Practical Designs for Noise Barriers Based on Lead

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Acoustical theory predicts that sheet lead and soft plastic materials loaded with finely divided lead should be excellent sound barriers. Seven case histories are given to show how this "limp mass" has been applied in practical problems.

Introduction

ONE OF THE most common solutions to industrial noise problems is the enclosure of the noise source to reduce the noise level to bearable limits. This situation is easily recognized. The difficulties attendant to enclosure are easily recognized, too. Usually openings are required for feed of material or parts to and from the noisy operation. Almost always there must be provision for access or at least visual inspection. These and other requirements often indicate that a complex shape will be required of the enclosure. And this, in turn, increases the difficulty of achieving monolithic, leak-free construction in practice.

In addition to these practical difficulties, which apply to the construction of even a single noise enclosure, there may well be a question of optimizing performance of the noise barrier in terms of noise reduction versus weight, thickness, or cost. This is particularly important where noise reduction requirements are unusually demanding, or where a large number of the enclosures will be needed.

Sheet lead and lead-loaded flexible plastic sheet recommend themselves in both particulars cited above. First, from a practical point of view, consider sheet lead used as a barrier in the plenum above hung ceilings. The lead sheet, approximately 1/64-inch thick in a typical case, is allowed to hang freely between the roof slab above and the hung ceiling below. Perforations for pipe, conduit, air ducts, etc., can be tightly sealed by the simple expedient of hand-crimping the surplus lead to the surface of the pipe and taping it there with duct-sealing tape. The lead surplus is created by folding a single 1-inch tuck vertically to coincide with the pipe. The significant fact about these installations is that the measured performance is excellent and usually in close agreement with theoretical predictions. This happy result is all too uncommon in noise control work and may be attributed, in large part, to the ease with which leak-free construction is attained on the job.

Second, acoustic theory and practical experience alike show lead (and lead-loaded plastic) sheet to be excellent barriers to noise. This fact has its foundation in the *intrinsic lack of stiffness of the sheet*. The so-called "limp mass" thus furnished blocks noise transmission without any detrimental coincidence effects. Another theoretical prediction borne out in practice is that, where the lead is correctly used with other building materials in a composite noise barrier, it can suppress or help suppress the unfavorable coincidence dip of the other materials.

Types of Construction

At one extreme the simple hung sheet of lead or leaded plastic mentioned above has proved effective. Even at one pound per square foot (psf) this simple expedient produces about 25 db as a nine-frequency average transmission loss. Other schemes of increasing complexity have been used; there is no point in going into great detail concerning

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them, but typical arrangements and performances may serve as an index of suitability:

Typical Noise Barriers Based on Lead

Nine-frequency average	Barrier Description	Notes
25 db	Sheet lead or leaded vinyl plastic weighing 1 psf	Standard tests
30 db	0.9 psf leaded vinyl over 2 inches of low-density glass fiber as pipe enclosure	Estimated (see case 1)
30 db	0.5 to 1.0 psf leaded vinyl with sheet metal skin and glass fiber blanket retained by screen or perforated sheet	Estimated (see cases 2 and 3)
35 db	Light sheet metal clamped to either side of 3 psf leaded vinyl sheet	Estimated (see case 4)
40 db	3 psf lead laminated to 18-gage steel	Standard test
40 db	3 psf lead laminated to ⅜ inch plywood	Standard test
40 db	4 psf lead laminated to 10-gage steel, glass fiber inside enclosure	Estimate (see case 5)
45 db	Conventional drywall with 4 psf lead furred off ¾ inch and acoustical tile furred off	Field test (see case 6)
51 db	4 inch lightweight concrete block with 4 psf lead on ¼ inch fir plywood furred off one side	Standard test
65–70 db	Two leaves of 8 psf lead on wood frames separated by 9 inch space containing two 2-inch glass blankets on each leaf	Field test (see case 7)

Case 1—Fluid Noise and Pipe Line

An arrangement pioneered at the Public Service Gas and Electric Company of New Jersey has now been employed all over the North American continent. The noise source was a set of pipes and valves in a pressure reduction station. Upstream of the valves the gas is at a pressure of about 150 psi: Pressure on the downstream side varies with the type of service, but 15 psi is typical. To maintain a set downstream pressure in the face of extremely wide variations in demand, double V-port regulating valves are used. With this high-pressure drop and correspondingly high flow, a wide-spectrum noise of 110 to 130 db is created.

FIGURE 1. View of leaded vinyl-covered pipes in the gas pressure reduction station.

The enclosure (Figure 1) was a 2-inch blanket of fine yarn glass fiber (6 pounds per cubic foot) overwrapped with a single layer of reinforced leaded vinyl sheet. This fabric-backed, flexible material weighs 0.87 psf and is 0.055 inch thick.

Considerable care was exercised in taping all seams completely closed (Figure 2) with a tape of the same material.

The result was to reduce the peak intensity from 130 db to 100 db. While higher than desirable, this brings the noise into a range where conventional ear protectors can cope with it.

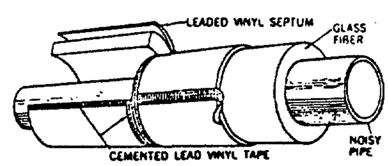

FIGURE 2. Exploded view shows how leaded vinyl and glass fiber are applied.

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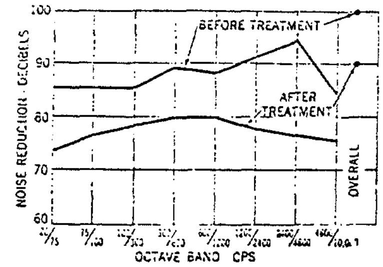

FIGURE 3. "Before" and "after" curves show the additional noise reduction achieved by adding glass fiber and leaded vinyl sheet to the enclosure for an internal combustion turbine.

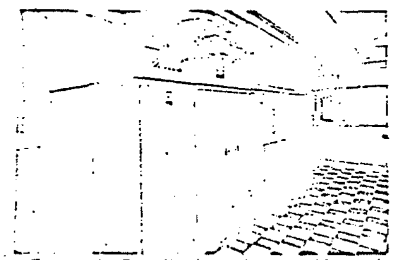

FIGURE 4. Overall view of the turbine unit. Smaller box at lower left is ducting for the air intake system.

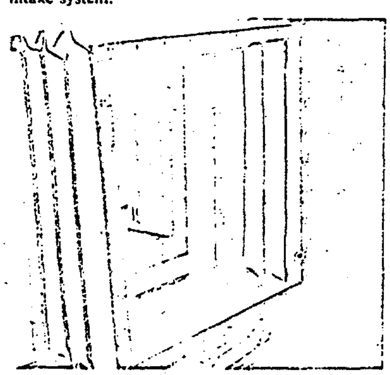

FIGURE 5. The flexible bellows (30 inches square) is used to connect the intake duct to the air intake of the turbine. It provides a reasonable transmission loss for noise without introducing a rigid structural tie between turbine and ducting.

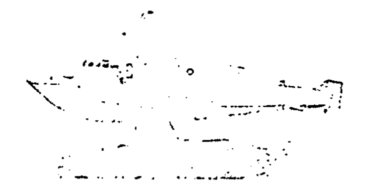

FIGURE 6. Noisy power sources constitute a real problem aboard a hydrofoil vessel like HS Denison. Since the vessel must lift itself out of the water to "fly," every pound counts, and sound barriers must have top efficiency.

Cases 2 and 3—Gas Turbine Noise

The gas turbine is an increasingly popular prime mover and, as is evident by Figure 3, it is a fairly noisy one. The "before treatment" curve in Figure 3 is the gas turbine with an enclosure, but before the addition of leaded plastic.

The before and after data shown in the curve are based on tests carried out on a stationary gas turbine unit measuring 5 by 16 feet (Figure 4) and producing 750 kilowatts of electric power. Air for the combustion is taken in at a rate of 11,000 cfm when the unit operates at rated load and the intake duct is 30 by 30 inches.

To provide vibration isolation between the unit and the intake ducting, a flexible bellows of leaded plastic was used. The plastic sheeting weighed 0.87 psf (Figure 5). The same material was used to line the interior of the metal cabinet, and the internal face of the cabinet was glass fiber batting retained by screen cloth.

Substantially the same scheme was used in a movile gas turbine—the power unit of the hydrofoil vessel HS *Denison* (Figure 6). Because weight was at a great premium in this foil-borne vehicle, a still lighter leaded plastic sheet was used. Its effect was enhanced by supporting it on 2-foot centers. The sheet weighed only 0.48 psf and was used, as before, in conjunction with glass fiber absorptive material (Figure 7).

Case 4—Sheet Metal Noise

The wide-spectrum noise produced by impact in expanses of sheet metal is quite a

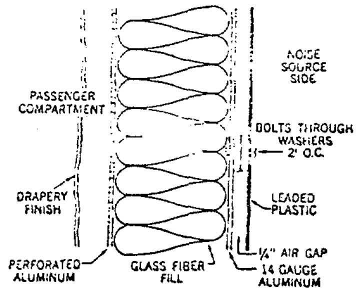

FIGURE 7. Section through the sound barrier used in HS Denison. It is basically similar to that used in the stationary turbine (Figure 4) except that lighter leaded vinyl sheet is employed and it is point-suspended for maximum limpness.

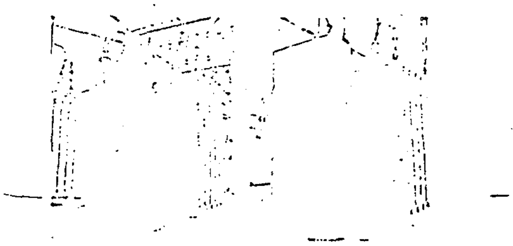

FIGURE 8. One of the power transformers before and after enclosure. The enclosure is 14 feet high.

common problem. In one case, an enclosed chute, or duct, was being used to convey roasted coffee beans from the upper floor of a plant to one of the lower floors for packaging. Although no actual sound measurements were made, the noise levels—particularly the enervating high-frequency noises—were well beyond the annoyance level. Short tempers and worker inefficiency were directly traceable to the noise of millions of coffee beans bouncing through the chute.

The solution was quite simple. A sleeve of flexible leaded vinyl sheet weighing 3 psf was hung inside the vertical chute. The sleeve was made with sealed seams so that noise could not leak through it. Because coffee is a foodstuff, a second sheet metal chute was inserted through the sleeve as a liner. The prime intent was to remove any possibility of contact of the food with a lead-bearing material. Actually, however, the inner liner probably made the arrangement more effective because it forced the leaded plastic and sheet metal into loose contact, thus enhancing the damping effect.

The result was completely satisfactory. The beans cause only a quiet murmur now, and frayed nerves have long since healed in that department.

Case 5—Transformer Noise

The "hum" of big power transformers is an unusually stubborn noise and typifies noise spectrums of low frequency, which sometimes occur in industrial work. Low-frequency performance of most sound barriers is notoriously poor; thus the achieved improvement of 17 to 20 db achieved by Portland General Electric Company is especially noteworthy.

The transformers in question (Figure 8) were each rated at 41.7 Mva, stood about 14 feet high, and required an enclosure measuring approximately 5 by 10 by 14 feet. This enclosure was a built-up laminate of 10-gage steel, 4-pound (1/16-inch) lead with an interfacing of glass fiber. Some noise escapes the enclosure via the radiator network. As an indication of the excellent detailing of the design, this loss was held to only 5 db. Tests of the completed enclosure without the radiators in place showed a 22-db improvement over the unenclosed transformer. When the radiators were again installed, the level rose, cutting the noise reduction to 17 db.

This construction is classed as approximately a 40-db noise barrier because of the many openings of this sort that had to be left in the transformer enclosure as it was assembled. Had it been complete or substantially complete, the reduction would certainly have been of the order of 40 db.

Case 6—A "Quiet Room" in a Noisy Environment

Franklin Institute in Philadelphia is well known for its excellent contract research work. One project at the institute was a study

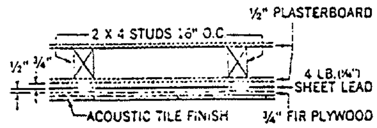

FIGURE 9. Section through the wall employed in the Franklin Institute test room. The original drywall (gypsum board faces and wood stud framing) existed and the lead and finish were added.

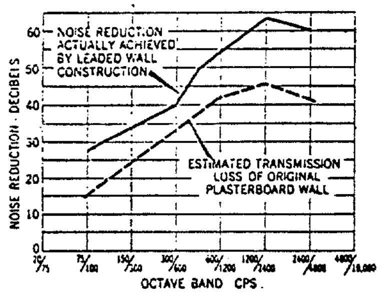

FIGURE 10. Acoustical performance of the original wall and the wall after sheet lead had been added clearly shows the improvement. (Original wall performance shown is estimated and probably quite conservative.) The curve for the leaded wall is not corrected for "flanking" or passage of sound around the wall.

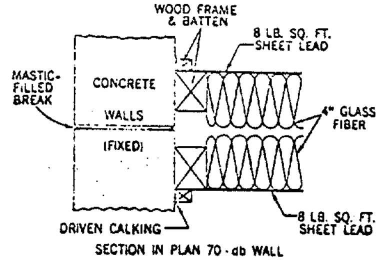

FIGURE 11. Section through the 70-db wall.

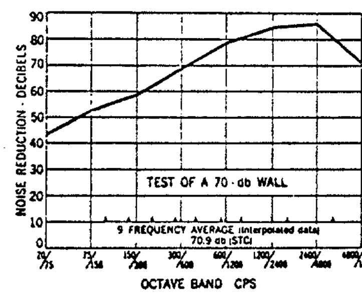

FIGURE 12. Actual performance of the 70-db wall as tested.

of noise made by bearings. Good bearings are, of course, rather quiet in operation, and the only space available for testing was not! It had, in addition to normal traffic and conversation, machinery running continuously under test, occasional light sheet metal work, and the background rumble of downtown Philadelphia's heavy street traffic.

Beginning with a room 13 feet 6 inches by 9 feet 6 inches by 10 feet high with plasterboard walls on wood studs, the institute constructed the wall shown in section in Figure 9. Note that the original wall was retained and that no new framing or dismantling of existing structures was required. Other measures included use of sound-absorptive facing on the walls and ceiling and addition of mass to the ceiling by dumping sand in it from above (there was no floor over the joists) and careful sealing of cracks and openings throughout.

The result, shown in Figure 10, was to increase the noise reduction from outside the room to inside from 32 to 45 db. While this wall would not meet really critical requirements (for a broadcast studio, for example), it was attained at a reasonable cost in a short time. Actually it was six weeks between the first inquiry about the use of lead for noise control and the successful use of the completed room. No outside contractor was required, the work being done by the regular building and maintenance staff.

Case 7—A 70-DB Wall in an Acoustical Test Facility

Sometimes the need arises for a barrier with a rating of 60+ db. As a practical matter, this often means that some alternative solution to the problem should be sought, since it is not usually possible to attain ratings of this sort in practice. One of the few places where such performance really is required and really can be attained is in test facilities.

The wall described here forms the permanent dividing wall between the source and the receiving rooms. As such it must be capable of dismantling and reassembly as test panels of various sizes are substituted for it. Although it is hardly a thin or lightweight wall, it is much thinner and lighter than the solid concrete block that makes up the other walls of the test facility. And of course it is conveniently handled in sections so that test panels of several sizes can be accommodated—a problem of considerable magnitude had any other construction of similar acoustic rating been chosen.

The wall (Figure 11) has faces of 1/8-inch (8-psf) sheet lead separated by 8½-inches of space. The faces are separately framed with wood. To eliminate structural bridging of the two faces, slots have been sawed in the concrete floor, sidewalls, and ceiling of the test facility. These are sealed with nonhardening mastic. Within the wall, each lead face is backed with 4 inches of fiber fill. A wooden retaining batten around the edge of each panel serves two purposes—it clamps the lead face to the frame and provides an opening into which calking material can be driven.

The performance curve of this wall has been checked in the facility itself and, as shown in Figure 12, is a remarkable 70 db. It must be understood that this performance would not be achieved in any noise barrier where it was not possible to use extreme care in hunting down and correcting small leaks through cracks, etc. Neither this wall nor any other should be considered a practical solution to the type of field problem where access is required through the barrier, or where leakage or flanking paths or movement or mechanical wear is liable to be a factor.

Conclusions

Where noise must be blocked or cantained by a barrier, there are three cardinal requirements to be met in order to get the best performance:

First, the more massive the barrier is, the higher the transmission loss it is capable of.

Second, the less stiffness the barrier possesses, the better the performance that may be expected of it.

Third, to achieve good transmission loss, the barrier must be free of leaks—either air leaks or structural features that constitute sound paths.

Sheet lead and leaded plastic sheet have been shown to possess high mass relative to their thickness and sufficient "limpness" to produce excellent results in practical noise barriers. Although it cannot be demonstrated as a separate effect in the case histories reviewed here, part of the effectiveness stems from the ease with which the materials can be formed to seal or minimize leaks.

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