Pin 1 and Engineering and Purchasing
Personnel

LEAD INDUSTRIES ASSOCIATION

292 MADISON AVENUE
NEW YORK 17, N. Y.

October 24, 1960

SUBJECT: IMPROVED SOUND BARRIERS
EMPLOYING LEAD

To Members of the Lead Industries Association:

The attached engineering report has just been published by the Lead Industries Association and explains in detail how to calculate the effectiveness of a partition or sound barrier. It is based on a study made for our Expanded Research Program by one of the country's leading acoustical engineering firms, Bolt Beranek and Newman, as a result of earlier recommendations made to us in the report of Skidmore, Owings & Merrill, architects and engineers, on expanding the use of lead in building construction. It deals with office partitions, machinery enclosures, and other sound-containing structures.

Among other things, it demonstrates that if a wall or partition is to be built of one material, such as brick, wood, lead, etc., the lightest wall that can be built to meet a sound barrier requirement is lead. In addition to showing the sound transmission characteristics of a number of conventional wall constructions and lead, the report includes calculation methods applicable to most simple partitions.

We believe that the data included will enable design engineers, architects and others concerned with the control of sound to determine how the use of lead may help them solve their problems.

The report is being circulated immediately to some 15,000 architects, building contractors, design engineers, and manufacturers of building equipment and components.

Additional copies are available to members in quantities up to 25 free of charge and in larger quantities at our cost of 10 cents per copy.

Very truly yours,

Secretary

RLZ:JRM

Att.

IMPROVED SOUND BARRIERS
EMPLOYING LEAD

Including an engineering report by Bolt, Beranek and Newman, acoustical consultants, on the effectiveness and applications of this material in buildings and mechanical equipment.

A.I.A. NO. 39

LEAD INDUSTRIES ASSOCIATION
292 MADISON AVENUE, NEW YORK 17, NEW YORK

LOOK AHEAD WITH LEAD

the need for a better sound barrier

How valuable is silence? Though there are few instances where we can get a firm dollar-and-cents answer to this question, there is no doubt that the noisy plant or office, hotel room or home has a nuisance value. Often that "nuisance" produces fatigue and irritation leading to errors. People prefer a quiet place to live and work. And, by and large, people do a better job when they have a quiet place to work.

Yet, what office can operate in today's business world without typewriters and telephones? What homes are without radios, TV and record players? The plant that has no sources of disturbing noise is rare indeed.

Because we cannot do without the equipment which causes noise, our homes and offices, schools and factories must be designed to minimize its effect and as we surround ourselves with more mechanical aids, the noise reduction problem becomes more important.

Two noise reduction problems are involved. The first is the prevention or minimizing of sound reflection --the use of drapes or acoustical tiles are examples. The second, reduction of sound transmission, has relied on massive construction and "solid" walls to confine sources of noise.

As a result of studies made for the Lead Industries Association by the acoustical consulting firm of Bolt, Beranek and Newman some surprising facts about reducing sound transmission have come to light. They have found that it is quite possible to build walls and partitions which look "massive" to sound, yet actually weigh less and occupy less space than conventionally constructed walls.

It is hoped that the report on the following pages will serve as an aid to architects and design engineers in producing building and mechanical equipment with better characteristics for reducing sound transmission and will encourage them to investigate fully the usefulness of lead in solving problems of this kind.

table of contents **page**

IMPROVED Sound Barriers Employing Lead

what blocks sound?

The list of new materials and architectural products to block sound has grown and is growing longer. It includes surfacing materials, acoustical tile and plastics, movable partitions and door types. There are special building techniques, too, for laminating materials, for panels, doors, walls, and ceilings.

It is important to discern between materials that stop sound transmission and those which simply prevent sound reflection. A room finished in acoustic tile, for example, seems less noisy because sounds originating in it are not reflected back to a listener in the room. A noisy conversation next door, however, can penetrate the tile. And noises from the tiled room leak out to adjoining rooms.

To block this sort of "leakage" the partition or sound barrier must have two key properties:

weight — The greater the weight (per square foot) the greater the isolation, or transmission loss, given by the partition material.

limpness — The acoustical efficiency of any material as a sound isolator depends not only on its weight but on its "bending stiffness." If a partition is stiff enough it can actually lose much of the advantage it gains by being heavy. This happens because the stiffness of a partition increases much more rapidly than its weight as its thickness is increased.

A general rule is:

lead approaches the ideal

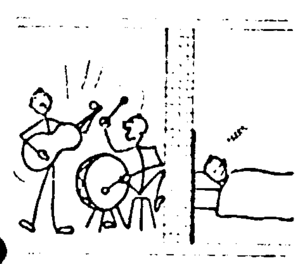
Lead is an obvious choice in the search for a heavy, limp material for construction of partitions. Having a density two or three times that of common building materials (and 10 to 15 times that of wood) it is also a "limp" material in the acoustical sense. This combination of properties, approaching the ideal for acoustical barriers, leads to the surprising conclusion that *if two equally effective sound barrier partitions are built, one of lead and one of any other common construction, the lead barrier will almost invariably be the lighter.*

Table I compares thickness and cost for lead alone versus common partition materials.

TABLE I

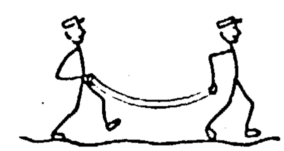
Type of Partition	Weight of Partition		Weight Ratio	Material Cost		Thickness	
	lb/sq ft	equiv. lead lb/sq ft		$/sq ft	equiv. lead $/sq ft	inches	equiv. lead inches
Plywood	2.25	0.47	4.9	0.33	0.14	3/4	1/28
Sheet Steel[1]	3.0	1.8	1.75	1.75[2]	0.57	1/16	1/32
Solid Plaster	18	3.75	4.8	0.33[2]	1.12	2	1/16
Cinderblock	22	5.5	4.0	0.35[2]	1.69	6	3/32
Plaster on studs	12	7.5	1.6	0.43[2]	2.25	4-6	1/8
Plaster on double studs	16	11.0	1.4	0.55[2]	3.37	5-8	3/16
Brick	104	15.0	7.0	1.00	4.50	8	1/4

NOTES: 1) as employed in a movable partition, for example.
2) *estimated by dividing total erected costs by two to get material costs.*



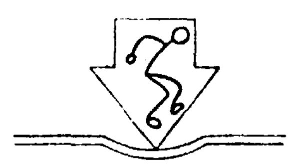
WEIGHT BLOCKS SOUND

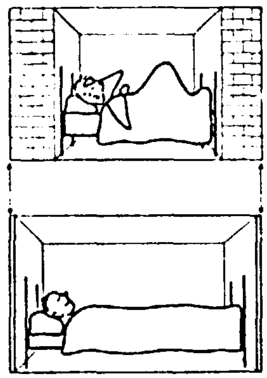
low weight + high rigidity = poor sound isolation



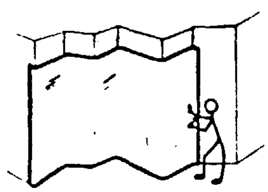
LIMPNESS BLOCKS SOUND

high weight + low rigidity = good sound isolation





LIMP WEIGHT SAVES SPACE

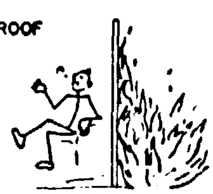


MALLEABLE

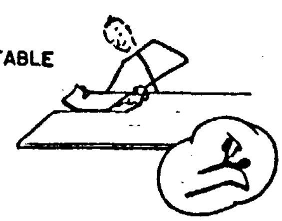
Surfacing:

TACKABLE
PAINTABLE

FIREPROOF



CUTABLE



savings with lighter partitions

The advantage of low weight to the structural engineer is of more significance than might at first be obvious. For example, while a cinderblock partition weighs 22 lb sq. ft., $5\frac{1}{2}$ lb sq. ft. of lead will accomplish the same acoustical isolation task. Thus, there is a saving of $16\frac{1}{2}$ lb for every sq. ft. of partition erected or 165 lb for every linear foot if the ceiling height in the room is 10 ft. This added weight will be reflected in increased floor slab thickness required for support of the partitions and also in supporting beams, columns and so on all the way down to the footings.

Another area for general consideration in which weight may be more important than any other factor is where, for one reason or another, an acoustical barrier has to be moved periodically. Sound isolating doors or folding partitions are examples.

savings with thinner partitions

A review of the Table shows that other materials take up to thirty times as much thickness as lead to accomplish equal speech privacy. The actual saving represented by decreased partition thickness must be based on the increased useful area within a building. By replacing a brick wall with $\frac{1}{4}$ in. lead sheets (allowing a 2 in. thickness for a structural framing system for the lead) a 6 in. strip of useful floor space can be saved. Based on an average building cost today of approximately \$15 per sq. ft., this 6 in. strip represents a savings of approximately \$7.50 per linear foot of partition.

looking at lead as a building material

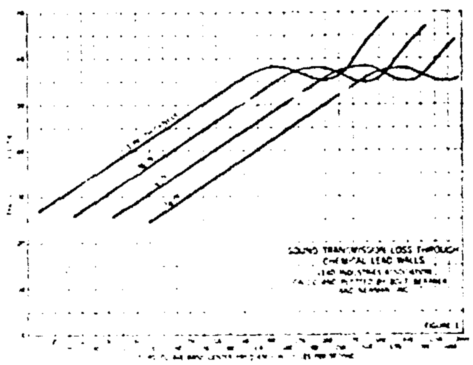
Using lead for sound barrier partitions may, at first, seem unorthodox. Of course radio and television studios, as well as other facilities where critical sound conditions prevail, have long used lead as an integral part of walls, doors, and partitions. Aside from novelty, is there anything to recommend or condemn lead as a sound barrier in buildings?

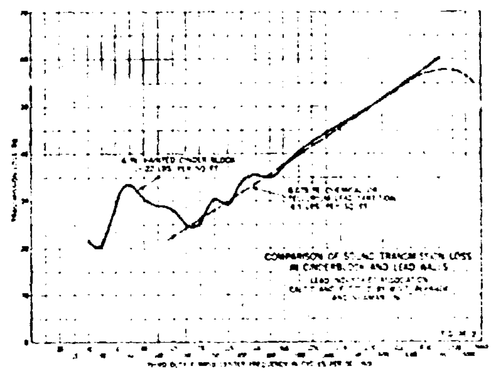
Let's look at cost. The most expensive lead partition considered in Table I cost \$4.50 per square foot, or \$45 per running foot in a room with a ten foot ceiling. Of this, about \$7.50 worth of usable space is returned per foot and an unknown saving is made because a lighter building structure is required. It would appear, though, that lead cannot economically replace interior two-course brick walls at about \$10 per running foot for interior partitions unless building space or weight is at a high premium.

Considering cinderblock, sheet steel, or even conventional stud-and-plaster walls, on the same basis, it can be seen that the costs of a lead partition wall are competitive. Indeed, lead has quite an advantage over conventional metal partitions.

Aside from considerations of cost, lead has many assets as a building material. It is tackable - it can be nailed, stapled, or, in light weights, even cemented in place. It is paintable - lead sheet as supplied is ready for painting without any further surface preparation, and it forms a durable bond with all conventional paints. Lead is fireproof. It is malleable - fold it or bend it over any regular surface. It can even be "dressed" over complex surfaces. Finally, lead is easily cut and worked. A saw, shears, or even a knife can be used in fitting lead.

What the data show

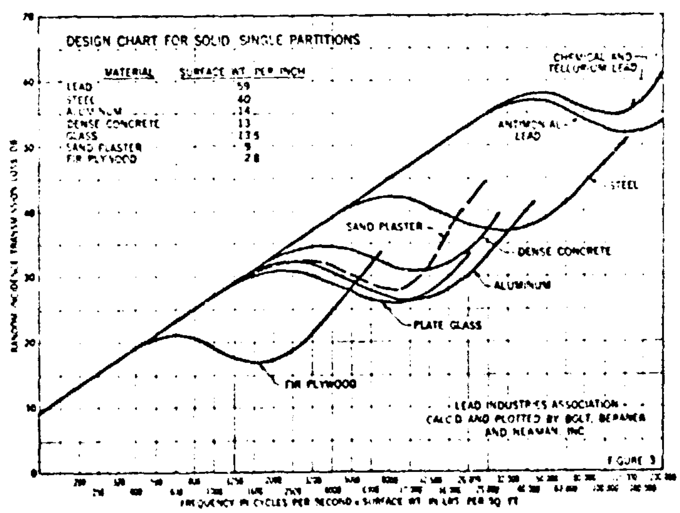




When the transmission loss of a lead partition is plotted against the frequency, (Figure 1) it can be seen that the loss increases with frequency up to the point where the transmission loss reaches about 55 to 60 decibels. Somewhat above this frequency a dip in the transmission loss curve occurs. At higher frequencies, the loss increases more rapidly. At lower frequencies the transmission loss is set by the weight of the lead. The dip is set by the stiffness of the lead. (The less stiffness the partition has, the higher the frequency of the dip, thus the higher the overall transmission loss.)

In Figure 2, field measurements for a painted cinderblock wall are compared with the calculated effect of a partition of lead 0.075 in. thick.

As a final comparison, Figure 3 shows the TL's of several common solid partitions. These curves have been plotted against the product of frequency and the surface weight of the partition. Figure 3 shows clearly the uniquely high density-to-stiffness ratio of lead, especially when compared with a cellular material such as plywood.



How lead can be used as an acoustical barrier

lead "wallpaper"

Many existing problems of noise transmission could be remedied if the weight of the wall could be significantly increased without increasing its stiffness significantly. Since the weight of many typical partitions could be doubled by the addition of a layer of lead as thin as $\frac{1}{8}$ in. on each side, few modifications have to be made in the construction to significantly increase the acoustical isolation provided. Leaded cloth similar to leaded vinyls already in production might also be used in a wallpaper-like fashion.

door linings

There may be considerable application in improving the acoustic isolation properties of doors. Approximately $\frac{1}{16}$ in. thick lead sheets with a decorative wood veneer laminated to one face of the sheet and a pressure sensitive adhesive laminated to the opposite face can easily be added to one or both faces of doors where high acoustic isolation through the doors is required – such as in broadcast studios, music schools, and doctors' offices. Thus, for example, when a doctor takes over an old building with typical lightweight panel doors, these doors can be converted into doors of higher acoustic isolation and modern flush wood appearance by simply cementing lead sheet and trimming the edges.

machinery enclosures

Lead laminated to fairly thin sheets of materials such as aluminum can be formed into machinery enclosures for noisy pieces of equipment. Such a construction has the advantage of higher transmission loss and considerable damping while the exterior material provides a hard, clean, working surface.

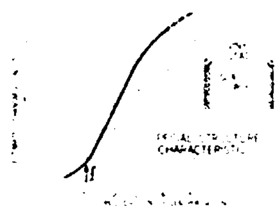
A leaded fabric and pressure-sensitive adhesive or simply thin lead foil with pressure sensitive adhesive has considerable application both in the fabrication of new machinery enclosures and in improving the acoustical properties of existing enclosures. For example, in the manufacture of small window room air conditioners after the individual elements of the case have been formed and attached to one another, the use of such a lead tape serves three functions: First, it increases the weight of the enclosure and thus improves its transmission loss. Second, it provides some vibration damping for the enclosure. And finally, because it will lap over joints in the enclosure, it seals it airtight.

A similar application could be envisioned immediately in the field of oil-cooled transformers for electrical substations within buildings.

Additional applications for such a pressure-sensitive lead tape might be found in the field of plastic phonograph and radio enclosures as well as in commercial metal loudspeaker enclosures for installation in the ceilings of buildings.

special high transmission loss lead structures

As the title suggests, this is a very general type of proposal. As an example of a structure of this type one might consider a 5-layer lamination as follows: vinyl film, $\frac{1}{8}$" lead sheet, 3" of relatively low density Fiberglass or other resilient board, $\frac{1}{8}$" lead and a final coat of vinyl.



Theoretically, such a construction would have the transmission loss shown. If the very high transmission losses, particularly at low frequencies, indicated by theory were realized in practice, such a panel would have considerable application, particularly in special areas such as jet engine test cells, dynamometer cells, special audiometric facilities and other types of research labs.

lead backed acoustic tile

One of the major problems now facing the manufacturers of standard acoustical tile is that the low weight and porosity of most effective sound absorbing materials permits the transmission of sound. Modern building techniques and economics require that most partitions be erected up against the bottom surface of the acoustic tile in such a manner that they do not extend from the acoustic tile ceiling up to the structural slab above. As a result, more and more difficulty is experienced with sound transmission through the acoustic tile over the top of the partition and down into the next space.

Several of the manufacturers have begun adding layers of opaque paint or paper or even sheet metal to the back surfaces of acoustic tile. Others have modified the ingredients from which the tiles are made to render the back surface more airtight, providing higher transmission loss.

The application of very thin lead foil to the back of [illegible] tile will prove acoustically effective and should permit the tile manufacturer to sell all of his various decorative patterned tiles with or without the required transmission loss without modifying his production run in a serious way.

a specific panel material

By carefully selecting the maximum stiffness compatible with the requirement for transmission loss, a laminated lead partition can be acoustically tailored to solve many specific problems. Such a partition, which might have considerable application in the field of movable office partitions would be constructed of a $\frac{1}{16}$" thick lead sheet bonded between two ½" layers of plywood and would have the following advantages:

a. Transmission loss tailored to solve speech privacy problems between offices having the background noise levels typical for quiet, air conditioned offices.

b. Sufficient structural rigidity to be supported in full height panels between small metal posts 3' or 4' on center.

c. Attractive appearance whether finished in natural wood, paint or other coatings.

d. Field cutability without special equipment.

e. Good surface to receive thumbtacks, screws, small nails and which may be readily refinished, using standard equipment.

f. Extreme thinness compared to conventional construction resulting in low shipping costs, easy storage and eventual space saving in the erected position.

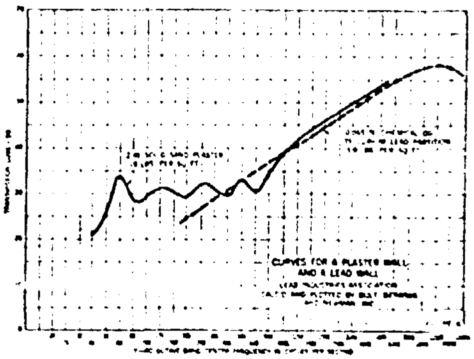
Engineering and design calculations

Figures 4, 5, and 6 are valuable comparisons of the effect of sheet lead with three conventional wall constructions. In designing partitions to reduce sound transmission, however, the starting point will be the sound reduction required and not the material of construction. In other words we will see how much of each type of partition material is needed to achieve a satisfactory sound reduction. As the first step in doing this, we must know what sound levels are permissible. Fig. 7 has been established by studies of tests in typical offices and thus serves as a guide to what transmission loss is needed for quiet environments. It can be seen that very quiet offices require a very high transmission loss partition.

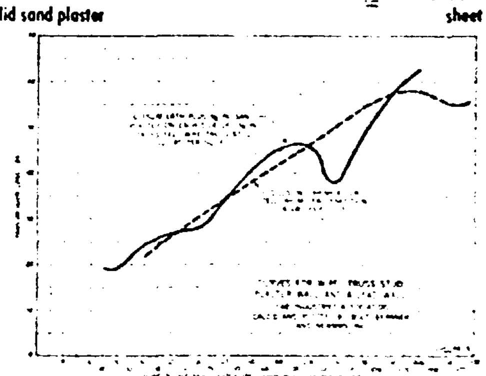
How can the transmission loss of a simple partition be found? It is governed by the familiar factors of weight and stiffness. In the case of any partition material where a simple structure is used (e.g. steel, lead, or plywood—but not plaster on wood or wire lath with studs), the transmission loss will increase from low to high frequencies at a rate of about 6 decibels per octave. In other words, when the frequency of the sound doubles, the intensity will be roughly half as great for sound passing through the panel.

This 6 db octave increase in transmission loss is solely a function of the surface weight of the partition. At some frequency, it will drop off into the "plateau." And the frequency at which the plateau starts is a function of the stiffness of the material. Above the plateau, the rise in transmission loss with frequency will increase to about 10 db octave. This increased rate of rise with frequency lasts, usually, only until the curve comes within about 5 db of a projection of the low frequency portion. From this point on, it remains parallel to and about 5 db below the projection of the low frequency curve.

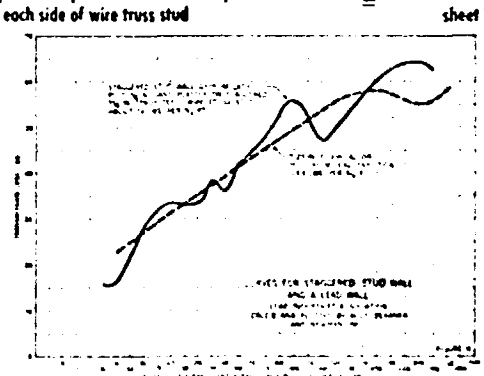
Refer again to Fig. 3 (page 5). All of the curves shown are based on a surface weight of 1 pound per square foot of surface. The point at which each plateau begins is related to the stiffness of the material in this weight. Fir plywood, quite stiff in this weight relative to the other materials, shows a plateau beginning at 19 db. Aluminum, nearly three times as thick as steel in the same weight, is much stiffer and thus starts its plateau at 29



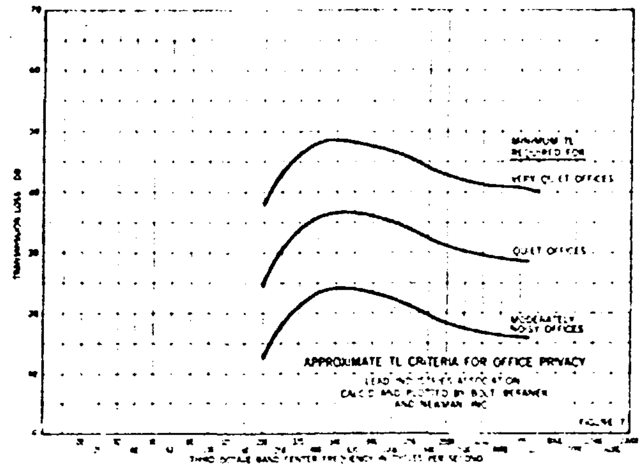
2 inches of solid sand plaster = **1/16 inch of sheet lead**



Gypsum lath plus 1/2 inch of sand plaster on each side of wire truss stud = **1/8 inch of sheet lead**



Staggered stud gypsum lath plus 1/2 inch of sand plaster on staggered wire truss studs = **1/4 inch of sheet lead**



db, while steel starts at 40. Limpest of all, lead shows a plateau starting 56 db. The width of each plateau is also a characteristic of the given material.

Thus it can be seen that there is much the curves have in general:

- they have the same 6 db octave slope below the plateau
- they have the same general shape in the plateau region, but differ in point of onset according to the stiffness of the material and in plateau width
- they have the same general shape above the plateau, starting with a 10 db octave rise which flattens into a 6 db octave rise as the curve approaches within 5 db of the projection of the low frequency slope

Apparently, then, the whole curve for any material can be defined if only we know the location and width of the plateau. And to help locate the plateau we know that each material has a characteristic transmission loss in db, depending on its stiffness, at which the plateau starts. All of this information is generalized in Fig. 8.

The only problem remaining is to find the frequency at which the plateau starts or—to put it another way—to find the height or intercept of the low frequency portion of the curve at some known frequency. To do this, we rely on the formula:

$TL_{400} = 20 \log W + 19$ (in db)

where — TL_{400} is the transmission loss in db at 400 cps

W is the actual surface weight of the partition per square foot

(19 is a numerical constant)

TYPICAL EXAMPLE

Finding the transmission loss of 3/8 in. fir plywood

1) From the first column of the table in Fig. 8, find a density of 3 lb/sq ft for 1 inch thick fir plywood.

Then,

$$\frac{3\ \text{lb}}{\text{sq ft} \times \text{in.}} \times \frac{3}{8}\ \text{in.} = 1.125\ \text{lb/sq ft.}$$

(actual partition weight)

2) Find the transmission loss of this panel at 400 cps. This is purely a function of surface weight according to the formula

$TL_{400} = 20 \log W + 19$ db

therefore,

$= 20 \log 1.125 + 19$

$= 20\,(0.0512) + 19$

$TL_{400} = 1.024 + 19$ **say 20 db**

3) Plot the point: 400 cycles per second and 20 db transmission loss.

4) Through this point, lightly draw the line representing a 6 db per octave rise in transmission loss. (An octave is an exact doubling of the frequency. Hence at 800 cps the loss would be 26 db, at 1600 cps it would be 32 db, etc.)

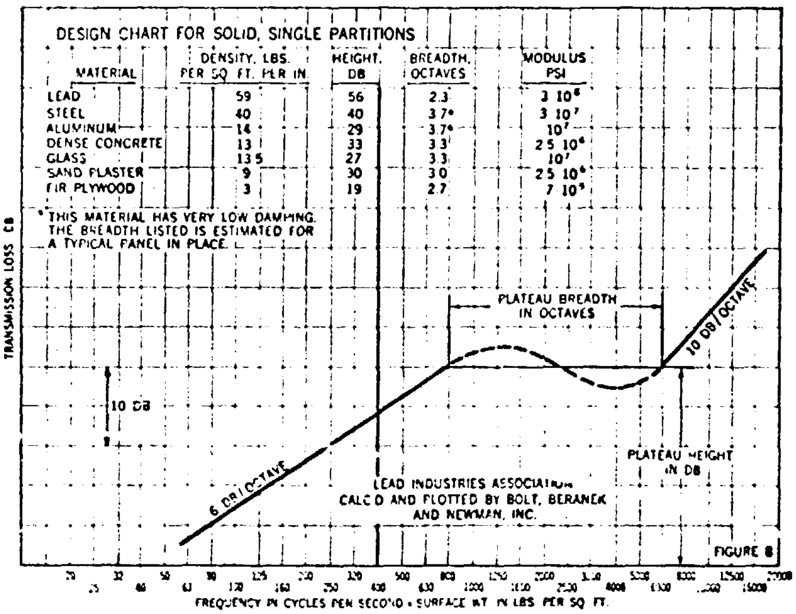
5) Refer to the second column of the table in Fig. 8 to find that the transmission loss height for the onset of the plateau for fir plywood is 19 db. Mark this point (approximately 340 cps, 19 db) on the low frequency curve you have drawn.

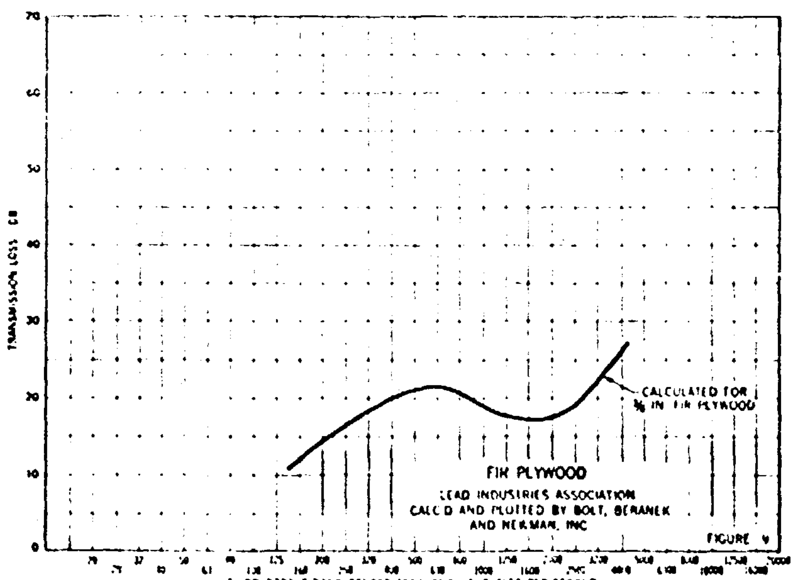
6) From column three of the table, take a plateau width for fir plywood of 2.7 octaves. Mark this off on the 19 db level. This may be done graphically (three divisions equal one octave). The plateau will end at about 2200 cps.

7) Above the end of the plateau (2200 cps, 19db) the loss curve will start to rise at 10 db octave and in this particular case will begin to drop off to 6 db octave somewhere beyond the range of hearing (15,000 to 20,000 cps).

8) Sketch in the plateau curve. The maximum and minimum will be about 2.5 to 3 db above and below the mean plateau level of 19 db.

By comparing the plot for a 3/8 in. fir plywood partition, just drawn


DESIGN CHART FOR SOLID, SINGLE PARTITIONS
MATERIAL | DENSITY, LBS. PER SQ FT. PER IN. | HEIGHT, DB | BREADTH, OCTAVES | MODULUS PSI
LEAD | 59 | 56 | 2.3 | 3 10⁶
STEEL | 40 | 40 | 3.7* | 3 10⁷
ALUMINUM | 14 | 29 | 3.7* | 10⁷
DENSE CONCRETE | 13 | 33 | 3.3 | 2.5 10⁶
GLASS | 13.5 | 27 | 3.3 | 10⁷
SAND PLASTER | 9 | 30 | 3.0 | 2.5 10⁶
FIR PLYWOOD | 3 | 19 | 2.7 | 7 10⁵
*THIS MATERIAL HAS VERY LOW DAMPING. THE BREADTH LISTED IS ESTIMATED FOR A TYPICAL PANEL IN PLACE.
TRANSMISSION LOSS DB
PLATEAU BREADTH IN OCTAVES
10 DB/OCTAVE
10 DB
6 DB/OCTAVE
PLATEAU HEIGHT IN DB
LEAD INDUSTRIES ASSOCIATION
CALC'D AND PLOTTED BY BOLT, BERANEK AND NEWMAN, INC.
FIGURE 8
FREQUENCY IN CYCLES PER SECOND × SURFACE WT. IN LBS. PER SQ. FT.


TRANSMISSION LOSS DB
70
60
50
40
30
20
10
0
CALCULATED FOR ⅜ IN. FIR PLYWOOD
FIR PLYWOOD
LEAD INDUSTRIES ASSOCIATION
CALC'D AND PLOTTED BY BOLT, BERANEK AND NEWMAN, INC.
FIGURE 9
THIRD OCTAVE BAND CENTER FREQUENCY IN CYCLES PER SECOND

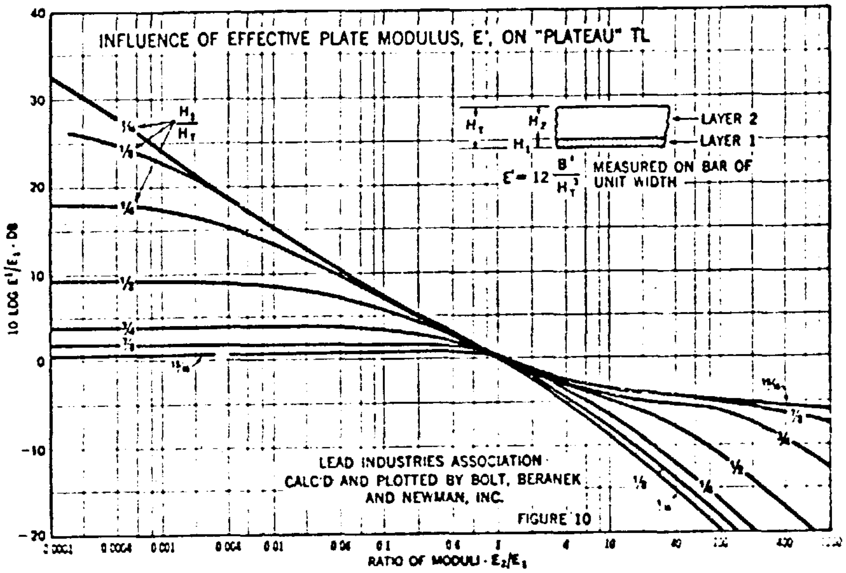


FIGURE 10

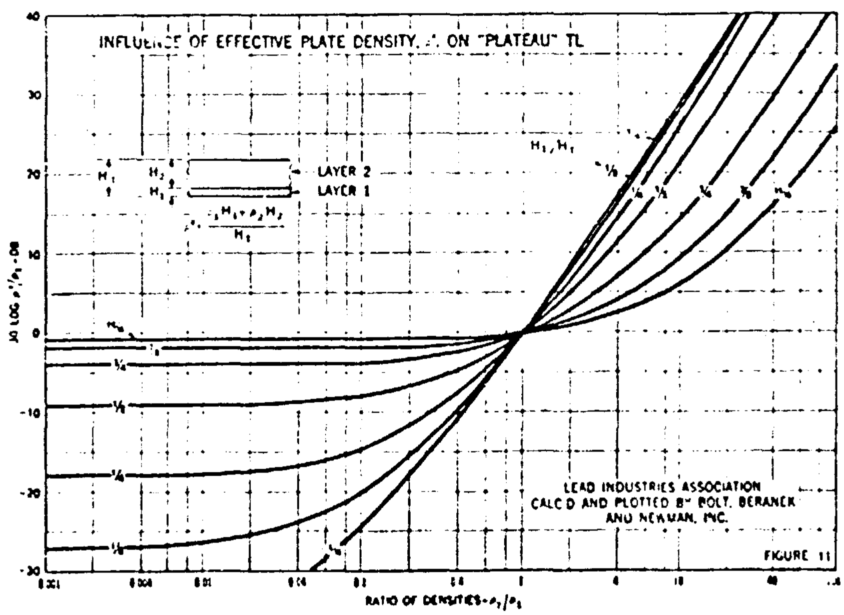


FIGURE 11

(Fig. 9), to the permissible sound level data of Fig. 7, you can see that such a partition will not be satisfactory. It will help to reduce the sounds with frequencies above 2000 cps--high frequency clicks and hisses--but permits too much sound to pass in the normal voice frequency range (200-2000 cps) and is relatively transparent to hums, rings, bumps and whines of office or production machinery. Using a thicker partition of plywood would tend to shift the whole curve to the left (into a lower frequency range) without raising it. It can be calculated that to shift the curve far enough to the left to give satisfactory transmission loss to meet the "moderately noisy office" standard, the plywood partition would have to be something like 3 to 4 inches thick!

Quite obviously all these construction materials except lead are inadequate for sound transmission loss in problem situations. Is it possible to improve the sound transmission loss of a partition by using a *laminate* of some desired partition material with lead? Indeed it is. In some cases the lamination of lead will produce a dramatic increase of transmission loss: in others the increase is small or marginal.

TABLE II

Approximate thickness of single, simple partitions to meet permissible transmission loss requirement

Material	Thickness required in inches: Moderately noisy office	Quiet office	Very quiet office
Fir plywood	3.67	6.67	13.33
Sand plaster	.20	4.45	8.9
Glass	.13	4.70	9.3
Dense concrete	.14	4.85	12.2
Aluminum	.13	5.7	11.3
Steel	.045	.20	7.0
Lead	.030	.135	.54

The stepped line through the table indicates the break between those partition materials which are limp enough so that their weight is efficiently used (below the line) and those which are so stiff that part of the effectiveness of their weight is lost (above the line).

TYPICAL EXAMPLE

Finding the effect of laminating lead to plywood

As an example of the sort of increase that can be expected, consider the effect of cementing 1/16 in. of lead to a 3/8 in. plywood panel. The two familiar factors of surface weight and stiffness will come into play in two ways. First, the new surface weight will be higher than that of fir plywood alone, so the transmission loss in the low frequency portion of the curve will be higher. Second, the new combination of surface weight and stiffness will produce a plateau height somewhere between those of plywood and lead.

To find the new low frequency transmission loss follow the procedure on page 8.

1) 3/8 in. plywood will have a surface weight of 3 lb sq ft if 1 in. thick, thus 1.125 lb/sq ft in 3/8 in. thickness. The sheet lead laminated to it will, from the listed density of 59 lb sq ft per in., have a surface weight of—

$$59 \times 1/16 = 3.68 \text{ lb/sq ft}$$

adding these, we get — 1.125
3.68
4.80 lb/sq ft

2) The transmission loss at 400 cps. then, (if the partition had no stiffness) would be—

$$TL_{400} = 20 \log 4.80 + 19 \text{ db}$$
$$= 20\,(.680) + 19 \text{ db}$$
$$= 13.6 + 19 \quad \text{say } 32.6 \text{ db}$$

3) Plot the 400 cps transmission loss of 32.6 db

4) Draw the low frequency slope (6 db per octave)

Now at this point we must depart from the original procedure because the new plateau height will be determined by the stiffness and weight characteristics of the laminate.

5a) First, from the data in Fig. 10, we can find the effect of the change in partition stiffness. To use this data, we have to determine the ratio of thicknesses between the plywood base and the whole laminated partition:

$$\frac{\text{plywood base thickness}}{\text{total thickness}} \quad \frac{3/8}{3/8 + 1/16} = \frac{6}{7}$$

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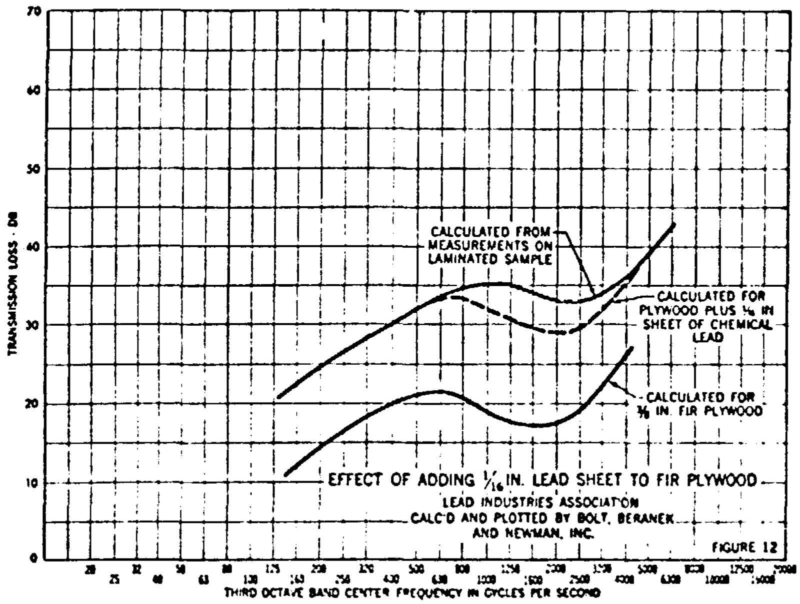

FIGURE 12

And we will also have to determine the ratio of moduli of elasticity for the two materials of the laminate. The moduli are given in Fig. 8.

$$\frac{\text{modulus for lead}}{\text{modulus for plywood}} \quad \frac{3 \times 10^6}{7 \times 10^6} = 4.3$$

With these two figures we can enter Fig. 10. At 4.3 on the ratio of moduli scale and 6:1 (just below the 7:1 parameter) the ordinate is −3 db. This is a decrease in the plateau height of the transmission loss curve due to the stiffening effect of the lead.

5b) Second, using Fig. 11, we will find the contribution of weight to the shift in the pateau height. Here, in addition to the thickness ratio used in step 5a, we will need the density ratio for the materials. From the table in Fig. 8, we have—

$$\frac{\text{surface weight per inch per sq ft for lead}}{\text{surface weight per inch for plywood}} \quad \frac{59}{3} = 20$$

Entering Fig. 11 at a density ratio of 20 we find, for a thickness-ratio parameter of 6:1, an increase in the plateau height of the transmission loss curve of 16 db. This increase is due to the surface weight increase brought about by laminating the lead to the plywood.

5c) The net effect of the lamination on the plateau height is therefore—

decrease due to stiffening	−3 db
increase due to added weight	16 db
Net increase	13 db

Going back to the table in Fig. 8 we find that the base material, fir plywood, had a plateau height of 19 db. Adding 13 db to this gives us the new plateau height of 32 db. The frequency at the beginning of the plateau will be about 370 cps.

6) The process of accurately determining the new plateau width is complex and need not be carried out. Actually, the result of laminating two materials with differing plateau widths will produce a new plateau width which is somewhere intermediate between the two original values. Since the effect of small changes in plateau width is insignificant in the whole transmission loss curve, it is good practice to take the larger of the plateau widths for the two starting materials. The actual performance of the laminate will always be slightly better than this.

Thus, we can take, from the table in Fig. 8, the plateau width of 2.7 given for fir plywood. Mark the 32 db level 2.7 octaves above the start of the plateau found at 370 cps. The plateau will end, then, at about 2400 cps.

7) Above the end of the plateau draw the 10 db octave rise which, again will begin to drop off to a 6 db octave rise somewhere above the normal hearing range.

8) Sketch in the plateau curve as before.

If we compare both this curve (Fig. 12) and the curve for unlaminated 3/8 in. plywood to the transmission loss criteria curves of Fig. 7, it can be seen immediately that adding the sheet lead has made the plywood partition acceptable for moderately noisy offices and, indeed, closer to the curve for quiet offices than to the former.

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