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REPORT OF INVESTIGATIONS/1989

Underground Coal Mine Track Inspection and Cleaning Vehicle

By Richard L. Unger

BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNITED STATES DEPARTMENT OF THE INTERIOR
Manuel J. Lujan, Jr., Secretary

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

dB	decibel	in^2	square inch
ft	foot	lb	pound
ft/mi	foot per mile	lb/min	pound per minute
ft/min	foot per minute	mg/m^3	milligram per cubic meter
ft^2/in^2	square foot per square inch	mph	mile per hour
ft^3	cubic foot	pct	percent
ft^3/mi	cubic foot per mile	psi	pound (force) per square inch
ft^3/min	cubic foot per minute	rpm	revolution per minute
gal/min	gallon per minute	V ac	volt, alternating current
h	hour	V dc	volt, direct current
hp	horsepower	W	watt
in	inch	yd^3	cubic yard
in/ft	inch per foot	yd^3/mi	cubic yard per mile
in H_2O	inch of water	yr	year

UNDERGROUND COAL MINE TRACK INSPECTION AND CLEANING VEHICLE

By Richard L. Unger[1]

ABSTRACT

The U.S. Bureau of Mines has designed, fabricated, and tested a prototype track maintenance vehicle for underground coal mines. The vehicle uses a stiff rotating brush to clean the track so that a visual inspection is possible. It is also equipped to measure track gauge and cross-level. The objective of this report was to describe the track maintenance vehicle and detail the results of investigations into present underground track inspection procedures and cleaning technologies, which led to the development of the prototype. Recommendations are made concerning the integration of components of this prototype vehicle into current track cleaning and inspection systems used in underground mines.

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INTRODUCTION

Federal regulations covering underground coal mining contain provisions to guard against the major causes of haulage-related accidents, such as defective vehicles, obstructed clearances, and ineffective traffic control systems. However, guidelines have not been developed for underground haulage track installation, inspection, and maintenance to ensure that the tracks support the safe operation of mine cars and other equipment.

Accordingly, in the late 1970's, the Bureau of Mines initiated a research program with the following objectives: (1) develop guidelines for maintaining, installing, and inspecting track haulage systems in underground coal mines, and (2) provide an inspection manual and recommend methods and devices that will assist an inspector in determining if the track haulage systems are safe.[2]

Based on one recommendation resulting from this research program, the Bureau designed, fabricated, and tested a prototype track maintenance vehicle. This vehicle was intended to clean the track so that a visual inspection of the roadbed was possible, and also to perform critical track geometry measurements now done manually. The appendices summarize the Bureau's findings on the current state of the art in underground track inspection and cleaning procedures which led to the development of the vehicle.

OVERVIEW OF TRACK MAINTENANCE VEHICLE DESIGN

Appendix A describes the study of existing track inspection and cleaning technologies which led to the decision to construct the prototype track maintenance vehicle (fig. 1). Early in the project, it was decided to try to develop a simple machine, which if successful, a large mine would be capable of duplicating. This meant that commercially available components were used whenever possible to allow a mine building the machine to concentrate on the assembly effort, minimizing fabrication and debugging.

This approach resulted in using components that were not previously tested for use underground, which presented certain risks. For example, the track measuring device and brush assembly chosen for use on the prototype are currently used by surface railroads. However, neither system had ever been tested underground and it was not certain whether they could withstand the harsh environment.

[2]Cunney, E. G., T. J. Rudd, and S. Hawkins. Construction, Inspection and Maintenance of Mine Haulage Track, volume 1. Final report (contract H0166048, Ensco, Inc.). BuMines OFR 49 (1)-79, 1977, 188 pp.; NTIS PB 295 553.



Figure 1.–Prototype track maintenance vehicle.

The use of standard structural shapes increased the weight of the vehicle, but fabrication was simpler because flame cutting and welding could be used in place of extensive machining and metal forming. Parts were avoided that required expensive tooling for their fabrication.

The major subsystems of the track maintenance vehicle are described in the following section.

PROPULSION METHOD AND VEHICLE FRAME

There are two ways to propel a vehicle through a mine. It can either be towed by a prime mover, as is the case with the American Mine Door[3] cleaner described in appendix B, or be self-propelled.

A design analysis indicated that a self-propelled vehicle would require many additional expensive components such as motors, speed reducers, and controls, which would only add to the cost and complexity of the vehicle. This would be counterproductive in a mine that already has a number of locomotives. Since the cleaning would generally be done in a nonproduction shift, locomotives would be available for use as tow vehicles. Also, the Mine Safety and Health Administration (MSHA) approval work would have been much more extensive for a self-propelled vehicle than for a towed vehicle, adding to the cost of the project.

The vehicle frame is a four-wheeled, specially designed flatbed car (fig. 2). The underframe is mounted on two axle-wheel assemblies, whose capacity is 6,000 lb each. The basic structure consists of four No. 6 longitudinal channels and two lateral end beams. The rear lateral

[3]Reference to specific products does not imply endorsement by the Bureau of Mines.

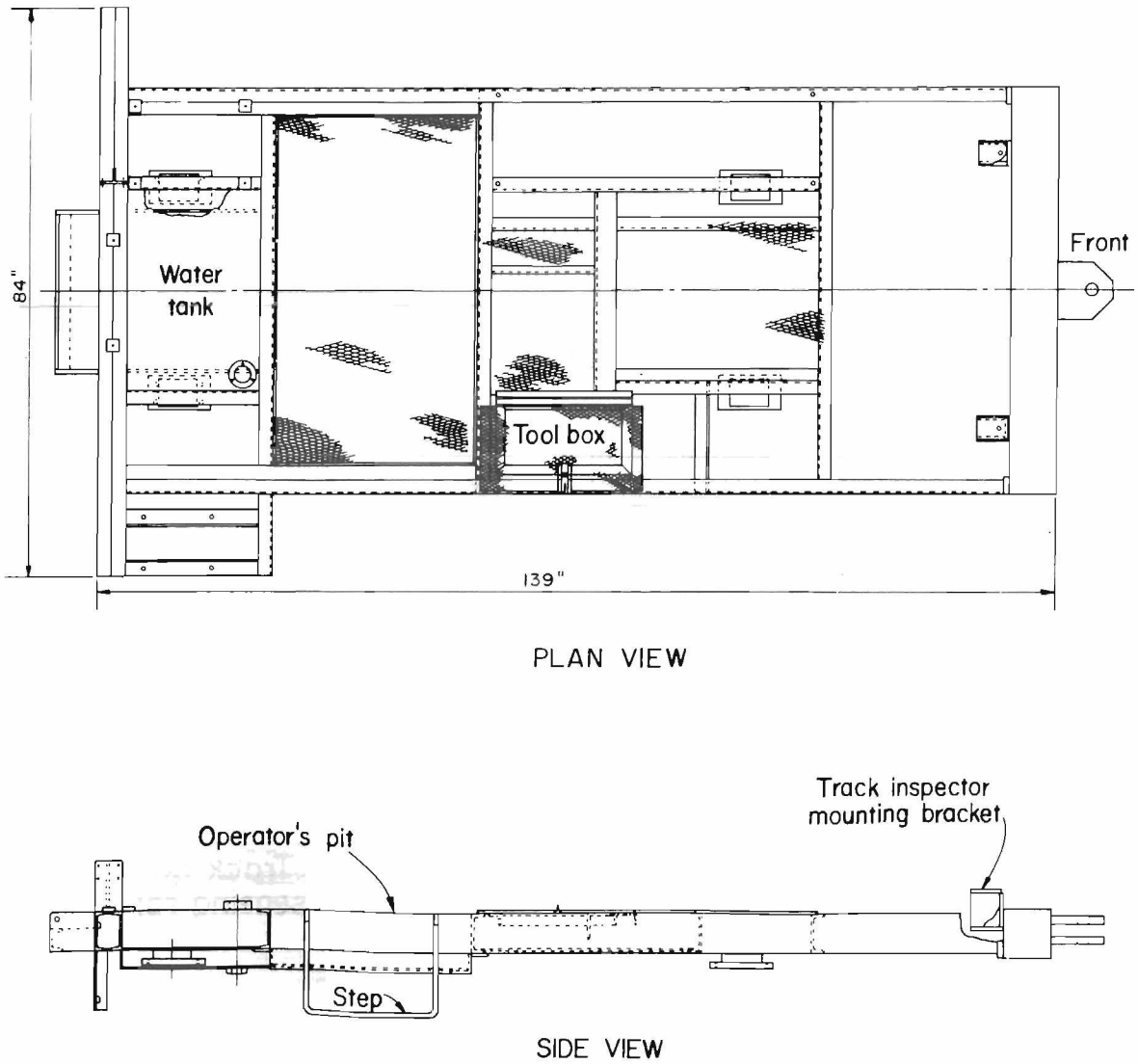


Figure 2.–Vehicle frame. Frame consists of welded tubular steel and channel.

beam has a rectangular cross section and provisions for mounting the brush assembly. The front lateral beam is a solid steel square bar, which acts as a counterweight that balances the weight of the brush assembly. The front lateral beam also has provisions for connecting with a locomotive by means of a drawbar set. Two brackets welded to the front beam are designed for mounting the track measuring device.

There are several lateral structural angles and channels welded to the longitudinal channels. These serve as the framework for mounting the seat and auxiliary equipment such as the hydraulic reservoir, main electrical cabinet, generator set, and motor-pump unit. The structure also incorporates a built-in water tank and tool box.

MECHANICAL TRACK MEASURING DEVICE

A survey of existing track measuring equipment located three devices which measure both track gauge and cross-level. These two measurements are considered to be the minimum necessary to obtain an adequate knowledge of track conditions. These devices were (1) the Geismar combination track level and gauge, (2) the Trak and Chek level and gauge, and (3) the Nordberg Model "B" track inspector. All three devices would have required modification from the standard railroad gauge (56-1/2-in) to the smaller underground track gauge (nominally 42-in).

An investigation of the three devices indicated that the Geismar device would be inconvenient to use because the operator would have to leave the car every time a measurement was performed. The Trak and Chek level and gauge performed the measurements automatically, but had the readout meters located in close proximity to the track. In an underground mine, where visibility is poor, it would be difficult to read the remote meters.

The final device, the Model "B" Nordberg track inspector, was the one ultimately chosen. It weighs only 76.5 lb, which makes it portable and easily shareable between different mines. This was a desirable feature since the track measuring device would be far and away the most expensive component on the prototype vehicle. It also performed the measurements automatically, with readout

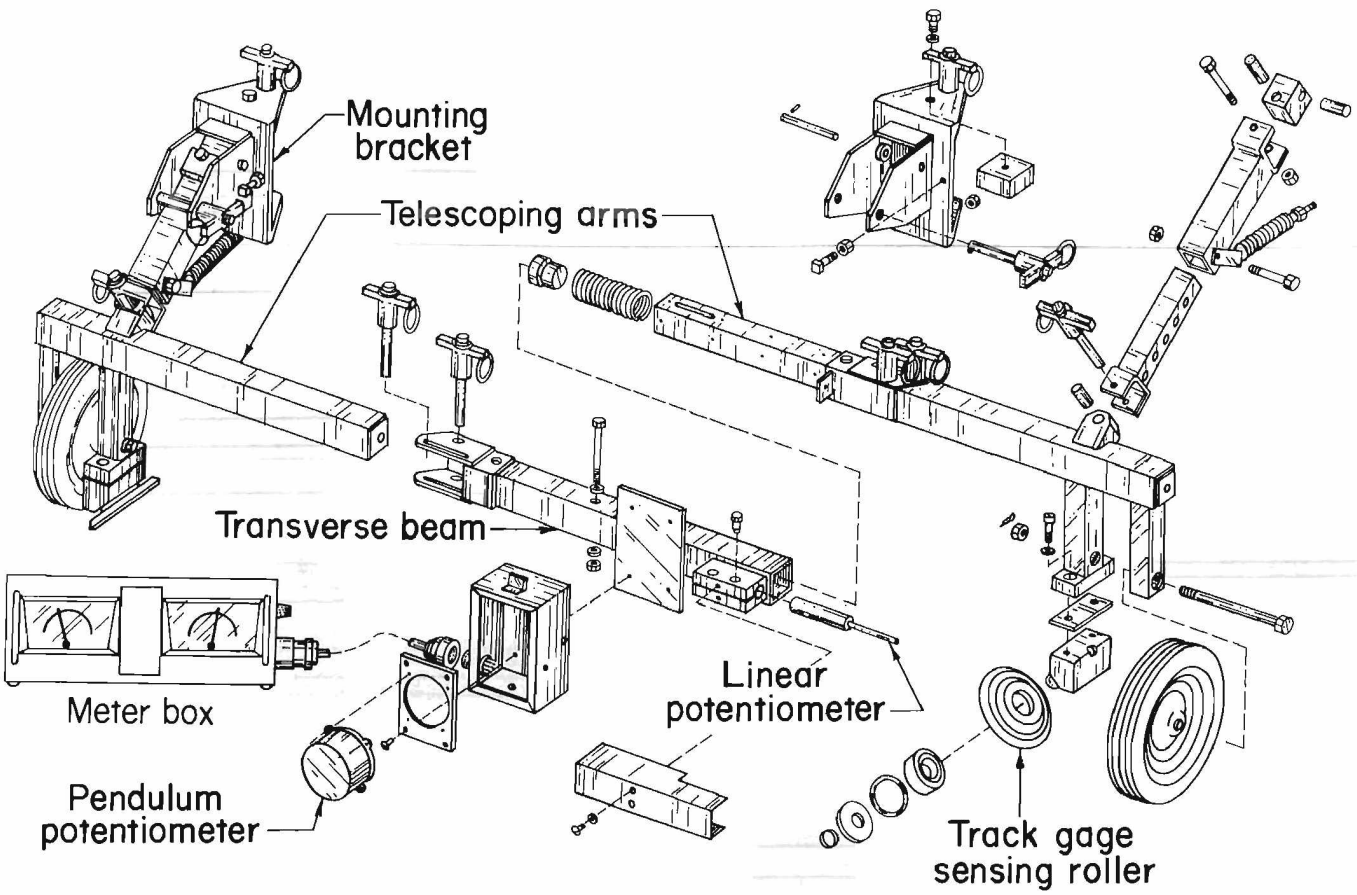


Figure 3.–Exploded view of Nordberg track inspector.

meters attached to the device with a 20-ft shielded cable, allowing them to be positioned anywhere on the vehicle.

The Nordberg track inspector had to be specially ordered from the manufacturer to fit the common underground track gauge of 42 in. The device consists of two main parts: the track inspector assembly and the meter box. Both track gauge and cross-level deviation measurements are based on a change of voltage as generated by the following components:

1. A potentiometer for cross-level deviation.

2. A linear, variable differential transformer for track gauge deviation.

Figure 3 shows an exploded view of the device. The mechanism is attached to the vehicle frame using two mounting brackets. Two wheels provide contact with the rails and are held by means of two telescopic arms and a transverse beam.

The length of the telescopic arms is adjustable for the height of the mounting brackets on the vehicle frame. Springs provide the preload to the wheels. The transverse beam keeps the track gauge sensing roller in continuous engagement with the side of the rail. Ball lock pins are used for easy assembly and disassembly of the mechanism.

For tramming while not in use, the track inspector can be raised to a stow position by the use of a hydraulic cylinder, which is actuated by a control located in the operator's compartment. An alternate method of moving the track inspector to the stow position is to raise the telescopic links manually and secure them with ball lock pins.

BRUSH ASSEMBLY

A stiff brush was selected as the method for cleaning the track based on the results of the surveys described in appendix A. There are a number of manufacturers of brushes that are currently used on surface railroads. Because this technology was available, they were contacted for recommendations. A summary of their suggestions are as follows:

1. Use a hydrostatic drive for the brush. This type of drive provides high torque at low speed, which is necessary in switch areas and when the amount of material being swept is large.

2. The advancing speed should be in the 1 to 5 mph range, as determined by the amount of material being swept.

3. Use at least a 15 hp motor for the brush drive with a speed range for the brush from 0 to at least 125 rpm.

4. The brush swing angle should not exceed $\pm 5°$ maximum.

5. The brush mixture should be a combination of polypropylene and steel wire bristles. An all-wire brush has a tendency to mat and an all polypropylene brush is not sufficiently stiff.

6. The brush should have a 32- to 36-in diameter.

Based on the above recommendations, a brush was selected for the prototype vehicle (fig. 4). The brush wafers are stacked on a 6-ft mandrel driven by two hydraulic motors. The double-acting swing cylinder is pinned to the frame and swing plate. The brush swing is accomplished by pressurizing the swing cylinder blind end or rod end. A single acting lift cylinder is anchored to the rear hole on the frame by a pin and to the upper hole of the lift bracket by another pin. The pin joins the bracket and the frame. The chain and shackle connect the bracket to the frame. When the lift cylinder rod retracts, it turns the bracket about the pin, pulls the chain, and lifts the brush. After hydraulic pressure is removed, the frame and brush lower until their own weight is balanced by an adjustable spring assembly. The brush preload and wear can be compensated by adjusting the length of the chains. Two pins anchor the frame to the track cleaning car structure.

MATERIAL REMOVAL SYSTEM

The composition of material that must be cleaned from the track system is as varied as the different mines using track. The composition may include, but not be limited to: coal dust, rock dust, coal spillage, rocks (small roof falls), metallic objects (spikes, lost tools, bolts, nuts, etc.), garbage, and sand.

The size of the individual objects vary from fine dust to large pieces of coal and rock. The ground conditions in the coal mines surveyed in the study of inspection procedures (appendix A) varied from dry to very wet; but according to mine personnel, a really muddy condition along the track route is rarely encountered.

The actual amount of debris to be removed depends on many factors. For the sake of simplicity a hypothetical track (fig. 5) was used for calculation purposes. The sizes of the rails and the tie are typical for many mines.

Figure 5 shows that only a modest amount of material would cover the ties and lower portion of the tracks. In

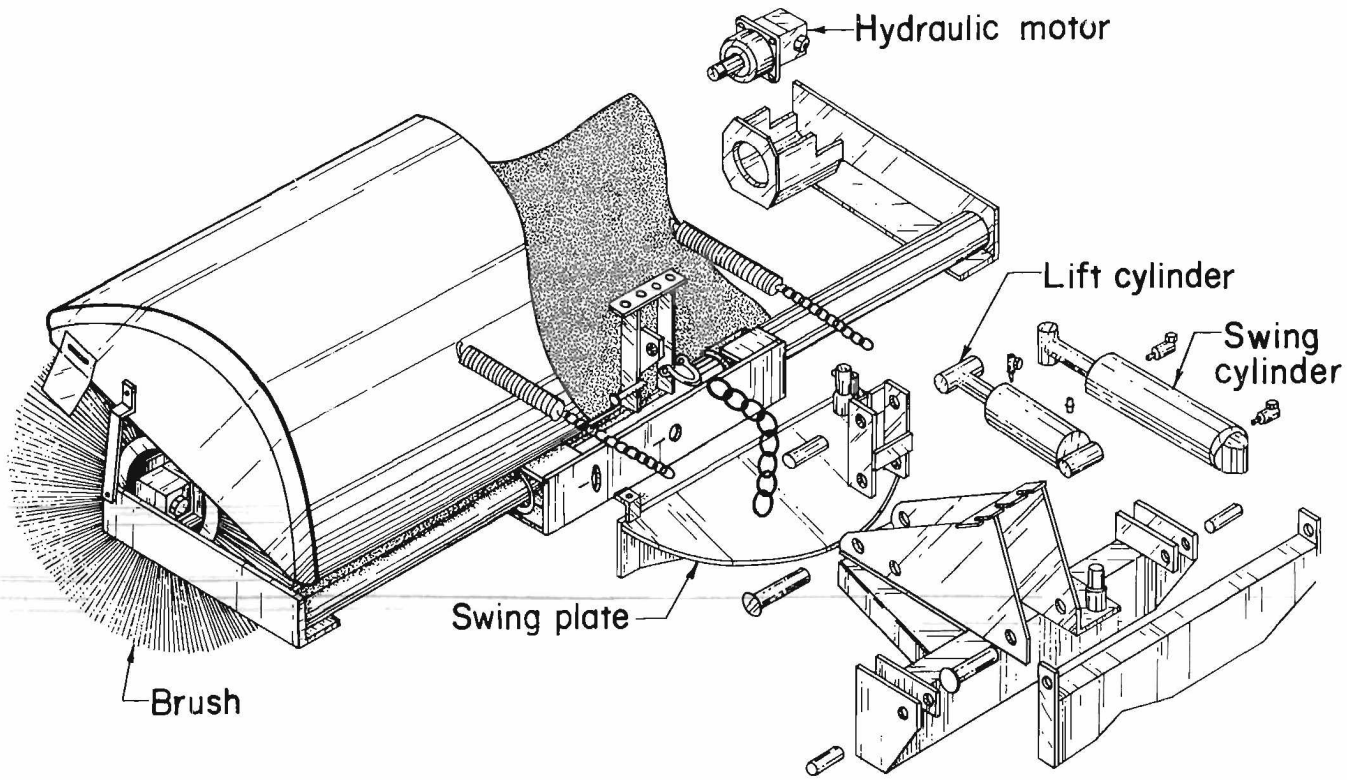


Figure 4.–Cleaning brush assembly.

reality, it would not be limited to an even 2-in, but would vary from spot to spot.

It was assumed that the material would be removed in two steps: primary and secondary cleaning. For primary cleaning, the following calculations gave a rough idea of the amount of material needed to be removed from a mile of track,

$$V_1 = L(H - H_2) - 2B(H - H_2)$$

or

$$V_1 = (L - 2B) \times (H - H_2)$$

where V_1 = material volume for primary cleaning,

L = 78 in, tie length,

H = 2 in, material depth,

H_2 = 0.4 in, material depth after scraping,

and B = 5.19 in, rail width, therefore by substitution

$$V_1 = \frac{(78 - 2 \times 5.19)}{12 \text{ in/ft}} \times \frac{(2 - .04)}{(12 \text{ in/ft})} \times 5{,}280 \text{ ft/mi}$$

$$= 3{,}967 \text{ ft}^3\text{/mi}$$

$$= 147 \text{ yd}^3\text{/mi.}$$

This is the material that would be removed using a machine such as the American Mine Door track cleaner (appendix B). After this material has been removed, the volume of debris remaining would be as shown in figure 6.

For secondary removal, the amount of material that must still be removed is given by the equation:

$$V_2 = [(L - 2B)H_2 + 2 \times ((H - H_2)B - A_{rail})]$$

where A_{rail} = $(H - H_2) \times 0.56$ in (for 85 lb weight rail) = .90 in^2

and L, B, H, and H_2 were denoted previously.

$$V_2 = [(78 - 2 \times 5.19) \times 0.4 + 2 \times ((2 - 0.4) \times 5.19 - .90)] \times 1/144 \text{ ft}^2/\text{in}^2 \times 5{,}280 \text{ ft/mi}$$

$= 1{,}534.7\ ft^3/mi$

$= 56.8\ yd^3/mi.$

These calculations indicated that the amount of material remaining on the track after the primary cleaning would be significant. Three material removal methods were considered for the secondary cleaning operation. They included:

1. Vacuum collection.
2. Pneumatic removal.
3. Mechanical removal.

Vacuum collection incorporates a rather sizeable system, which picks up particles of various sizes and deposits them in a hopper. Since the amount of material collected would be large, frequent cleaning and emptying of the hopper box would be needed, which would require an additional switching locomotive and a car. This would result in an additional operating expense and the actual material removal rate would be slowed because of the amount of time required for switching of cars and motors.

Pneumatic removal utilizes a collector head, duct, exhauster, and an exhaust pipe. Instead of being accumulated in the hopper, the material is deposited outside of the track area. Estimates indicated that the material would be leaving the exhaust pipe with a very high velocity, possibly causing a deterioration of air quality and displacement of rock dust on the ribs.

Of the various material handling equipment investigated, a mechanical conveyor seemed the most practical choice for this application. The material particles, loosened by the brush bristles, tend to move on trajectories tangential to the brush circumference. A specially

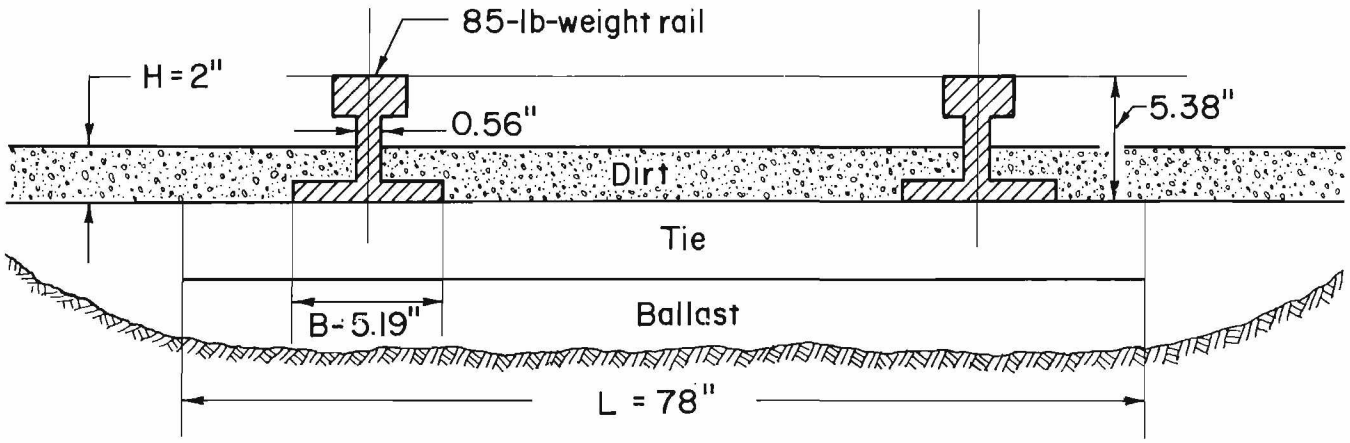


Figure 5.–Cross section of typical mine track.

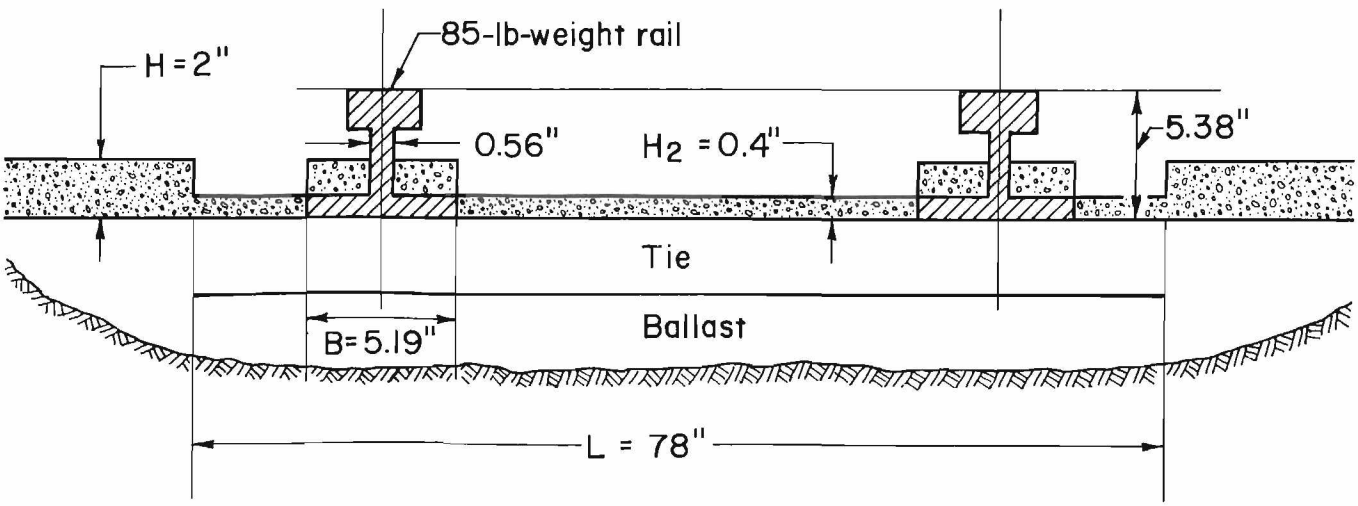


Figure 6.–Cross section of mine track after primary removal of material.

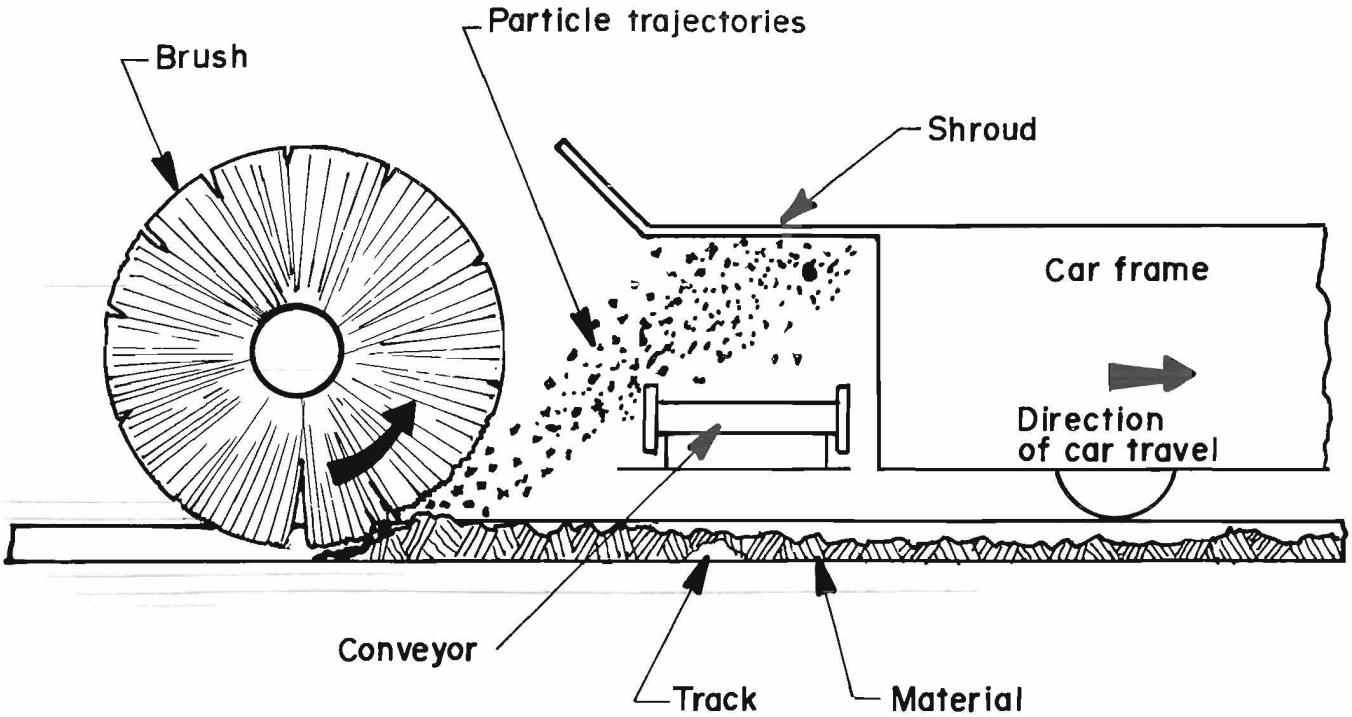


Figure 7.–Material removal system design concept.

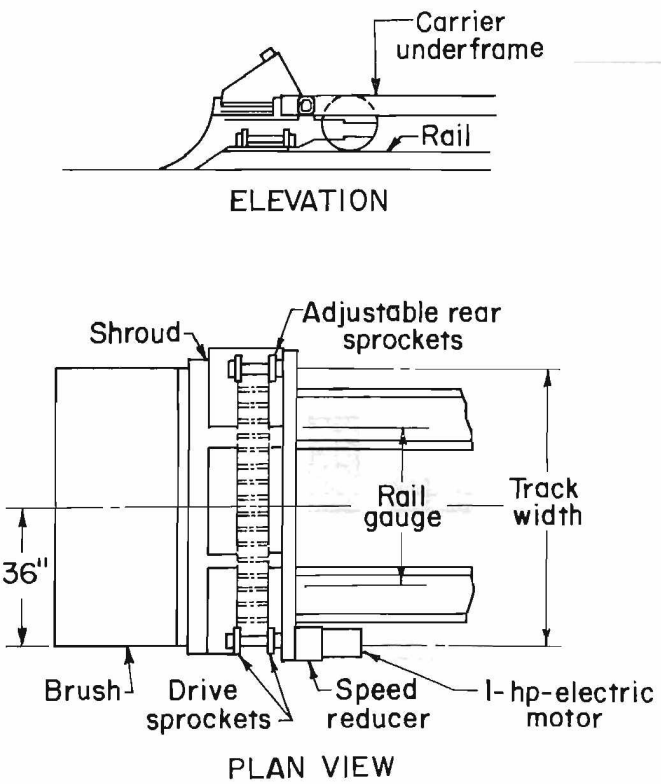


Figure 8.–Material removal system layout.

designed shroud is used to divert the particles onto a conveyor, which deposits them outside of the track area (fig. 7).

Figure 8 identifies the components that comprise the material removal system. The shroud contains the materials coming off of the brush and the conveyor transports it off to the side of the track. The shroud is bolted to the vehicle underframe and is designed so that the debris is dumped onto the conveyor pan. A 1-hp electric motor transmits torque through a speed reducer to the driving sprockets, which pull the chain and flights along the bottom of the shroud. The rear sprockets are adjusted to tighten the chain. A drag chain conveyor, rather than the belt type, is used because it is better suited to handle both dry and wet material.

Since the amount of dust that would be generated by the brush and conveyor was unknown, a dust suppression system was added to the design. It is comprised of a water tank, electric motor, water pump, and several flat spray nozzles.

ELECTRICAL SYSTEM

The track maintenance vehicle is towed by a standard locomotive and works in well ventilated haulageways. Since the locomotive employs totally enclosed electrical equipment, it was decided to use the same type of enclosure for the motors and auxiliary equipment.

The primary test site, a Bureau test track, has a 300 V dc trolley wire. The standard voltages for the 15-hp pump drive motor is 240 or 500 V dc and 90 or 180 V dc for the 1-hp conveyor motor. Three options were considered for reconciling the difference between the test site voltage and the standard motor voltage:

1. Use a resistor to drop the voltage–Calculations indicated that the amount of heat needed to be dissipated was unacceptable.

2. Invert direct current voltage to alternating current voltage–Analysis and estimates from vendors indicated that for the given power, the invertor sizes, prices, and reliability were unacceptable.

3. Use a direct current voltage-alternating current voltage generator–All efforts to locate a standard, commercially available 300 V dc to 230 V ac generator proved to be unsuccessful.

For these reasons, it was decided to build a generator to power the conveyor motor and other systems. The brush is driven by its own 300 V dc motor. Although specially built, the generator cost was about one-third that of a similar power invertor. The generator consists of a coupled 7-1/2 hp 300 V dc motor and a 230 V ac alternator and is sized to cover the high starting current requirements of the conveyor motor.

Table 1 lists the electrical equipment, controls, and electrical parameters such as voltage, power, and speed range.

TABLE 1.–Electrical equipment

Electrical equipment	Voltage	Power or current	Speed range, rpm constant	Controls
Conveyor drive motor.	230 V ac	1.5 hp	1,725	On-off Forw-rever.
Generator set .	From 300 V dc	7.5 hp	NAp	On-off.
Lights[1]	230 V ac	120 W	NAp	On-off.

NAp Not applicable.
[1]Electrical cabinet; operator's station, brush assembly, track inspector.

HYDRAULIC SYSTEM

Two hydraulic systems are incorporated into the track maintenance vehicle design: the hydrostatic brush drive system and the much smaller electrohydraulic power unit. For the hydrostatic brush drive (fig. 9), a 15-hp dc electric motor drives a variable displacement piston pump through a chain coupling. The pump provides oil flow and pressure to two low-speed, high-torque motors, which transmit the torque to the brush. The brush motor speed is controlled by changing the pump displacement with a remotely operated actuator arm. Figure 9 also shows the auxiliary equipment for this close loop circuit. It includes an oil reservoir with sight gauge and cap, filter assembly, shut off valve, oil cooler, hoses, and fittings.

A small electrohydraulic power unit provides oil flow and pressure to the brush assembly lift and swing cylinders and the track measuring device lift cylinders. The unit includes a motor, pump, tank, and directional control and relief valves.

HUMAN FACTORS CONSIDERATIONS

Several standards of the Society of Automotive Engineers (SAE) were identified during a search for guidelines covering aspects of human factors related to this work. They included:

1. SAE J185 - Access Systems for Construction and Industrial Equipment.

2. SAE J209 - Instrument Face Design and Location for Construction and Industrial Machinery.

3. SAE J833a - USA Male and Female Physical Dimensions for Construction and Industrial Equipment.

4. SAE J898a - Control Locations for Construction and Industrial Equipment Design.

5. SAE J925 - Minimum Access Dimensions for Construction and Industrial Machinery.

These standards provided information in several areas including anthropometric dimensions for the U.S. male and female population, size of handrails, location of the instrument panel, and the sizes of the steps.

The operator is located in a long reclining chair crosswise to the vehicle (fig. 10). This allows observation of both ends of the vehicle without a change of body position and is based on Bureau recommendations for the 5 percentile and 95 percentile operator in a 33-in workspace.

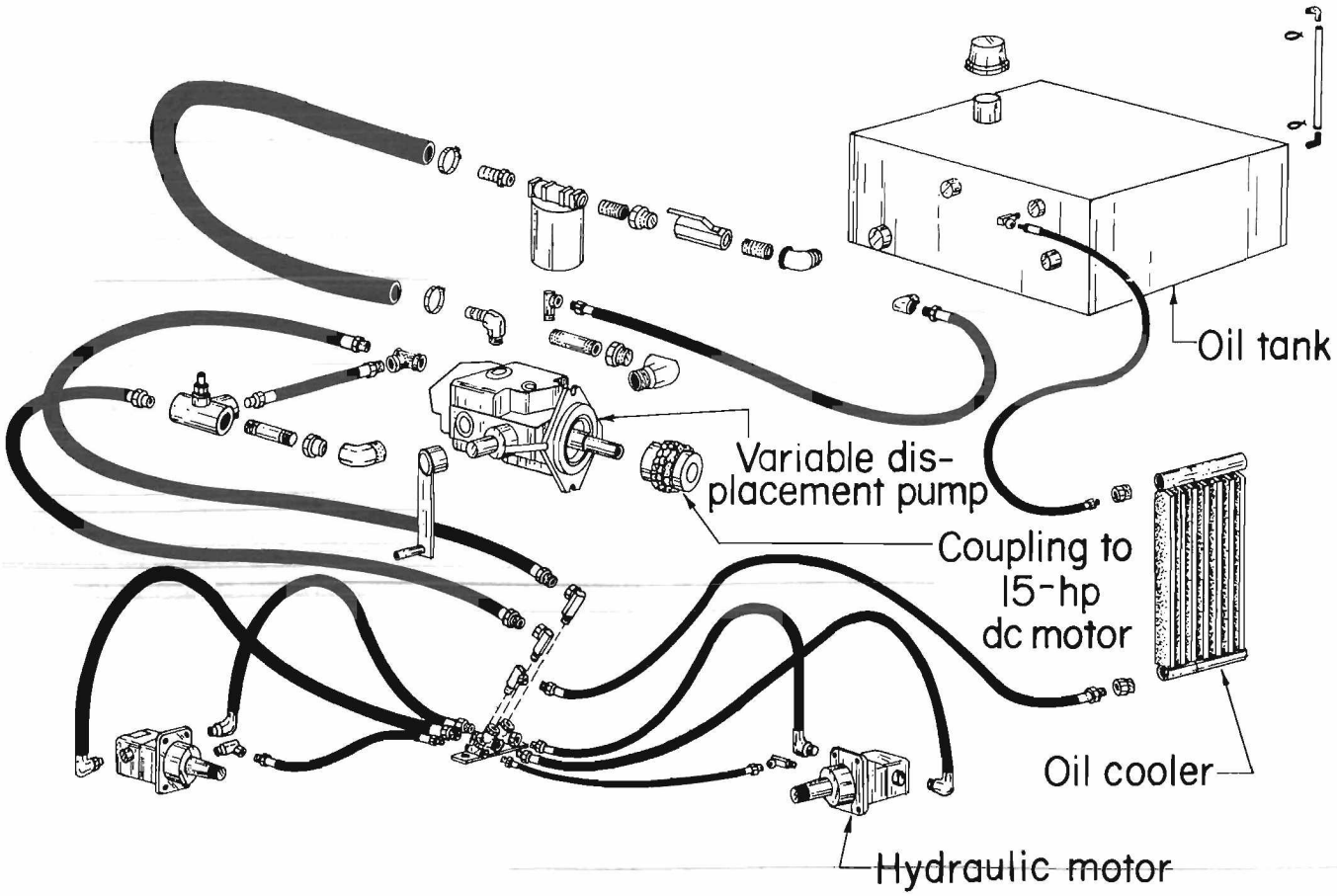


Figure 9.–Main hydraulic system components.

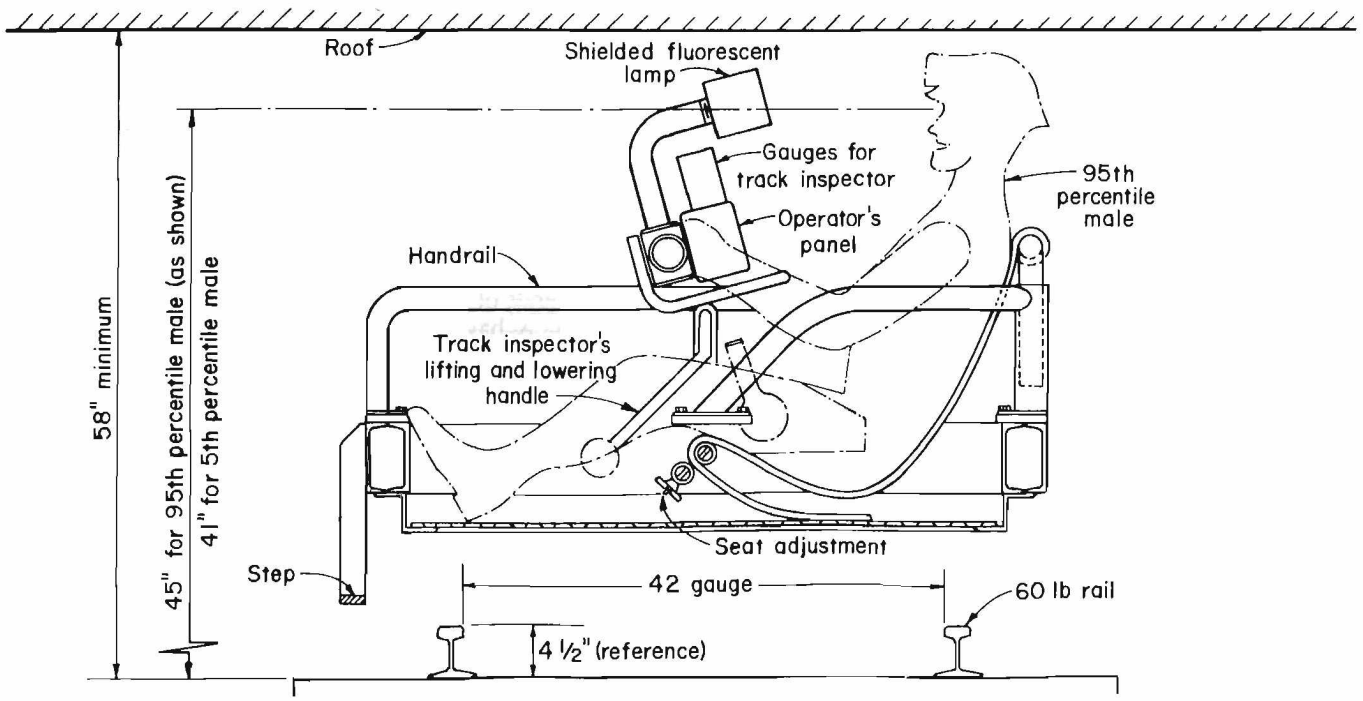


Figure 10.–Operators compartment layout.

DESIGN SUMMARY

The overall layout of the track maintenance vehicle is illustrated in figure 11 . The following summarizes the design of the prototype:

1. Basic Capabilities - The Bureau's prototype track maintenance vehicle was designed to:

a. Make the underground track suitable for visual inspection by cleaning the entire upper tie surface, including upper surfaces of fishplates and spike heads, ballast surfaces between the ties, and side surfaces of the rails.

b. Clean turnouts, frogs, switches, and crossings.

c. Perform measurements to determine out of tolerance gauge and cross-level.

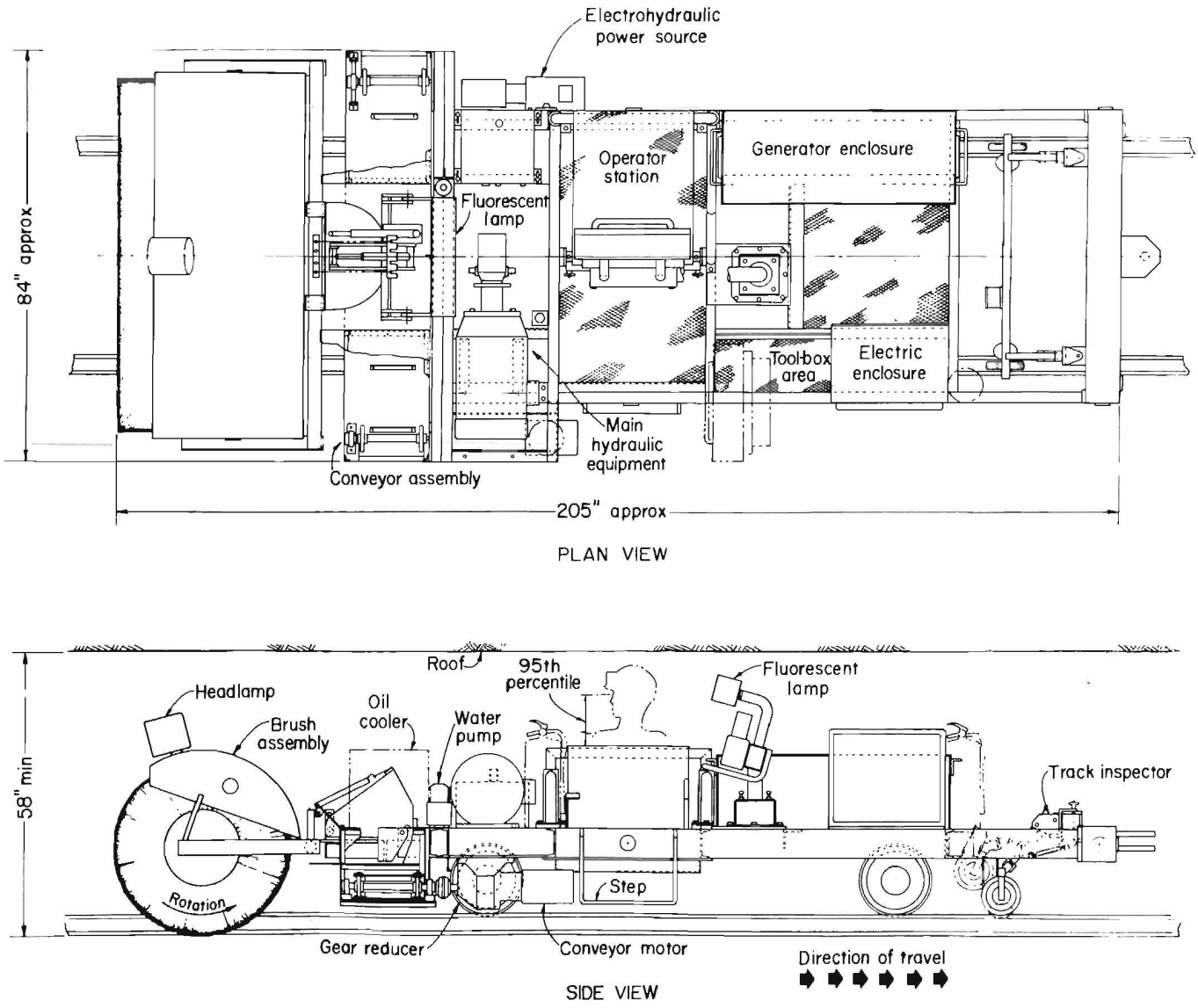


Figure 11.–Layout of prototypes main components.

d. Perform the cleaning without damaging the tops of the ties or the electrical bonding of the rails.

2. Prototype Testing - The track maintenance vehicle was designed to be tested primarily at the Bureau's surface test track and, if possible, in a cooperating underground coal mine.

3. MSHA Requirements - Although the machine is nonpermissible, certain components are subject to MSHA review. Also, applicable State regulations have been adhered to, such as allowing at least 12-in between the equipment and the trolley or feeder wire.[4]

4. Configuration and Basic Systems - The track maintenance vehicle is rail mounted and pulled by a locomotive. The car has the following systems:

a. Vehicle frame - A specially designed four-wheel flatbed car to carry the entire system, including a hitch adaptable with that of most common locomotive types.

b. Brush assembly:

Brush diameter - 36 in.
Brush width - 72 in.
Drive power - 15 hp.
Brush speed range - 0 to 125 rpm.
Vertical travel - 6 in.
Horizontal swing - ±5°.
Bristle material - polypropylene and steel wire.

c. Material removal system - Drag chain conveyor to remove the bulk of material generated by the brush. Dust suppression in very dry areas is accomplished by water sprays.

d. Electrical equipment - Table 1 summarizes the basic components of the track maintenance vehicle's electrical system.

5. Hydraulics - There are two hydraulic power systems, one for the brush rotation, and one for the brush lift and swing.

6. Track inspection system - Track gauge and cross-level deviation are displayed on meters located in the operator's compartment. Deviations beyond a preset gauge tolerance actuate an audible alarm.

7. Controls - Hydraulic and electrical controls are ergonomically located within the operator's compartment. An additional emergency cutoff switch has been located on the carrier frame.

FABRICATION AND TESTING

PROTOTYPE FABRICATION

The fabrication of the prototype track maintenance vehicle was performed at a Bureau facility. The materials cost approximately $35,000, with at least $10,000 of that cost owing to the optional track measuring device and its support mechanisms. Fabrication took approximately 1 yr, with a good deal of that time spent in waiting for suppliers to deliver parts.

A simple machine shop was used to fabricate and assemble the various components. It was equipped with the following: lathe, drill press, milling machine, electric welder, cutting torch, power hand tools, and overhead crane. No special problems were encountered during fabrication. The use of off-the-shelf components greatly simplified the task, as did the use of standard structural members. Upon completion of the prototype, initial debugging was performed in the shop. The vehicle was then shipped to the Bureau's mine car test track.

SURFACE TESTINGS

Surface testing of the prototype track maintenance vehicle was carried out at the Bureau's outdoor mine car test track located at the Lake Lynn Laboratory, Pittsburgh, PA (fig. 12). The test facility consists of 400 ft of straight 42-in gauge track with one 100 ft siding. The average grade is 4 pct and the trolley system is powered with 300 V dc.

Run-of-mine material was placed on the track and lightly tamped down using a hand tamper. The track maintenance vehicle was then operated on the test section of track to assess its cleaning ability (figs. 13-14). Approximately 25 h of testing was performed. After each pass, additional run-of-mine material was placed on the track using the same procedure. Videotape and still photography were used to document the results. The most significant are summarized below:

1. The track maintenance vehicle cleaned track, switches, and crossover structures (frogs)[5] down to

[4]Foster-Miller Associates, Inc. Track Maintenance Systems: Track Cleaning-CAR, Phase II Report (contract H0318082), 1982, 74 pp.; available upon request from R. L. Unger, BuMines, Pittsburgh, PA.

[5]Frog-a device permitting the wheels on one rail of track to cross an intersecting rail.

the level of the ties, at a maximum speed of 3 mph (figs. 15-16).

2. The brush was able to loosen all of the debris and deposit it on the conveyor for removal beyond the ties. In fact, if the operator ran the brush below the tie level, it would deposit ballast from between the ties onto the conveyor.

3. The track measuring device performed adequately throughout the tests. There were no failures. Actual hand measurements of the track indicated that the device was working within design specifications.

4. One problem encountered during surface testing was conveyor jams. When the amount of dirt or ballast above the tie level on the track exceeded approximately 3 in of depth, the chain conveyor would often jam due to the excess material. In most of the cases where this occurred, the jam was loosened by simply reversing the conveyor. Attempts were made to modify the conveyor and housing with limited success. This included the replacement of the 1 hp conveyor motor with a 1.5 hp motor. The dust suppression system was not tested during the surface testing due to the high wind levels at the test site.

Following the surface tests, the prototype was shipped to an underground mine for further testing.

UNDERGROUND TESTING

The prototype was operated in an underground mine in Osage, WV (fig. 17). Repeated failures of the material removal system forced the termination of the testing. The dust suppression system was not tested due to the unavailability of a water car at the mine. This was considered a serious setback since it had not been tested during the surface trials. The important findings of the underground testing included:

1. The brush was able to pick up the debris off the track surface, switches, and frogs and deposit it in the conveyor housing. After cleaning, it was possible to see the track components well enough to perform a visual inspection.



Figure 12.–Bureau's outdoor mine car test track.

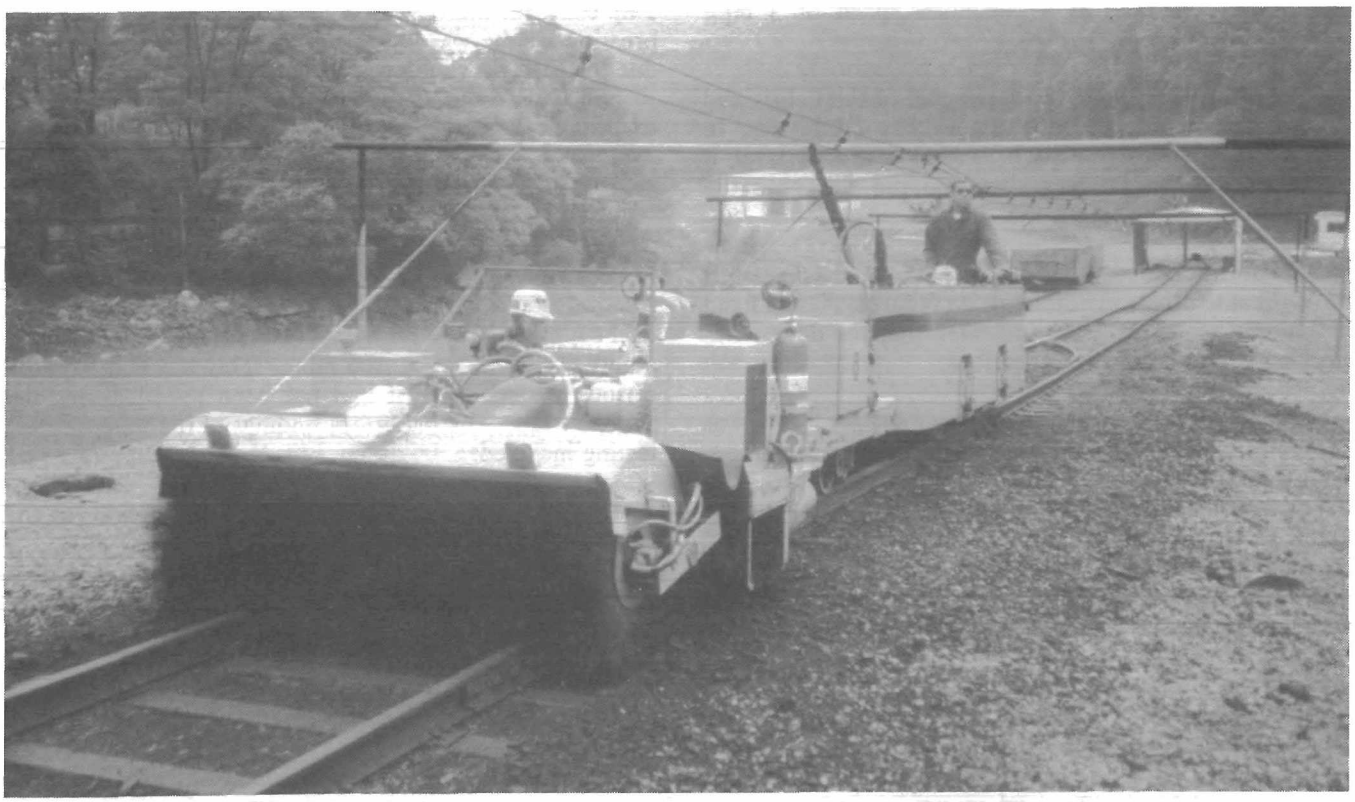


Figure 13.–Track maintenance vehicle during surface tests.

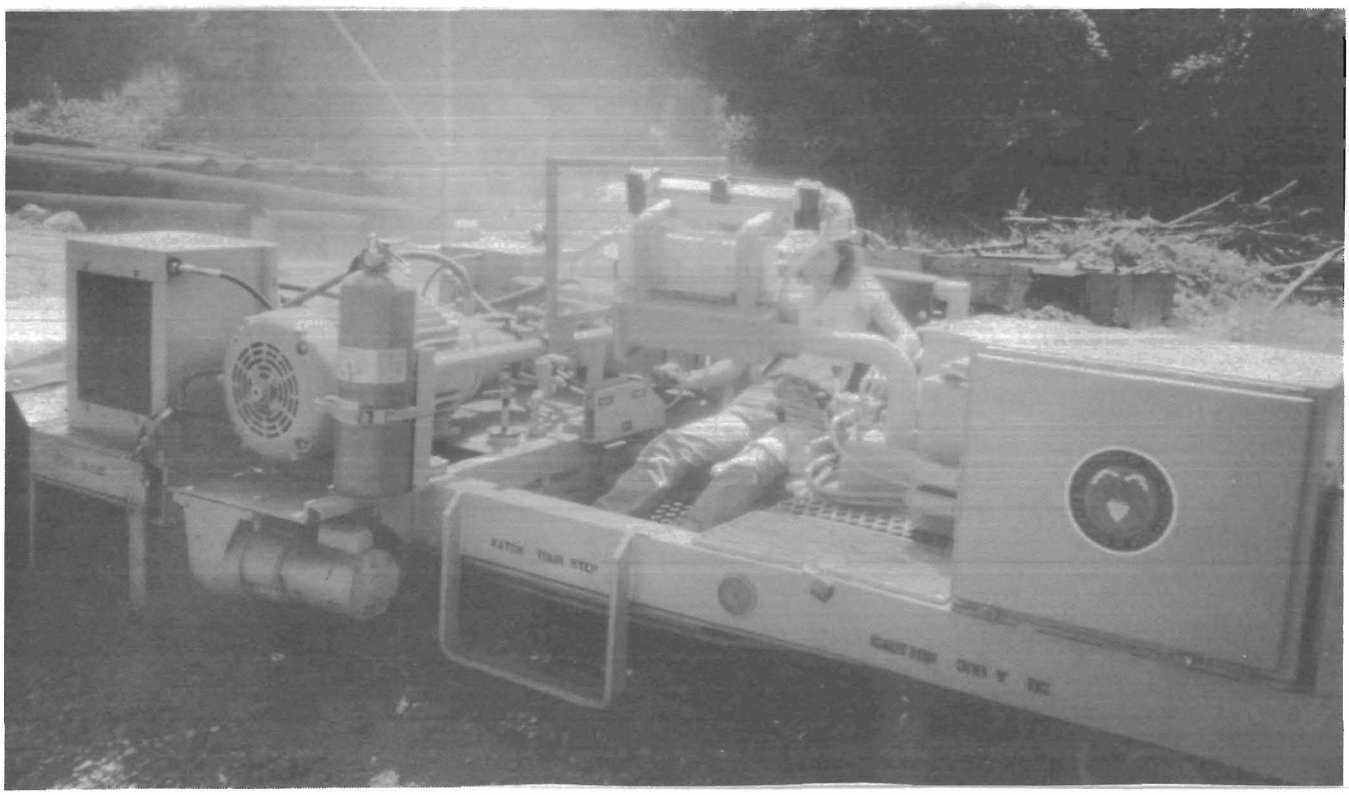


Figure 14.–Transverse operator's station designed to allow easy viewing in both directions.

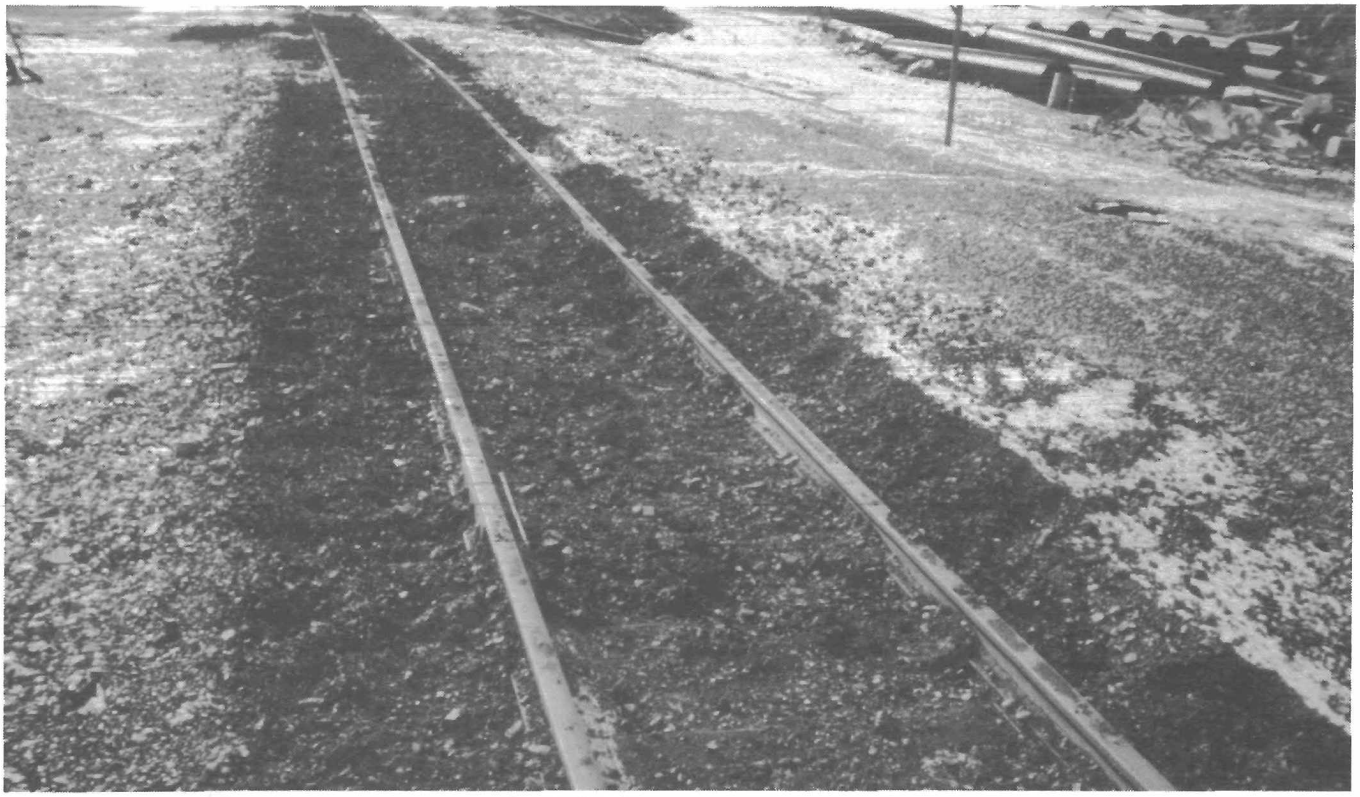


Figure 15.–Test track before cleaning. Run-of-mine material was lightly packed down on track for this test.



Figure 16.–Test track after cleaning. Material deposited at sides of track.

2. The track measuring device performed as well underground as on the surface. Both gauge and cross-level were accurately measured.

3. As with the surface test, the material removal system was the primary problem with the prototype. The conveyor tended to jam under heavy loading and was often difficult to clear. In some cases, pieces of metal, such as heavy bolts, had to be pried out of the conveyor chain by hand. Also, the conveyor housing was too flimsy, and structural failures occurred on two occasions. In both cases, temporary repairs were made and the tests continued (fig. 18). The third failure of the conveyor housing resulted in the termination of further testing.

4. The illumination system needs to be modified to allow better illumination of the track surfaces.

5. As stated earlier, the dust suppression system was not tested. However, mine personnel familiar with the operation of the American mine door machine indicated that the levels of visual dust generated by the prototype were about the same.

6. The operator compartment proved to be comfortable, with easy ingress and/or egress and an easily operated control panel (fig. 19). The only desired improvement would be to increase the visibility over the brush ahead of the machine by raising the height of the seat.

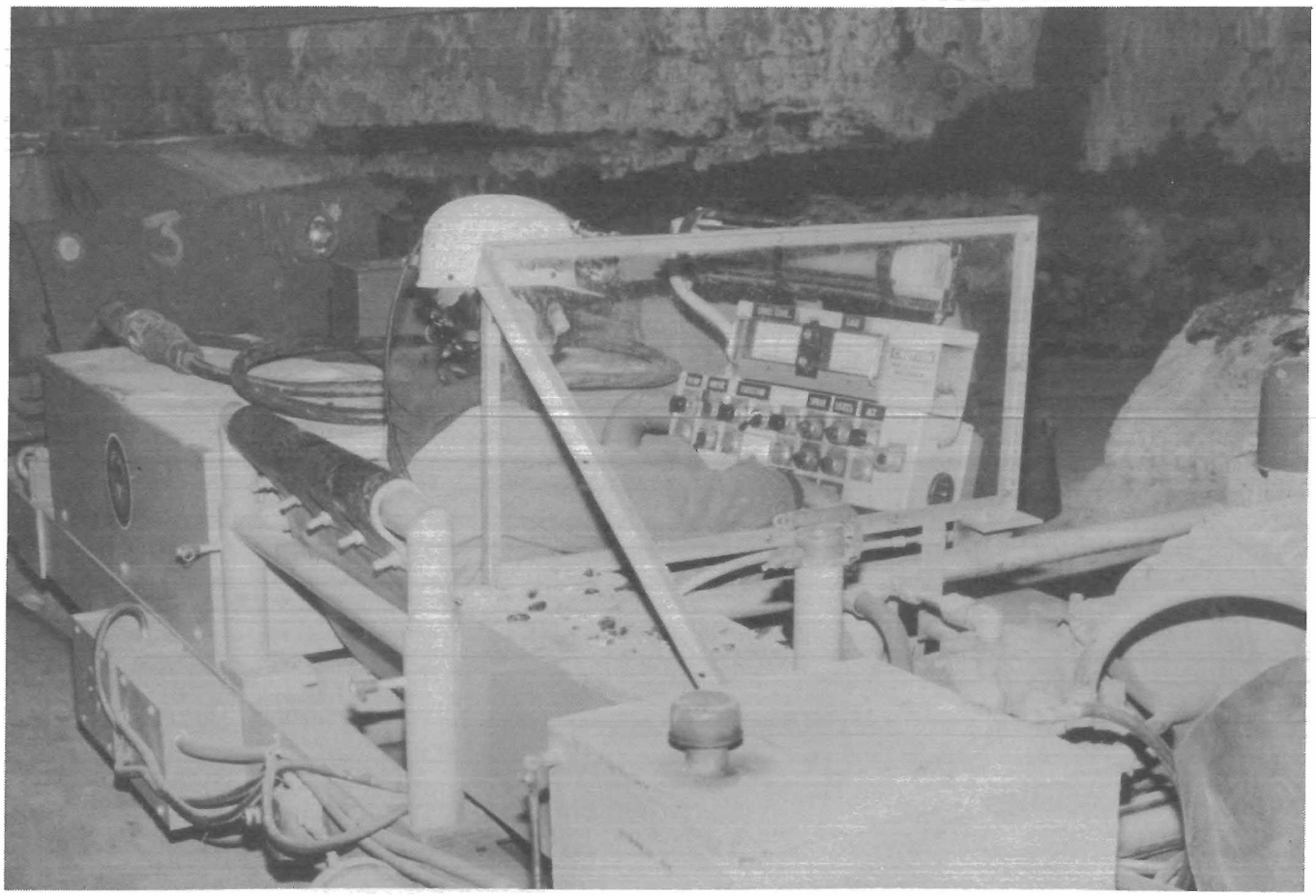


Figure 17.–View of operator's station during underground testing.

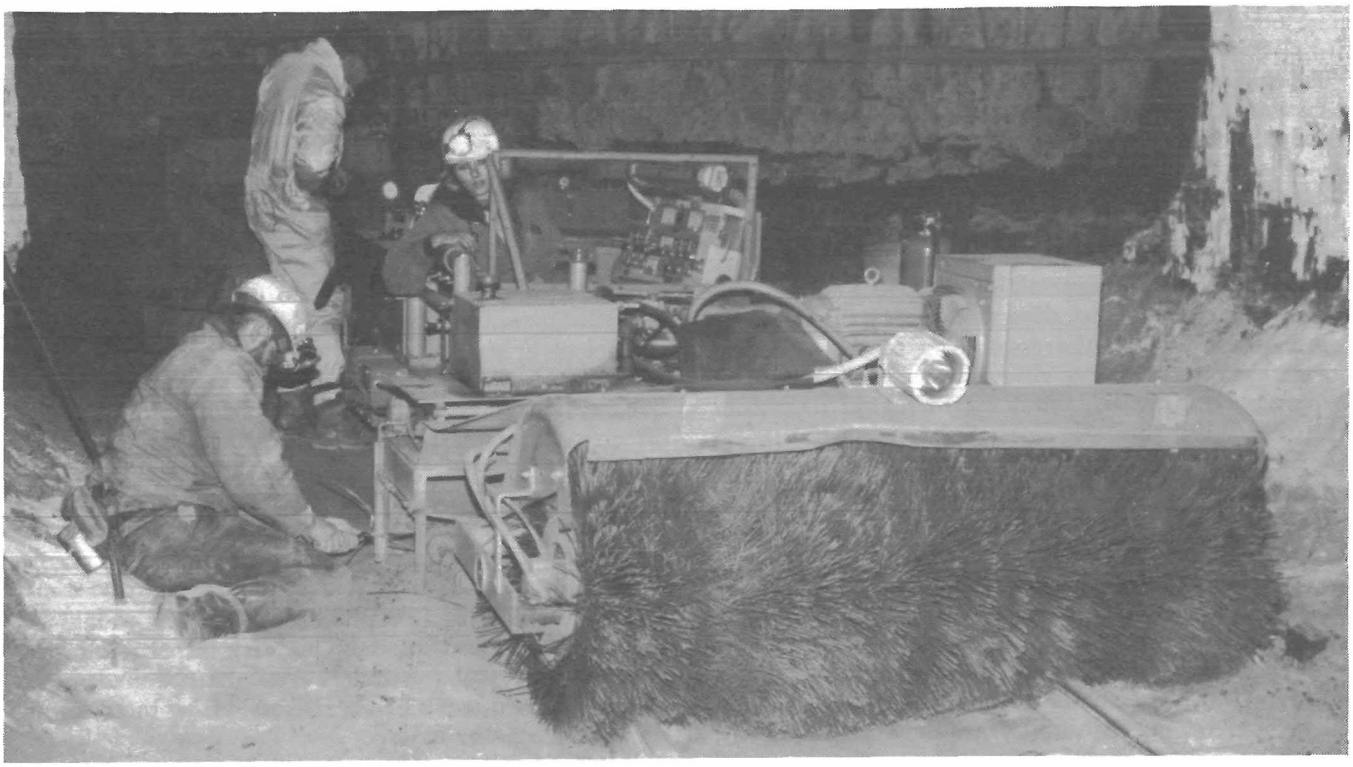


Figure 18.–Bureau technicians making one of two temporary repairs to conveyor system during underground tests.



Figure 19.–Operator station control panel. Note hydraulic controls at lower left.

DISCUSSION AND RECOMMENDATIONS

The original objective of this program was to investigate the current state of the art in track inspection and cleaning procedures. From this work, came the project to develop and test a simple, low-cost prototype track maintenance vehicle.

These objectives were met and a prototype vehicle was tested (to a limited extent) in an underground coal mine. The review of current inspection practices as well as the specification, design, fabrication, and testing stages of the project all resulted in the assembling of the following information:

1. The only currently available commercial track cleaning device, the American mine door track cleaner, does adequate primary cleaning of the track surface. It removes the bulk of the debris from the track, but does not leave it in a state suitable for visual inspection. The machine cannot clean track structures such as switches and frogs.

2. There are currently no known automatic track inspection devices manufactured specifically for the underground mining industry. Track is inspected visually, or by walking it and taking manual measurements.

3. The prototype track maintenance vehicle can be fabricated in a mine shop using only basic shop tools (welder, cutting torch, drill press, and power hand tools).

4. Brushes can be used in an underground environment for effective track cleaning. In both surface and underground tests, the brush was able to clean the track down to the level of the ties. This effectively accomplishes the secondary cleaning of the track. The adverse effects of visual dust generation were lessened because of the air velocity in the haulageways and reduced exposure because of minimum personnel in the mine on the maintenance shift. The brush also worked well in cleaning switches and frogs.

5. The track measurement device operated according to specifications. Both gauge and cross-level readings were taken while the track cleaning was in progress.

6. The concept of a material removal system consisting of a chain conveyor appears to be feasible after some modifications are made. The prototypes' system was flimsy, and the torque generated by the motor and speed reducer were inadequate to transport the volume of material picked up by the brush.

Based on the above findings, the following recommendations are made concerning further use of this technology by the industry:

1. Any further development of track cleaning and inspection devices should be carried out in conjunction with original equipment manufacturers (OEM's) or individual mining companies. The cooperation of OEM's would be critical in transferring this technology to the industry.

2. A simple, self-propelled rail vehicle should be developed for mounting only the track inspection device. Track geometry measurements could then be made easily by maintenance crews or supervisors during their normal travels through the mine.

3. The American mine door track cleaner could be modified to incorporate the brush technology demonstrated by this program. This would result in a machine that would accomplish both primary and secondary cleaning and be capable of cleaning switches and frogs.

4. Mines have different perceptions of how clean haulage track should be. Many mines concentrate their main cleaning and maintenance efforts on the critical switch areas. For these mines, a special rail vehicle should be developed that incorporates the brush technology only. This vehicle would be a simplified version of the prototype tested in this project and used only for cleaning switch areas.

APPENDIX A.–TRACK INSPECTION AND CLEANING IN UNDERGROUND MINES

CURRENT METHODS OF TRACK INSPECTION[1]

Track inspection methods are summarized in the final report on Bureau of Mines contract HO166048, "Construction, Inspection and Maintenance of Mine Haulage Track" by Ensco, Inc., Springfield, VA. Bureau representatives visited 14 underground coal mines and 6 manufacturers of rail products in order to obtain first-hand information on conditions, problems, available track components and tools, and opinions of leaders in the industry. Track maintenance and construction was also discussed with Federal and State inspectors, and information was obtained from numerous manufacturers and suppliers by mail. Main line railroad track, sidings, and yards were visited, and track maintenance was discussed in a division engineer's office. Also, the experience of the Ensco, Inc. project engineers concerning the construction and maintenance of transportation facilities was used to evaluate the relevant information in the literature.

Determination of Track Condition

In the underground coal industry, track condition is generally determined through visual observation, and ride quality from motors and mantrips. The track is inspected by motorpersons and supervisors, who observe the track carefully when they ride over it and who note the ride quality as shown by the pitch and roll of the cars and by the jolts caused by track defects. Mechanics inspect switches and frogs[2] periodically when they lubricate the switches. In a few cases, supervisors walk their sections of track and inspect them periodically.

Track geometry and track defects are usually only inspected when reportable accidents occur. On a day-to-day basis inspection tools are not commonly used, either to detect worsening conditions or to control the adjustment of the track.

The same inspection procedures are used for supply and section track as for the main haulage track, with the emphasis on frequent visual inspection of all the track and periodic close inspection of turnouts when the switches are lubricated. However, the inspection of this track is less rigorous, as rail traffic can be operated at very low speeds where necessary to safely pass track defects.

Excessive wear and damage to frogs can often be seen as shown in figure A-1, but comparison to frogs in good condition or hand measurements are needed in order to determine the amount of wear. Cluttered frog flangeways[3] or debris that obstructs switch points[4] or the flangeways at crossings are found by visual inspection.

Missing bolts and loose bolts (fig. A-2) are detected by careful visual inspection; loose bolts are checked by tapping them lightly with a hammer, and bolt tension is checked with a hand wrench. If most of the bolts at a joint are loose, the clatter that the joint bars make when a car passes over the joint may be heard from the car.

Loose spikes are often visible, as the heads stick up higher than those of adjacent tight spikes. Questionable spikes are tapped lightly with a hammer, and incorrect spiking is found by making a check against known correct spiking patterns. Incorrectly positioned tie plates[5] and incorrectly installed track fastenings are detected visually by supervisors and inspectors who are familiar with the design of the track and the correct installation of track components, or by others who check the track components against the installation diagrams provided by manufacturers.

Large spalls and fractures (fig. A-3), can be found by visual inspection, but cracks and internal rail defects that may lead to rail breaks can be detected only with special equipment. Low joints (fig. A-4) can be found by observing the movement of a rail under traffic.

Defective fastenings (fig. A-5) are found by looking for fractures or signs of movement, such as the raised end of a guard rail, a guard rail that is not parallel to the running rail, a wide gap between a rail end and the end of a frog, cuts and marks on ties, wheel marks on frogs and rails, sharp kinks in the rails at joints, and bent switch rods.[6]

Deteriorated switches are detected by looking for bent switch throw rods (fig. A-6), by searching for signs of damage or wear at the switch points (fig. A-7), by checking the action of the switch and the positioning of the point rails when the switch is thrown, by checking all fasteners at switches for looseness and signs of movement, and by measuring gauge and other critical dimensions (such as the spread between the heels of the switch point rails and the stock rails,[7] and the switch throw at the switch rod).

The wear at the ends of rails is estimated. When it appears to be excessive, it is checked by measuring downward from a straight edge placed along the tops of the rails. Lateral deformation of the heads of rails is often checked by touch, as a lip that forms on the inside edge of a railhead[8] can be felt before it can be seen.

Other track-related problems, such as soft ground, mud pumping, and debris on the track or in the side clearance zones are more easily detected by mine personnel. In some cases, where the track is covered with dirt or debris almost to the top of the rails, wide gauge can be seen without measuring the track, because of the marks left in

[1]See text footnote 2.

[2]See text footnote 5.

[3]Flangeway–a slot or passageway through which wheel flanges move at structures such as frogs and guard rails.

[4]Switch point–a movable, tapered length of rail used to change the path of a wheel from one rail to another.

[5]Tie plate–a steel or plastic plate placed under the rail on top of the tie to protect the tie and help hold the rail in position.

[6]Switch rod–a rod connecting a pair of switch points so that they move as a unit.

[7]Stock rail–a running rail against which a switch point operates.

[8]Railhead–the top portion of the rail; the portion of the rail with the surface on which the wheels run.



Figure A-1.–Frog showing marks of wear.



Figure A-2.–Example of loose bolts at rail joint.

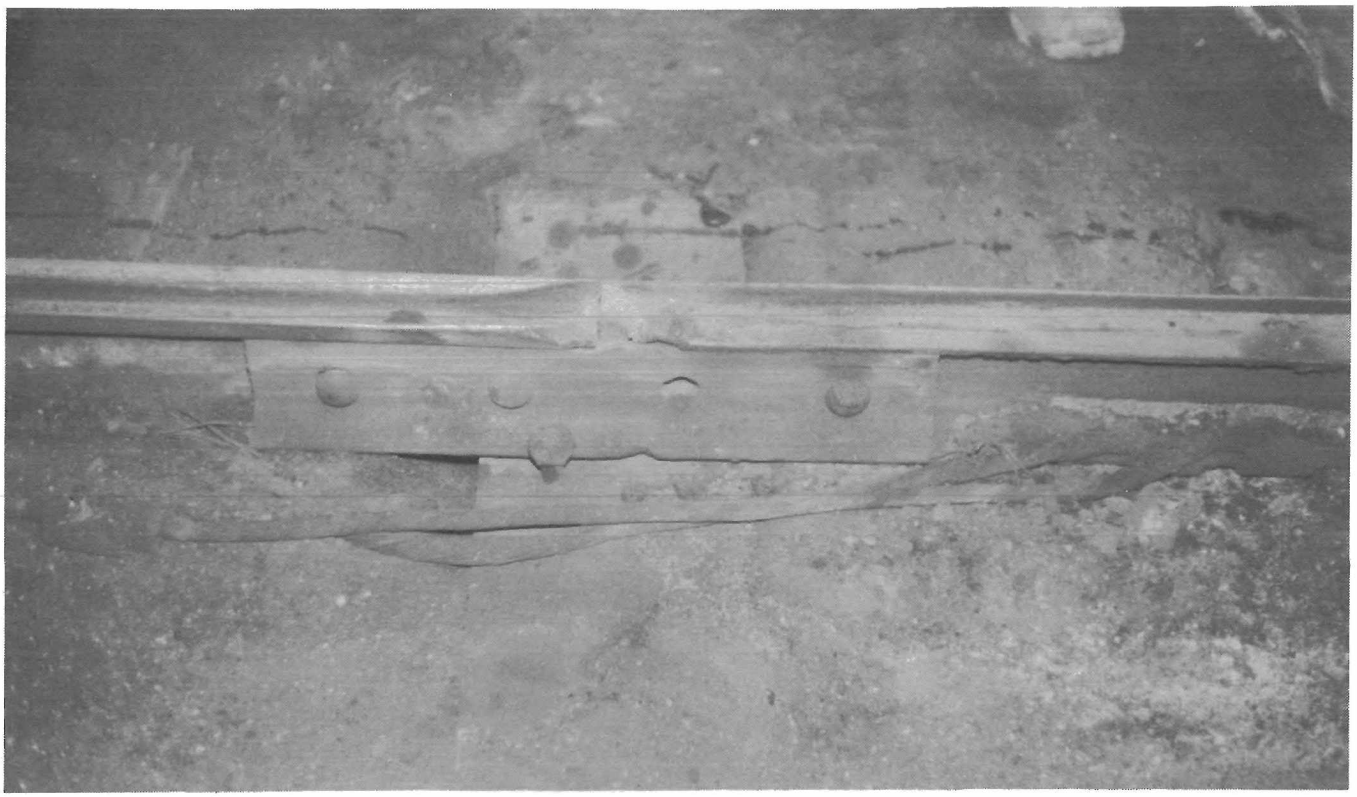


Figure A-3.–Large spalls at rail ends.

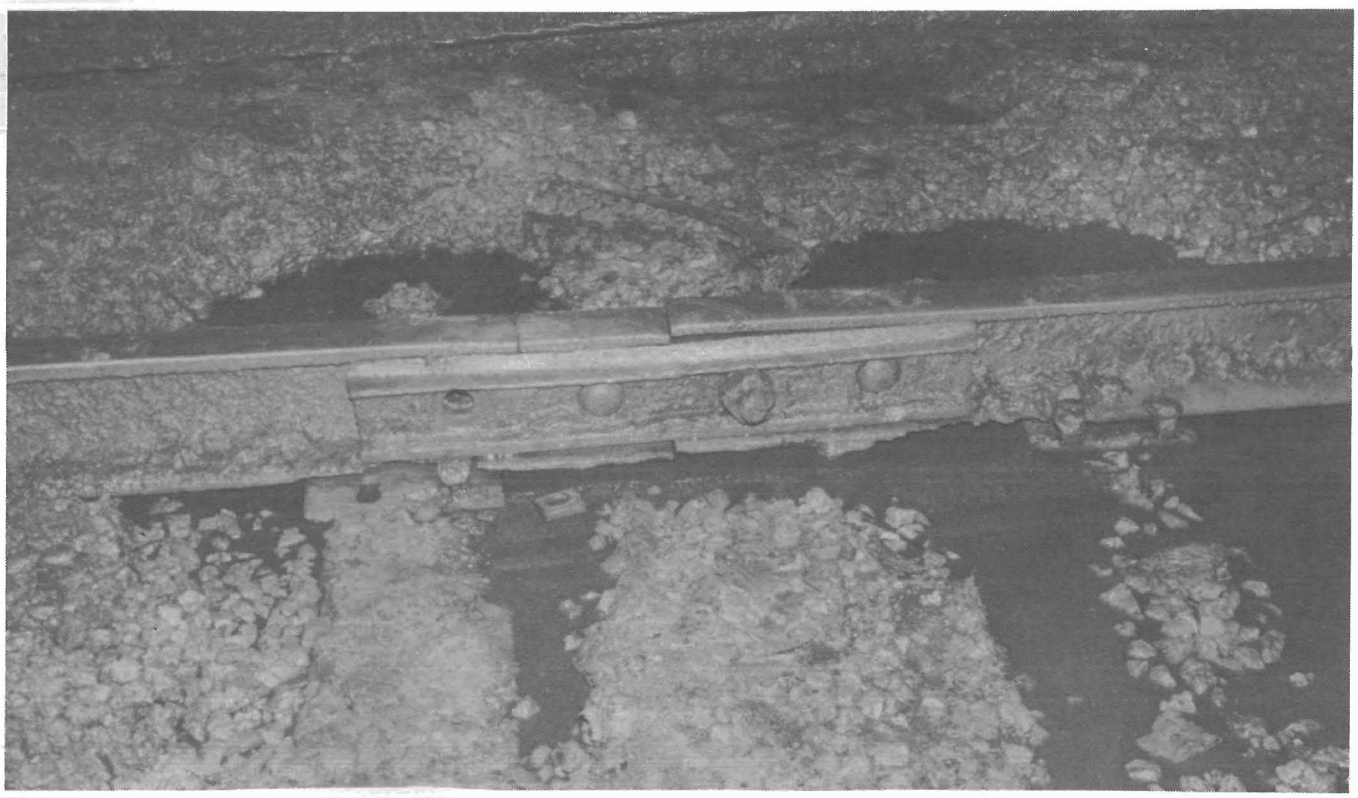


Figure A-4.–Muddy areas can lead to low joints.

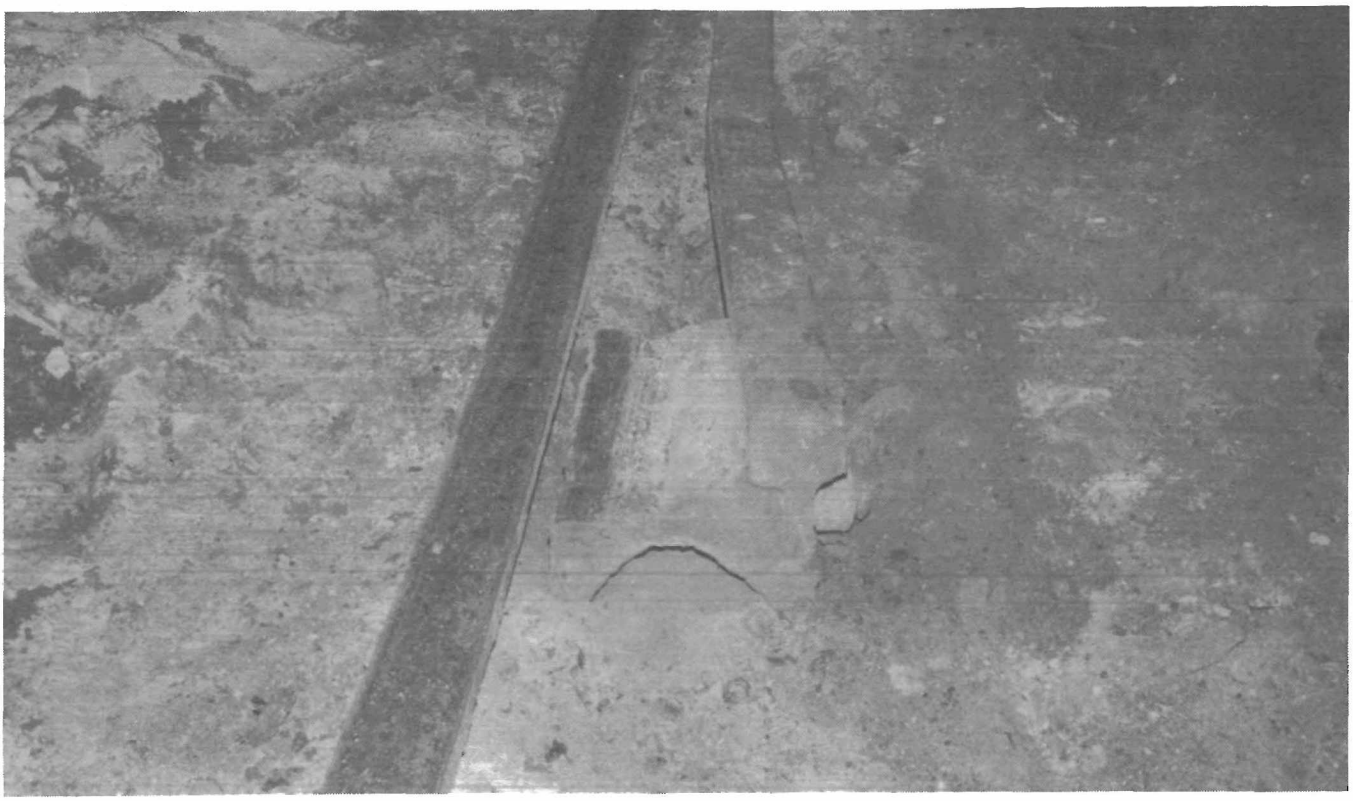


Figure A-5.–Loose guard rail opposite frog.

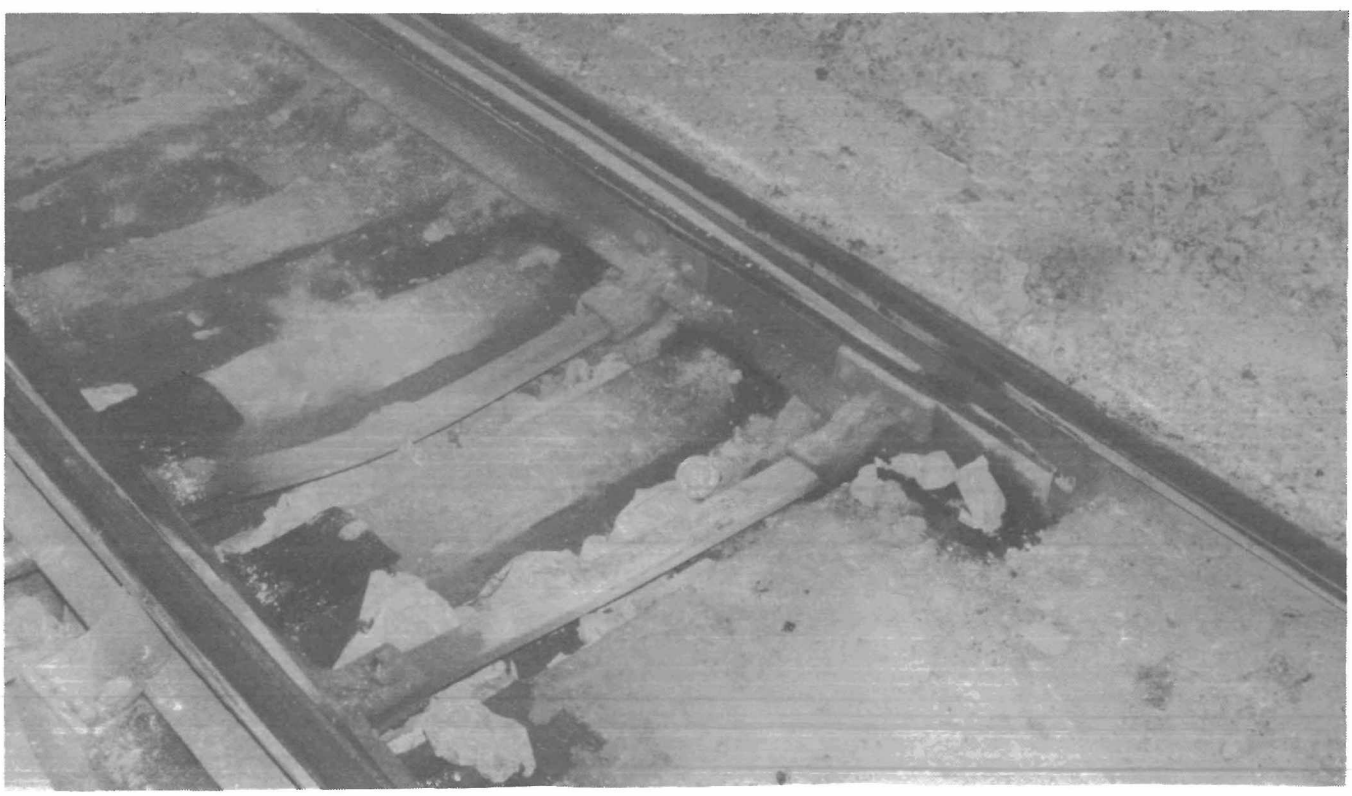


Figure A-6.–Bent switch throw rod.

the dirt by the wheel flanges. However, wide or tight gauge cannot normally be detected by visual observation, and other track defects that are worsening gradually are not usually noticed until they become serious. Thus, defects are often not reported until they become significant, requiring expensive corrective work.

In general, the reliance on visual observation and memory is not misplaced. At most mines, only a few miles of track is used and it is observed closely by many people. In addition, most serious track defects, such as broken joints or low joints in soft ground, are easily detected. However, visual inspections from moving cars alone are not sufficient for the detection of many defects, such as slightly loose bolts or cracked joint bars. No visual inspections can identify *all* track defects in time for the conditions to be easily corrected before they become dangerous. Careful visual inspections may not reveal cases of tight or wide gauge, small cracks in joint bars, internal rail defects, or joints that deflect badly under wheel loads, but appear satisfactory when the track is not loaded.

Visual inspection is highly subjective, except for a few items that can be categorized and counted, such as missing or broken bolts. Accordingly, different people can have varying opinions on the seriousness of the same defects; and, even if all of the track were inspected frequently by one person, that individual's opinion on the seriousness of a track defect could vary from time to time. This variation in inspection arises from the use of a moving-base comparison, in which the observed, but unmeasured defects are compared with the conditions remembered from the last time the inspector viewed the track, instead of being compared with fixed standards.

Persons who inspect the track become tolerant of defects that gradually grow worse. Such defects may go unreported and may cause derailments. Track defects that are difficult to detect by visual observation alone, or whose degree of seriousness and urgency is difficult to estimate until they become dangerous, include: tight gauge on curves, wide gauge, twist, low joints, bad cross-level, cracked joint bars, and internal rail defects. Even loose bolts are difficult to see until unnecessary wear or damage occurs. To detect these flaws, mechanical inspection methods are needed to supplement visual inspections.

Track levels and other hand tools are available for measuring the track, but these devices are seldom used during the visual inspection of track. Inspection tools are used to measure track after derailments or when other damage has occurred that require reports. However, the track is seldom measured when minor derailments occur.

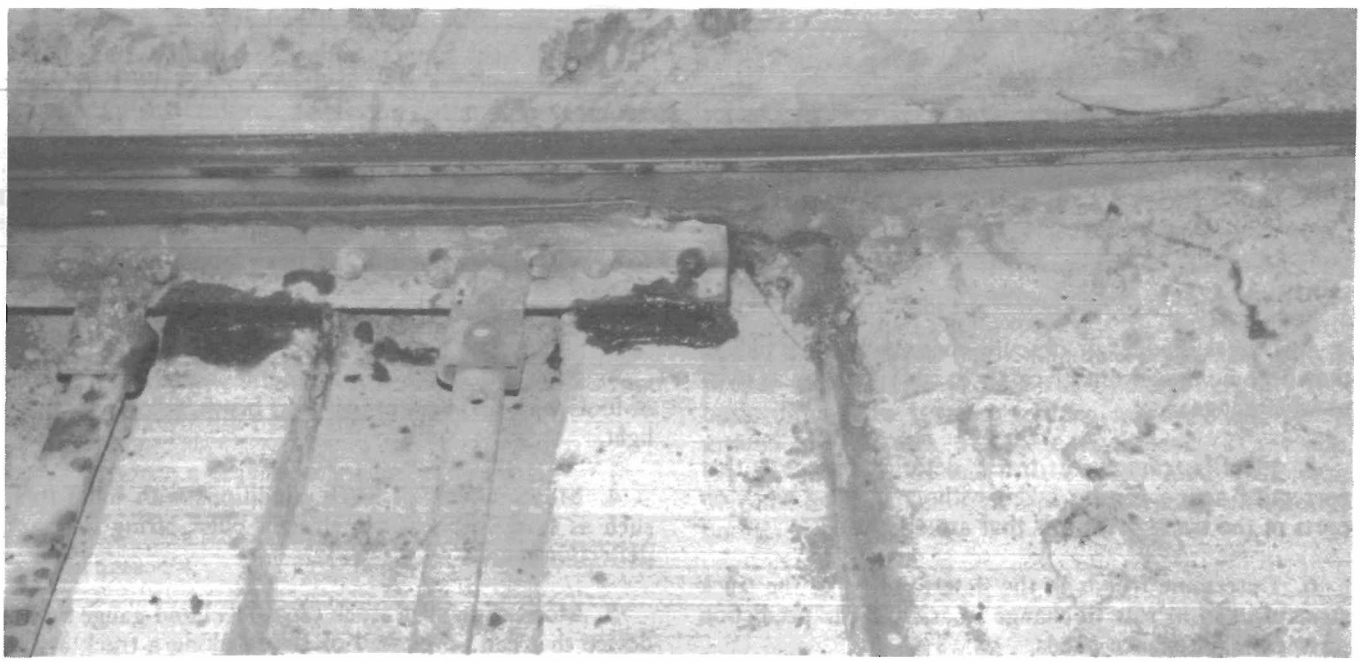


Figure A-7.–Damaged switch point.

Reporting of Track Defects

Track defects and deficiencies observed by motorpersons are normally reported to the dispatcher. The dispatcher notes the report and informs the track supervisor or the maintenance supervisor when they check at the office, or the dispatcher may leave a written note for the supervisor if unavailable. Defects observed by other inspectors or supervisors are reported informally by telephone calls, notes, or discussion with the track supervisor. Informal records and reminders are kept for only a short time.

In mines that stress maintenance, the reliance on visual inspections and memory results in the reporting of some imaginary or insignificant track defects and the performance of unnecessary maintenance work that could be omitted if measurements were made and recorded. Records would help identify costly maintenance practices, such as the repetitive tamping of ballast into mud at low joints, and indicate how maintenance costs could be reduced.

Track Inspection Goals

Track inspection should fill several distinct needs:

1. Determine track conditions and repair work required or changes in speed limits to comply with safety standards or track conditions.

2. Control track construction, alteration, and major repair.

3. Detect large changes in track conditions that occur unexpectedly and present serious hazards (such as obstructions caused by rock falls, damaged switches, and broken rails).

4. Detect gradual or obscure changes in track before they become dangerous or costly to correct (such as twist or wide gauge).

5. Identify causes of track deterioration, so that corrective action can be taken without wasting work on parts of the track structures that are adequate.

6. Determine trends in the deterioration of the track structure and its rate of change to assist in the prediction of track maintenance needs.

From this evaluation of the inspection needs, it was determined that several frequencies and intensities of track inspection are necessary, and that the methods and equipment used should suit the levels of inspection intensity. Daily inspections are necessary during track construction, alterations, and major repairs. Accurate measurements should be made to ensure compatibility with plans and specifications. Frequent visual inspections from cars are necessary to detect obvious unsafe conditions and observe other track conditions that can be seen from a car. Detailed inspections on foot are necessary at all reported track defect locations; these should include cleaning and a detailed examination of track parts and major track components, plus measurements of track geometry to uncover conditions that may have contributed to the defects. Detailed inspections are necessary at the site of derailments or other damage. The entire track should be inspected periodically to obtain detailed information on the condition of the track structure and components and information on changes in conditions for the planning and scheduling of routine maintenance work.

With detailed inspections, emphasis should be placed on measuring track geometry (the position of the rails and the deflection of the rails under load), because conditions at the rail heads represent the cumulative effect of the conditions of all components and parts of the track structure. Often the first indication of deterioration in other parts of the track structure is indicated by changes in the position of the rails or by increases in the deflection of the rails when heavily loaded wheels pass over them. For example, excessive deflection under load is an important indicator of weak support under a tie, damaged joint bars, or other conditions that will worsen rapidly and cause serious trouble unless corrected.

The methods that should be used by an inspector are listed in ascending order based on the amount of time and the complexity of the inspection equipment needed:

1. Visual inspection of the track from moving cars.

2. Visual inspection while on foot.

3. Close examination of track components with the use of tools such as hammer, pry bar, brush, rule, and strong light.

4. Measurement of track conditions with hand tools such as track level, gauge, straight edge, string line, and deflection meter.

5. Measurement of track cross-level and gauge with a device that can be pushed or towed along a track at low speed.

6. Measurement of rail alignment and profile with a device that can be pushed along a track by an operator.

CURRENT METHODS OF TRACK CLEANING[9]

Current underground track cleaning practices were investigated by Bureau researchers and their representatives by means of telephone surveys, visits to mines and manufacturers, and a detailed literature survey. This information was gathered as a precursor to the design of an underground track maintenance vehicle under Bureau contract HO318082, "Track Maintenance Systems: Track Cleaning Car" by Foster Miller Inc., Waltham, MA.

Federal regulations require mine operators to maintain safe, clean walkways, however, they are not required to clean the track to make it suitable for inspection. As noted in the previous section, visual inspection is an important component to a good overall track maintenance plan.

Information on underground track cleaning policies and practices was obtained from 24 government agencies and mining company officials. Their responses to questions concerning underground track cleaning are listed below. They reveal that there are many variations in the frequency and methods of track cleaning.

1. Responses to questions on the frequency of track cleaning:

a. On a regular basis (weekends, off-days, midnight shift).

b. Constantly around belt, track, or roadways.

c. Twice a year.

d. Every 6, 7, or 8 months.

e. Every 3 or 4 months.

f. When coal is piled up so badly it is a necessity.

g. Only when issued a citation, usually for not properly maintaining a walkway.

h. Once a year from spalling of the roof.

2. Responses to questions on the methods of track cleaning:

a. Entirely by machine.

b. Entirely by the use of hand tools.

c. On a 50-50 basis (hand or machine).

d. By machine, when there is a lot of spillage.

e. By hand, when there is not too much spillage.

f. Constantly by hand (3 or 4 laborers cleaning 1,000 ft at a time).

There have been various attempts at mechanized track cleaning. The American Mine Door Co., Canton, OH manufactures one of only two commercially available underground track cleaners in the United States. The machine was originally introduced in 1948 and approximately 180 units have been sold since then. The CARD Equipment Co., Westwood Station, Denver, CO, has begun marketing the Mastek L-5R Loader to clean track. As of 1986, there have been no units sold in the United States. Several mines have developed modified loaders to clean track, and two vacuum cleaning devices have been used underground. Brief summaries of the operation of all these systems can be found in appendix B.

SURFACE RAILROAD TRACK INSPECTION AND CLEANING

The state of the art in surface railroad track cleaning and inspection was also looked at as a part of this program. In the United States, the railroad industry operates about 33,000 miles of surface track, and as such has accumulated enormous experience in developing procedures, regulations, and equipment to accomplish the proper maintenance of their roadbeds. There are four basic differences between surface railroads and underground mining track, (1) the environment, (2) the size, (3) the travel speeds, and (4) the design loads. The basic objective of maintaining safety on the track is common to both industries.

[9]See text footnote 4.

Surface railroad cleaning and inspection is summarized as follows:

1. *Cleaning Practices* - The track and ballast are cleaned at regular intervals in accordance with well established procedures.

2. *Inspection* - Inspection procedures are established and standardized by the Federal Railroad Administration.

3. *Equipment* - There are at least three commercially available surface railroad track cleaners, which make the track suitable for visual inspection. Although all three differ in design features, the principles of their operation are essentially similar and utilize a two step process:

a. *Removal of the bulk of the dirt* - Scrapers are used to loosen hard packed material, plows to gather the material in the center, bucket elevators to lift it and drop it into a hopper, and a belt conveyor to move the material into the railroad car.

b. *Brushing* - All railroad cleaners have rotating brushes of approximately 40-in diameter and 9-ft width. The function of the brushes is to clean the top of ties, ballast, fishplates, and spikes. In switch and crossover areas, the brushes are used without previous use of scrapers.

The results of cleaning with this two-stage process can be seen in figures A-8 through A-10.

CONCLUSIONS OF THE TRACK INSPECTION AND CLEANING STUDY

The results of the study of the state of the art in underground track inspection and cleaning are reviewed below:

1. *Inspection* - There are no established standards or procedures that are used throughout the industry. Many defects remain hidden from an inspector due to layers of dirt and debris on the ballast, spikes, fishplates, etc. There is no specialized training for personnel assigned to inspect the track, and few inspection records are maintained. However, an executive from one coal company has stated that there is a need for some type of instrumentation which would measure the track gauge and the cross-level of the rails. According to this official, this would allow the company to realize about $28,000/yr in labor cost savings for each of their mines. Visual inspections should be augmented by mechanical measurement of track geometries.

2. *Cleaning practices* - Owing to the many variations in frequency and requirements of track cleaning from mine to mine, there is a need for a general cleaning method capable of maintaining the track in a state suitable for periodic visual inspection.

3. *Cleaning equipment* - The American Mine Door Co. markets the only machine designed exclusively as an underground track cleaner that is known to be operating in the United States. It is a mucking machine which clears the track and walkways of large amounts of debris. It does allow movement of the traffic without damage to the bottom of the rolling stock and relatively safe passage through the walkways.

The necessity of having a clean and structurally sound track is accepted throughout the mining industry, but exact track cleaning and inspection requirements and methodologies are understood differently by different people. The interviews with mining company personnel revealed that the goal of maintaining a clean track suitable for visual inspection is shared by many corporate safety officials. The underground maintenance personnel generally consider the track clean and safe when the traffic moves, coal is delivered to the surface, and walkways are clear from obstacles.



Figure A-8.–Unidentified railroad track cleaning machine.

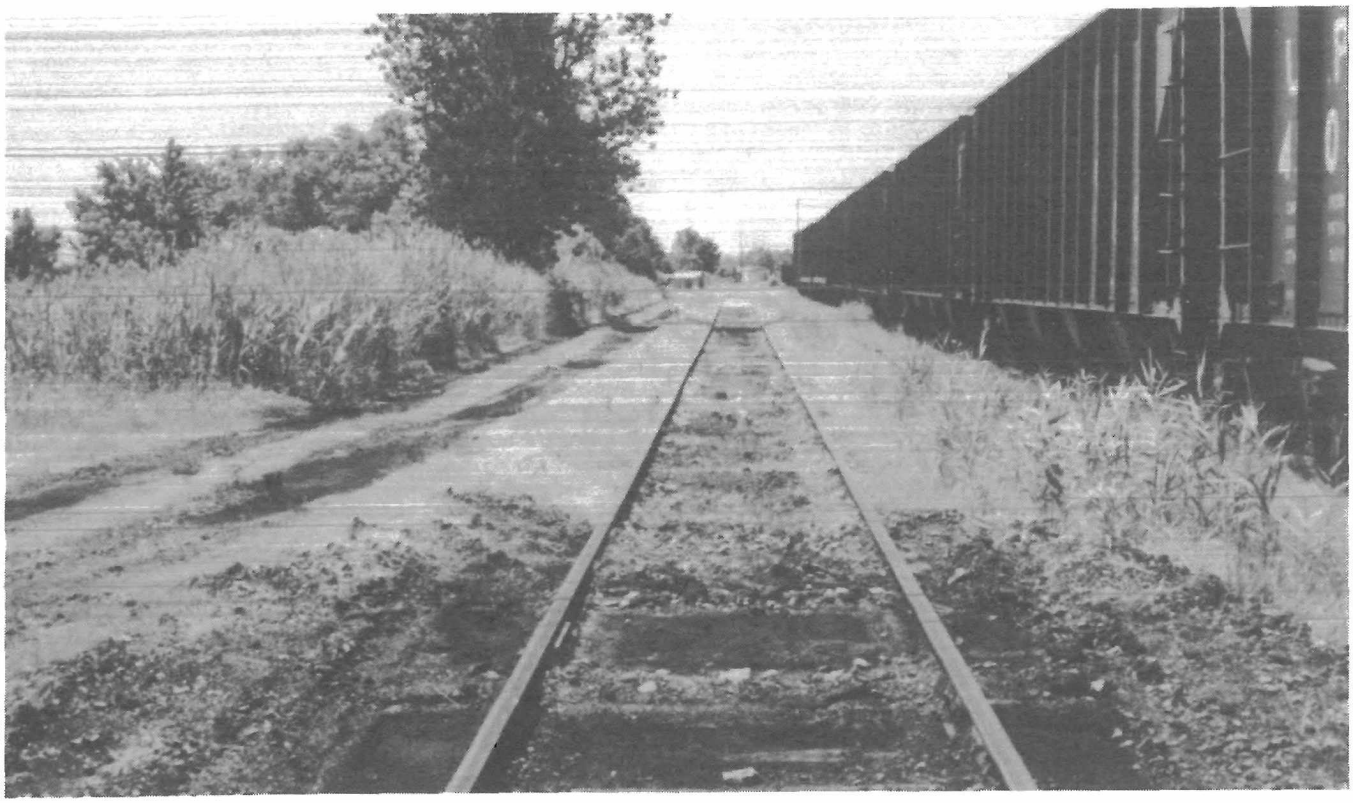


Figure A-9.–Original surface railroad track condition.



Figure A-10.–Track after cleaning. Note top surface of ties and spike heads.

APPENDIX B.–TRACK CLEANING DEVICES

AMERICAN MINE DOOR TRACK CLEANER

The American Mine Door Co. produces the model 70 track cleaning machine (fig. B-1). It has a scraping pan which can be raised or lowered and two hydraulically operated side arms that move horizontally and vertically. As the cleaner is pulled by a locomotive, the dirt and debris are forced up the slope of the pan by a gathering conveyor. A large chain conveyor transports the debris toward the end of the machine and into a coal car. To tip the scraping pan, the whole unit is rotated about the front wheel axis by means of a lever and a hydraulic cylinder.

Two hydraulically operated side arms are used for gathering debris from the side of the track (walkways) and guiding it into the gathering pan. A 50-hp hydraulic power unit, which is energized from the main trolley line, drives both conveyors and the cylinders' operation.

Operation of the cleaner was observed in four mines. The machine, which works smoothly, does a fairly good job in removing the bulk of the debris from the track and the walkways. However, the track is not cleaned to the extent needed to perform a proper visual inspection. Also, despite its bulky construction, there were some complaints that the machine is flimsy, particularly when it is raised, or lowered. In addition, the scraping pan tends to rip out rail bonds that have not been buried between the ties (fig. B-2).

MODIFIED LOADER

Several mines have modified loaders for track cleaning purposes. The performance of one of these machines was observed in a mine visit (fig. B-3). The machine has slots cut into the gathering pan so that it can be lowered below the top of the rail.

In comparison with hand shoveling, the modified loader quickly removes the bulk of the debris. However, the gathering pan can only be raised 2 in from its nominal down position, and since there is no auxiliary dirt removal system, it is useless in crossovers, switches, and frogs. Therefore, these areas must be cleaned by hand.

Modification of the loader to perform track cleaning is usually done in the mine shops, and if drawings and instructions are supplied, it is possible that many of these shops have the capability to produce a workable track cleaning machine.

MASTEK L-5R LOADER

Limited information could be found about the Mastek L-5R loader used for cleaning track. The device is similar to the American mine door machine with the addition of a back-hoe type shovel to push material onto a chain conveyor (fig. B-4). As of 1986, no units are known to be operating in the United States.

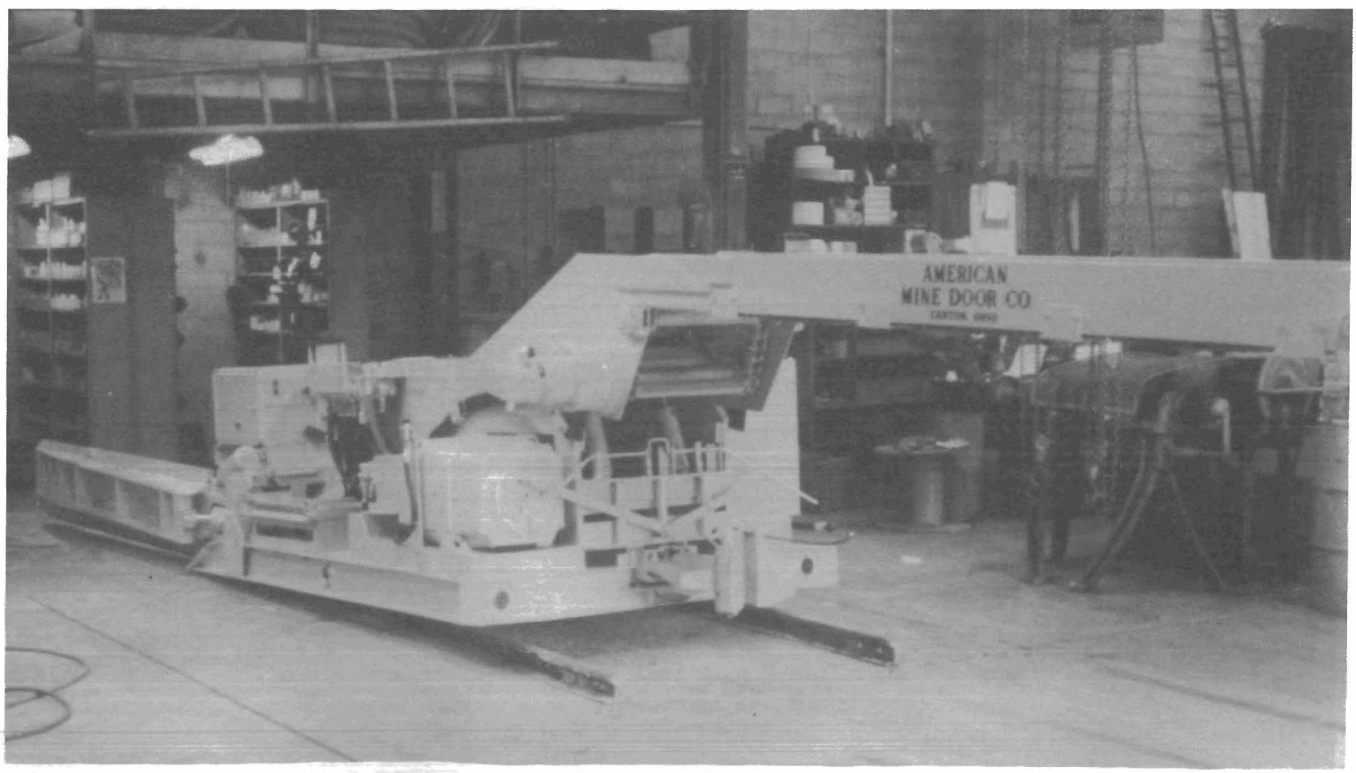


Figure B-1.–American mine door track cleaner model 70 as of 1982.

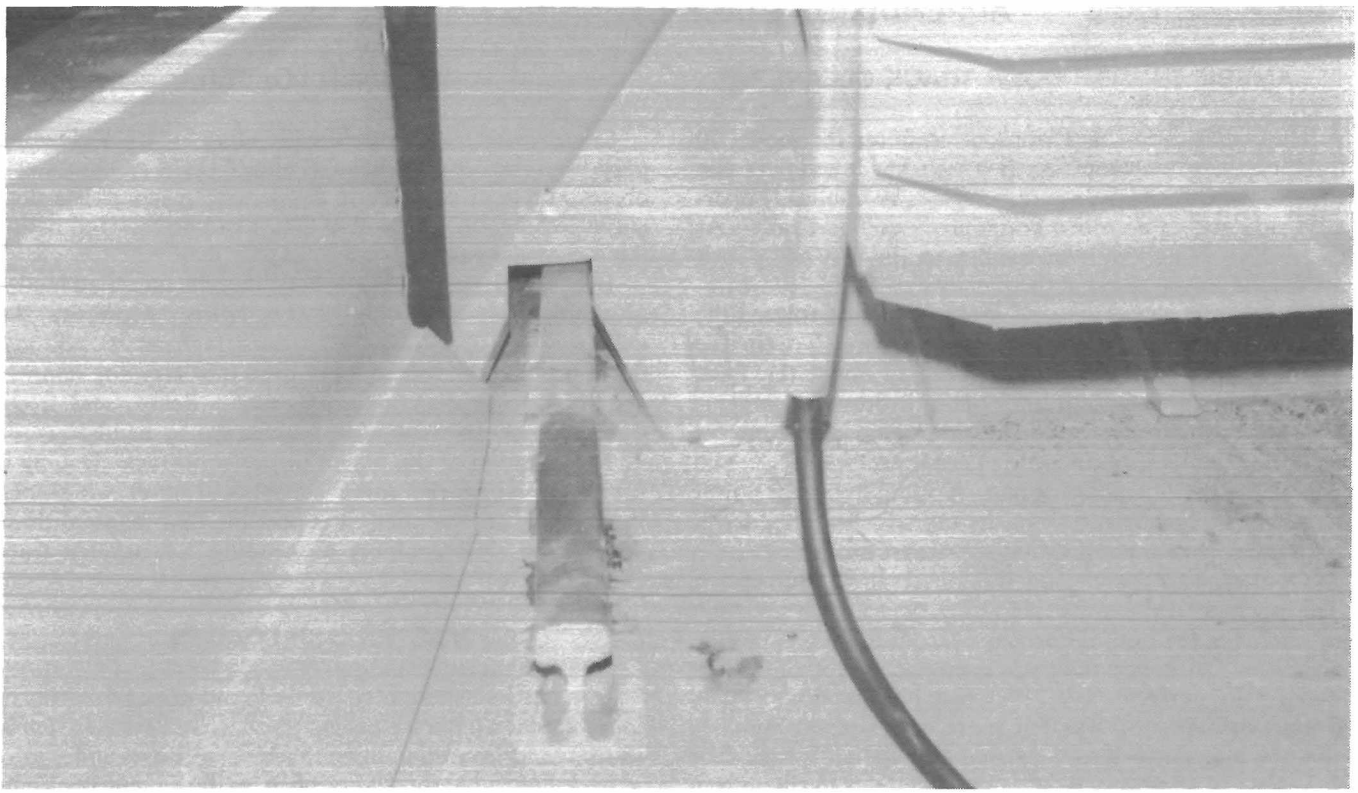


Figure B-2.–Close-up of American mine door track cleaner scraping pan. It fits over rails and may rip out rail bonds.

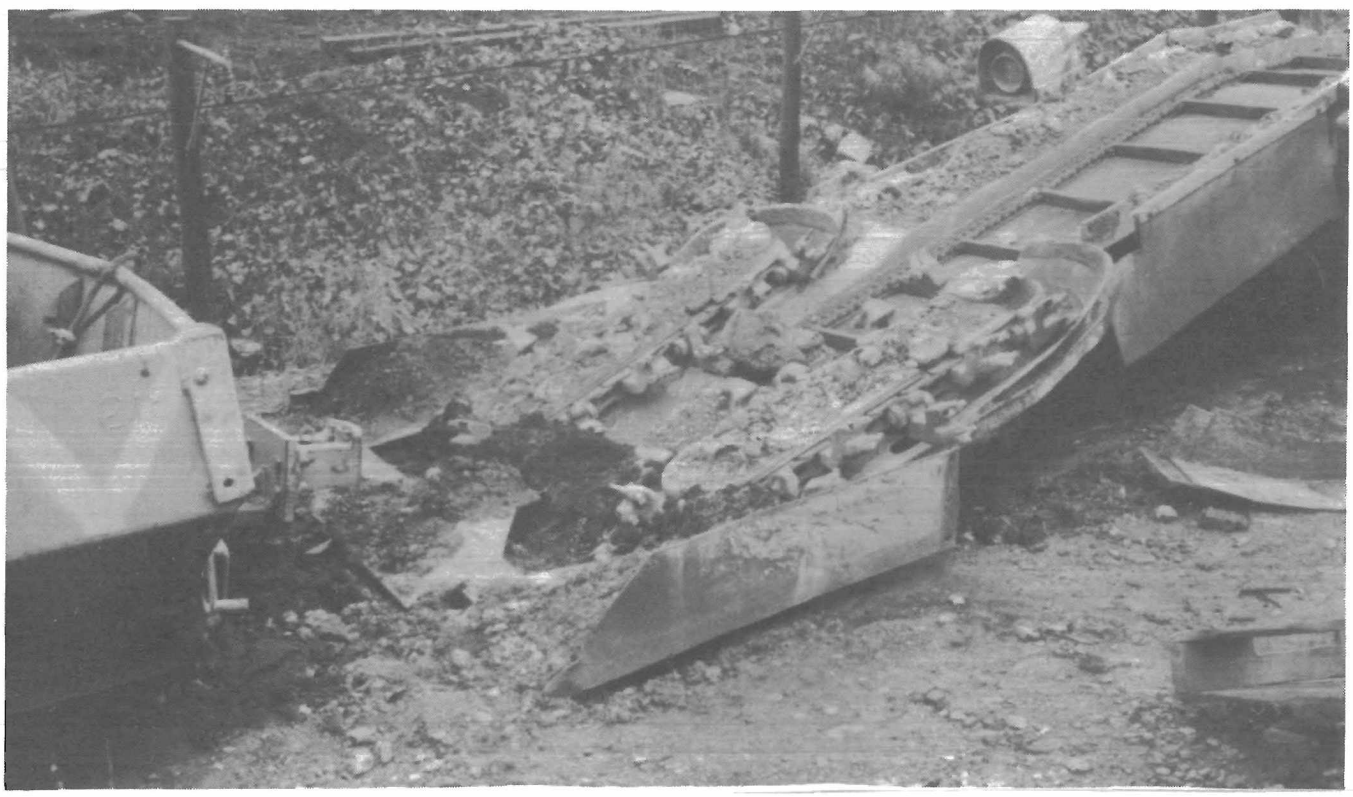


Figure B-3.–Modified loader for track cleaning.

VACUUM CLEANING DEVICES FOR UNDERGROUND MINES

Although the previously described machines are the main ones used for track cleaning, there are some vacuum devices that have been used underground.

Hi-Vac System

This system is used in an underground asbestos mine for removal of a slurry consisting of water, rock, and asbestos from numerous drainage ditches.

The Hi-Vac machine features a positive displacement vacuum pump driven by a 50-hp diesel engine, three filtration stages, controls and protection devices. The system consists of two rail-mounted cars: the vacuum cleaning car and a 3.2 yd^3 intercept tank car. The cars are coupled and pulled by a locomotive.

Material from the ditch is sucked through a pickup hose into the intercept tank and most of it falls out of the airstream. Lighter dust particles and mist keep moving and go through a centrifugal separator, a linear separator, and finally through a cloth bag. The manufacturer claims that exhaust air passing through the vacuum pump and muffler silencer is virtually free from all respirable particles.

According to the manufacturer, the system draws in about 10 st of slurry per hour. After the intercept tank is full, it is towed away and emptied at a dump station, where water runs off and asbestos mineral is reclaimed.

Coal Mine Vacuum Sweeper

The mobile mine vacuum sweeper (fig. B-5) was designed to remove loose coal and coal dust and to do cleanup work in belt entries and against ribs. The sweeper design can be divided into the following subsystems:

1. Nozzle and articulated boom.
2. Dust separation.
   a. Primary separation.
   b. Secondary separation.
3. Material transport.
4. Air moving system.
5. Water moving system.

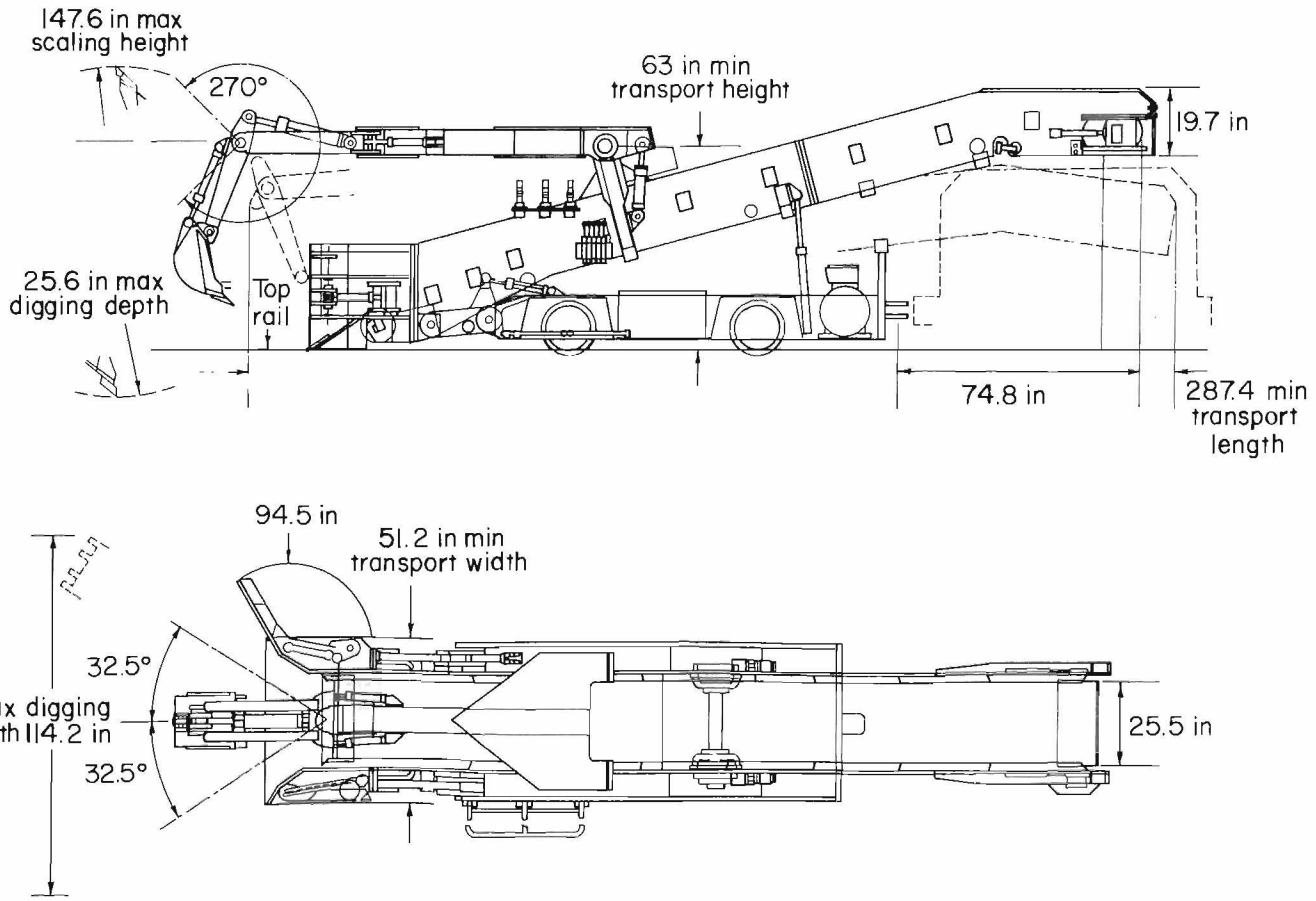


Figure B-4.–Mastek L-5R loader.

The nozzle-boom assembly consists of two hinged joints, which allow an outer joint articulation of 90° and an inner joint articulation of about 55°. The nozzle can be lifted or lowered by a hydraulic cylinder.

The primary separation system consists of two spaced baffles that are at right angles to the airflow (fig. B-6). Each baffle contains an orifice followed by a deflector. The orifice is sprayed with a hollow cone nozzle. Secondary separation includes a Venturi scrubber with a throat velocity of 25,000 ft/min, followed by a cyclonic mist eliminator.

The primary and secondary separation systems are integrally contained as a module within a 150 psi American Society of Mechanical Engineers (ASME) pressure vessel. In addition to the separation systems, the first stage of the material transport system is also contained within the pressure vessel. Collected material falls into the bottom of the pressure vessel, where a screw conveyor operates against the slopping bottom of the vessel chamber. The conveyor moves material to an exit port which is covered and sealed by a rotating external valve seal. During the unloading cycle, material from the exit port drops into a hopper for a second screw conveyor. The second conveyor transports the collected material to the conveyor belt under which the sweeper is operating.

The sweeper was designed for:

1. Inlet dust loading of 200 lb/min.

2. Outlet dust loading of <10 mg/m^3.

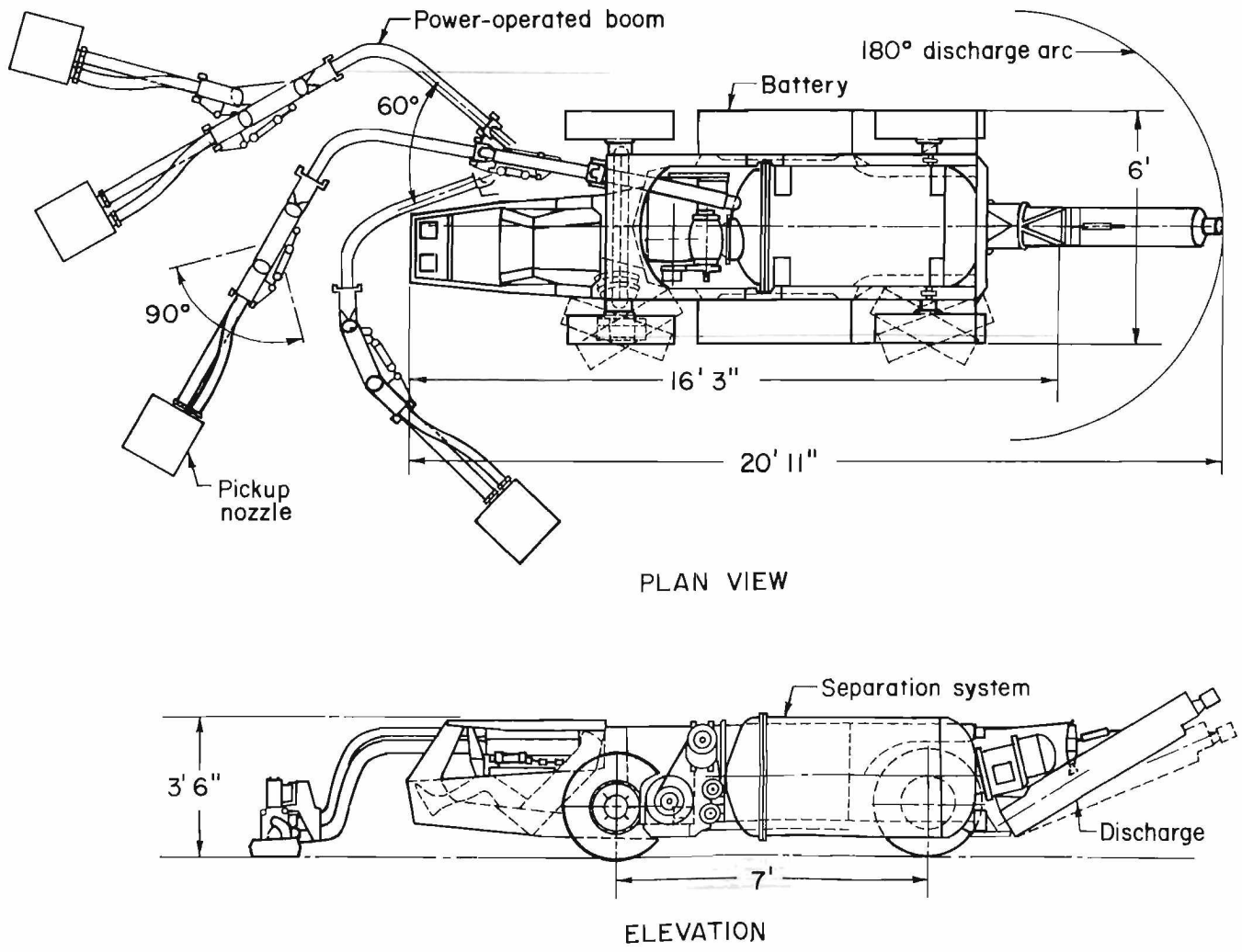


Figure B-5.–Coal mine vacuum sweeper.

3. Average water input rate of 2.3 gal/min.

4. System pressure drop of 50 in H_2O column.

5. Venturi throat velocity of 25,000 ft/min.

6. Airflow volume of 750 ft^3/min.

Figure B-6 illustrates the water and air moving system for the design requirements. Collected water droplets from the primary separation system are pumped through a permissible flow-sensing switch which causes the exhauster to shut down if there is no water in the circuit. The recovered water is then pumped to the two sprays on the baffle orifices and the spray unit for the entry pipe to the pressure vessel. Only fresh water is supplied to the Venturi throat.

The exhauster is a positive displacement gear-type air pump. The unit is belt-driven from a 15-hp motor. The exhauster pumps air from the separation system into a muffler, which provides about 30 dB of noise reduction. Discharge air from the muffler is directed towards the rear of the sweeper away from the operator.

Demonstration tests were performed for the sweeper in a mine and several problems were observed:

1. The boom design made controlling the height of the nozzle very difficult. Nozzle-to-floor distances are critical to some nozzle designs.

2. The sweeper was battery-powered and thus, constrained by power capacity.

3. The sweeper attempted to collect both loose coal and coal dust, thus imposing a broad range of collection and conveyance conditions.

Conclusions from the sweeper tests included challenging the decision to design a wet collection system. Work capacity limitations were imposed by the wet system since:

1. A water storage tank had to be refilled periodically.

2. Coal and rock dust slurry in the separation system bridged over and stuck to the conveyor screw, causing increased maintenance. Also, additional horsepower was required to move the screw with slurry buildup.

3. Some explosions were reported in the separation chamber during preliminary above ground tests. These may have been caused by reduced spray water injection.

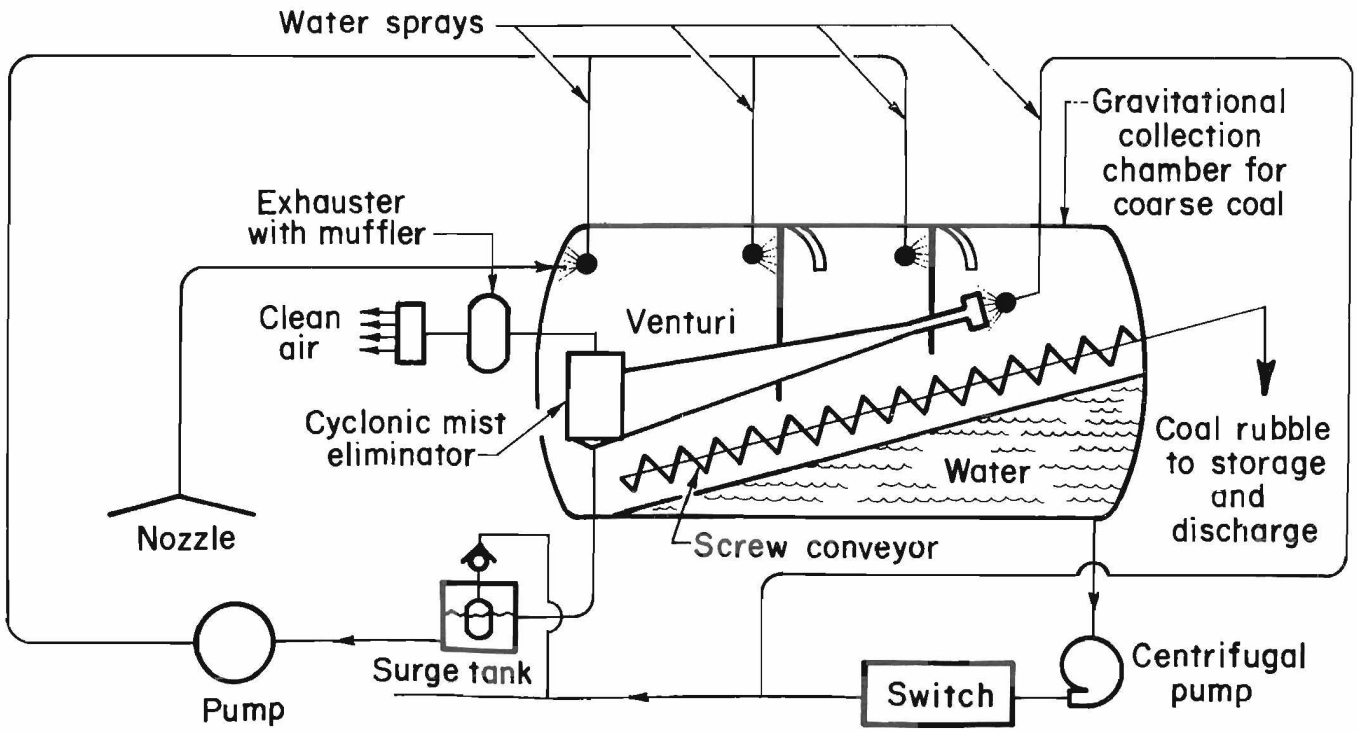


Figure B-6.–Schematic of dust separation system for coal mine vacuum sweeper.

In addition to the above conclusions, a later review of the sweeper design and tests as part of this program highlights the following:

1. The sweeper is very complex with a double-jointed articulated boom, venturi scrubber, two screw conveyors, high-pressure drop exhauster, and water service requirements.

2. Water is recirculated to sprays without treatment. Fines buildup in the recirculated water will cause nozzle corrosion and reduced collection efficiency. As dust levels increase in a suspended state within the separation chamber, the potential for explosion increases.

The experiences of the sweeper program suggest that a dry collection system is probably the preferred approach provided that adequate grounding, exhaust velocities, and other explosion prevention measures are designed into the system. There are also distinct advantages to keeping the design simple by such measures as collecting a relatively narrow size range of material, keeping the system pressure drop to a minimum, and reducing material handling to a minimum.