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A STUDY OF ROPE-HAULAGE SYSTEMS

JAMES H. COBBS ENGINEERING
TULSA, OKLAHOMA

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by

Louis R. Reeder
and
James H. Cobbs

James H. Cobbs Engineering
Tulsa, Oklahoma

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PREFACE

This report was prepared by James H. Cobbs Engineering of Tulsa, Oklahoma under USBM contract S0122047. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of WO with Mr. W. E. Bruce acting as the technical project officer. Mr. A. G. Young was contract administrator for the Bureau of Mines.

The report is a summary of the work recently completed as part of this contract during the period September 1, 1972 to June 1, 1973. This report was submitted by the authors on June 18, 1973.

This technical report has been reviewed and approved.

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EXECUTIVE SUMMARY

Investigation of the Coolie Car and Similar Haulage Systems

This work was authorized under Bureau of Mines Contract S0122047 and investigated endless-rope haulage, and specifically the rope-hauled Coolie Car system and equipment, manufactured by Maschinenfabrik Scharf GmbH of The Federal Republic of Germany.

Other similar haulage systems were studied during the progress of the investigation and information relative to them supplements the text to show the European trends in haulage that presently differ from those in the United States.

Reason for Investigation

The investigation was to determine whether the installation of rope-hauled Coolie Car systems is likely to improve upon the present methods of moving men, materials and supplies in underground bituminous coal mines in the United States. The materials handling function is the largest single cost item in deep mining of bituminous coal, and is directly related to 50 percent of the lost time accidents in those mines. This study was initiated with the objective of increasing safety and efficiency in materials handling systems and man-riding.

History of Rope Haulage

Endless-rope haulage and main-and-tail haulage were developed in Great Britain in 1844 (40). These two systems became established for use on main and gate roads and continued as the principal haulage method in coal mines of the world for many years.

More flexible transport systems of higher capacity were necessitated by increased coal production in the United States before the end of the 19th century. Many new and improved haulage systems were developed and adapted well to the relatively low gradient roadways of coal mines in the United States and eliminated endless-rope and main-and-tail haulage almost completely by 1930.

Direct-rope haulage probably antedates endless-rope and main-and-tail haulage by many years, but documentation of this assumption is lacking. Direct-rope systems are still used in many mines for haulage on steep, straight roadways.

European mining methods, in highly pitching and faulted seams did not encourage the abandonment of rope-haulage systems. Instead, it fostered an atmosphere for the development of more sophisticated rope-haulage systems which were developed parallel to, but always ahead of, systems using other methods of traction. Now a large percentage of European mines operate highly developed rope-haulage systems complementing diesel and electric rail haulage, and rubber tired electrically powered vehicles.

Description of Rope Haulage

Rope haulage is a means of moving loaded or empty vehicles by means of wire rope. It is used generally on steep inclines where other methods of traction are inefficient or will not function.

Endless-rope haulage, main-and-tail haulage, and direct-rope haulage are the three basic types of rope haulage with numerous variations and modifications of design being applicable to each type. The Coolie Car system is a modification of main-and-tail haulage (30).

Endless-Rope Haulage

Endless-rope haulage is a popular system in British coal mines. Two rail tracks are used; one for empty cars traveling inby and one for loaded cars hauled outby simultaneously. The endless steel rope passes around a wheel that is rotated by an engine through suitable gearing, and around a return sheave at the inby end of the haulage road. Cars are attached singly or in sets at regular intervals to the rope which travels continuously in one direction at speeds of $1\frac{1}{2}$ to $2\frac{1}{2}$ mph. The system is capable of hauling over long distances, but requires wide roadways to accommodate the double track. Endless-rope haulage is used normally on relatively straight, inclined to flat roadways.

The recent introduction of captivated rope, captive-rail haulage systems into European mines has revitalized rope haulage. Modifications of endless-rope and/or main-and-tail haulage, known as Coolie Car, Road Railer or monorail have added ease of operation and flexibility heretofore lacking in rope haulage systems. Four principal developments differentiate these systems from conventional systems: (1) A series of spring loaded cruciform pulleys and fully caged pulleys, fastened to the track, which permit an unrestricted number of controlled turns while laterally restraining the haulage rope, but permitting it to travel freely between the haulage sheave and the return sheave; (2) A system of bogie wheels positioned on a channel or I-section track, which permits free running, but prevents derailment;

(3) A reserve rope drum that allows the system to extend rapidly to keep up with face development; and (4) Short, light, prefabricated lengths of track that can be laid or taken up rapidly.

Main-and-Tail Haulage

Main-and-tail is a single track haulage system operated by a single haulage engine but with two drums, each with a separate rope. The engine usually is located at the outby end of the system. The main rope is attached to the outby end of the set of cars, and the tail rope, which is twice the length of the haulage road, passes around a sheave inby and is then attached to the rear end of the set. To draw the full set out, the main rope is wound in, and the tail rope is allowed to run free. To draw the empty set inby, the tail rope is wound in, while the main rope is allowed to run free. Main-and-tail haulage is adopted when the gradient is irregular, the road is crooked, and the empty set will not run in by gravity.

Direct-Rope Haulage

Direct-rope haulage is a system of incline haulage, comprising one rope and one drum. The winding engine hauls the journey of loaded cars up the incline. The empties are connected to the rope and returned to the bottom by gravity. The drum incorporates a clutch to allow it to run loose on the shaft when required. Direct-rope haulage can be used on gradients from 1 in 15 upwards. With special hoisting cars and safety devices the system may be used on very steep inclines.

Example of a Rope-Haulage System

A ski tow is an elementary, but well known example of an endless-rope haulage system, but the classic example is the famous cable cars of San Francisco. Examples of main-and-tail haulage are more difficult to identify, but many aerial tramways are at least a modified form of this system. A car being winched uphill can be associated with direct-rope haulage.

Application of Rope-Haulage Systems

Generally, rope-haulage systems are applicable to situations where coal is being mined in steeply pitching seams and where roadway gradients are too steeply inclined for other forms of traction. One of the most severe limitations of rope-haulage systems is lack of flexibility. In many European mines where rope haulage is used, flexibility must be a secondary consideration because rope systems are the only methods of negotiating the steep roadway gradients. However, communications from European mining engineers and design engineers indicate a desire to eliminate rope-haulage systems wherever conditions permit.

Except for direct-rope systems used for handling men and materials on steep slopes and entries, conventional rope systems are not compatible with operations in bituminous coal mines in the United States. The rope-hauled captive-rail systems do have a degree of flexibility which permits their use for handling men and materials to the face in longwall and shortwall mining operations. These systems are not useful in room-and-pillar operations, and lose their effectiveness in large operations in horizontal seams.

Scope

Limits of the Investigation

The investigation was initiated as a detailed study of endless-rope haulage systems, and specifically the modified endless-rope system known as the Coolie Car, manufactured by Maschinenfabrik Scharf GmbH of The Federal Republic of Germany. During the progress of the study several highly developed modified endless-rope systems were found to be in use in European mines. These systems were studied in as much detail as possible from the information available, and data concerning them are included as appendices to this report. Descriptions of the operation of main-and-tail haulage and direct-rope haulage are made for informational and comparative purposes only and are not evaluated.

Approach to Investigation

Two criteria, safety and cost effectiveness, were used to evaluate the potential usefulness and effectiveness of endless-rope haulage systems for bituminous coal mines in the U. S. An initial review of each rope system was made establishing its overall adaptability to the U. S. system of mining, and following the initial review, each system was examined for safety. If, from available statistics, a rope system could not be shown to be as safe as or safer than alternate systems, its use in the U. S. was not recommended. However, a cost comparison was made between existing systems used in the U. S. and the systems investigated.

Recommendations

The study of rope-haulage systems presently in use in European mines produced the recommendations given below for each system.

Direct-Rope Haulage

Direct-rope haulage is used in many mines in the U. S. with steep slope entries and where roadway gradients prevent use of other forms of haulage. It is not considered in this study except for information purposes. No recommendations are made.

Conventional-Endless-Rope Haulage

The conventional-endless-rope system is not suited for use in mines in the United States. The system is inflexible and the exposed rope constitutes a safety hazard. This type of haulage usually is limited to only one roadway and is difficult to extend. It has no advantage over existing systems.

Conventional-Main-and-Tail Haulage

Conventional-main-and-tail haulage no longer is suited for use in coal mines in the United States. Although more flexible than conventional-endless-rope-haulage, it nevertheless suffers from the same major disadvantages.

Captive-Track Rope-Haulage Systems

Captive-track rope-haulage systems, which are modifications of endless-rope and/or main-and-tail haulages are not feasible in the room-and-pillar operations employed in the majority of bituminous coal mines in the U. S. However, they can be applied to longwall and shortwall operations with distinct advantage in pitching seams and where the roadway gradient is steep.

Rope-Hauled Coolie Car. - The rope-hauled Coolie Car system is not suitable for room-and-pillar operations in bituminous coal mines in the U. S. It can be used to advantage in longwall or shortwall operations in pitching seams or where steep roadway gradients are present. The moving rope and sheaves constitute a hazard in the roadway. Overall, the system does not show an improvement in safety or economics over haulage systems now being used.

Rope-Hauled Road Railer. - The same conclusions may be made for the rope-hauled Road Railer system as were made for the rope-hauled Coolie Car.

Rope-Hauled Monorail. - The rope-hauled Scharf monorail system is not suitable for bituminous coal mines that are exploited by the room-and-pillar method of mining. The system can be used advantageously in pitching seams, and on steep roadway gradients to support longwall or shortwall operations, or in small operations for transport of minerals, men and materials. The Scharf monorail system makes the most use of the cross sectional area of a roadway, but the moving rope and sheaves are a hazard in restricted areas, and the system cannot be used with unstable roof conditions. Costwise, the system will not improve on most systems now used.

The rope-hauled Becorit monorail system is similar to the Scharf monorail system and the comments made for the Scharf system are applicable.

Systems Summary

The rope-hauled Coolie Car was most costly, and did not show an increase in safety over the various systems of haulage presently being used in bituminous coal mines in the U. S. Recommendation is made that further study of these systems by the Bureau of Mines be discontinued.

Table 1 gives a general outline of the advantages and disadvantages of various rope haulage systems.

TABLE 1. - Main features of different types of rope-hauled material transporting systems

	Advantages	Disadvantages	Limitations
Conventional Rope Haulage	1. Simple and relatively inexpensive to install for larger capacity systems. 2. The available systems can together cover gradient up to 45^{o} (1 in 1). 3. Low maintenance cost. 4. Can be used for handling mineral, dirt, men and materials.	1. Driver, divorced from train, relies on signals. 2. Extension of the system is not simple. 3. Slow haulage speeds 4. Derailment is common, and no built-in breaking system on older systems. 5. New fail-safe brake systems decrease in effectiveness rapidly as gradient increases. 6. Cars must be attached to moving rope. 7. Exposed sheaves and moving unrestricted rope in roadway is a serious hazard.	1. Severe changes in directions cannot be made easily. 2. System restricted to one roadway unless secondary haulages are installed. 3. On long hauls multiple engine station installations may be necessary.
Rope Hauled Coolie Car	1. System is easily and rapidly installed and extended. 2. Derailment impossible. 3. Can travel to the working face carrying heavy loads on steep gradients and negotiating 90^{o} curves on a 13 ft. radius. Usable in roadways of limited height and width. 4. Capable of traveling at speeds of up to 8 mph. 5. Can serve more than one roadway.	1. Driver, divorced from train, relies on signals. 2. Use of pallets essential to avoid unnecessary manhandling of materials. 3. Cannot pass over belt conveyors or similar obstructions except under unusual conditions. 4. Relatively stable floor conditions needed. 5. High capital cost.	1. Total load controlled by rope size and gradient. 2. Length of system limited by rope size permissable. 3. Only suitable for secondary system.

TABLE 1. - Continued

	Advantages	Disadvantages	Limitations
Rope Hauled Coolie Car (Continued)	6. Can be used for handling men, material and dirt. Can haul mineral in small operations.	6. Exposed moving rope pulleys, and sheaves a hazard.	
	7. Built in fail-safe system.	7. Complete flexibility limited by rope	
	8. Low maintenance cost.	8. Several systems sometimes needed if two or more areas are to be served.	
	9. Good on gradients up to 45° (1 in 1).		
Rope Hauled Road Railer	1. System is easily and rapidly installed and rapidly extended.	1. Driver, divorced from train, relies on signals.	1. Total load controlled by rope size and gradient.
	2. Derailment impossible.	2. Use of pallets essential to avoid unnecessary manhandling of materials.	2. Length of system limited by rope size permissible.
	3. Can travel to the working face carrying heavy loads on steep gradients and negotiating 90° curves on a 13 ft. radius. Usable in roadways of limited height and width.	3. Cannot pass over belt conveyors or similar obstructions except under unusual conditions.	3. Only suitable for secondary system.
	4. Capable of traveling at speeds up to 10 mph.	4. Relatively stable floor conditions needed.	
	5. Can serve more than one roadway.	5. High capital cost.	
	6. Can be used for handling men, materials and dirt. Can haul mineral in small operation.	6. Exposed moving rope, pulleys and sheaves a hazard.	
	7. Built-in fail-safe braking system.	7. Complete flexibility limited by rope.	
	8. Low maintenance cost.	8. Several systems sometimes needed if two or more areas are to be served.	
	9. Good on gradients up to 45° (1 in 1).		

TABLE 1. - Continued

	Advantages	Disadvantages	Limitations
Rope Hauled Monorail	1. System is easily and rapidly installed.	1. Driver, divorced from train, relies on signals.	1. Suspension strength of the system can be limiting.
	2. Derailment impossible.	2. Use of pallets essential to avoid unnecessary manhandling of materials.	2. Roof support distortion can be critical.
	3. Can travel to the working face carrying heavy loads on steep gradients and negotiating 90° curves on 13 ft. radius. Usable in roadways with restricted width and heaving floor.	3. High capital cost.	3. Length of system limited by rope size permissible.
	4. Capable of traveling at speeds up to 6 mph.	4. Lateral stability often not good.	4. Total load controlled by rope size, gradient.
	5. Can serve more than one roadway.	5. Relatively stable roof conditions needed.	5. Only suitable for secondary system.
	6. Can also be used for handling men, materials and dirt. Can haul mineral in a small operation.	6. Exposed moving rope, pulleys and sheaves a hazard.	
	7. Built-in fail-safe braking system.	7. Complete flexibility limited by rope.	
	8. Low maintenance cost.	8. Several systems sometimes needed if two or more areas are to be served.	
	9. Good on gradients up to 45° (1 in 1).		
	10. Can pass over belt conveyors or similar obstructions, either at an angle or parallel to the length.		
	11. Hand operated chain hoist enables loads to be lifted or lowered at any point in the system.		

INTRODUCTION

Background

Endless-rope haulage and main-and-tail haulage were developed in Great Britain in 1844 (40). These two systems became established for use on main and gate roads and continued as the principal haulage methods in coal mines of the world for many years. Direct-rope haulage undoubtedly antedated endless-rope, and main-and-tail haulage, but no information was available to confirm this assumption. However, direct-rope is the only form of rope haulage that has remained in constant use in the U. S. bituminous coal mines.

In the United States the impending demise of endless-rope haulage was signaled in 1870 when the first steam locomotive was placed in an underground coal mine by the Wilkes-Barre Coal and Iron Co. The phasing out of the system had accelerated by 1882 when compressed air locomotives were introduced for mine haulage, and its fate was determined by about 1890 when electric locomotives began working underground (9). As production increased more flexible transport systems became necessary to accommodate the demand for uninterrupted and increased haulage capacity. The flat to relatively low gradient roadways of most mines in the United States aided considerably in the acceptance of new systems, not rope dependent, and the phasing-out of the old rope systems. Nevertheless, in 1921, results of a survey of haulage systems in 7,088 coal mines ranked rope haulage third. Rope haulage was used in 15 percent of the mines, electric haulage was used in 46.2 percent of the mines, and animal haulage was used in 71 percent (1). Within a few years after this survey all endless-rope and main-and-tail haulage systems probably had been completely phased out.

Since 1969, five modified main-and-tail captive-track monorail systems for transport of materials and minerals have been installed in three anthracite mines in Pennsylvania. Two systems are in the Thirty Slope Mine at Shenandoah, two systems are in the Glen Nan Mine at Wilkes-Barre, and one system supporting a shortwall operation is in an unidentified mine at Wilkes-Barre.

In the United Kingdom the transformation from main-and-tail, and endless-rope haulage systems to other mechanized systems of transport has been slower than in the United States. The greatest advance in underground transport followed the nationalization of the British coal industry in 1951. One of the many recommendations by the Report of the Technical Advisory Committee 1945 (Reid Report) was the replacement of rope haulage in British coal mines by alternative methods of transport, principally conveyors or locomotive, according to the particular circumstance (46). Since the nationalization of the British coal industry there has been a progressive decrease in the use of rope haulage annually, but rope systems will continue to be used in the U. K. for many years. Older collieries may be fully committed to some form of rope haulage, and many are financially unable to resort to alternate systems. The policy of the National Coal Board is to phase out endless-rope haulage systems as main haulage systems, but not to restrict or discourage its use as a supporting system to transport men and materials. Many European mine managers indicate that rope systems are advantageous under certain duties and conditions, especially in pitching seams and roadways of steep gradients. Those familiar with these systems indicate further, that much of the supposed inefficiency comes from the ability of the system to function in the worst possible roadways and under deteriorating standards of maintenance of rolling stock, tracks, and rope rollers (15).

The material obtained thus far on haulage developments in Continental mines, and mines in other areas of the world is somewhat sketchy and incomplete, but rope-haulage systems commonly are being used. Developments probably were similar to those described for the United States and the United Kingdom.

Since the commercial development of the captive-track system in about 1960, more than 1,100 miles of these systems have been installed in German and British mines. Many more miles of these systems are installed in other Eastern European and Western European coal mines, but the amount is not known.

In Europe the emphasis has been on diesel traction for these captive-rail systems, and rope haulage is used as a supplementary system when roadway gradients are too steep for the diesel locomotives. Rope haulage may be used to assist diesel traction over steepest portions of roadways. The diesel traction and rope-hauled captive-track systems have undergone exhaustive tests in the British and German governments' research and testing establishments and have been approved for use in coal mines. Captive-track systems have an experience record of over 12 years in underground coal mines.

An electric trolley model is now in the process of development and testing by Becorit. It was designed specifically for export to the United States and Canada.

Much information used throughout the remainder of the text was gained through personal communication with many persons. Their willing and helpful assistance is greatfully acknowledged. Each person's name and organizational affiliation is listed in Appendix II.

Relation of Task to Bureau's Mission

The materials handling function is the largest single cost item in deep mining of bituminous coal in the United States, and is directly related to 50 percent of the lost time accidents in those mines. Since the impetus of this task derives from the Federal Coal Mine Health and Safety Act of 1969, a review of endless-rope haulage with emphasis on the Coolie Car system was initiated to see if an improvement could be made toward increasing the safety and efficiency of materials handling and manriding systems, and if an endless-rope system is practical for moving men, materials and supplies in underground bituminous coal mines in the U. S. Parameters guiding the study and their order of importance are: Effect on the health and safety of the coal miner, and cost effectiveness of the system and the European experience in the operation of rope systems.

Scope of Report

The investigation was to determine whether endless-rope haulage, and specifically the Coolie Car system, could be effectively integrated into a coal mine haulage system that uses conveyor belts and locomotives on rail as primary haulage. The evaluation also was to relate the application of the system to conventional room-and-pillar mining, and to longwall mining and shortwall mining. The evaluation was to determine the effect of mine size on system operation for large mines (over 400,000 tons per year), medium sized mines (100,000 to 400,000 tons per year), and small mines (less than 100,000 tons per year). The effects of differences in mining regions and underground terrain was to be considered.

At the beginning of this study the fact became apparent that little useful information was available from sources in the United States, and that a study of endless-rope haulage would have to be expanded to include main-and-tail haulage in order to more fully understand the operation of the recently developed captive-track systems, to which the rope-hauled Coolie Car belongs.

Data Collection

Data collection was divided into four phases; literature search, contact with manufacturers, contact with government agencies, and contact with mine operators or persons acquainted with rope systems.

Libraries

United States and European literature was reviewed in The University of Tulsa, Born Technical Library, and in The University of Missouri Library at Rolla, Missouri. The latter source holds many useful publications from the United Kingdom and Germany.

Manufacturers

Twenty manufacturers of rope-haulage equipment in the United Kingdom and the Federal Republic of Germany were contacted. At the time of preparation of this report nine had responded. Those that did respond also sent a considerable amount of literature related to their haulage systems. The Scharf representative forwarded motion picture films of the Coolie Car and monorail systems in operation. The Becorit representative showed motion picture films and slides of the Road Railer and monorail in operation and gave a detailed talk on the systems. All manufacturers contacted are listed in Appendix II.

Government Agencies

The National Coal Board, the Ministry of Power, and the Department of Trade and Industry of the U. K. were contacted by letter. All responded with references to source material and comments related to conventional and captive-track rope haulage systems. The German Consul General in Houston, Texas furnished addresses of mining companies in the Federal Republic of Germany to contact for information.

Mining Companies and Labor Organizations

The International Labour Office suggested companies and agencies to contact for information. Mining companies contacted are shown in Appendix II.

Individuals

Personal contact was made with eleven persons, all of whom are listed in Appendix II. Matthew Spedding of the Dowty Corporation and John M. Beardsley of Becorit (GB) Limited, both made an extraordinary effort to provide literature from sources in the U. K. and information from their own experience.

BASIC TYPES OF ROPE HAULAGE

Rope-haulage systems may be divided into three basic types: Direct-rope, main-and-tail rope, and endless-rope. To clarify the method of operation of each type and to relate the equipment studied for this report to the proper system, a cursory description of each basic system is given. A description of the Coolie Car and other closely related systems is given also, but consideration of the many other possible modifications and variations of the basic systems is outside the scope of this report.

Direct Rope Haulage

Direct-rope haulage, single or balanced, has been used widely where the slope gradient is neither undulating nor less steep than that required for empty cars to gravitate down slope at a desired speed with due regard to safety and preservation of the attached rope. The plane may have curves and varying grade, if all are against the load, and provided minimum grade is greater than the angle of rolling friction. Direct-rope haulage may serve different levels or entries by switches from the main slope, with rollers or sheaves to guide the rope around turns. Inasmuch as this system is similar in character to conventional hoisting, it has had extensive use on slope entries and underground drift haulage. Direct-rope haulage introduces a shuttle element into the overall transport system, and in inby situations where it may be sandwiched between other systems of transport, difficulty may arise because of the manpower requirements necessary for the transfer of rolling stock and/or material. However, the shuttle element and the transfer requirements decrease in importance as the length of the direct-rope element becomes a larger percentage of the total transport length and when the tonnage per trip is relatively high. Under these conditions the system can be very efficient.

Balanced direct-haulage systems are almost always less expensive to operate and usually are more reliable in performance than unbalanced systems when large tonnages are being handled and heavy loading is consistant. Because double tracks are necessary to accommodate the loaded cars moving outby and the balancing train of empties moving inby, a wider roadway is generally necessary for a balanced system (15).

Main-and-Tail Haulage

Main-and-tail haulage is applicable to straight, curved, inclined, level or undulating tracks on either a single main track or on a track including branches. Main-and-tail haulage is a necessity, particularly where roadways bend and prohibit the use of endless-rope or when the gradient does not allow the use of other types of haulage, such as locomotives or rubber-tired vehicles (15). Two ropes are used in this system; a main or haulage rope and a smaller tail-rope. Each winds and unwinds from its own freely revolving drum, which may be thrown into gear by friction clutches. When a loaded trip is to be hauled from the inside intersections, the main rope is coupled to the first car and the tail rope to the last car. Upon signal, the main drum is engaged, the tail-rope drum is free on its shaft, and the engine is started. The main rope, which is wound entirely on the drum at the completion of the run, pulls the trip from the mine and the trip drags the tail rope after it, unwinding the rope from its drum. The reverse process where the tail-rope pulls the trip, which in turn pulls the main rope, returns the empties to the mine.

Each side entry has a rope reaching from its mouth to a tail sheave at or near its inby end and back again to the main entry. This rope is provided at each end with couplings similar to those of the main-entry ropes. When an empty trip is to be pulled into a side entry, the main tail rope is uncoupled from the trip and the branch rope coupled in its place. The free end of the main tail rope is coupled to the remaining free end of the branch rope at this time. The branch rope can now pull the empties and main rope to the end of the side entry, and the reverse operation will haul loads to the mouth of the side entry. Signaling apparatus must be installed so that the haulage operator may be promptly notified to stop or start the trip at any point in its course (47).

Endless-Rope Haulage

Prior to 1900 in the United States and prior to 1960 in the United Kingdom, endless-rope haulage was the predominant system for main haulage. This system is suitable for any gradient less than that at which the transported mineral or material would spill from the car (15).

In endless-rope haulage systems a wire rope passes from the haulage-engine drum to and through the main entry to a sheave at the end of the workings, thence around the sheave and back along the main entry or a parallel entry to the engine drum. The ends of the rope are spliced together, forming an endless rope to which cars are attached, either singly by grips or in groups of two or more cars pulled by a grip car (47).

The system usually is installed with two tracks, which may be laid in the same entry if the roof is stable enough to permit the necessary width. If the roof is unstable, usually single tracks are laid in parallel entries of standard width, using one road for inby and the other for outby traffic.

Two general types of endless-rope haulage are based on speed of the rope. With the low-speed system, which is the original type, the rope moves continuously in the same direction at the rate of 132 fpm to 352 fpm. Two separate tracks are used, and the cars are attached to the rope singly at intervals of 100 to 200 feet. Whenever possible, as many inbound empty cars as outbound loaded cars are attached to the rope. In the high-speed system the rope travels at a speed of 1320 fpm to 2200 fpm and the cars are attached to the rope in groups of 50 or more by means of a grip car. There is usually but one track which is used for both inbound and outbound traffic, and the direction of motion of the rope is reversed to correspond to the direction in which it is desired to move the trip.

On the original low-speed system the rope ran under the cars and was referred to as an under-rope system. In mines with numerous swilleys the rope, generally, was carried over the cars and was known as an over-rope system. This reduced the problem of the rope riding up excessively when the swilleys were crossed, but curves were difficult to negotiate with this system. A side-rope system was tried, but did not gain popularity because of its tendency to cause excessive derailment of cars when starting.

The endless-rope system is not readily adaptable to haulage on side or cross entries. Where the road is straight, the grades uniform, and no branches are working, little difference exists between the high-speed endless-rope and the main-and-tail haulage systems, except that the latter requires 50 percent more rope. On the other hand, low speed endless-rope can use a simpler engine because its direction of motion is not reversed. On curves the endless-rope must be carried around small sheaves placed in the center of the track; this arrangement is not as satisfactory as in the main-and-tail system where large sheaves are placed outside the rails. On down-grades with endless-rope, because the trip is attached to the rope at only one point, the grip car, the possibility always exists that the cars will override and damage the rope. The main-and-tail rope system is superior to the endless-rope system in servicing laterals, not only from the standpoint of labor, but for ease and efficiency. The horsepower demand of the engine is the same for either system (47).

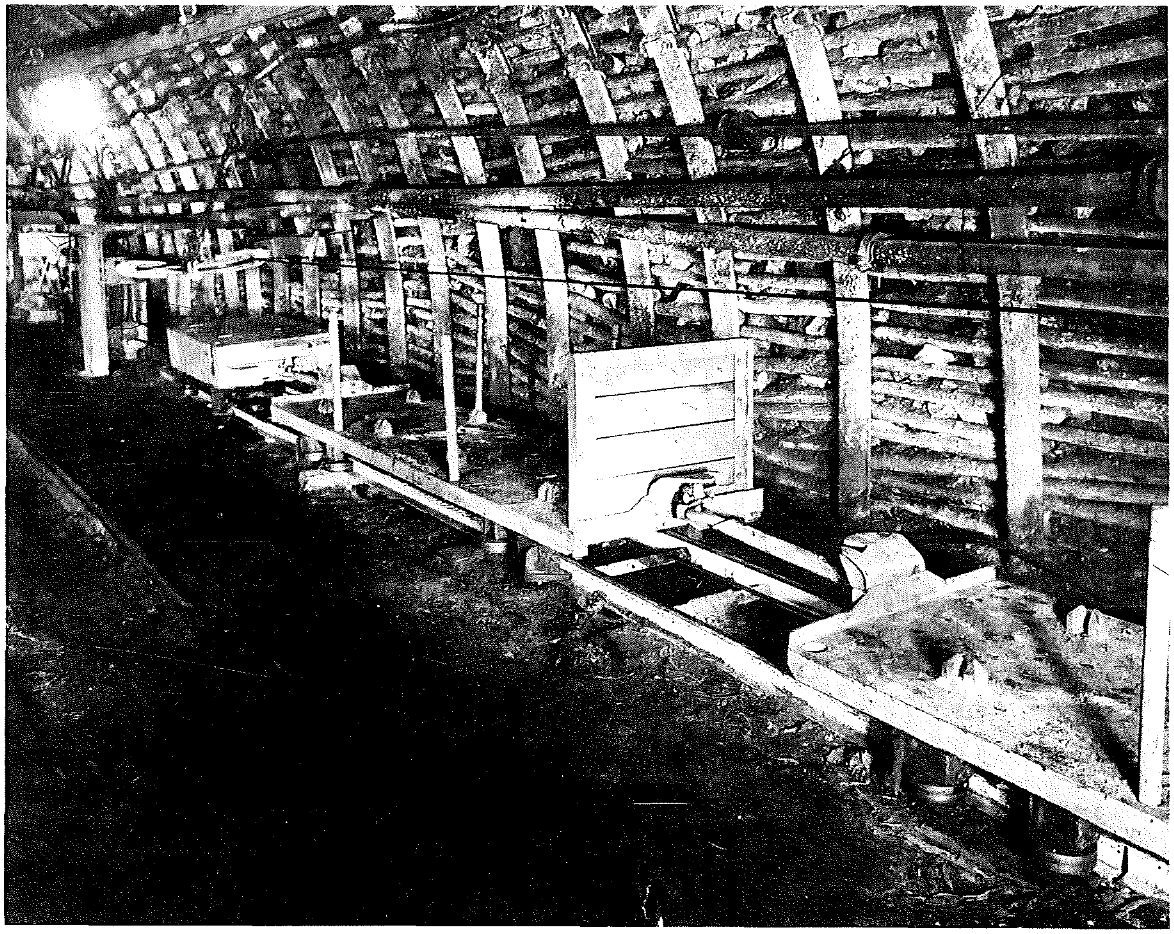

FIGURE 1. Coolie Car 500M braking bogie and material platforms. Note guide wheels captive in rail, and plow ahead of wheels to clean track. This system is integrated with monorail system, upper left, and conventional rail, lower left. (Photo courtesy Maschinenfabrik Scharf GmbH.)

Rope-Hauled Coolie Car

The Coolie Car (Fig. 1) was developed by Scharf in Germany about 1960 as a rope-hauled, floor-mounted, secondary system of transport for men and materials to service longwall operations in coal mines. The system has become widely used throughout Continental and British coal mines because of the high percentage of steeply inclined roadways which automatically eliminates all methods of traction except rope.

The rope haulage for the Coolie Car generally is referred to as an endless-rope system, but in reality it is a modification of main-and-tail haulage. The continuity of the rope is broken at the brake

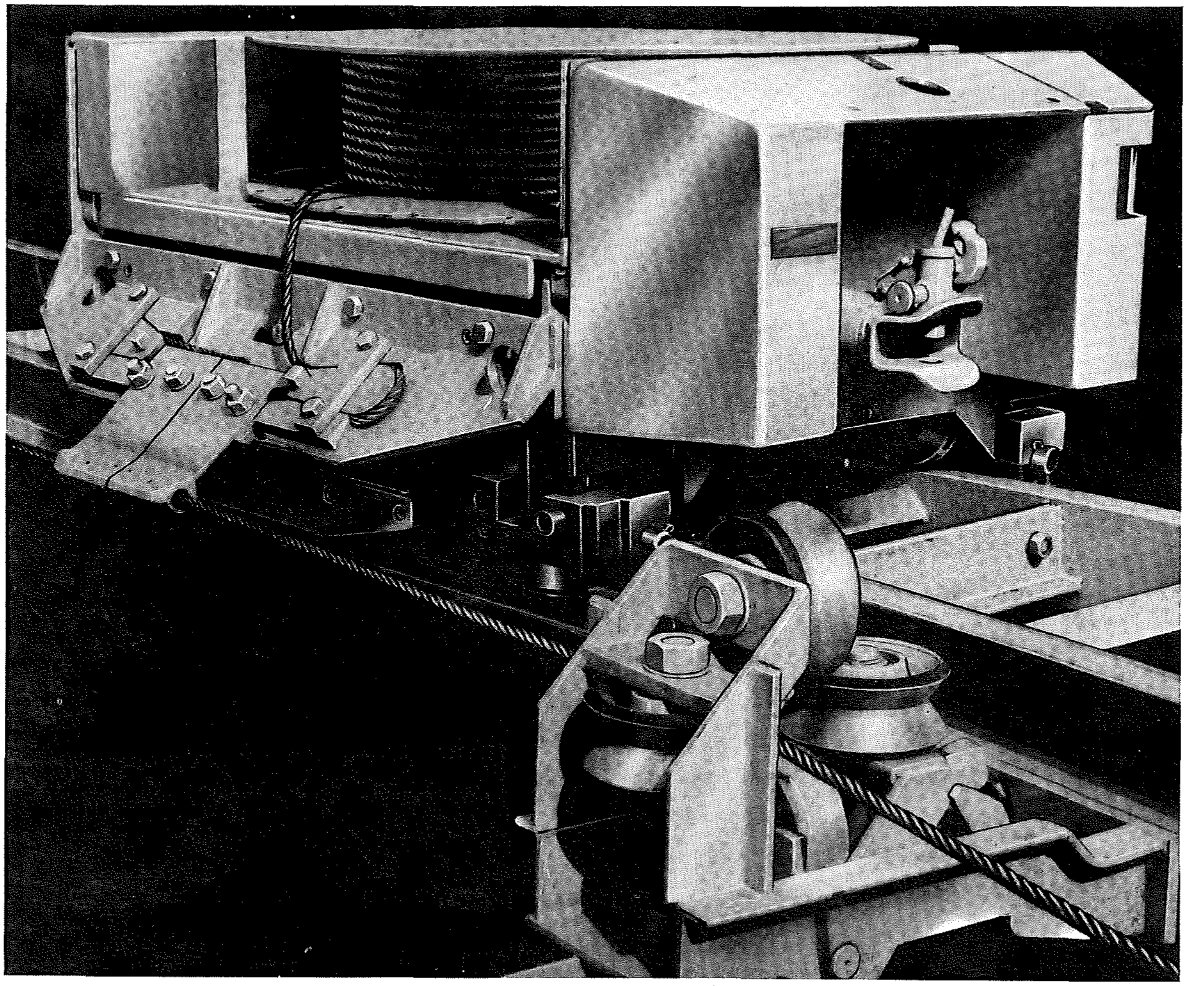

FIGURE 2. Coolie Car 500S braking bogie with reserve rope drum, showing rope attachment to striker plate and rope-captivating pulley cluster. (Photo courtesy Maschinenfabrik Scharf GmbH.)

car or Coolie Car to allow excess rope to be spooled onto a reserve drum (Fig. 2), which permits easy and rapid extension or retraction of the system to conform to the advance or retreat of a working face. The rope is moved by a Duesterloh winch or hydraulic, Koepe-type hoist (Figs. 3, 4) rather than a two drum unit normally associated with main-and-tail haulage. Use of a Koepe-type hoist reduces the rope needed for any given distance by one-third of that needed in conventional main-and-tail haulage. However, the shuttle element of the conventional main-and-tail haulage remains with the Coolie Car system. The system is applicable to straight, curved, inclined, level or undulating roadways on either a single track or on a track including branches.

The most unique feature of the Coolie Car system is the captive-track and car-bogie arrangement. The Coolie Car rails

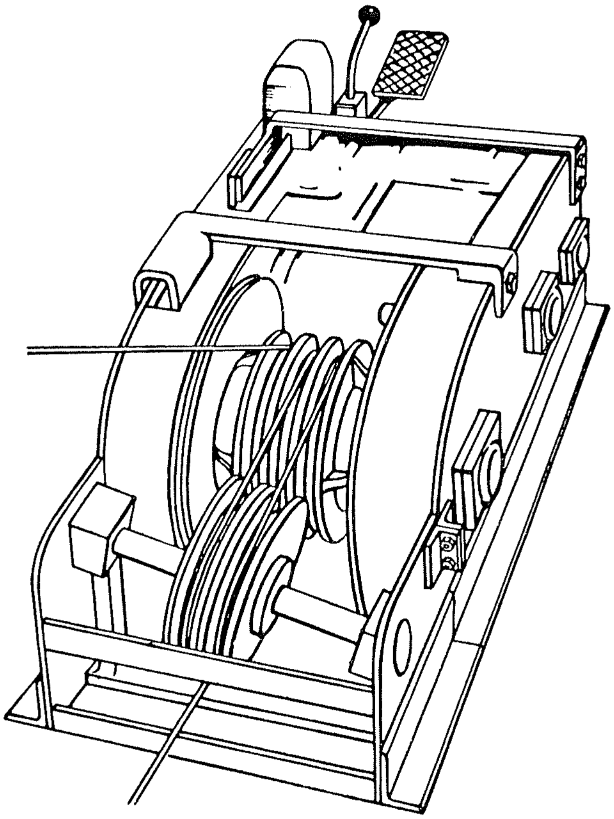

FIGURE 3.

Schematic diagram of Duesterloh winch. (National Coal Board Bulletin 63/242.)

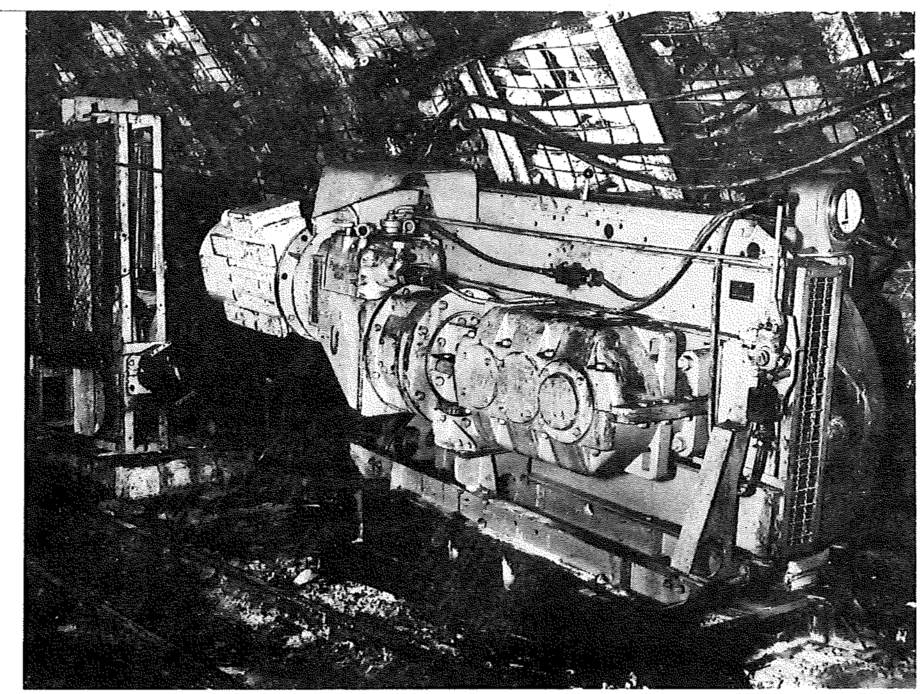

FIGURE 4. Haulage unit, hydraulic Koepe-type hoist. Note rope tensioning device forward of haulage unit. (Photo courtesy Maschinenfabrik Scharf GmbH.)

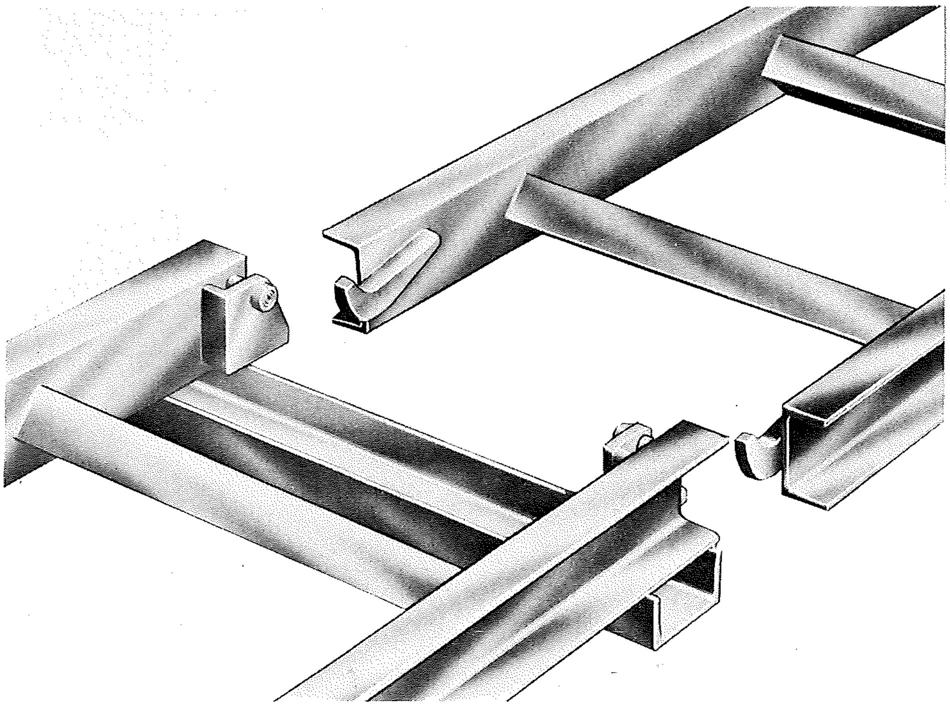

FIGURE 5. CHANNEL STEEL TRACK, SHOWING CONNECTIONS, ANGLE IRON SPACERS AND CHANNEL IRON SLEEPER. (PHOTO COURTESY MASCHINENFABRIK SCHARF GMBH.)

consist of two 4 in. x 2 in. channels, in lengths from 6 ft. 8 in. to 10 ft., welded back to back with angle iron spacers arranged in a ladder-like construction with 1 ft. 8 in. rail gauge (Fig. 5). The car is built up of two swiveling bogies and an intermediate platform section with a capacity of 8800 lbs. Each bogie unit has two pairs of load carrying wheels and two pairs of guide wheels (Figs. 6, 7). The guide wheels are captive within the flanges of the track section and provide lateral alignment of the bogies and eliminate the risk of derailment.

The rope also is captivated in this system. Captivation is accomplished with a cluster of four pulleys. One pulley in the cluster is spring loaded and is depressed as the towing arm passes through. It then snaps back into place keeping the rope captive and close to the track and prevents it from moving excessively either horizontally or vertically (Fig. 6). Return pulleys trap the rope either by an overlapping of pulley flanges or by a steel ring encircling the pulley.

During the past 5 years diesel locomotives (Fig. 8) with induced traction have been developed as prime movers for Coolie Car systems. Their use has been emphasized by European miners and manufacturers,

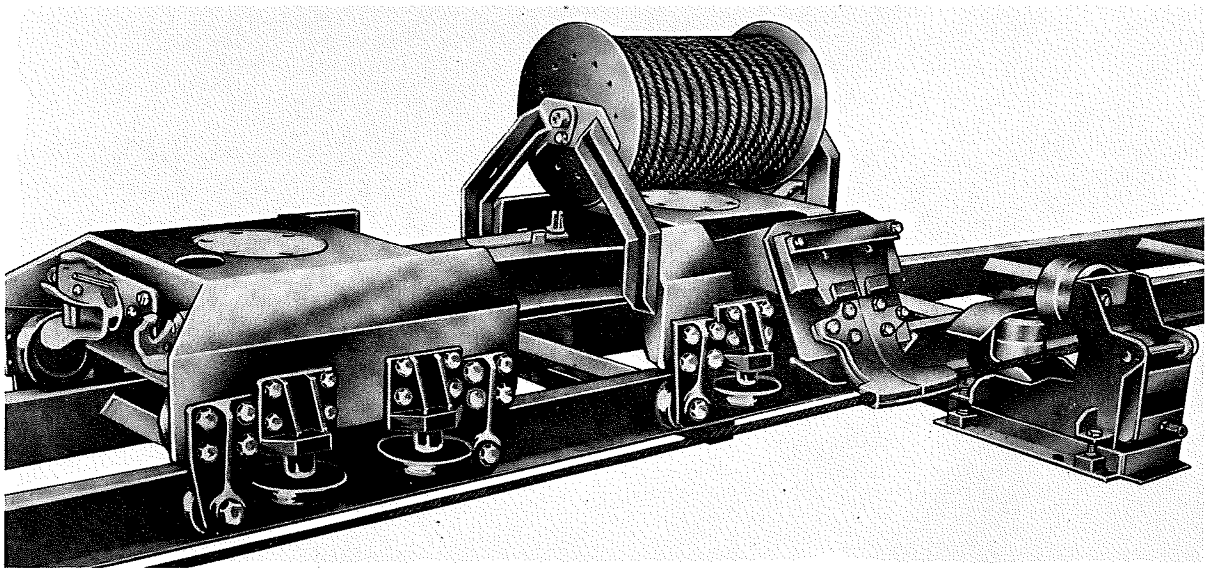

FIGURE 6. TRACTION AND BRAKING BOGIE WITH RESERVE ROPE DRUM 500S (LONG BASE TYPE). SHOWS RUNNING WHEELS AND GUIDE WHEELS ON CAPTIVE TRACK; ALSO STRIKER PLATE AND ROPE-CAPTIVATING PULLEYS. (PHOTO COURTESY MASCHINENFABRIK SCHARF GMBH.)

and rope haulage is used only to supplement or assist the diesel traction when gradients become too steep. The diesel powered systems can operate economically on gradients of 1 in 7 and operate safely on a gradient of 1 in 5. The same track is used for both diesel and rope-haulage.

More data relating to Coolie Car systems and associated equipment are included in Appendix III.

Other Rope-Hauled Systems

During this investigation several types of rope haulage systems closely related to the Coolie Car system were found to be in common use in European coal mines. These are mentioned briefly in the text for reference only; operating and equipment data are found in the appendices. Several endless-rope systems of limited use for man-riding only, and others for light materials handling, were studied. They are considered to be outside the scope of this investigation, are unadaptable to U. S. coal mines, and are not discussed further.

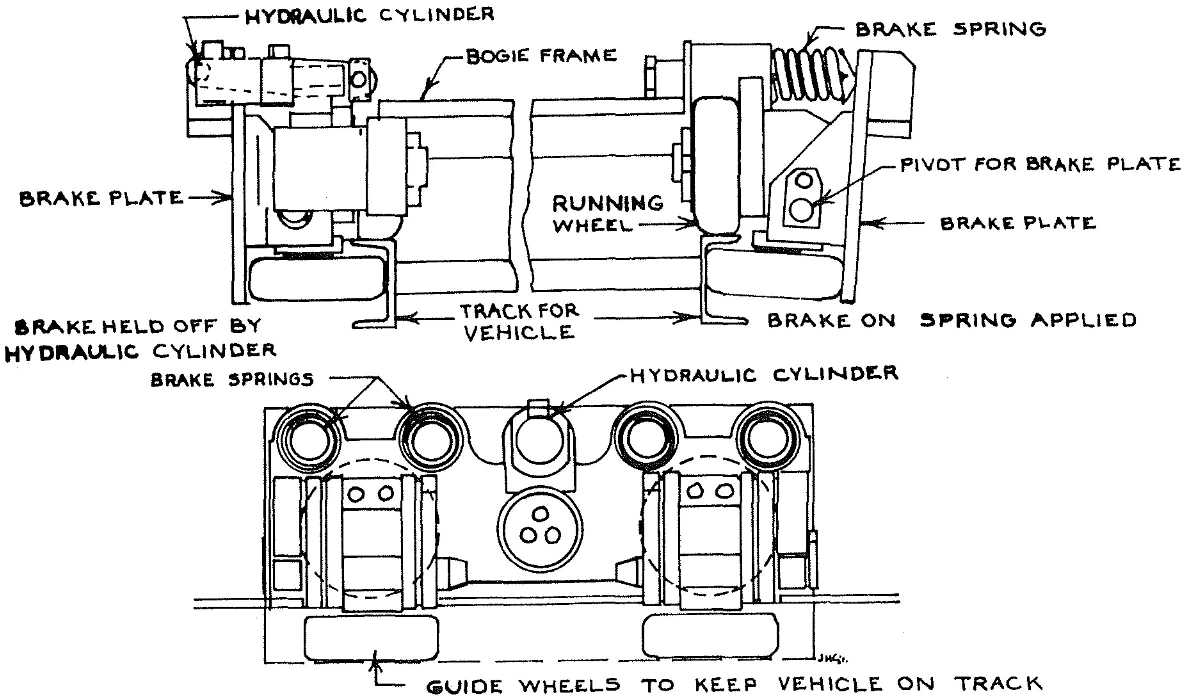

FIGURE 7. DIAGRAM OF COOLIE CAR BOGIE WHEEL ASSEMBLY SHOWING METHOD OF CAPTIVATION WITH TRACK, AND BRAKING SYSTEM IN RUNNING AND BRAKING POSITIONS. (COURTESY MASCHINENFABRIK SCHARF GMBH.)

Rope-Hauled Road Railer

A rope-hauled Road Railer system, manufactured by Becorit, is floor mounted and is similar to the Coolie Car. However, major differences in track design exist, as do differences in the rope captivating device (Appendix IV).

Rope-Hauled Monorails

The rope-hauled monorail is a roof mounted system running on an I-Section rail. The haulage and general operating characteristics are essentially the same as for the Coolie Car. A system is manufactured by Scharf (Appendix V), and a similar system is manufactured by Becorit (Appendix VI).

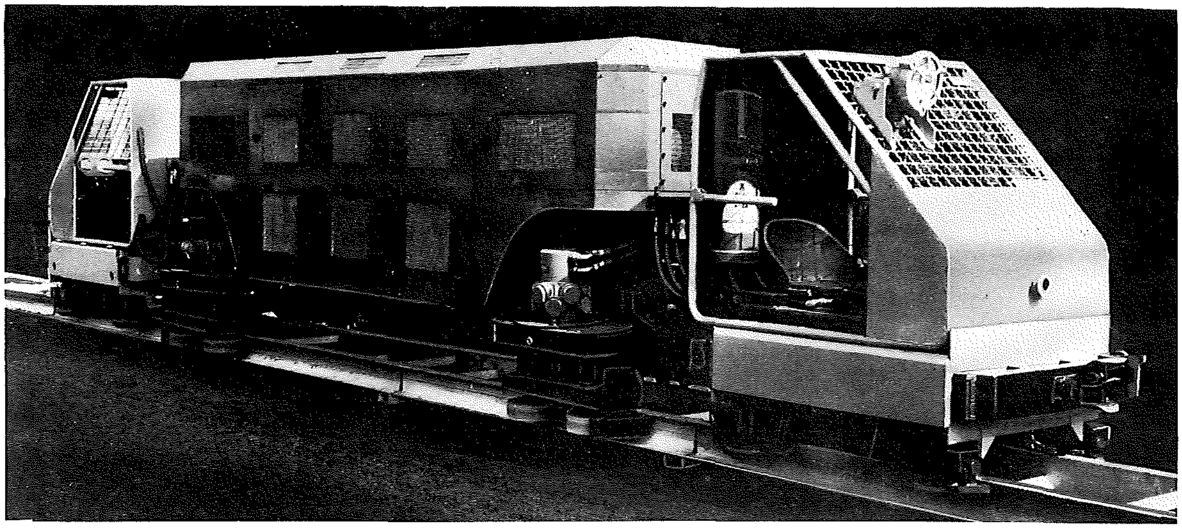

FIGURE 8. Diesel locomotive for Coolie Car system. (Photo courtesy Maschinenfabrik Scharf GmbH.)

RELATIVE SAFETY OF ROPE-HAULAGE SYSTEMS

General

Establishing the relative safety of a given system is a difficult problem to solve. Because the older systems, conventional endless-rope and main-and-tail haulage, have not been used in the U.S. for many years no comparative information is available, and past accident statistics do not show accidents related to those systems alone. Therefore, the percentage of total transport represented by the systems at a given time must be estimated to establish a relevancy for accident figures, to evaluate opinions from individuals who have worked with or seen the system working, and to rate sources of information in other countries where the systems may be in use.

The Coolie Car system, for which no experience exists in the U.S., necessitates the use of European statistics to provide a comparison for safety. Opinions of many individuals, knowledgeable in the operation of the Coolie Car system, were sought, and many foreign professional and governmental publications were consulted on the safety aspects of the system.

All conclusions reached in this section reflect a studied examination of the available statistics, the experience of various individuals and published comments from professional and governmental services.

Direct-Rope Haulage

This system, now in use in many U.S. coal mines, is not relevant to the haulage systems being investigated and is outside the scope of this report. It was included in an earlier section for information purposes only to identify one of the basic types of rope-haulage systems, and will be given no further consideration.

Main-and-Tail Haulage

United States accident statistics cannot be used as any indication of the relative safety of main-and-tail or endless-rope haulage. These systems were slowly being replaced from before 1900 and were phased-out completely by 1930. No indication is available as to what percentage of the total transport system they occupied, except the 1921 Survey (1), noted in the Background section of this report.

Statistics from British mines, although not indicative of the whole story, show a trend toward a reduction in accident frequency as rope systems were phased out. Prior to 1951, and nationalization of British mines, the entire underground transport system, main and secondary, was rope-hauled. Following the recommendation of the Reid Report (26) the National Coal Board, in 1951, began to phase-out rope-haulage as a means of primary haulage for mineral in main and gate roads, and replace the rope systems with belt conveyors. Rope systems were retained as secondary systems for the transport of men and materials. Table 2 shows the accident frequency rate before and during a portion of the transition period during which rope-haulage was being phased-out. Later accident rates are not incorporated into this example because they introduce increased mechanized mining methods, reduction in labor force and other variable factors not compatible with the period 1947 to 1957.

Conventional main-and-tail haulage systems are not safer than haulage methods presently in use in bituminous coal mines in the U.S. Spedding and Beltz, during conversation with the writers, agreed that conventional main-and-tail haulage, like endless rope haulage is hazardous because of exposed rope and sheaves in motion in roadways. The heavy demand for labor at transfer points also constitutes an additional exposure risk.

Endless-Rope Haulage

The relative safety of endless-rope haulage, cannot be determined from past U.S. accident statistics, for the same reasons given for main-and-tail haulage. Table 2, is even more applicable to endless-rope haulage, because endless-rope systems were in use in much greater

TABLE 2. - Transport accidents: Death and injury rates per 100,000 manshifts 1/ worked by all persons underground in the United Kingdom.

Type Accident	Frequency Rate										
	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
Fatal	0.08	0.08	0.08	0.07	0.07	0.08	0.07	0.06	0.09	0.06	0.07
Reportably Injured 2/	0.46	0.46	0.37	0.40	0.35	0.37	0.34	0.32	0.33	0.35	0.35
3 Day Injuries 3/	25.7	33.2	41.4	33.9	29.8	27.9	26.8	24.0	22.8	22.5	20.1

1/ A manshift is defined as 7½ hours plus one winding.

2/ For purposes of this table a reportable injury is the result of any accident causing fracture of the head or of any limb, or any dislocation of any limb or any other serious personal injury.

3/ Three day injuries means injuries resulting in disablement for more than three days.

Source: Crook, A. E., Safety Aspects of Underground Transport in Coal Mines (11).

number. However, in any area or mining district committed to rope-haulage, the endless-rope and main-and-tail haulage systems are usually so closely interrelated that a statistical breakdown for each system is virtually impossible.

Conventional endless-rope haulage systems are not safer than haulage methods now in use in bituminous coal mines in the U. S. The concensus of all persons, familiar with rope haulage, with whom the writers had communication is that conventional endless-rope haulage is hazardous, and is not suitable for installation in the high capacity, highly mechanized mines in the United States. Under poor roadway conditions, derailments, undetected by the remote haulage operator, generally are the cause of much damage to roadway supports, track and electrical equipment as the derailed cars are dragged along the roadway. This also is true of main-and-tail haulage. In correspondence with the writers Scott-Owen refers to endless-rope haulage as, "slow and man power hungry." The endless-rope system requires even more labor than main-and-tail haulage at transfer points, thus creating even higher exposure risks to personnel.

Rope-Hauled Coolie Car

No operating experience for the Coolie Car exists in the U. S. Accident frequency rates from the U. K. are used for indication of the relative safety of rope-hauled Coolie Car systems. The accident frequency listed under rope-and-drawgear breakage and mechanical haulage (Table 3) is represented almost completely by secondary systems for transporting men and materials and is limited to rope haulage systems, including the rope-hauled Coolie Car. Because no breakdown of haulage-accident frequency rates in the U. S. is available, the frequency rates from the rope-hauled men-and-materials systems of the U. K. are compared to the U. S. frequency rates for all haulage. These comparative frequencies are shown in Table 3.

Table 3. - Comparative Haulage-Accident Frequency Rates
United States - United Kingdom

Location and Accident Cause	Accident Frequency Per Million Man Hours		
United Kingdom	1966	1967	1968 1/
Rope & Drawgear Breakage	0.04	0.05	
Mechanical Haulage	13.81	13.03	
Horse, Hand, and Gravity	4.14	3.11	
Conveyors & Gate-end Loaders	4.98	4.59	
	22.97	20.78	18.65
United States (all haulage)	10.75	10.55	9.73

1/ No breakdown of accident frequencies for 1968.

Source: H.M. Chief Inspector of Mines Annual Report 1968 (13). BuMines, Injury Experienced in Coal Mining, IC 8419, 1966 (27); IC 8555, 1967 (28); and IC 8556, 1968 (29).

Reducing the U.K. haulage accident frequency by removing Horse, Hand, and Gravity haulage as well as conveyor accidents shows (Table 3) that the accident frequency in the U.K. exceeds that in the U.S. in the years 1966 and 1967, by 28.8 and 23.9 percent respectively.

The accident frequency in the U.K. is even greater than shown because the only accidents reported are those that result in 3 or more days lost time, excluding the day of the accident.

The exposed rope and moving pulleys in the roadway, typical of any rope-haulage system, are the most obvious hazard. The Coolie Car system with its rope captivating device reduces the hazard to some degree by keeping the rope close to the rail. Also in case of a rope break, whipping of the broken rope through the roadway is confined to the distance between the captivating pulley clusters (usually about 100 feet).

Overturning of loaded captive-track vehicles and track was experienced in British coal mines according to published material sent to the writers by Carver. However, during a visit with the writers, Beardsley stated, that this situation now has been remedied by the judicious use of ground bolts to anchor rails and sleepers to the floor.

Lateral track distortion between the angle iron spacers and bending of the angle iron spacers are common occurrences on Codie Car trackage. Beardsley related the cause of the lateral distortion to excessive lateral pressure exerted by the bogie guide-wheels on the web of the channel iron rail when braking. Track distortion has not been linked to an accident in any of the material reviewed by the writers, but the accident potential is evident. If the distortion becomes great enough to reduce the track gage to less than the bogie guide-wheel gage derailment becomes a possibility. The problem may be solved by this time but it is a real one of which operators are aware.

An incident not attributed to a Coolie Car system specifically, but a potential hazard of all rope-haulage systems was noted by a British Colliery. A pulley, frozen on its axle because of poor inspection routine and improper lubrication, was rubbed completely in two and the axle nearly worn through before it was discovered. The wear and strain on the rope during the time it was in contact with the frozen pulley is difficult to calculate, and a complete wearing through of the axle could have produced enough snagging and plucking to have caused a rope break. Speculation of what might have happened does not stop with these circumstances. Upon examination, the rope and pulley around the point of contact were calculated to have reached a temperature of 750°C. With a collection of waste material near the contact point or with a critical methane-air mixture in the roadway there could have been ignition, exposing personnel of the mine to the dangers of explosion and fire.

After studying haulage accident frequency rates, many professional papers, films, and manufacturers' brochures covering rope-haulage systems, and speaking to manufacturers' representatives and mining engineers who have seen the systems in operation, the professional opinion of the writers is that the introduction of the Coolie Car system into the bituminous coal mines of the U. S. will not decrease the haulage accident frequency rate in those mines in which it is used, and may cause an increase because of the introduction of new hazards.

Introduction of the rope-hauled Coolie Car into bituminous coal mines of the U. S. also will introduce the new hazards of moving rope, sheaves, and pulleys, to which most U. S. bituminous coal miners are unaccustomed.

During the investigation in correspondence with the writers was the following statement made by Scott-Owen, "Most British mining engineers would opt tomorrow for loco traction and trailer traction if conditions would allow. We are all trying to find something far more streamlined than endless or monorail to meet today's needs."

This summarizes the consensus in the U.K. on rope-haulage.

Other Rope-Hauled Systems

The systems included in this section, both floor and roof mounted, are only those related to the Coolie Car system through similarity of design and operating principles. Systems not in the category outlined, are not within the scope of this report, and are not discussed.

Rope-Hauled Road Railer

The relative safety of the rope-hauled Road Railer system is similar to that of the Coolie Car and the discussion of the relative safety of the Coolie Car can be considered applicable to the Becorit Road Railer system.

One item of the Coolie Car discussion that does not apply to the Becorit Road Railer is that of track distortion. The Road Railer uses 4 inch by 2 inch channel iron for track section similar to the Coolie Car track, but the track design is radically different (Appendix IV). In the Road Railer system the braking force is not applied laterally to the web of the channel rail section by the guide wheels, as with the Coolie Car, but is applied, through brake pads, to the upper and lower surfaces of the top channel flange similar to a disc brake used in a linear fashion. In the opinion of the writers, based on information studied, this system will not improve upon the relative safety of haulage systems presently in use in bituminous coal mines in the U.S.

Rope-Hauled Monorail

The relative safety of roof-mounted, rope hauled monorail systems is comparable to the floor-mounted systems. The overall discussion and accident frequency rate table used for the Coolie Car is applicable to monorails.

Hanging the rail from roof bolts or roadway roof supports is peculiar to monorail installation. Great care must be exercised to install the rail properly to be able to carry safely the intended load. Lateral instability in widely varying degrees is common to monorail systems, and is evidenced by car sway when the train is in motion. A partial remedy to the swaying car problem, is use of the proper methods and techniques in hanging the rail. Trains that sway badly constitute a serious accident hazard especially when used by or near personnel not familiar with their operating characteristics.

Although limited experience exists with these systems in anthracite mines in the U.S., accident frequency rates relating to them are not available. It is the opinion of the authors, based on information studied during the investigation, that monorail systems will not improve upon the relative safety of haulage systems presently in use in bituminous coal mines in the U.S.

COMPARATIVE COST EFFECTIVENESS

Rope-Hauled Coolie Car

Data were not available at the time this report was prepared to relate the Coolie Car purchase price and operating costs to a ton of coal mined. Tables 4 and 5 that follow show a comparison of capital costs for various haulage system equipment and the equipment costs for each yard of lateral extension of the system. The rope-hauled Coolie Car system in all instances except for diesel locomotive installations, is the most expensive system to install and advance for an equivalent cargo carrying capacity. Materials handling labor would be reduced considerably below the requirements demanded by conventional rope-haulage systems. A reduction in labor is not likely using the rope-hauled Coolie Car system in lieu of haulage systems presently used in bituminous coal mines in the U.S.

Table 4 - Equipment costs[1/] of manriding and materials haulage systems used in coal mines in the United Kingdom in 1968

Type of Equipment	Total cost of equipment for an installation of 1000 yds.[2/]	Fixed costs of equipment [3/]	Equipment cost per yard of linear extension for system [4/]
Diesel locomotive, 100 hp (2 locomotives @ $13,031 & 4 x 24 sheepbridge cars w/capacity 96 men) Maintenance garage also included @ $32,400	$132,631	$67,740	$ 8.40
Conventional endless-rope haulage 125 hp haulage (4 x 24 sheepbridge cars w/capacity of 96 men)	$ 67,718	$31,934	$15.60
Two way manriding belt conveyor, 120 hp.	$ 61,466	$10,401	$41.40
Ski lift manriding installation (176 chairs)	$ 37,634	$10,800	$ 6.60
Coolie Car, 50 hp., equipped for manriding (42 men)	$ 66,737	$28,934	$15.96
Hanslet MT-30 diesel tractor w/2 trailers to handle materials and 21 men.	$ 16,214	$16,214	------

1/ Costs based on 1966-1968 prices converted to $U.S. at the rate of $2.40/£ on January 2, 1968.

2/ Does not include installation, roadway drivage, or repair costs.

3/ Fixed costs are for those pieces of basic equipment essential to the operation of the system and independent of the length of the system. Maintenance facilities are not included.

4/ Includes track, rope, pulleys and other integral fittings essential for the linear extension of an operating system.

Source: Sheldon, J. - Manriding Systems and Facilities (39).

Table 5 - Equipment costs:[1] Rope-hauled Coolie Car system, and selected systems now used in bituminous coal mines in the U.S. and Canada

Type of Equipment	Cost of equipment for a 1000 yd. installation.[3]	Equipment cost per yd. of roadway advances of system.	90° curve station complete per unit	Personnel carriers (trolley) equipment cost.[4]	Personnel & materials carriers (battery powered) equipment cost.[5]	Material and mineral carriers (trailing cable) equipment cost.[6]
Rope-hauled Coolie Car [2]	$ 92,345	$ 47.00	$ 2,202			
Joy 127B, 5 man capacity				$ 6,500		
Joy 139B, 7-9 man capacity				$ 7,800		
Joy 125D1, 18 man capacity				$11,760		
Joy 125CD, 16 man capacity				$13,675		
Kersey 2 man personnel carrier					$ 4,290	
Kersey 4 wheel steerer, 4 wheel drive supply tractor					$ 8,800	
Kersey articulated steerer tractor w/o scoop					$14,000	
Kersey heavy duty articulated steerer tractor w/scoop					$22,700	
Kersey rubber tired supply trailers 5-6 tons capacity					$ 1,200	
Kersey rubberrail supply vehicle 5-6 ton capacity					$ 2,000	
Joy 21SC shuttle car						$39,235
Joy 10SC 22, 5613 shuttle car						$45,485

Table 5 (continued)

1/ Based on 1972-1973 equipment prices. Note: No direct comparison can be made or is intended to be made between the systems shown. Each has a specific use and specific conditions for optimum performance. Each system must be equated to a particular situation and compared on the basis of how it performs in that situation to achieve the results desired.

2/ Based on three standard platforms and one heavy duty platform with total capacity of 22,000 pounds of 24 men; straight roadway.

3/ Installation costs are not included.

4/ Vehicle only; Rail, wire to power source, and installation costs are not included.

5/ Vehicle only; Batteries and charging equipment costs are not included.

6/ Vehicle only; Power source extension costs are not included.

Other Rope-Hauled Systems

Costs for other ground-mounted rope-hauled captive-track systems will correspond closely to the costs presented for the Coolie Car system. Roof-mounted, rope-hauled monorail systems generally will average less in equipment costs for a given length of installation than floor-mounted systems.

Rope-Hauled Road Railer

A typical cost of equipment for a rope-hauled Road Railer system on a 1000 yard installation of straight roadway, designed to handle 48 men or a payload of 13,200 pounds is given by Powell (36) as $79,820.

A Road Railer system with the same specifications, but hauled by a 40-hp diesel locomotive is listed by Powell (36) at $108,940.

A Road Railer locomotive operating from electric trolley is being developed for the U.S. and Canadian market. No costs are now available for this new unit.

Rope-Hauled Monorail

The Becorit rope-hauled monorail unit, designed to cover a distance of 1000 yards with 2 containers and lifting trolleys and fittings is listed by Powell (36) at $37,870. The 25-hp diesel locomotive-hauled version with the same overall specifications is listed at $59,810.

The cost of a Scharf rope-hauled monorail system will be in the same range as the price of a Becorit system of approximately the same overall dimensions.

APPLICABILITY OF ROPE-HAULAGE SYSTEMS

Rope-hauled captive-track systems, Coolie Car, Road Railer, and monorails, are used extensively throughout European coal mines, especially in Germany and Great Britain. These systems were designed for the steep roadway gradients associated with highly faulted mining areas and pitching seams, and for "in seam roadways", they have proved highly successful. However, during the past 5 years, with the higher degree of successful and dependable diesel flameproofing and induced traction, the diesel locomotive-hauled Coolie Car and similar systems have been used in preference to rope-hauled systems where the roadway gradients will permit. Rope-hauled systems are confined to the steepest roadways, or to portions of a diesel system as an aid or support system for the diesel-hauled units.

The rope-hauled Coolie Car and Road Railer can haul loads of 8800 pounds each on standard platforms, or loads of 13,200 and 15,400 pounds respectively, on heavy duty platforms up gradients of 1 in 1 or 45°. The rope-hauled monorails can carry cargos of 6600 pounds in each container up the same gradients. These rope-hauled captive-track systems are performing at their best when roadway gradients become too steep for conventional electric and diesel locomotives, and rubber tired vehicles.

The length of the haul is determined by the rope length. The systems can be run effectively over undulating floors, straight and level roads, around curves of 180°, and on gradients of up to 45° (1 in 1).

Mining Method

Longwall

The Coolie Car and similar rope-hauled captive-track systems were developed in the Ruhr to support longwall mining for transport of materials and for manriding. These rope-hauled systems deliver materials and equipment to the working face, with a minimum of transfer and handling. The moving rope and pulleys constitute the only drawback in the confined haulways. Where gradients of the roadways and pitch of the seams have permitted, the rope hazard has been overcome in many mines in Europe by using diesel-hauled units with which skillful crews can deliver and set hydraulic roof props at the working face. The reserve-rope drum provides flexibility for the rope systems in that they can be advanced or withdrawn with a minimum of effort.

Monorail systems have proved popular in many mines for materials transport in entries leading to longwall faces. The transporter units travel above the stage loader and other equipment, which normally take up considerable space in the gate roads.

Scott-Owen, in a letter to the authors, comments on the use of rope-hauled systems for longwall and shortwall operations in the U.K. as follows:

> Wherever possible loco haulage will be used as near to working places as conditions allow for both men and material. This is rarely applicable in most mines, and there is often either endless or combination of loco and endless to working districts where gradients preclude locos from shafts to such districts.
>
> From district centres to working places either diesel

> traction, mono-rail or endless is used. Diesel traction is rare and limited by the Inspectorate due to ventilation and gas etc. Where roads are continuously extending the endless rail system usually entails a payout drum attached to the set. This can allow for progressive extensions from 50 yards to 1,500 yards. Payout ropes also exist with mono-rail. Mono-rail is preferred in the many conditions where floor heave is prevalent. Manriding is rarely allowed with the subsidiary extending endless rail system and never with mono-rail. The mono-rail has not got the same weight carrying capacity as the endless rail system, but needs less extension equipment and is faster to put down and take up.

The Coolie Car can be successfully used in longwall mining in the U.S., but the Coolie Car and similar rope-haulage systems are shuttle systems that rely upon signals to a remote operator to monitor their roadway progress.

Shortwall

The rope-hauled Coolie Car and related systems can be used to support shortwall mining and have had success in doing so in Great Britain. The same criteria are needed to justify the installation of the system as with longwall mining, and the system still suffers from the same disadvantages.

Room-and-Pillar

The rope-hauled Coolie Car and other rope-hauled captive-track systems are not suited for room-and-pillar operations because the rope is too great a restriction upon the flexibility of the system. None of the persons with whom the writers made personal contact, including the manufacturers' representatives, disagreed with this observation. Powell (36) gives an illustration of a room-and-pillar operation in South Wales that uses a Road Railer for transport of men and materials, but the system is diesel locomotive hauled.

Concerning the modern British experience with rope-haulage in room-and-pillar operations, Scott-Owens wrote the authors stating: "This is limited in this country but transport of both men and material are usually by diesel loco to district centres, and diesel tractor or cable reel endless or mono-rail. Supplies have remained a major problem in this type of mining."

Because the inflexibility of rope-hauled systems makes them generally unadaptable to room-and-pillar operations, the Coolie Car and related systems are eliminated from potential use in a large percentage of bituminous coal mines in the U.S.

Mine Size

The adaptability of the rope-hauled Coolie Car, Road Railer, and monorails does not appear affected by mine size in longwall and shortwall operations, from the examples studied. In most instances these rope-hauled systems are subsidiary and are integrated into two or three other haulage systems, each determined by its ability to handle the haulage needs of a particular area of a mine. The systems must be compatible with each other to provide the minimum handling of materials. Powell (36) in pointing out a major disadvantage to rope-haulage, states, "Arrangement of points system to serve more than one district presents problems, and usually entails the installation of several haulage units if more than one or two areas are to be served."

In mines producing 100,000 to 200,000 tons annually the rope-hauled systems can be used to transport coal as well as men and materials. This is now being done with monorail systems in three anthracite mines in the area of Shenandoah and Wilkes-Barre, Pennsylvania.

Mining Province

The rope-hauled Coolie Car, Road Railer, and monorails are adaptable for use in any mining province. They do become more effective, however, in provinces of faulted and pitching seams where conventional haulage methods are limited because of steep roadway or entry gradient.

Seam Configuration

The rope-hauled Coolie Car can operate in a 42-in. seam, but the minimum for effective use of the rope-hauled Road Railer is about 48-in. because of the higher Road Railer track profile. Diesel-hauled Road Railers are effectively operating in 54 in. seams in Great Britain, according to Beardsley.

The National Coal Board in Great Britain (30) recommended a minimum of 68-in. roadway height for use of the standard monorail container. Becorit has developed a monorail platform for use in low coal (Fig 9). The minimum roadway height for using this vehicle is not known.

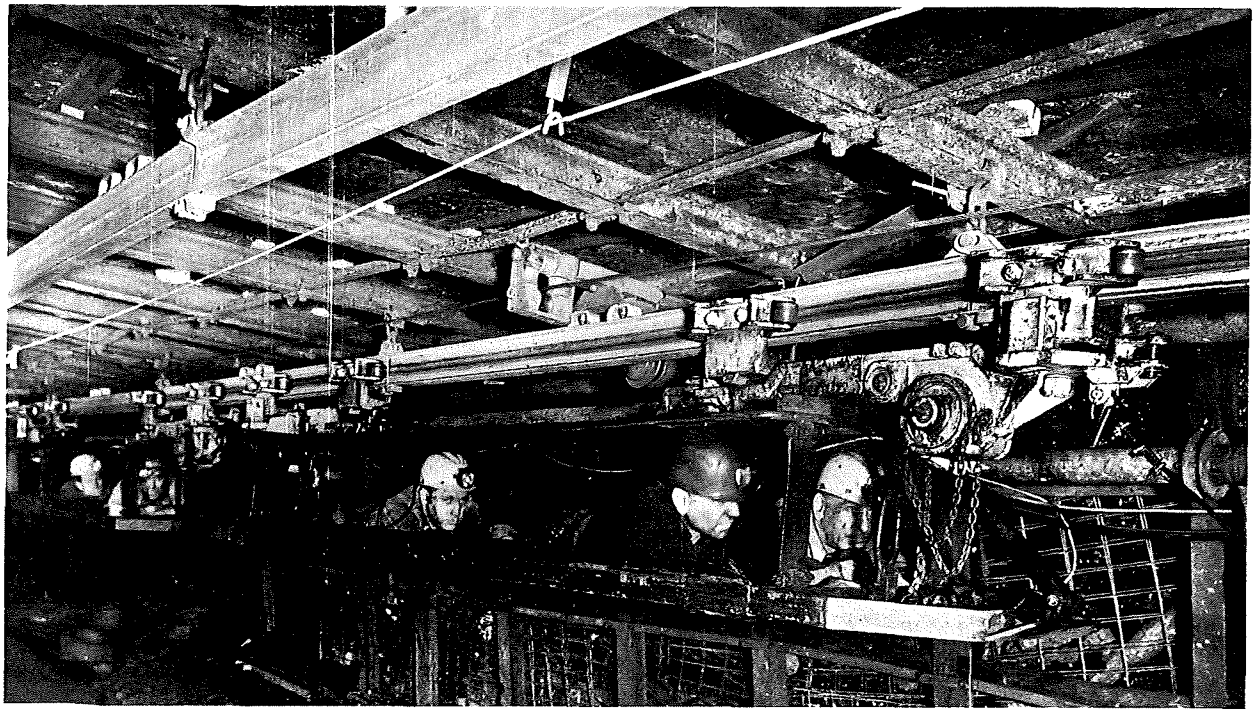

FIGURE 9. Becorit monorail platform developed for use in low coal. Minimum height capabilities not shown in illustration. (Photo courtesy Becorit Grubenausbau GmbH.)

SUMMARY AND CONCLUSIONS

The rope-hauled Coolie Car and related rope-hauled systems generally are not adaptable to the greatest number of bituminous coal mines in the U.S., which have room-and-pillar operations. The rope-hauled systems can be integrated into the haulage scheme of longwall and shortwall operations, but the systems are not being applied effectively until seam pitch or roadway gradients are steep enough to limit the use of other methods of traction. Five rope-hauled monorail systems are integrated into the transport systems of three Pennsylvania anthracite mines.

Accident frequency rates for the rope-hauled man and material subsidiary systems in British coal mines show them to be 28.8 and 23.9 percent higher than the frequency rates for all underground haulage in the U.S. during 1966 and 1967 respectively. These data indicate that the rope-hauled Coolie Car and related rope-hauled systems are not as safe as haulage systems now in use in bituminous coal mines in the U.S. Because of variables in determining the frequency rates, and some conventional rope-systems in the U.K. statistical population, the rates cannot be accepted as competely conclusive. However, study of the systems and the accident statistics, indicates that a rope-hauled Coolie Car system installed in a given mine in the U. S. will not improve on the accident frequency rate of the present haulage used in that mine. The most consistent danger present in the roadway with a rope-hauled system is the moving rope, pulleys and sheaves to which personnel would be exposed.

The cost of the rope-hauled Coolie Car system for an installation of 1000 yards ranged from 103 to 2062 percent higher than other subsidiary haulage vehicles used in bituminous coal mines in the U. S. for basic equipment costs. Comparison with heavier electric locomotives would show a smaller percentage of difference in equipment costs favoring the electric locomotive haulage. However, each vehicle is designed for a specific use under a specific range of operating conditions. Placing the vehicle in an operating environment incompatible with that for which it was designed invalidates any direct comparison between different types of vehicles.

The rope-hauled Coolie Car and related rope-hauled systems have been tested and evaluated in both the British and German governments' mine equipment testing establishments. These rope-hauled systems have over 12 years of use underground, on over 1100 miles of track, with thousands of hours and several hundred thousand miles running experience. The rope-hauled captive-track system is a proven system and no longer belongs in the research and evaluation category. For this reason it is recommended that no Government research and development funds be expended for evaluation or demonstration of this equipment. Evaluation for use in a particular coal mine, to fit a particular transport problem, can best be done by the company organization of the mine in question. The Scharf monorail with five working units in Pennsylvania anthracite mines illustrates the ability of private business to adapt a particular system to fit its needs. Powell (36), reports a remote control monorail locomotive undergoing trials for transporting ore in a copper mine in the U. S. This example, although not related to coal, also illustrates the ability of private industry to adapt equipment to specific needs.

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APPENDIX I

Glossary

Bogie	a) A rail truck or trolley of low height for carrying timber or machine parts underground. b) A weighted truck run foremost or next to the rope in a train or trip. c) A two-axle driving unit in a truck. Also called tandem drive unit.
Bollard	An upright wooden or metal post anchored securely into the masonry or concrete of a quay wall as a mooring for vessels, or fixed to a curb as a protection against traffic. In rope-haulage systems the upright posts are rollers used to control the radius and confine the movement of rope around curves. (Also vertical turnout rollers.)
Capel	a) A fitting at the end of a winding or haulage rope to enable bridle chains or couplings of cage or car to be connected by a pin through the clevis. b) A rope socket in which the rope end is separated out into a brush and embedded in a plug of white metal inside the hollow center of the socket.
Captive rail (track) system	A rail system, using I section or channel section rails, either roof or floor mounted, whereby the trolleys or bogies of the transporter units have wheels so arranged as to be allowed to run freely within the rail sections, but to render derailment impossible and insure captivation of trolleys or bogies by selective wheel positioning within the tract section.
Captive track rope haulage	A captive track system in which the motivating power is provided by moving rope.
Captivating the rope	A method of preventing the moving rope from running unrestrained along the roadway between the haulage and the return sheave. Usually accomplished by allowing the rope to pass through a spring loaded cruciform pulley arrangement or a pulley suspended within a steel ring.

Direct-rope haulage	A system of incline haulage, comprising one rope and one drum. The engine hauls up the train of loaded cars. The empties are connected to the rope and returned to the bottom by gravity.
Endless-rope haulage	A system of haulage by rope, where the ends have been spliced together. The endless rope moves in one direction, one part carries loaded cars from the mine at the same time that another part returns the empties into the mine.
Gradient	The inclination or the rate of regular or graded ascent or descent (as of a slope, roadway or pipeline). Webster 3d. A part (as of a road or pipeline) that slopes upward or downward; a portion of the way that is not level; slope, grade, ramp. Webster 3d.
Groove diameter	The diameter of the depression in the periphery of a sheave.
Journey	Welsh term for train of mine cars moved mechanically.
Main-and-tail haulage	A single track haulage system operated by a haulage engine with two drums each with a separate rope. The main rope is used to draw out the full cars and the tail rope is used to pull back the empties.
Points system	Predetermined locations along the route of a transport system, or at the intersections of various systems, for the orderly loading or unloading of material and/or men, or for the orderly transfer of men, materials and/or rolling stock from one system to another. Also transfer points.
Pulley or sheave flanges	The annular extensions of the pulley or sheave rim which form the walls of the groove.
Rope-drum trolley	A trolley carrying a drum used for spooling extra rope for convenience in advancing a roof mounted rope haulage system i. e. monorail.
Safety factor	a) The ratio between breakage resistance and load. Nichols. b) The ratio, allowed for in design and manufacture, between the breaking load on a member or appliance and the permissible load on it. Nelson. c) The ratio of the ultimate breaking strength of the

Safety factor (continued)	material to the force exerted against it. Brantley 2. d) Ratio of breaking stress to working stress. BuMines Bull. 587, 1960, p. 2.
Set	A train of mine cars.
Shuttle	A back-and-forth motion of a machine which continues to face in one direction.
Sleeper	The pressure-creosoted wood, steel or precast concrete beams laid crosswise under the rails of a rail track and holding them at the correct rail gage. Also called sole plate or tie.
Splay	To spread out; expand. To slope or slant.
Splay-legged	Legs or supports inclined or set at an angle; not vertical.
Swilley	A depression in a mine road from which the road rises both ways.
Tread diameter	The diameter of a sheave measured at the maximum groove depth or tread.
Trip	A small train of mine cars. A number of cars moved at one time by a transportation unit.
Trolley	1. A wheeled carriage running on an overhead rail or track. 2. Any of various vehicles of the cart type. Local Eng. 3a. A current collector operating in connection with a trolley wire. 3b. An electric car. Webster 3d.

APPENDIX II

Persons and Companies Who Contributed Information or Materials to This Report

Becorit (GB) Limited
John M. Beardsley, Products Manager
Nottingham, England

Becorit Grubenausbau GmbH
Recklinghausen, Fed. Rep. of Germany

Bergbau - Berufsgenossenschaft
Dr. Bauer, Hauptgeschaftsfuhrer
Bochum, Fed. Rep. of Germany

German Consulate General
Houston, Texas

John S. Beltz, Chief Engineer, Underground Mining (Retired),
Jeffrey Mining Machinery Co.
Columbus, Ohio

British Ropeway Engineering Co. Ltd.
G. B. Williamson, Project Manager
Sevenoaks, Kent, England

Department of Trade and Industry
J. Carver, H. M. Principal Inspector of Special Development Duties
London, England

Dowty Corporation
Matthew Spedding, Vice President
Zelienople, Pennsylvania

International Labour Office
Rene Linchen, Chief, Conditions of Work and Life Dept.
Geneva, Switzerland

Jeffrey Mining Machinery Co.
W. A. McLeish, Group Manager, Haulage and Ventilation
Douglas Bolton, Sales Engineer
Peter Sharp, Sales Engineer
Columbus, Ohio
Gary Marsden, Sales Engineer
Johnstown, Pennsylvania

Joy Manufacturing Company
C. L. Woolbright, Sales Engineer
Mt. Vernon, Illinois

Joy Manufacturing Company (U.K.) Limited
R. E. Collins, Sales Director, Heavy Machinery Division
W. S. Scott-Owen, Development Engineer
Chesterfield, England

Kaiser Steel Corporation
Sunnyside, Utah

Kersey Manufacturing Co.
D. Clevenger
Bluefield, Virginia

Lone Star Steel
Dallas, Texas

Machinenfabrik Scharf GmbH
Hamm, Fed. Rep. of Germany

Mid-Continent Coal and Coke Co.
Carbondale, Colorado

Ministry of Power
London, England

National Coal Board
J. L. Collinson, Chief Safety Engineer
London, England

Pennsylvania State University
Robert Stefanko, Prof. of Mining Engineering and Assistant Dean for Continuing Education
State College, Pennsylvania

Pickrose & Company Limited
S. Shortt, Export Field Sales Manager
Manchester, England

Qualter Hall & Co. Ltd.
A. Archer, Fluid Power Engineer
Barnsley, England

Ruhrkohle Aktiengesellschaft
Rudolf Sander
Essen, Fed. Rep. of Germany

Sheepbridge Equipment Limited
Chesterfield, England

Thirty Slope, Inc.
Edmund H. Watkins, Scharf Agent U.S.A.
Shenandoah, Pennsylvania

U. S. Bureau of Mines
Forrest T. Moyer
Horace T. Reno
Arlington, Virginia
Carl H. Roach
Leonard P. Larson
Ottey Bishop
John Kelly
Denver, Colorado

Versuchsgrubengesellschaft mbH
D. Kurt Reinke, Geschäftsführer
Dortmund, Fed. Rep. of Germany

Westfälishe Berggewerkschaftskasse
Seilprüfstelle, Institut für Fördertechnik und Werkstoffprufung
Bochum, Fed. Rep. of Germany

APPENDIX III

Coolie Car

The rope-hauled Coolie Car system is a ground-mounted, modified main-and-tail haulage with the added features of relatively easy installation, and rapid extension or withdrawal. The Coolie Car system uses special track with rolling stock designed to be captive on it, and a specially designed pulley system to captivate the haulage rope.

The equipment is manufactured by Maschinenfabrik Scharf GmbH, Hamm, Federal Republic of Germany and their licensee Underground Mining Machinery, Ltd., Aycliffe, England.

A general description of the main characteristics of the system and standard operating limits of the equipment not covered in the text follow with additional illustrations.

The rope-captivating pulley device and the captive rail arrangement were described in the Basic Types of Rope-Haulage section of the text. The braking system and general operating statistics are described below.

Braking System

The brake car usually carries the braking unit, the reserve-rope drum and the rope attaching, or towing device. More than one brake car can be attached to a train when needed.

The braking force is applied to the web of the track channels by the guide wheels when the system is actuated, and the force is delivered by powerful springs to pivoted plates which hold the guide wheels. The guide wheels move inward from the normal free running position until they bear forcefully against the channel web. The brake springs normally are kept compressed and in the off position by hydraulic pressure. The hydraulic pressure can be released by an overspeed governor thus applying the brakes. Brakes can also be actuated by rope breakage, or by manual means (Fig. 7) The braking system is claimed to be effective on gradients up to 45^{o} (1 in 1).

Operating Data

Road Length:	Up to 6,000 m (19,684 ft.)
Gradient:	A gradient of 45^{o} can be negotiated, according to the manufacturers' information.

Operating Data (continued)

Curve Radius:	The minimum curve radius that can be negotiated with standard equipment is 4 m (13ft.)
Traveling Speed:	The system is designed to travel at speeds of 2 to 4 m per second (394 to 788 fpm)
Winder Pull:	6,000 kg (13,200 lbs.)
Drive :	Electric-motor, air-turbine, or electro-hydrostatic drive.
Rope Diameter:	16 mm (5/8 in.) or 19 mm (3/4 in.)
Carrying Capacity:	4,000 kg (8,800 lbs.) per car with standard equipment. 6,000 kg (13,200 lbs.) with heavy duty platform.
Maximum Capacity Each Train:	Determined by rope strength, winder pull, gradient, and safety factor desired.
Track Flexibility at Joints:	1^{o} horizontally, 7^{o} vertically.
Other Methods of Traction:	Diesel locomotive haulage is also available for the Coolie Car system.

Figures 10 to 18 show Coolie Car equipment and Coolie Car systems at work under various roadway conditions.

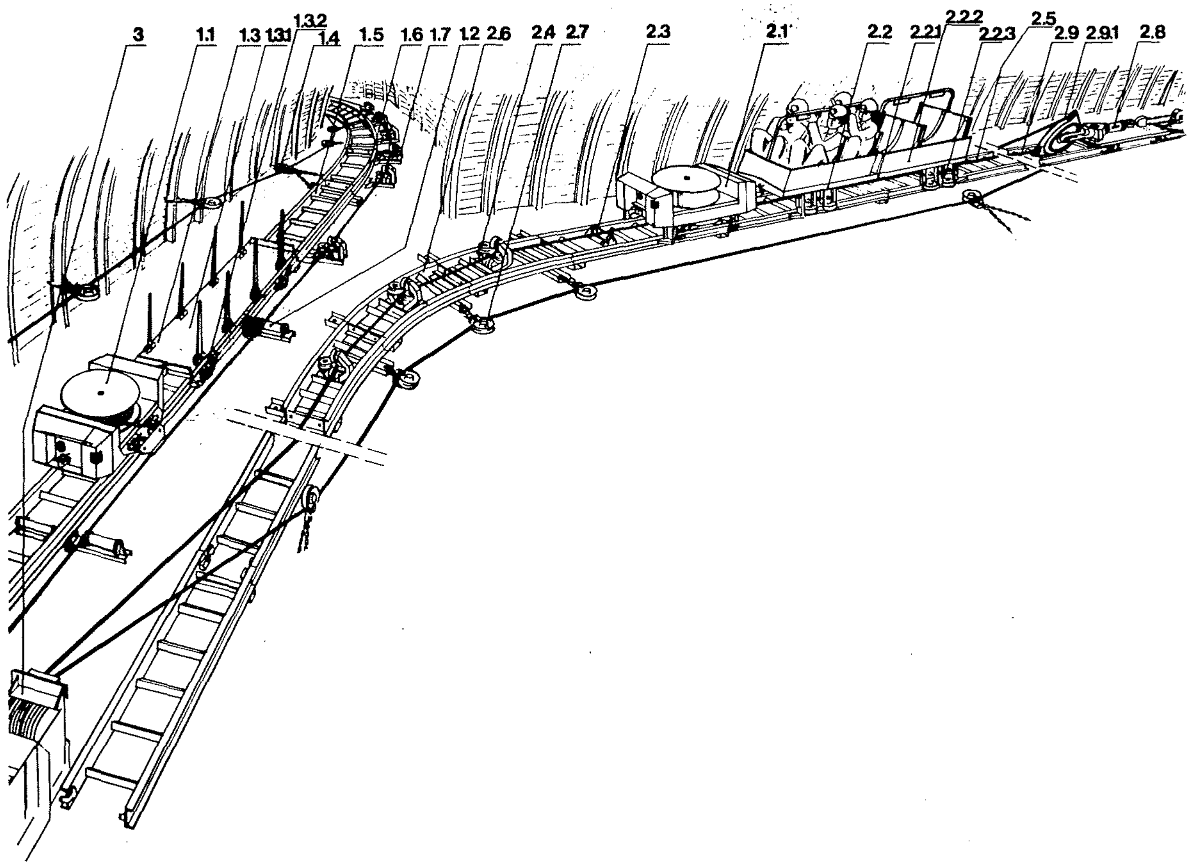


ILLUSTRATION LEGEND

1. Coolie Car 500 S (lateral captive rope guide)
1.1 Braking car
1.2 Rope drum
1.3 Transport car with hinged stanchions
1.3.1 Platform
1.3.2 Chassis
1.4 Rope guide roller
1.5 Coolie-car track
1.6 Curve track
1.7 Coolie roller trestle

2. Coolie Car 500 M (central captive rope guide)
2.1 Coolie Car
2.2 Transport car with seating arrangement
2.2.1 Platform
2.2.2 Seating arrangement
2.2.3 Chassis
2.3 Rope drum
2.4 Coolie roller trestle
2.5 Coolie-car track
2.6 Curve track
2.7 Rope guide roller
2.8 Return unit
2.9 Pulling rope
2.9.1 Empty rope

3. Haulage Drive

FIGURE 10. Schematic diagram of rope-hauled Coolie Car system illustrating lateral captive rope guide (500S) and central captive rope guide (500M) (Courtesy Maschinenfabrik Scharf GmbH.)

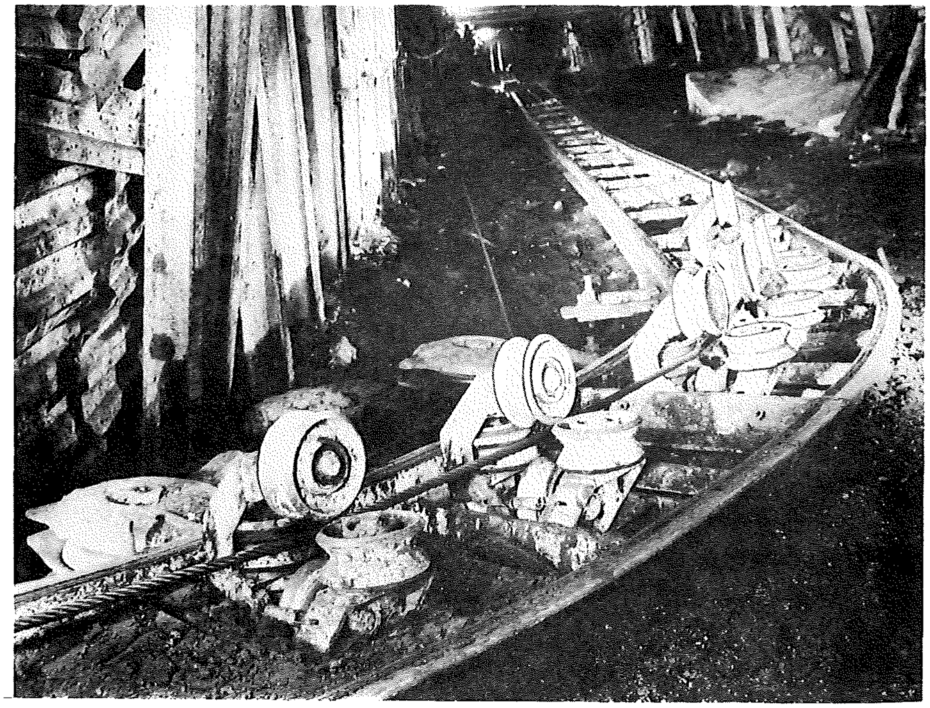


FIGURE 11. Coolie Car 500M, captive rope guide in curve. (Photo courtesy Maschinenfabrik Scharf GmbH.)

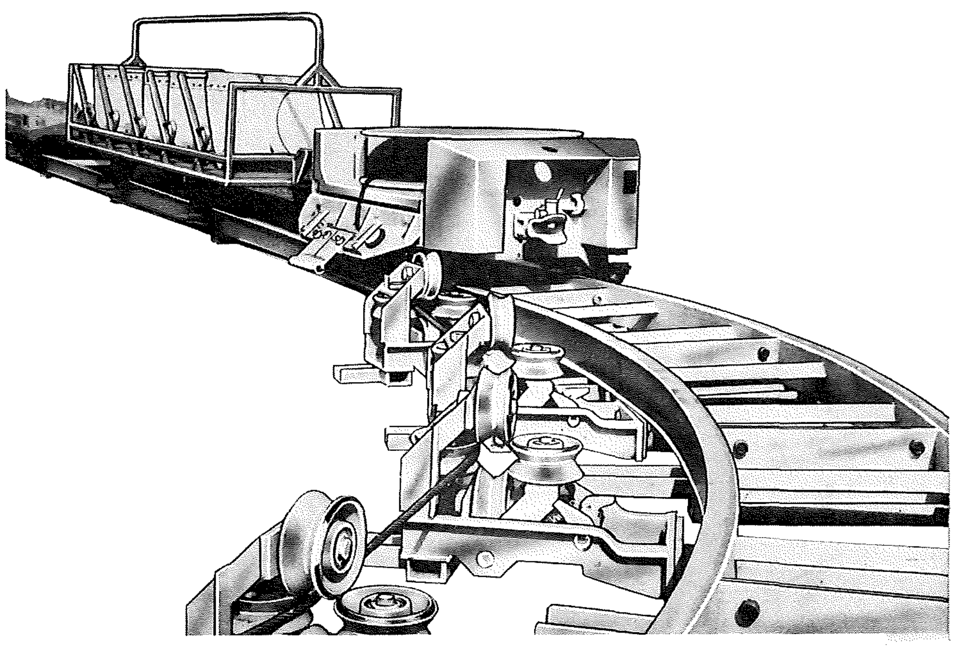


FIGURE 12. Coolie Car 500S, captive rope guide in curve, braking bogie with reserve rope drum and manriding car. (Photo courtesy Maschinenfabrik Scharf GmbH.)

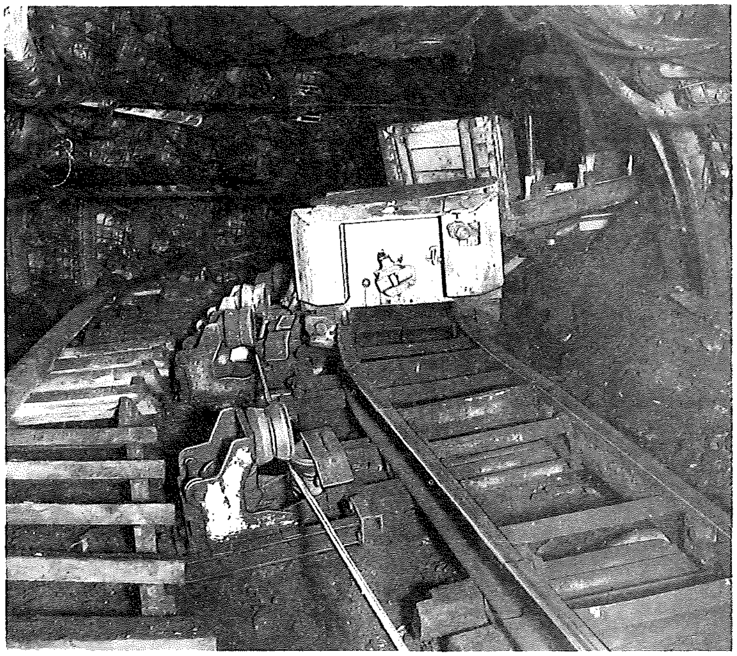


FIGURE 13.

Coolie Car 500S, braking bogie with reserve rope drum, and material platform on steeply inclined curve. Note stairway in left of photo. (Photo courtesy Maschinenfabrik Scharf GmbH.)

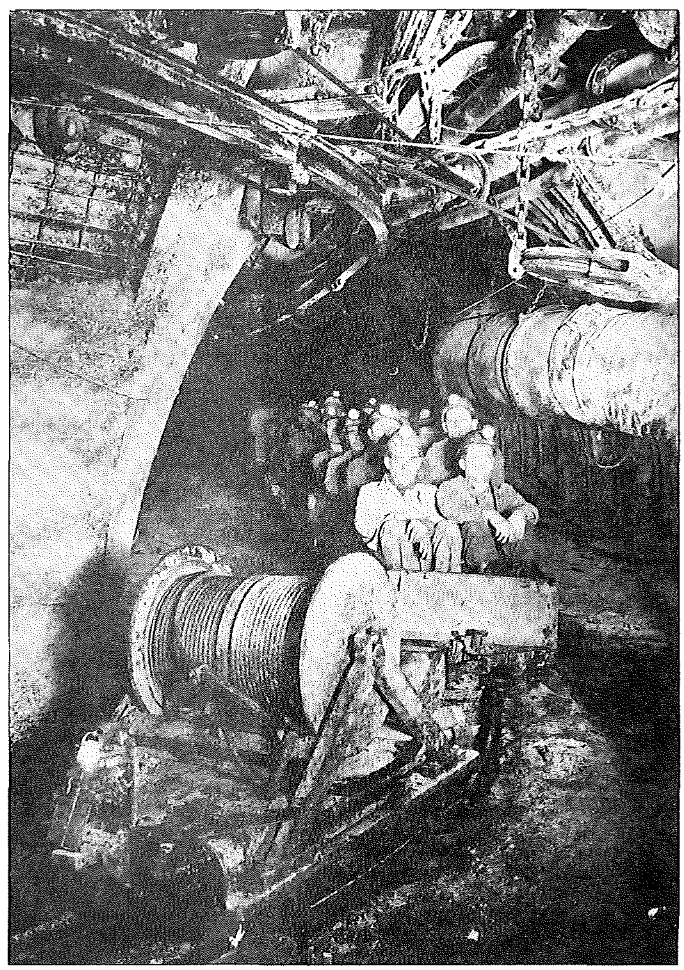


FIGURE 14.

Coolie Car 500M personnel transport on inclined curve. Note monorail installation on roof. (Photo courtesy Maschinenfabrik Scharf GmbH.)

FIGURE 15.

Coolie Car 500M personnel transport unit on incline. Note height of rope above low point of floor where rope has not been captivated. (Photo courtesy Maschinenfabrik Scharf GmbH.)

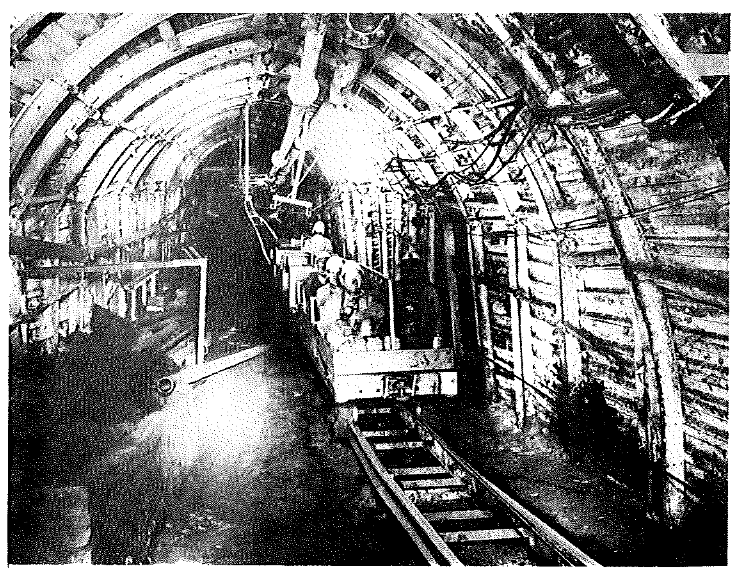
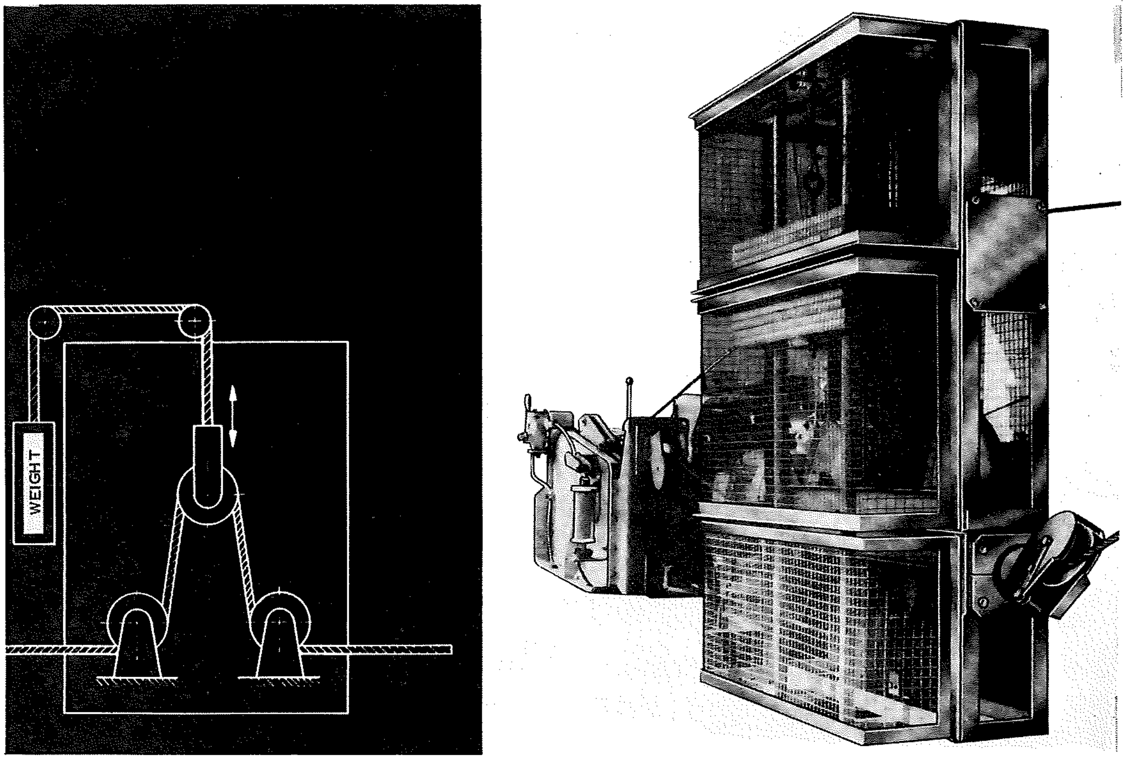


FIGURE 16.

Coolie Car 500M personnel transport unit on undulating straight roadway. (Photo courtesy Maschinenfabrik Scharf GmbH.)



E 17. Rope tensioning device and haulage unit. (Photo courtesy Maschinenfabrik Scharf GmbH.)

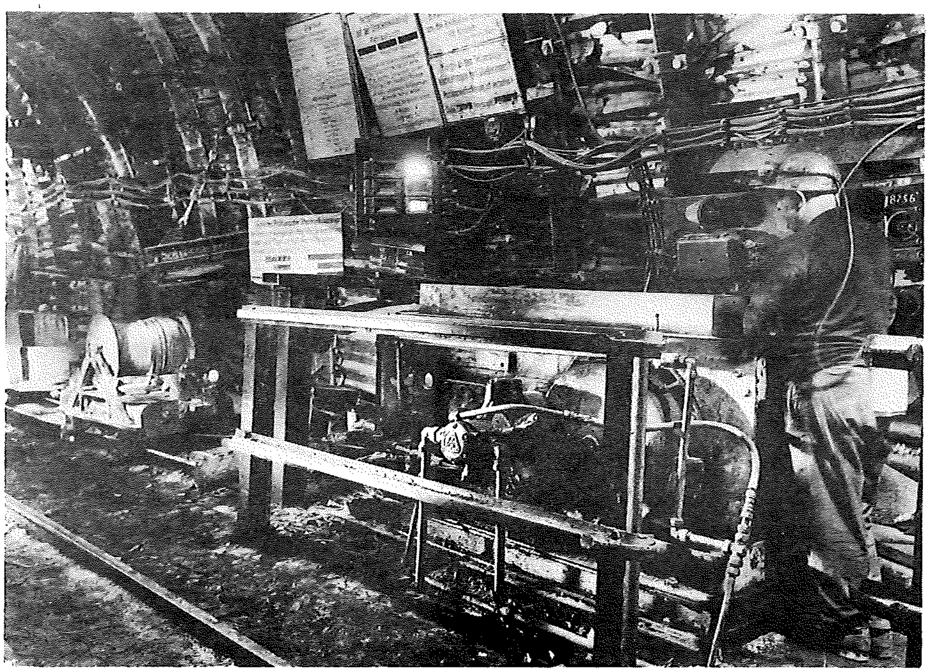


FIGURE 18. Haulage unit and control station. (Photo courtesy Maschinenfabrik Scharf GmbH.)

APPENDIX IV

Road Railer

The rope-hauled Road Railer operates as a modified main-and-tail haulage with rope captivating pulleys and captive track similar to the Coolie Car system, but of slightly different design.

The Road Railer is manufactured by Becorit Grubenausbau GmbH, Recklinghausen, Federal Republic of Germany and their licensee Becorit (GB) Limited, Nottingham, England.

Road Railers are available in two standard models, the 250 and the 400; the number designation is established by the rail gauge.

Captive Track

The Road Railer track section consists of 4 in. by 2 in. channels welded with the flanges, or toes, pointing inward with a gap between the flanges of 8 in. on the 400 model and a gap of 4 in. on the 250 model The car, model 250 bogie has eight running wheels and two guide wheels. The guide wheels and four running wheels run inside the rail section and trap the car bogie. The channel sections are raised from the floor by means of splayed feet, which keep the track clear of any floor debris. Despite the increased height of 9-1/8 in. stability is maintained by the 2 ft. 4 in. spread of the supporting feet (Fig. 27). Track is manufactured in 3 and 4 m (10 and 13 ft.) lengths.

Road Captivating Pulleys

The pulleys are arranged in a cruciform manner forming an enclosure through which the rope may run freely without excessive vertical or horizontal movement. Two of the pulleys are spring loaded and are attached to studs, one vertical and one horizontal, along whose longitudinal axis the pulleys may move. When the striker plate of the brake car, attached to the rope, hits the pulleys they spring apart allowing the plate to pass through after which they close, keeping the rope trapped (Fig. 21).

Braking System

In the Road Railer system the braking force is applied to the upper and lower surfaces of the top channel flange, or toe, similar to a disc brake applied in a linear configuration. The spring-loaded brake shoes are normally held in the off position by hydraulic pressure. With rope breakage, overspeed of the train, or manual application, the hydraulic pressure is released and the brakes are applied by the springs.

Operating Data

Road Length:	Up to 4,000 m (13,123 ft.)
Gradient:	Gradients of 45° can be negotiated successfully.
Curve Radius:	The minimum curve radius that can be negotiated with standard equipment in 4 m (13 ft.).
Traveling Speed:	The equipment can safely run at speeds up to 4 m per second (394 fpm).
Winder Pull:	6,000kg (13,200 lbs.)
Drive:	Electric-Motor, air-turbine, or electro-hydrostatic drive.
Rope Diameter:	19 mm (3/4 in.) for 250 model 25 mm (1 in.) to 33 mm (1 5/16 in.) maximum for 400 model.
Carrying Capacity:	4,000 kg (8,800 lbs.) per car for 250 model. 7,000 kg (15,400 lbs.) per car for 400 model.
Braking Force of Brake Car:	3,000 to 6,000 kg (6,600 to 13,200 lbs.)
Maximum Capacity Each Train:	Determined by rope strength, Winder pull, gradient, and safety factor desired.
Other Methods of Traction:	Diesel locomotive haulage is also available for the Road Railer system.

Figures 19 to 28 show Road Railer equipment, and Road Railer systems at work under varying roadway conditions.

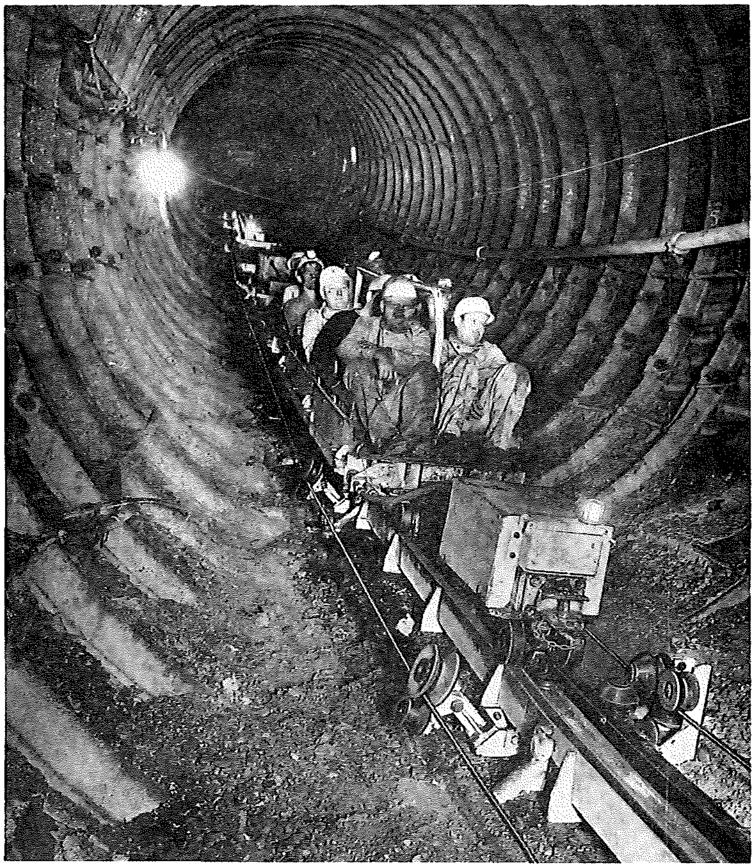


FIGURE 19. Road Railer personnel transport on inclined roadway. (Photo courtesy Becorit Grubenausbau GmbH.)

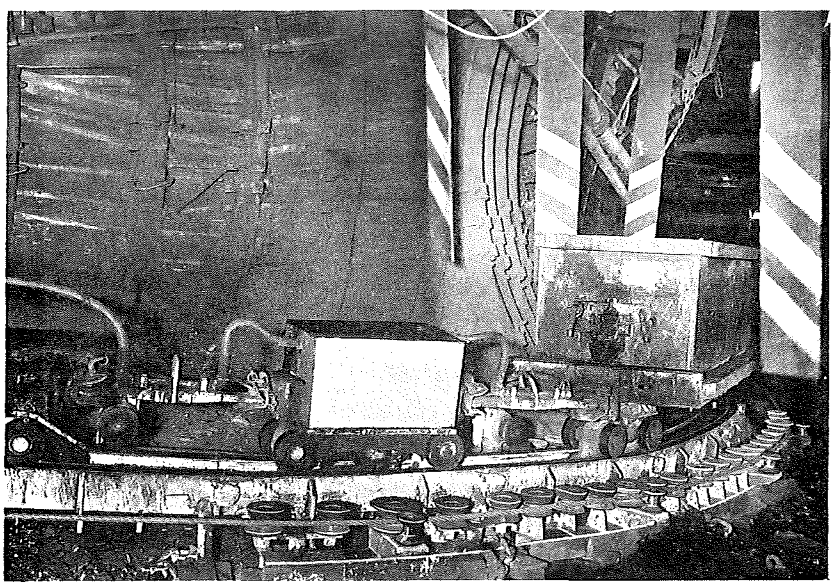


FIGURE 20. Road Railer material transport unit on curved inclined roadway. (Photo courtesy Becorit Grubenausbau GmbH.)

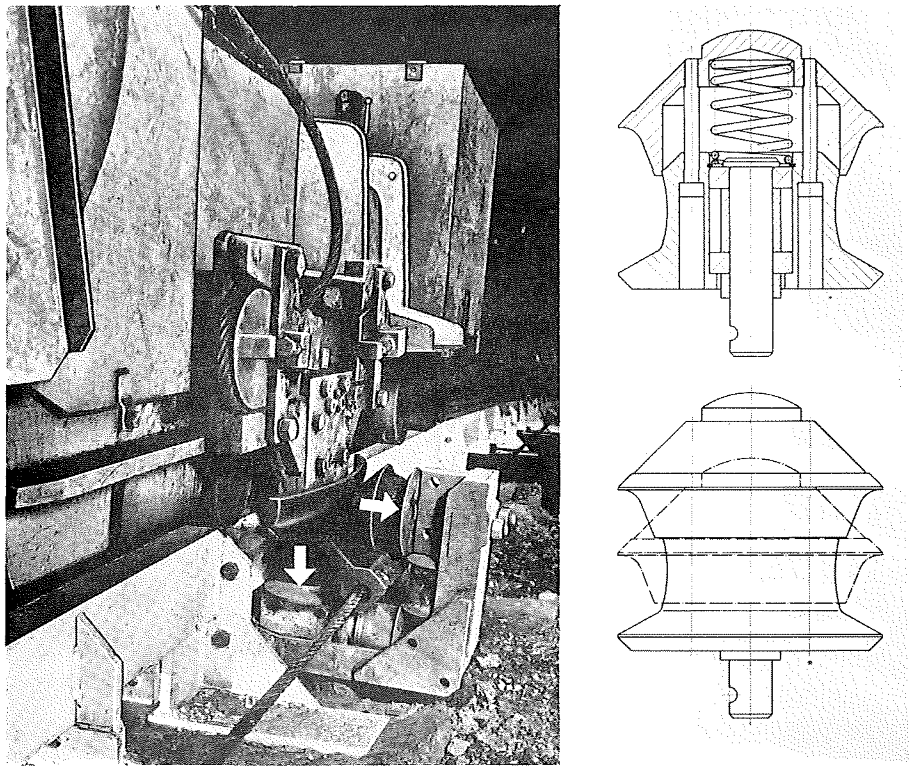


FIGURE 21. Road Railer bogie showing attached rope, striker plate and rope captivating pulley cluster. Diagram shows spring action of opening pulleys. (Photo courtesy Becorit Grubenausbau GmbH)

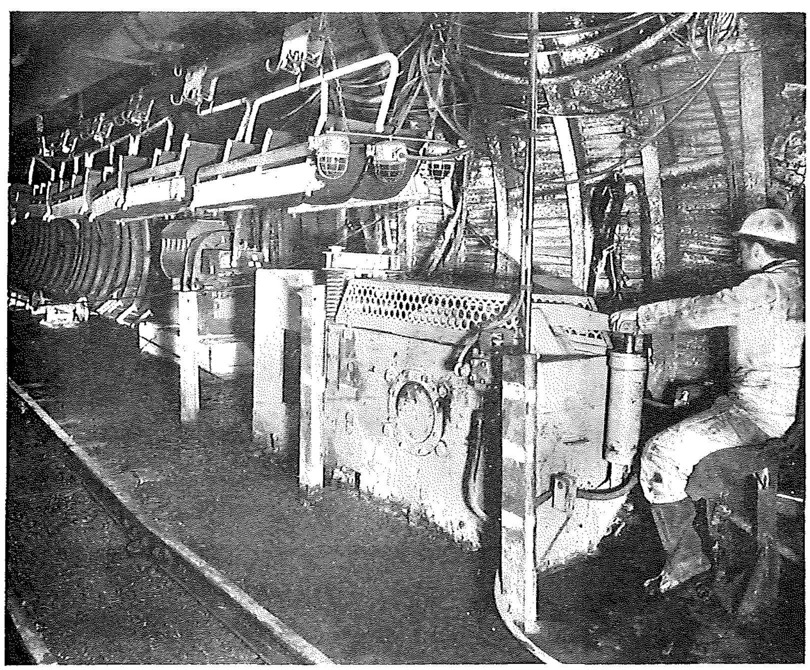
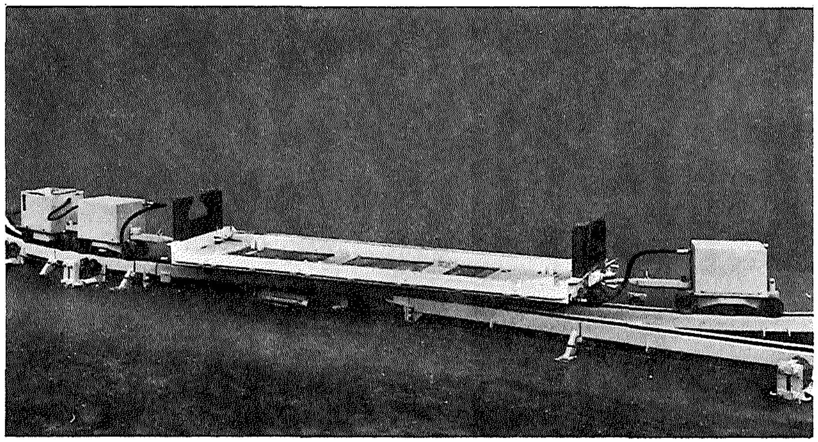
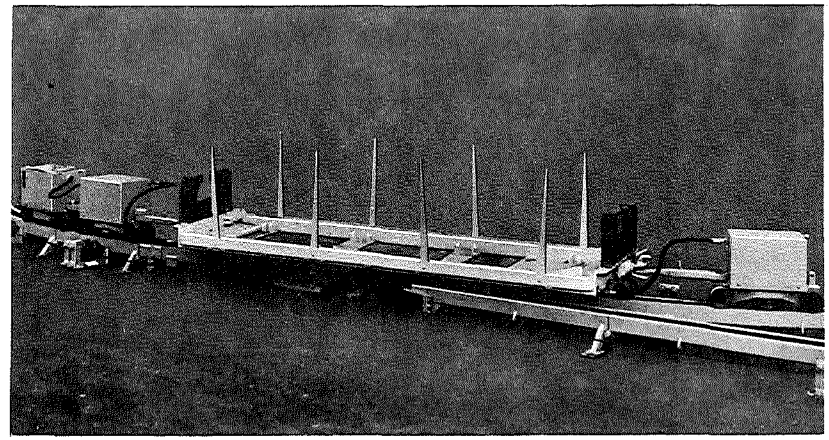


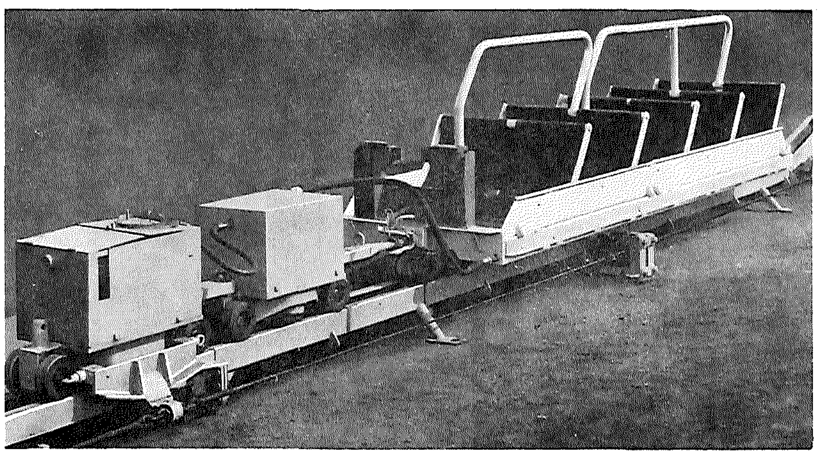
FIGURE 22. Haulage unit and control station. Note removable personnel units for Road Railer, stored on monorail. (Photo courtesy Becorit Grubenausbau GmbH.)



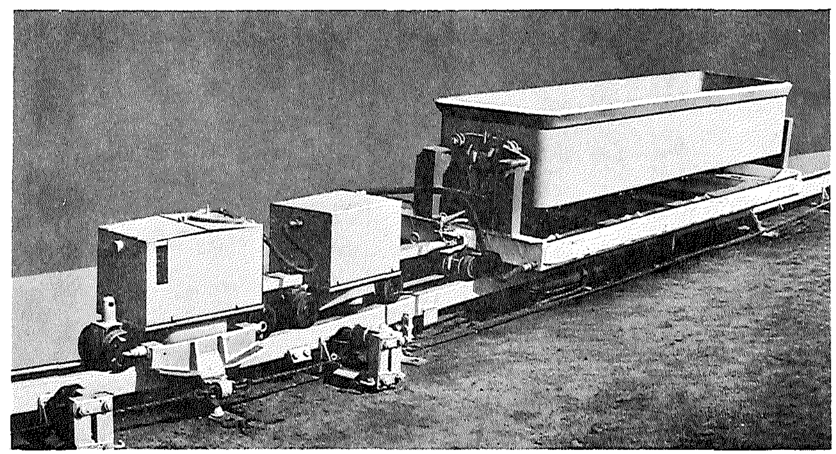
A



B



C



D

FIGURE 23. A. Road Railer basic platform. B, C and D types quickly converted to from basic platform. A & B equipped with two braking bogies. (Photo courtesy Becorit Grubenausbau GmbH.)

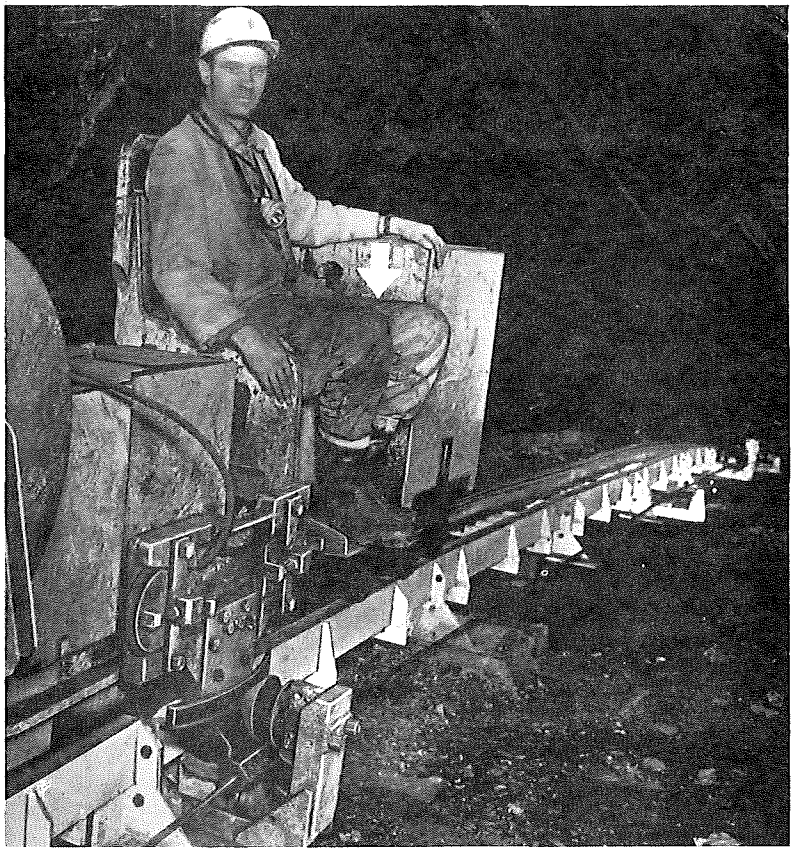


FIGURE 24. Road Railer with brakeman, and equipped with deadman control, (Photo courtesy Becorit Grubenausbau GmbH.)

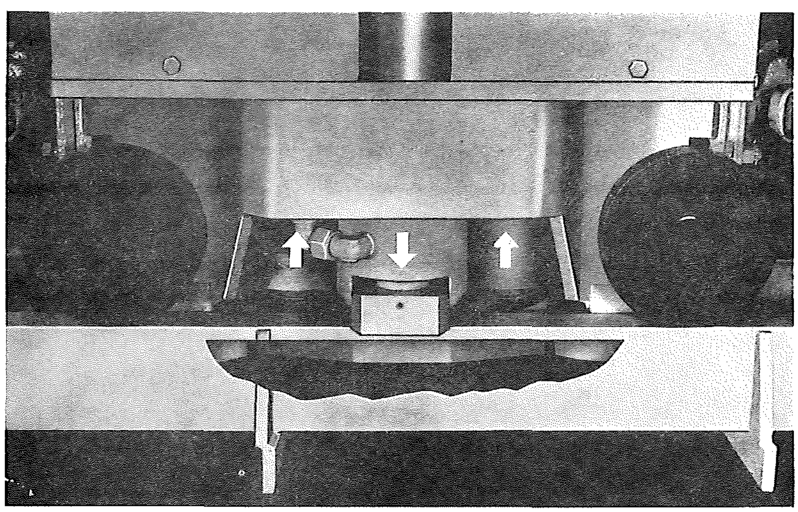


FIGURE 25. Road Railer braking system. Spring loaded brake pads exert pressure on upper and lower sides of top rail flange in disc brake-type action. (Photo courtesy Becorit Grubenausbau GmbH)

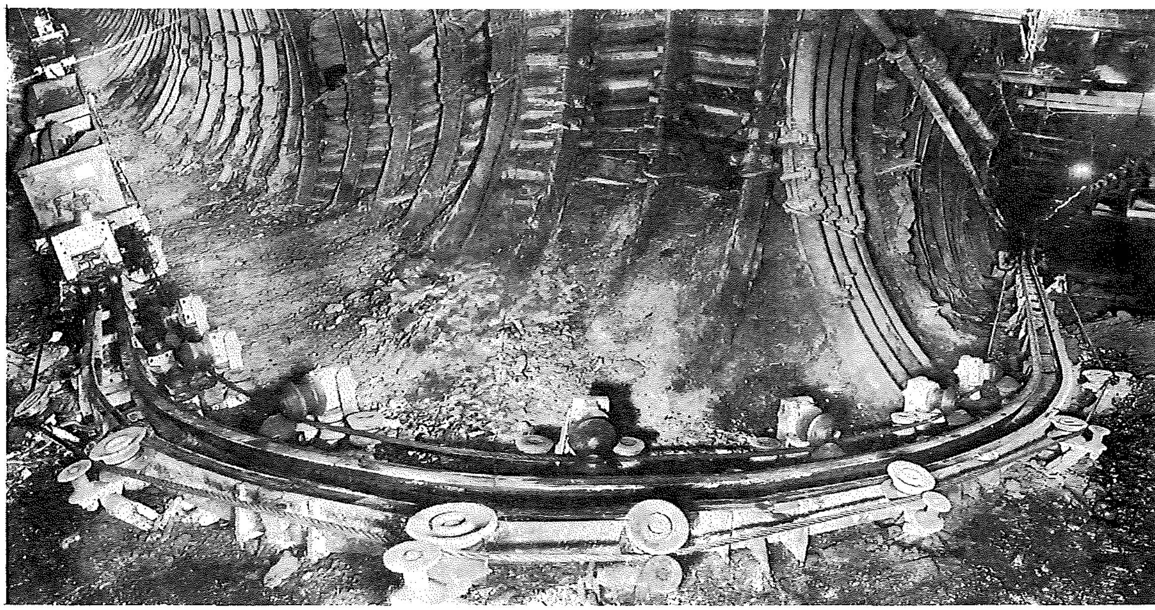


FIGURE 26. Road Railer 400 on steeply inclined roadway negotiating a curve of about 140°. (Photo courtesy Becorit Grubenausbau GmbH.)

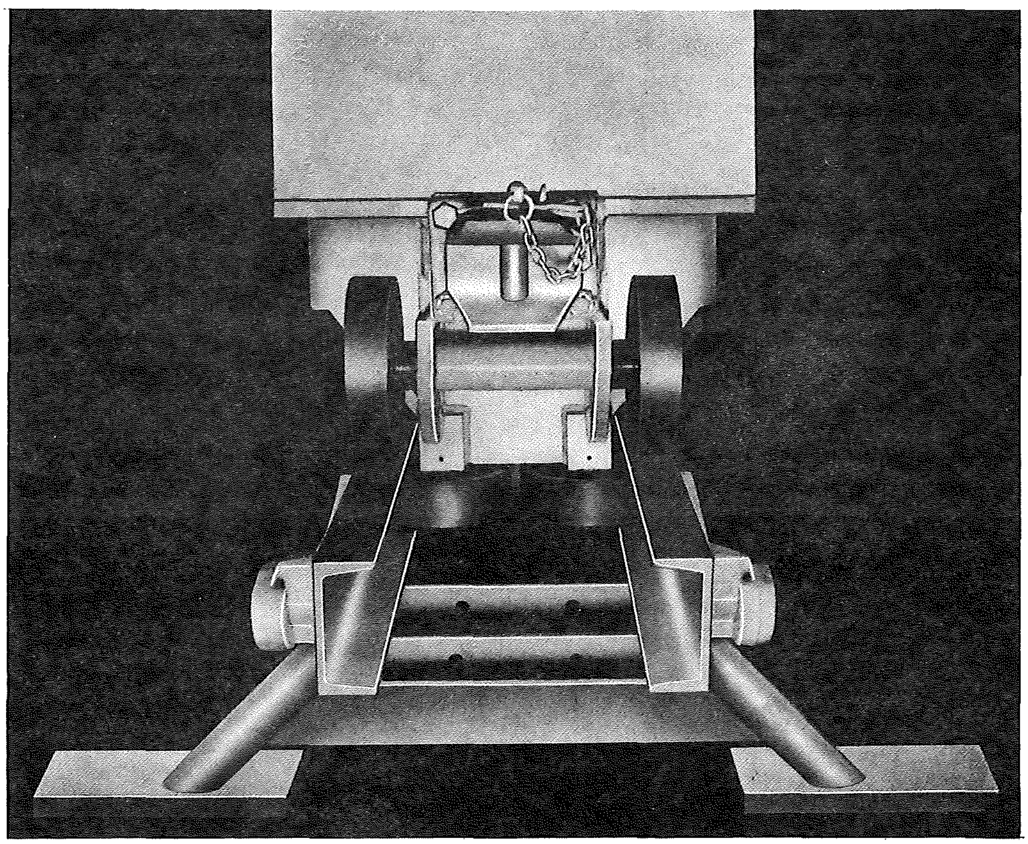


FIGURE 27. Road Railer 400 track section showing captivating system. (Photo courtesy Becorit Grubenausbau GmbH.)

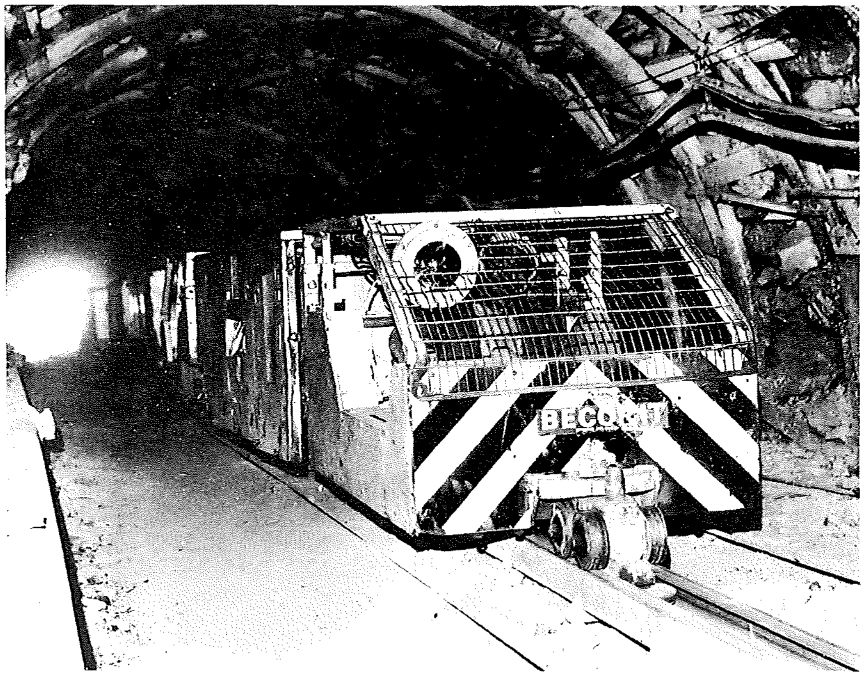


FIGURE 28A. Road Railer diesel locomotive (Photo courtesy Becorit (GB) Limited & NCB South Durham Area)

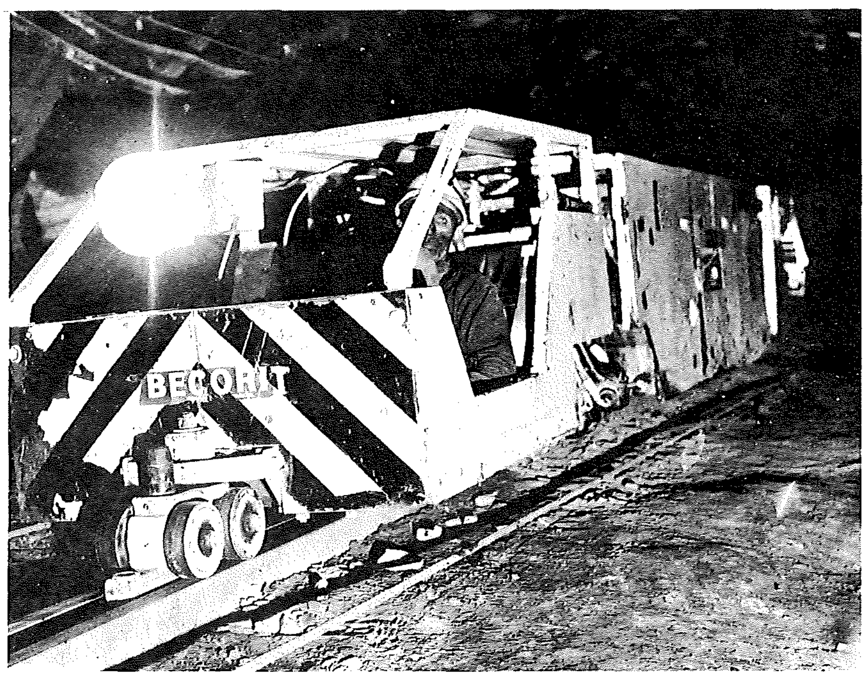


FIGURE 28B. Road Railer diesel locomotive (Photo courtesy Becorit (GB) Limited & NCB South Durham Area)

APPENDIX V

Scharf Monorail

This mining-type monorail, designed in part to make better use of the available cross-sectional area of a roadway, consists of a modified main-and-tail haulage system attached to a wheel-mounted underslung car. These are captive and run on the bottom flange of a single I-beam-rail suspended from roof bolts or roadway supports. The role of the monorail has been one of the materials handling until recently when it has been improved to provide transport of personnel.

Running Equipment and Braking

The captive track system is similar to that described for the Coolie Car, but adapted to the I-section track of the monorail (Figs. 31 and 33). The rope captivating device is the same as that used for the Coolie Car system. The braking system is similar to that of the Coolie Car but has been adapted to a trolley unit for overhead running and is reduced in size. It is equipped with a fail-safe overspeed device (Fig. 34).

Operating Data

Road Length:	Up to 3,000 m (9,843 ft.)
Gradient:	A gradient of 45^{o} (1 in 1) can be negotiated.
Curve Radius:	The minimum curve radius that can be negotiated with standard fittings is 4 m (13 ft.).
Traveling Speed:	The system is designed for travel speeds of 2 m per second (394 fpm).
Winder Pull:	3,000 kg (6,600 lbs.)
Drive:	Electric-motor, air turbine, or electro-hydrostatic drive.
Rope Diameter:	16 mm (5/8 in.)
Carrying Capacity:	3,000 kg (6,600 lbs.) per container unit.
Braking Force of Brake Trolley:	3,000 kg (6,600 lbs.)

Operating Data (continued)

Track Flexibility at Joints:	7^{o} horizontal deflection and 7^{o} vertical deflection
Other Methods of Traction:	Diesel locomotive haulage is also available for this monorail system.

Figures 29 to 35 show Scharf monorail equipment, and Scharf Monorails in use under varying roadway conditions.

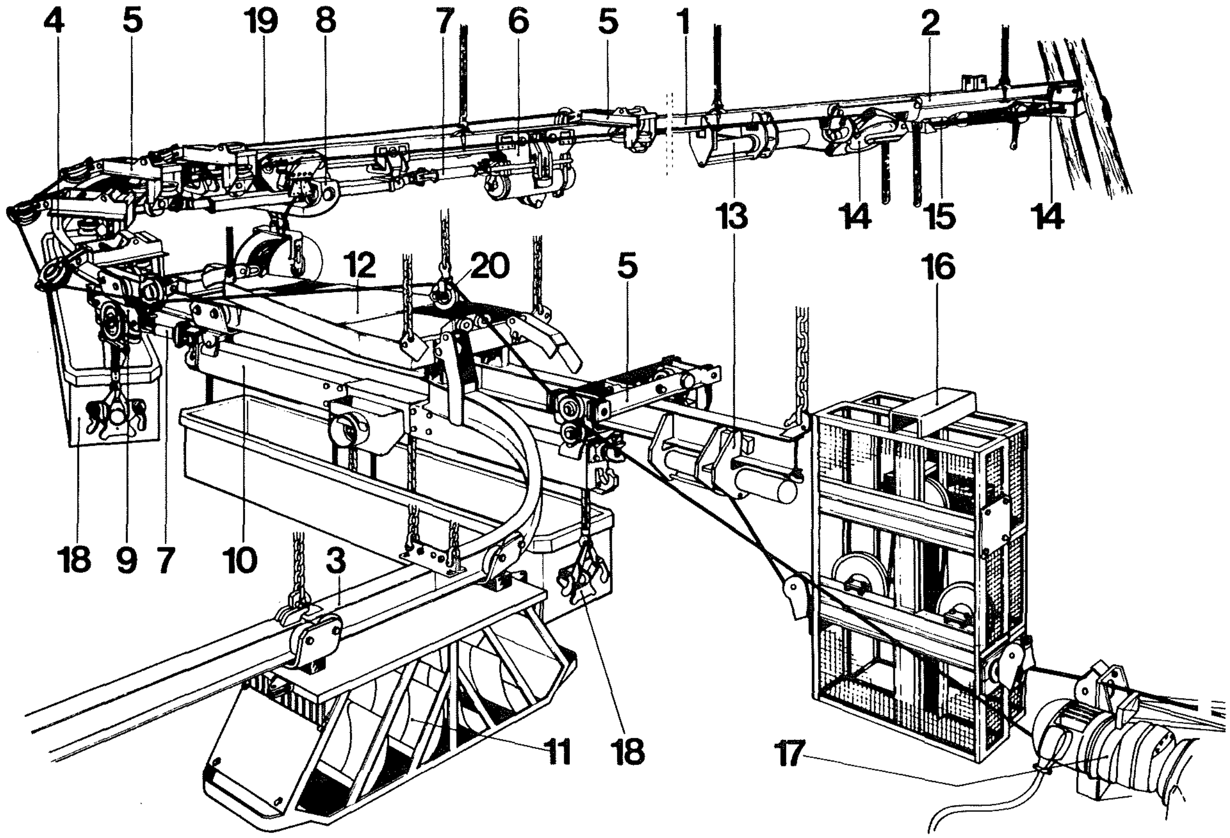


ILLUSTRATION LEGEND

1. Rail, 3 m long
2. Rail, 3 m long with trestle flange
3. Connecting rail
4. Curve unit
5. Roller trestle for rope guide
6. Brake trolley
7. Tie rod
8. Autorail locomotive with reserve rope drum
9. Trolley with chain tackle block and distance rod
10. Lifting beam
11. Man-riding compartment 8 persons
12. Fork type switch
13. End buffer
14. Return unit
15. Dynamometer
16. Rope tensioning device
17. Haulage
18. Container, tiltable
19. Endless pulling rope
20. Rope guide roller

FIGURE 29. Schematic diagram of Scharf monorail system. (Courtesy Maschinenfabrik Scharf GmbH.)

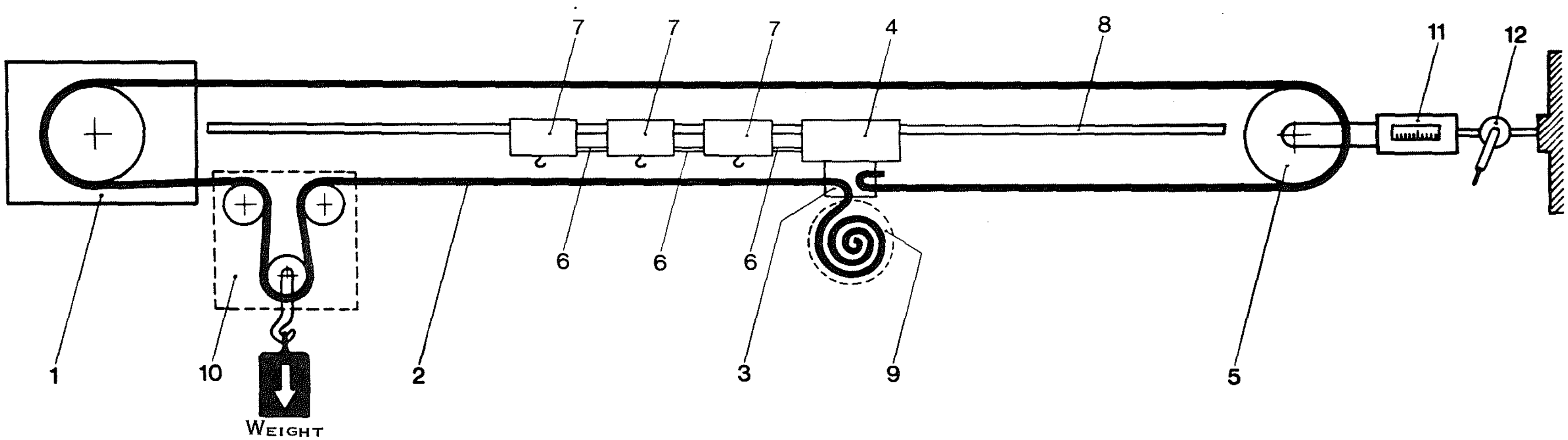


ILLUSTRATION LEGEND

The endless wire rope (2) is driven by the haulage (1). The arm (3) of the autorail locomotive (4) is connected to the wire rope (2). At the end the wire rope (2) runs via a return pulley (5). Autorail locomotive (4) together with coupling rods (6) and trolleys (7) forms a traction unit. The traction unit is captive-guided on the rail (8). The rail (8) consists of several hinge-connected sections and is suspended from the support. With lengthening or shortening of the Monorail the endless wire rope must be lengthened or shortened accordingly. For this the Monorail is provided with a rope reserve drum (9). The wire rope can be coiled or uncoiled and clamped on the arm (3). The rope tensioning device (10) prevents slack rope and slipping of the endless rope on the sprocket drum. The rope tension is checked by means of the dynamometer (11) and adjusted by means of the hoisting gear (12).

FIGURE 30. Schematic diagram of Scharf Monorail haulage action. (Courtesy Maschinenfabrik Scharf GmbH.)

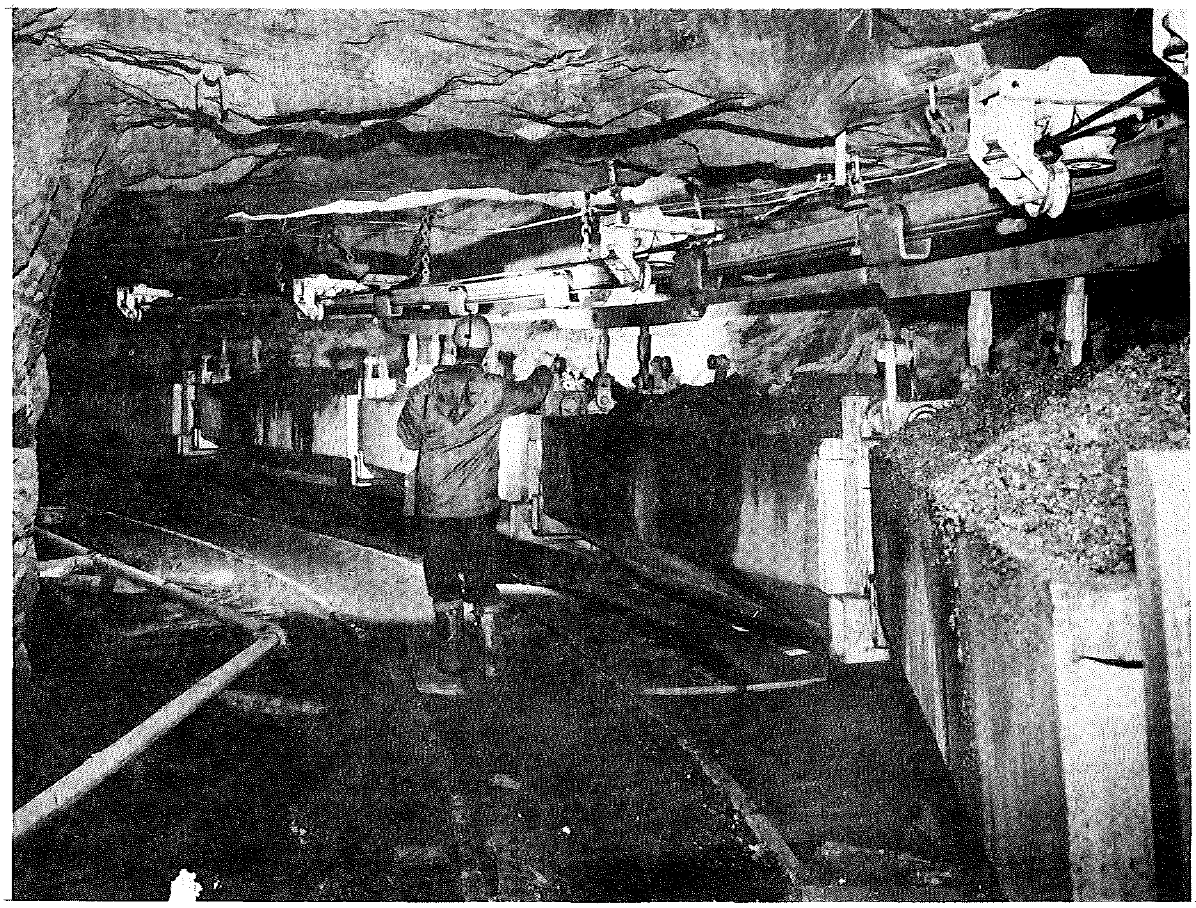


FIGURE 31. Debris transport in Scharf monorail bottom dump containers. (Photo courtesy Maschinenfabrik Scharf GmbH.)

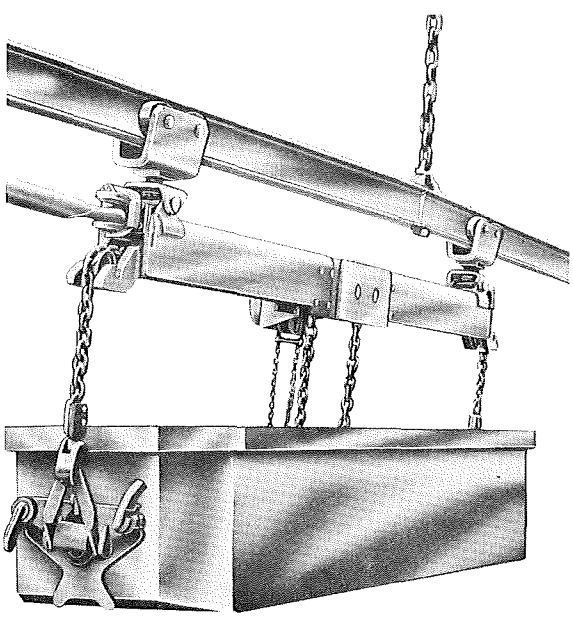


FIGURE 32.

Scharf monorail lifting beam and tipping container (Photo courtesy Maschinenfabrik Scharf GmbH.)

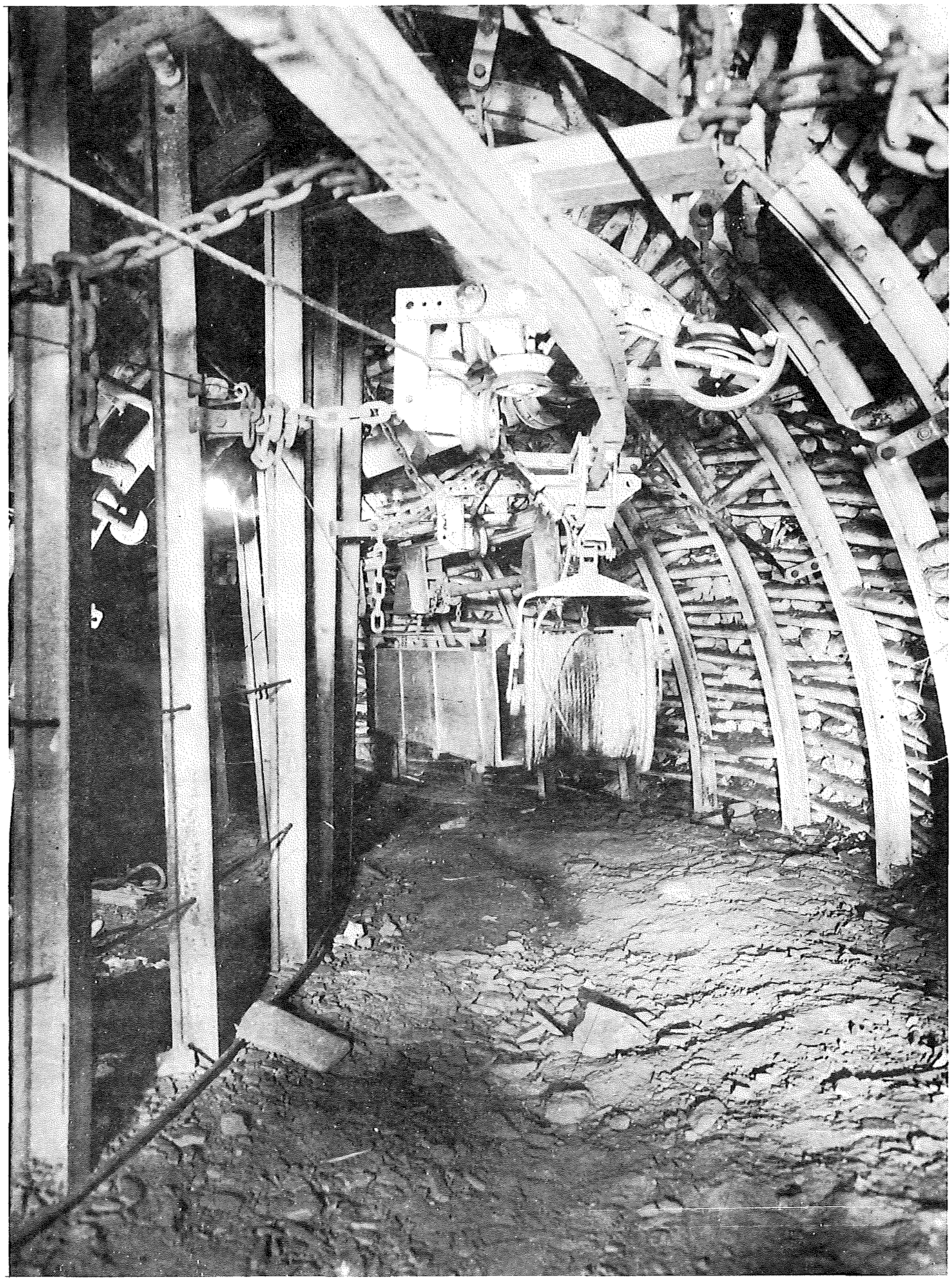


FIGURE 33. Scharf monorail traveling in limited roadway space. Note chains giving horizontal stabilization to curved track section. (Photo courtesy Maschinenfabrik Scharf GmbH.)

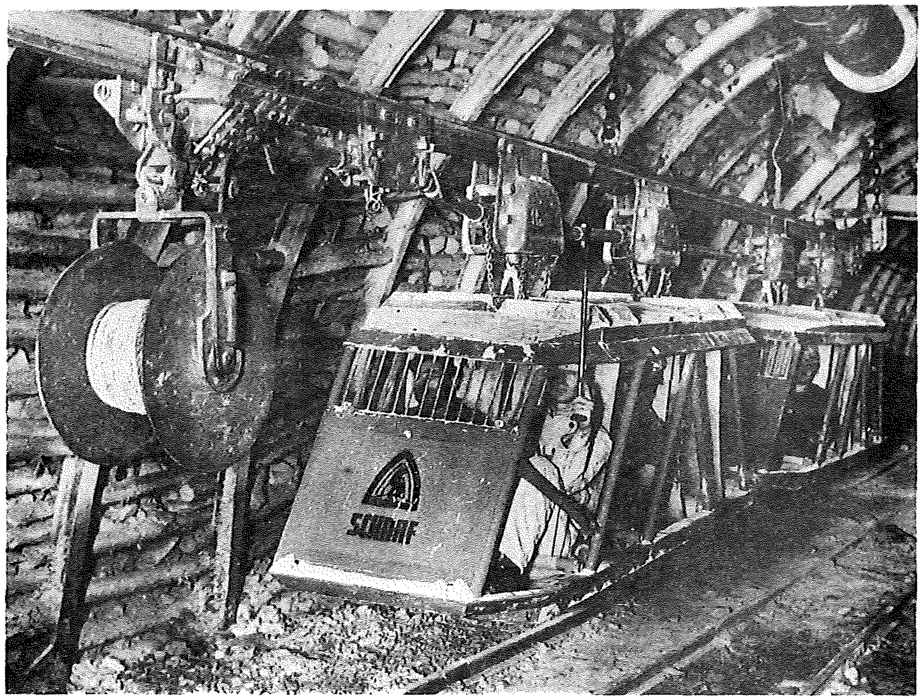


FIGURE 34. SCHARF MONORAIL FOR MANRIDING. NOTE MANUAL BRAKING CONTROL, BRAKING AND TRANSPORTER TROLLEY, LIFTING TROLLEYS, AND RESERVE ROPE DRUM. (PHOTO COURTESY MASCHINENFABRIK SCHARF GMBH)

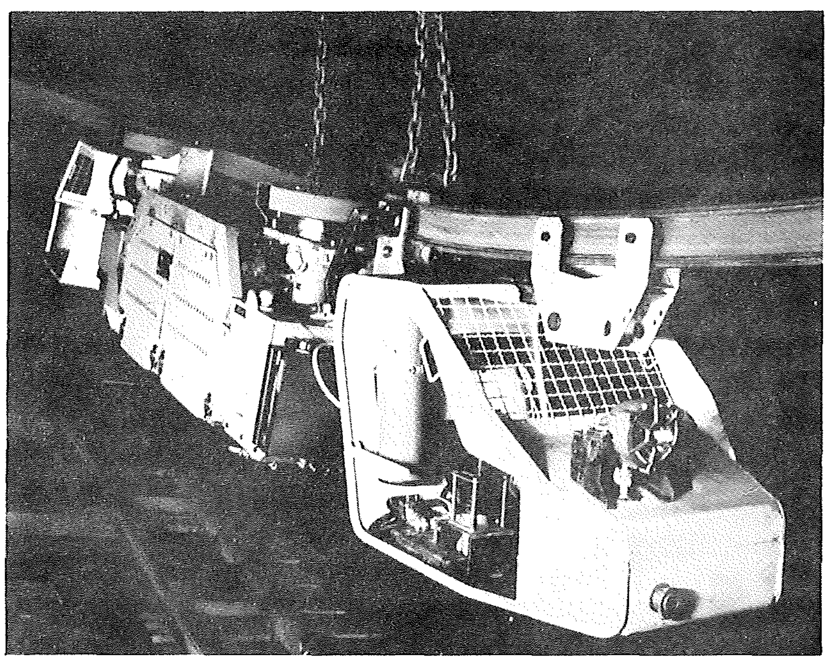


FIGURE 35. SCHARF MONORAIL DIESEL LOCOMOTIVE. NOTE COOLIE CAR TRACKS BELOW (PHOTO COURTESY MASCHINENFABRIK SCHARF GMBH.)

APPENDIX VI

Becorit Monorail

The Becorit monorail is basically similar to the Scharf system described in Appendix V. The rope captivating pulley assembly is the same as that designed for the Road Railer system, and the trolley captivating system has four running wheels on the bottom flange of the I-beam-rail and four guide wheels running between the upper and lower flanges of the rail, thus captivating the trolley. The braking system is similar to that of the Road Railer, but has been adapted to fit the monorail trolley. When an overspeed, 25 percent above normal running speed, is reached the brakes are applied by a fail-safe device. Track is 5 in. by 3 in. section up to 3 m (10 ft.) in length.

Operating Data

Road Length:	Up to 3000 m (9,843 ft.)
Gradient:	A gradient of 45^{o} (1 in 1) can be negotiated.
Curve Radius:	The minimum curve radius that can be negotiated with standard fittings is 4 m (13 ft.)
Traveling Speed:	The system is designed for travel speeds of 2 m per second (394 fpm).
Winder Pull:	3,000 kg (6,600 lbs.)
Drive:	Electric-motor, air turbine, or electro-hydrostatic drive.
Rope Diameter:	16 mm (5/8 in.) or 19 mm (3/4 in.)
Carrying Capacity:	3,000 kg (6,600 lbs.) per container unit, with heavy duty units 5,500 kg (12,100 lbs.)
Braking Force or Brake Trolley:	3,000 kg (6,600 lbs.)
Track Flexibility at Joints:	6^{o} horizontal deflection and 9^{o} vertical deflection.
Other Methods of Traction:	Diesel locomotive haulage is also available for this monorail system.

Figures 36 to 39 show Becorit monorail systems in use under various roadway conditions.

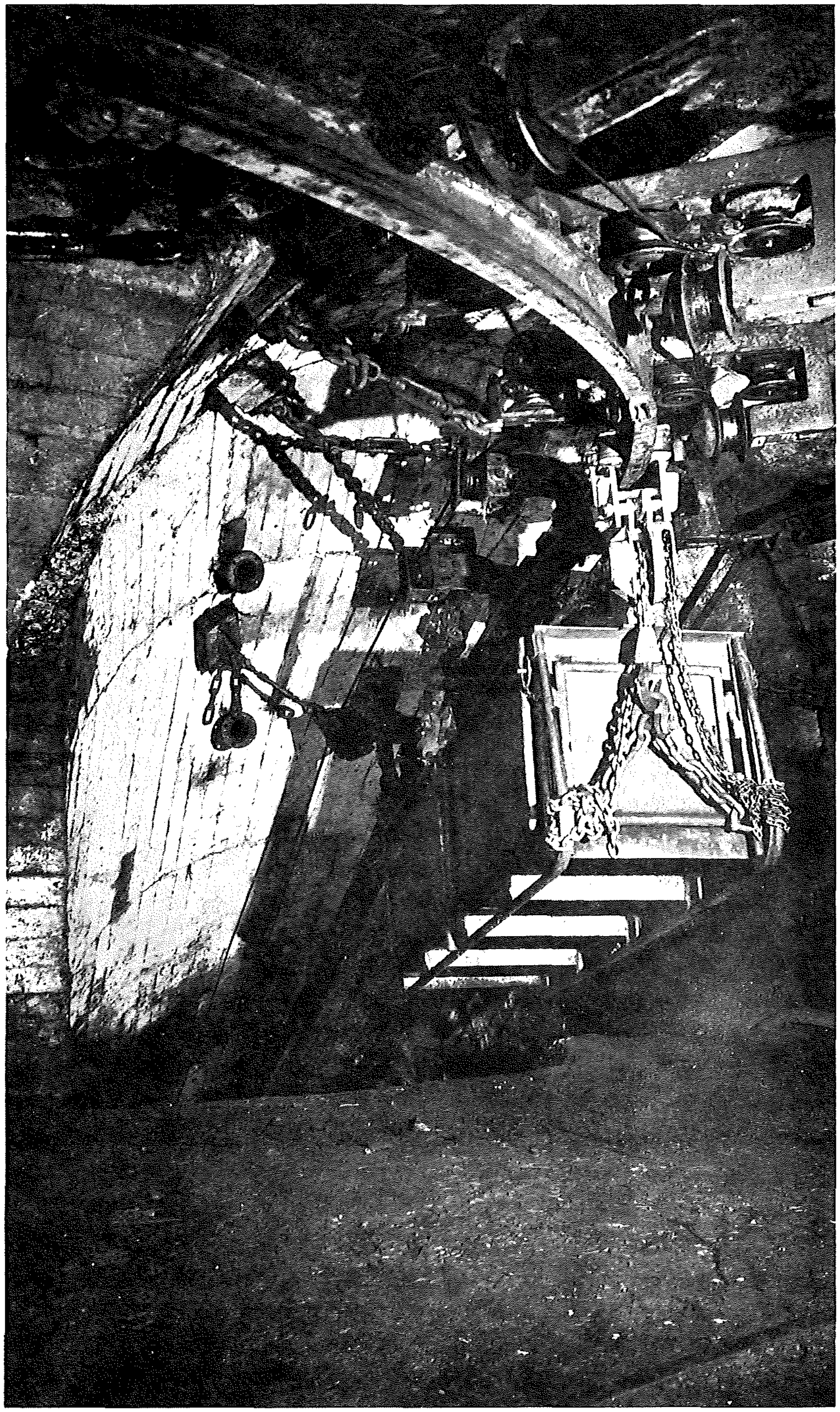


FIGURE 36. Becorit monorail container (heavy duty 12,100 lbs capacity) rounding curve at head of steep incline (Photo courtesy Becorit Grubenausbau GmbH.)

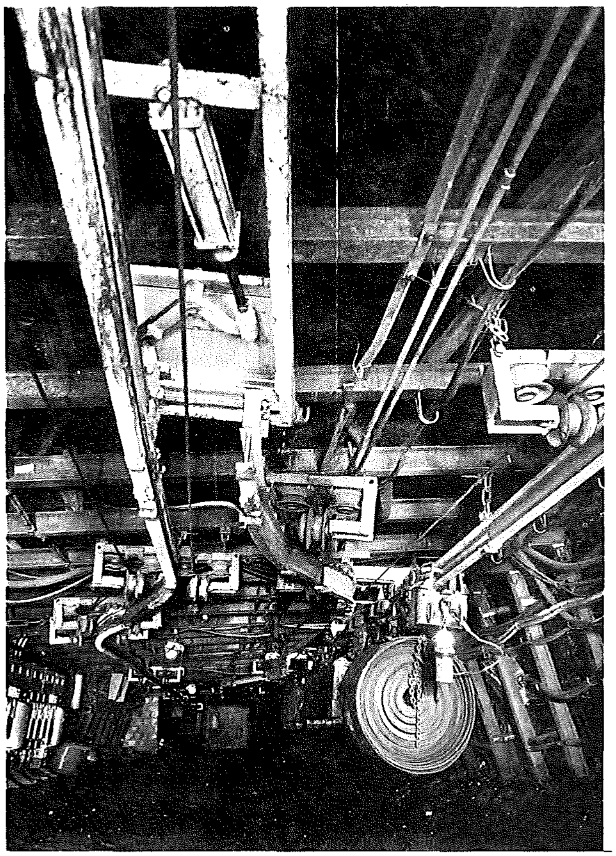
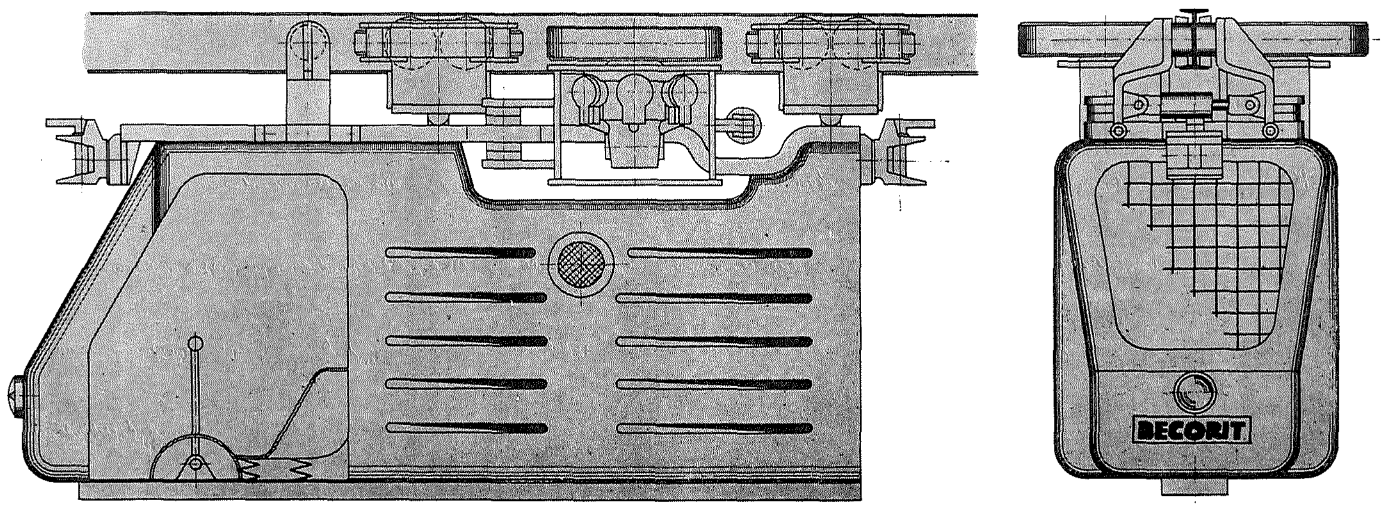


FIGURE 37.

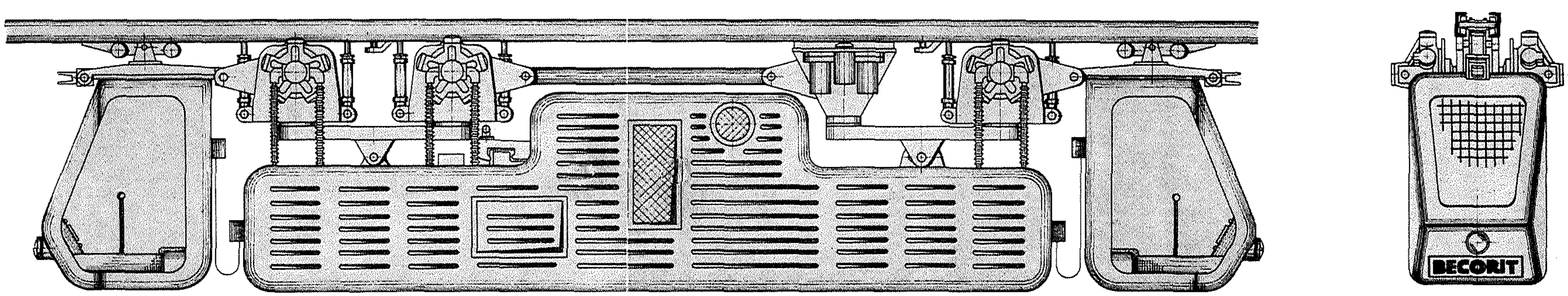
BECORIT MONORAIL MATERIALS HAULAGE, MULTIPLE INSTALLATION WITH SWITCHING SYSTEM. (PHOTO COURTESY BECORIT GRUBENAUSBAU GMBH.)

FIGURE 38.

BECORIT MONORAIL HAULING MATERIALS IN NARROW ROADWAY ABOVE BELT CONVEYOR. (PHOTO COURTESY BECORIT GRUBENAUSBAU GMBH.)



A



B

FIGURE 39. A. Diagram of small Becorit monorail diesel locomotive for use on I-Section track.

B. Diagram of Becorit monorail diesel locomotive, of greater capacity than "A", for use on double channel track similar to Road Railer (Courtesy Becorit Grubenausbau GmbH.)

APPENDIX VII

Sheepbridge Conventional Rope-Haulage Systems

Sheepbridge Equipment Limited has developed manriding equipment for conventional rope-haulage systems to where the equipment is stronger and safer than it has ever been. The cars can be used on direct-rope, endless-rope or main-and-tail haulage systems.

All Sheepbridge cars are fitted with automatic-fail-safe features so that any failure in the hydraulic system, parting of the train, overspeed running or malfunctioning of any component causes the brakes to be applied automatically. A unique feature is that hydraulic pressure (800 psi) in diaphragm units is used to keep brakes off, braking being effected by dissipating this pressure as quickly as possible so that the cars sit down on the tracks, their weight being taken by the brake shoes instead of the axle. Cars working on steep gradients are supplied with a wheel lifting device which insures 100 percent braking load. Brake shoes are positioned at each corner of the car to give maximum force and aft stability when braking.

Standard cars are fabricated in mild steel to carry 12, 18 or 24 men per car. They are built as low as possible to give a low center of gravity for stability and safety, and to provide maximum headroom. Low tare weight, achieved without sacrificing strength, enables a longer train carrying more men to be used, and in the case of new installations reduces the power and size of the haulage engine required for transporting a given number of men.

Figure 40 shows the Sheepbridge conventional rope-haulage manriding equipment.

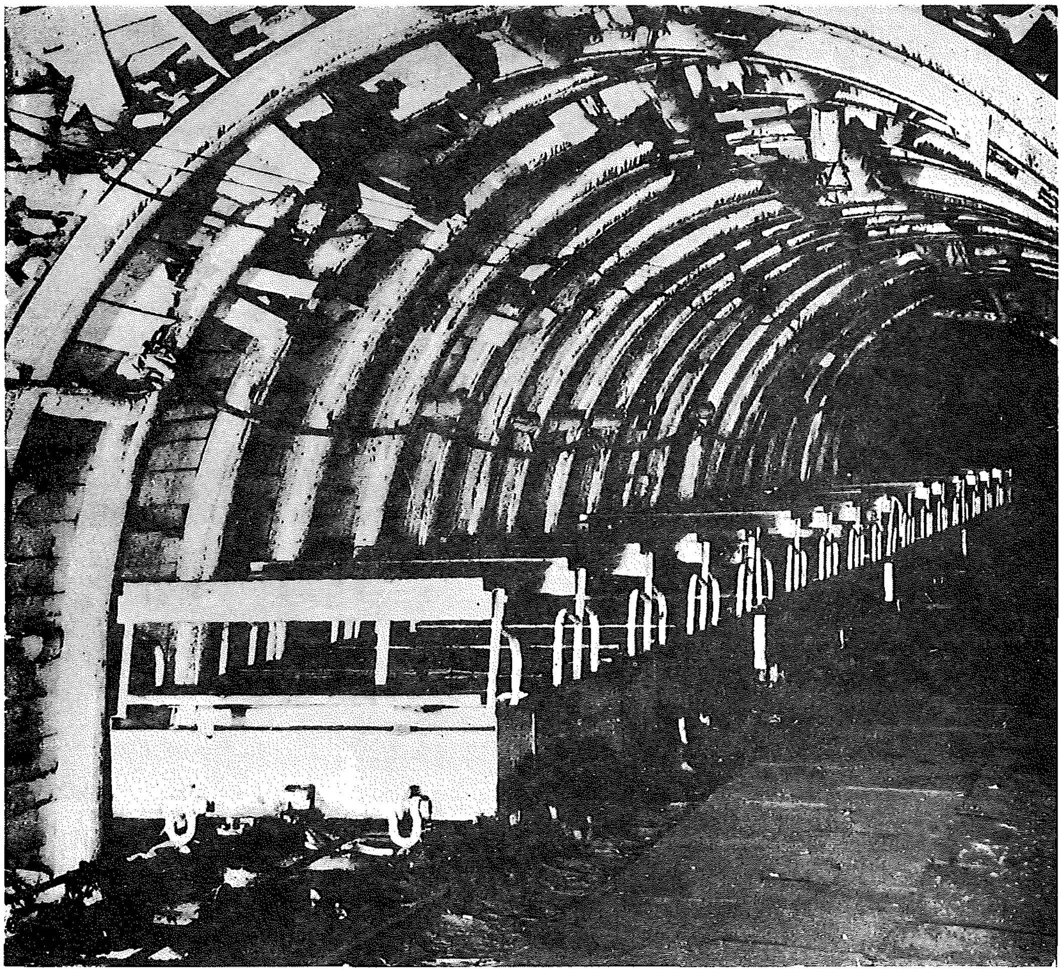


FIGURE 40. Sheepbridge conventional rope-haulage manriding cars can be used direct, endless, or main-and-tail. Photo is endless-rope haulage. (Photo courtesy Sheepbridge Equipment Ltd.)