

CASE HISTORY 41: INDUCED-DRAFT FAN
(Community Noise Problem)

Robert M. Hoover
Eric W. Wood
Bolt Beranek and Newman Inc.
50 Moulton Street
Cambridge, Massachusetts 02138
(617) 491-1850

The use of large induced-draft fans (greater than 5000 hp), common in new fossil-fueled electric power plants, may cause noise problems in communities near the plant. In the following case history, a successful noise control treatment for an electric power plant induced-draft fan system is described.

Problem Description

Two oil-fired units, each capable of generating 600 Megawatts (MW) of electricity, were constructed within 1500 ft of a suburban community in the northeastern section of the United States. A serious community noise problem, caused by plant noise radiating into the community, became evident shortly after the first generating unit became operational. Verbal and written complaints were received by the utility, adverse letters and articles were published in the local newspapers, and threats of legal action were received.

Bolt Beranek and Newman Inc. consultants were retained to study the problem and recommend appropriate noise control treatments. They determined that the plant noise heard in the community was generated by the induced-draft fans and was radiated primarily from the top of the discharge stack and secondarily from the fan discharge breeching.

The fans involved are two backwardly inclined, 12-bladed, centrifugal units, each of which delivers about 800,000 ft³/min at 19 in. of water static pressure at a gas temperature of about 300°F. They are driven by 5000-hp, 900-rpm, single-speed electric motors. The induced-draft fan system layout of Figure 6.41.1 is similar to the layout described in this case history.

Problem Analysis

Octave-band and tape-recorded measurements were made of the noise in the community, late at night and early in the morning, with and without the plant operating. These data provided the maximum amount by which the plant noise exceeded the residual ambient sounds and helped to establish the noise reduction goal. The goal was to reduce the continuous plant noise to approximately the level of the residual ambient in the community prior to plant operations.

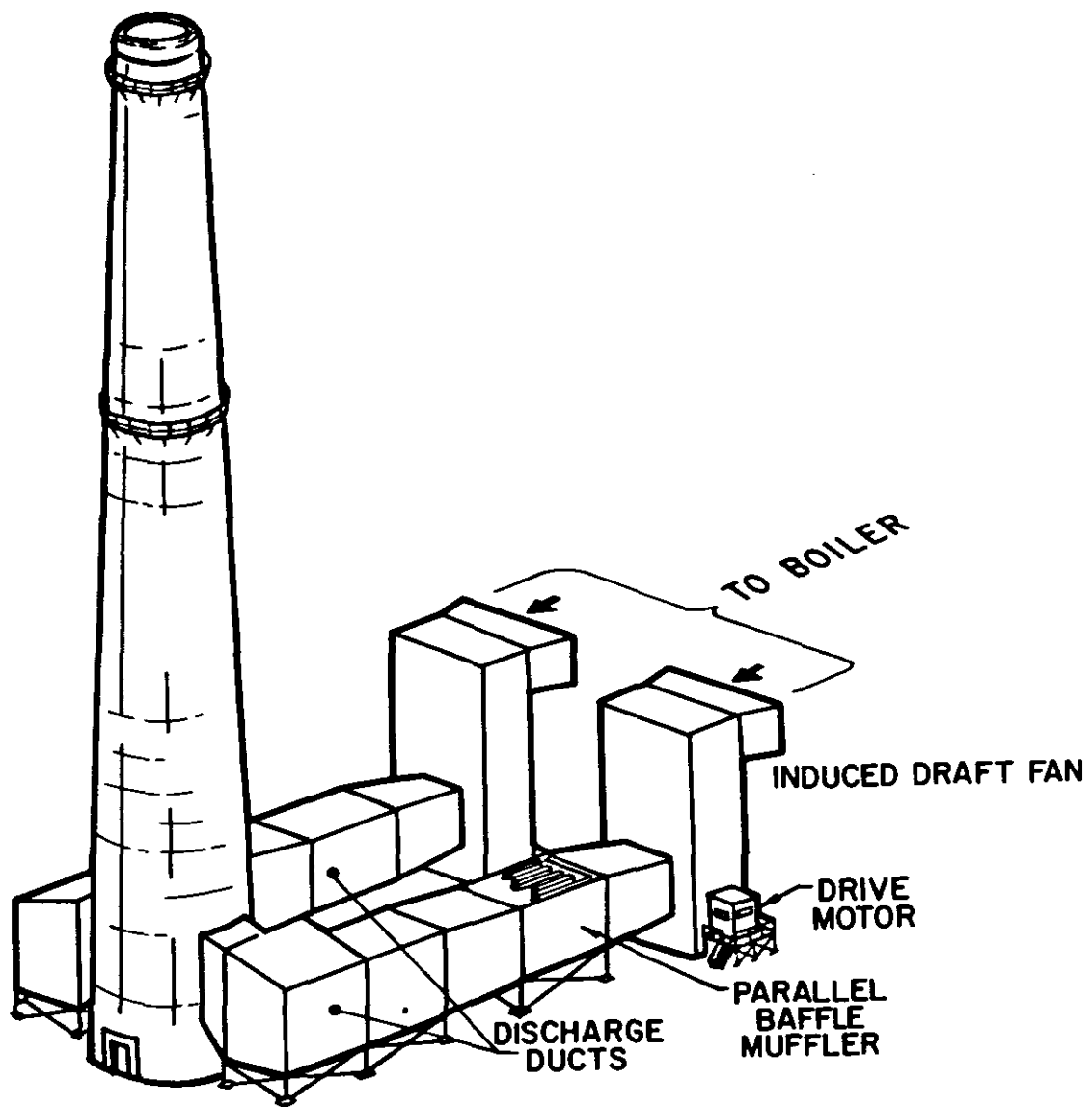


Figure 6.41.1. Induced draft fan system layout.

To identify the plant noise sources that contributed to the sounds measured in the community, data were obtained close to possible noise sources and used to estimate their contribution to the levels measured in the community. For example, Figure 6.41.2 illustrates octave-band sound pressure level measurements of the fan noise that were obtained on the boiler house roof, about 200 ft from the stack opening and just below the top of the stack. This position is in the far field of the stack opening, but not

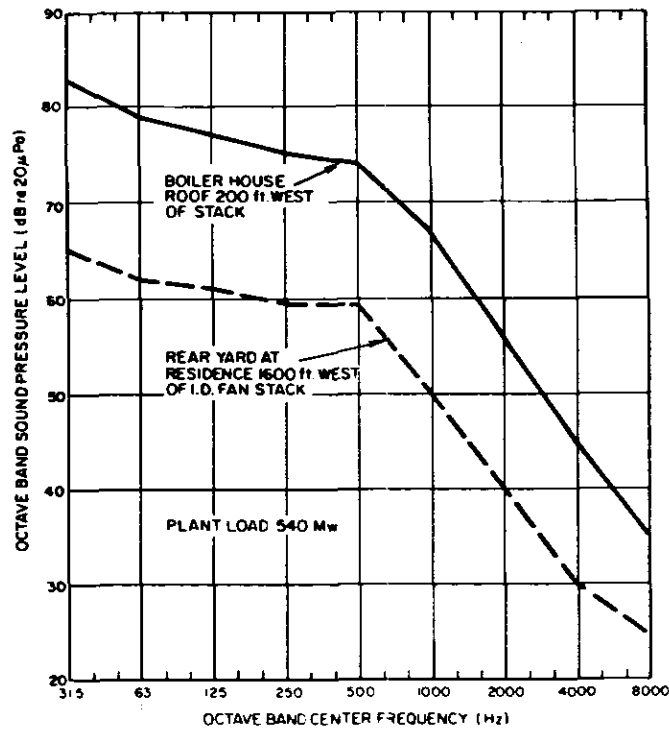


Figure 6.41.2. Measurements of fan noise.

so distant that sound measurements are complicated by varying sound propagation conditions. Also shown in Figure 6.41.2 is a measurement made in the community. The differences between the close-in and community position sound pressure levels are (except in the high-frequency range where ambient sounds influenced the community measurements) consistent with the assumption that community noise is dominated by sounds radiated by and hemispherically spreading from the sound measured – the stack opening. Of course, sound radiating from the stack originates within the fan itself. Similar close-in measurements indicated that the ductwork between the fan and the stack was a contributing source.

It was concluded that a suitably designed muffler, inserted in the fan discharge duct near the fan discharge, could solve the noise problem. The muffler would attenuate the fan sounds before they propagated into the ductwork and thus would control the emissions from both identified important noise sources (the ductwork and the stack opening).

Control Description

To alleviate the community noise complaints from the first operational unit and to avoid complaints about the second unit, a parallel baffle absorptive muffler was designed. The muffler

design incorporated adequate insertion loss to ensure that the fan sounds would be nearly inaudible in the community and considered structural requirements, aerodynamic pressure losses, corrosion, erosion, clogging from contaminated gas, self-noise, and available space for inspection. The muffler was installed in the discharge ducts of both fans, approximately as shown in Figure 6.41.1.

Results

The results achieved after installation of the fan discharge muffler are shown in Figure 6.41.3. The upper curve, from Figure 6.41.2, indicates the unmuffled sound pressure levels measured in the community. The lower solid curve shows the sound pressure levels measured at the same location after the fans were muffled. The cross-hatched range shows the lower ambient levels measured during the day and the night. As can be seen, the muffled fan sound pressure levels are close to the community ambient. Complaints about noise from these fans have ceased. On the basis of the success of the mufflers in the first generating units, similar mufflers were installed in the second unit while it was being constructed.

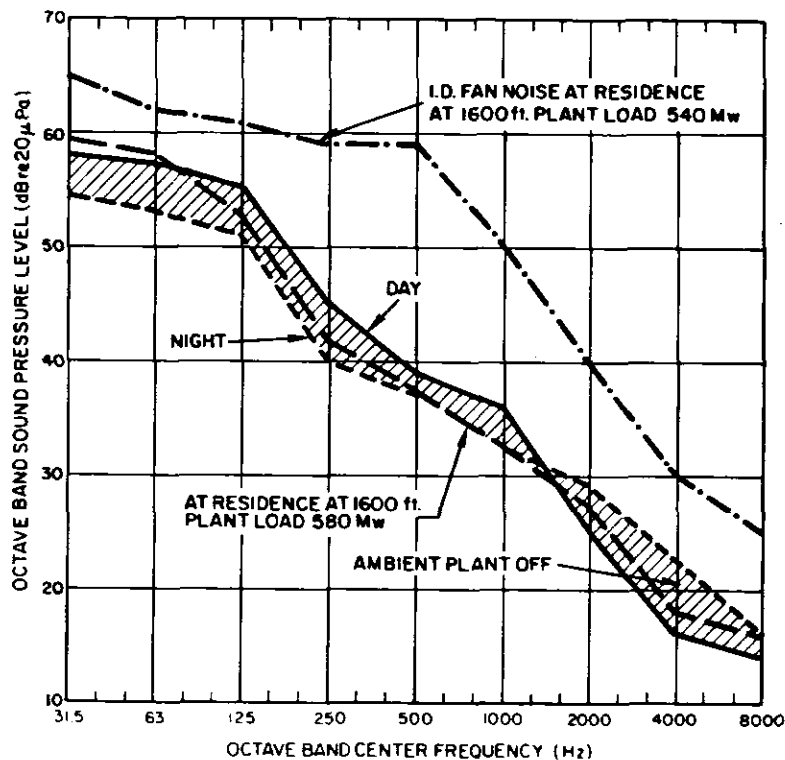


Figure 6.41.3. After installation of fan discharge muffler.

Information on fan noise prediction can be found in Graham (1972*) and muffler design information is available in Beranek (1971[†]). Clogging of muffler elements by contaminated flue gas can be a significant problem for absorptive mufflers installed in induced-draft fan systems, and recent information about this potential problem is given in Ver, Biker, and Patel (1978**). Miller, Wood, et al. (1978^{††}) provide further information about the control of exterior noise from power plants and their fan systems.

*Graham, J.B. May 1972. How to estimate fan noise. Sound and Vibration, pp. 24-27.

[†]Beranek, L.L., ed. 1971. Noise and Vibration Control. Ch. 12. McGraw-Hill, New York, NY.

**Ver, I.L., Biker, W.E., Patel, D.K., 1978. Design of a Tuned Muffler for Large Induced-Draft Fans. Proc. Inter-Noise 78, Noise Control Foundation, Poughkeepsie, NY.

^{††}Miller, L.N., Wood, E.W., et al. Electric Power Plant Environmental Noise Guide. To be published by Edison Electric Institute, 1978.

CASE HISTORY 42: PROCESS STEAM BOILER FANS
(OSHA Noise Problem)

Industrial Acoustics Co.
1160 Commerce Avenue
Bronx, New York 10462
(212) 931-8000

Problem Description

At several of their outdoor process steam boilers in Winston-Salem, N.C., staff members of the R.J. Reynolds Company found that excessive noise was being generated by the fans supplying air to the boilers and the blowers feeding air to the firing units.

Problem Analysis and Control Description

The use of silencers to minimize the fan and blower noise at the inlets to this equipment was considered, as was the effect of the silencer on available pressure head. A careful analysis of the system determined that at the peak operating condition the centrifugal fan could sustain a total additional loss of 0.9 in. of water, and the head loss available for the overfire air fan was 0.25 in. of water.

Next, it was necessary to select a silencer configuration that was compatible with the air inlets to the fan and blower as well as the surrounding equipment. An IAC Model 3PL 24-in. x 72-in. rectangular Power-FLOW silencer was chosen for the centrifugal fan. This silencer provides required acoustical performance at a satisfactory pressure loss. The cross section of this particular Power-FLOW silencer is readily mated with the fan inlet duct.

A tubular Power-FLOW silencer, Model 16 PCL 36, was chosen for use with the overfire air fan, as the round shape was easily adapted to match the blower inlet. The acoustical and aerodynamic performance requirements of the silencer were closely examined in selecting the required silencers.

Placement of the silencers is shown in Figure 6.42.1. At current prices, the two silencers would cost approximately \$3000.

Results

Silencers for one boiler system were installed and an acoustical test conducted. With the silencers installed, there was no change in the sound levels measured with or without the boiler in operation. As a result of these tests, silencers were installed on three other boiler systems. Figure 6.42.2 shows the sound pressure levels measured 3 ft from the fans before and after the IAC

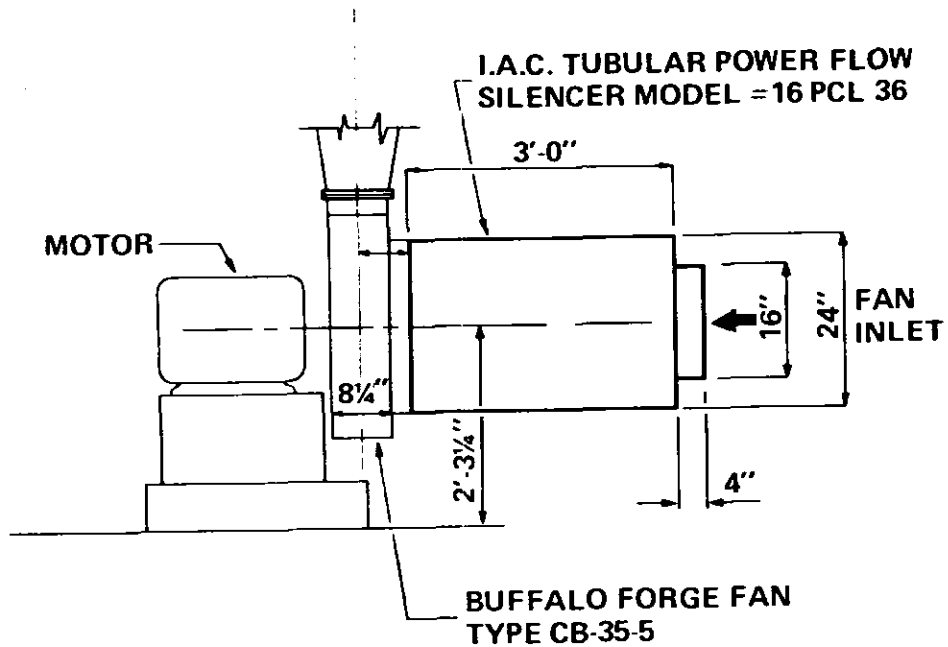
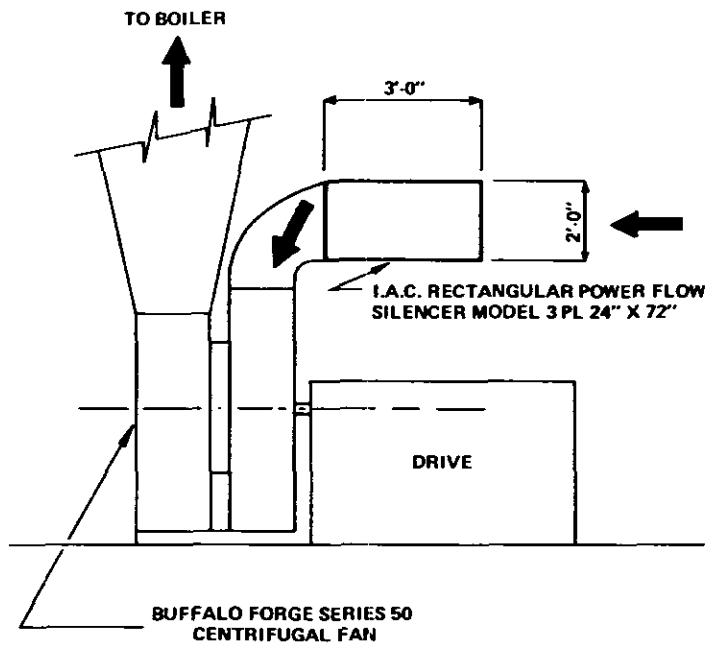


Figure 6.42.1. Elevation drawings showing how two fans at an R.J. Reynolds Tobacco Co. plant in Winston-Salem, North Carolina were quieted by IAC tubular and rectangular Power-FLOW silencing units.

Power-FLOW silencers were installed. Because of extraneous noise sources, it was not possible to measure the full effectiveness of the silencers. The residual sound pressure levels measured during boiler operation are therefore indicative of sounds from both the silenced boiler and the ambient noise sources.

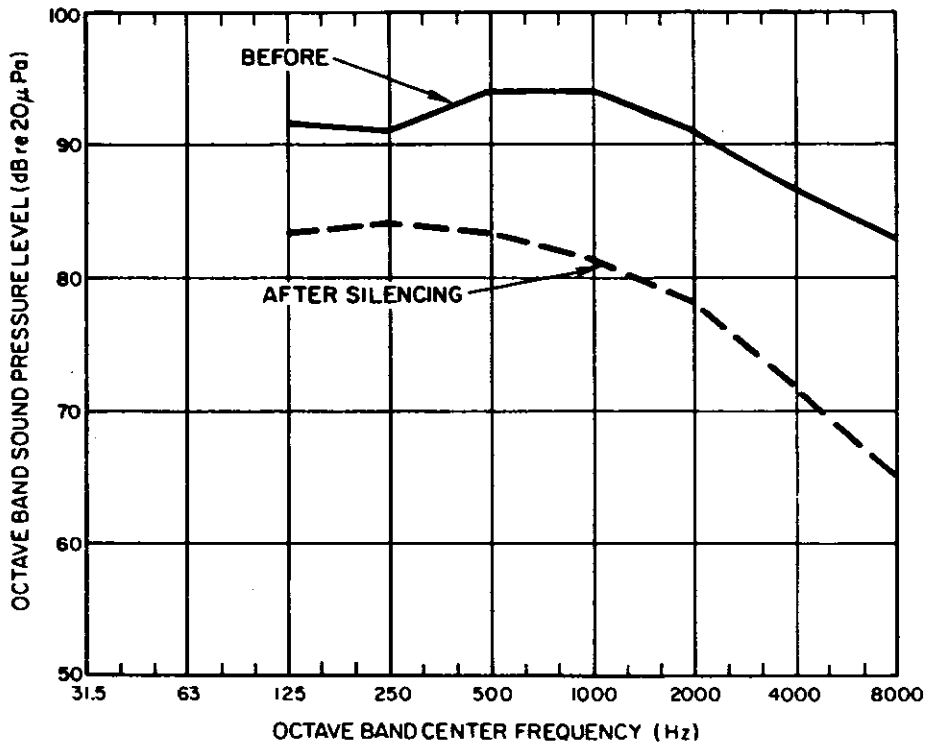


Figure 6.42.2. Sound pressure levels 3 ft from fans (converted from old octave-band designations).

CASE HISTORY 43: GAS TURBINE GENERATOR
(Community Noise Problem)

Robert M. Hoover
Eric W. Wood
Bolt Beranek and Newman Inc.
50 Moulton Street
Cambridge, Massachusetts 02138
(617) 491-1850

Gas Turbine

Gas turbine (also called combustion turbine) generators are used to supply emergency reserve capacity and peaking power for electric utility systems. When they are located near residential areas, they can cause community noise complaints unless adequate noise control treatments are provided. This case history is a discussion of the installation of additional exhaust mufflers at a gas turbine installation to alleviate community complaints about low-frequency exhaust noise.

Problem Description

Three gas turbine units capable of generating 60 MW of electricity were installed in a rural/suburban area of New England. Each generating unit had a single generator driven by four aircraft-type jet engines; each pair of engines shared a common exhaust. Each generating unit was originally installed with two muffled exhaust stacks approximately 4 m in diameter and 15 m tall.

The owner of the generating station received complaints about low-frequency noise from neighbors living about 300 m from the station.

Problem Analysis

The owner's acoustical consultant, Bolt Beranek and Newman Inc., was asked to investigate the generating station noise problems and to recommend corrective actions. Octave-band sound pressure level measurements and tape recordings were made at the station, at the nearest residential area, and at various intermediate locations during several station operating conditions. Measurements were also made along the stack wall and at the top of the stack. In addition, ambient measurements were obtained without the station operating.

Measurements obtained outside a neighbor's house are summarized in Figure 6.43.1. The lower frequency station sounds exceeded the ambient by at least 10 to 20 dB. In addition, the sound in the 31.5-Hz octave band exceeded 75 dB, a level at which complaints are sometimes made about vibration in a house. A

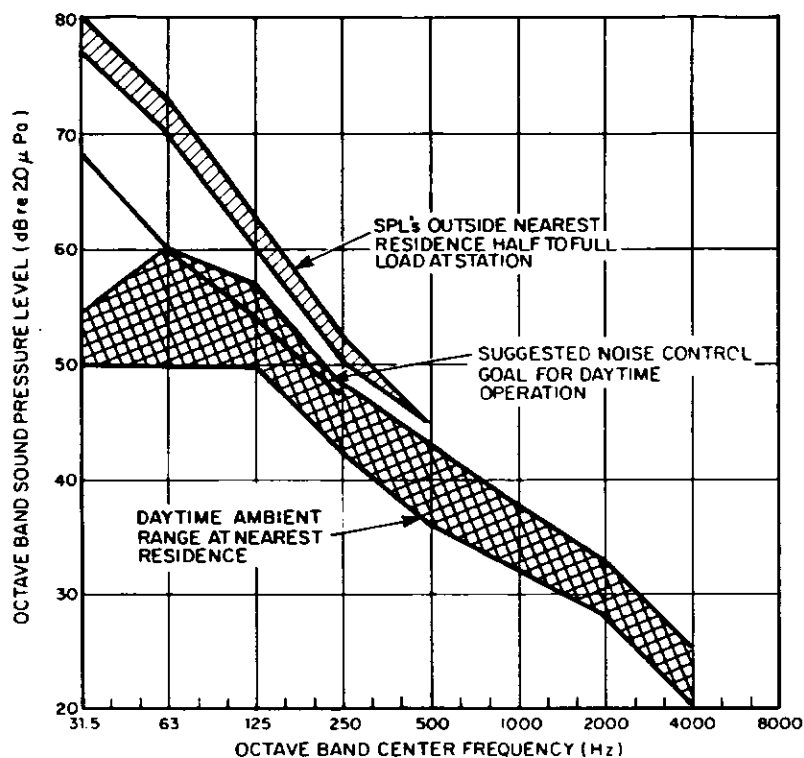


Figure 6.43.1. Sound pressure levels outside nearest residence at 300 m.

suggested noise control goal for daytime operation is also shown in Figure 6.43.1. Reductions of 10 to 13 dB in the 31.5- and 63-Hz octave bands are suggested to alleviate the community complaint problem.

Similar data obtained inside the nearest residence, 300 m from the station, are shown in Figure 6.43.2. These data are plotted with NC curves, which can be used to rate or judge an acoustic environment for various activities.

Narrowband analysis of the data tape-recorded at the station and at the nearest house indicated that the sound energy leading to the complaint was contained primarily in the range of about 18 to 75 Hz. To reduce this low-frequency noise, a tuned dissipative muffler was designed and added to each of the existing muffled stacks.

Control Description

The dominant radiation path for the low-frequency noise was from the open top of the six exhaust stacks. An initial concept design was prepared of a tuned dissipative muffler section to be inserted in the lower end of the stacks. Acoustic model tests were performed of numerous configurations to optimize the muffler's insertion loss in the frequency range of interest. Aerodynamic

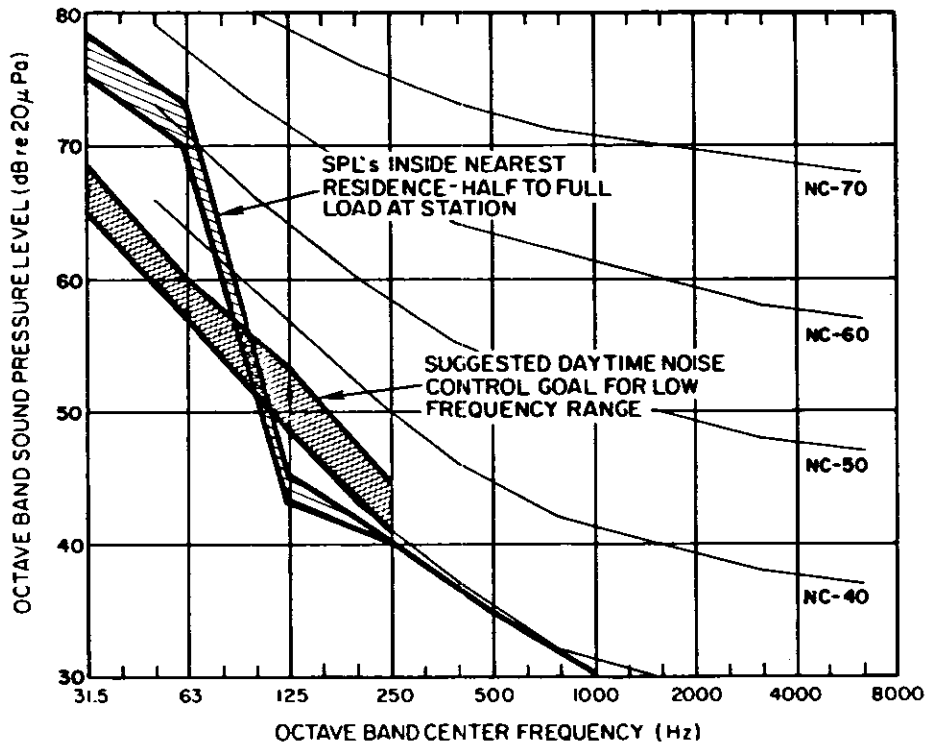


Figure 6.43.2. Sound pressure levels inside nearest residence at 300 m.

model tests were also conducted to ensure that the additional pressure losses through the new muffler section would not be excessive (high-pressure losses would reduce the generating capacity of the gas turbine unit.) Other considerations included fabrication cost and time, installation cost, aesthetics, self-noise, structural integrity, and weight.

As a result of these investigations, a prototype exhaust muffler was designed, fabricated, and installed. The muffler, 5 m in diameter and 8 m long, was installed at the lower section of the existing stack. The original stack was reinstalled above the new muffler. Field measurements were conducted to evaluate the muffler's low-frequency insertion loss, and five additional mufflers were subsequently fabricated and installed.

Result

Sound pressure level measurements near an exhaust stack with and without the new muffler section indicated an insertion loss of 11 and 12 dB in the 31.5- and 63-Hz octave bands. Outside and inside the nearest residence, the measured insertion loss was 8 to 9 dB in the 31.5-Hz octave band and 7 to 11 dB in the 63-Hz octave band. These favorable results indicate the success of this noise control project.

CASE HISTORY 44: JET ENGINE COMPRESSOR TEST CELL
(Community Noise Problem)

Richard C. Potter
Bolt Beranek and Newman, Inc.
50 Moulton Street
Cambridge, Massachusetts 02138
(617) 491-1850

Problem Description

Complaints about noise were received during testing of jet engine compressors at a research facility. With the rig at full power, the sound level in the residential neighborhood located across a body of water at a distance of approximately 1200 m was 66 dBA. In addition, a business neighbor at approximately 400 m was subjected to noise as high as 93 dBA. Most of the complaints were received during the occasions when testing had to be continued into the evening. An average ambient sound level of 53 dBA was measured in the residential neighborhood, due to traffic, wind, and surf noise.

The compressor test cell consists of a turbine drive unit to which the compressor under test is connected, a filtered inlet to provide air into the test cell, and three exhausts, located on the roof, into which the compressor discharges pressurized air.

Problem Analysis

Octave-band sound pressure level and A-weighted sound level measurements were conducted both close-in to the compressor test cell and at representative receiver locations. Equipment used to obtain acoustic data consisted of a precision sound level meter with an octave-band filter set, and a tape recorder. Later analysis of recorded data was performed using a narrowband real-time analyzer.

From the close-in measurements, it was determined that the compressor noise came from the roof exhausts and the test cell inlet, with the noise from the exhausts dominant. It was determined that the inlet noise was not a problem because the strong 2620-Hz compressor tone at the inlet was not identifiable in the community, using a narrowband analyzer.

Figures 6.44.1 and 6.44.2 show the octave-band sound pressure levels of noise measured in the community at 400 and 1200 m from the rig, respectively, prior to the installation of noise control, in comparison to the measured ambient sound levels.

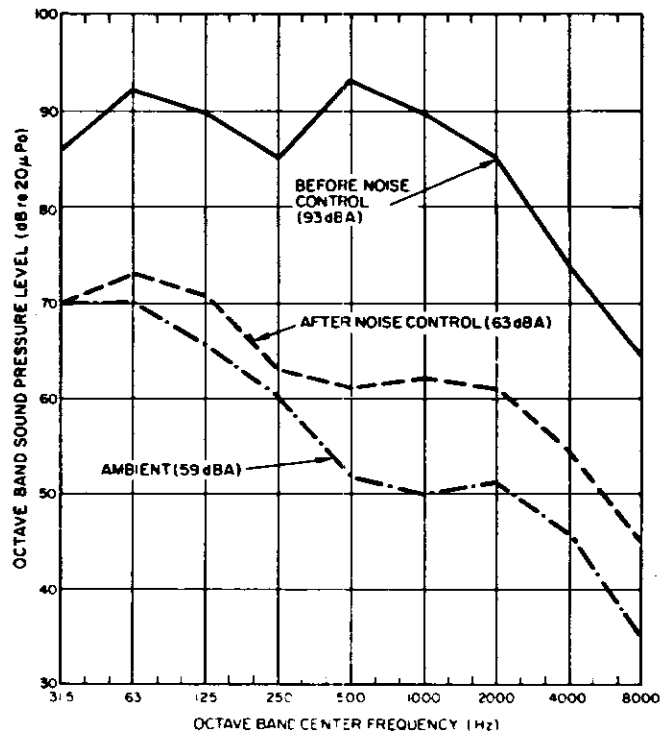


Figure 6.44.1. Octave-band sound pressure levels measured at business neighbors at approximately 400 m from compressor test cell.

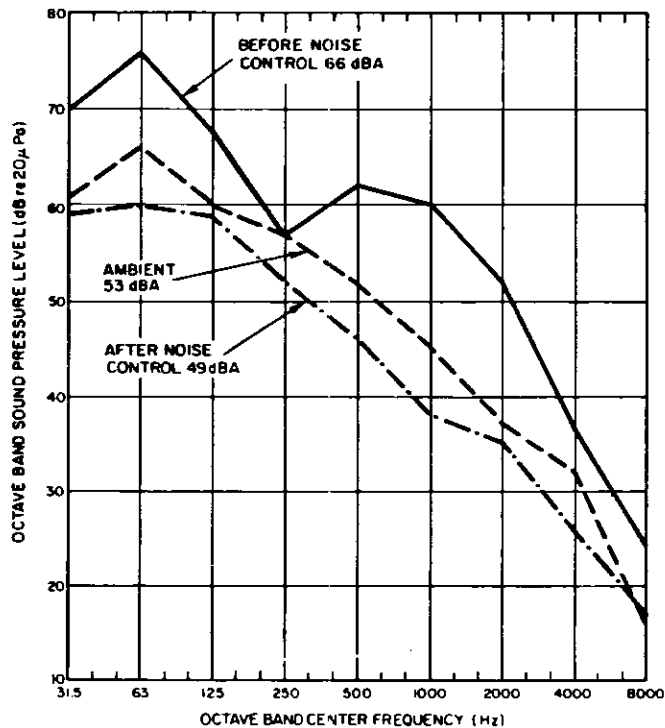


Figure 6.44.2 Octave-band sound pressure levels measured at residential neighbors at approximately 1200 m from compressor test cell.

The noise control goal was to reduce the noise to within 10 dBA of the ambient at the business neighbor location and such as to eliminate the complaints from the residential neighbors.

Control Description

Recommendations for noise control for this test cell were to muffle all exhausts with parallel baffle dissipative-type mufflers. Off-the-shelf-type mufflers were bought and installed on exhausts.

Results

The sound levels after the installation of the mufflers, Figures 6.44.1 and 6.44.2, were reduced significantly. The goal of reducing the noise to within 10 dBA of the ambient at the business neighbor location was achieved.

At the residential neighbor location, the sound of the rig could just be distinguished and it was measured to be below the design ambient. No further complaints of the noise of this rig were received.

Comments

Ambient noise is often used as the design goal for community noise problems. However, care is needed when the ambient noise can change because of the irregularity of the dominant sources controlling the ambient noise. In this case the measured noise of the test rig, following the installation of the mufflers, was less than the initially chosen design ambient sound levels. Only by conducting a major noise measurement exercise can a full description of the ambient noise be obtained.

The noise control engineer has the choice of using the lowest ambient or some statistical measure, such as the level exceeded 90% of the time, 50% of the time, etc., when proposing a criterion. Although generalizations are difficult to make, "the lowest ambient" is best used in critical situations, while statistical measures can be used when some degree of intrusive noise is acceptable.

CASE HISTORY 45: JET ENGINE TEST CELL
(Community and Hearing Conservation Noise
Problem)

Richard C. Potter
Bolt Beranek and Newman Inc.
50 Moulton Street
Cambridge, Massachusetts 02138
(617) 491-1850

This case history describes noise control efforts for a production test bed for small helicopter gas turbine jet engines.

Problem Description

A production test cell used for small turbo-jet engines was producing high exhaust sound levels in the vicinity of the cell and disturbing workers and other passers-by. The test cell is enclosed except for a muffled air inlet and a 15-m-tall exhaust pipe. The exhaust pipe is made significantly higher than the inlet to avoid reingestion of exhaust gas. Exterior sound levels were on the order of 85 dBA.

Problem Analysis

Bolt Beranek and Newman Inc. was called in to analyze the problem. Measurements near the exhaust and the muffled intake indicated that the noise was suitably muffled at the inlet and that the exhaust noise of the engine was the problem. A reduction of at least 20 dB was required.

Control Description

Because of the available space in the long exhaust duct, a two-stage exhaust muffler was designed. A lined section some 5 m long with a 1-m-diameter open center path was arranged at the bottom of the exhaust pipe, and a set of 3-1/2-m-long, 10-cm-thick absorbent splitters on 25-cm centers was set in the top of the exhaust stack. In this way, a very wide band absorber was designed.

Results

After installation, the noise of the engine running could not be distinguished above the sounds of other test functions and traffic.

Comments

The noise had been a problem because of the long daily usage of the cell. In this case, a required structure - the tall exhaust stack - could be used to provide the maximum sound reduction. The two-stage muffler gave noise reduction over a wide frequency range.

The muffler was designed to ensure that the backpressure was not excessive. The self-noise of the muffler, especially the splitters, was checked to determine that it did not become the critical sound.

CASE HISTORY 46: PNEUMATIC GRINDER
(OSHA Noise Problem)

Austin E. Morgan
Berkmont Industries, Inc.
Unicast Division, Union Mfg. Division
Box 527
Boyertown, Pennsylvania 19512
(215) 367-2116

Douglas H. Martin
Douglas Martin & Associates, Inc.
119 Heather Drive R.D. No. 7
Allentown, Pennsylvania 02138
(215) 435-2400

Problem Description

This case history concerns operation of hand-held penumatic grinders, devices often used throughout industry to clean, smooth, or otherwise improve surface features of metal parts. In this operation, the air tool noise was cited, in part, for contributing to OSHA noise overexposures in a gray iron foundry.

Problem Analysis

Analysis of the problem indicated that the tool was a major continuing noise source. Sound levels measured at the operator's ear ranged between 100 dBA and 109 dBA when the various tools were held in the free-spinning mode. Close-in measurements indicated most noise originated at the tool exhaust, and hence an exhaust muffler was considered to alleviate the problem. Metal prototypes of the muffler were designed and evaluated. Eventually, rubber mufflers were developed.

Control Description

The muffler, shown removed and mounted on a pneumatic tool in Figure 6.46.1, is essentially a "rubber band" that fits over the tool exhaust parts. Porous muffler stuffing slows the air stream and dissipates the energy of the moving air before it is exhausted. The muffler is commercially available from Allentown Minerals, Inc., P.O. Box 3214, Allentown, Pa., (215) 437-7177.

Results

Sound levels at the operator's ear are reduced to the 84-dBA to 88-dBA range for the free-spinning tool, depending on the tool tested. The tool treatment, coupled with other noise controls currently being implemented in the plant, will reduce noise exposures to levels in compliance with OSHA standards.

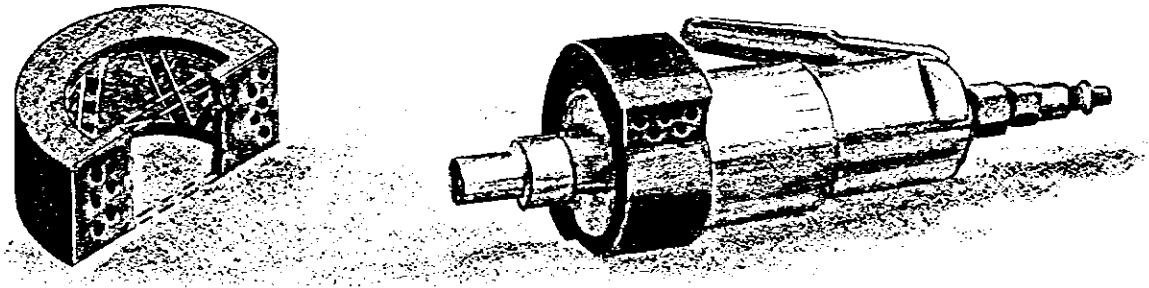


Figure 6.46.1. Muffler shown removed and mounted on pneumatic tool.

Comments

In many cases of pneumatic tool usage, tool noise dominates the noise exposures. In other cases, especially when light structures are worked on, workpiece-induced vibrations become more important than tool noise. In the latter situation, mufflers such as described above should be considered only partial treatment and should be coupled with enclosure (using glove-box-type controls), covering (using a heavy "blanket"), or other forms of noise control.

Note that tool manufacturers' claims for quieted air tools should be examined carefully. Although their quieted tools are indeed less noisy than original models, ANSI measurement standards specify a 1-m distance from the tool for making the measurement. In practice, an operator's ear may be closer than 1 m to the tool and, hence, his noise exposure higher than would be expected on the basis of tool manufacturers' promotional literature.