clearances or to recognize small objects on the right side.

Flat mirrors and various sizes of round convex mirrors are presently used as right mirrors on haulage trucks. A New Rectangular convex mirror is now being tested and will also be described.

ROUND CONVEX
12" DIAMETER
50" RADIUS

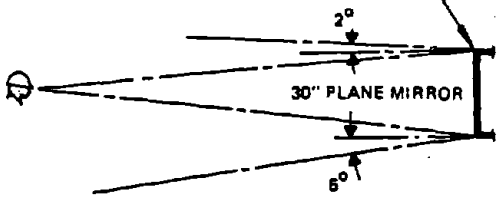
FIELD OF VIEW REQUIREMENTS

The right mirror is primarily used to check for the traffic and obstruction avoidance when turning right. It is also used in a general way to check truck position when backing and to check truck position in line with shovel bucket teeth when spotting on the left side of a shovel. As shown above, a large vertical field of view is required. A downward angle of view of about 35° is desirable for the same reasons that apply to left mirrors.

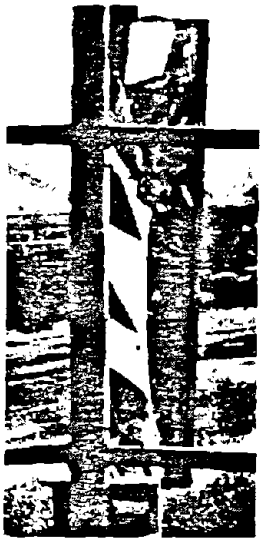
Right Mirrors (cont.)

RECTANGULAR CONVEX
12" x 16"
20" RADIUS

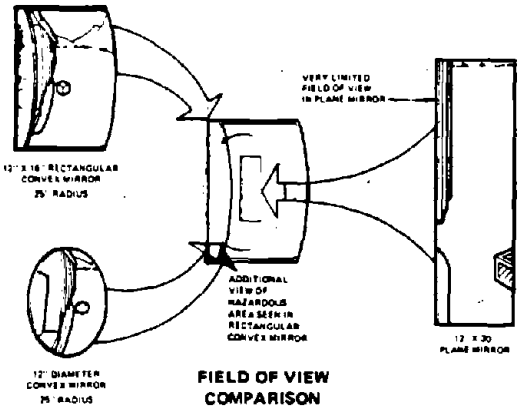
PLANE MIRROR 16 FEET FROM DRIVER



PLANE MIRROR
FIELD OF VIEW



8" x 30"
PLANE RIGHT MIRROR
20 FEET FROM DRIVER



FIELD OF VIEW
COMPARISON

MIRROR SCENE REQUIREMENTS

For traffic observation and hazard avoidance a reasonable field of view is required with the images in the mirror appearing large enough to be recognized. The same view features as the left mirror are needed to judge the relative position of obstacles. The above figure shows the mirror scenes of a flat mirror, a round convex mirror and the new rectangular convex mirror. The rectangular convex mirror has a better shape than the round convex mirror for the field of view and mirror scene requirements.

ROUND CONVEX MIRROR
12" DIAMETER
20" RADIUS

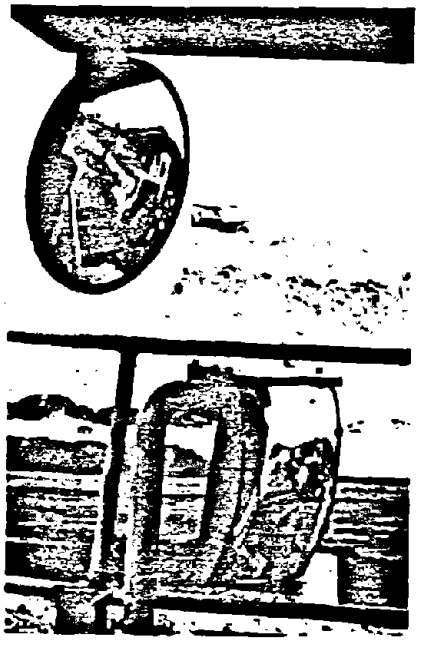
In a smaller convex mirror, (12" diameter) with a good field of view, recognition of objects in the scene is difficult unless the objects viewed contrast sharply with the background. Brightly painted objects can be seen better. The best conditions for a smaller convex mirror are sunny clear weather with a light colored background (light tan soil). On dark colored ground, with frequent overcast skies and reduced visibility weather, a larger convex mirror is needed for the same image recognition.

Right Mirrors (cont.)

ROUND CONVEX
18" DIAMETER
30" RADIUS

ROUND CONVEX
12" DIAMETER
50" RADIUS
NOTE DISTORTION

ROUND CONVEX
18" DIAMETER 30" RADIUS
RECTANGULAR CONVEX
12" x 16" 20" RADIUS



RIGHT MIRROR CHARACTERISTICS
(Approximate)

Size / Type	Radius of Curvature	Size of Images of Objects	*Vertical Field of View	*Horizontal Field of View
MINIMUM SPECIFICATIONS		Fair	40°	50°
PLAIN 12" x 30" Rectangular	Flat	Near life size	7°	9°
ROUND CONVEX				
12" Diameter Convex	15"	Poor	48°	94°
Most Typically Used	20"	Fair	36°	70°
	30"	Very good	24°	46°
	50"	Excellent	14°	28°
16" Diameter Convex	20"†	Fair	48	94
Increasing Usage →	25"	Good	38	74
18" Diameter Convex	25"	Good	43	84
Increasing Usage →	30"	Very good	35	68
20" Diameter Convex	25"†	Good	48°	94
	30"†	Very good	40°	78
	40"†	Excellent	30°	58
NEW RECTANGULAR CONVEX				
12" x 16" USBM	20"	Fair	48	70
12" x 20" R&D	30"†	Very good	40	46
12" x 30"	40"†	Excellent	42	34

Below minimum specification

† Not presently used on trucks.

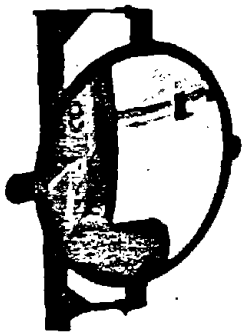
*NOTE: Field of view applies only through the center of a round convex mirror. A smaller field of view is more acceptable in a rectangular convex mirror. A percentage (10-40%) of the horizontal field of view is used to view the side of the truck.

TYPES AND SIZES OF CONVEX MIRRORS

Convex mirrors are generally specified only by size; however, the radius of curvature is very important. Typical convex mirrors vary from a radius of curvature of 15" to 50". In a convex mirror with a large radius, images of objects appear larger; however, the field of view is smaller. The above chart shows the approximate specifications of common and ideal right mirrors. In some applications some mirror characteristics may have to be compromised. The load bed shape can also compromise the view scene requirements. More than one mirror can be used.

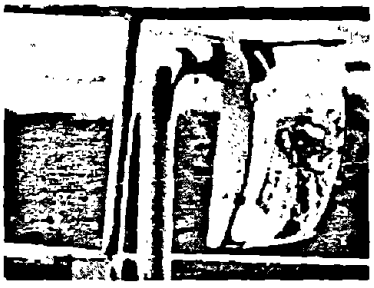
On tractor trailer trucks, right mirrors closer than 12' from the driver gain additional field of view and image quality.

Right Mirrors (cont.)

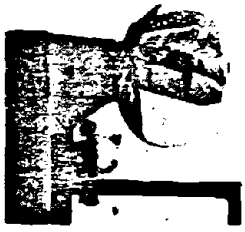


ROUND
CONVEX
18" DIAMETER
30" RADIUS
DECK POST MOUNT

ROUND
CONVEX
18" DIAMETER
30" RADIUS
LOAD BED
OVERHANG
MOUNT



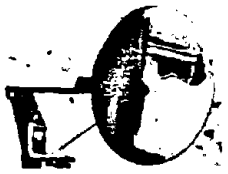
RECTANGULAR
CONVEX
12" x 18"
20" RADIUS
BENT PIPE
SWING-AWAY
MOUNT



ROUND
CONVEX
12" DIAMETER
50" RADIUS
POST ARM MOUNT

MOUNTING GUIDELINES

- The right mirror must be viewed without obstruction through the right door window of the cab.
- The right mirror should be mounted as far forward as possible.
- The right mirror is mounted slightly outboard of the truck so as to view the side of the truck. If mounted too close, the driver cannot judge where objects are; if mounted too far outboard, the mirror is vulnerable to damage.
- If needed, a shield/deflector mounted on the load bed will prevent damage from load bed spills.
- The mirror mounting post can be attached to the cab deck or load bed overhang. It should be strong enough to prevent vibration from interfering with the view scene.
- A swing-away release feature can prevent damage due to scrapes with garage doors and other structures.

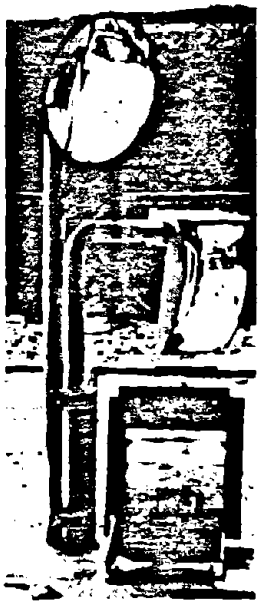


ROUND CONVEX
MIRROR
12" DIAMETER
50" RADIUS
WITH WAVY LINE
DISTORTION
HANDRAIL MOUNT

ROUND CONVEX
18" DIAMETER
30" RADIUS
DECK POST MOUNT

RECTANGULAR
CONVEX MIRROR
12" x 18"
20" RADIUS
BENT PIPE
SWING-AWAY
MOUNT

BLIND AREA
VIEWER
(FRESNEL LENS)

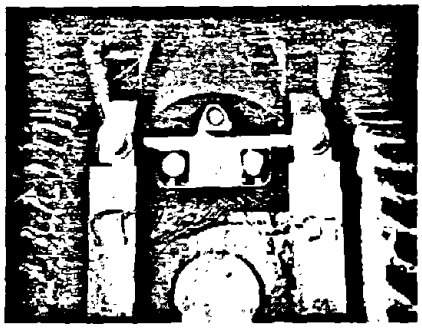


Mirror Usage

QUARTER SPHERE MIRROR 15" RADIUS

QUARTER SPHERE MIRROR 15" RADIUS ENGINE HOOD MOUNT

BACKUP LIGHTS AIMED TO AID MIRROR USE



DRIVER'S USE OF MIRRORS

Drivers tend to develop preferences for mirror placement based on their experience and will adjust mirrors for their own use. With large, well designed mirrors there is less need for this adjustment, and the clearer, well-oriented images improve driver confidence while driving and backing.

Drivers do become annoyed and frustrated by mirrors that are flimsy, loose, require constant readjustment or are easily damaged. Well designed, properly mounted mirrors create a reliable field of view and tend to be well maintained by drivers.

Mirrors do not provide a view directly behind the rear tires. This blind area is accommodated in 4 ways:

- Driver situation awareness of all traffic in the area
- Turning when backing . . . the mirror view sweeps the blind area
- Guidance from a man on the ground
- Mine traffic procedures that direct others to remain in the driver's view

MIRROR MATERIALS

Glass mirrors generally retain a good view quality until damaged. Damaged glass mirrors force replacement, but damaged plastic and metal mirrors frequently are kept in use even though the view quality has become degraded by dents and scratches.

ADDITIONAL USES FOR MIRRORS

Mirrors can be used to view blind areas in front of haulage trucks. As shown on the left, a quarter sphere mirror has a view of the area in front and to the sides of the forward bumper. For viewing forward and right blind areas. Fresnel lenses can give a better oriented view and are being tested for this application. See photo, page 21.

TRUCK LIGHTING

In addition to well placed stationary lighting at the dumps and shovels, mirror view at night can be greatly aided by aiming the backup lights to spotlight the ground in the mirror views. All other lighting on the truck is needed in order for traffic to judge the driving situation. Due to the short life of light bulbs and fewer supervisory personnel at night, redundant lighting on trucks is preferable.