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UNDERGROUND TRIALS OF A DIESEL-POWERED FACE HAULAGE VEHICLE

Final Technical Report

By
Robert J. Gunderman

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Work Performed Under Contract No. FC01-79ET10020

Jeffrey Mining Machinery Division
Dresser Industries, Inc.
Columbus, Ohio

U. S. DEPARTMENT OF ENERGY

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FINAL TECHNICAL REPORT
AS OF
NOVEMBER 15, 1979

Robert J. Gunderman

JEFFREY MINING MACHINERY DIVISION
DRESSER INDUSTRIES, INC.
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U. S. DEPARTMENT OF ENERGY
Assistant Secretary for Energy Technology
Solid Fuels Mining and Preparation
Mining Research and Development

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ABSTRACT

Two four-wheel drive articulated face haulage vehicles designed and fabricated under a previous government sponsored program were fitted with permissible diesel engines. The vehicles were originally designed for both increased productivity and as test vehicles for steam engine power. The vehicles, with diesel engines installed, were evaluated under operating conditions in an underground coal mine. Results were favorable and demonstrate capabilities in very harsh steeply pitching coal seams.

SECTION 1.0

EXECUTIVE SUMMARY

This report describes the complete program and the results achieved by the Jeffrey Mining Machinery Division, Dresser Industries, Inc. under Cooperative Agreement number DE-FC01-79ET10020 with the Department of Energy.

Under a separate subcontract on a Bureau of Mines program (U.S.B.M. HO 155121), two four-wheel drive face haulage vehicles were designed and fabricated by Jeffrey to be powered by steam engines. The steam engines were being specially designed by the prime contractor for underground coal mining face operations. However, engine development did not keep pace with the vehicle development, so an air cooled diesel engine was adapted temporarily to one of the vehicles to allow for above-ground test and evaluation. While this proved satisfactory for limited test purposes, the configuration was not permissible or suitable for underground coal mining.

In order to establish whether the vehicles meet the design goals of improved production rate capability (as well as serve as test vehicles for the steam engines) an underground demonstration was required. An expediency, since the steam engines were not ready, was to install diesel engines which were approved for underground coal mining applications.

Jeffrey is very interested in both the new vehicle performance and in collecting operational data on diesel powered haulage vehicles. Consequently, Jeffrey proposed and entered into a Cooperative Agreement with the Department of Energy to install Jeffrey owned diesel engines in the government owned vehicles and to evaluate their performance in an underground coal mine.

1.1 OBJECTIVE

The objective of the program is evaluation in an underground coal mine of two four-wheel drive face haulage vehicles that were originally designed to be powered by steam engines. Data to be collected included coal production rates, performance under actual mining conditions, durability, comparison with conventional haulage equipment, maintenance requirements and section air flow. Jeffrey was responsible for locating a mine site and making arrangements with the mine operator. Data was to be collected over a period of two months.

1.2 APPROACH

After locating the mine site for the test, requirements for the haulage vehicle were established. This was then the basis for modifying the two haulage vehicles already available at the Jeffrey facility as a result of the previous U.S.B.M. contract.

Permissible diesel engine packages were adapted to the vehicles by providing a new engine mounting frame, torque converter and a transfer gear case to line up with the existing transmission. Analyses were performed to determine adequacy of the drive train and other performance factors. Existing vehicle tires were replaced with larger sizes to increase the "footprint", allow heavier payloads and increase the ground clearance of the vehicle.

Eighteen inch side boards were installed in place of the six inch boards since the seam heights are in excess of seven feet. The operator compartment was modified to raise the seat and canopy heights, and to provide diesel engine controls. Increase in the operator eye level was necessary because the diesel engine package was considerably higher than the steam engine. Protective side rub bars were added to the trailer since the vehicle must operate in seams pitching at least 25 percent.

When the vehicles were ready and shipped to the mine, they were temporarily tried underground to determine both adequacy and to allow operator familiarization. This led to some additional vehicle changes such as no-slip differentials and a second set of hydraulic steering cylinders.

The vehicles were placed in operation in the second of three mines at the test site for approximately one month. They were then moved to the newest of the three mines where operating conditions were even more harsh. The vehicles were in this latter mine for three months. Data collection took place during the last two months.

1.3 RESULTS AND CONCLUSIONS

The objectives of this program were met. Vehicle performance was good although the vehicle was never designed for such difficult mining conditions. Most of the hardware failures were in the driveline which was originally designed for an engine of only one half as much power and for relatively flat seams.

Payloads of at least 13 tons in these government-owned four-wheel drive vehicles were successfully hauled up grades and cross grades on wet floors which pitched 25 percent. Conventional shuttle cars, with four wheel drive, carried typically 6 tons in these conditions. Diesel powered scoops carried typically 2-3 tons but had better tractive performance than the shuttle cars. Even with four-wheel drive there were some problems with slippage. Two-wheel drive vehicles just would not work under these conditions.

Unfortunately, data collection was not as comprehensive as planned. This was due to factors such as non-availability of an operator for the second haulage vehicle, the mine being down for installation of a haulage belt, the mine being down for roadway repairs or other problems, distraction from data notation because of equipment problems, etc. However, even though the data base is not large enough to calculate meaningful averages, the discrete data in all areas shows favorable results.

As a result of these trials, Jeffrey has used the information as input for design of a production version (referred to as the model 411-H) four-wheel drive diesel powered face haulage vehicle for application at this mine. A number of these production model vehicles are presently in operation at this mine.

A description of the vehicle as originally designed for increased productivity and to be powered by a steam engine is contained in Section 2.0. Adaptations of the vehicle to include a diesel engine and to meet other mine requirements are described in Section 3.0.

Section 4.0 briefly describes the mine conditions and activities associated with introducing the new prototype vehicles into the mine operations.

Data collected underground is contained in Section 5.0. This data is discussed and highlighted in the text. Section 6.0 discusses durability over the entire six month span during which the vehicles were at the mine.

At the conclusion of the tests both vehicles were returned to the Jeffrey facility and are being stored pending disposition instructions from the government.

SECTION 2.0

CONFIGURATION FOR STEAM POWERED ENGINE

This section describes the vehicle as designed for the steam engine. It is presented here to provide background understanding as well as to describe machine features being evaluated. Section 3.0, which follows, describes modifications to incorporate the diesel engine.

The vehicle concept, Figure 2.1, was patterned after the battery and diesel powered RAMCARs[1] that were developed at Jeffrey. It consists of a tractor section and a trailer section with an articulation joint between them for steering. Steering is accomplished via a pair of hydraulic cylinders between the tractor and trailer. A pivot on the longitudinal axis allows movement over uneven floors.

Payload discharge by the RAMCAR is accomplished by moving the telescopic body outward and then the ram-plate, thus pushing the coal off the RAMCAR end.

Key features designed into the Steam Powered RAMCAR to improve production include:

- Four wheel drive for maximum tractive effort.
- Pallet mounted engine for rapid changeout.
- Low height vehicle to accommodate a larger percentage of mines.
- Overhung canopy to eliminate operator visibility obstructions.
- Nine to fourteen ton payload capability.
- High tram speed.
- 60 degree pivot for sharper turns.

Interfacing a steam engine into the RAMCAR required a new vehicle design. Four wheel drive is a new feature and is important to the steam engine application because

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1. Reference to specific trade names does not imply endorsement by the Department of Energy.

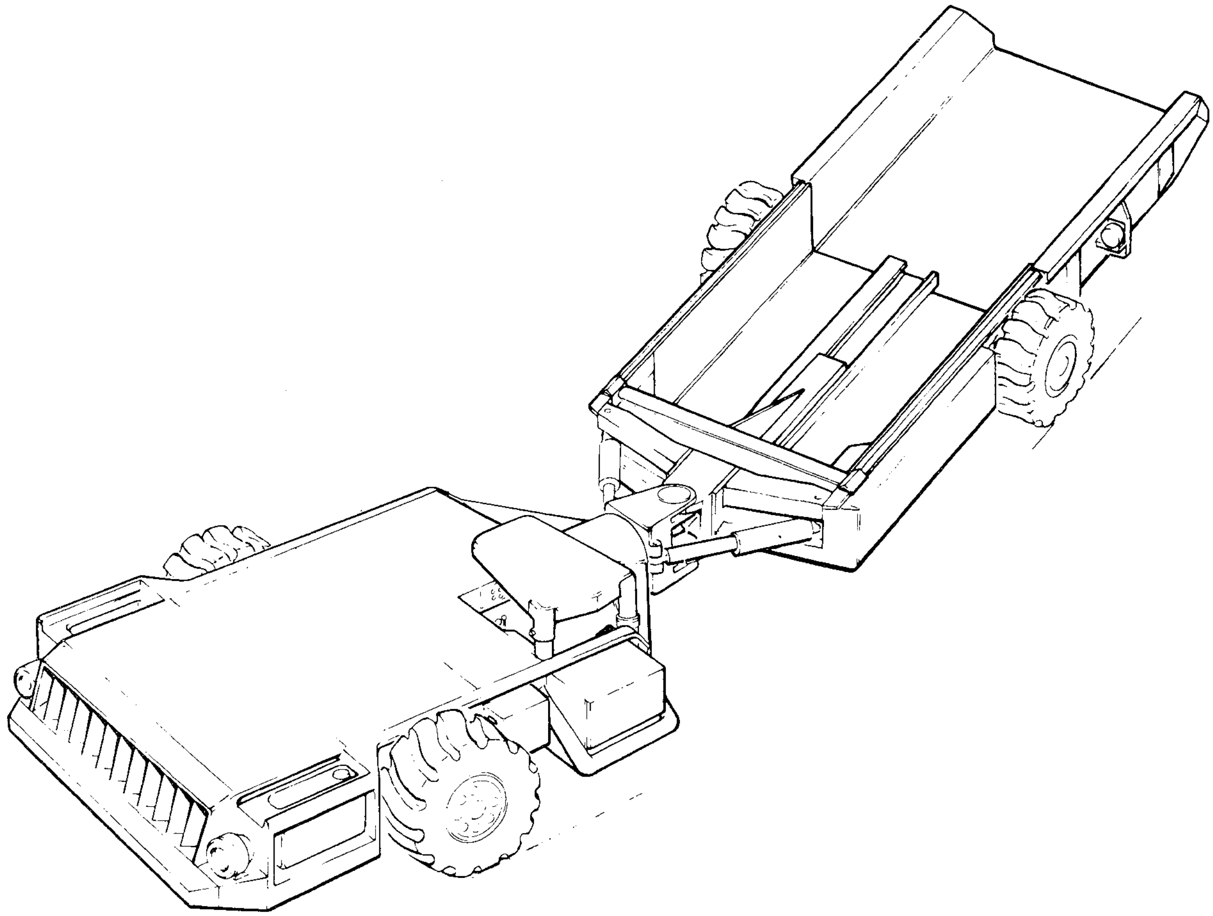

FIG. 2.1 ARTIST SKETCH OF PRELIMINARY DESIGN FOR THE STEAM POWERED RAMCAR

with larger payloads the weight is distributed more over the trailer. The mechanical drive retains the hard mounted axles and chain drive coupling that have been proven on the type 404 Jeffrey RAMCARs. The new design includes a long drop power shift transmission, a drive shaft through the pivot, hard mounted differentials and four traction drive gear cases.

A pallet mounted engine assembly has demonstrated value on the Jeffrey two-wheel drive diesel RAMCARs since it allows changeout of the complete engine package rather than attempting significant repair on the engine underground. This concept was included for the steam engine mounting.

Lower seam mines are now accounting for larger percentages of underground coal mining. Therefore, the basic height of this new RAMCAR was designed for 30" as compared to the 56" high two-wheel drive diesel RAMCAR.

A new canopy over the operator is suspended from only two posts, both of which are located behind the operator. As a result there are no supports to obscure his vision. Also, if seam height warrants, the canopy pivots around one support making ingress and egress much easier.

Payload weight (9 tons) is limited only by the tires when the smaller sizes (14.50 - 15) are used. Larger tires (18L - 20) along with larger sideboards can accommodate payloads up to 14 tons.

When it became apparent that availability of the steam engine for installation would be delayed, a Jeffrey recommendation to install an interim engine was approved. A readily available air cooled diesel engine was purchased and quickly adapted to the first vehicle. This enabled adjustment, checkout and test of many vehicle functions (with the non-approved engine). One of the prototype vehicles was checked and tested as far as possible with the interim diesel engine. See Figure 2.2.

The interim engine was never reinstalled into the second vehicle because of receipt of notice to terminate hard-

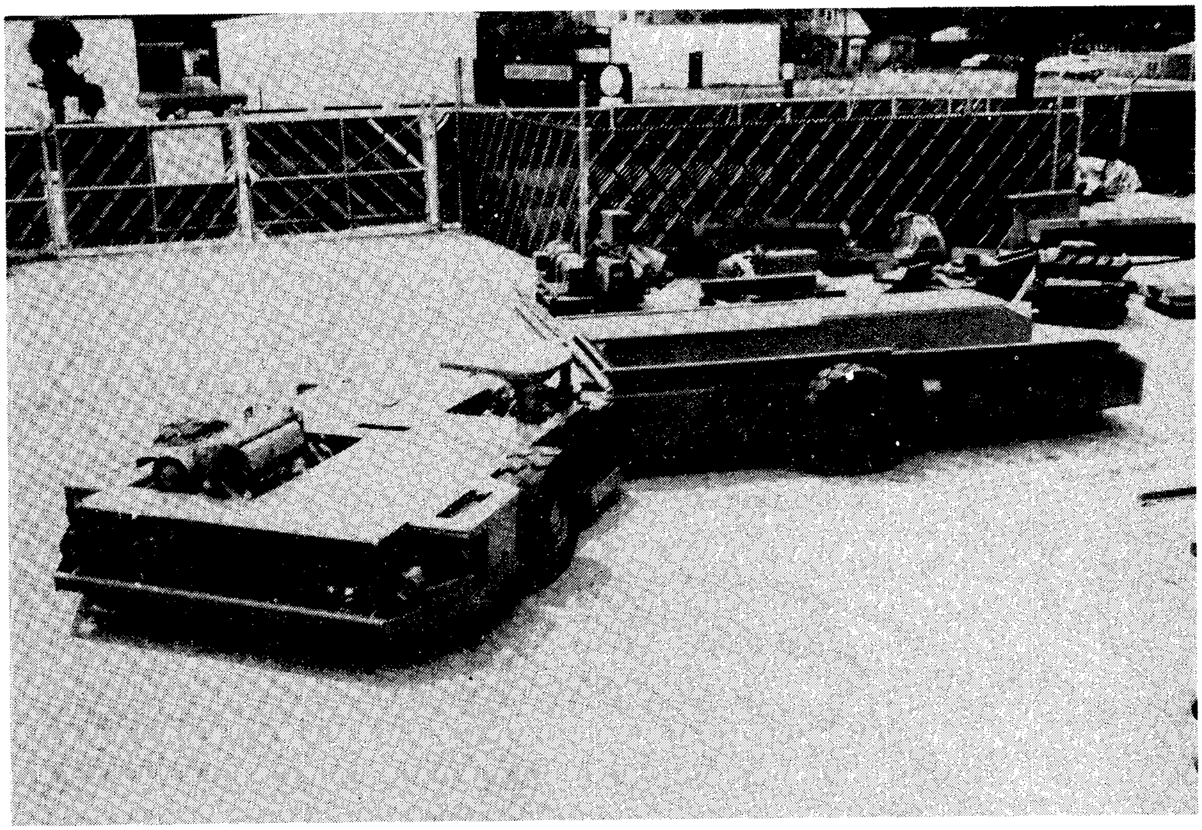

FIG. 2.2 PROTOTYPE RAMCAR WITH INTERIM ENGINE INSTALLED

ware work. Consequently, the second vehicle represented the design up to the beginning of test and did not incorporate those design changes made as a result of test.

Figure 2.3 shows the vehicle with the interim diesel engine in place during the coal discharge test. The resulting design along with some of the more significant considerations is briefly described in the following paragraphs.

2.1 OVERALL LAYOUT

The RAMCAR general layout shown in Figure 2.4 describes the vehicle which can operate in seams as low as 44" with canopy attached. Without canopy the car height is limited by the tires to 33.7 inches. Ground clearance is 6" under the tractor and 8" under the trailer.

This vehicle is of similar design to Jeffrey's current battery and diesel type cars, but it incorporated several significant design innovations to take full advantage of the planned steam power package capabilities. The first major innovation is full time four wheel drive. This feature allows design of a relatively lightweight vehicle with high tractive effort in bad bottom or steep grade conditions. Another change from Jeffrey's current design is the use of a long wheelbase with increased articulation angle; i.e. up to 60^{o}. Together these provide both a smooth ride for the operator and a sharp turning capability. An additional benefit of the turning capability is the ability to go to a wider car than is the usual practice (10' 4" vs. 9'6").

The operator location is carried over from the past experience. He is placed transversely well inside the confines of the car frame for safety and given good visibility for travel in either direction.

In order to provide a wide range of application, the car is designed with the structural ridgitity to carry loads up to 14 tons. Alternate, large size tires allow these loads in 65" (and higher) seams.

2.2 OPERATOR COMPARTMENT

The operator compartment and control location was de-

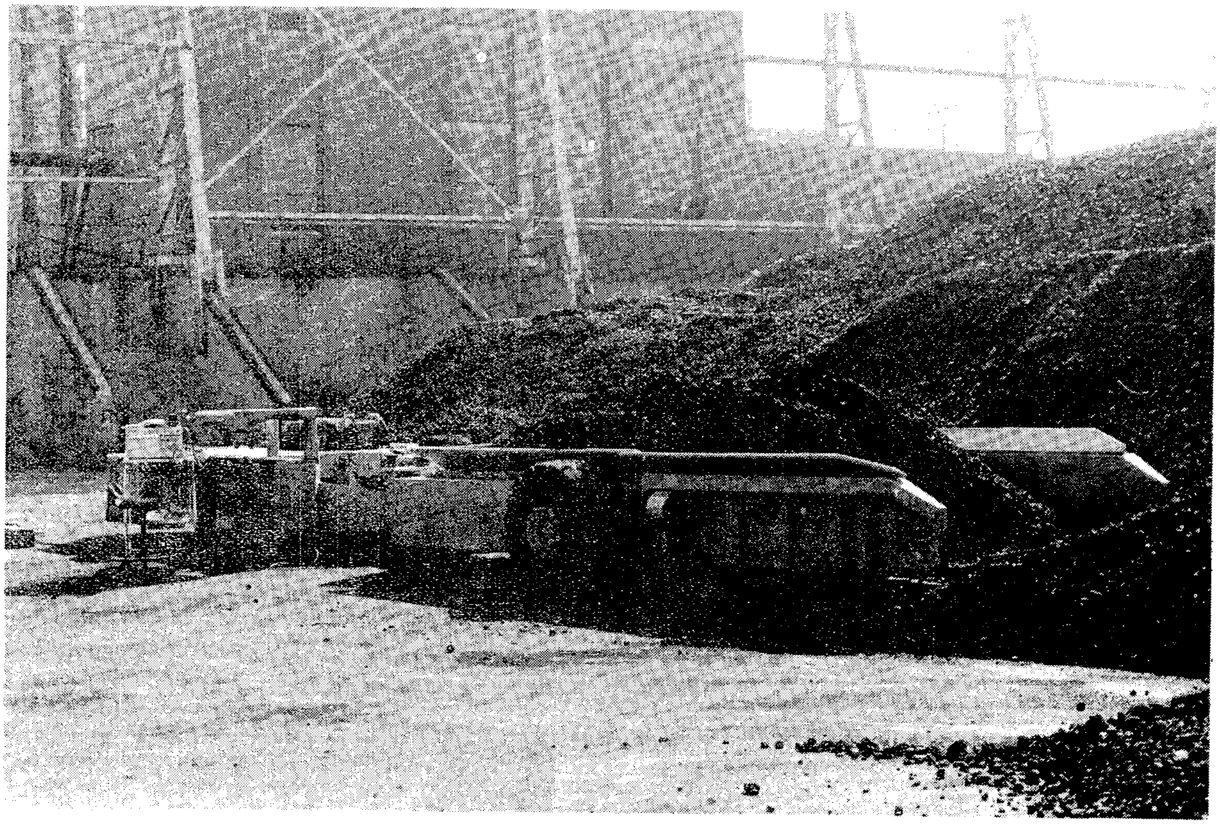

FIG. 2.3 COAL DISCHARGE TEST

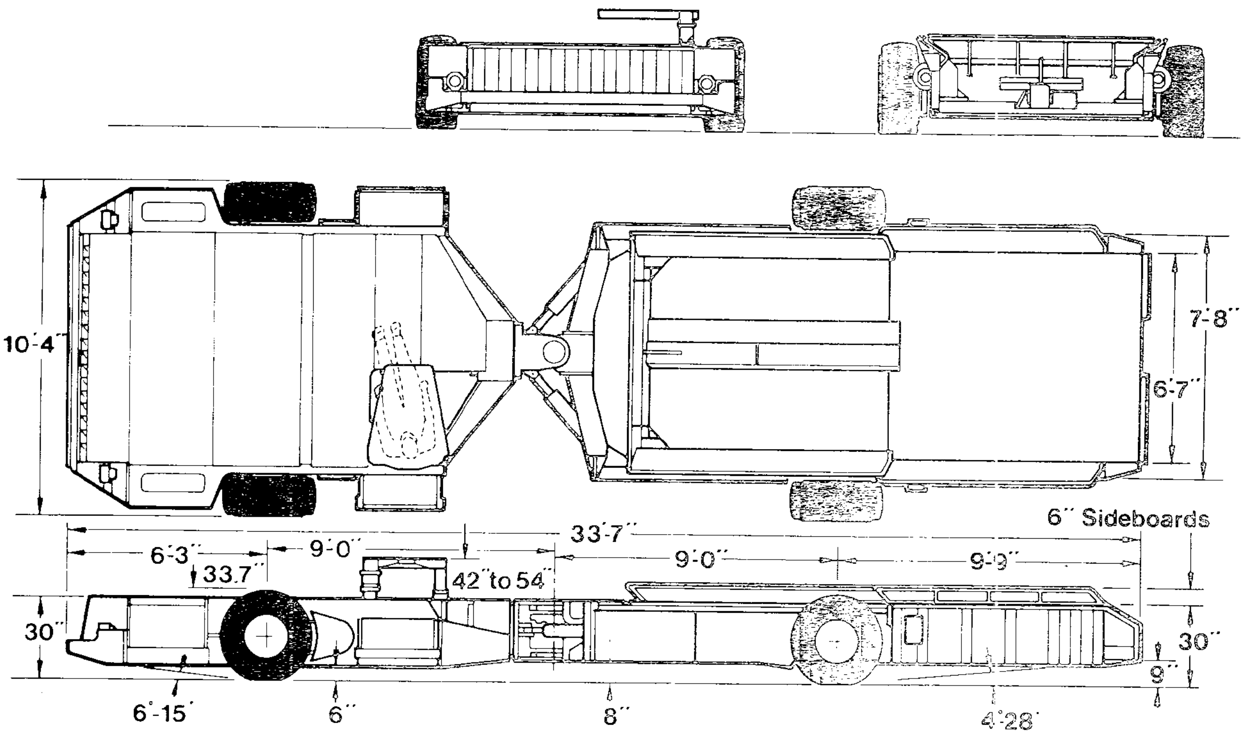

FIG. 2.4 STEAM POWERED RAMCAR GENERAL LAYOUT

signed taking into consideration recommendations gathered from another government contract for optimizing the operator compartment of the Jeffrey battery powered RAMCAR.

All controls are located in easily reached positions and operate in a normal, obvious fashion. Also, all controls operate in a horizontal plane so that the operator can rest his hands on any of them without fear of inadvertent operation.

Seat contours are similar to those of a USBM developed seat with both back and bottom cupped slightly to increase lateral support. The lower seat back is open to provide space for the self rescue and battery packages on a miner's belt.

The canopy is of two post cantilevered design for optimum visibility and is constructed such that height can be adjusted from 42" to 54" (above floor).

The compartment is within the wheelbase for a relatively smooth ride. Alternative operator locations, such as more outboard, do not allow acceptable body positions in accordance with established human factors criteria. Also, an operator compartment at the edge of the machine would leave the operator more vulnerable to injury.

2.3 LOAD CAPABILITIES

The total load capability of the trailer is 14 tons if the alternate size 18L-20 tires are used. For the standard 14.50 - 15 tires a maximum load rating of 9 tons is limited only by tire carrying capacity. The trailer volume is listed in the Table II.1 for various sideboard and heap combinations.

TABLE II.1 - PAYLOAD WITH DIFFERENT SIDEBOARDS

SIDE-BOARD	STRUCK	6 IN. HEAP	12 IN. HEAP
None	150 cu.ft.(4-1/2)	190 cu.ft.(5-1/2)	221 cu.ft.(6-1/2)
6 In.	201 cu.ft.(6)	247 cu.ft.(7-1/2)	283 cu.ft.(8-1/2)
12 In.	264 cu.ft.(8)	317 cu.ft.(9-1/2)	357 cu.ft.(10-1/2)
18 In.	317 cu.ft.(9-1/2)	367 cu.ft.(11)	407 cu.ft.(12)

NOTE: The figure in parentheses is the live load in tons based on 60 pounds per cubic feet material.

Vehicle performance as calculated for the steam engine remains basically unaffected by the high payload as the torque available for hauling is very much in excess of the drag torque produced by the high load.

Total maximum axle loads with the 14.50 tires are 13,500 pounds on the tractor axle and 30,500 pounds on the trailer. Because of the high trailer axle loads the 24 ply tire is to be used there, with the softer 16 ply tire used on the tractor to cushion the ride for the operator. This also results in equivalent wheel radius since the trailer weight is greater than the tractor weight.

Use of the larger tires (18L - 20) will allow the maximum trailer axle weight to go up to 40,500 pounds. This would also increase vehicle ground clearance by two inches.

In designing a low height trailer it was found that a tailgate at the rear of the vehicle sacrifices almost as much volume as it saves and is a costly, heavy, and high maintenance item. Therefore, a tailgate was not included. The higher the car or the sideboards, however, the more the effect of the tailgate. At 18" sideboard height the use of a gate offers payload advantages.

2.4 MANEUVERABILITY

As shown in Figure 2.5 the 60° articulation joint at the pivot allows the car to break sharply at the corner, and the long wheel base with the centered articulation joint allows the car to track. These two key points give the vehicle a high degree of maneuverability.

The car can turn in a narrow entry (15'9") with a square corner and one foot clearance on each side despite the overall vehicle width (10'4"). This is considerably better than previous RAMCAR designs despite the higher width.

This increased maneuverability is required to aid in control for increased tramming speeds. Together they should cut tram times considerably, thereby improving production.

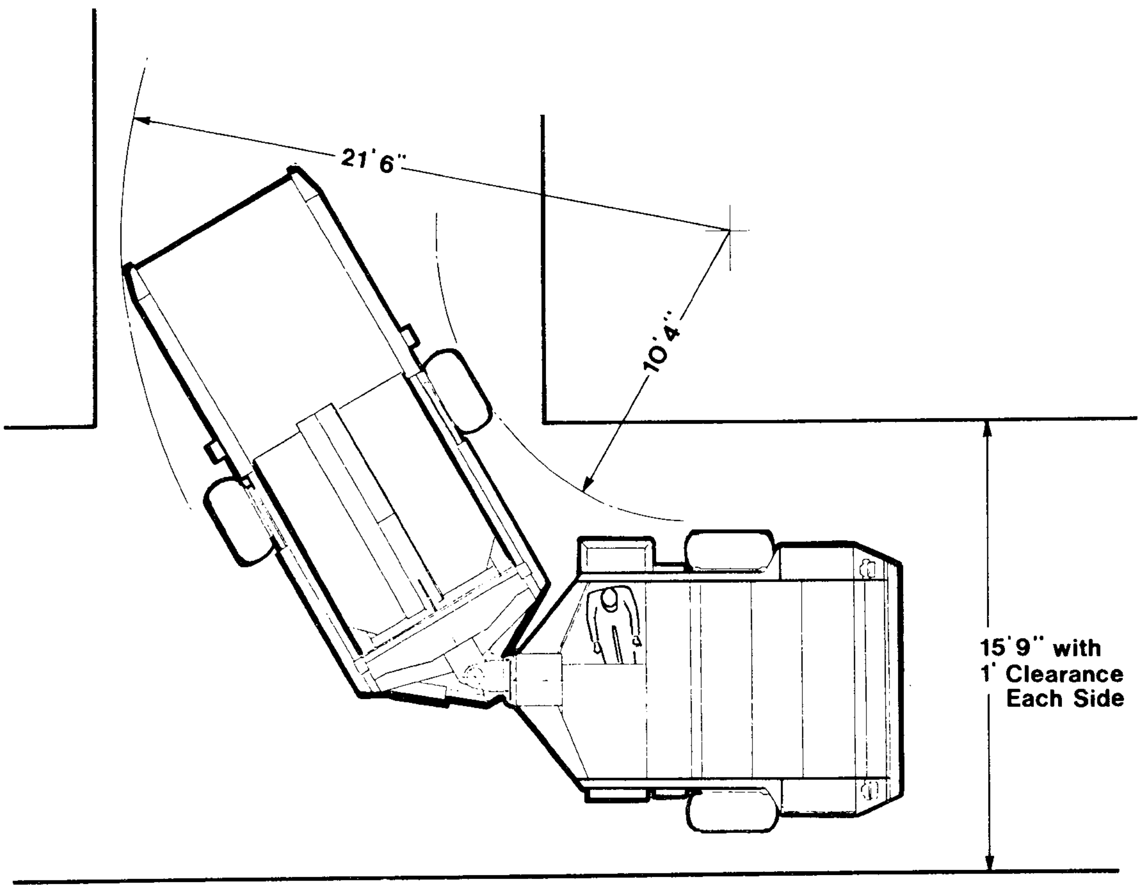

FIG. 2.5 STEAM RAMCAR TURNING CAPABILITY

2.5 TRAILER

Principle design considerations for the trailer centered around driving the trailer wheels.

The first decision in this regard was to go with 14.50 - 15 or optional 18L - 20 single tires due to their high load rating. It was then decided to drive these with chains down the car sides and a shaft and differential across the front since this minimized the lost payload capacity due to the driving arrangement.

The next major decision was to stiffen the rear of the trailer slightly and remove the tailgate which, in low height vehicles, is of very little value.

Another basic change from existing trailers was the relocation of the telescopic body and ramplate cylinders (Figure 2.6). These were dropped to the floor to clear the drive differential and to cut down on damage to or from the miner boom when the car is being loaded. The floor mounted cylinder housings are then used to form the track on which the ramplate is guided. This simplifies holding manufacturing tolerances and allows the ramplate to sit well behind the extremes of the wheel drive gear cases.

Another change from current RAMCAR design is the use of two bearing pads at the rear of the telescopic body instead of two rollers. The pads are used because of a height restriction problem between the wheel drive gear case and the top of the car. Bearing pads have been used in this application on the original prototype RAMCAR built by Jeffrey. There was no problem with this approach then, but rollers were found to cut down side frame height and reduce cost. The bearing pad material selected was a UHMW Polymer which has a very low friction coefficient, good wearability predictions and a maximum surface temperature under load of less than those permitted by regulations.

2.6 DRIVELINE

The drive train (Figure 2.7) starts with a Rockford torque converter which is bolted to the rear of the steam expander.

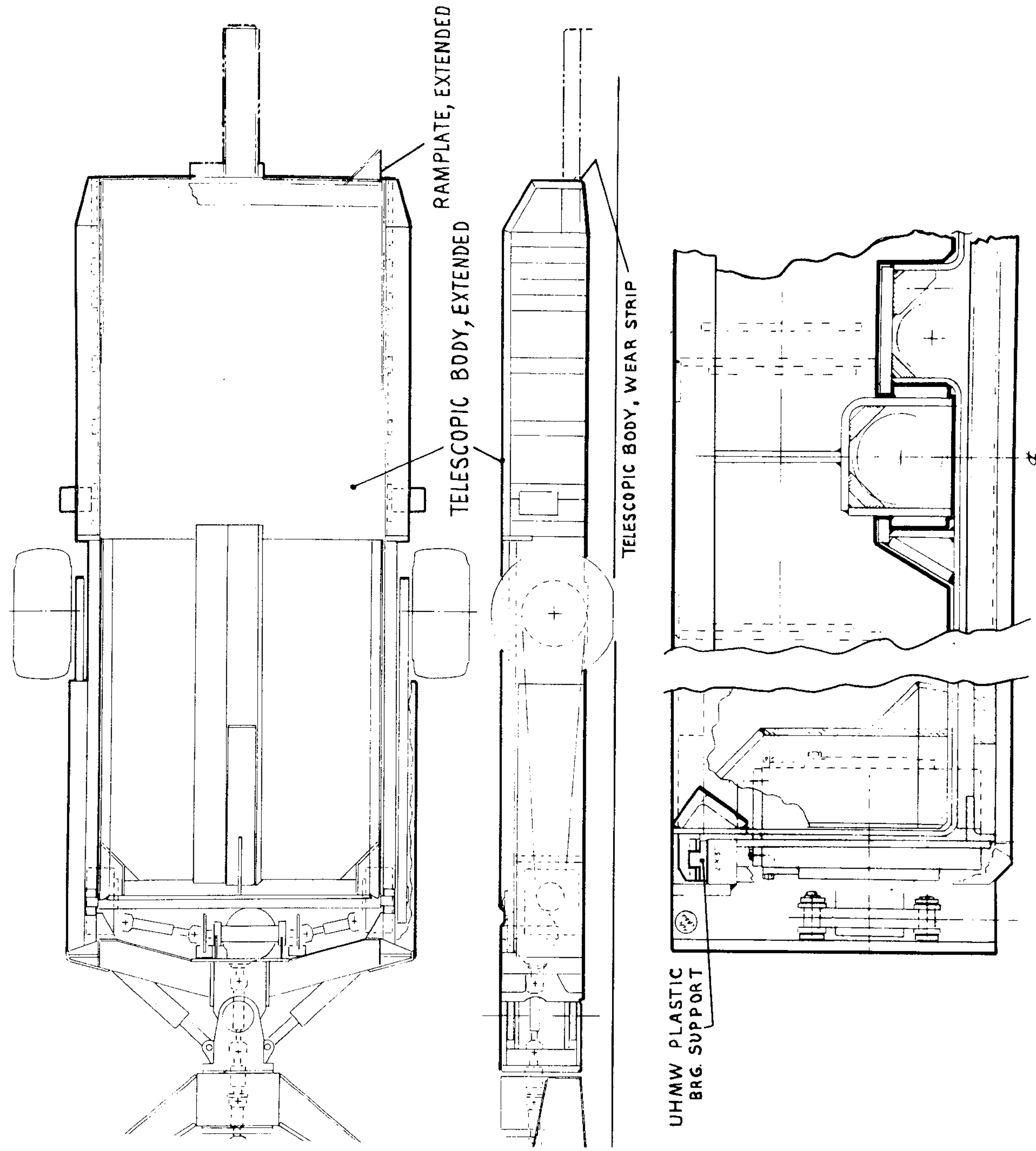

FIG. 2.6 RAMPLATE AND FLOOR GUIDANCE

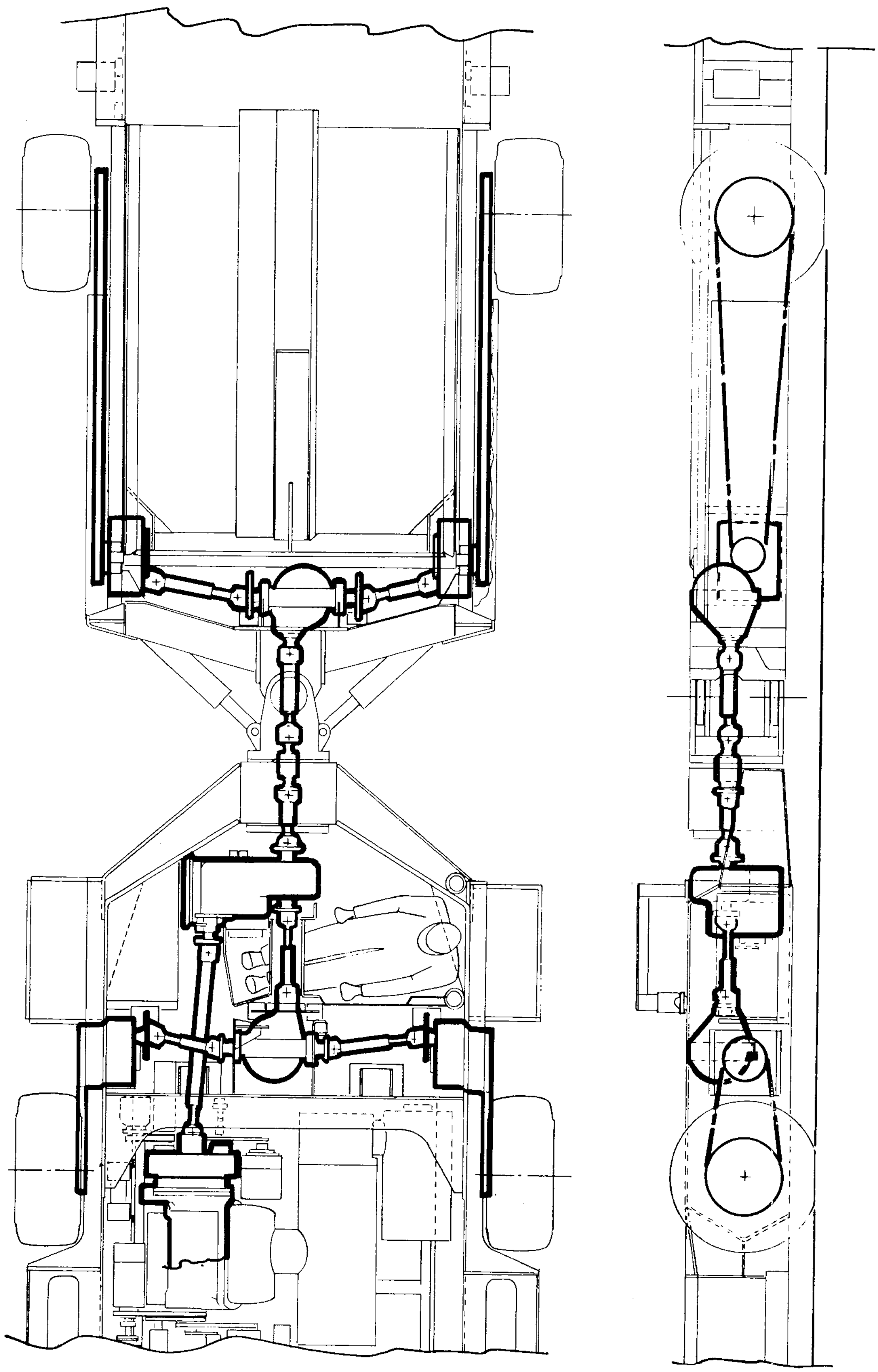

FIG. 2.7 RAMCAR DRIVE TRAIN

The Rockford was chosen from a number of other alternatives because of better overall efficiency. The torque converter is mounted in the inverted position to keep vehicle height low and shares a common oil system with the transmission.

The transmission is the next major component in the drive train and is a long drop Funk Model 1024 series four speed forward/reverse powershift transmission rotated 105° from the vertical. This orientation was established with the assistance of Funk Manufacturing, who ran the transmission in this orientation on their test stand. Results were excellent.

The 2nd, 3rd, and 4th ratios are used in this application with the 1st being blanked out since the excess torque is simply not required. Also the unit is mounted via vibration isolators to the tractor frame to deaden noise.

From here the drive runs forward in a trough formed by the tractor frame over the operator's feet to the front differential. A standard differential manufactured by NAPCO was selected for this application. It should be quite adequate since both front and rear axles drive full time. However, a no slip version is also available if desired.

The differential input flange is also the location chosen for the emergency/parking brakes (Figure 2.8). In this location, when properly adjusted, they can lock up all four tires with a full trailer load.

Outboard of the differential are the traction gear cases. There are four of these units on each car, two left hand and two right hand, all assembled out of the same set of individual parts. Those shown on the tractor also incorporate the service brake discs and calipers (Figure 2.9). The drive is then completed by means of chains and sprockets to the wheels.

The rear of the transmission is connected to the trailer differential by means of two universal joints and a pillow block. The first joint eliminates slight angular variations due to the swiveling of the articulation joint between tractor and trailer. The second joint operates entirely in the plane of the trailer and is a high angle

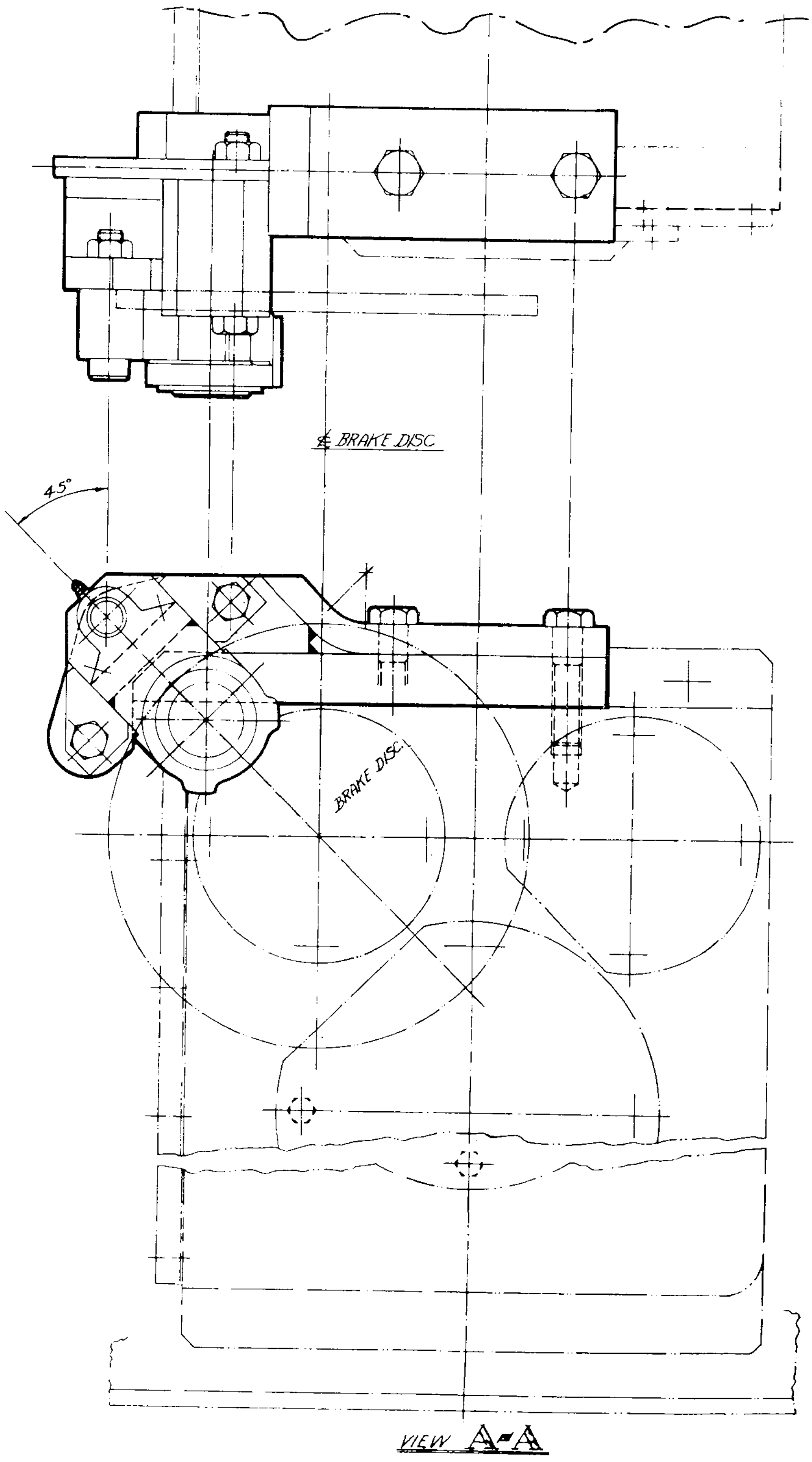

FIG. 2.8 SERVICE BRAKE AND TRACTION GEAR CASE LAYOUT

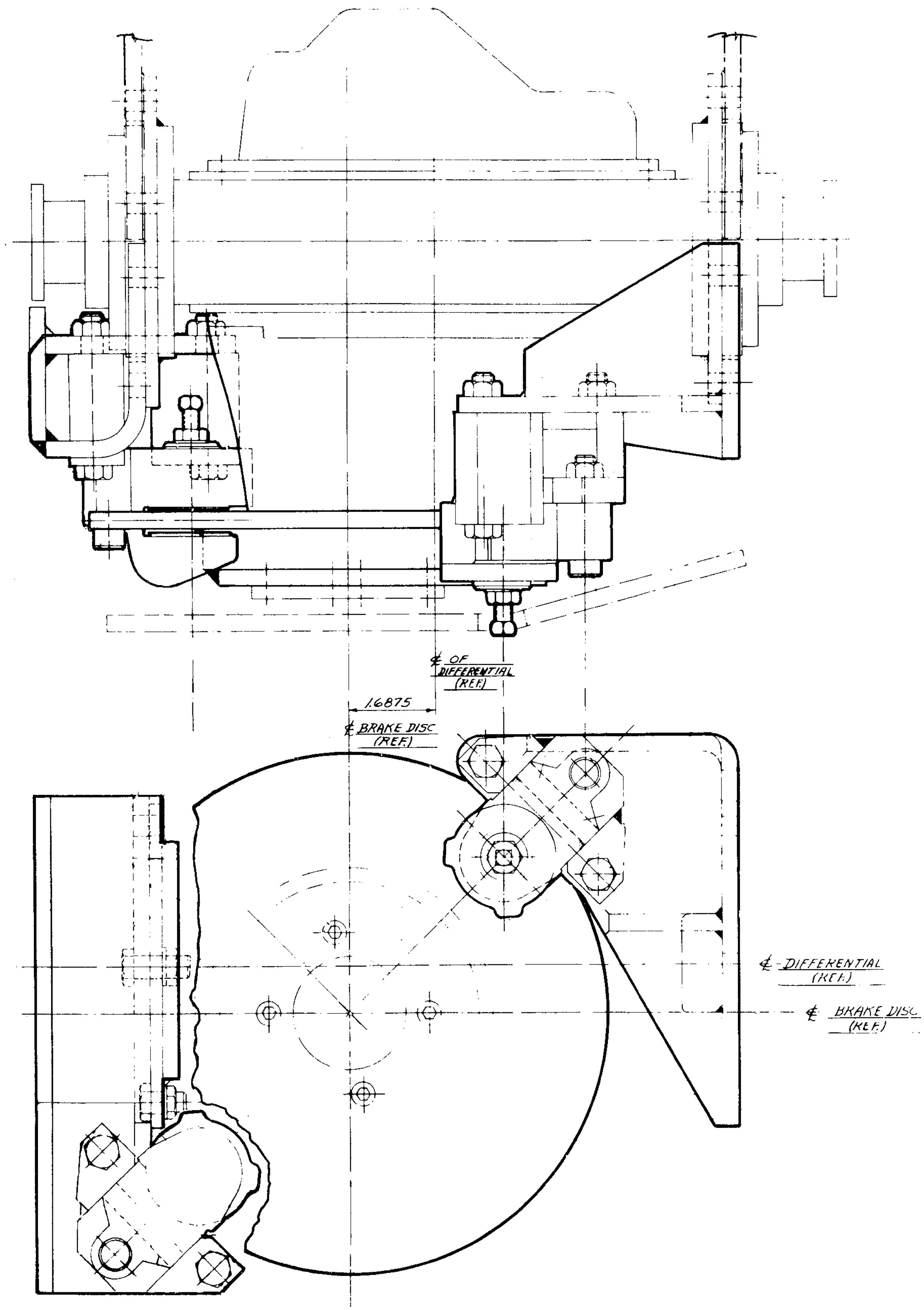

FIG. 2.9 PARKING BRAKE ASSEMBLY (ORIGINAL DESIGN)

joint. The pivot steering angle can run as high as 60^{o}, requiring a joint with 30^{o} per knuckle capabilities.

The differentials between wheels on the tractor or trailer are standard since the no-slip option seemed to have little benefit with 2 axles constantly driving and would unduly stress the rest of the drive train. The differentials, Napco Model LD 9750 units, were chosen because of their high input torque rating (1500 ft./lb.) and their availability in an axle-less housing.

The universal joints selected are Dana 1350 and 1480 series JTS. These were chosen because of their high angle (35^{o} per knuckle) and good life capabilities.

The traction drive system consists of four chain driven wheel units of the current Jeffrey 404 series RAMCAR design driven by four interchangeable wheel drive gear cases. Figure 2.10 shows the trailer drive arrangement.

The total reduction between gear case input and wheel is 5.78 to 1. This allows the use of physically smaller high speed universal joints and a considerably lighter, less complicated braking system.

The wheel spindles are designed to handle a considerably higher load than is possible with planetary wheel units. Drive train ratios can be easily adjusted to match tire size by varying the wheel sprocket.

The four gear cases are assembled from the same set of pieces into two different assemblies and are then mounted in four different orientations. The gear cases on the trailer also include a mounting point for the disc brake system where the trailer brakes are mounted off the differential.

The chain used is Bowman 2" pitch chain with an 80,000 pound breaking strength.

2.7 TRACTION CHARACTERISTICS

The axial pivot in the Jeffrey RAMCAR design assures that all four wheels are in good contact with the ground. Therefore, the four wheel drive system that was selected has the advantage of giving very high tractive effort despite a low initial vehicle weight.

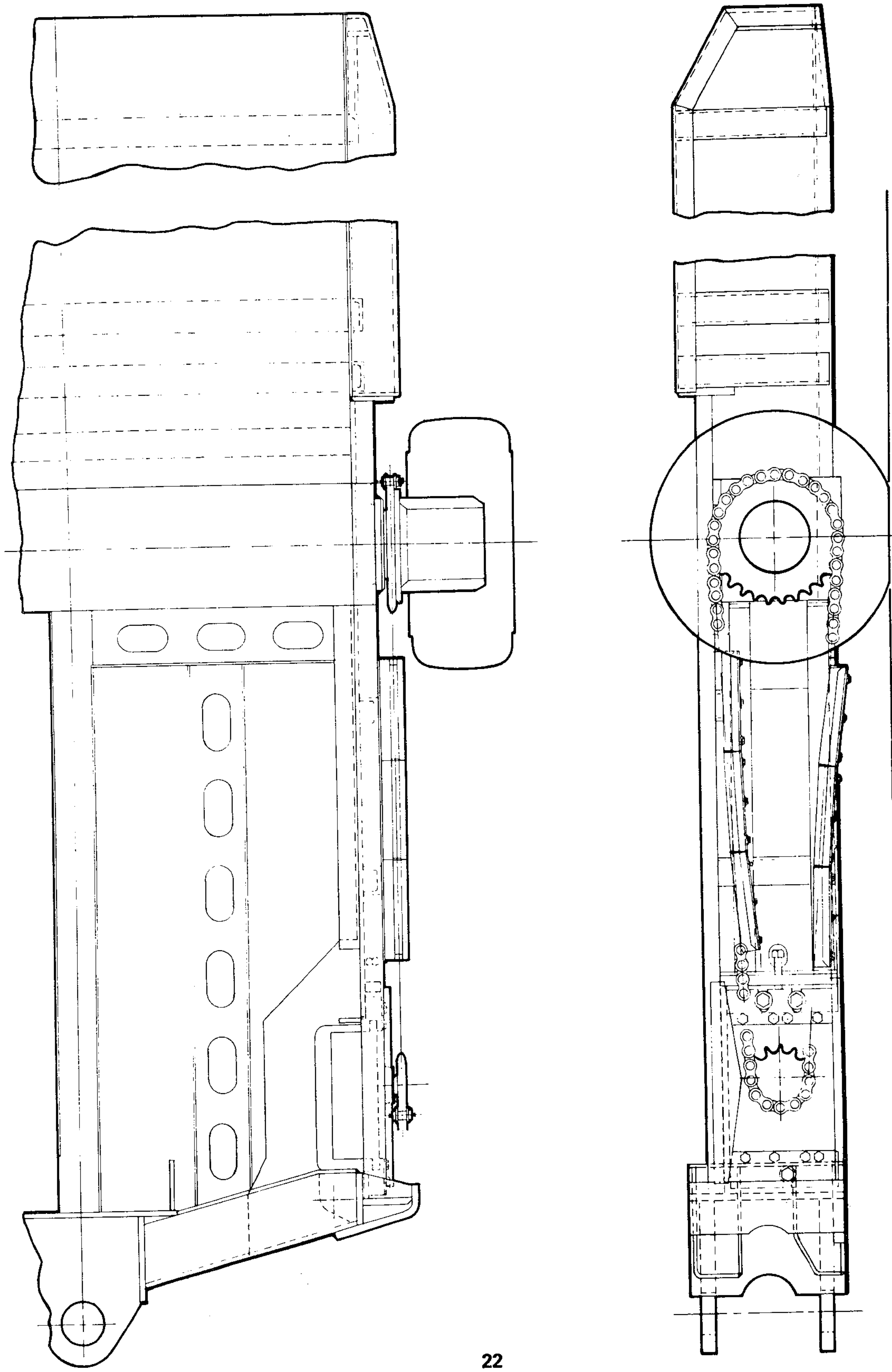

FIG. 2.10 TRAILER DRIVE TRAIN ASSEMBLY

The principle benefit of the steam power package is the high torque available. This (after an 80% efficient drive train) produces a calculated 36,500 ft. lb. total available torque at the wheels at stall and still allows a 6 mph top speed.

The available tractive effort was calculated as 27,000 lbs. which can spin all four tires with the vehicle empty at a 1.0 adhesion coefficient or with the car loaded to 14 tons at a 0.5 adhesion coefficient.

Gradability of the car was calculated as 30% @ 1 mph in 1st gear, 16% @ 2mph in 2nd gear and 6% @ 4 mph in 3rd gear. The car only requires a 0.35 adhesion coefficient to climb any of these grades with its four wheel drive (all gradability numbers based on 9 ton load and 75 lb/ton bottom resistance).

Acceleration was also expected to be quick with 6 mph reached in less than five seconds in average conditions.

2.8 HYDRAULIC

The hydraulic circuit was based on the current production 410HR Diesel RAMCAR hydraulics which have proved very effective and reliable.

The steering and brake circuits have priority over any other hydraulic valve to give a virtually constant flow to the steering circuit despite widely varied engine RPM. Lock to lock steering time will be approximately 10-12 seconds which conforms to the turning requirement for rounding corners. The steering is accomplished by means of a steering tiller which turns the tractor similar to the way a boat tiller turns the boat. In addition, an accumulator provides steering power for up to 10 seconds after engine shutdown (this is then bled off for safety reasons).

SECTION 3.0

VEHICLE ADAPTATION

Adaptation of the two face haulage vehicles to incorporate diesel engines and to satisfy the requirements for the conditions at the test mine required significant work. This section describes the mine haulage requirements, the engine selection, drive line modifications and the vehicle modifications.

3.1 HAULAGE VEHICLE REQUIREMENTS

Operation of diesel powered face haulage vehicles in underground coal mines is limited because of the unwillingness of some mining personnel, especially in the union mines, to accept diesel powered equipment. Published data on underground mine operations in the United Kingdom shows significant safety, as well as production, advantages with diesel power versus trailing cable electric powered haulage vehicles. Where diesel haulage has been tried in the United States reactions have been favorable.

The scarcity of opportunities was a factor in recommending the underground trials of this four-wheel drive vehicle with a diesel engine. There was a clear desire to both evaluate the capabilities of the newly designed vehicle and to gain operational experience with the diesel power in the underground coal mine. The conditions at the new Mettiki mine in western Maryland offered the opportunity under some of the most difficult mining conditions.

Initial underground operations at the mine were using conventional shuttle cars and some diesel powered scoops. The coal seam, although relatively high, pitches down as much as 30 degrees from the drift entries. Water seeps through the roof as well as coming in through the entries. The resulting wet clay floor makes traction very difficult.

Shuttle cars in this mine bogged down frequently and were unable to carry more than a few tons. The diesel powered scoops did much better on traction but were limited to a couple tons payload when used for face haulage. Consequently the need existed for a better haulage vehicle capable of carrying up to 14-tons of coal and/or rock at pitch angles up to 30 percent.

Additional requirements include higher tram speed and maneuverability. At the time of the underground trials, the loads were being carried to temporary belts or some times outside since the main haulage belt was not yet installed in one mine. Also, even with the belts in place the haulage distance could frequently approach 1000 feet from the continuous miner to the haulage belt.

3.2 ENGINE SELECTION

Design of the four-wheel drive RAMCAR was based upon the steam engine providing 75HP. It also included a pallet mounting concept for rapid engine changeout. The air cooled diesel engine, which provided 76HP at 2300 rpm, was readily adapted to the vehicle for test purposes and performed quite well. However, it was obvious that more horsepower would be required for the combined load and pitch conditions. Also, the engine must be permissible in underground coal mines.

At the time of the trials, Jeffrey had available a 145HP engine package using the Caterpillar model 3306 and which has been approved by MSHA for use in underground coal mines. Also available was a 90HP package using a British Ford engine and with appropriate flame arrestors and devices for safe operation in the coal mines. Approval for underground operation had not yet been obtained for the 90HP package.

The 145HP engine package was really the only choice because of the lengthy time to obtain MSHA approval. Also, 90HP would be marginal under the difficult mining conditions. The main concern in using the 145HP engine was the fact that the vehicle drive line requirements were for only half this power. Initial recalculations indicated significant margin in most of the drive line design without obvious need for drive line redesign. The universal joints appeared to be the weakest link.

Figure 3.1 shows the engine package and identifies major components. As shown in Figure 3.2, engine exhaust is passed through a water scrubber which purifies and cools the exhaust. The scrubber contains a water level sensor which will shut off the engine if the level drops too low.

3.3 DRIVELINE MODIFICATIONS

Mounting the engine was simplified by the fact that pallet mounting points already existed. A new frame to serve as

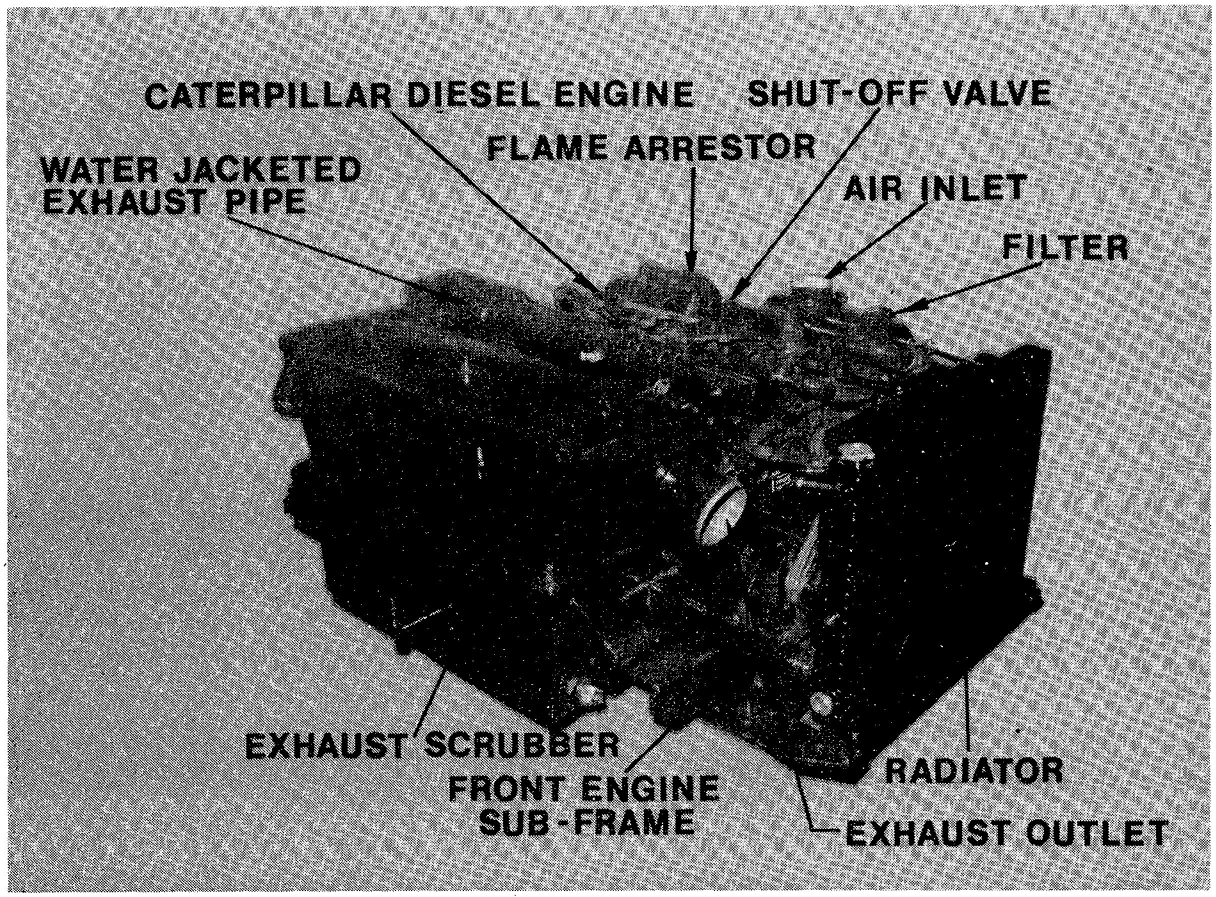

FIG. 3.1 145HP DIESEL ENGINE PACKAGE

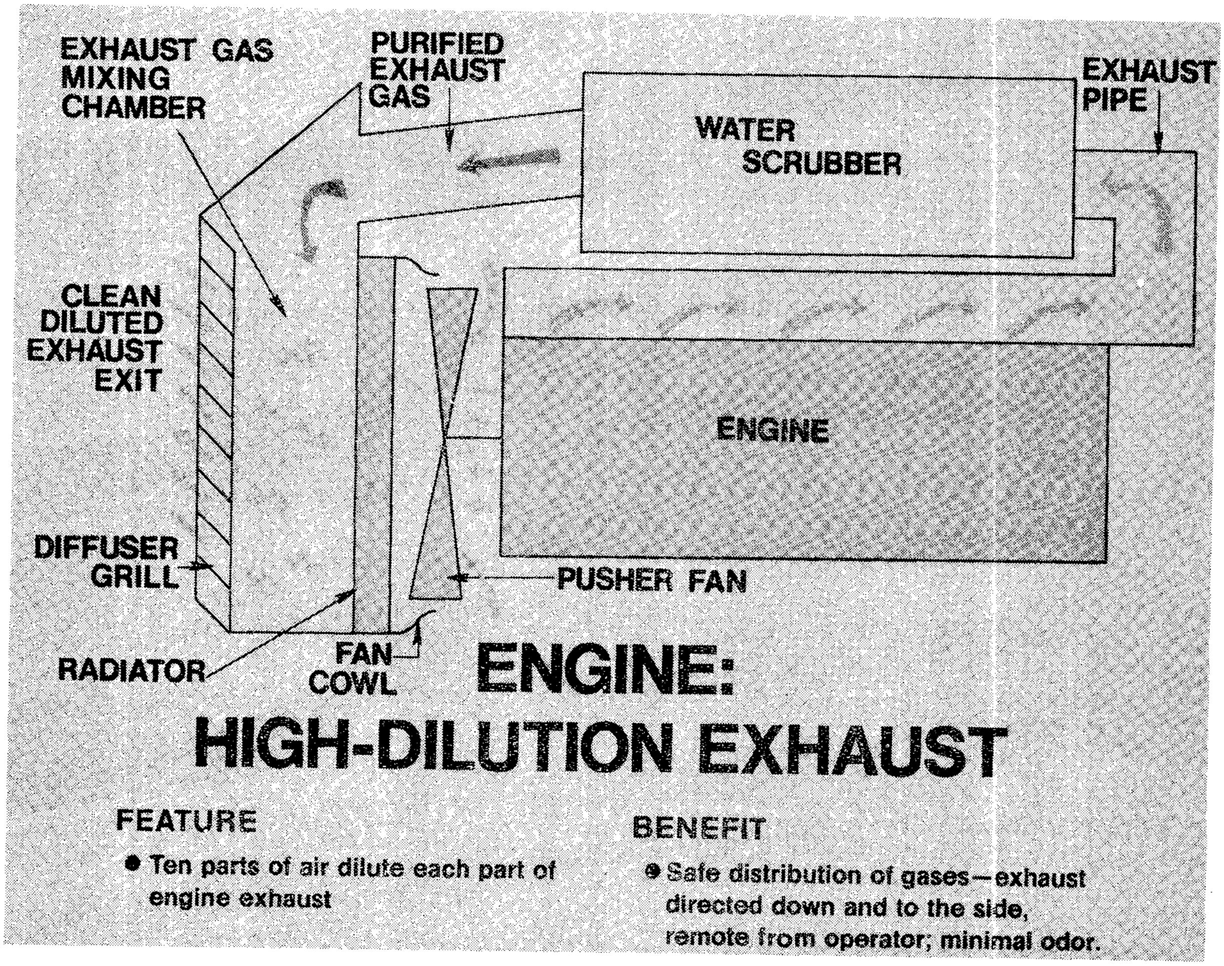

FIG. 3.2 DIAGRAM OF ENGINE EXHAUST DILUTION TECHNIQUE

the diesel engine pallet was designed, but, because of the package configuration, the engine itself had to be located on the vehicle centerline. The steam engine design placed the expander near the right side so the transmission input shaft is located on the right side. Therefore, a transfer gear case assembly (Funk Manufacturing model 56008 with model 4056556 flange) had to be selected in addition to a new torque converter (Funk model F20E13T). Also, a new drive shaft connecting the transfer gear case to the transmission input was provided.

The remainder of the driveline was originally unchanged, except for the tires. Size 14.00 - 20 tires (and wheels) were substituted for the 14.50 - 15. This increased the ground clearance from 6 to 12.3 inches as well as providing for the full 14-ton payload.

As noted later in Section 6.0, the universal joints and brakes were subsequently changed, as well as substitution of no-slip differentials.

As part of the engine installation a larger fuel tank was installed increasing the capacity from 26.5 gallons to 30 gallons. A makeup water tank for the scrubber was installed on the opposite side where space had been provided for the steam engine oil-water separator.

3.4 VEHICLE MODIFICATIONS

An extension section was installed between the tractor frame and the front bumper to accommodate the longer diesel engine package. This also included a larger grill to protect the radiator.

Tractor frame projections for holding the fuel tank and oil-water separator were modified to increase clearance from the larger tires (clearance was originally adequate for 18L - 20 tires but not 14.00 - 20 tires) by approximately 3 inches. Other changes in the tractor included a new seat bracket to raise the seat mounting height, extensions to raise the canopy, a control panel for the diesel engine functions and new closeout covers over the engine.

Significant changes to the trailer were installation of 18 inch sideboards in lieu of 6 inches and addition of protective side rub bars from the tail to the wheels.

The modified haulage vehicle is shown in Figures 3.3, 3.4 and 3.5 prior to shipment to the mine site. Some of the

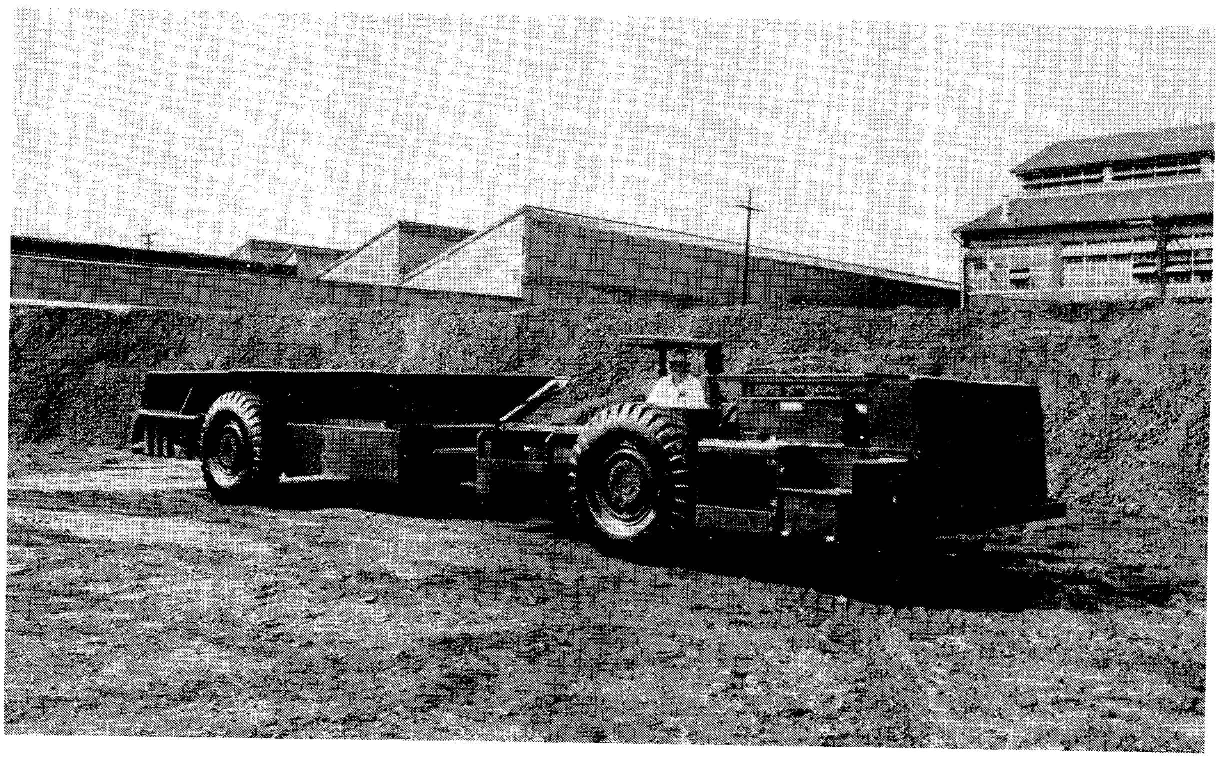

FIG 3.3 SIDE VIEW OF MODIFIED HAULAGE VEHICLE

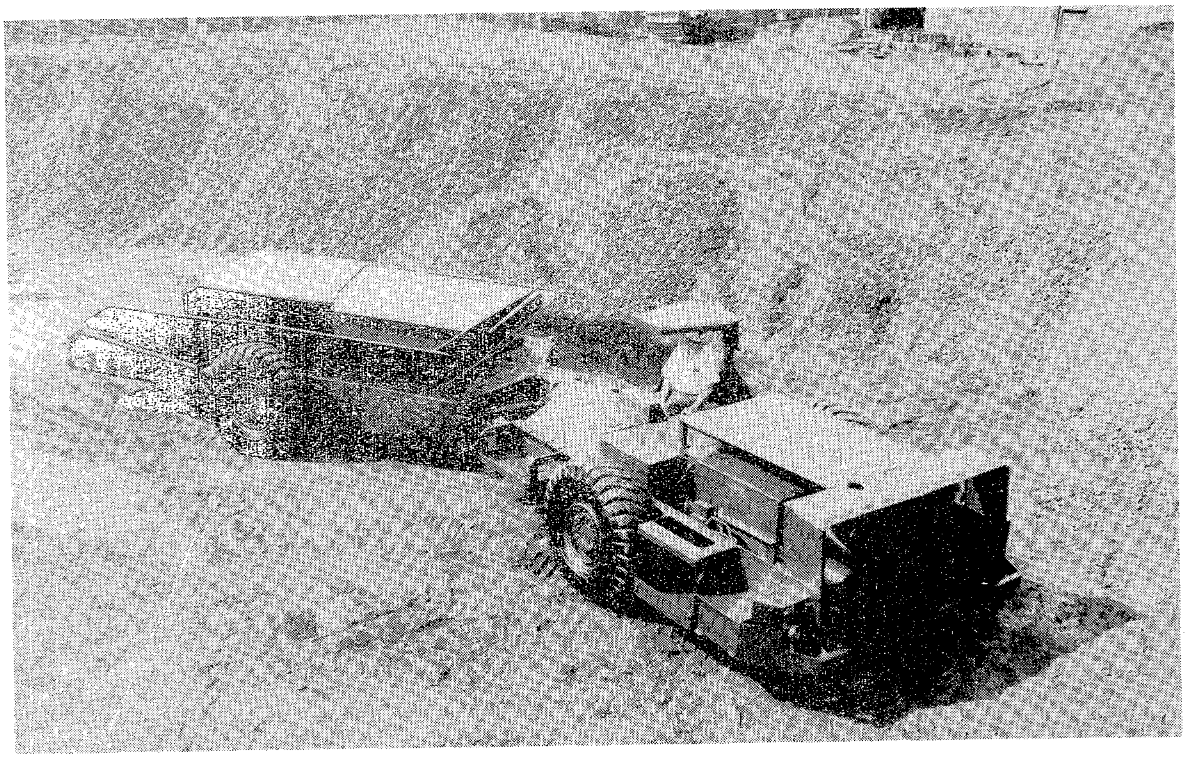

FIG. 3.4 TRACTOR END VIEW

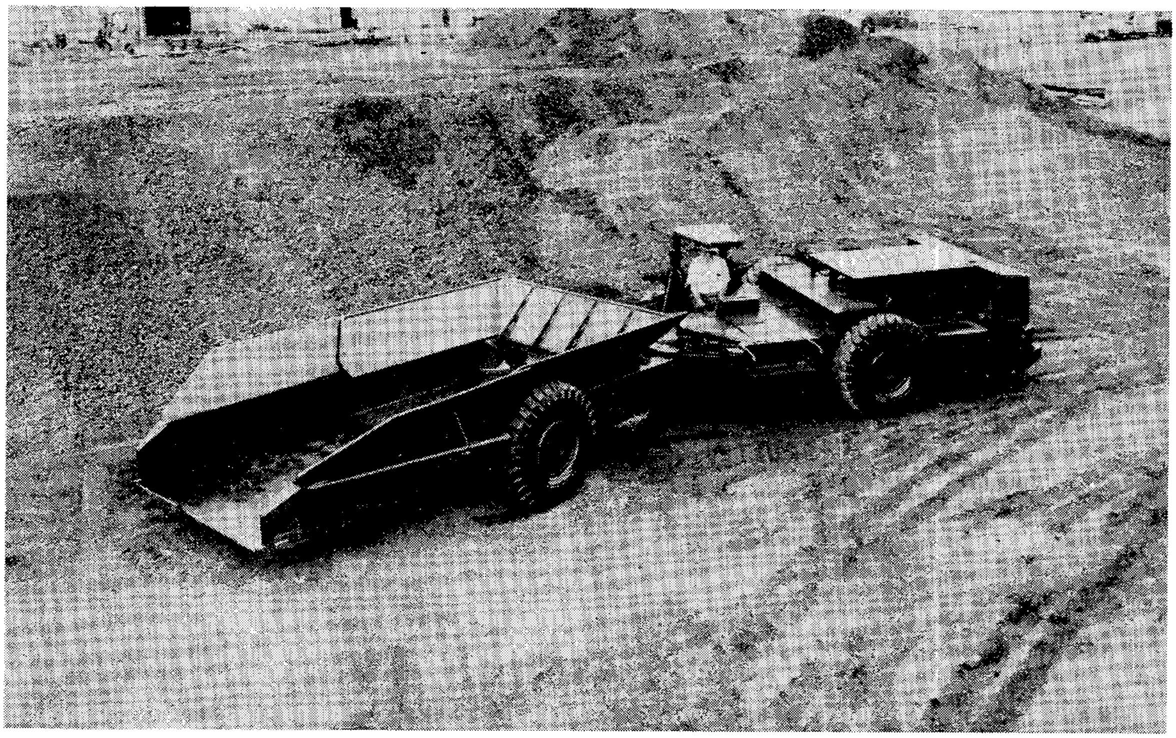

FIG. 3.5 TRAILER END VIEW

differences may be seen by comparing these pictures with Figure 2.3.

After introducing the modified vehicles to underground operation,additional side rub bars were installed on the trailer between the wheels and the pivot.

SECTION 4.0

ACTIVITIES AT THE MINE

The evaluation mine is located in Garrett County, Southeast of Oakland, Maryland. As described in recent trade journals, there are three mines in the Mettiki Coal Corporation complex with scheduled production of 200,000 tons in 1978 and 750,000 tons in 1979 as operations build toward full production.

This section briefly describes the mine conditions, the vehicle checkout and the introduction underground.

4.1 MINE DESCRIPTION

The three mines are drift entry in the Upper Freeport seam with an 8 foot height. The entries pitch down slope at 25% for the first 2500 feet and then gradually level as they approach the Potomic River. These diesel powered RAMCARs were first used at Gobbler's Knob Mine, the center mine, and then at the Big George Mine, which is southernmost. In both mines the steepest pitch was experienced because the entries had not penetrated very far at that time.

The mine plans call for developing 10 entries for two different units in each mine. Entries are 18 feet wide and on 90 foot centers. Crosscuts are on 90 to 100 foot centers.

Roof conditions are difficult and are reportedly compounded by vertical splits or cracks in the main sandstone roof. Vertical clay veins along with water seepage and steep pitch compound difficult conditions. Below the coal is fireclay, so some bottom coal is usually left. Unfortunately, in the areas where these vehicles were used the wet fireclay was frequently experienced. Uneven roof also presented some problems and the haulage vehicle canopies were deformed as a result of occasionally striking the roof.

Haulage paths varied as a function of floor conditions as well as face advance. The main belt haulage was installed in the Big George Mine only a few days before the vehicles were withdrawn from the mine.

4.2 VEHICLE CHECKOUT AT MINE SITE

The first vehicle was completed and sent to the mine in late September 1978 and the second in October 1978. During the above-ground checkout and operator familiarization, a few repairs and adjustments were required as might be expected for a new prototype machine. There was some delay before the vehicles could be taken underground while waiting for MSHA personnel to inspect the machines on site and issue approvals.

4.3 INTRODUCTION UNDERGROUND

When underground with loads during initial trials there were some occasions when opposite corner wheels would slip. With the steep grades and wet floor it appeared that slip would be a problem with the original design. Consequently, the decision was made to convert to no-spin differentials.

With the no-spin differentials the steering loads are greater under certain conditions. In order to assure adequate steering under the very severe conditions, a second set of steering cylinders was added (in parallel) on each vehicle. The extra cylinders were mounted to supports on top of the existing frame.

The first underground operation was started in the Gobblers Knob mine the end of November. Operation was interrupted occasionally because of various difficulties associated with starting a new mine and introducing new equipment. Difficulty with the disc brakes on the two RAMCARs was corrected by changing to a different supplier.

Another difficulty with the RAMCARs, originally suspected at the beginning of the program, was in the drive line. This drive line was designed for a 75HP engine whereas the diesel is rated at 145HP. The heavier loads caused loosening of bolts, universal joint and shaft failures, and failures of the input gear to the traction gear cases. Most of these problems occurred in the trailer portion of the drive line when loaded. Stronger universal joints, a redesigned input gear and other corrections were incorporated.

When operated for complete shifts at the Gobblers Knob mine the loads hauled were approximately 500 to 600 tons per shift. In mid-January, the mine operator moved the RAMCARs to the Big George mine where the floor conditions were worse. There were frequent stops in production at this mine to repair the roadways. The two RAMCARs were then used in production at the Big George mine and after familiarization was sufficient, data collection started.

SECTION 5.0

PERFORMANCE RESULTS

The two four-wheel drive haulage vehicles were underground from mid-December 1978 through early April 1979. For the first month they were in Gobblers Knob Mine and were then moved to the Big George Mine. The new mining operations had progressed to the point where a main haulage belt had already been installed at the Gobblers Knob Mine, but the permanent belt was not installed in the Big George Mine until the end of March.

Mine development work had been previously started using conventional shuttle cars and diesel powered scoops. When the two diesel powered RAMCARs were brought into the mine, the section crews had only a limited time in working together since being new formed, and the mining procedures at these locations were embryonic. With the holidays, mine downtime due to floor or roof problems, familiarization with different equipment, downtime due to equipment malfunction, options on which haulage equipment to use and downtime while the haulage belt was being installed there was little time to collect statistical data on production with the RAMCARs.

In early April 1979 the Jeffrey Mining Machinery Division started delivery of the new production version four-wheel drive RAMCAR, referred to as the model 411H. These production models were patterned after the vehicle design for the steam engine, but specifically designed from the beginning for diesel power and extremely harsh conditions such as experienced at the Mettiki mines. After the mine operator started using two model 411H vehicles in the Gobblers Knob Mine, he decided to withdraw the two Government-owned vehicles from the Big George Mine and replace them with two model 411H vehicles. Consequently, this terminated collection of further data on the Government-owned vehicles. However, the basic features had been accepted and are, in fact, in continuing use now in the model 411H vehicles.

This section contains the performance data that was obtained. Following, in Section 6.0, is information on vehicle durability.

5.1 DATA COLLECTION PLAN

The data collection objective, as stated in the Jeffrey letter proposal, was to collect data for at least six complete shifts over a period of two months. Some preliminary data was to be collected during an indoctrinary period with the haulage vehicles underground, and then the detailed data collection would take place when it appeared that operating techniques had stabilized.

Data to be collected was identified as follows:

Start of Shift

- Note fuel levels; both vehicles
- Measure entry airflow
- Note mining conditions
- Note face locations as reference for determining advance
- Note maintenance performed

Record For Both Vehicles Through Entire Shift

- Payload
  - Maximum
  - Typical
  - Maximum on steep grade without tailgate

- Cycle time, by elements
  - Speed empty
  - Speed loaded
  - Discharge time
  - Load time
  - Turn around time
  - Changeout time
  - Waits/interruptions/downtime
  - Number of trips
  - Drive gears employed (typical)

Periodically During Shift

- Measure temperatures in exhaust region
- Note any fuel additions
- Note any maintenance
- Measure airflow in entry
- Note any changes in operating conditions
- Obtain comments from operators re:
  - Performance and handling
  - Visibility
  - Comfort
  - Suggestions

At End of Shift

- Measure and note face advance
- Record fuel consumption for each vehicle
- Note maintenance performed or required
- Obtain mine operator values for the section/ shift production

In addition to collecting data on the two RAMCARs, it was planned to also collect data on a similar section using shuttle cars and/or diesel powered scoops. This would be used for comparative evaluation and the economic analysis.

At least three, and preferably four persons were required for taking data. These persons were located at the continuous miner, the change points and at the discharge point. Synchronized timepieces were used for data entry. Visual estimates of payload were made as follows:

Poor	= Load slope to trailer floor = 156 cu.ft. = 4.68 tons
Fair	= 75% of struck load = 238 cu.ft. = 7.14 ton
Good	= Struck load = 317 cu.ft. = 9.51 ton
Heaped	= 407 cu.ft. = 12.21 ton

Forms were developed for data notation. These are shown in the tables in Section 5.2 which follows.

5.2 HAULAGE DATA

Actual data collection was less than planned as a result of numerous delays in the new mine operation and the availability of newly designed production model 411H four-wheel drive diesel powered RAMCARs.

Preliminary data (collected by one Jeffrey person) was taken in December and again on January 26.

In December, at the Gobblers Knob Mine, times were noted for one of the two vehicles. This is shown in Tables V.1 and V.2. Haulage distance was in excess of 550 feet, and assuming an unload time of 45 seconds each, the average haulage vehicle speed was:

$$\frac{53.19-14.96-(7 \times 0.75)}{7} = 4.71 \text{ min./trip}$$

$$\frac{2 \times 550}{4.71 \times 88} = 2.65 \text{ mph}$$

TABLE V.1 - PRELIMINARY HAULAGE DATA
GOBBLERS KNOB MINE, DECEMBER 1978

VEHICLE	LOAD TIME	TRAVEL AND UNLOAD TIME	TOTAL CYCLE TIME
#1 #2	2.22 Min.	4.03 Min.	6.25 Min.
#1 #2	1.23	5.09	6.32
#1 #2	1.39	4.8	6.19
#1 #2	2.35	5.23	7.58
#1 #2	1.62	5.3	6.92
#1 #2	1.54	5.24	6.78
#1 #2	3.03	8.54	11.57 (4 min.wait)
#1	1.58	____	1.58 (Load time only)
	14.96 Minutes		53.19 Minutes

Face advance = 7.75 X 18 X 19 = 2651 cu.ft. = 116 tons

Average vehicle load = $\frac{2651}{15}$ = 177 cu.ft.; i.e. poor load

Haulage distance: approximately 540 feet.

Note: Two vehicles running, but times recorded for only #1

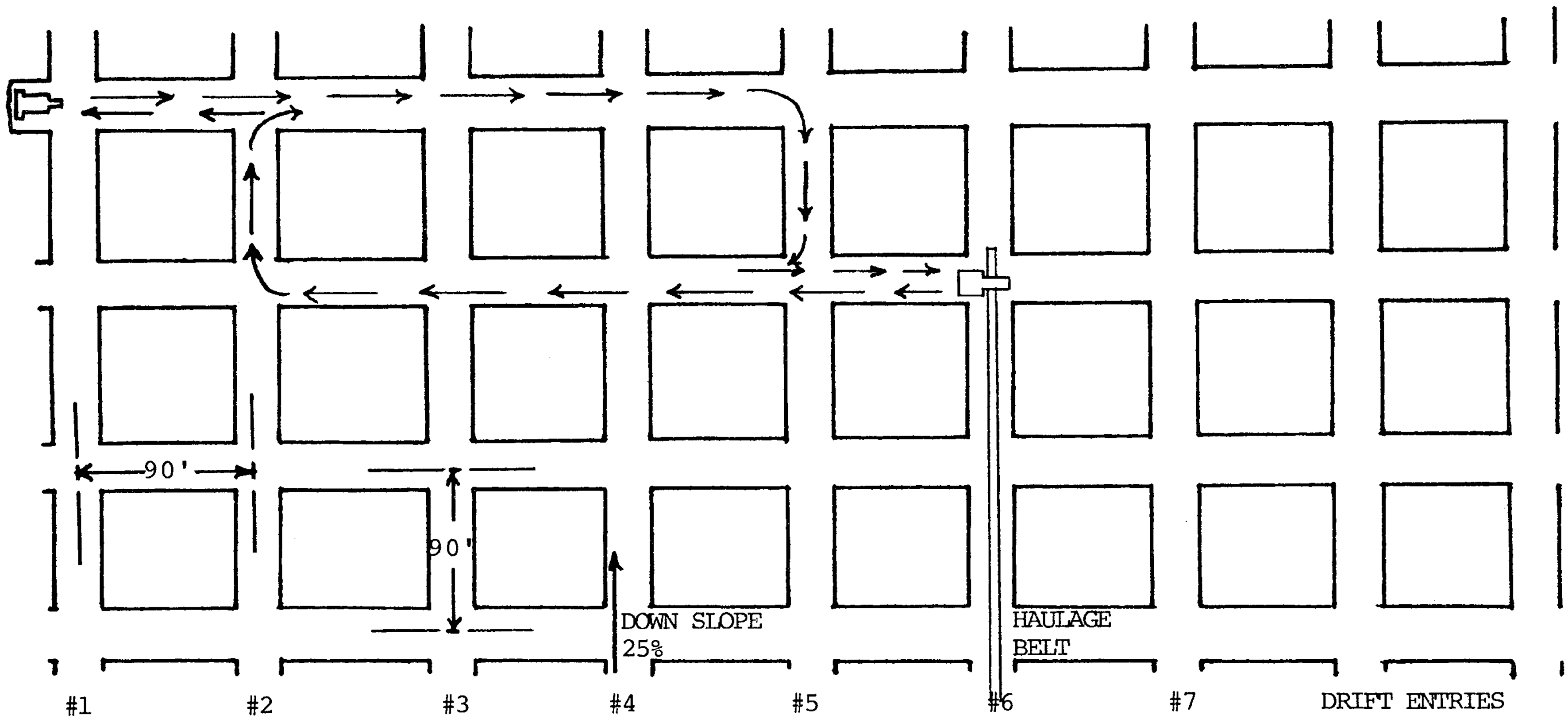

TABLE V.2 HAULAGE ROUTE FOR DATA IN TABLE V.1

On January 26, 1979, during one shift at Big George Mine, the face was advanced 70 feet. The two four-wheel drive haulage vehicles transported approximately 469 tons in that shift.

In late February 1979, three Jeffrey personnel were at the mine site for two weeks in order to collect data. Of these days, coal was being hauled by these vehicles on February 27, 28, March 2 and March 8. Only one vehicle was run the first three days due to lack of an operator (due to illness). On March 8 the number 2 vehicle went down due to a broken drive chain.

Jeffrey personnel returned again to the mine for the week of April 9th after this mine was down for installation of the permanent haulage belt. Operations did not resume until the afternoon of April 11th so data was only collected again on April 11th and April 12th.

Even though the data collection procedures were extensively planned, there were some inconsistencies and lack of notation. This is due mostly to the dynamic conditions during the mining operations. The data collected during February, March and April is all recorded on Tables V.3 through V.28.

It is difficult to draw quantitative conclusions because of the limited amount of data available. Work was frequently interrupted due to mining conditions or problems with the machines. Therefore, values such as tons mined per shift, average travel time, average loads hauled, etc. should not be quoted quantitatively from this data. However, conclusions on vehicle performance can be drawn from examination of discrete elements of data.

Table V.3 lists the recorded payload trips. As noted in Section V.1, visual estimates identified the payload size within one of four categories. At a density of 60 pounds per cubic foot the loads are then 4.68, 7.14, 9.51 or 12.21 tons. The table then shows the approximate total tons hauled and, on an average, this is 8.94 tons per trip.

The greater percentage of loads were in the good category, with a large percentage in the fair category. Lack of a tailgate on the trailer combined with wet, slippery loads and the trailer being pitched down 25% to preclude more heaped loads. In many instances the load literally slid off the trailer until it was a gently sloped load. This

TABLE V.3 - ESTIMATED PAYLOADS						
DATE	HEAPED	GOOD	FAIR	POOR	NOT RECORDED	TOTAL LOADS
2-27	-	11	1	3	-	15
2-28	-	20	1	-	-	21
3-2	-	10	24	2	-	36
3-8	1	5	5	-	2	13
4-11	4	6	-	-	-	10
4-12	10	3	1	-	-	14
	15	55	32	5	2	109
$\frac{\text{TONS}}{\text{TRIP}}$	12.21	9.51	7.14	4.68		
TOTAL TONS	183	523	228	23		957

AVG. TONS PER TRIP $\frac{957}{107}$ = 8.94 TONS

TABLE V.4 - DATA COLLECTED RANDOMLY

DATE	START STOP	FUEL CONSUMP. (GAL.)	OPR. TIME (HRS.)	AIR FLOW (CFM) (TIME)	AMBIENT TEMP. (°F)	TEMP. NEAR EXHAUST (°F)	DRIVE GEAR	EST. LOADS HAULED (TONS)
2-27	8:15a 2:22p		6.12	19700-2:25p				126
2-28	8:20a 1:49p	15	5.15	28705-8:30a 28350-1:15p			#1 on hill #2 on level #3 empty	197
3-2	8:20a 1:33p	21.25	7	16739-8:00a 17550-11:00a 19575-1:30p			#1 on hill #2 on hill #3 empty	276
3-8	8:20a 1:33p	12.5	5.22	30950-8:30a	36.4°	90.6° at 4" 80.3° at 10" 80.64° at 12"	#2 loaded #2 empty	241
4-11	5:30p 8:13p		2.72	30665-6:26p 42900-7:39p				96
4-12	11:15a 1:54p		2.65		47-51°	197° at 2" inside exhaust 56° at 10' downwind		158

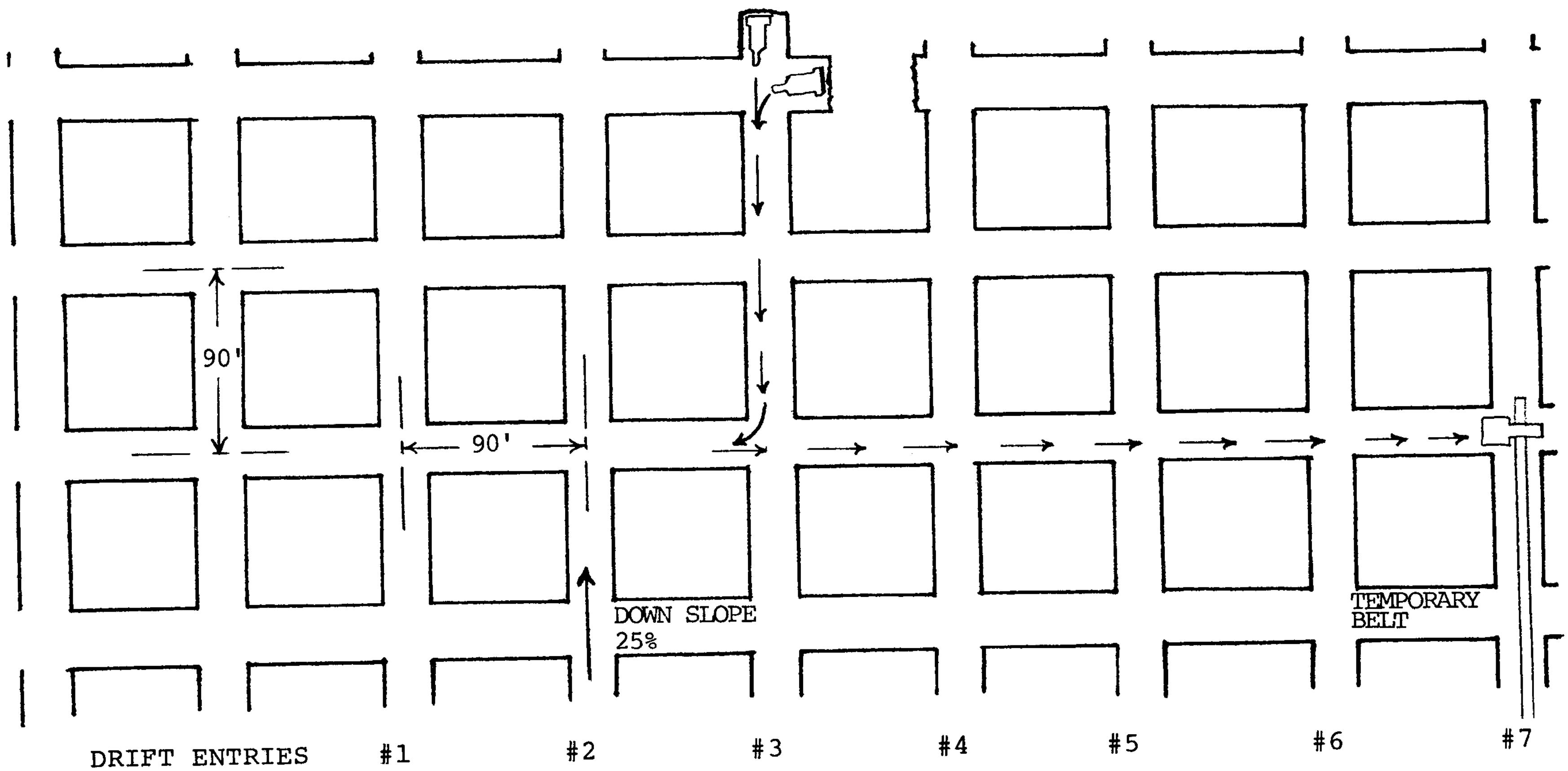

TABLE V.5 - HAULAGE ROUTE ON FEBRUARY 27

TABLE V.6 - DATA COLLECTED AT MINER ON FEBRUARY 27

CAR NO.	ARRIVE EMPTY	START LOAD	STOP LOAD	LEAVE LOADED	PAYLOAD (EST. TONS)	TRAVEL TIME LOADED (MIN.)	TRAVEL SPEED LOADED	DIST. TO DUMP (FEET)	LOAD TIME (MIN.)	START: 8:15a DATE: 2-27-79 STOP: 2:22p OBS: REMARKS
2	3.12	5.58	7.79	7.85	Good	3.13		594'	2.24	Crosscut from 3 to 4
2	17.44	17.50	18.48	19.01	Fair	4.89			.98	Fall on Miner and crosscut
2	35.53	37.77	39.82	42.01	Good			600'	2.05	Clean up Fall. Ft. of advance:6'Dx18'Wx8'H
1	214.49	214.77	215.32	215.55	Poor	3.33		574'	.55	Clean up Fall, Repair roads change place:#3 Entry st.
1	239.90	240.19	241.88	241.90	Good	3.08			1.69	Clean Entry #3
1	248.83	248.92	250.62	250.70	Good	4.00			1.70	Clean Entry #3
1	259.70	260.75	262.76	262.82	Good	3.28			2.01	Clean Entry #3
1	269.33	307.49	309.42	309.47	Good	2.73			1.93	Move Bolter, Hang curtain
1	316.62	316.65	316.82	316.90	Poor	2.50			.17	Clean Entry #3,mostly gob
1	322.24	322.23	323.18	323.24	Poor	2.47			.95	Clean Entry #3, Gob
1	328.66	328.91	330.43	330.46	Good	2.39		574'	1.52	Clean Entry #3, Gob Box cut, right side
1	365.54	365.82	368.11	368.15	Good	5.77			2.29	
1	377.42	377.57	378.65	378.82	Good	2.30			1.08	
1	384.14	384.32	385.78	385.83	Good	2.65			1.46	
1	391.70	391.82	393.73	393.82	Good	32.58		578'	1.91	#3 Engry box cut. Ft. of adv.9'Wx8'Hx3.92'D

TABLE V.7 - DATA COLLECTED AT CHANGE POINT ON FEBRUARY 27

CAR NO.	ARRIVE EMPTY	LEAVE EMPTY	ARRIVE LOADED	LEAVE LOADED	WAIT TIME EMPTY (MIN.)	WAIT TIME LOADED (MIN.)	DIST. TO LOAD PT. (FEET)	DIST. TO DUMP (FEET)	START: 8:15aDATE:2-27-79 STOP : 2:22p OBS: REMARKS
2			9.70	10.22		.52	220	374	
2	16.65	17.25	20.42	20.92	.60	.50			
2	35.81		96.62						RAMCAR stuck coming up hill, build bridge
1	212.31	219.08	219.91	220.34	6.77	.43	200	374	Place change
1	239.05	239.71	242.21	242.56	.66	.35			#1 RAMCAR pulls better than #2
1	248.01	248.65	252.70	253.25	.64	.55			
1	259.06	259.61	264.32	264.98	.55	.66			
1	268.72	269.25	310.42	311.13	.53	.71			Bolter stuck
1	315.52	316.00	317.68	218.38	.48	.60			
1	321.45	321.58	324.22	324.63	.13	.41			Coal very wet, lost approx. 3 tons pulling incline
1	327.82	328.26	331.32	331.76	.44	.44			Belts down
1	364.12	364.27	369.02	369.58	.15	.56			
1	376.82	377.07	379.51	280.09	.25	.58			
1	383.51	383.90	386.75	387.20	.39	.45			
1	391.03		394.83	395.35		.52			

TABLE V.8 DATA COLLECTED AT DISCHARGE POINT ON FEBRUARY 27

CAR NO.	ARRIVE DISCHARGE CHG.PT.	LEAVE DISCHARGE CHG.PT.	ARRIVE DUMP	START DUMP	STOP DUMP	LEAVE DUMP	TRAVEL TIME EMPTY (MIN.)	TRAVEL SPEED EMPTY	DUMP TIME (MIN.)	START: 8:15a DATE: STOP: 2:22p 2-27-79 REMARKS OBS: F.P.
2	10.00	10.52	10.98	12.40	13.26	13.32		4.12	.46	Examine feeder position
2	22.70	23.20	23.90	24.05	32.35	32.49		3.04	8.30	
2	(#2 Vehicle was left in entry and did not come to dump)									Remove rock from feeder
1	218.02	218.45	218.88	219.10	220.61	220.70		19.20	1.51	
1	244.20	244.55	244.98	245.20	246.01	246.12		2.82	.81	
1	253.65	254.20	254.70	255.74	255.82	255.85		3.85	.08	
1	265.12	265.78	266.10	266.25	266.95	267.05		2.08	.70	
1	311.10	311.81	312.20	312.35	312.98	313.10		3.52	.63	
1	318.29	318.89	319.25	319.40	319.98	320.05		2.19	.58	
1	325.01	325.42	325.71	325.80	326.30	326.65		2.01	.50	
1	332.04	332.48	332.85	362.20	362.65	362.85		2.14	.45	Belt down
1	372.95	373.51	373.92	374.06	374.75	374.80		2.62	.69	
1	380.12	380.70	381.12	381.25	381.90	382.05		2.09	.65	
1	387.51	387.96	388.48	388.53	389.09	389.30		2.40	.56	
1	425.46	425.98	426.40	426.61	427.10				.49	

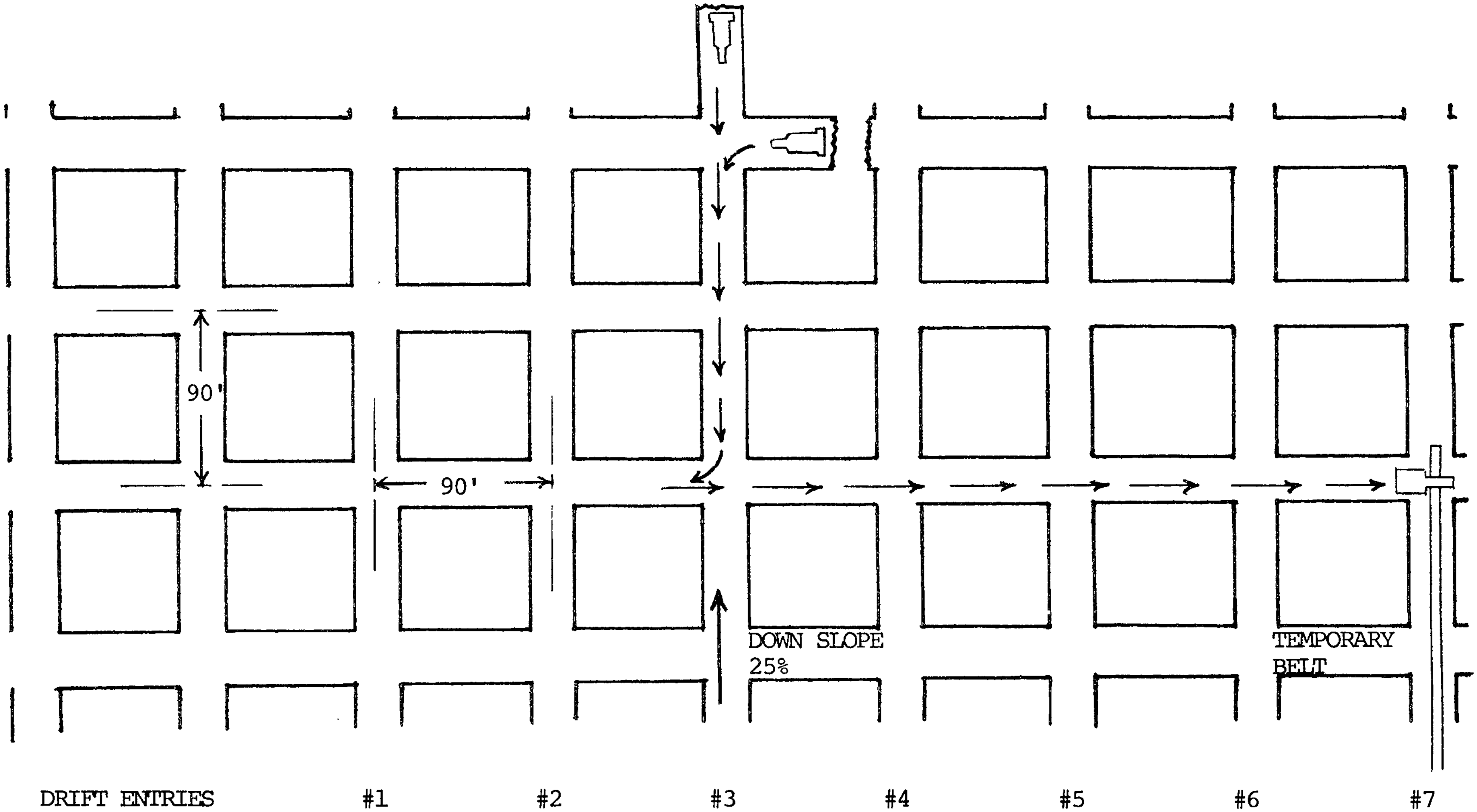

TABLE V.9 - HAULAGE ROUTE ON FEBRUARY 28

TABLE V.10 - DATA COLLECTED AT MINER ON FEBRUARY 28

Sheet #1 of 2

CAR NO.	ARRIVE EMPTY	START LOAD	STOP LOAD	LEAVE LOADED	PAYLOAD (EST. TONS)	TRAVEL TIME LOADED (MIN.)	TRAVEL SPEED LOADED	DIST. TO DUMP (FEET)	LOAD TIME (MIN.)	START: 8:20a DATE: 2-28-79 STOP: 1:49p OBS: REMARKS
1	63.69	63.75	66.46	66.52	Good	15.99		590'	2.71	Miner and belt down. #1 car running: #3 entry st.
1	89.79	89.88	90.89	90.92	Good	2.98			1.01	
1	97.82	98.12	100.82	100.33	Good	3.02			2.10	
1	107.03	107.09	112.05	112.27	Good	2.75			4.96	
1	118.44	118.50	120.12	120.23	Good	3.30			1.62	Reposition miner clean up.
1	126.45	126.60	128.88	128.91	Good	9.24			2.28	Clean
1	141.34	141.42	144.94	145.42	Good	3.09			3.52	Clean
1	133.11	153.15	155.00	158.56	Good	29.76			1.85	Repo.miner #1 cut in #3 entry. clean up.Ft.adv7'2"Dx 9'Wx8'H.
1	189.51	191.83	191.63	192.69	Fair	12.47			.80	Place change #3-#4 Crosscut
1	209.34	209.54	211.17	211.30	Good	3.24			1.63	
1	218.42	218.69	220.09	221.88	Good	1.65			1.40	RAMCAR couldn't get around turn bottom slick
1	227.41	227.52	228.82	229.54	Good	3.00			1.30	Ft.adv. in #3-#4 crosscut: 11.5'Dx9'Wx8'H,box cut,rght.
1	236.59	236.62	244.24	244.83	Good	2.58			7.67	
1	251.53	251.95	253.32	253.51	Good	4.47			1.37	
1	265.62	265.71	267.03	267.10	Good	3.58			1.32	
1	274.07	274.10	276.08	276.13	Good	2.83			1.92	
1	282.68	282.73	284.19	284.38	Good	4.03			1.46	

TABLE V.10- DATA COLLECTED AT MINER (Cont'd)

Sheet #2 of 2

CAR NO.	ARRIVE EMPTY	START LOAD	STOP LOAD	LEAVE LOADED	PAYLOAD (EST. TONS)	TRAVEL TIME LOADED	TRAVEL SPEED LOADED	DIST. TO DUMP (FEET)	LOAD TIME (MIN.)	START: 8:20a DATE:2-28-79 STOP: 1:49p OBS: REMARKS
1	292.00	292.73	293.19	293.38	Good	3.23			1.46	
1	300.48	300.53	301.73	302.00	Good	2.86			1.20	
1	309.11	309.20	310.51	210.59	Good	5.24			1.31	Ft.adv.3-4 crosscut left side 15.25'Dx9'Wx8'H,lift cut
1	219.54	319.76	324.09	324.46	Good	2.86			4.33	

TABLE V.11- DATA COLLECTED AT CHANGE POINT ON FEBRUARY 28

Sheet #1 of 2

CAR NO.	ARRIVE EMPTY	LEAVE EMPTY	ARRIVE LOADED	LEAVE LOADED	WAIT TIME EMPTY (MIN.)	WAIT TIME LOADED (MIN.)	DIST. TO LOAD PT. (FEET)	DIST. TO DUMP (FEET)	START: 8:20a DATE: 2-28-79 STOP: 1:49p OBS: REMARKS
1		62.62	69.42				220'	370'	Belts & miner down at start, Tightened trailer drive chains both cars.
1	89.22	89.71	92.18	92.78	.49	.60			Only running #1 car
1	96.80	97.20	101.87	102.21	.40	.34			Good load :mud 12"-16"deep
1	105.60	105.98	113.42	113.90	.38	.48			
1	117.02	117.60	121.82	122.52	.58	.70			
1	125.24	125.74	129.26	129.87	.50	.61			Surveyor's setting sights
1	140.12	140.57	146.29	146.80	.45	.51			Surveyor's setting sights
1	159.42	159.90	184.74	185.25	.48	.51			Chg.places: 3-4 crosscut
1	188.24	188.75	203.63	204.21	.51	.58			Miner down
1	207.31	207.81	212.97	213.60	.50	.63			
1	217.23	217.83	221.69	222.43	.60	.74			
1	225.53	226.01	230.53	231.35	.08	.82			
1	234.60	235.05	245.67	246.20	.45	.53			
1	249.36	250.25	256.10	256.80	.89	.70			Dumping coal in ruts
1	264.04	264.58	268.30	269.50	.54	1.20			Turn around corner getting very bad:16"-18"mud
1	272.59	273.02	277.33	277.94	.43	.61			RAMCAR sliding into corner
1	280.77	281.35	287.21	287.92	.58	.71			
1	290.41	290.80	294.75	295.40	.39	.65			

TABLE V.11- DATA COLLECTED AT CHANGE POINT (Cont'd)

Sheet # 2 of 2

CAR NO.	ARRIVE EMPTY	LEAVE EMPTY	ARRIVE LOADED	LEAVE LOADED	WAIT TIME EMPTY (MIN.)	WAIT TIME LOADED (MIN.)	DIST. TO LOAD PT. (FEET)	DIST. TO DUMP (FEET)	START: 8:20a DATE: 2-28-79 STOP: 1:49p OBS: REMARKS
1	298.68	299.09	302.10	303.81	.40	.71			
1	307.40	307.88	311.90	312.75	.48	.76			
1	317.90	318.20	325.62	326.20	.40	.58			

TABLE V.12- DATA COLLECTED AT DISCHARGE POINT ON FEBRUARY 28

Sheet #1 of 2

CAR NO.	ARRIVE DISCHARGE CHG.PT.	LEAVE DISCHARGE CHG.PT.	ARRIVE DUMP	START DUMP	STOP DUMP	LEAVE DUMP	TRAVEL TIME EMPTY (MIN.)	TRAVEL SPEED EMPTY	DUMP TIME (MIN.)	START: 8:20a DATE:2-28-79 STOP: 1:49p OBS: REMARKS
1	80.81	86.90	82.51	82.58	83.30	83.55	4.24		.32	Pump cable caught in trailer
1			93.90	95.10	96.00	96.04	1.78		.90	Move #2 car
1			103.35	103.45	104.60	104.65	2.38		1.15	
1			115.02	115.15	116.05	116.14	2.30		.50	
1			123.53	123.64	124.30	124.40	2.05		.66	
1			138.15	138.32	139.06	139.15	2.19		.74	
1			148.51	148.82	149.42	149.55	3.56		.60	Engineers setting spads
1			186.32	186.40	187.20	187.35	2.16		.80	Engineers setting spads
1			205.16	205.34	206.16	206.38	3.01		.82	
1			214.54	214.68	215.31	215.38	3.04		.63	
1			223.53	223.74	224.51	224.73	2.68		.77	
1			232.54	232.72	233.76	233.82	2.77		1.04	
1			247.41	247.47	248.37	248.56	2.97		.90	
1			257.98	258.08	258.81	263.12	2.50		.73	
1			270.68	270.89	271.70	271.76	2.31		.81	Cleaned gob from around ram cylinder
1			270.96	279.04	279.89	279.96	2.72		.85	
1			288.41	288.51	289.46	289.53	2.47		.95	

TABLE V.12 - DATA COLLECTED AT DISCHARGE POINT (Cont'd)

Sheet #2 of 2

CAR NO.	ARRIVE DISCHARGE CHG.PT.	LEAVE DISCHARGE CHG.PT.	ARRIVE DUMP	START DUMP	STOP DUMP	LEAVE DUMP	TRAVEL TIME EMPTY (MIN.)	TRAVEL SPEED EMPTY	DUMP TIME (MIN.)	START: 8:20a DATE: STOP: 1:49p 2-28-79 REMARKS OBS:
1			296.61	296.82	297.73	297.83	2.65		.91	
1			204.86	305.02	306.83	307.02	2.09		1.81	
1			315.83	316.89	3.6.89	317.01	2.53		.91	
1			327.32	327.47	328.91	329.08			1.44	

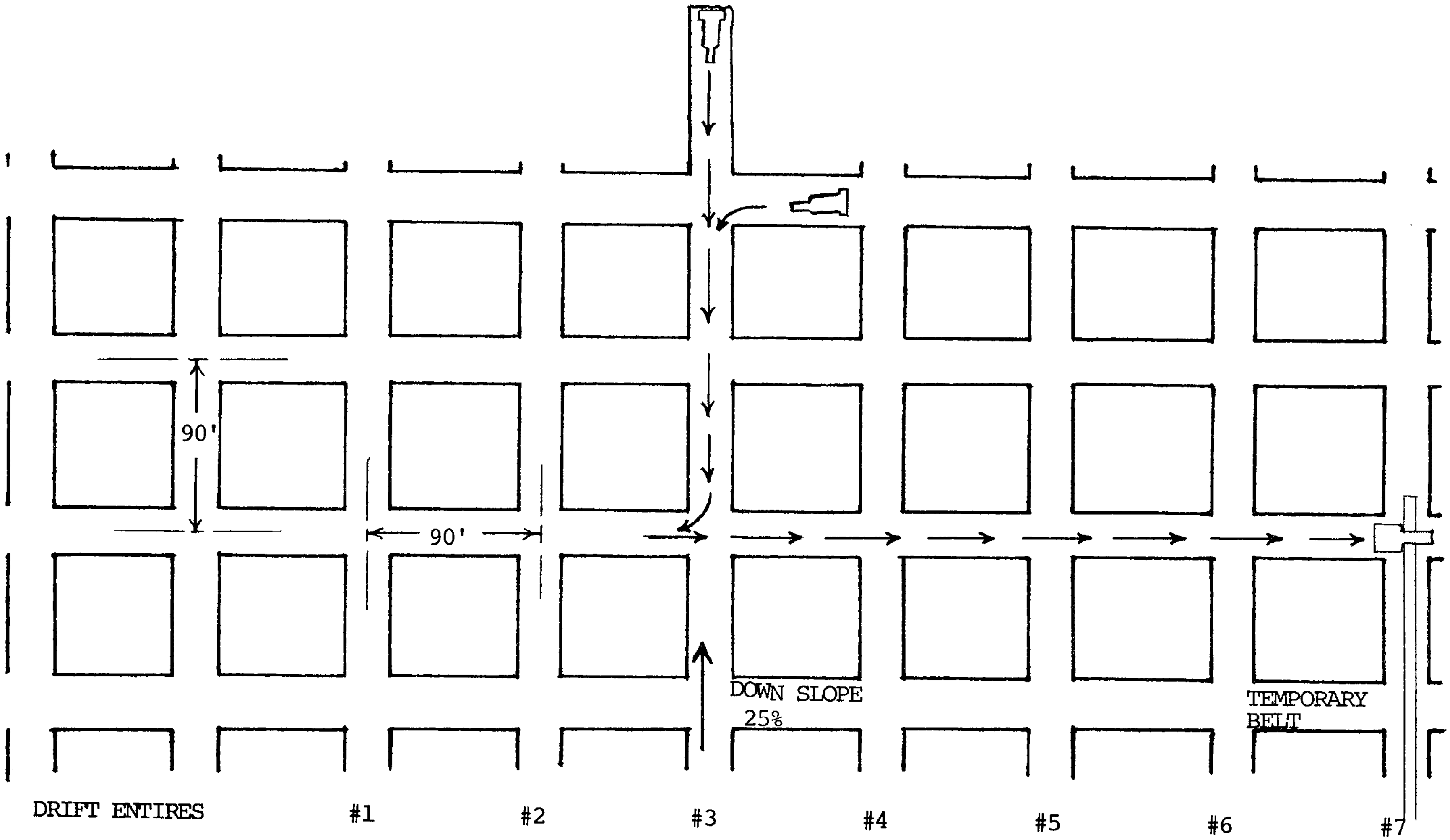

TABLE V.13 - HAULAGE ROUTE ON MARCH 2

TABLE V.14- DATA COLLECTED AT MINER ON MARCH 2

Sheet #1 of 3

CAR NO.	ARRIVE EMPTY	START LOAD	STOP LOAD	LEAVE LOADED	PAYLOAD (EST. TONS)	TRAVEL TIME LOADED	TRAVEL SPEED LOADED	DIST. TO DUMP (FEET)	LOAD TIME (MIN.)	START: 7:45a DATE: 3-2-79 STOP: 2:45p OBS: D.L. REMARKS
1	19.61	19.63	20.98	21.05	Fair	8.05		490	1.35	Build bridge. #3 entry st. clean gob
1	34.54	34.66	35.30	35.46	Fair	6.94			.64	Clean gob
1	47.06	47.12	47.89	47.92	Fair	5.04			.77	Clean gob
1	59.93	59.96	60.63	60.81	Fair	3.61			.67	Clean gob
1	67.88	68.08	69.07	69.11	Fair	2.88			.99	Clean gob
1	76.37	76.39	77.47	77.67	Fair	3.96			1.08	Clean gob. Ram working slow.
1	85.86	85.94	86.96	87.33	Fair	3.71			1.02	Clean gob
1	102.65	102.80	104.17	104.21	Fair	1.97			1.37	Clean gob
1	111.76	111.82	112.92	112.96	Fair	3.16			1.10	Clean gob
1	119.78	119.80	120.66	120.75	Fair	2.93			.86	Clean gob
1	127.12	127.28	128.57	128.80	Fair	7.09			1.29	Clean gob
1	141.08	141.30	142.27	142.37	Fair	2.71			.93	Clean gob, very wet
1	148.40	148.58	149.23	149.28	Fair	5.71			.65	Clean gob, very wet
1	158.03	158.56	159.09	159.13	Fair	3.88			.51	Clean gob, very wet
1	165.73	165.78	166.75	166.81	Fair	2.97			.93	Clean gob, very wet
1	173.32	173.56	174.35	174.44	Fair	2.77			.79	Clean gob. very wet
1	181.55	181.78	182.59	182.78	Fair	2.61			.81	Clean Gob, very wet

TABLE V.14-DATA COLLECTED AT MINER (Cont'd)

Sheet #2 of 3

CAR NO.	ARRIVE EMPTY	START LOAD	STOP LOAD	LEAVE LOADED	PAYLOAD (EST. TONS)	TRAVEL TIME LOADED	TRAVEL SPEED LOADED	DIST. TO DUMP (FEET)	LOAD TIME (MIN.)	START: 7:45a DATE: 3-2-79 STOP: 2:45p OBS: D.L. REMARKS
1	190.04	190.07	190.96	191.07	Fair	3.12			.89	Clean gob, very wet
1	197.71	198.20	198.68	198.84	Fair	2.89			.48	Clean gob, very wet
1	205.30	205.56	207.05	207.12	Fair	2.81			1.49	Clean gob, very wet
1	217.40	217.76	218.62	218.91	Fair	3.68			.86	Clean gob, very wet
1	225.20	226.83	227.72	227.83	Good	8.37		530	.89	Repo.miner, hang curtain #3 entry st.,lift cut R/side
1	255.40	255.61	256.78	256.82	Good	4.56			1.17	
1	265.13	265.38	266.76	266.90	Good	4.02			1.38	
1	274.70	274.72	276.24	276.35	Good	7.61			1.52	
1	288.20	288.26	289.80	290.01	Good	3.25			1.54	
1	297.80	297.86	299.29	299.51	Good	3.21			1.43	Ft. of adv.lift cut right side 15.25'Dx9'Wx8'H
1	306.44	306.46	307.38	307.66	Fair	3.53			.92	Clean gob, very wet
1	316.11	316.15	316.90	317.10	Fair	3.45			.75	Clean gob, very wet
1	327.07	327.15	329.91	330.00	Fair	7.58			2.76	Crib block in miner conv.
1	342.60	342.68	343.95	344.31	Good	3.07			1.27	Box cut,left side #3 entry dump dry coal on roadway
1	361.30	361.36	362.54	362.74	Good	3.22			1.18	
1	386.23	386.64	387.72	388.13	Good	4.19			1.08	Check oil in miner auger
1	396.90	396.93	397.96	398.24	Good	2.74			1.03	

TABLE V.14- DATA COLLECTED AT MINER (Cont'd)

Sheet #3 of 3

CAR NO.	ARRIVE EMPTY	START LOAD	STOP LOAD	LEAVE LOADED	PAYLOAD (EST. TONS)	TRAVEL TIME LOADED	TRAVEL SPEED LOADED	DIST. TO DUMP (FEET)	LOAD TIME (MIN.)	START: 7:45a DATE: 3-2-79 STOP: 2:45p OBS: D.L REMARKS
1	405.00	405.04	406.44	406.53	Poor	3.34			1.40	Clean gob, very wet
1	413.61	413.62	414.66	414.84	Poor	4.11			1.04	Clean gob, very wet. Box cut left side: Ft.adv.9'2.5"Dx 9'Wx7.5'H

TABLE V.15- DATA COLLECTED AT CHANGE POINT ON MARCH 2

Sheet #1 of 2

CAR NO.	ARRIVE EMPTY	LEAVE EMPTY	ARRIVE LOADED	LEAVE LOADED	WAIT TIME EMPTY (MIN.)	WAIT TIME LOADED (MIN.)	DIST. TO LOAD PT. (FEET)	DIST. TO DUMP (FEET)	START: 7:45a DATE: 3-2-79 STOP: 2:45p OBS: T. W. REMARKS
1			22.25	28.11		.80	180	310	Stop to hang cable; 5.06 min.
1	33.22	33.80	36.48	37.20	.58	.72			
1	45.75	46.25	49.20	51.50	.50	2.30			Timber bridge; 2.03 min.
1	58.45	58.90	61.90	62.65	.45	.75			
1	66.45	67.10	70.20	71.50	.65	1.30			Missed turn, backup
1	74.95	75.47	78.62	79.52	.52	.90			
1	84.20	84.82	88.80	89.60	.62	.80			Belts down
1	101.28	101.80	105.10	105.85	.52	.75			
1	109.90	110.61	113.90	114.66	.71	.76			
1	118.16	118.75	121.65	122.46	.59	.81			
1	125.70	126.22	133.65	134.40	.52	.75			
1	139.75	140.25	143.35	144.05	.50	.70			Car stuck, dump coal on road
1	146.78	147.30	150.25	151.35	.52	1.10			Missed turn, backup
1	156.80	157.25	160.15	160.80	.45	.65			
1	164.15	164.70	167.70	168.42	.55	.72			
1	171.94	172.50	175.53	176.84	.56	1.31			Missed turn, backup
1	179.80	180.41	183.41	184.28	.61	.87			
1	187.21	187.74	192.05	192.93	.53	.87			

TABLE V.15- DATA COLLECTED AT CHANGE POINT (Cont'd)

Sheet #2 of 2

CAR NO.	ARRIVE EMPTY	LEAVE EMPTY	ARRIVE LOADED	LEAVE LOADED	WAIT TIME EMPTY (MIN.)	WAIT TIME LOADED (MIN.)	DIST. TO LOAD PT. (FEET)	DIST. TO DUMP (FEET)	START: 7:45a DATE: 3-2-79 STOP: 2:45p OBS: T.W. REMARKS
1	196.15	196.72	199.74	200.50	.57	.76			
1	203.42	203.90	208.02	208.70	.48	.68			
1	213.30	213.88	219.68	220.40	.58	.72			
1	223.58	224.16	228.77	229.40	.58	.63	220	310	
1	255.05	225.53	259.08	259.82	.48	.74			
1	263.20	263.84	267.92	268.68	.64	.76			
1	273.32	273.76	277.88	279.58	.44	.70			Dump dry coal in ruts
1	286.38	286.88	291.10	291.82	.50	.72			
1	296.60	297.00	300.54	301.56	.40	1.02			Missed turn, backup
1	305.04	305.46	308.50	309.38	.42	.88			
1	314.67	315.25	318.42	318.99	.58	.57			
1	322.20	326.10	335.28	335.98	3.90	.70			Car stuck
1	339.56	339.98	345.30	345.91	.42	.61			
1	358.70	359.23	363.85	364.90	.53	1.05			Dump dry coal in ruts
1	384.56	385.10	390.25	391.00	.54	.75			Missed turn, backup
1	395.38	395.95	399.20	399.82	.57	.62			Add hyd.oil in transmission and dump dry coal in ruts
1	403.56	404.10	408.02	408.70	.54	.68			
1	412.15	412.65	417.28	417.98	.50	.70			

TABLE V.16- DATA COLLECTED AT DISCHARGE POINT ON MARCH 2

Sheet #1 of 3

CAR NO.	ARRIVE DISCHARGE CHG.PT.	LEAVE DISCHARGE CHG.PT.	ARRIVE DUMP	START DUMP	STOP DUMP	LEAVE DUMP	TRAVEL TIME EMPTY (MIN.)	TRAVEL SPEED EMPTY	DUMP TIME (MIN.)	START: 7:45a STOP: 2:45p REMARKS DATE:3-2-79 OBS: F.P.
1			29.10	29.98	31.50	32.40	2.14		1.52	Car stuck on feeder
1			42.40	42.70	43.80	44.08	2.92		1.10	
1			52.96	55.89	56.22	57.80	2.13		.33	Reposition feeder
1			64.42	64.62	65.46	65.62	2.36		.84	
1			71.99	72.60	73.92	74.12	2.25		1.32	Belt down
1			81.63	81.96	82.98	83.24	2.52		1.02	Belt down
1			91.04	91.15	92.46	100.02	2.63		1.31	Clean ram guides
1			106.18	107.91	108.92	109.05	2.71		1.01	
1			116.12	116.31	117.29	117.36	6.40		.98	
1			123.68	123.94	124.81	124.92	2.20		.87	
1			135.89	136.24	137.21	139.01	2.07		.97	
1			145.08	145.23	146.08	146.15	2.25		.83	
1			152.11	154.86	154.92	154.99	3.04		.06	Repo.car on feeder
1			162.11	162.31	163.01	163.11	2.62		.70	
1			169.78	169.99	170.92	171.04	2.28		.93	
1			178.21	178.38	179.12	179.20	2.35		.74	
1			185.49	185.74	186.38	186.47	4.43		.64	

TABLE V.16-DATA COLLECTED AT DISCHARGE POINT (Cont'd)

Sheet #2 of 3

CAR NO.	ARRIVE DISCHARGE CHG.PT.	LEAVE DISCHARGE CHG.PT.	ARRIVE DUMP	START DUMP	STOP DUMP	LEAVE DUMP	TRAVEL TIME EMPTY (MIN.)	TRAVEL SPEED EMPTY	DUMP TIME (MIN.)	START: 7:45a DATE: 3-2-79 STOP: 2:45p REMARKS OBS: F.P.
1			194.19	194.46	195.16	195.24	2.47		.70	
1			201.73	201.94	202.52	202.63	2.67		.58	
1			209.93	210.22	210.91	211.98	5.42		.69	
1			221.68	221.82	222.48	222.59	2.61		.66	
1			236.20	236.40	237.64	237.75	17.65		1.24	Fill #1 car with fuel
1			261.38	261.62	262.45	262.56	2.57		.83	
1			270.92	271.12	272.20	272.30	2.40		1.08	
1			283.96	284.21	285.24	285.36	2.84		1.03	
1			293.26	293.39	294.79	295.68	2.12		1.40	
1			302.72	302.83	303.94	304.16	2.28		1.11	
1			311.19	311.68	312.72	313.50	2.21		1.04	
1			320.55	320.79	321.48	321.50	6.17		.69	
1			337.58	337.76	338.70	338.75	3.85		.94	
1			347.38	347.46	348.64	348.76	12.54		1.18	#1 car operator looking for oil for miner
1			365.96	366.14	367.14	367.24	18.99		1.00	Put oil in transmission of #2 car
1			392.32	393.30	394.40	394.53	2.37		1.10	
1			400.98	401.15	402.51	402.60	2.40		1.36	

TABLE V.16- DATA COLLECTED AT DISCHARGE POINT (Cont'd)

Sheet #3 of 3

CAR NO.	ARRIVE DISCHARGE CHG.PT.	LEAVE DISCHARGE CHG.PT.	ARRIVE DUMP	START DUMP	STOP DUMP	LEAVE DUMP	TRAVEL TIME EMPTY (MIN.)	TRAVEL SPEED EMPTY	DUMP TIME (MIN.)	START: 7:45a STOP: 2:45p REMARKS DATE: 3-2-79 OBS: F.P.
1			409.87	410.02	411.17	411.27	2.34		1.15	
1			418.95	419.12	420.27				1.15	Stuck on feeder

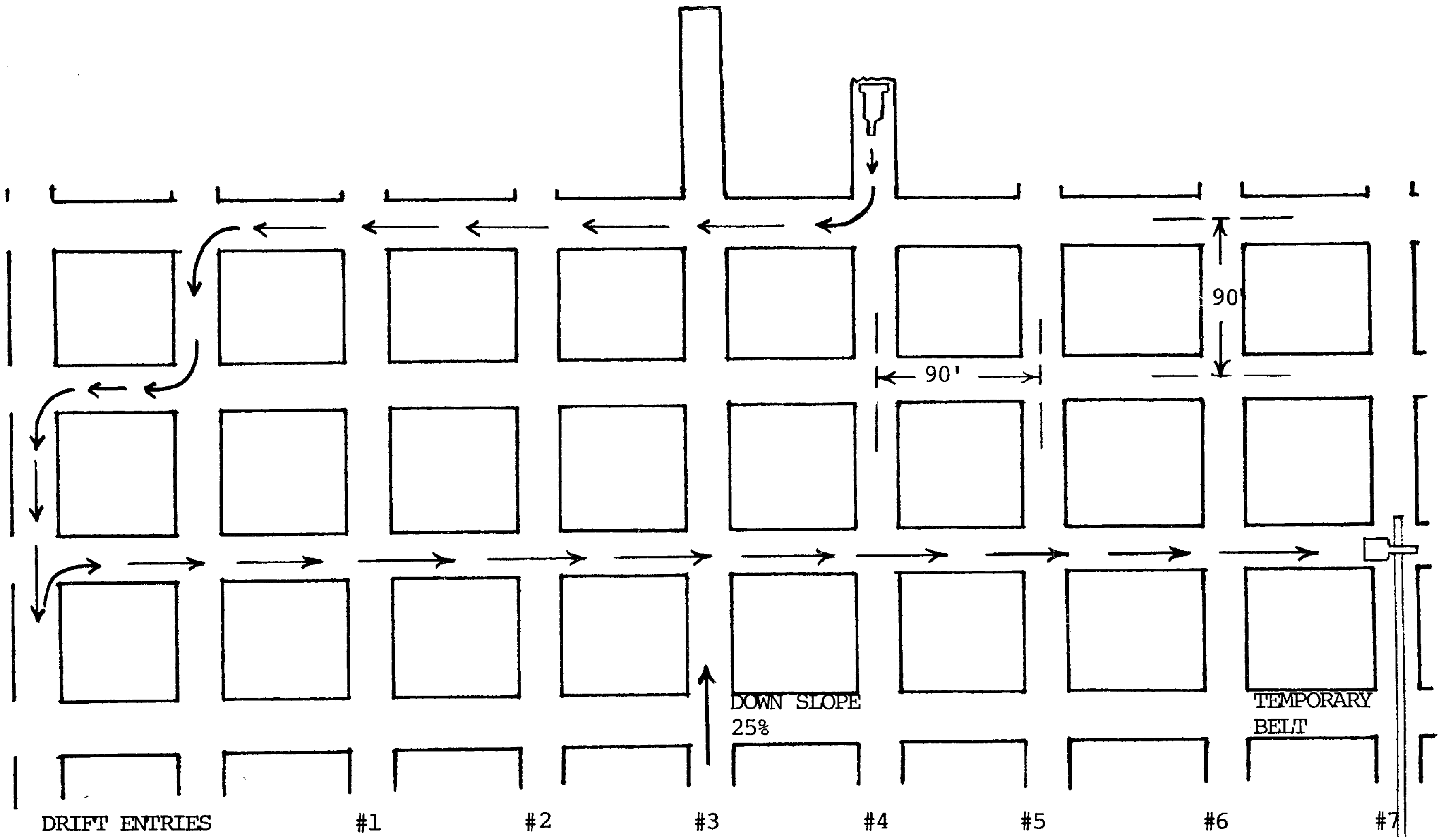

TABLE V.17 - HAULAGE ROUTE ON MARCH 8

TABLE V.18 - DATA COLLECTED AT MINER ON MARCH 8

Sheet #1 of 2

CAR NO.	ARRIVE EMPTY	START LOAD	STOP LOAD	LEAVE LOADED	PAYLOAD (EST. TONS)	TRAVEL TIME LOADED	TRAVEL SPEED LOADED	DIST. TO DUMP (FEET)	LOAD TIME (MIN.)	START: 8:20a DATE: 3-8-79 STOP: 1:33p OBS: D.L. REMARKS
1	9.50	9.60	10.60					1210		Clean up
		11.70	12.04							Reposition miner
		13.03	14.56	14.67	Fair	6.55			2.87	
1	31.30	31.46	33.88	33.96	Good	7.69			2.42	
1	46.53	46.78	49.00	49.10	13.4 tons max. load	4.75				Size of this cut 4'x9'x 8.5'
1	58.82	58.95	60.52	60.66	Fair	5.63			.57	Reposition miner
1	69.85	69.90	75.32	75.40	Good	5.82			5.42	Mostly cleanup
1	86.35	86.37	90.30	90.39	Good	7.15			3.93	Lift cut R.S. 15'7"x9'x 7.25'
1	110.98	111.43	113.54	113.76	Good	20.22			2.11	Miner down - lost water
1	142.90	142.93	143.75							Wait: Inspector, set jacks & hang curtain
		145.26	147.40	147.58	Good	6.06			1.96	Chg.place: box cut left side 2.33'x7.25'x9'
1	171.67	171.78	173.61							Clean up
		173.68	174.22	174.42	Fair	5.32			1.37	Chg.place LC. L.S. #4 entry backup Hill
1	204.02	204.65	206.45							Clean up #4 entry
		208 73	209.66	209.64	Fair	5.58			2.73	
1	222.38	222.40	223.00							
		227.10	233.59	233.84	Fair	7.19			7.09	Miner having trouble cutting up hill.

TABLE V.18- DATA COLLECTED AT MINER (Cont'd)

Sheet #2 of 2

CAR NO.	ARRIVE EMPTY	START LOAD	STOP LOAD	LEAVE LOADED	PAYLOAD (EST. TONS)	TRAVEL TIME LOADED	TRAVEL SPEED LOADED	DIST. TO DUMP (FEET)	LOAD TIME (MIN.)	START: 8:20a DATE: 3-8-79 STOP: 1:33p OBS: D.L. REMARKS
1	248.89	248.93	249.37							Miner having trouble cutting up hill
		250.45	251.72							Minner having trouble cutting up hill
		259.27	265.79	266.19	(not recorded)	5.97			8.38	Miner having trouble cutting up hill.
1	278.98	286.21	290.44		(not recorded)	6.55		1210		#4 entry start up hill
		305.62	307.49							Lay planks so miner can climb up hill
		308.39	310.13							Dig muck from around miner
		310.79	313.13						2.34	Miner cannot sump in coal up-hill

TABLE V.19 -DATA COLLECTED AT CHANGE POINT ON MARCH 8

CAR NO.	ARRIVE EMPTY	LEAVE EMPTY	ARRIVE LOADED	LEAVE LOADED	WAIT TIME EMPTY (MIN.)	WAIT TIME LOADED (MIN.)	DIST. TO LOAD PT. (FEET)	DIST. TO DUMP (FEET)	START:8:20a DATE:3-8-79 STOP:1:33p OBS: T.W. REMARKS
1			17.60				630'	580'	Hauling with #1 car; #2 car down with broken drive chain
1	28.30	29.12	35.60	35.90	.82	.30			
1	44.05	44.50	50.30	50.80	.45	.50	Return trip 270	Return trip 280	Changed return path
1	56.40	56.90	62.22	62.74	.50	.52	270	280	
1	67.34	67.80	77.18	77.88	.46	.70	270	280	
1	82.85	83.20	91.70	92.22	.35	.52	270	280	
1	99.70	100.20	129.20	129.62	.50	.42	630	580	Return path chg'd to match haul path
1	134.80	135.62	149.80	150.36	.82	.56			
1	164.20	164.64	175.70	176.18	.44	.48			Checked scrubber
1	199.30	199.72	210.85	211.30	.42	.45			Stop for lunch
1	217.64	218.04	235.60	236.10	.40	.50			Scrape road to feeder with scoop
1	244.03	244.64	267.68	268.12	.61	.44			
1	274.73	275.20			.47				

TABLE V.20- DATA COLLECTED AT DISCHARGE POINT ON MARCH 8

CAR NO.	ARRIVE DISCHARGE CHG.PT.	LEAVE DISCHARGE CHG.PT.	ARRIVE DUMP	START DUMP	STOP DUMP	LEAVE DUMP	TRAVEL TIME EMPTY (MIN.)	TRAVEL SPEED EMPTY	DUMP TIME (MIN.)	START: 8:20a DATE: 3-8-79 STOP: 1:33p OBS: REMARKS
1			21.22	21.35	22.22	28.21	3.09		.87	Fuel in car 12"
1			41.65	41.85	42.69	42.85	3.68		.84	Put dry coal at intersection #5 entry
1			53.85	53.92	54.99	55.38	3.44		1.07	
1			66.29	66.41	67.11	67.28	2.57		.70	
1			81.22	81.33	82.58	82.71	3.64		1.25	
1			97.54	97.71	98.79	98.92	12.06		1.08	Put fill in #5 intersection
1			133.98	134.35	135.12	135.31	7.59		.77	Feeder chain running slow to prevent spillage on belt.
1			153.64	153.81	155.79	156.01	15.66		1.98	Slows RAMCAR dump
1			179.54	179.75	180.65	184.35	19.67		.90	Add scrubber water
1			215.22	215.41	216.42	216.49	5.89		1.01	Add hydraulic fluid
1			241.03	241.11	241.92	242.02	6.87		.81	
1			272.16	272.22	273.42	273.56	5.42		1.20	

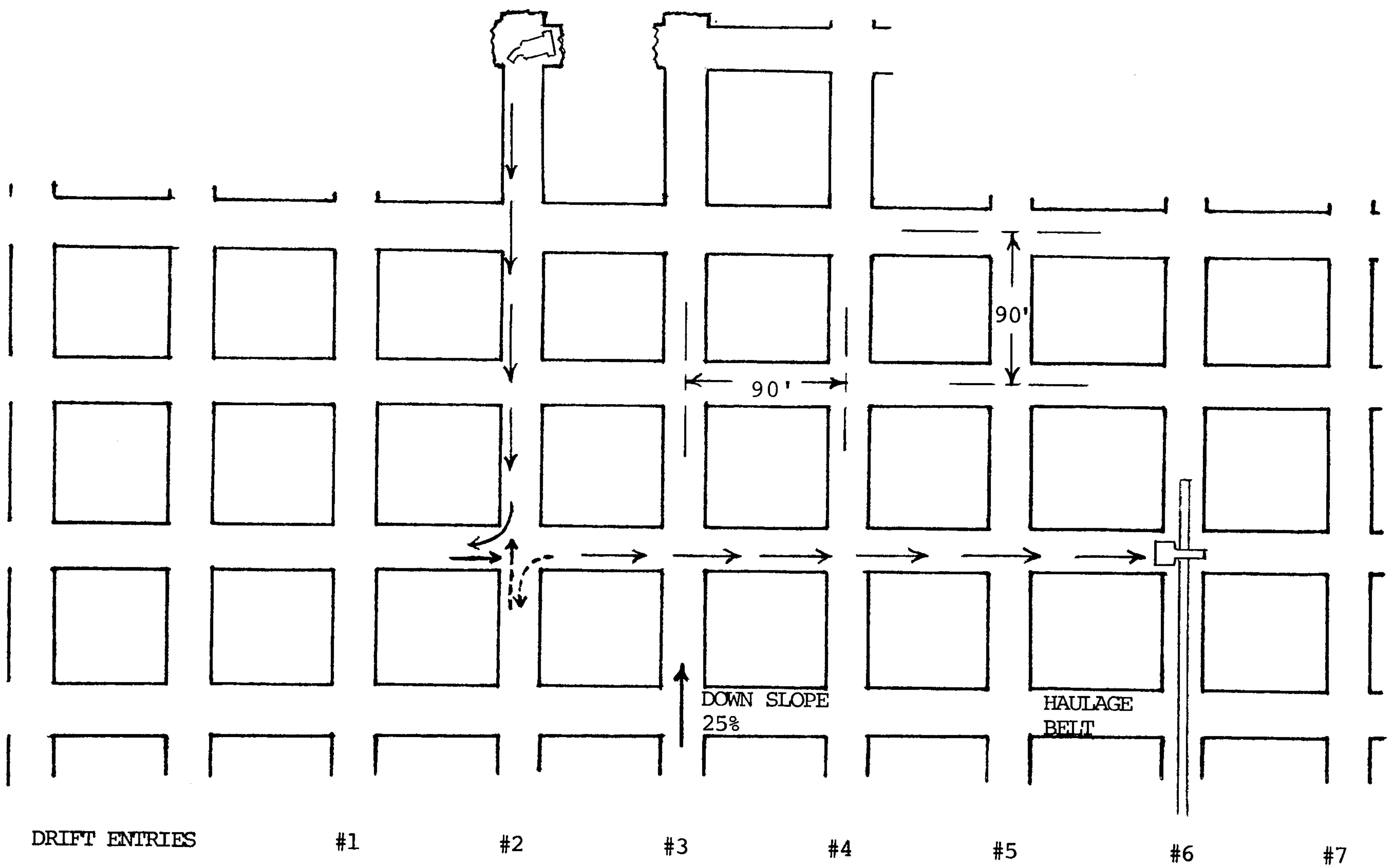

TABLE V.21 - HAULAGE ROUTE ON APRIL 11

TABLE V.22- DATA COLLECTED AT MINER ON APRIL 11

CAR NO.	ARRIVE EMPTY	START LOAD	STOP LOAD	LEAVE LOADED	PAYLOAD (EST. TONS)	TRAVEL TIME LOADED	TRAVEL SPEED LOADED	DIST. TO DUMP (FEET)	LOAD TIME (MIN.)	START: 5:30p DATE: 4-11-79 STOP: 8:13p OBS: T.W. REMARKS
1	10.60	10.61	12.42	12.44	Good 8.5T	2.21		660'	1.81	
2	13.52	13.58	16.68	16.70	Heaped 12T	3.92			3.1	O-ring on filter leaking
1	22.95	22.96	25.03	25.05	Heaped 10.5T	2.68			2.07	
1	32.70	32.70	33.75	33.77	Heaped 11T	2.64			1.05	
1	39.33	39.35	41.30	41.35	Heaped 10T	2.53			1.95	
1	46.91	46.92	50.60	50.61	Good 8.5T	2.8			3.68	
1	60.61	60.62	63.45	63.46	Good 8T	4.19			2.83	
1	71.54	71.54	73.85	73.88	Good 8T	2.65			2.31	
2	76.15	76.17	78.40	78.43	Good 9T	4.19			2.23	
1	81.31	81.31	83.90	83.10	Good 8.5T	47.85			2.59	Trouble getting up hill - had to be pulled out with #2 car. Miner down rest of shift

TABLE V.23- DATA COLLECTED AT CHANGE POINT ON APRIL 11

CAR NO.	ARRIVE EMPTY	LEAVE EMPTY	ARRIVE LOADED	LEAVE LOADED	WAIT TIME EMPTY (MIN.)	WAIT TIME LOADED (MIN.)	DIST. TO LOAD PT. (FEET)	DIST. TO DUMP (FEET)	START: 5:30p DATE: 4-11-79 STOP: 8:13P OBS: L.D. REMARKS
1									
2	10.58	14.88			4.30		300'	360'	
1			12.98	13.56		.58			
1	17.12	22.24	25.82	26.20	5.12	.38			
2			17.54	18.05		.51			
2	23.60								Parked #2 car at 51.45 with oil leak at filter
1	30.65	31.74	34.38	34.62	1.09	.24			
1	38.68	38.80	41.82	42.36	.12	.54			
1	46.09	46.43	50.90	51.44	.34	.54			
1	59.58	59.93	63.94	64.48	.35	.54			
1	70.69	70.96	74.45	74.82	.27	.37			
2		75.05	79.30	79.84		.54			
1	79.62	80.05			.43				
1									

TABLE V.24- DATA COLLECTED AT DISCHARGE POINT ON APRIL 11

CAR NO.	ARRIVE DISCHARGE CHG.PT.	LEAVE DISCHARGE CHG.PT.	ARRIVE DUMP	START DUMP	STOP DUMP	LEAVE DUMP	TRAVEL TIME EMPTY (MIN.)	TRAVEL SPEED EMPTY	DUMP TIME (MIN.)	START: 5:30p DATE: 4-11-79 STOP: 8:13p OBS: F.P. REMARKS
1			14.64	14.93	15.70	15.80	7.15		.77	
2			20.62	20.73	21.65	21.90			.92	
1			27.73	28.10	29.50	29.60	3.1		1.4	
1			36.41	36.59	37.42	37.51	1.82		.83	
1			43.88	44.20	44.94	45.15	1.76		.74	
1			53.41	53.92	58.48	58.65	1.96		.56	Belt down 4 min.
1			67.65	67.89	68.72	68.94	2.6		.83	
1			76.53	76.81	77.75	77.91	3.4		.94	
2			82.62	82.76	84.80	85.02			.89	Belt down 3 min.
1			130.95	131.04	132.10	132.20			1.06	

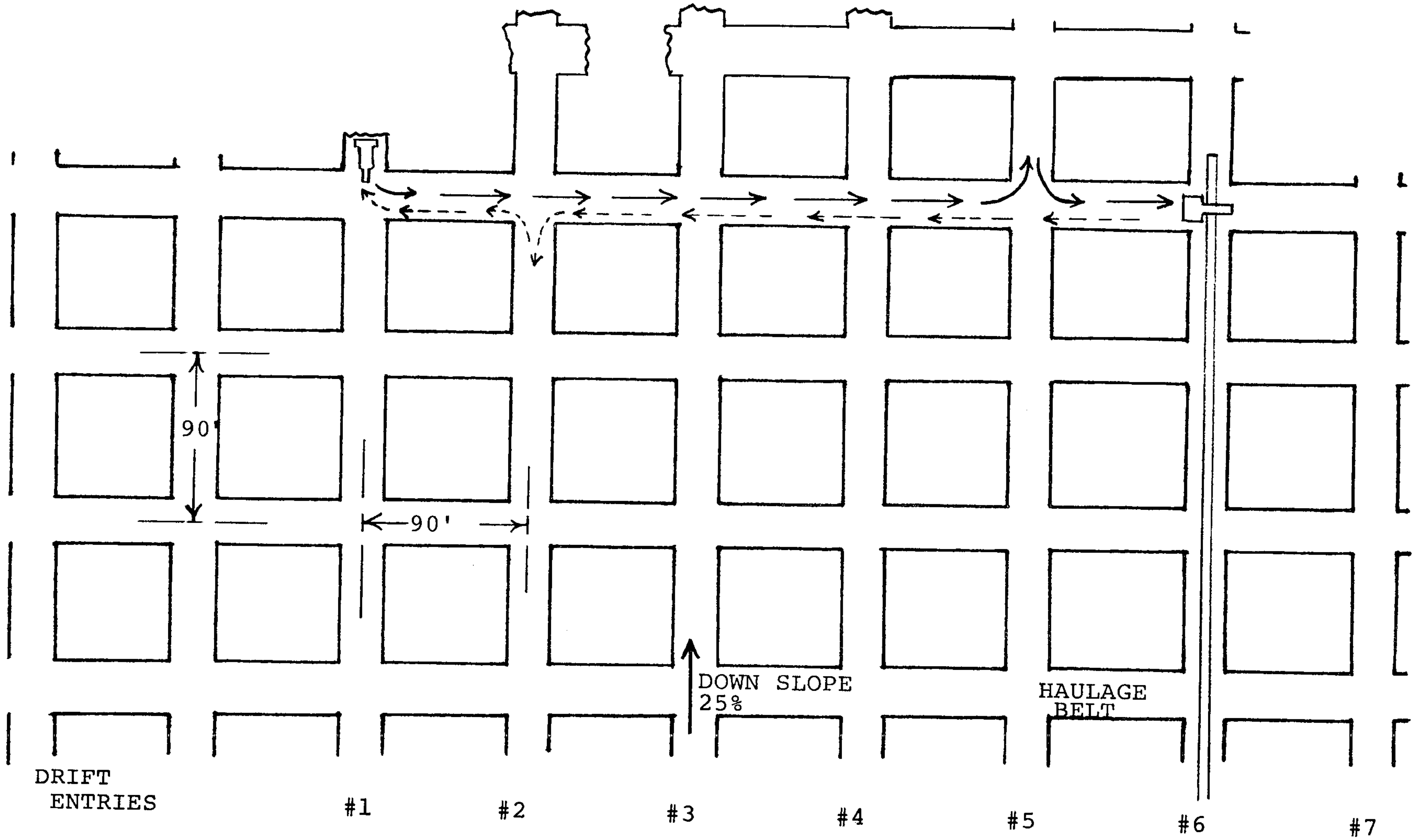

TABLE V.25 - HAULAGE ROUTE ON APRIL 12

TABLE V.26- DATA COLLECTED AT MINER ON APRIL 12

CAR NO.	ARRIVE EMPTY	START LOAD	STOP LOAD	LEAVE LOADED	PAYLOAD (EST. TONS)	TRAVEL TIME LOADED	TRAVEL SPEED LOADED	DIST. TO DUMP (FEET)	LOAD TIME (MIN.)	START: 11:15a DATE: 4-12-79 STOP: 1:54p OBS: T.W. REMARKS
1	21.51	21.52	25.41	25.60	Heaped	6.5		400	3.89	Making cut to right
2	26.80	26.82	29.80	29.90	Heaped	14.6			2.98	
1	45.70	45.79	48.09	48.11	Good	5.99			2.03	Advance: 38'x10.5'x7.5'
2	49.80	50.70	52.61	52.74	Heaped	6.26			1.91	
1	60.49	60.53	62.55	62.57	Heaped	4.53			2.02	20' clean up
2	64.40	65.70	68.58	68.80	Good	4.75			2.88	
1	73.40	73.90	76.50	76.50	Heaped	7.4			2.06	
2	77.70	77.96	80.30	80.34	Heaped	6.76			2.34	
1	96.64	97.47	98.94	99.27	Fair	5.83			1.47	
2	104.46	104.47	109.75	110.24	Heaped	3.36			5.28	
1	114.87	114.87	116.71	116.73	Good	3.37			1.84	
2	117.86	117.90	119.49	119.54	Heaped	3.31			1.59	O-ring at filter leaking in #2 car
1	126.21	126.21	129.75	129.88	Heaped	10.72			3.54	
1	145.71	145.73	148.87	148.90	Heaped	4.7			3.14	

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TABLE V.27- DATA COLLECTED AT CHANGE POINT ON APRIL 12

CAR NO.	ARRIVE EMPTY	LEAVE EMPTY	ARRIVE LOADED	LEAVE LOADED	WAIT TIME EMPTY (MIN.)	WAIT TIME LOADED (MIN.)	DIST. TO LOAD PT. (FEET)	DIST. TO DUMP (FEET)	START: 11:15a DATE: 4-12-79 STOP: 1:54p OBS: L. D. REMARKS
1									
2	23.05	26.38			3.33				
1	44.12	45.34			1.22				
2	47.68	48.80			1.12				
1	59.00	59.94			.94				
2	62.15	63.25			1.10				
1	71.74	72.64			.90				
2	76.24	77.20			.96				
1	86.92	87.75			.83				
2	95.68	101.97			6.29				
1	113.20	113.55			.35				
2	117.05	117.40			.35				
1	122.52	123.36			.84				
1	143.07	144.42			1.35				

TABLE V.28- DATA COLLECTED AT DISCHARGE POINT ON APRIL 12

CAR NO.	ARRIVE DISCHARGE CHG.PT.	LEAVE DISCHARGE CHG.PT.	ARRIVE DUMP	START DUMP	STOP DUMP	LEAVE DUMP	TRAVEL TIME EMPTY (MIN.)	TRAVEL SPEED EMPTY	DUMP TIME (MIN.)	START: 11:15a DATE: 4-12-79 STOP: 1:54p OBS: P.M. REMARKS
1	27.85	28.50	32.10	40.60	41.50	41.75	3.95		.90	Belt down
2	32.60	43.15	44.50	44.60	45.60	45.90	3.9		1.	
1	50.40	51.40	54.10	54.35	55.05	55.30	5.19		.70	
2	56.90	57.85	59.00	59.05	60.25	60.50	3.9		1.20	
1	64.85	64.90	67.10	67.15	68.05	69.25	4.15		.90	
2	70.25	70.75	73.55	73.70	74.25	74.55	3.15		.55	Dump coal in haul road
1	78.75	78.75	83.90	84.00	84.75	84.90	11.74		.75	
2	85.55	86.10	87.10	87.15	88.10	88.30	16.16		.95	
1	103.50	103.50	105.10	105.15	106.00	106.15	8.72		.85	
2	111.90	112.45	113.60	113.65	114.65	114.90	2.96		1.	
1	118.45	118.50	120.10	120.15	120.85	120.85	5.36		.70	
2	120.80	121.80	122.85	122.90	123.90	124.10			1.	Parked car #2;leaking hyd. filter
1	138.05	138.10	140.60	140.70	141.65	141.85	3.86		.95	
1	151.25	151.45	153.60	153.65	158.55	159.10			4.90	Difficult unloading

was an obvious learning process and a tailgate was designed and provided on the production model 411H RAMCARs.

Data collected randomly over the six days of operation has been summarized in Table V.4. Only 28.86 hours of operating time was recorded, and during much of this time only one haulage vehicle was operated.

Fuel consumption averaged 1.7 gallons per hour. The 30 gallon fuel tank proved to be more than adequate for a full shift of operation.

Operator selection of drive gear depended upon conditions. They usually selected the fastest ratio (3rd), and used lower ratios only where necessary.

Air flow in the entries was good. There were no detectable odors or heat problems associated with the diesel engines. Exhaust temperatures were less than 100°F except for one measurement that was made 2 inches inside the exhaust outlet.

In Tables V.5 through V.28 the data is arranged in the sequence of haulage route, data collected at the miner, data collected at the change point and data collected at the discharge point, for each day.

Travel speed loaded is deliberately not filled in on the tables. An average can be calculated by dividing the distance to the dump by the travel time loaded. The fastest average from this data was 4.06 mph. However, waits, change-out time, etc. are included. What is really wanted is the highest travel speed experienced, but there was no practical method for measuring this value. Tests performed before shipping the vehicles gave values in excess of 6 mph.

Load discharge time was usually longer than the capability of the vehicle. The fastest recorded time was .08 minutes which is assumed to be invalid data since the vehicle function normally takes at least 15 seconds. The fastest, presumed valid, time was 0.33 minutes. Typical load discharge times ranged from 0.5 to 0.8 minutes.

Floor conditions made shuttle car operation difficult. When holes or ruts became very deep the shuttle car wheel(s) would "drop" into the holes and no longer provide traction. The articulated vehicles, with the longitudinal axis pivot, could accommodate much more uneveness in the floor.

Some mine section reports were obtained but these are not directly comparable to the tonnage estimated by vehicle load size. In some instances some payloads were also hauled by vehicles other than the two 4-wheel drive diesel RAMCARs.

Mine operator reports for three day shifts in the Gobblers Knob Mine using two type 10SC shuttle cars were 391, 372, 415 tons. Conditions there were more favorable than in the Big George Mine where the two RAMCARS were working. One diesel powered 4-wheel drive RAMCAR, working under less favorable conditions, hauled more than half as much as the pair of shuttle cars on the same days. It can be projected that two 4-wheel drive haulage vehicles operating properly can easily out-perform shuttle cars in this application. This has been subsequently proven with the production model 411H vehicles.

SECTION 6.0

DURABILITY

The two vehicles were at the mine site for over six months. There were a number of problems in the driveline, some associated with the engine package but very few associated with the structure. Both vehicles showed evidence of severe external rubbing against ribs, etc. Figures 6.1 and 6.2 show the vehicles after return to the Jeffrey facility.

As noted earlier, some changes were incorporated shortly after arrival of the vehicles at the mine site. These included:

- No-slip differentials. The no-slip was eventually removed from the trailers and retained only in the tractors.

- An extra pair of steering cylinders on top the pivot. With the no-slip differentials the steering loads were increased.

- Additional protective rub bars on the trailers between the wheels and pivots. Also, additional support was added to the rear rub bars.

Shortly after introduction underground, problems with the disc brakes were experienced. The pads broke loose from the discs which then allowed the pistons to push out. This was remedied by using brake pads from a different supplier. A product quality problem, rather than design, existed here.

An extensive series of universal joint failures were then experienced as originally predicted. Most of these were on the shafts between the trailer outboard gear case and the differential. Substitution of a larger size universal joint solved that problem, but then some shaft failures also occurred. This was solved by going to hybrid drive shafts where a heavier shaft was used with the larger universal joint.

About two months operation was in the Gobblers Knob Mine. Just prior to relocation of the vehicles into the more difficult conditions at the Big George Mine, an hydraulic

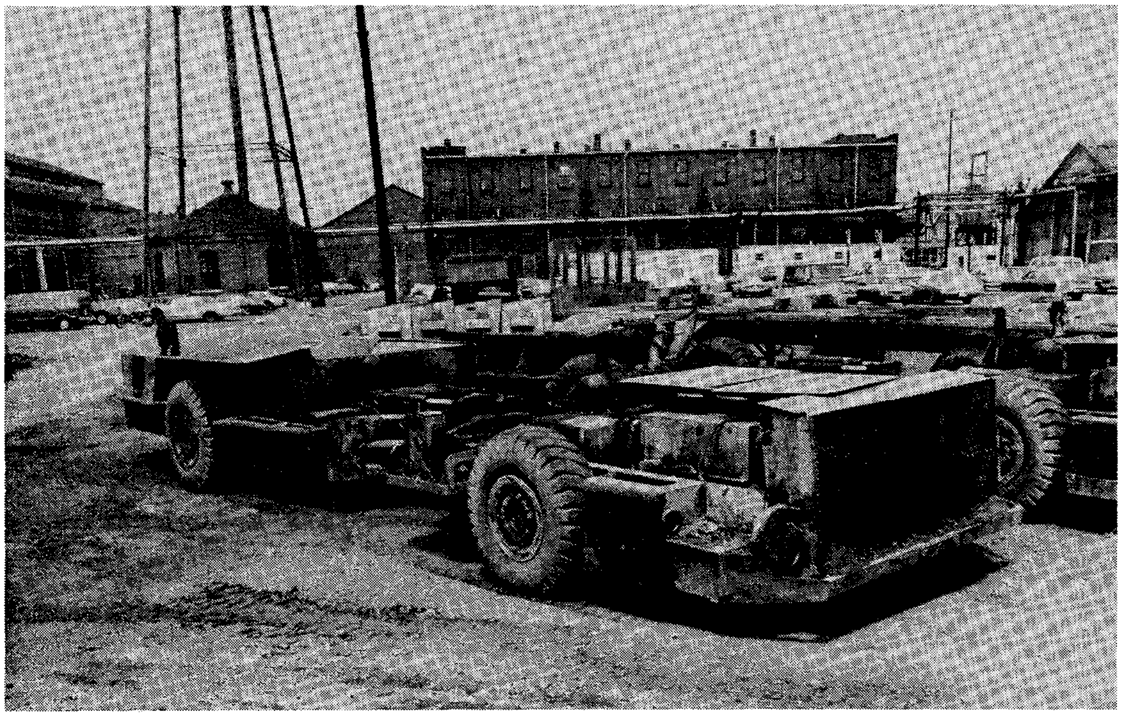

FIG. 6.1 HAULAGE VEHICLES AFTER EVALUATION - RIGHT SIDE

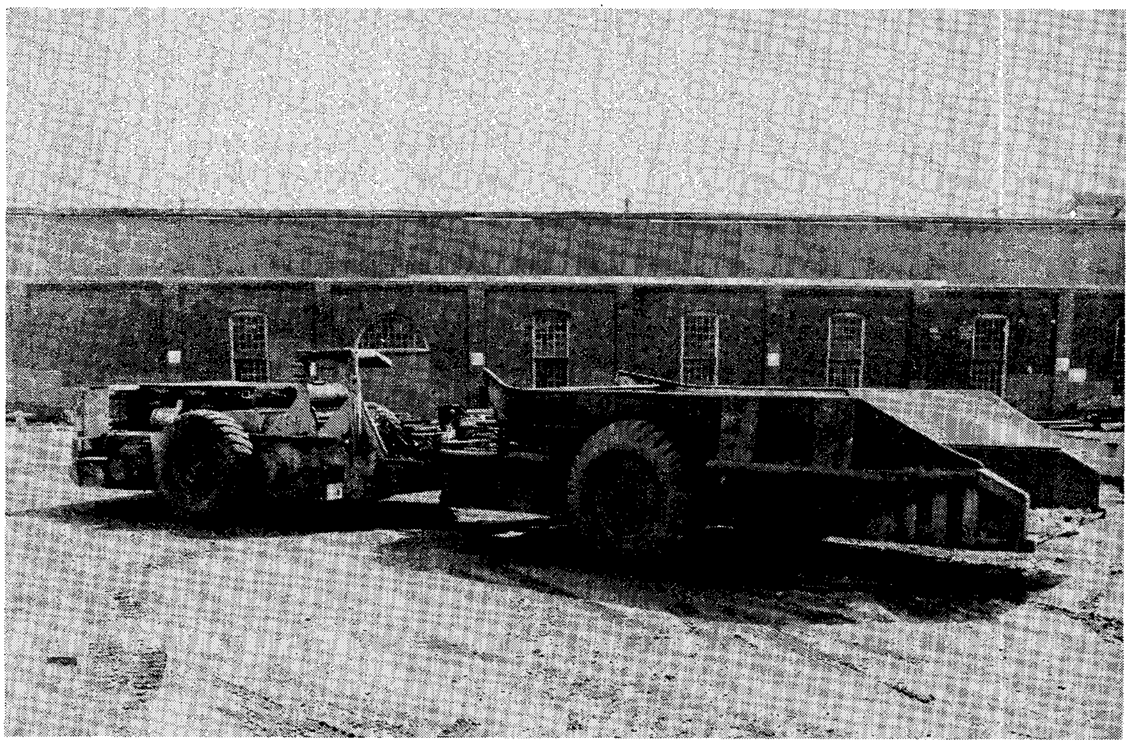

FIG. 6.2 HAULAGE VEHICLES AFTER EVALUATION - LEFT SIDE

pump on vehicle #1 failed. This was diagnosed as due to contamination.

From mid-January through mid-February, both vehicles ran good. There was a failure of one input gear on one outboard gear case assembly. This again was a result of applying much higher driveline torque than required in the design. These gears have been redesigned to minimize the deep undercut on the shank.

The no-slip differentials in the trailers were removed on March 10th.

Both vehicles had the high angle joint pillow block through the pivot come loose. Also, the differential cases came loose. Through bolts, larger size bolts, and tack welds corrected these problems. The production design was changed to incorporate a large key in the pillowblock to take the loads and to double the number of mounting bolts for the differentials.

After six months at the mine the vehicles had experienced many little problems, most of which relate to the fact that the vehicle was designed for a more mild environment. But aside from these aspects which were redesigned in the production model 411H, the vehicles proved very durable.

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