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JUNE 1983**

**NOISE CONTROL OF RUBBER-TIRED
FRONT-END LOADERS
USED IN SURFACE MINING**

Contract J0395028
Bolt Beranek and Newman Inc.
10 Moulton Street
Cambridge, MA 02238

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**BUREAU OF MINES
UNITED STATES DEPARTMENT OF THE INTERIOR**



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16. Abstract (Limit: 200 words) The objectives of this program were to assess and demonstrate retrofit noise control technology for front-end loaders. The treatments had to be practical, cost-effective, and able to be easily installed by mine personnel. Two loaders, a Caterpillar 988 and an International H-400B, were chosen for the program and the noise sources and acoustic paths that contribute to the operator's noise exposure were identified. Retrofit noise control treatments were designed and installed on the loaders, and noise reductions of more than 10 dBA at the operator position were achieved on both machines. The retrofit packages are low cost and have been field tested in two mines for more than 2 yrs. The results of the program were communicated to the mining industry through a series of noise control workshops and a field manual. The workshops were given in nine States across the United States and more than 440 manuals were distributed to attendees. An audiovisual slide presentation was also developed that summarizes the program.		13. Type of Report & Period Covered Contract research, 4/13/79--5/31/83	
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FOREWORD

This report was prepared by Bolt Beranek and Newman Inc., Cambridge, MA, under Contract No. JO395028. This contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of the Pittsburgh Research Center with Roy Bartholomae acting as Technical Project Officer. Joseph Gilchrist was the Contract Administrator for the Bureau of Mines. This report is a summary of the work completed during the period April 1979 to May 1983. This report was submitted by the authors on June 1983.

The cooperation of the Ratcliff and Childers Coal Company and Drummond Coal Company is gratefully acknowledged.

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1. INTRODUCTION

The Federal Mine Health and Safety Act of 1977 has specified the allowable noise exposure for mine workers. In response to this regulation the U.S. Bureau of Mines issued Contract JO166057 [1] to assess the noise exposure of surface miners, and to identify those pieces of mining equipment that are responsible for the greatest contribution to noise overexposure, as defined by the act. One of the conclusions of this study is that bulldozers and front-end loaders are by far the two largest noise problems in the surface mining industry (see Fig. 1).

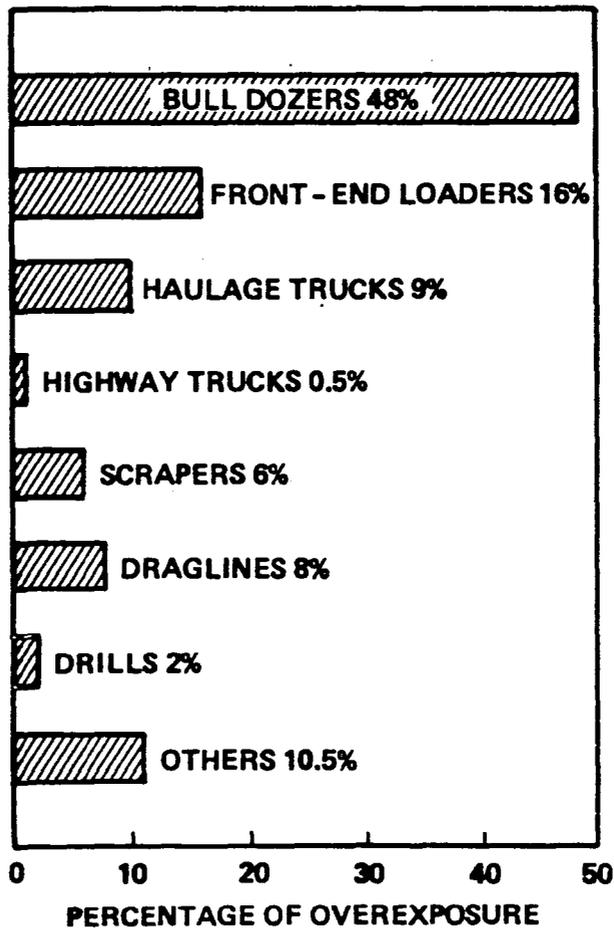


FIG. 1. PERCENT OF TOTAL MINER OVEREXPOSURE BY MACHINE - U.S. SURFACE MINES 1977 [1].

Bulldozers are responsible for approximately 48% of the miner noise overexposure, while front-end loaders are responsible for 16%. The bulldozer noise control problem was the subject of USBM Contract JO177049 [2], in which retrofit noise control treatments were demonstrated on three bulldozers. The current program was developed to help solve the front-end loader noise control problem. Clearly, the successful performance of these two contracts will have a major impact on improving the workplace for surface coal miners.

The objectives of this program were to assess and demonstrate retrofit noise control technology for front-end loaders. The treatments had to be practical, cost-effective, and able to be easily installed by mine personnel. The technology was then to be passed on to the mining industry through a field manual and a series of workshops at centers around the country. In addition, an audio-visual record of the workshops was prepared for the Bureau of Mines.

At the start of this program an assessment was made of the availability of existing retrofit noise control treatments from loader manufacturers and other vendors. The results from this work were summarized in a Task 1 report [3]. For the demonstration phase, two of the most common front-end loaders, a Caterpillar 988 and an International H-400B were chosen. Figure 2 illustrates the reason for choosing these machines; since Caterpillar and International are the two largest manufacturers of loaders, and the 988 and H-400 are the most popular models.

Section 2 of this report describes the noise control treatments for the 988 and H-400B loaders and the performance and durability of the treatments. Section 3 describes the industry technology transfer and Sec. 4 presents the program conclusions.

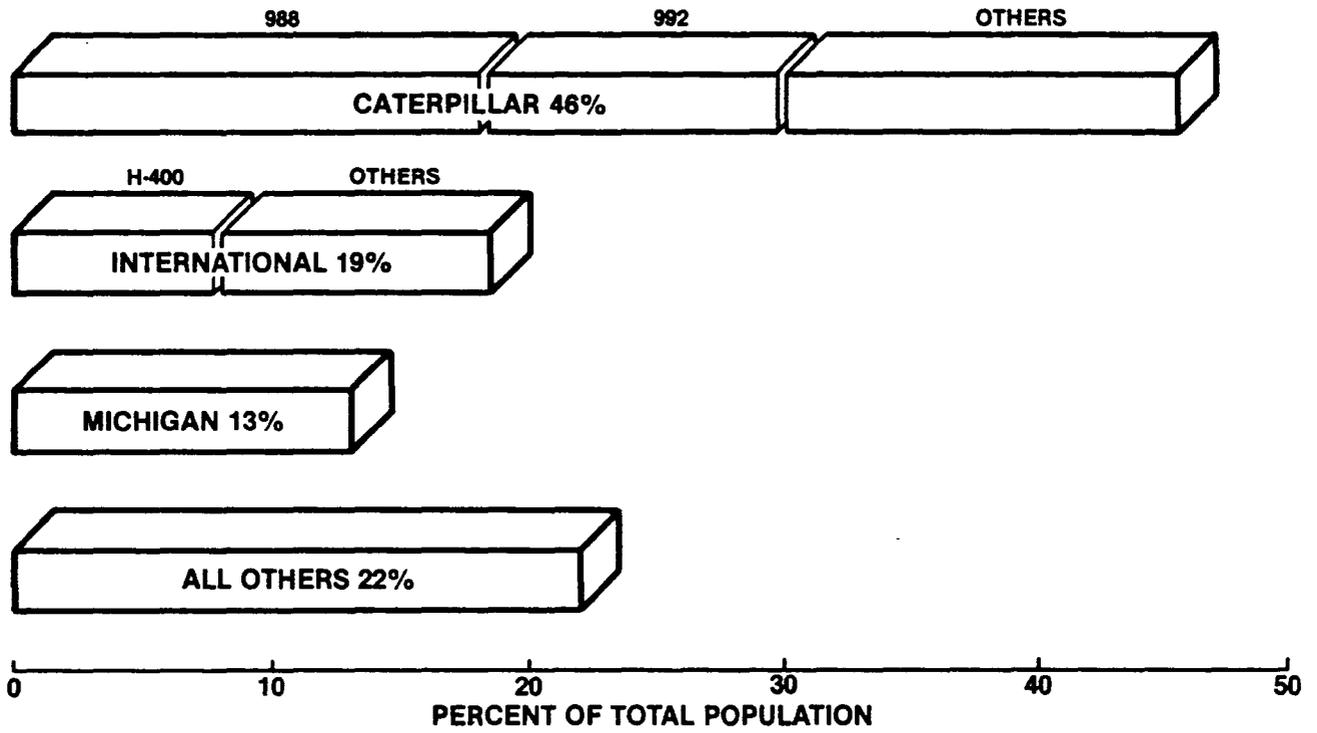


FIG. 2. PERCENT OF TOTAL LOADER POPULATION BY SPECIFIC MANUFACTURER AND MODEL. U.S. SURFACE MINES 1977 [1].

2. NOISE CONTROL TREATMENTS

2.1 Caterpillar 988

2.1.1 Initial noise levels and source diagnosis

The Caterpillar 988 front-end loader selected for this demonstration is shown in Fig. 3. The loader was fitted with a standard weather cab with no existing noise control treatments. The loader has a 7 cu yd bucket and is powered by 375 hp turbo-charged diesel engine. The engine compartment is open on both sides and has a single top engine cover. A muffler had been fitted to this machine as original equipment and it was in good condition. The radiator cooling fan is located at the rear of the machine, while the hydraulic tank and valves are located directly below the operator cab. The cab of the 988 is attached to the engine half of the machine, rather than the front half, which carries the bucket.

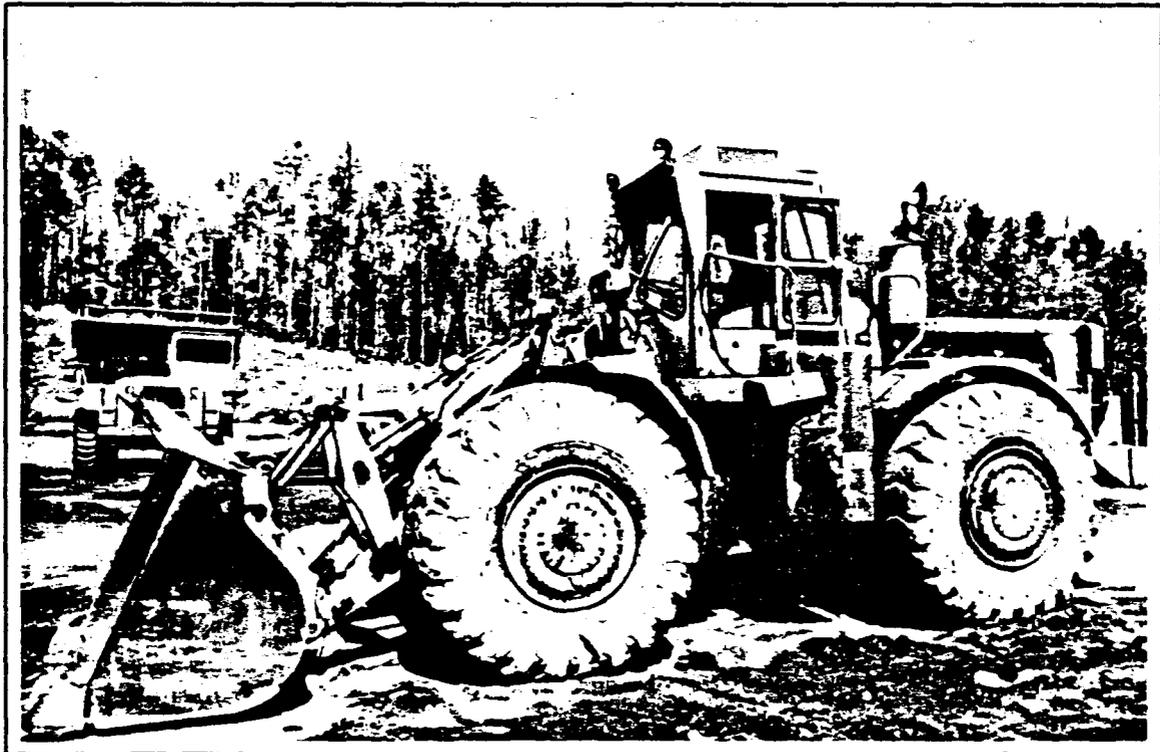


FIG. 3. CATERPILLAR 988 FRONT-END LOADER.

The noise levels inside the operator's cab were measured under a number of stationary and moving conditions. The one-third octave band noise levels at high idle (maximum governed speed), at hydraulic stall, at torque converter stall (TCS), and at idle are shown in Fig. 4. The A-weighted levels for these stationary tests were 99 dBA at high idle, 100 dBA at hydraulic stall, and 98 dBA at TCS.

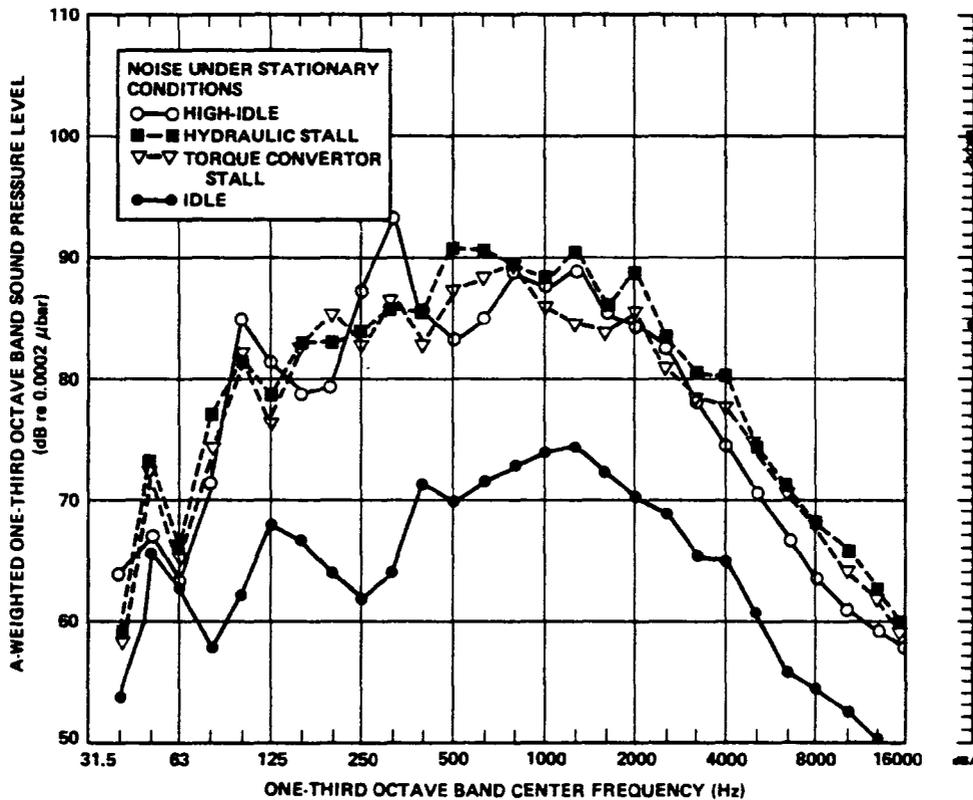


FIG. 4. ONE-THIRD OCTAVE BAND NOISE LEVELS MEASURED AT THE OPERATOR POSITION OF CATERPILLAR 988 UNDER STATIONARY CONDITIONS (CAB DOORS OPEN).

Operating noise levels were obtained with the loader performing the standard SAE J1166 work cycle test. In this test the operator's noise level was integrated over a complete work cycle as the loader was working on a pile of coal. Typical one-third octave band spectra for the moving tests are shown in Fig. 5.

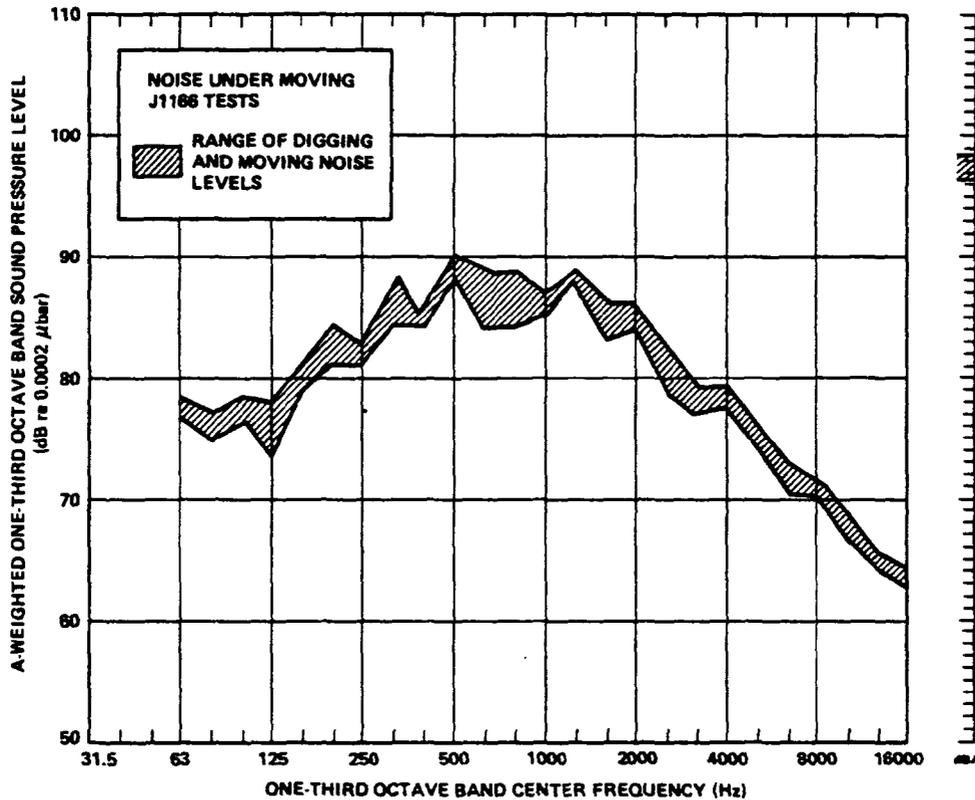


FIG. 5. ONE-THIRD OCTAVE BAND NOISE LEVELS MEASURED AT THE OPERATOR POSITION OF CATERPILLAR 988 UNDER MOVING CONDITIONS, SAE J1166 WORK CYCLE TEST (CAB DOORS OPEN).

The A-weighted levels are approximately 98 dBA. All of these measurements were obtained with the operator cab door open. Similar measurements were made with the doors closed and the difference in level (door open - door closed) for each one-third octave band is shown in Fig. 6.

With the doors open the low-frequency tone from the engine exhaust is more prominent inside the cab. However, with the doors closed noise in the 200 Hz to 500 Hz range increases, probably due to a cab cavity resonance. Consequently, the A-weighted operator noise is approximately 1 to 1.5 dB higher with the doors closed.

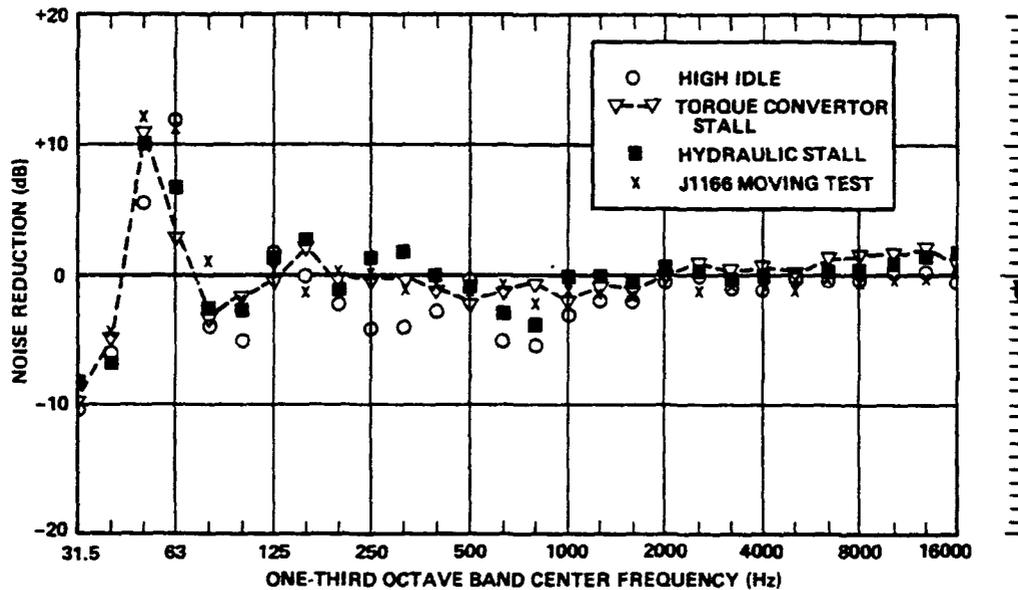


FIG. 6. DIFFERENCE IN OPERATOR NOISE LEVEL FOR CATERPILLAR 988 WITH THE CAB DOORS OPEN AND DOORS CLOSED.

The major noise sources on front-end loaders are illustrated in Fig. 7. The contributions from these major noise sources to the overall operator noise level were measured [4]. Diagnostic measurements were obtained through temporary noise control treatments installed on a Caterpillar 988 loader, and through a series of transfer function measurements. The measurements show that exhaust noise predominates at low frequencies (up to 400 Hz), particularly in the absence of a muffler. In the 160 Hz to 315 Hz range, noise from the radiator cooling fan can be significant, while at frequencies above 500 Hz, engine casing noise predominates. The results from the source diagnosis indicate that the major noise path is airborne sound reaching the cab interior primarily via the intervening air. The airborne sound path for the exhaust is obvious. For engine casing noise, this predominance is not surprising, in view of the open engine sides and the unobstructed sound transmission path in the pivot area under the cab, as seen in Fig. 8.

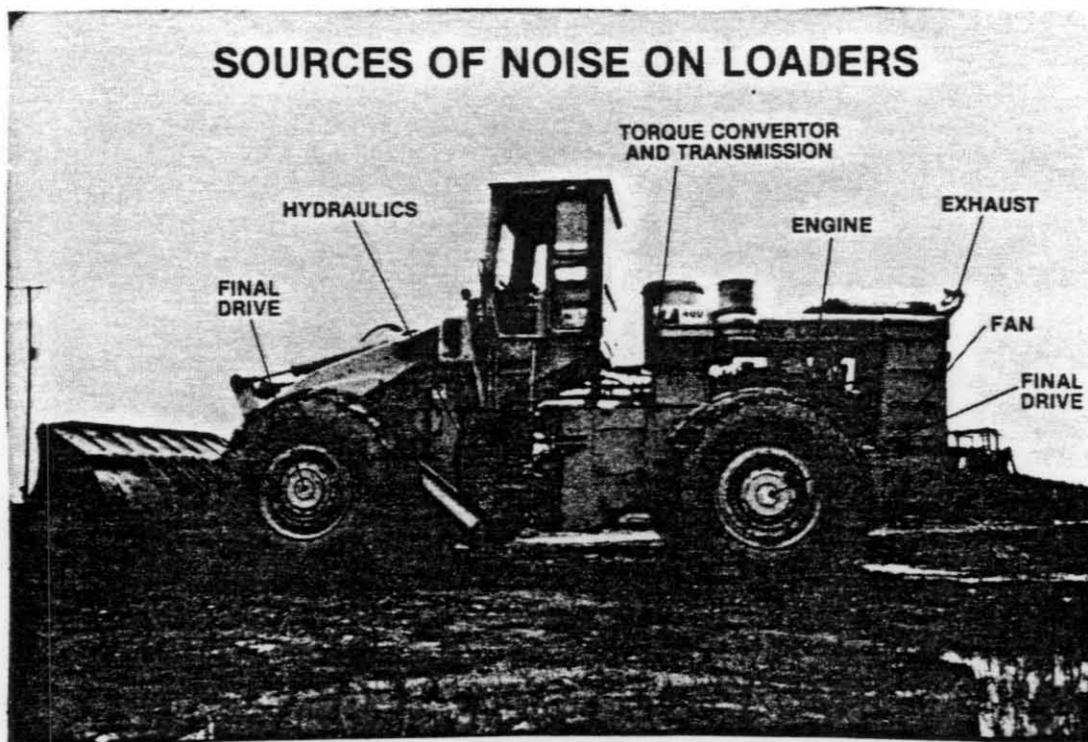


FIG. 7. MAJOR NOISE SOURCES ON FRONT-END LOADERS.

The contribution from structureborne sound was evaluated by measuring the acceleration levels of all the major vibrating surfaces inside the operator cab.

The major panel acceleration levels inside the 988 cab are shown in Fig. 9. Included in these measurements are data obtained from the side and rear window panels of the cab. Except for the low-frequency resonance on the side window, these acceleration levels are generally low and contribute very little to the A-weighted operator noise levels.

2.1.2 Noise control treatments

The measurements discussed in the previous section indicated that the direct airborne sound transmission was the predominant

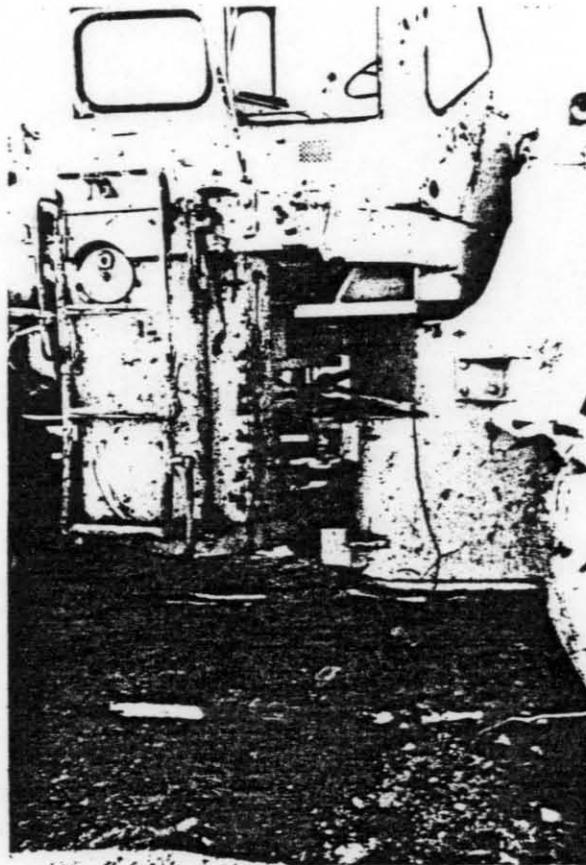


FIG. 8. PIVOT AREA UNDER CAB OF CATERPILLAR 988 LOADER.

sound path. In consequence, the noise control treatments were designed either to interrupt or alter to this transmission path to the operator. Five categories of noise control treatments were installed on the 988 loader (see Fig. 10). In order of installation, they are:

- Cab wall seals
- Canopy and rear cab wall sound absorption
- Floor mat
- Pedestal seals
- Additional sound absorption.

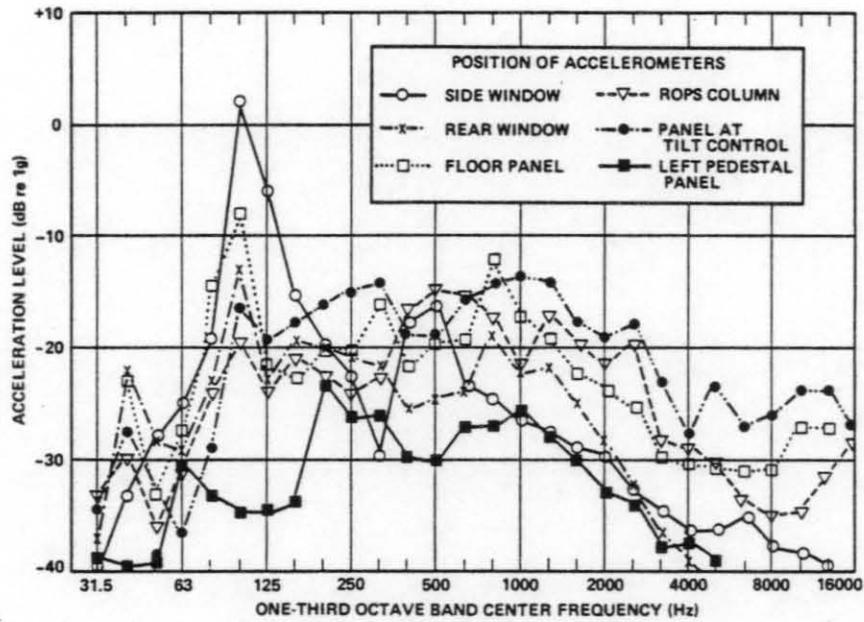


FIG. 9. TYPICAL VIBRATION LEVELS MEASURED ON VARIOUS SURFACES INSIDE THE OPERATOR CAB OF A CATERPILLAR 988 LOADER.

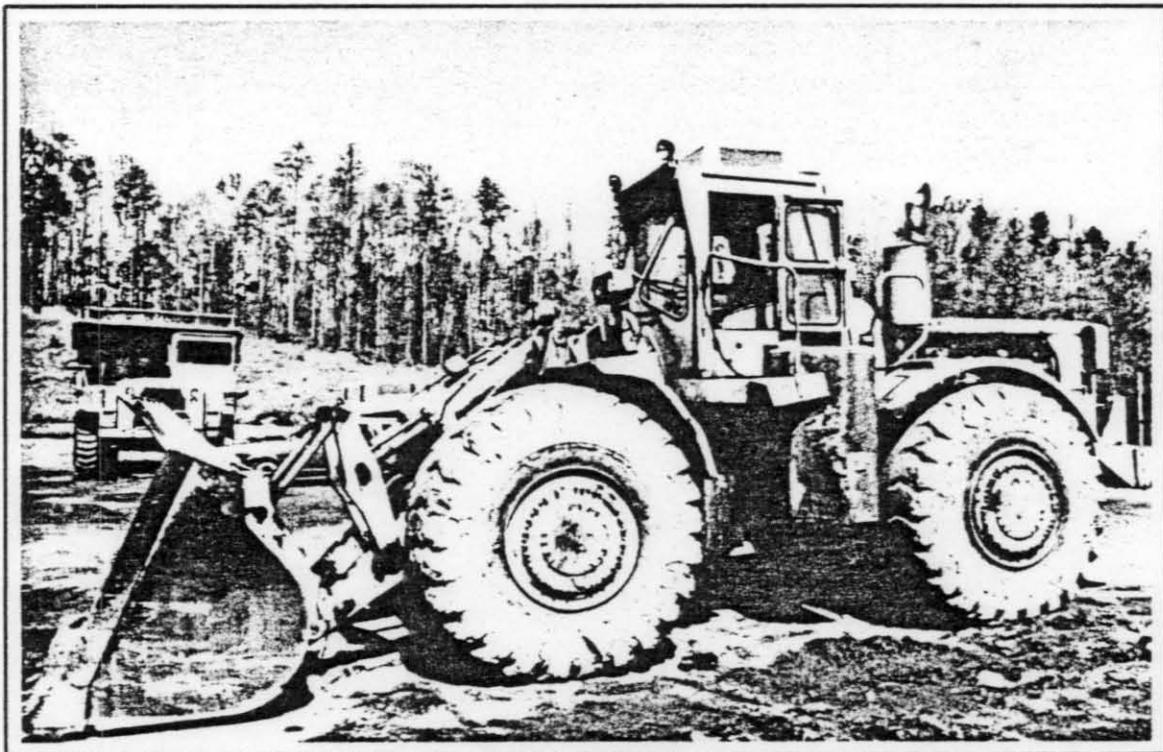


FIG. 10. NOISE CONTROL TREATMENTS INSTALLED ON CATERPILLAR 988 LOADER WITH CAB.

Note that an exhaust muffler was not part of this package, since one had been installed as original equipment by the manufacturer. A muffler should be installed on all loaders on which it is not standard equipment.

The cost of the materials used in the noise control package for this 988 loader was \$410 (in 1979). A cost summary of the individual treatments and the estimated labor required for installation is given in Table 1.

TABLE 1. SUMMARY OF TREATMENTS AND LABOR COSTS FOR NOISE CONTROL PACKAGE ON CATERPILLAR 988 LOADER WITH CAB.

Treatment	Approximate Material Cost (1979)	Est. Labor (Man-Hours) Mechanic
1. Cab Wall Seals	\$ 58	7
2. Canopy and Rear Cab Wall Sound Absorp- tion	200	8
3. Floormat	39	3
4. Pedestal Seals	50	6
5. Additional Sound Absorption on Cab Interior	63	5
Total	\$410	29

The treatments were installed in 29 man-hours. This included time for removing the cab and for a mechanic and his helper to install the complete treatments.

2.1.3 Treatment performance

The fully treated loader working at a surface mine in Alabama is shown in Fig. 11. The loader was returned to service in July 1979 and the performance and durability of the treatments have been monitored at regular intervals.



FIG. 11. FULLY TREATED CATERPILLAR 988 FRONT-END LOADER IN SERVICE AT ALABAMA MINE.

The reduction in noise level at the operator's position for each successive treatment is shown in Fig. 12. The most important or loudest noise path, the cab seals, was treated first, then the next most important path, and so on. The total A-weighted noise reduction for all the treatments was 11.5 dBA at high idle. This reduced the operator noise level to 90 dBA, ensuring compliance with Federal noise regulations. Similar noise reductions were also achieved at hydraulic stall, TCS, and the moving J1166 tests. These results are illustrated in Fig. 13.

With the treated front-end loader the operator noise levels were lowest with the cab doors closed. An 8 dBA noise reduction

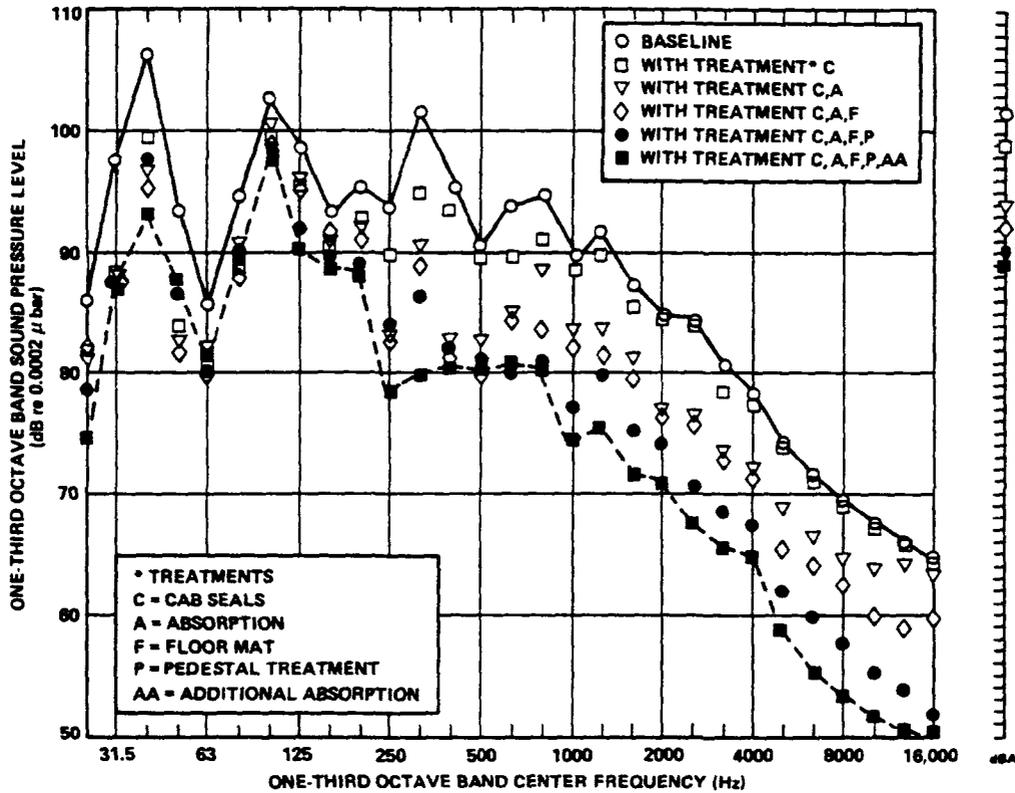


FIG. 12. NOISE AT OPERATOR POSITION OF CATERPILLAR 988 AT HIGH IDLE WITH EACH SUCCESSIVE NOISE CONTROL TREATMENT ADDED (CAB DOORS CLOSED).

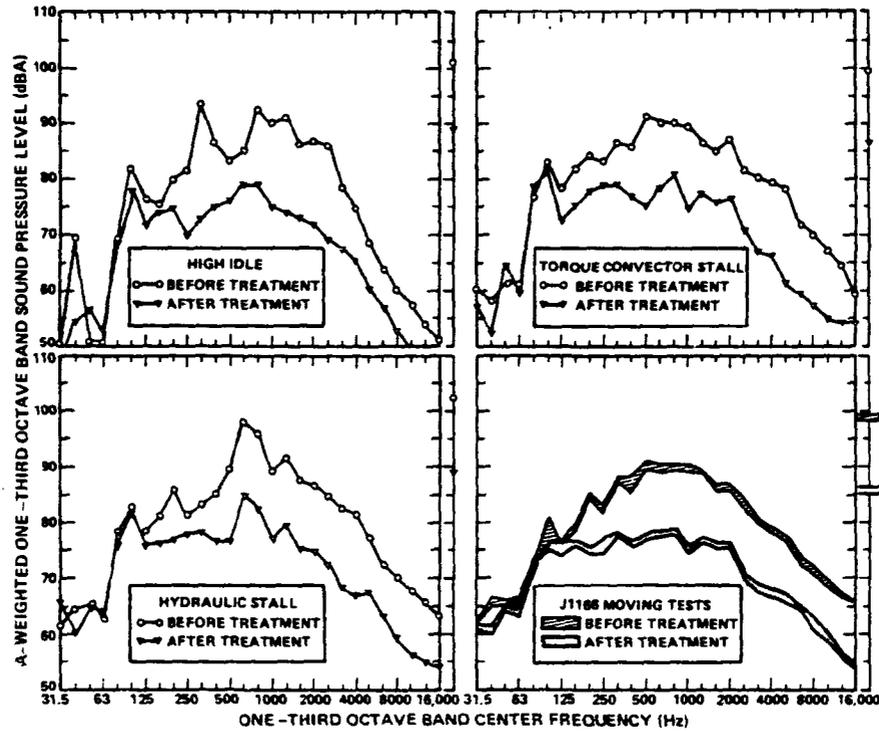


FIG. 13. ONE-THIRD OCTAVE BAND OPERATOR NOISE LEVELS BEFORE AND AFTER NOISE CONTROL TREATMENTS WERE INSTALLED ON CATERPILLAR 988 (STATIONARY AND MOVING TESTS, CAB DOORS CLOSED).

was achieved with the cab doors open, reducing the noise at the operator position to 91 dBA.

Regular visits were made to the loader during the in-service evaluation phase of this program. The noise levels after the treatments had undergone 20 months of mine service are summarized in Table 2. No significant change was found in the acoustic performance of the treatments. Noise dosimeter measurements made by the operating mine indicated that the daily noise dose for the loader operator was 75%.

TABLE 2. IN-SERVICE NOISE LEVELS OF TREATED CATERPILLAR 988 LOADER, CAB DOORS CLOSED.

Test Condition	Treated Level		
	Before Treatment (dBA)	After 20 Months In Service (dBA)	Noise Reduction (dBA)
High Idle	101.5	89.5	12
Torque Converter Stall	100.5	87	13.5
Hydraulic Stall	102.5	87	13.5
J1166 Moving Cycle	99 - 100	86	13 - 14

Photographs of the condition of some of the treatments after the in-service test are shown in Figs. 14 and 15. In general the treatments were in excellent condition and suffered little wear. One piece of cab seal had come away from around the side door, and this seal was repositioned and bonded in place. The floormat had suffered a number of cuts and tears, but was still blocking gaps around the control pedals. The absorption material needed cleaning, but otherwise was in good condition. The in-service tests have demonstrated that the treatments are extremely durable

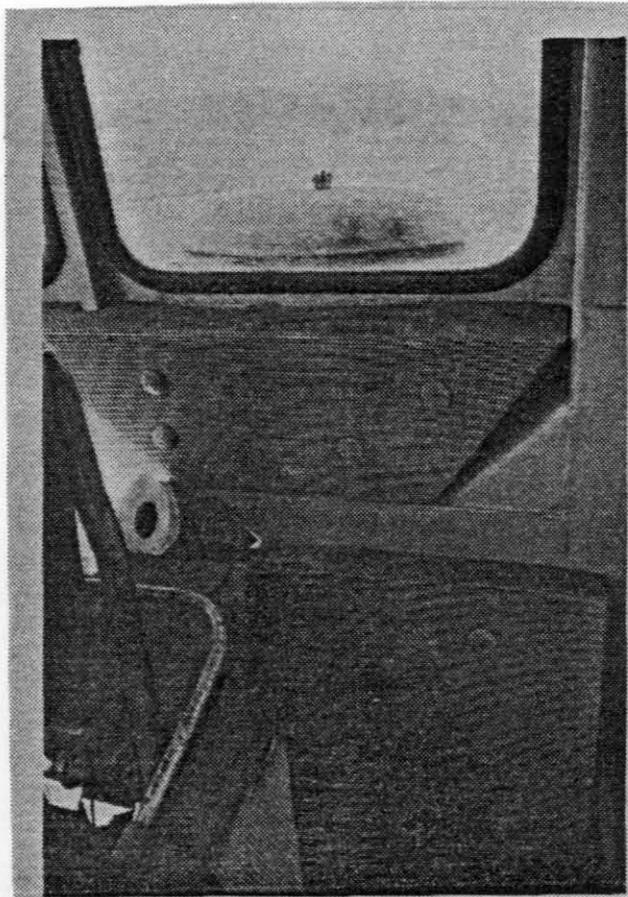


FIG. 14. CONDITION OF ABSORPTION TREATMENT AFTER 20 MONTHS IN SERVICE.

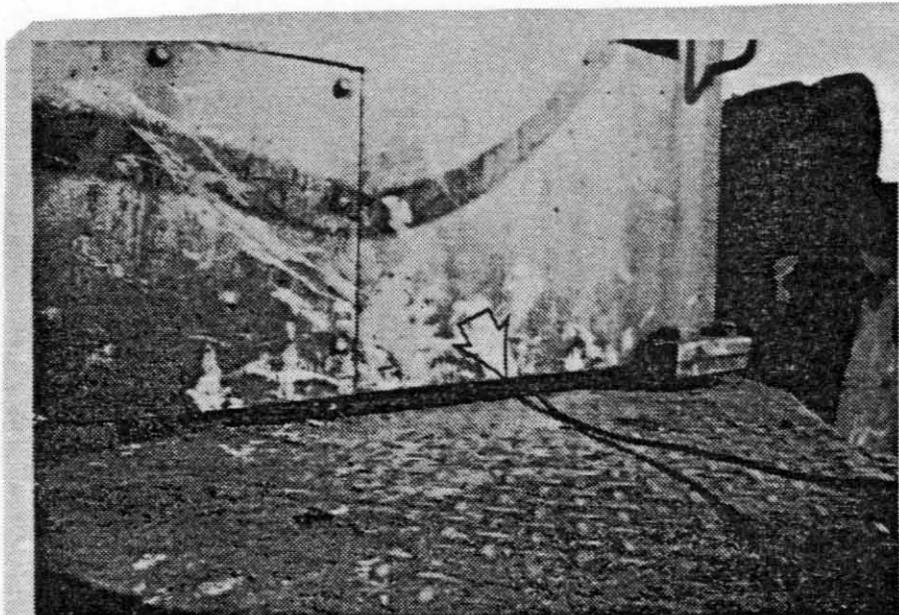


FIG. 15. CONDITION OF CAB SEALS AFTER 20 MONTHS IN SERVICE.

and can continue to provide more than 12 dBA of noise reduction at the operator's position.

2.2 International H-400B

2.2.1 Initial noise levels and source diagnosis

The International H-400B front-end loader is an 11 cu yd bucket machine powered by 635 hp turbocharged diesel engine. The H-400B selected for this demonstration is shown in Fig. 16; it is a much larger loader than the Caterpillar 988.

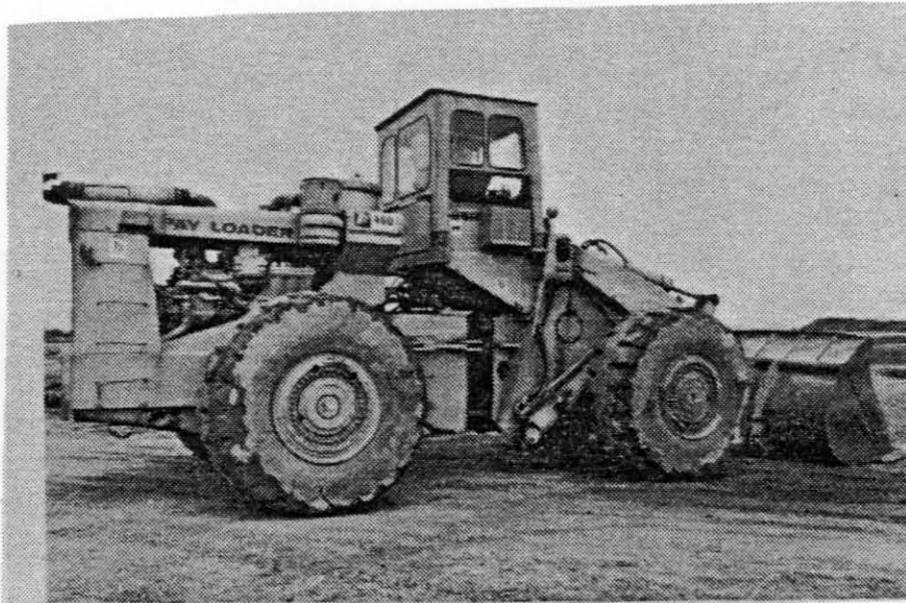


FIG. 16. INTERNATIONAL H-400B FRONT-END LOADER.

The H-400B and the 988 have similar configurations except for the location of the operator cab. The H-400B has the cab mounted to the front half of the machine, while the 988 has the cab mounted to the rear. In addition, the H-400B is fitted with a dual muffler system, with the exhaust exit at the very rear of the machine. Both these factors contribute to lower operator noise levels inside the cab.

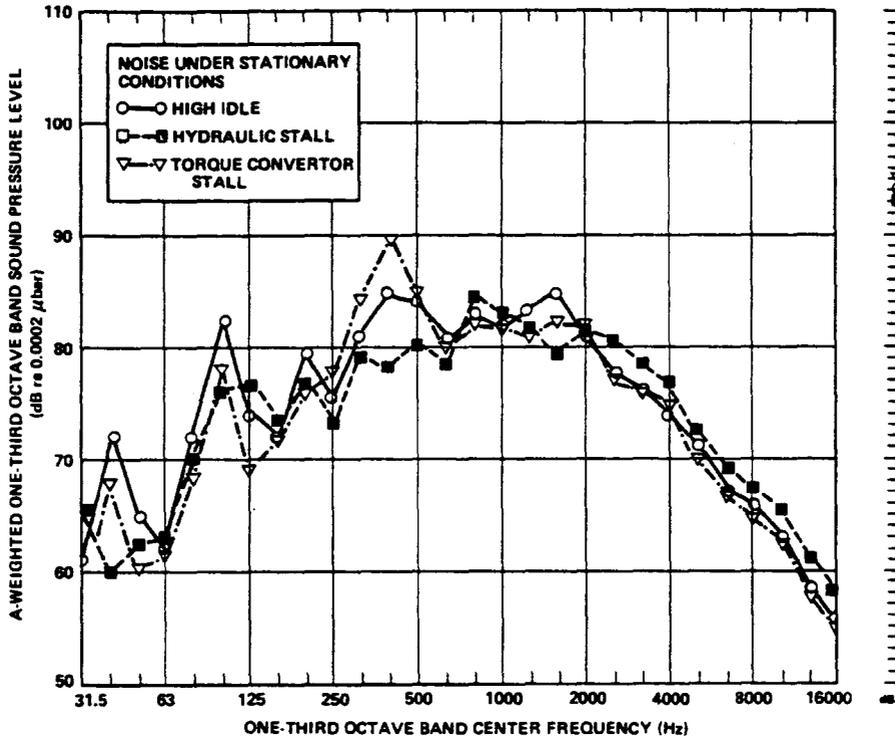


FIG. 17. ONE-THIRD OCTAVE BAND NOISE LEVELS MEASURED AT THE OPERATOR POSITION OF INTERNATIONAL H-400B UNDER STATIONARY CONDITIONS (CAB DOORS OPEN).

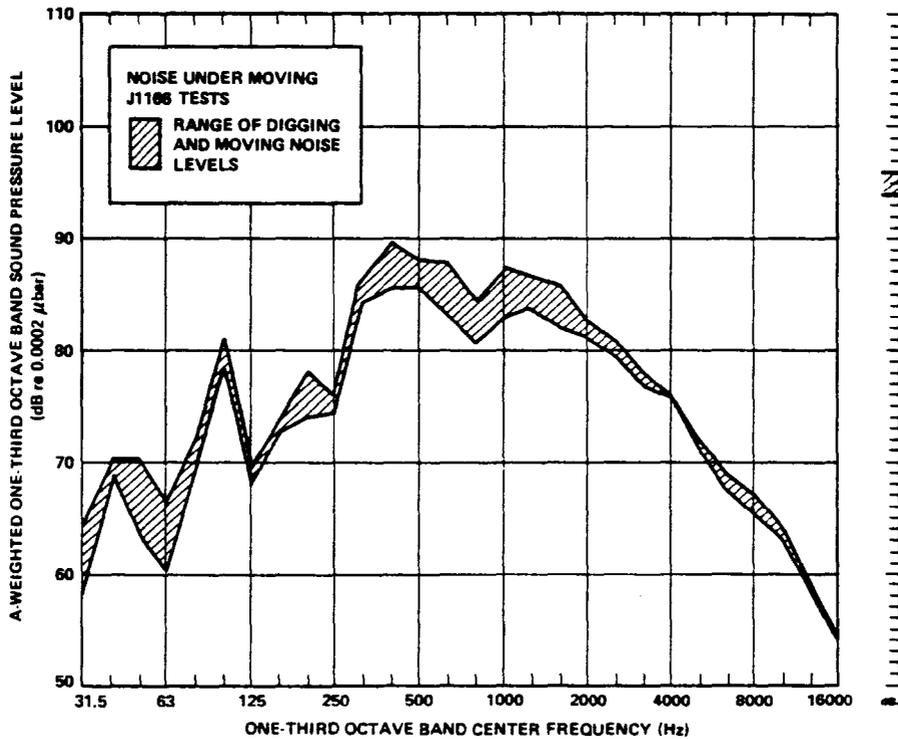


FIG. 18. ONE-THIRD OCTAVE BAND NOISE LEVELS MEASURED AT THE OPERATOR POSITION OF INTERNATIONAL H-400B UNDER MOVING CONDITIONS, SAE J1166 WORK CYCLE TEST (CAB DOOR OPEN).

The one-third octave band noise levels at high idle, hydraulic stall, and torque converter stall are shown in Fig. 17. The A-weighted operator noise levels for these stationary tests were 93 to 95 dBA, with the cab doors open. Measurements from the SAE J1166 moving work cycle tests are shown in Fig. 18. The A-weighted levels are 94 to 96 dBA. The operator noise levels with the cab doors open was approximately 1 dB higher than the corresponding tests with doors open.

The noise sources on the H-400B loader are essentially the same as on the 988. Exhaust noise, although lower due to the dual muffler system, still dominates at low frequencies. Fan noise produces tones in 250 - 400 Hz range, while frequencies above 500 Hz are dominated by engine casing noise and noise from the hydraulic systems. As with the 988, the dominant noise path on the H-400B is airborne sound. Vibration levels measured on the cab surfaces on the H-400B were even lower than those shown in Fig. 9, indicating that structureborne sound was not a significant noise source on this machine.

2.2.2 Noise control treatments

The noise control treatments installed on the International H-400B are shown in Fig. 19. In order of installation, they are:

- Cab wall seals
- Cab sound absorption
- Floor mat.

An exhaust muffler was not part of this package, since one had been installed by the manufacturer. A muffler should be installed on all front-end loaders on which it is not standard equipment.

The cost of the materials used in the noise control package for this H-400B loader was approximately \$580 (in 1979). A cost

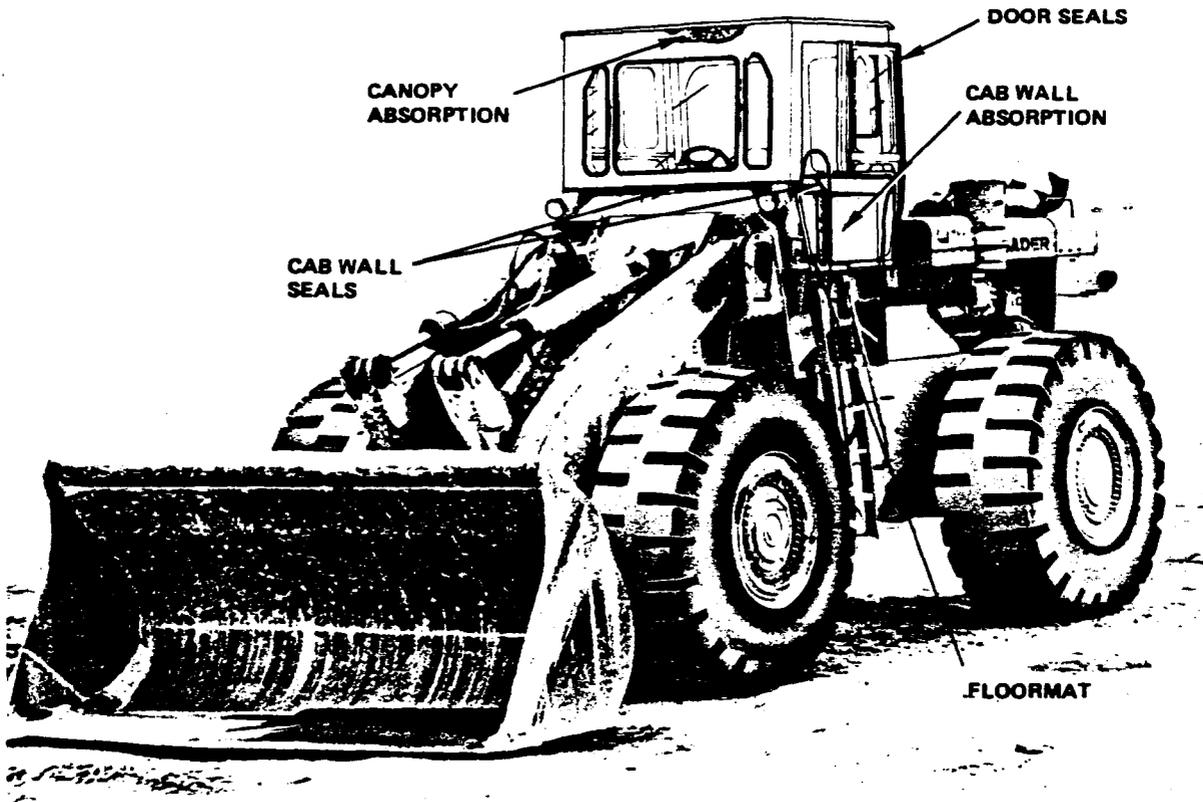


FIG. 19. NOISE CONTROL TREATMENTS INSTALLED ON INTERNATIONAL H-400B FRONT-END LOADER.

summary of the individual treatments and estimated required labor is given in Table 3. The treatments were installed in approximately 19 man-hours. This included time for removing the cab and for a mechanic and his helper to install the complete treatments.

2.2.3 Treatment performance

The fully treated loader operating at a surface mine in Kentucky is shown in Fig. 20. The loader was returned to service in October 1979 and the performance and durability of treatments have been monitored at regular intervals.

The reduction in operator noise level as each successive treatment was applied as shown in Fig. 21. The total A-weighted noise reduction at high idle was 12 dB, reducing the in-cab level

TABLE 3. SUMMARY OF TREATMENT AND LABOR COSTS FOR NOISE CONTROL PACKAGE ON INTERNATIONAL H-400B LOADER WITH CAB.

Treatment	Approximate Material Cost (1979)	Est. Labor (Man-Hours) Mechanic
1. Cab Wall Seals	\$138	8
2. Cab Sound Absorption	393	8
3. Floormat	49	3
Total	\$580	19

**FIG. 20. FULLY TREATED INTERNATIONAL H-400B FRONT-END LOADER IN SERVICE AT KENTUCKY MINE.**

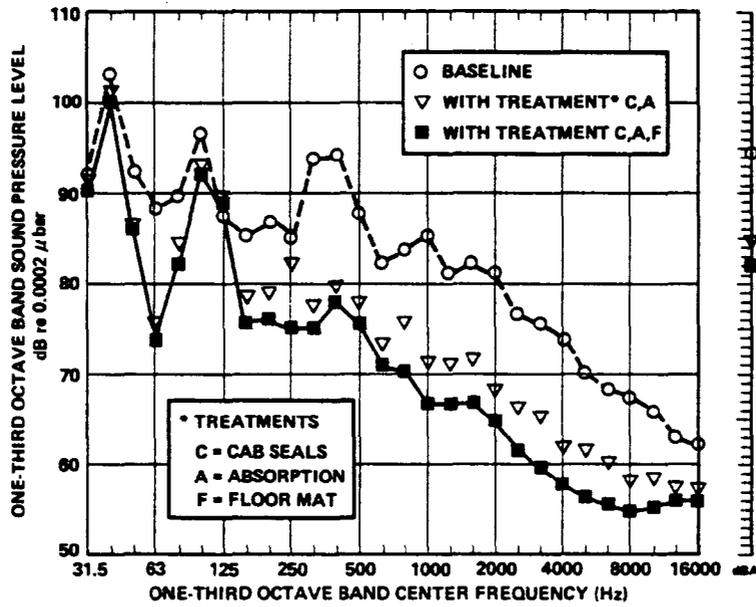


FIG. 21. NOISE AT OPERATOR POSITION OF INTERNATIONAL H-400B AT HIGH IDLE WITH EACH SUCCESSIVE NOISE CONTROL TREATMENT ADDED (CAB DOORS CLOSED).

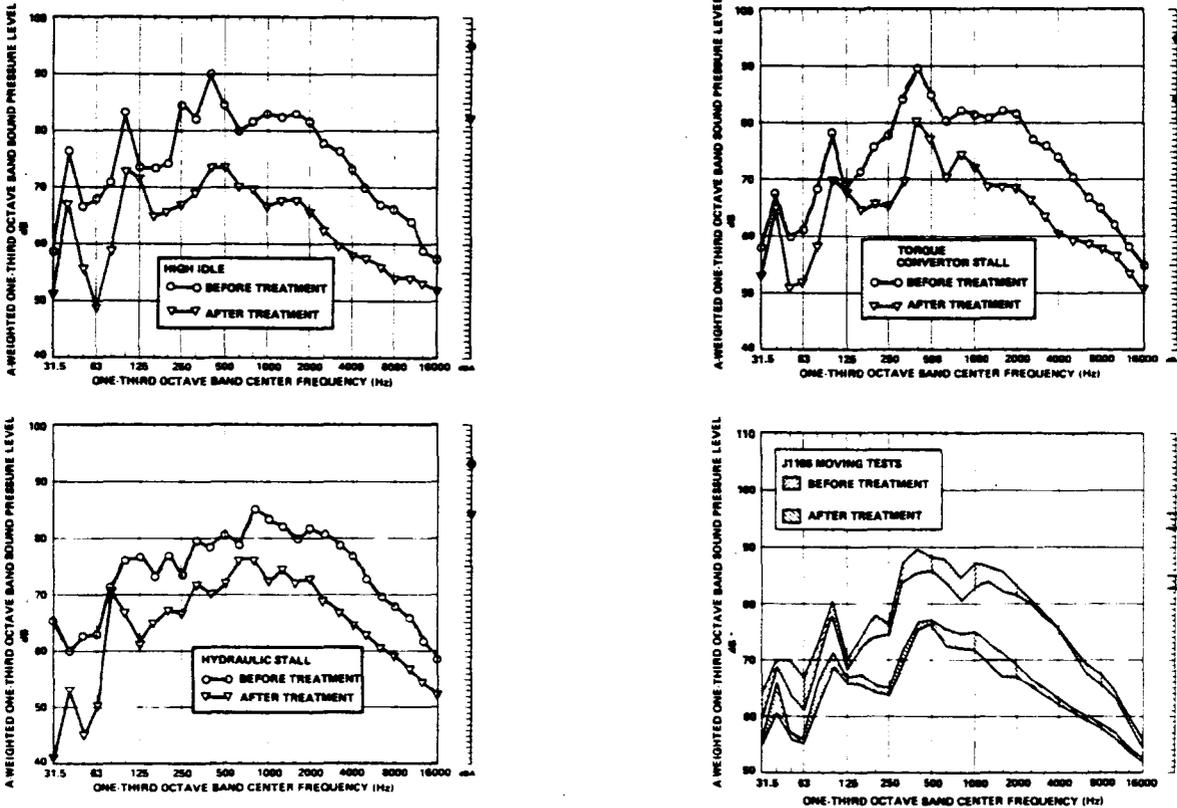


FIG. 22. ONE-THIRD OCTAVE BAND OPERATOR NOISE LEVELS, BEFORE AND AFTER NOISE CONTROL TREATMENTS WERE INSTALLED ON H-400B LOADER. STATIONARY AND MOVING TESTS (CAB DOORS CLOSED).

to 83 dBA, with the doors closed. The noise reductions for other stationary and moving test conditions are shown in Fig. 22.

For all of these test conditions the treatments reduced the operator noise to significantly below the 90 dBA level. Even with the cab doors open, the level at high idle was reduced by 8 dBA to 87 dBA.

Regular monitoring visits were made to the machine during the in-service evaluation phase of this program. The noise levels after the treatments had undergone 12 months of mine service are summarized in Table 4. No significant change in the acoustic performance was seen during this period.

TABLE 4. IN-SERVICE NOISE LEVELS OF TREATED INTERNATIONAL H-400B LOADER (CAB DOORS CLOSED).

Test Condition	Before Treatment (dBA)	Treated Level After 12 Months In Service (dBA)	Noise Reduction (dBA)
High Idle	95	82.5	12.5
J1166 Moving Cycle	94 - 96	84 - 85	10 - 11

Photographs of the condition of the treatments after 12 months service are shown in Figs. 23 and 24. The treatments on this machine have proved extremely durable and there were no problems with any of the treatments. All the cab seals remained in place and the floormat suffered only two minor tears.

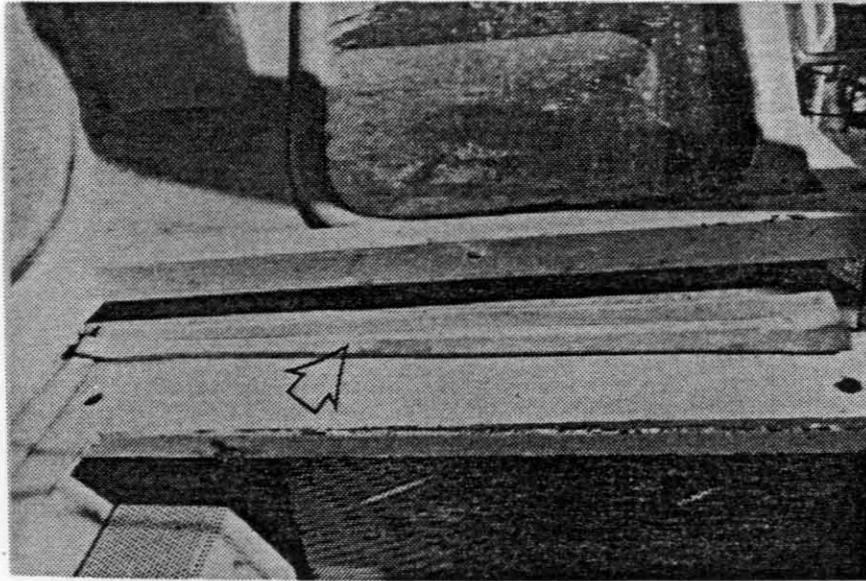


FIG. 23. CONDITION OF CAB SEALS AFTER 12 MONTHS IN SERVICE.

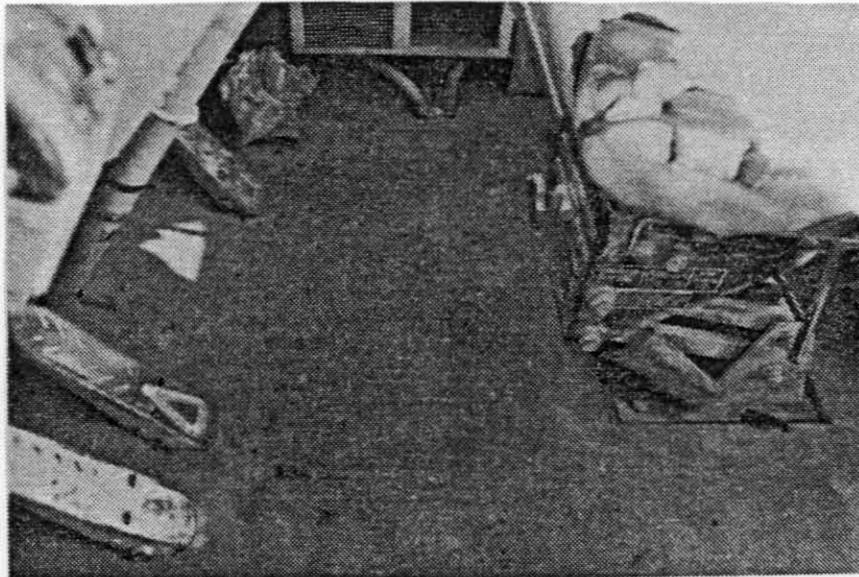


FIG. 24. CONDITION OF FLOORMAT AFTER 12 MONTHS IN SERVICE.

3. TECHNOLOGY TRANSFER

Following the successful demonstration of these retrofit noise control packages on two front-end loaders, a technology transfer program was started. The objective was to describe the results obtained from this program to the mining community, so that they could use this information to install similar treatments on their own equipment. This was achieved through a field manual for each machine and through a series of workshops on loader noise control. An audio-visual record of the workshops was prepared for future distribution to the mining community.

3.1 Noise Control Manual

A field manual entitled "Loader Noise Control" was written to describe the noise control treatments installed on the 988 and H-400B loaders. The cover of the manual is shown in Fig. 25. The manual, containing more than 150 pages, provides detailed step-by-step instructions on the installation of the noise control treatments. Mines that have either a 988 or an H-400B can

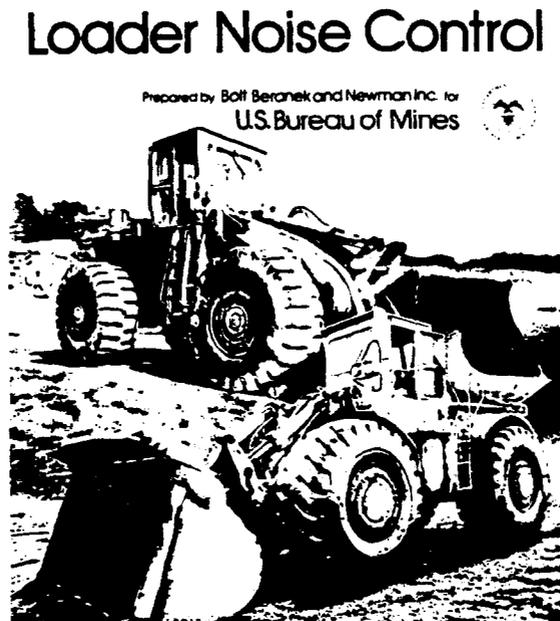


FIG. 25. LOADER NOISE CONTROL MANUAL.

follow the details exactly. In addition, the manual was written so that mines with other types of loaders can use the material. Some modifications to dimensions and material quantities will have to be made for these other loaders, but the general methods are the same. In this way the manual can be used by as many mine operators as possible.

The manual consists of the following sections:

Introduction

Noise Control of CAT 988 Loader

Noise Control of H-400B Loader

Noise Regulations

Noise Measurements

Modifications to ROPS/FOPS Structures

List of Noise Control Materials.

The introduction provides the general background to this program and describes the results and performance of the retrofit noise control packages for the two loaders. The main body of the field manual consists of the two noise control sections. These two sections are laid out identically for each front-end loader, and examples of the instruction pages are shown in Fig. 26. The instructions are clear and concise, and provide for easy installation of the treatments.

The appendices to the manual provide information on the Federal noise regulations and give a detailed description of noise measurement and the instruments used. In addition, there is a section on the cautions to be aware of before making any modifications to the roll over protective structures (ROPS). Finally, there is a complete list of the manufacturers, including addresses and phone numbers, that sell noise control materials. The last two pages of the manual are complete parts lists for the

988: CANOPY/CAB WALL ABSORPTION

16. Make up cardboard templates and weld mounting studs for the rear cab wall absorption, following the same instructions given in Steps 2 to 6. Figure 2.16 shows typical templates used for the rear cab wall, and Fig. 2.17 shows the mounting studs with threaded rod attached.

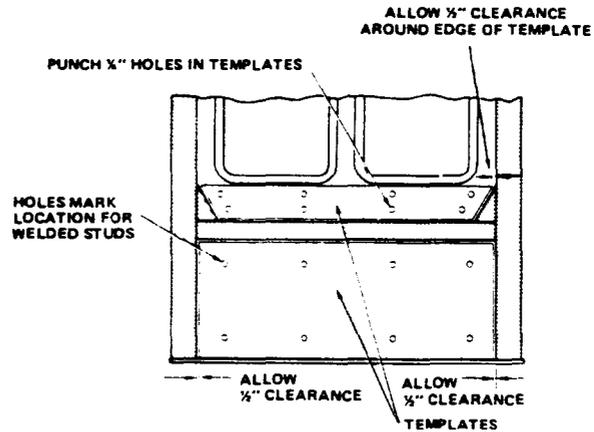


FIG. 2.16. TYPICAL TEMPLATES USED FOR REAR CAB ABSORPTION.



FIG. 2.17. THREADED ROD AND STANDOFFS ATTACHED TO EACH MOUNTING STUD ON REAR CAB WALL.

2-13

FIG. 26. EXAMPLES FROM LOADER NOISE CONTROL MANUAL.

H-400B: CAB WALL SEALS

INSTRUCTIONS

1. The cab must be removed from the machine in order to install the cab wall seals. Unbolt the ROPS mounting bolts, and remove the cab (see Fig. 6.2).



(a) Unbolting ROPS Bolts

(b) Lifting Cab Off

FIG. 6.2. REMOVING THE OPERATOR CAB ON H-400B LOADER.

CAUTION

Follow standard safety procedures to remove the cab. Block the cab while working under it or inspecting parts.

2. Check the ROPS bushings (see Fig. 6.3) for wear or deterioration. Inspect each of the bushings, and replace if worn.

FIG. 26 (CONT'D.).

retrofit treatments used on each loader. Using these lists a mine could purchase all the necessary materials required for the installation.

3.2 Noise Control Workshops

In conjunction with the noise control manuals a series of one-day workshops was held in nine strategic locations around the country. The workshops were intended for mine operators, shop foremen, safety personnel, and others responsible for mobile equipment noise control. The locations and dates of these workshops are given in Table 5. Extensive advertising in all the major mining magazines and journals was done to encourage people to attend these seminars. Appendix A lists the magazines that were contacted. In addition, most of the district, sub-district, and local MSHA offices were contacted for their help in advertising the workshops. Mining companies were contacted directly through mailing lists and through the USBM technical news release listings.

TABLE 5. FRONT-END LOADER WORKSHOPS.

<u>City</u>	<u>State</u>	<u>Date</u>
Washington	PA	29 September 1981
Louisville	KY	2 October 1981
Duluth	MN	7 October 1981
Denver	CO	14 October 1981
Seattle	WA	29 October 1981
Anaheim	CA	22 June 1982
Phoenix	AZ	25 June 1982
Dallas	TX	22 July 1982
Washington	DC	27 July 1982

The topics covered in the workshops included the fundamentals of noise measurement and control, as well as detailed fabrication and installation of the specific treatments. Again, the emphasis was to ensure that the attendees would be able to reproduce the results from this program on their own equipment. A summary of the workshop format is given in Appendix B.

A series of five visual display panels was used at the workshop sessions. Each panel was an exhibit of the major noise control treatments applied to the front-end loaders.

Figure 27 shows the panels assembled together, forming a backdrop for the workshops. In addition to the displays, a number of smaller exhibits were made, which modeled specific fabrication and installation techniques. These models were very beneficial in showing the workshop attendees how the various treatments were assembled.

A large number of different types of noise control materials were also on display, and several equipment manufacturers lent sound level meters and dosimeters for the workshops.

More than 400 people attended these workshops and each attendee received a copy of the noise control manual. The attendees were mainly from either the mining industry or MSHA inspections. A breakdown of the various categories is given in Table 6. A broad range of mining personnel attended these workshops, from mine owner to loader operator. The overall comments were that the workshops were very useful and provided detailed information on how to install the treatments. A workshop evaluation sheet was obtained from each attendee and copies of these have been forwarded to the USBM.

A follow-up survey was also conducted to evaluate the impact of the workshops. This survey consisted of telephone interviews with the workshop attendees in which a number of questions were asked regarding the workshop and manual.

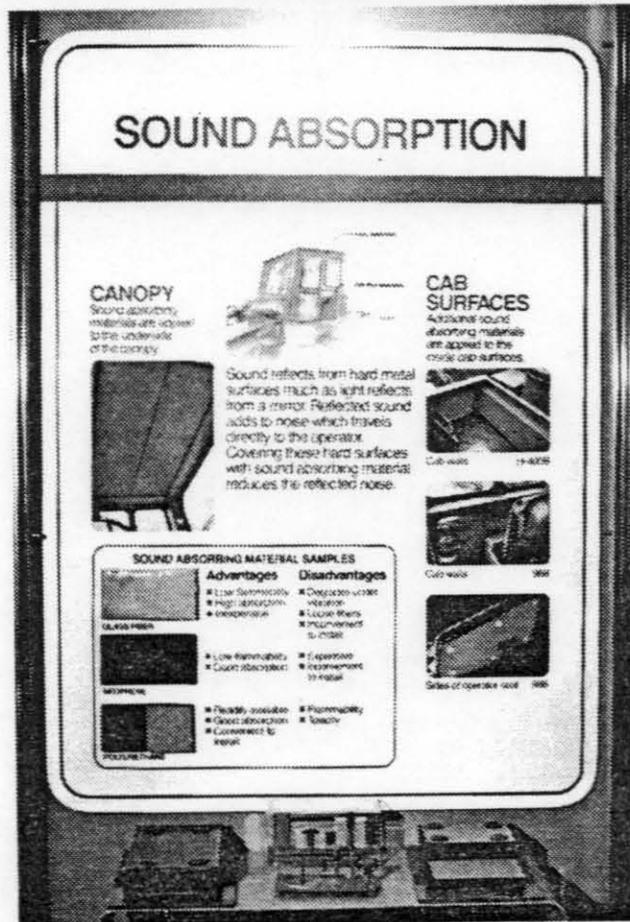
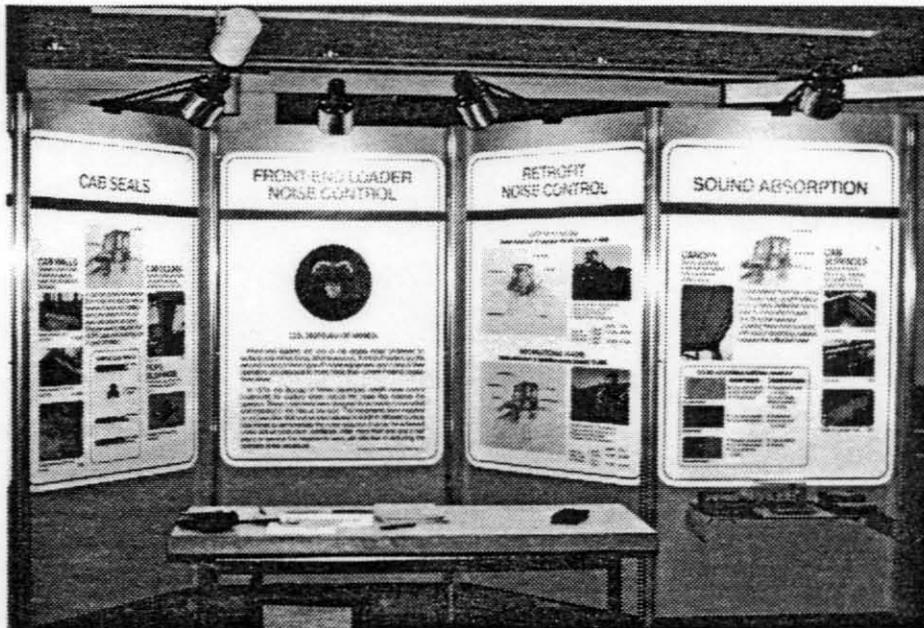


FIG. 27. EXHIBIT PANELS USED IN USBM FRONT-END LOADER WORKSHOP.

TABLE 6. ATTENDEES AT USBM FRONT-END LOADER NOISE CONTROL WORKSHOP.

Location	Industry	MSHA	U.S. Government and State Officials	Equipment Vendors	Others	Total
Washington, PA	39	21	6	-	-	66
Louisville, KY	24	18	2	4	1	49
Duluth, MN	37	28	2	4	1	72
Denver, CO	14	10	11	-	1	36
Seattle, WA	13	15	5	3	-	36
Anaheim, CA	23	7	-	-	-	30
Phoenix, AZ	29	10	15	-	2	55
Dallas, TX	29	11	1	5	2	48
Washington, DC	4	5	3	-	-	12
Total	212	125	45	16	6	404

The telephone survey was made fourteen months after the first series of loader workshops and six months after the second series. A total of 82% of the available attendees were contacted; many had been laid off or phones disconnected after this period of time. The complete results of the survey are given in Appendix C. More than half of the attendees had installed noise control treatments on their own equipment, and 85% of these had done it after attending the workshops. Some thirty different mining operations were identified that had treated a wide range of front-end loaders as well as other types of mobile equipment.

3.3 Audio-Visual Presentations

Two audio-visual presentations were prepared for the Bureau of Mines. The objectives of these presentations were to provide a permanent record of the loader workshops, which the Bureau would be able to use in response to future requests for work-

shops. A slide show with an accompanying narrative was chosen as the most useful format, to send out to small groups or individual organizations within the mining community.

The first audio-visual presentation was a two-hour series of slides with narrative, that was aimed at helping maintenance engineers, mechanics and mine personnel in fabricating and installing the noise control treatments on their loaders. In essence, the presentation is a shortened version of the workshop, except that it is a self taught program with slides and a recorded tape. The first hour covers the basics of noise and noise control methods. There are also sections on the Federal regulations, noise measurement, and loader noise control. The second hour consisted of instructions for the installation of the treatments. Each treatment is covered in detail from material selection and fabrication, through to installation.

The second slide presentation is a one-hour session that is a condensed version of the first presentation. The emphasis was more on loader noise control techniques and the treatment results. The session was aimed at mine safety engineers and mine superintendents that are more interested in the general results of the program rather than the detailed assembly and installation instructions.

Using both these audio-visual presentations and additional copies of the field manual, it is felt that the Bureau will continue to be able to provide the mining industry with practical information on loader noise control.

4. CONCLUSIONS

Two front-end loaders, a Caterpillar 988 and an International H-400B, were chosen for this noise control demonstration program. Noise source diagnostic measurements were made on these loaders, and the operator noise levels for both stationary and moving conditions obtained. Typical noise levels at the operator's position were 98 to 100 dBA for the 988 and 94 to 95 dBA for the H-400B. Retrofit noise control treatments that were designed for both machines provided 11 to 12 dBA of noise reduction. The treatments were designed to be low cost and easily constructed by mine personnel. After the treatments were installed the operator's noise level on the 988 was 89 dBA, and on the H-400B, it was 83 dBA, at high idle.

The loaders were then returned to service at two surface coal mines and the performance of the treatments was monitored over a period of up to two years. During that time there was no significant change in the acoustic performance of these treatments. The durability of the materials on both machines was excellent. The only minor problems were one 6 in. section of cab seal on the 988 that needed to be repaired, and minor cuts on the floormat material.

A one-day noise control workshop was developed to transfer the information obtained from this demonstration program to the mining industry. The workshops discussed the fundamentals of noise and noise measurements, as well as fabrication and installation of the treatments. A number of exhibits and displays were fabricated and used in conjunction with the workshops. Each of the different noise control treatments was illustrated on a large five panel display. A 150-page front-end loader noise control manual was written, which contained detailed, step-by-step instructions on the fabrication and installation of the treatments on the 988 and H-400B. The manual also contained useful information on Federal noise regulations, noise measurement,

instrumentation, and material suppliers. Each person attending the workshops received a copy of this manual. The workshops were given in nine states across the U.S., and over 440 manuals were distributed to attendees. Workshop evaluation forms were obtained from the attendees and the overall comments were extremely favorable. People found the exhibits and slides very informative, and the exhibits were useful in illustrating specific installations. The manual was well received and there have been many requests for additional copies. In addition, a telephone survey of the attendees, conducted six months after the last workshop, showed that many mining operations are using the information to install treatments on their own equipment. A two-hour and a one-hour audio-visual presentation of the workshops has been produced. The slide and tape recorded sessions are aimed at providing training for mine personnel interested in loader noise control.

REFERENCES

1. "A Census of Mobile Machines Used in U.S. Surface Coal Mines," USBM Contract No. JO166057, BBN Report 3616, July 1977.
2. "Noise Control of Large Track Dozers Used in Surface Mining," USBM Contract JO177049, BBN Report No. 5296, April 1983.
3. "Assessment of the State of the Art - Noise Control of Rubber-Tired Front-End Loaders Used in Surface Mining. Task 1 Report. USBM Contract JO395028, BBN Report 4453, July 1980.
4. "The Noise of Mobile Machines Used in Surface Coal Mines: Operator Exposure, Source Diagnosis, Potential Noise Control Treatments," USBM Contract JO166057, BBN Report 3764, August 1978.

APPENDIX A: WORKSHOP ADVERTISING

The front-end loader noise control workshops were advertised in numerous ways. News releases were prepared and sent out to all mining magazines and journals for publication either as an article or in the "calendar" section of each journal. A separate news release was prepared for the Department of Interior, which was then circulated to more than 7000 people on the department's mailing list. Workshop announcements, such as the one shown in Fig. A.1, were sent to all the MSHA District and Sub-District Offices. In addition, the District offices in the nine workshop locations were contacted by phone, and lists obtained for all coal, and metal/nonmetal mines in the area. Workshop flyers were sent directly to more than a thousand mines. News releases and flyers were sent to the many coal mining operators and associations around the country. Twenty-six executives, who represent the state crushed-stone associates, were contacted and sent literature. Local newspapers were contacted and several ran short announcements on the workshops. Local mining colleges and universities were also informed of the workshops.

The major groups to which advertising literature was sent are listed below.

Magazines and Newspapers

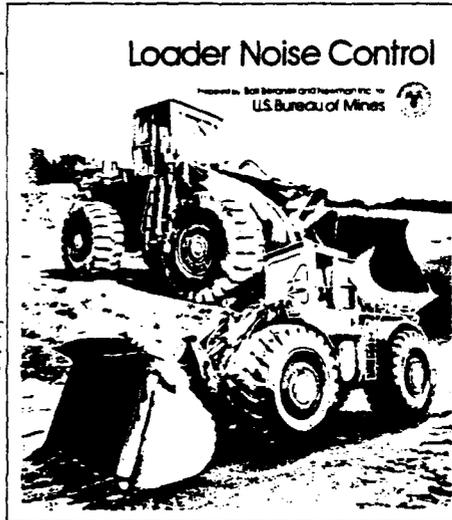
Coal Age	UNC Mining and Milling
Mining/Processing Equipment	Services, The
World Mining	UMW Journal
Mining Congress Journal	Coal People Magazine
Coal Mining and Processing	American Mining Congress
Skillings' Mining Review	Journal
Rock Products	Mining Engineering
Pay Dirt	Engineering & Mining Journal
Pit and Quarry	Limestone
Mines Magazine (Colorado	The International Operating
School of Mines)	Engineer
Western Prospector and Mining	Voice of the Cement, Lime,
The National Limestone	Gypsum & Allied Workers
Institute	Coal Industry News

Announcing . . .

A free half-day workshop on

Retrofit Noise Control of Front-End Loaders

Workshop participants will receive this free noise control manual.



Workshop Information

The Bureau of Mines is sponsoring a series of free half-day workshops on front-end loader noise control. These workshops, presented by Bolt Beranek and Newman Inc., are intended for mine operators, shop foremen, safety personnel, or others responsible for mobile equipment noise control.

The workshop format will be similar to the recent, very successful Bulldozer Noise Control workshops. Topics to be covered include fundamentals of noise measurement and control (applicable to all mobile equipment) as well as fabrication and installation of specific treatments. Examples of noise control hardware and materials will be displayed. The noise control treatments, which can provide more than 10 dB of noise reduction, have been field tested for two years in surface coal mines. The specific treatments that will be described are relatively low cost (approximately \$500 in materials per machine) and can be readily fabricated and installed in the field by mine personnel.

Each person attending a workshop will receive a 150-page *Front-End Loader Noise Control* manual, which contains complete detailed instructions on fabrication and

installation of the noise control treatments. The manual also contains useful information on current Federal noise regulations, noise measurement techniques and instrumentation, and materials suppliers.

To reserve a place at the workshop nearest your mine and obtain more information on workshop locations, please contact Carol Prybylo Bolt Beranek and Newman Inc. 50 Moulton Street Cambridge, MA 02238 (617) 491-1850

Workshop Locations

CITY	STATE	DATE
Washington	Pennsylvania	29 September, 1981
Louisville	Kentucky	2 October, 1981
Duluth	Minnesota	7 October, 1981
Denver	Colorado	14 October, 1981
Seattle	Washington	29 October, 1981

Comments from Workshops on Dozers

"Excellent overall presentation, an impressive example of government-industry cooperative approach to solving noise problems. Washington, PA

"The material was well organized and presented. This was the first realistic approach to noise control that I've encountered. Pikeville, KY

"Very interesting and well presented. Will be of great value when installing noise control treatments. Denver, CO

"Overall this is the best presentation of its kind I have attended, and I've had to pay for most of the others." Caryville, TN

"Overall very useful and informative, demonstrations, displays and audio-visuals really complemented factual presentation. Charleston, WV

"Most comprehensive workshop I have attended on specific applications of noise control. Lakeland, FL

"An absolutely superb presentation in every respect. Installation techniques and tips were very helpful. Madisonville, KY

"The presentation was precise, professional and most enjoyable. I wish more personnel from the plant could have attended." Albuquerque, NM

FIG. A.1. TYPICAL ADVERTISING LITERATURE FOR LOADER WORKSHOPS.

Coal Outlook
Coal Week
Independent Coal Operator

Arizona Republic
Tucson Daily Citizen
Arizona Daily Star

Associations

Alabama Mining Institute
Alabama Surface Mining-
Reclamation Council
American Society of Safety
Engineers
Big Sandy-Elkhorn Coal
Operators Assoc.
Central Pennsylvania Coal
Producers' Assoc.
Coal Operators & Assoc., Inc.
The Colorado & New Mexico Coal
Operators Assoc.
Coal Producers Assoc. of IL
Eastern Bituminous Coal Assoc.
Harlan County Coal Operators
Assoc.
Hazard Coal Operators Assoc.
Illinois Coal Assoc.
Indiana Coal Assoc.
Kanawha Coal Operators Assoc.

Kentucky Coal Assoc.
KY-TN Coal Operators Assoc.
Keystone Bituminous Coal
Assoc.
Logal Coal Operators' Assoc.
Mid-West Coal Producers Insti-
tute, Inc.
Northern WV Coal Assoc.
OH Valley Coal Operators'
Assoc.
PA Coal Mining Assoc.
Southern Coal Producers'
Assoc.
Southern Virginias Coal Assoc.
Southwestern Interstate Coal
Producers Assoc.
Virginia Coal Assoc.
West Virginia Coal Assoc.
Western PA Coal Operators
Surface Mine Operators Assoc.

Sent to twenty-six State Crushed-Stone Associations.

Government

Dept. of Interior News Release
U.S. Bureau of Mines
MSHA District Office
(coal and metal/nonmetal)

MSHA Sub-District Offices
State Mine Inspectors Offices
OSHA
EPA

APPENDIX B: WORKSHOP FORMAT

The format for the loader noise control workshop is shown below.

	<u>Start Time</u>	<u>Duration (Min)</u>	<u>Session Length</u>
Introduction	8:15	5	
Federal Noise Regulations	8:20	8	
Background	8:28	6	1 Hr
Fundamentals of Noise	8:34	15	
Noise Measurements	8:49	26	
BREAK	9:15	15	
FEL Noise	9:30	3	
Noise Control Methods	9:33	12	
Noise Control Demonstration	9:45	10	1 Hr
FEL Results	9:55	10	
Registration	10:05	15	
Noise Control Manual	10:20	10	
BREAK	10:30	20	
Treatment Overview	10:50	5	
Cab Seals	10:55	15	
Floormat	11:10	8	
Pedestal Seals	11:18	10	1 Hr
Muffler	11:28	2	
Sound Absorptions	11:30	25	
END	11:55		

APPENDIX C: WORKSHOP FOLLOW-UP SURVEY

This section summarizes the results obtained from a telephone evaluation of the workshop attendee's experience in a retrofit noise control. The objectives of this survey were to determine whether attendees were using the information obtained at the workshops, and what, if any, where their experiences in using the field manual.

The telephone survey was made fourteen months after the first series of loader workshops and six months after the second series. A total of 404 people attended these workshops including 212 from industry, 125 from MSHA, and 67 from U.S. Government Agencies, equipment vendors, insurance companies, and others. This last group of 67 were eliminated from the survey since they were unlikely to have had any experience in retrofit treatment.

Data Sample

A summary of the number of telephone responses is presented in Table C.1. In the industry group, 67 of the attendees were either laid off, no longer with the company, or the phone had been disconnected. In cases where there were more than one attendee from the same company, only the response from the senior person in that company was noted. Approximately half of the 125 MSHA attendees were multiple registrations from the same offices.

TABLE C.1. SUMMARY OF THE NUMBER OF TELEPHONE RESPONSES FROM WORKSHOP ATTENDEES.

Industry	124	Contacts
	67	Laid off, no longer with company, disconnected phone
	15	No answer after three calls
	<u>6</u>	Waiting for return call
Total	212	
MSHA	40	Contacts
	69	Multiple registrations
	<u>16</u>	Waiting for return call
Total	125	

Eliminating the laid off industry attendees, and the multiple MSHA registrations, leaves a total of 201 potential responses. Of these, we have obtained 164 responses, or 82% of the useful data base. Since many people had to be called several times before contact was made, the total survey has involved more than 400 phone calls.

Results

The results from the industry survey are shown in Tables C.2 and C.3. Almost all the attendees found the workshops helpful, beneficial, and that it was one of the best seminars they had attended. Many found the ideas and suggestions very practical, others felt that the material helped reinforce some of the concepts they already knew. Only 2% were unhappy with the workshops, since they felt that the retrofit treatments were too expensive. Technically they found the workshops excellent.

TABLE C.2. RESULTS FROM TELEPHONE EVALUATIONS FROM INDUSTRY ATTENDEES AT THE USBM LOADER NOISE CONTROL WORKSHOPS.

Question	Yes	No
1. Did you find the Workshops helpful?	98%	2%
2. Have you installed noise control treatments on your equipment?	58%	42%
	Before	After
3. Were the treatments installed before or after the workshops?	15%	85%
4. What types of equipment did you treat, and what were the results?	See Table 3	
5. Did you find the manual helpful in the fabrication and installation of the treatments?	100%	-
6. Did you make any changes or improvements in treatment design?	5%	95%

TABLE C.3. SUMMARY OF NOISE CONTROL TREATMENTS INSTALLED BY COMPANIES AFTER REPRESENTATIVES ATTENDED THE USBM NOISE CONTROL WORKSHOPS.

Type of Operation	City, State	Equipment Treated	Results		Comments
			Before Treatment (dBA)	After Treatment (dBA)	
Metal/ Nonmetal	Tahavas, NY	CAT 988 Loader CAT 988 Loader Marion 131M	- - -	Abated citation Abated citation Into compliance	
Coal	Butler, PA	CAT 980 Loader CAT 980 Loader	98 - 95	89 - 88	Into compliance
Metal/ Nonmetal	Youngstown, OH	Loader Off-Highway Truck	- -	Avoided citation -	No data
Metal Nonmetal	Pittsburgh, PA	CAT Loader	95	86 - 88	Into compliance
Copper	Claypool, AZ	Dragline	95	84	Abated citation
Sand/Gravel	Irvine, CA	Allis Chalmers Loader	-	-	Significant noise reduction
Sand/Gravel	Burnsville, MN	CAT 988 Loader	-	-	Noise reduction achieved
Lignite	College Station, TX	CAT D9H Dozer	-	-	Entire manual treatment will be ready 6/83
Metal/ Nonmetal	Marquette, MI	Terex 50 Dozer	-	-	Absorption treatments
Taconite	Eveleth, MN	Scraper	98	88	Abated citation
Sand/Gravel	Los Angeles, CA	D8 Dozer D8 Dozer D8 Dozer Total of 15 Front-End Loaders	105 - 103 98 - 94	92 - 93 89 - 86	Abated citations Some machines had treatments started just prior to workshops
Taconite	Mt Iron, MN	Reel Crane	-	-	Abated citation
Stone/ Limestone	Mew Enterprise, PA	Loader	-	-	Into compliance
Metal/ Nonmetal	Cleveland, OH	CAT 988 Loader	-	-	Significant noise reduction

TABLE C.3 (CONT'D.).

Type of Operation	City, State	Equipment Treated	Results		Comments
			Before Treatment (dBA)	After Treatment (dBA)	
Sand/Gravel	Canfield, OH	Several CAT 988 Loaders Michigan 175 Loaders Off-Highway Trucks	-	-	Abated citations Started work before workshops. Manual very helpful in con- tinuing work.
Gravel	St. Paul, MN	Loaders Dozers	- -	- -	Into compliance
Metal/ Nonmetal	Pittsburgh, PA	CAT 977 Loader Loader Loader	- - -	- - -	All achieved "great results."
Coal	Luttrell, TN	CAT D9 Dozer	105	93	Abated citation
Stone	Louisville, KY	Off-Highway Truck Track Drills	7 DB reduction 20 dB reduction		Built acoustic enclosure
Sand/Gravel	Louisville, KY	CAT 988 Loader Euclid R13 Truck	-	-	Treatment planned in 6/83
Coal	Patriot, IN	CAT 980 Loader CAT D7 Dozer	- -	- -	Significant noise reduction. Abated citation.
Metal/ Nonmetal	Pikeston, OH	CAT Loaders Michigan Loader Dozer	- - -	- - -	Several done prior to workshop. Manual used for all makes.
Stone	Shepardsville, KY	Loader	-	-	Into compliance
Stone	Crestwood, KY	CAT 988 Loader Clark 275 Loader Red Dart Off-Highway Truck	275X Dose - -	95X Dose - -	Into compliance Significant noise reduction
Sand/Gravel	Everett, WA	CAT 980 Loader	-	-	No data
Cement	Haviana, NY	Loaders Dozers			Floormat treatments
Coal	Kittanning, PA	CAT M-Lift Loader Lima 1250 Shovel	- -	- -	Significant noise reduction No data
Sand/Gravel	Temple Hill, MD	CAT 970 Loader CAT 970 Loader CAT 970 Loader CAT 970 Loader			Brought all four loaders into compli- ance
Coal	Pittsburgh, PA	Loaders Dragline	- -	- -	No data No data
Sand/Gravel	Barkely Springs, WV	D8 Dozer Crane			Into compliance No data

Just over a half of the attendees have installed noise control treatments on their own equipment, and 85% of these did it after the workshops. The major reason given for not doing noise control was due to the poor economic conditions. This was particularly true with coal, copper, and taconite operations. Several taconite mines have been shut down for more than a year. Many felt that in better economic times they would have tried the treatments, and some operators still have plans to retrofit their equipment when the economy turns around. Other reasons for not doing the treatments were that they are using hearing protection, or that they have purchased all new factory equipment with sound suppressed cabs.

Fifteen percent of the attendees had tried some noise control treatments before the workshops. Many of these found that the workshop information provided additional insight and ideas on specific treatments. All the attendees found the field manual to be extremely useful, and some have used it step-by-step on their equipment. Few instances of modifications or improved treatment design were reported. Although a number of people have tried different floormat treatments with success.

The types of equipment and the results from these treated machines are shown in Table C.3. Unfortunately, it is often difficult to get specific treatment information and noise level data from the attendees. Attempts were made wherever possible to obtain specific information. In many cases noise citations were abated after the treatments had been installed. In other instances, no citation had been issued but the operator noise exposure was brought into compliance.

Table C.3 illustrates that a variety of mobile equipment have been treated. In addition to front-end loaders, equipment such as scrapers, shovels, off-highway trucks, and cranes were treated.