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# Sound Retardant Doors And Windows Monograph



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## List of Acronyms and Abbreviations

<b>ASTM</b>	American Society for Testing and Materials	<b>dB</b>	Decibel
<b>DIAM</b>	Defense Intelligence Agency Manual	<b>GSA</b>	General Services Administration
<b>Hz</b>	Hertz	<b>NCAC</b>	National Council of Acoustical Consultants
<b>NIST</b>	National Institute of Standards and Technology	<b>NR</b>	Noise Reduction
<b>NVLAP</b>	National Voluntary Laboratory Accreditation Program	<b>RAL</b>	Riverbank Acoustical Laboratories
<b>SCIF</b>	Sensitive Compartmented Information Facility	<b>STC</b>	Sound Transmission Class
<b>TL</b>	Transmission Loss	<b>UL</b>	Underwriters Laboratories

## Overview

Sound-retardant doors and windows are used extensively not only in performing arts centers, concert halls, broadcast studios, auditoriums, movie theaters, elementary, secondary and post-secondary educational facilities, but also in critical industrial, aerospace, and defense installations, as well as locations where noise control and/or voice privacy is required.

Overly Door Company offers one of the broadest ranges of sound-retardant doors and windows of any company in the market. The Company's metal swinging doors are available in virtually any size with Sound Transmission Class (STC) ratings of STC 43 to STC 57. The company's wood swinging doors are available in up to 4' x 8' leaf size with STC ratings of STC 41 to STC 49. All products are tested under ASTM procedures that meet the acoustical needs for most applications, both conventional and special.

Overly Door Company's continuous testing program is predicated on the constant improvement in standards and testing technology and the resulting need for upgrading the capabilities of sound-retardant products.

All of the sound control products supplied by Overly have been tested and certified by the Riverbank Acoustical Laboratories of Geneva, IL, one of the nation's first facilities to qualify under the NVLAP criteria of the National Institute of Standards and Technology. Testing conditions are tightly controlled. Virtually all flanking path transmissions within the lab are eliminated. Because of the measurement equipment used, there is a 95% confidence level of certainty with regard to the repeatability of tests.

## Good Design Practices

Testing is done under ideal conditions. In the field, less-than-ideal conditions are often encountered. It is recommended that the specifier require installation of acoustical doors and windows with higher STCs than good practice or usage might initially suggest. Flanking paths are often inadvertently designed and/or built-in. Such field conditions cause unforeseeable degradation of what would otherwise be a controlled sound environment.

By selecting higher-rated acoustical laboratory-tested products than may be indicated by usage, the specifier is assured that the finished composite sound barrier will be as efficient as was initially anticipated. Higher STC-rated acoustical doors and windows will partially compensate for field inaccuracies or poor installations. Overly recommends selecting products which are 3 to 5 STC rating points higher than field performance desired to compensate for these field inaccuracies or poor installations.

## Sound Retardant Doors and Windows

Noise levels may range from being a mere annoyance, to a disturbance, or, in the extreme, sufficient to cause physical pain and irreparable damage to the human ear. In basic terminology, noise is defined as any unwanted sound.

It is not the purpose of this monograph to provide an in-depth review of the physics of acoustics. Instead, the reader interested in a more detailed explanation should refer to the various publications listed at the end of this monograph. However it is necessary to define some of the basic terms pertaining to architectural acoustics.

Also, because of the complexity of the field of architectural acoustics, it is advisable to retain an acoustical consultant or acoustician for major projects. A list of members of the National Council of Acoustical Consultants (NCAC) may be obtained by writing its headquarters at 9100 Purdue Road, Suite 200, Indianapolis, IN or by viewing the information on its website, [www.ncac.com](http://www.ncac.com).

Sound is defined as pressure variations (oscillations) in air, water, or other mediums that can be detected by the human ear. The number of vibrations per second is referred to as the frequency of sound and is measured in Hertz (Hz). The human hearing range is from approximately 20 Hz to 20,000 Hz, with the frequencies of speech ranging from 20 to 8,000 Hz. To simulate the varying sensitivity of the human ear, sound level meters are designed with a series of filters over the audible frequency range. This is referred to as A-Weighting, and Measured Sound Power Levels are designated as dBA.

A room sound level is the combination of the directly transmitted sound waves plus the reflected wave effect, or reverberation. When the sound wave meets a barrier, part of its energy can be absorbed by the barrier, and part reflected. The remaining vibrating energy puts the barrier into motion and it becomes a second transmitter, thereby radiating sound into adjacent areas. The construction materials and techniques used in enclosing the source noise will govern the amount of energy transferred from the source area to adjoining spaces.

## Sound Absorbers

Sound or noise levels can be reduced within a source room by use of porous absorbers (usually fissured, fibrous material, perforated board, foams, fabrics, or carpets). In these materials the sound waves produce motion in the fibers or granules, thereby doing work and dissipating energy as heat. This reduces the acoustical energy remaining in the room itself. (Other specialized products, i.e. diaphragm or resonate absorbers or reactive materials, which are beyond the scope of this monograph, may be employed).

It should be emphasized that most fibrous or porous sound absorbent materials offer only minimum resistance

to low frequency sound waves and permit their passage to the other side relatively unattenuated. Only when these materials are very dense or very thick will they somewhat reduce the amplitude of the sound waves as they pass through. A rule of thumb is that if air, light, or water can pass through a material, so can sound. Because of inherent porosity, a fibrous absorber alone is usually not an effective sound barrier.

The inadequacies of most sound-absorbent materials to control low frequency noise can be enhanced by augmenting them with more dense membranes, creating diaphragming or cavity-type absorbers

## Sound Dampening Materials

To reduce the amount of energy radiated by a barrier, damping material may be applied. Typically such materials are limp, and have a high areal density that have both energy dissipation and energy storage capabilities. An example of dampening material is rubbery polymeric loaded vinyl sheets. These limp-mass materials provide excellent vibration control and damping characteristics.

Lead is also commonly used as a sound dampening material. Due to long term health concerns focusing on lead, it is important to note that Overly Door Company does not use lead in the manufacturing of any of its sound control products.

## Sound Barriers

The transmission loss effectiveness of a material is a function of its mass, damping, and stiffness. However, the effectiveness of a barrier material may be enhanced by combining absorptive and dampening characteristic

materials. Although a limp-mass material offers good sound properties, it isn't practical for exterior applications.

Therefore, most sound barrier exterior materials are hard, stiff, dense and very reflective, and can provide good resistance to the passage of sound waves. The composite

functions as an absorptive barrier. Such composites are used in sound-retardant doors, also known as acoustical doors.

## Development of Sound Retardant Doors Technology

Until almost fifty years ago, the efficient application of the effect of these three properties - mass, dampening, and absorption - generally were not clearly understood by door manufacturers. Initially the common practice in sound-retardant door design generally followed that for commercial freezer and refrigerator doors, using wood, metal, cork, mineral insulation, lead sheets, and other materials in a thick "sandwich" configuration was typical.

The prevailing theory was that, as sound impinged on the surface materials of the "sandwich" configuration, each material according to its mass would retard penetration of a segment of the particular frequencies involved.

Results were generally good, but the doors were massive-four, five, or six inches thick-and required special hardware which was derived from commercial refrigeration doors.

Aesthetically, the product was unappealing and the hardware did not serve the developing needs for fire safety, easy ingress and egress, and could not be readily keyed into a building locking system.

It was not until the 1950's that events took place to usher in the new age of sound-retardant doors.

These included growing demand from architects and designers for sound barrier doors that were compatible in appearance with conventional hollow metal doors along with perceived need to develop comparative performance data on products from different manufacturers. Prior to this, each manufacturer offered his own claim of effectiveness. In addition, the world about us was becoming noisier as technology progressed and our population increased.

It was not until a standard performance test was promulgated by the American Society for Testing and Materials (ASTM) that order began to develop and research started on new approaches to door design.

Technically known as E90-50T (the last two numbers denote the year of its adaptation; "T" stands for Temporary), the "Standard Method for Laboratory Measurements of Airborne Sound Transmission Loss of Building Partitions," marked a decisive point in the development of not only partitions or solid walls but of the doors and windows that went into them. E90 has been repeatedly revised and refined since the -50T edition was originally published. Following is a discussion of how it has evolved over the years.

Initially, in order to rate or rank the performance of tested products, an averaging method was developed which used the decibel value of the transmission losses at nine of the eleven test frequencies, to derive a single number performance level rating. Under E90-50T, tests were conducted at eleven 1/2 octave frequencies in the range of three allowable noise sources. The most frequently used at the time was designated as a warble tone. As testing procedures and equipment for determining transmission loss improved, the ranking technique was refined and as a result a separate ASTM Standard E413-70T was developed. This standard established a standard contour curve that is fitted into transmission loss values measured at sixteen 1/3 octave bands. This produces a single number rating known as the Sound Transmission Class (STC), which will be discussed in detail later. E413-70T has been revised twice, the first revision being E413-87. E90 has gone through many revisions, with the current standard being E90-2009. Significant changes in the E90 standard occurred in E90-66T when measurements were changed from eleven at 1/2 octave bands to eighteen at 1/3 octave bands and the frequency modulated (warble) tone was changed to a broad band white or pink noise spectrum. In E90-81 the confidence level was increased to 95%. With one set of criteria (test standards) established, it was then possible for manufacturers to address the architectural acoustical requirements, since rating-not shear bulk or mass-could be compared.

Since then, ASTM has revised the E90 standards six more times to the current ASTM E90-2002 testing standard.

## On Going Testing

In the early 1960's Overly Manufacturing began a wide-ranging research and experimentation program under the premise that bulkier was not necessarily better.

The result is a number of patents awarded to the Company, not only for sound-retardant door designs that are more efficient and thinner than previous door configurations, but for sound seals and gasketing systems as well. The product was a 1-3/4 inch metal door, weighing only about

250 lbs., which looked like all the other doors in a building. These doors easily attained an STC level of 45 or better.

By the late 1970's and the early 1980's three factors encouraged Overly to launch yet another development effort. The three factors were the demand for more efficient (i.e. higher STC-rated) door systems, dissatisfaction by architects with elevated thresholds, and

the increasing refinements in ASTM E90 which essentially invalidated earlier test reports.

In the 1990's, the need for lightweight doors due to increasing ADA concerns lead Overly to undertake a new development effort. This effort provided a complete line of patented door constructions, which are the lightest weight, highest performing doors in the industry.

The results of this program was the introduction of an entire new line of doors which eliminated both the generally inefficient "automatic door bottom" and represents the current state-of-the-art with performance in the range of STC 50 to 57, rated under E90. The magnitude of the achievement will become evident by reviewing subsequent sections in this monograph.

## A Note on Vision Lights

While the balance of this monograph concerns itself primarily with either doors or vision lights, distinction between the two products should be addressed.

A door or a window is a dynamic part of the overall design, while Overly's vision lights are non-operable and are constructed of different materials. Glass, the primary product, is an extremely rigid material. It lacks good damping properties and is not a good sound-retarding material. Despite its high areal density, high levels of sound will be transmitted into adjacent areas at certain frequencies, particularly if the glass is monolithic.

Double glazing with two panes of monolithic glass of the same thickness can tend to increase the coincidence effect and reduce the noise reduction value of the assembly over a similar unit with different thickness panes. The coincident effect is the result of sympathetic reverberation at the resonant frequencies common to the two panes.

Knowledgeable manufacturers overcome these inherent limitations of glass in a variety of ways; using laminated

glass (the interlayer acts as damper) of different thickness; isolating glass from the frame by flexible gaskets and using resilient isolation material between frame sections.

Although there is difference of opinion on the acoustical effectiveness of sloped glazing, practice has shown that nonparallel panes reduce annoying glare and reflections within or from the vision light.

Overly's tests show that a single-glazed vision light with 3/4" thick laminated glass and having a weight of 17.3 lbs./ft<sup>2</sup> provides an STC 42, far lower than an STC 52 door having a weight of 11.2 lbs./ft<sup>2</sup>. On the other hand, by using the above techniques, a double-glazed unit weighing just 12.5 lbs./ft<sup>2</sup> (4.8 lbs./ft<sup>2</sup> less than the STC 42 unit) was tested and achieved a rating of STC 52. This is a quantum leap in effectiveness. Overly manufactures fixed window systems up to and including STC 55 vision lights in both single and dual glazed configurations utilizing both conventional neoprene and pre-moulded zipper gasketing glazing systems.

## Determining Effectiveness

The acoustical effectiveness of a sound barrier is basically determined by laboratory testing in accordance with ASTM E90. In the laboratory, these measurements are conducted in two adjacent highly reverberant rooms, presenting a diffuse sound field, requiring walls with acoustical properties far superior to the test specimen. The specimen to be tested is sealed in an opening between the two rooms and a calibrated noise source and frequency spectrum is activated.

The same rotating microphone is used in each room to transmit measured sound levels to analyzers that determine the Transmission Loss (TL) in decibels (dB) at each of the eighteen 1/3 octave bands between 100 and 5,000 Hz (cycles per second). The Noise Reduction (NR)

is determined by measuring the difference between the source and receiving rooms.

The noise reduction values derived from this procedure determine the sound barrier performance of a door, vision light, window, or panel. Then, after other receiving room acoustic parameters are applied the Transmission Loss (TL) of the barrier is calculated. Measurements are recorded and calculated at the eighteen 1/3 octave center frequencies from 100 Hz to 5,000 Hz.

The Transmission Loss (TL) of a door is a measure of its effectiveness in preventing the sound power incident on one side from being transmitted through it and radiated on the other side, taking into account the area of the door and the absorption in the receiving room.

## The Meaning of "STC"

Sound Transmission Class is a relatively simple concept, but an understanding of the test methodology used to establish this single number rating is needed.

The sixteen TL readings between the 125 and 4,000 Hz 1/3 octave bands are plotted against a standard contour curve as established by ASTM Standard E413 (Classification for Rating Sound Insulation). The result is

a convenient single number rating (STC) that covers the primary speech frequencies and is an easy way for users to rank the relative effectiveness of sound barrier products. The ASTM Standard E90, "Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions" includes sound barrier doors and windows within its scope.

Factors affecting the acoustical performance of a specific door assembly are not only the internal construction of the door, but also that of the perimeter seals, hardware, frame, and its integration into the wall.

It is important to make sure that the STC rating of a door or window is for the complete system, and includes all items required for a unit.

## Logarithmic Comparison

It should be pointed out that the transmission loss when measured in decibel (dB) units is a logarithmic ratio, and thereby is not a specific unit such as pounds or feet. Five feet is five times one foot, but 5 dB is not a direct multiple of 1 dB.

A 3 dB change on the logarithmic scale implies a factor of one-half on the sound power unit scale. Following are two tables of transmission loss versus the fraction of incident sound power transmitted. The first is in steps of 3 dB; the second is in steps of 10 dB.

<b>Table 1</b>		<b>Table 2</b>	
STL, dB	Fractions Transmitted	STL, dB	Fractions Transmitted
0	1.00	0	1.0
3	0.50	10	0.1
6	0.25	20	0.01
9	0.13	30	0.001
12	0.063	40	0.0001
15	0.032	50	0.00001
18	0.016	60	0.000001
21	0.008	70	0.0000001
24	0.004		
27	0.002		
30	0.001		

For instance, to improve transmission loss of a 20 dB panel to 30 dB where only one-thousandth of the incident sound power is transmitted is relatively easy. However, it becomes more difficult to improve it even further to 40 dB so that only one -ten-thousandth is transmitted. To realize a further reduction in the fraction transmitted, especially with a movable panel such as a door, is very difficult. To achieve a 60 dB reduction, implying, as it does, that only one-millionth of the incident sound power is transmitted, is outstanding.

Scale Number	Depth of Well
<b>0</b>	1 foot
<b>10</b>	10 feet
<b>20</b>	100 feet
<b>30</b>	1,000 feet
<b>40</b>	10,000 feet
<b>50</b>	100,000 feet
<b>60</b>	1,000,000 feet

It may be easier to appreciate ratio scales when the numbers increase and the subject is more physical. Suppose we start with a well one foot deep and assign to it a scale number depth of zero. And suppose we decide for some arbitrary reason that the depth measured by the scale number will increase by 10 every time the depth measured in feet multiplied by ten.

It would be much more difficult to continue drilling from a depth of scale 40 to scale 50 than it would from scale 10 to scale 20. In a like manner, while there exists many sound doors in a range from STC 30 to STC 40, few manufactures have doors rated greater than STC 50.

## Important Caveats to Specifiers

Since the controlled laboratory environment does not reflect the realities of field conditions and construction practice, it is essential that the specifier make all building trades aware of the need to maintain acoustical integrity. Penetrations into partitions should be minimized and flanking paths must be avoided. The effectiveness of well

designed acoustical walls can be destroyed by even relatively small openings. For such items as sound-retardant doors, it is highly recommended to specify the complete system-door, frame, and gasketing-from one manufacturer having test data from a NAVLAP approved, independent test facility.

Also, because of the almost inevitable degradation of the laboratory-tested acoustical partition created by field construction practices, it is highly desirable to specify doors in higher STC ratings than that of the wall construction selected. Dependent on the area involved, the selection of a high-rated sound barrier door can actually

improve the performance of the entire wall system. The specifier should also require the contractor to closely adhere to the manufacturer's detailed installation instructions, or obtain the services of authorized factory trained installers.

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