

## MANTRIP NOISE CONTROLS

By Roy C. Bartholomae<sup>1</sup> and Thomas G. Bobick<sup>2</sup>

## ABSTRACT

The interior noise of an underground mine rail-operated personnel carrier (mantrip vehicle) was cost effectively reduced by replacing some standard components with acoustically treated components. The noise control features included a softer suspension, softer motor mounts, damped panels, sound-absorbing motor enclosures, and helical gears.

Depending on operating conditions, the modified vehicle was 6 to 7.5 dBA quieter than an unquieted mantrip. The noise level in the mantrip interior was reduced to approximately 85 dBA at an average vehicle speed. These noise control features increased the overall mantrip cost by less than 5 pct.

## INTRODUCTION

During a normal working shift, underground coal miners are exposed to a variety of noise sources, one of which is the rail personnel carrier, or mantrip vehicle, that transports them between the entrance and working sections of the mine.

The interior noise level of most mantrips ranges between 90 and 100 dBA at typical operating speeds (6 to 14 mph). Consequently, the mantrip vehicles contribute to the total daily noise dosage received by the workers. Although mantrips are less noisy and are used for shorter periods (30 to 60 min per shift) than other mining equipment, their cumulative contribution to noise exposure in mines is substantial because they affect a large number of workers.

This paper describes a follow-on project of a previous retrofit program for an existing mantrip. This work extends and incorporates noise control treatments into the standard design of a new FMC<sup>3</sup> mantrip model, with the goal of achieving an interior sound level of 85 dBA or less

at an average operating speed. A second goal was to design noise control treatments of general scope, so they could be incorporated into mantrips produced by other manufacturers.

Untreated Mantrip

Several kinds of mantrips are produced, primarily by five manufacturers. Most of the vehicles have closed tops and are trolley operated, but there are also some open-top and some battery-operated models. Although drive trains and suspension systems differ from one vehicle manufacturer to another, generally the basic structure of all mantrips is the same.

The FMC model selected for this project has a closed top, is trolley operated, and has duplicate controls that allow operation from either end of the vehicle. The interior is divided into a middle (passenger) and two-end (operator) compartments and is only accessible from one side of the vehicle (fig. 1).

The vehicle body consists of a steel framework that supports the floor plates, sidewall panels, and roof panels. The chassis is suspended on two wheel sets, each consisting of flanged wheels on solid axles. The FMC suspension uses a trailing arm system. Each of the four suspension arms is pinned to the frame by a spherical bushing on one end and by a

<sup>1</sup>Supervisory electrical engineer.

<sup>2</sup>Mining engineer.

Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.

<sup>3</sup>Reference to specific products does not imply endorsement by the Bureau of Mines.

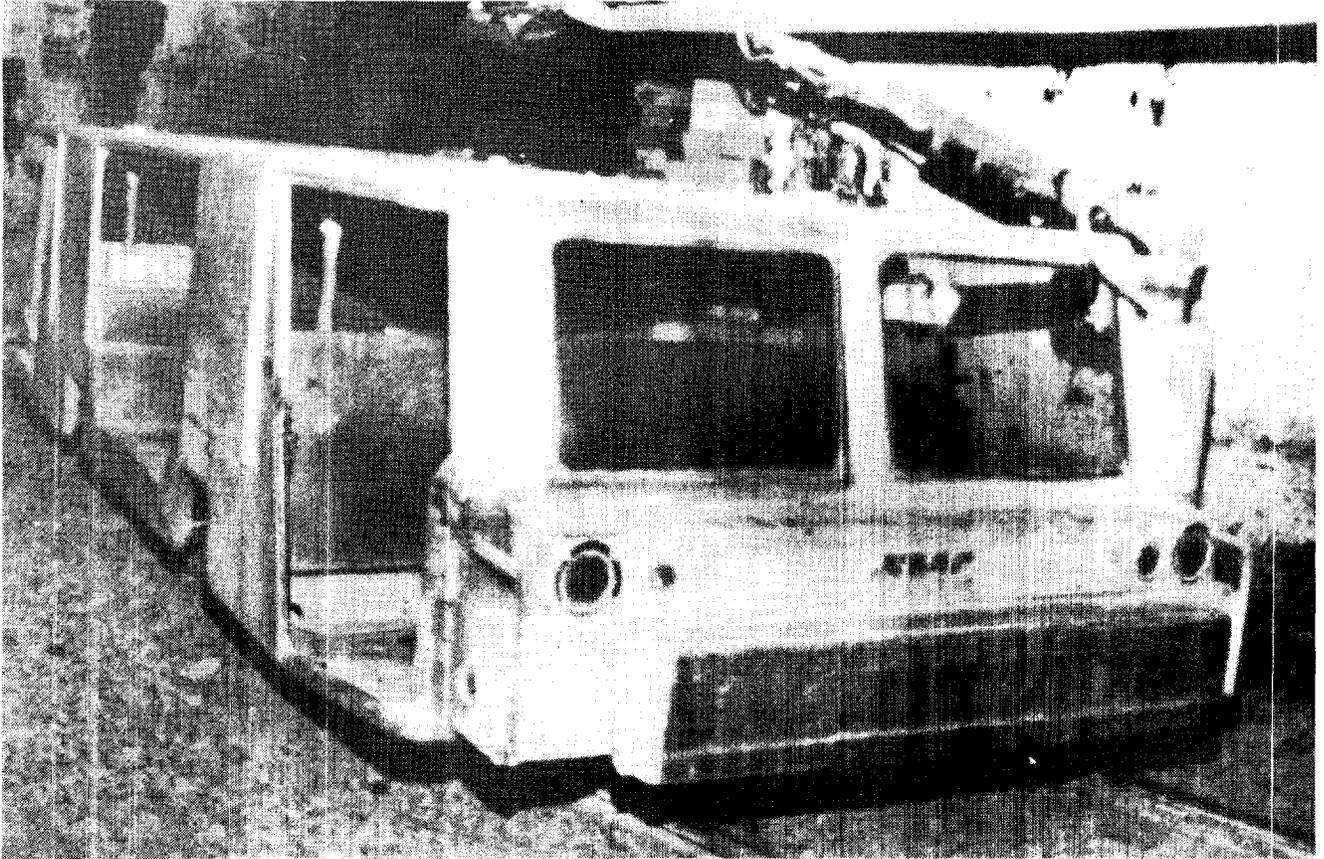


FIGURE 1. - FMC model 2510 high-frame mantrip.

coil spring-shock absorber combination on the other end. Two vertical guide plates restrain lateral arm movement.

The drive system consists of electric motors, traction drive gear cases, and the axle wheel sets, usually with one motor per axle. The motors are located inside the passenger compartment next to the closed side of the vehicle. They are connected to the gear cases, which are outside the compartments, with a drive shaft through a hole on the sidewall. The drive train components are interconnected with universal joints. Service brakes are attached to the axle or to the gearbox output shaft.

Depending on the model, the FMC mantrips transport 10 to 26 persons at a maximum speed of up to 17 mph. The mantrips are available in sizes ranging from 15 to 24 ft in length, 6 to 8 ft in width, and 2 to 4.5 ft in height above the rail.

#### Noise Sources

Noise from the mantrip is generated by the wheel-rail system, the drive motor, and the drive train. It reaches the vehicle interior through airborne and structureborne paths. These noise sources are shown in figure 2.

The primary wheel-rail noise is structureborne. It is transmitted into the main structure through the suspension arm bushing and the spring (fig. 2A). Another contribution results from lateral or vertical impacts at the suspension arm guide. The rail itself contributes airborne noise.

The motor (fig. 2B) contributes both airborne and structureborne noise; the former is emitted by the motor components, while the latter is radiated by the vehicle panels.

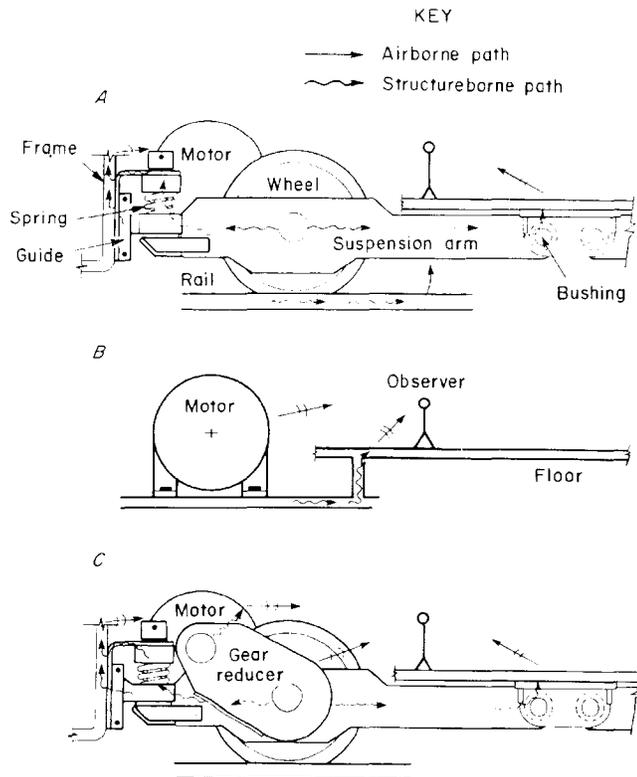


FIGURE 2. - Mantrip noise sources and paths.  
 A, Wheel-rail; B, motor; C, drive chain.

Drive train noise is produced primarily by gear teeth engagement forces. Airborne noise is radiated from the gear reducer housing. Vibration that generates structureborne noise is transmitted to the structure through the motor and through the suspension arm (fig. 2C).

Additional sources, such as intermittent impacts from loosely supported panels, are of secondary importance. They are not addressed in this paper because they can be eliminated through proper maintenance.

#### Testing Procedures and Results

The contributions of the major airborne and structureborne noise sources were determined by a series of baseline and diagnostic tests. The baseline tests were conducted in an underground coal mine; and, since the reverberation effects of tunnels are negligible in the

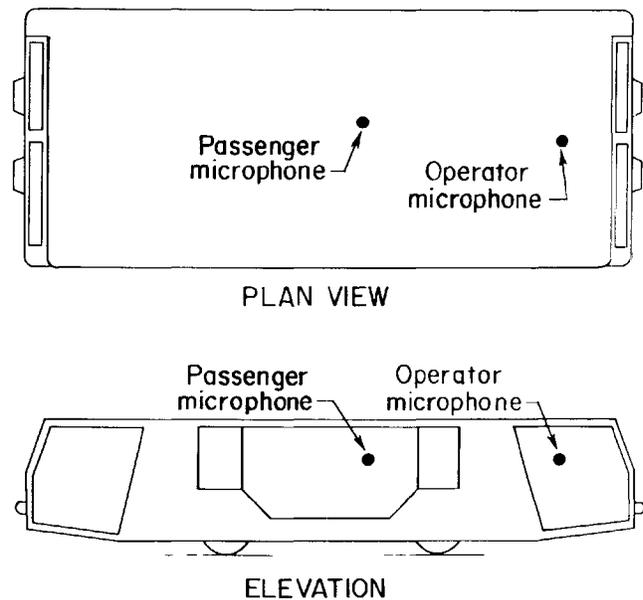


FIGURE 3. - Mantrip noise measurement locations.

interior of closed-top mantrips,<sup>4</sup> the diagnostic tests were conducted in the manufacturer's assembly plant, where conditions were well controlled. The noise was measured in the middle compartment and in one end compartment (fig. 3), referred to as passenger and operator compartments, respectively.

Ideally, all tests should have been performed on mantrips of the same model. This was impossible, however, and the underground baseline tests and the above-ground diagnostic tests were performed on untreated FMC 2870 and an untreated FMC 2510 models, respectively. That is, for the noise source diagnosis and selection of treatments, it was assumed that the noise characteristics of most equal size and weight FMC mantrips are similar. However, this assumption, which is discussed further in a later section, had no impact on the final evaluation of the

<sup>4</sup>Galaitis, A. G., P. J. Remington, and M. M. Myles. Noise Control of a Mine Operated Rail Personnel Carrier. Volume I. Design and Performance of Noise Control Treatments (contract JO166090, Bolt Beranek and Newman Inc.). BuMines OFR 133-78, 1977, 116 pp.; NTIS PB 289 711.

treatments, which were performed by directly comparing the underground noise of two mantrips, one treated and one untreated, of the same model.

Typical underground noise spectra measured in the operator and passenger compartments of an FMC 2870 mantrip are shown in figure 4. It was observed that the mantrip noise increased with speed. Measurements taken between 8 and 14 mph showed that the A-weighted sound level increased by approximately 0.7 dBA per each 1-mph speed increase. The data shown in figure 4 were obtained at 10 mph, the average speed in the mine that purchased the treated mantrip.

The aboveground diagnostic tests identified different source contributions by suppressing certain other sources. Various methods were used, including temporary acoustical treatments, disengagement of drive train components, and artificially created operating conditions. For example, the wheel-rail noise was eliminated by operating the vehicle on jacks; similarly, the drive train noise was eliminated by disengaging the motor from the gear reducer. Additional details on the diagnostic tests and the spectral composition of noise contributions are found in Ferrari and Galaitsis.<sup>5</sup>

The diagnostic tests were performed at 12.8 mph, a speed that could be maintained constant for a sufficiently long period of time. At this speed, the contributions of the major noise sources at the passenger's compartment were as follows, in decibels (A-weighted):

Wheel-rail....	94
Motor.....	88
Drive train...	83

The wheel-rail noise and the motor noise each exceeded the 85-dBA goal, and

<sup>5</sup>Ferrari, V., and A. Galaitsis. Integration of Quietening Technology Into New Mantrip Vehicles (contract JO199068, ESD Corp.). BuMines OFR 62-82, 1981, 164 pp.; NTIS PB 82-203241.

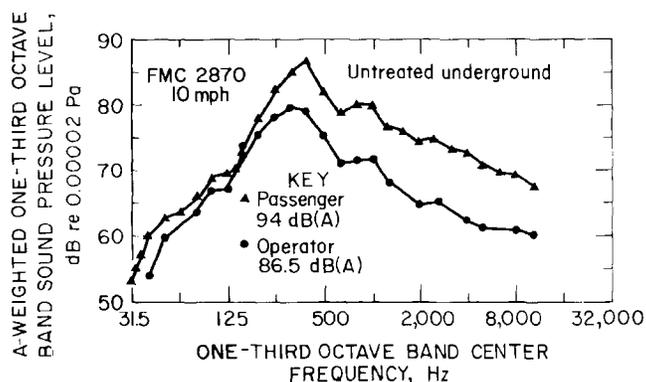


FIGURE 4. - Typical mantrip noise in different compartments, at a 10-mph speed.

therefore treatment of the associated noise sources and/or paths was mandatory. The drive train was also treated to lower noise reduction requirements for the wheel-rail and motor noise contribution.

#### Acoustical Treatments

Initially, the list of potential noise control treatments for the mantrip included resilient wheels, damped wheels, self-steering truck,<sup>6</sup> constrained layer damping, sound-absorbing panels, isolated suspension spring seat, isolated suspension shock mount bushing, isolated suspension arm bushing, suspension arm guide plate isolation, resilient motor mounts, tightly sealed and sound-absorbing motor enclosures, helical gears, and constant-velocity U-joints. After a cost-benefit analysis, performed by the manufacturer, the following noise control treatments were selected for installation on an FMC 2450 mantrip: panel damping, soft spring seats, soft suspension arm bushings, suspension arm guide plate isolators, motor enclosures, motor mounts, and helical gears.

<sup>6</sup>List, H. A., W. N. Caldwell, and P. Marcotte. Proposed Solutions to the Freight Car Truck Problems of Flange Wear and Truck Hunting. ASME paper 75-WA/RT-8, 1975, 7 pp.

Scheffel, H. Self-Steering Wheelsets Will Reduce Wear and Permit Higher Speeds. Railw. Gaz. Int., v. 132, No. 12, 1976, pp. 453-456.

The composite loss factor of the standard 1/8-in steel walls and ceiling of the untreated mantrip was between 0.003 and 0.02. Approximately 70 pct of these panels were replaced by damped NEXDAMP--II sheets, which resulted in a composite loss factor between 0.02 and 0.1.<sup>7</sup> The NEXDAMP-II, manufactured by U.S. Steel, is a three-layer (steel-viscoelastomersteel) laminate available in various thicknesses. Sheets of 0.148-in-thick NEXDAMP-II, consisting of a 0.020-in viscoelastic layer sandwiched between two 0.064-in steel layers were selected for the current application.

The suspension system modifications were designed to reduce the wheel-rail structureborne noise. The treatments consisted of resilient components introduced at the three contact areas between each suspension arm and the main structure, that is, at the bushing, spring,

and guide plates (fig. 5). Specifically, two 1/4-in rubber sleeves and two 3/8-in washer-shaped rubber seats (all 55-durometer) were used per spring; the standard metal bushing was replaced by a 2-1/8-in-ID, 3-1/2-in-OD, 55-durometer rubber bushing; strips of 1/4-in Linerite abrasion-resistant polymer backed by 3/8-in rubber were inserted between the suspension arm tip and its guide plates.

In the standard configuration, the motors, which are located in the passenger compartment, are safeguarded by partial metal covers. The motor airborne noise was reduced by replacing these covers with tight fitting ones and by lining the walls and ceiling of the resulting enclosure with sound-absorbing material (fig. 6). The sound-absorbing liner was 1-in-thick Owens Corning fiberglass type 705, attached to the enclosure walls by bendable-tip acoustical material fasteners. Proper ventilation was maintained through the sidewall opening (between the

<sup>7</sup>Work cited in footnote 5.

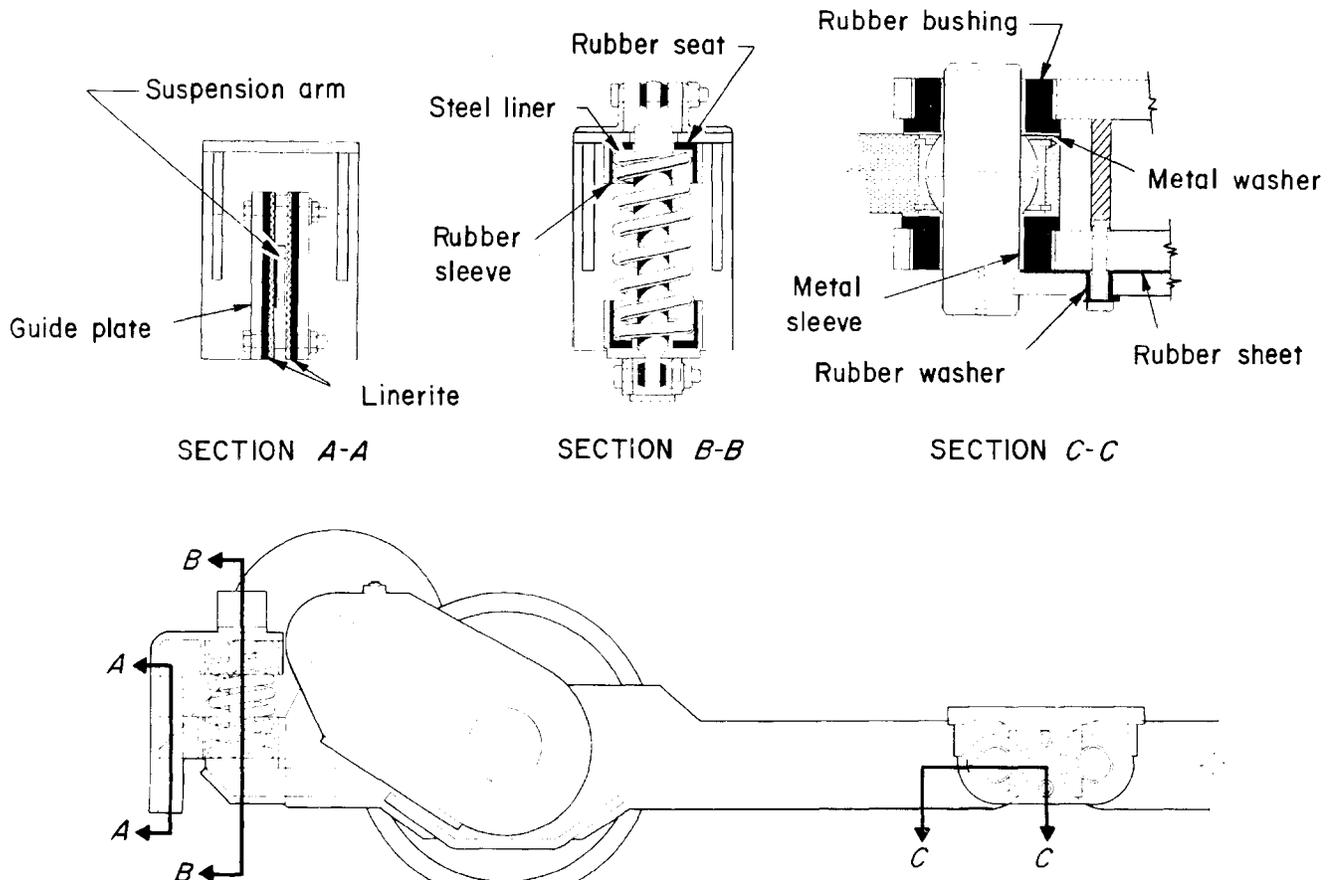


FIGURE 5. - Major features of modified suspension components.

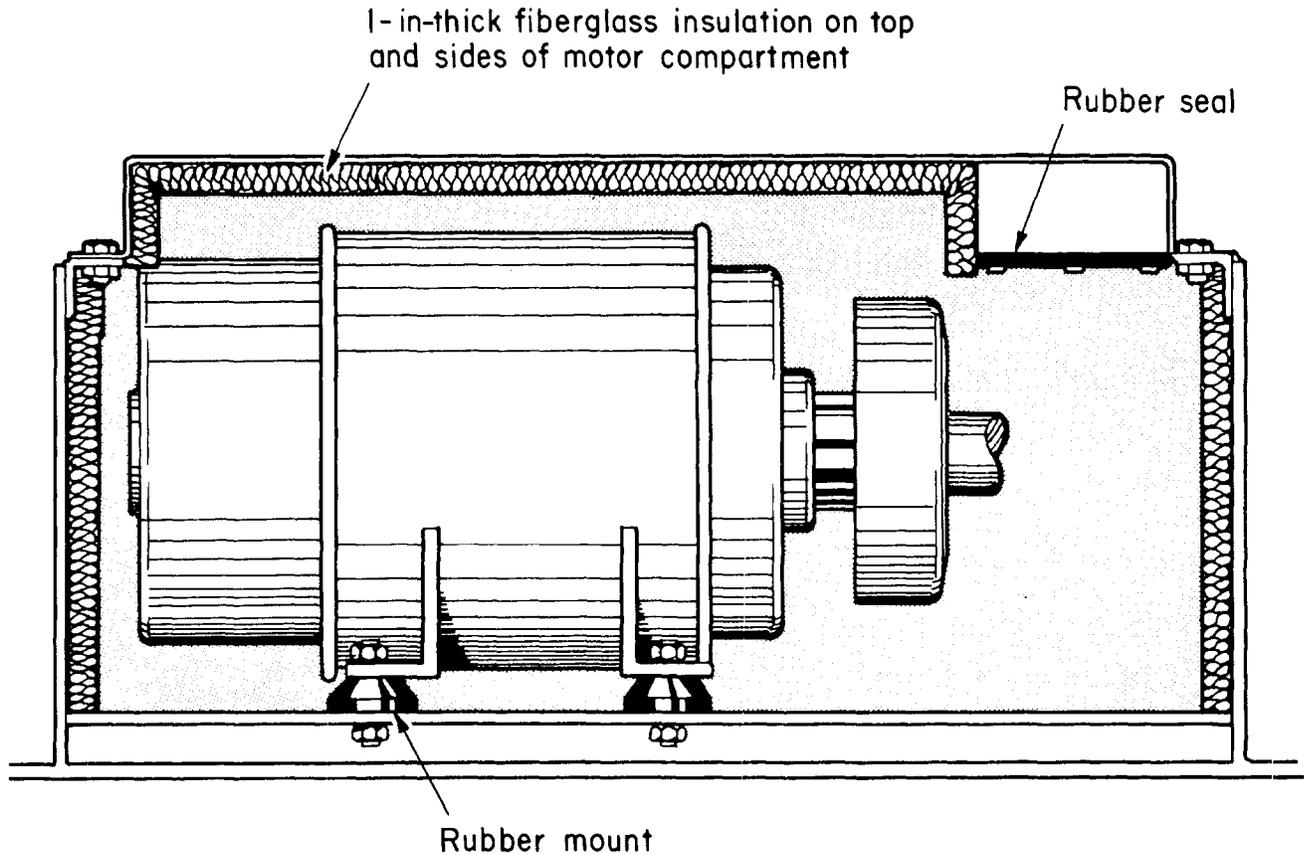


FIGURE 6. • Treatments for the reduction of motor noise.

enclosure and the exterior of the vehicle) that accommodates the drive shaft. The motor structureborne noise was reduced by attaching the motor to the frame with Barry Industries type G05-04 mounts. Finally, the drive train noise of the modified mantrip was reduced by replacing the standard spur gears with helical gears.

The basic materials for the various treatments (NEXDAMP-II, Fiberglas, Linerite, etc.) are commercially available, but they required some cutting or shaping prior to installation. The only items that were specially made, but are now FMC stock items, were the suspension rubber bushings and the helical gears.

#### Effectiveness of Noise Controls

The effectiveness of the noise control treatments was determined by comparing the sound levels of a treated and an untreated FMC 2450 mantrip, in the same

underground mine under similar operating conditions. The results are summarized in figures 7 through 9.

Figures 7 and 8 show typical time histories and noise spectra of the two vehicles at 10 mph. Both figures indicate that the selected treatments resulted in a significant noise reduction.

Figure 7 shows that the short-time-average noise level fluctuates even at a constant speed. This variation stems from uneven track conditions associated with rail joints, rail wear state, and track slope. The time traces correspond to simultaneous recordings in the two compartments during inbound runs. The two vehicles were tested at different times, but within the same day and over approximately the same track section.

Typical noise spectra in both compartments of the treated and untreated vehicles are compared in figure 8; they

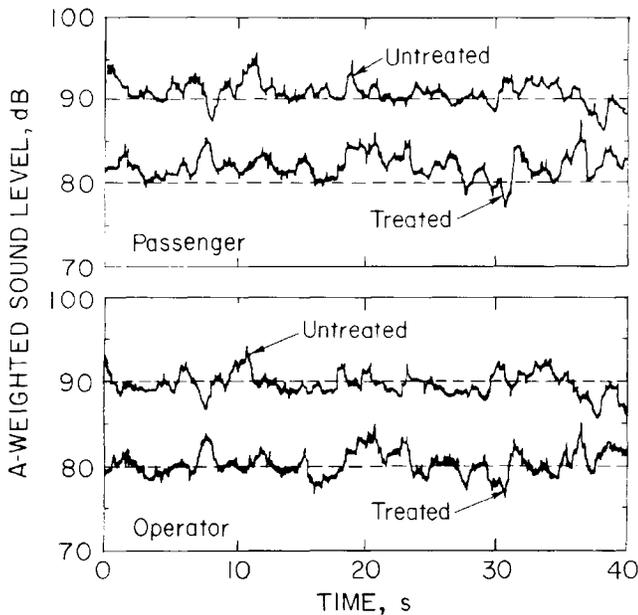


FIGURE 7. - Typical noise-time histories in passenger and operator compartments of untreated and treated mantrips, at a 10-mph speed.

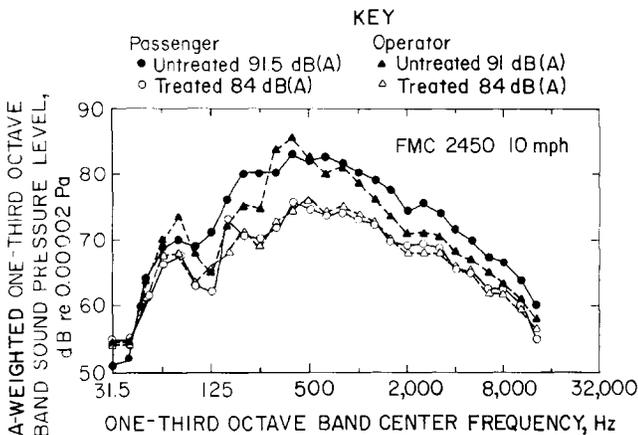


FIGURE 8. - Typical noise spectra in treated and untreated mantrips, at a 10-mph speed.

correspond to 4-s samples selected randomly from the 40-s-long traces of figure 7. The combined noise reduction from all treatments is maximum between 125 and 2,000 Hz, where the untreated vehicle noise is dominant.

Figure 9 shows the vehicle noise dependence on speed. Multiple measurements were performed at each speed over different track sections to estimate the typical data spread (shaded areas) resulting

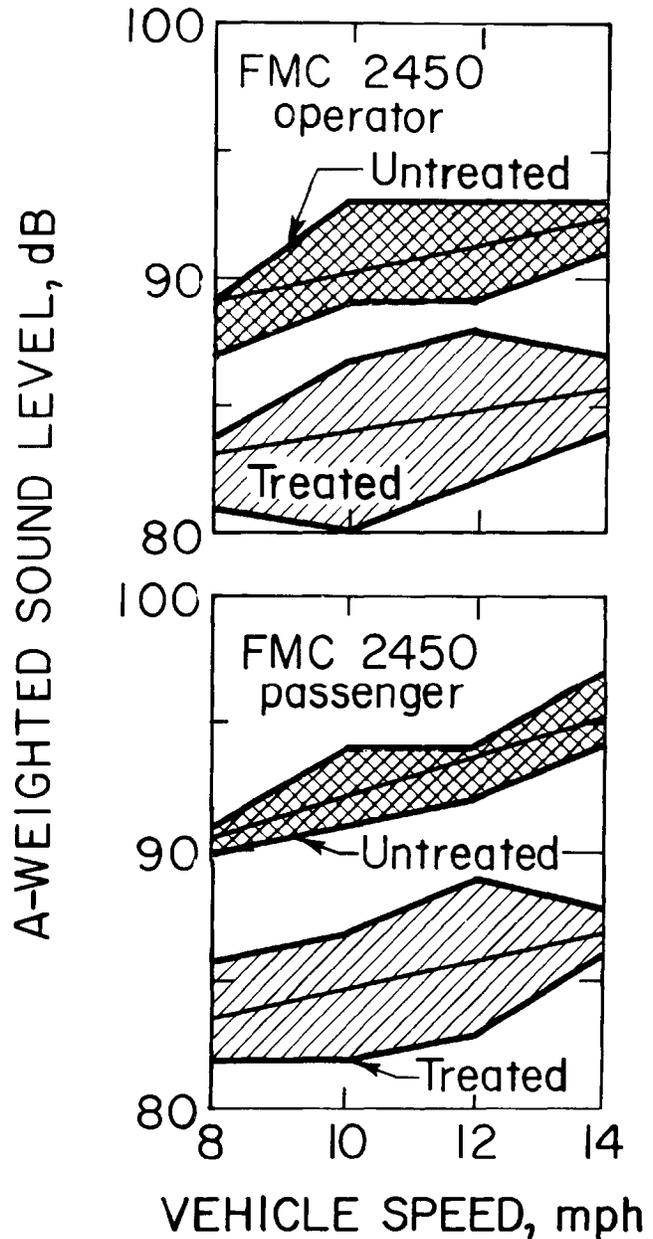


FIGURE 9. - Dependence of mantrip noise on speed.

from uneven track conditions. The straight lines represent the fit of a least squares curve through each group of points, and they may be used to estimate the average noise within the range of measured speeds.

Figures 4 and 8 also shed some light on the validity of the assumption that all FMC mantrips generate similar noise. Clearly, there is a general resemblance (major peak at 315 to 400 Hz) between the

traces of the untreated FMC 2870 (fig. 4) and FMC 2450 (fig. 8) models, corresponding to the same compartments. There are also noticeable differences (lack of 80-Hz peak for the operator of the model 2870); however, such differences are to be expected in view of the noise variations recorded for a single mantrip (fig. 9); therefore, the general-similarity assumption made during the diagnostic stages of the study was justifiable.

Prolonged observations during the underground measurements showed that the average operating speed in the mine that

owned the treated vehicle was about 10 mph. Therefore, personal noise exposure from the treated mantrip should be described in terms of the 10-mph sound pressure levels. Figure 8 shows that at a vehicle speed of 10 mph, the sound levels inside the operator and passenger compartments were reduced from approximately 91 dBA to 84 dBA. Clearly, the 85-dBA goal has been achieved only for FMC 2450 mantrips operated at an average speed of 10 mph or less; typical noise levels for different average operating speeds may be obtained from figure 9.

#### CONCLUSION

The selected noise control treatments met the objective of an interior vehicle noise level of less than 85 dBA under average operating conditions. In the opinion of the workers using the vehicle, these treatments also improved the vehicle riding comfort; this benefit resulted primarily from the compliant bushings, which improved the isolation between the vehicle body and the wheels.

After 18 months of underground vehicle service, none of the treatments has shown signs of wear; therefore, their durability is satisfactory. According to the manufacturer, the modifications raised the cost of a new mantrip by 4.3 pct. The treatments can also be installed on most existing FMC models on a retrofit basis during equipment overhaul.

**Information Circular 8986**

## **Noise Control**

**Proceedings: Bureau of Mines Technology Transfer  
Seminars, Pittsburgh, PA, July 24, 1984,  
and Denver, CO, July 26, 1984**

**Compiled by Staff, Bureau of Mines**



**UNITED STATES DEPARTMENT OF THE INTERIOR  
William P. Clark, Secretary**

**BUREAU OF MINES  
Robert C. Horton, Director**

Library of Congress Cataloging in Publication Data:

Bureau of Mines Technology Transfer Seminars (1984 :  
Pittsburgh, PA, and Denver, CO)

Noise control.

(Information circular / United States Department of the Interior, Bureau of Mines ; 8986)

Includes bibliographies.

Supt. of Docs. no.: I 28.27:8986.

1. Noise control--Congresses. 2. Mine safety--Congresses. I. United States. Bureau of Mines. II. Title. III. Series: Information Circular (United States. Bureau of Mines) ; 8986.

TN295.U4 622s [622'.4] 84-600 194