Meeting the Market's Growing Need for High-STC Walls:

Innovative Solutions for a High-Density World

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June 20, 2007

National Gypsum®

Introduction

While the casual observer might identify architecture as a discipline primarily concerned with visual aesthetics, noise control has long been an important focus of building design. Reducing the transmission of sound from one room to another through partition walls has engaged the attention of architects for decades, and a variety of solutions have been devised to accomplish this goal. Recently, the need for reliable, cost-effective noise-reduction strategies has grown rapidly as a result of several converging trends in the housing, healthcare and hospitality markets. In terms of housing, these include a trend toward higher-density development and more multi-family housing, as well as increasing litigation initiated against building owners by disgruntled residents upset by their noisy neighbors. Hospitals and other healthcare facilities are eager to satisfy their patients' need for privacy and to comply with new stringent federal regulations protecting the privacy of patient information. In the hospitality industry, hotels are seeking new ways to attract guests by differentiating themselves from the competition. Such market forces are driving growth in demand for construction materials that deliver significant reductions in sound transmission through walls. In response to this demand, new solutions have been developed that promise reliability superior to previously existing solutions at a competitive cost. The following paper discusses these trends and new solutions to address sound transmission through walls.

A Growing Market

The concept of home as sanctuary has always implied shelter from the intrusions of the outside world, including that most ubiquitous of intruders – noise. Whether it is traffic, music blaring from a neighbor's stereo, or the wail of an emergency vehicle's siren, people do not want to hear noise once they arrive home and close the door behind them.

But if a man's home is indeed his castle, it is growing increasingly difficult to ensure undisturbed peace and quiet inside the moat. A number of factors, including increasing land costs, higher housing prices and a dwindling supply of available land, are driving trends toward higher-density housing in the form of town homes and condominiums and more vertical construction as seen in the growth of high-rise residential projects.

This trend is evident nationwide. A prime example can be found in San Diego, Calif., the nation's eighth-largest city and one of the nation's least-affordable housing markets. In 2006, building permits for multifamily housing, including apartments, town homes and condominiums, exceeded the number of permits for single-family homes for the first time since 1990. Looking at the for-sale residential market, fully 69 percent of new homes sold in San Diego County in 2006 were condominiums and townhouses. Fewer detached single-family homes are being built, and those that are being built are going up on smaller lots because rapidly increasing land costs and rising home prices have threatened to put the "American Dream" out of the reach of many would-be buyers.

More people living in close proximity naturally results in an increased potential for all of the problems associated with living in a multifamily building. Of all of these, noise is the single most frequently cited annoyance. In a recent national survey of more than 1,500 adults conducted for National Gypsum Company by Alan Newman Research, noisy neighbors were far and away the No. 1 complaint of people who live in multifamily buildings. Nearly two-thirds of those surveyed (62 percent) listed "Noise/

Hearing my neighbors through the walls" as their top complaint, with more than half (55 percent) specifically identifying loud music as the chief culprit. Arguing neighbors, barking dogs, and sounds between neighboring unit bedrooms were identified by other survey respondents as the most vexing noises coming from next door.

Residents of detached single-family homes have similar requirements for privacy and limiting the transmission of sound from one room to another. Survey results show that reducing sound transmitted through walls from the master bedroom was a primary concern of this group. Containing noise from the laundry room was also a significant concern. Given that the survey cited loud music as the No.1 noise complaint, the growing trend in home theaters is obviously the focus of noise-reduction concerns for more homeowners today.

In the healthcare market, hospitals, doctors' offices and other healthcare facilities have turned their attention to protecting the privacy of their patients, in part as a result of the federal healthcare privacy law called the Health Insurance Portability and Accountability Act or HIPAA. Under HIPAA, healthcare institutions are under strict directives to ensure that information and data about individual patients remain strictly confidential. As a result, hospitals are responding to the new regulatory environment, as well as to the perceived needs of their patients.

In similar fashion, competition in the hospitality industry is driving industry participants to seek out new ways to attract guests, from offering the best Wi-Fi setup or more comfortable beds to promising enhanced privacy through the use of sound-deadening partition walls separating rooms.

Although not an exhaustive list, the above-mentioned market trends represent important drivers of the widespread and growing need for sound-reducing solutions on residential as well as commercial construction projects. The challenge facing architects and builders is understanding the variety of solutions available to them today and determining which will enable them to meet their project goals.

Transmission of Airborne Sound

Learning a few acoustical concepts and terms is key to understanding how sound is transmitted through walls and how sensitive we are as humans to changes in noise levels. First, let us clarify that we are talking about airborne sound. This is acoustical energy in one space that is transmitted in the form of vibrations of an intervening structure, and that is then transmitted through the air and creates sound pressure variations at a receiver such as the human auditory system. The character of the sound will be determined by the frequency components that are heard, which determines the pitch of the sound, and by the intensity of the pressure fluctuations, which determines how loud people perceive the sound to be. Of course, the resulting sound level will also be affected by the nature of the structural medium through which the vibrations must pass before reaching the receiver.

The most common measure of frequency is called a hertz, which is equal to one cycle per second. In visual terms, one can think of it as the number of sound pressure fluctuations that occur at a fixed point within a second. A healthy child with normal hearing is capable of detecting sound frequencies between 20 hertz (Hz) and 20,000 Hz; but as we age, the ability to hear higher-frequency sounds deteriorates significantly. (Thus, the phenomenon of the "Teen Buzz" craze, in which clever teenagers created a cell phone ring tone that registers at about 17,000 Hz, making it inaudible to their older teachers and enabling them to text message in class with impunity.) Humans are typically most sensitive to sounds within the range of 500 Hz and 4,000 Hz. However, people can also be quite sensitive to lower frequency sounds in the range of 125 Hz, especially when they are present as tones. Speech and most typical sounds within a building are found over this broad frequency range. In terms of how different frequencies "sound" to us, humans perceive frequency as pitch. Low-pitched sounds such as that of a pump running in the basement might be around 125 hertz, while high-frequency, high-pitch sounds would include the whine of an electric "weed whacker," for example.

The intensity of sound, or loudness, is measured in decibels (dB). A quiet whisper might register at 20 dB, compared to about 65 dB for normal conversation at a distance of 5 feet, 80 dB for an alarm clock two feet away, 75 dB for average traffic, up to 105 dB for a power lawnmower, 120 dB for a rock concert or thunderclap, or 140 dB for a shotgun blast or a firecracker. The decibel scale is logarithmic, not linear, as we can see by comparing the loudness of a conversation with that of a lawnmower running full tilt. Obviously the latter is not twice as loud but orders of magnitude louder than the former. Sound level changes on the order of 1 to 2 dB will be difficult to perceive if the character of the sound remains unchanged. A change of 5 dB in sound intensity will generally be clearly noticeable, while an increase of 10 dB will be perceived as a doubling in loudness and 20 dB as a quadrupling in loudness. This is important to keep in mind as we turn to discussing the effectiveness of various construction materials and techniques in preventing unwanted external noise from penetrating partition walls.

Typical dBA levels of some common sounds:			
Threshold of hearing	0 dB	Motorcycle (30 feet)	88 dB
Rustling leaves	20 dB	Food blender (3 feet)	90 dB
Quiet home	30 dB	Subway (inside)	94 dB
Quiet whisper (3 feet)	40 dB	Diesel truck (30 feet)	100 dB
Quiet street	50 dB	Power mower (3 feet)	107 dB
Normal conversation	60 dB	Pneumatic riveter (3 feet)	115 dB
Inside car	70 dB	Chainsaw (3 feet)	117 dB
Loud singing (3 feet)	75 dB	Amplified rock & roll	120 dB
Automobile (25 feet)	80 dB	Jet plane (100 feet)	130 dB

Change in Sound Level	Change in Perception of Loudness
1 dB	Generally not perceptible
3 dB	Just perceptible
5 dB	Clearly noticeable
10 dB	Twice or 1/2 as loud
20 dB	Four times or 1/4 as loud

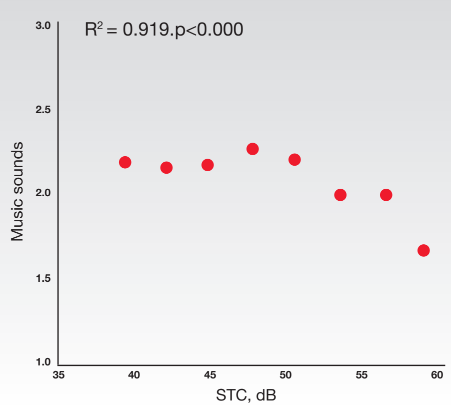
Measuring Noise Reduction

The importance of noise reduction as a goal of building design is underscored by the establishment of standards by both government and industry to achieve acceptable noise levels in residential and commercial construction. In the United States, these performance criteria are based primarily on a standard that measures the ability of walls, floors and doors separating rooms to prevent the intrusion of noise from adjoining rooms. This system is called Sound Transmission Class (STC), and employs a series of ratings determined by ASTM International and based on strictly controlled laboratory testing.

For wall partitions – walls separating rooms in a structure from other rooms – the testing protocol is ASTM E 90, which is designed to measure the ability of building materials or specific wall assemblies to reduce the transmission of airborne sound from one space to another. Another ASTM standard, ASTM E 413, governs methods of calculating ratings for both laboratory and field measurements of sound attenuation. Testing rates a wall partition's overall ability to resist the transmission of airborne sound at 16 frequencies between 125 Hz and 4,000 Hz. Taking into account this wide range of airborne sounds at sharply differing pitches produces a composite rating intended to reflect real-world conditions. Generally, the higher the STC rating of a partition, the greater is its ability to reduce transmission of airborne sound from one side of the partition to the other.

What constitutes an acceptable noise level? One way to answer this question is to look at the results of a prominent study by the National Research Council of Canada, which are contained in a report published by the NRCC, *Deriving Acceptable Values for Party Wall Sound Insulation from Survey Results*, by J.S. Bradley. A survey conducted as part of the study looked at the attitudes of residents in 600 multifamily dwellings (representing 300 party walls between them). Residents with lower STC-rated walls were more likely to want to move, be awakened by noises, have trouble falling asleep because of noises, and think their neighbors were inconsiderate.

Decline in noise complaints as STC rating increases



Average responses concerning neighbors' music-related sounds versus STC rating.

In terms of specific ratings, Bradley concluded from the survey results that an STC rating of 55 was generally a realistic goal for acceptable sound insulation, and that an STC rating of 60 or greater would effectively eliminate negative effects of noises from neighboring dwelling units. The report also found that music-related sounds that often include low frequency components may require the highest STC-rated walls – a conclusion that appears to agree with the results of the aforementioned National

Gypsum survey, which found that loud music was the No. 1 complaint of survey respondents living in a multifamily dwelling.

Federal noise reduction criteria used by the Department of Housing and Urban Development mirror the findings of the NRCC study. HUD's three-tier system for classifying the quality of construction in terms of sound attenuation uses an STC-55 rating or above as the criteria for a Grade 1 dwelling – primarily high-quality, even luxury multifamily units where tenants have an expectation of a quiet living environment. Extremely high-end projects may actually build to a STC-60 or STC-65 rating or when very different uses are placed next to each other in adjoining units. Grade 2 denotes a STC-52 rating, and Grade 3 would represent a dwelling falling below STC-52. An STC rating of 50 has been designated as the minimum allowable design rating for unit-to-unit multifamily construction in the model building codes.

What does an STC rating of 55 actually mean in terms of noise reduction? Put simply, a resident in a condominium complex with STC-55 rated partition walls should be able to enjoy the use of the unit without the intrusion of many common sounds, although a partition wall with an STC rating of 60 or above may be needed to reduce loud music coming from next door to an acceptably unobtrusive level. As a reminder, remember we are speaking only of airborne sound in this particular case and not other sources of noise such as structure-borne sounds like footfalls and structural vibrations that might be the result of planes taking off nearby or a fully loaded dump truck rumbling along the street below. Also, remember that, like decibel ratings, the STC rating system is logarithmic rather than linear, so a difference of 3-5 decibel rating can be significant, depending on the specific point on the rating scale.

Achieving Acceptable Noise Levels

As noted earlier, reducing sound transmission through partition walls is a longstanding goal of architects and builders, and unfortunately for many building owners and inhabitants, a somewhat elusive goal at that. The fact that noise complaints from residents of multifamily buildings are now a key source of lawsuits against building owners partially reflects the difficulty of achieving reliable sound transmission loss using some of the existing noise-reduction techniques being employed in construction projects today.

There are essentially three strategies available to those seeking to reduce noise in buildings: Eliminate the cause or source of the noise, employ materials that absorb rather than reflect sound, and use sound barriers (partitions) in building layout to prevent sound from being transmitted from one adjoining area into another. Realistically, the first strategy is not available in a multifamily setting where tenants have little or no control over the actions of their neighbors, so one must look to either of the latter two noise-reduction options.

Most of the existing solutions being employed today fall into the third category of building a sound barrier into the partition wall to reduce sound transmission. In designing a wall to a higher STC rating, several techniques can be used alone or in combination with others to achieve the goal:

- *Increasing the mass of the wall – and thus the amount of material airborne sound waves must penetrate to reach the adjoining room – is an obvious tactic that has been accomplished in a variety of ways, including the use of multiple layers of gypsum board or masonry construction. However,* *the approximate rule of thumb that it requires a doubling of the mass of a partition to achieve a 6 dB increase in transmission loss speaks to the practical limitations of taking this approach alone.*

- *Increased damping, or the ability of the partition to dissipate the vibrational energy produced by the sound waves, thus reducing the quantity of energy remaining to pass through to the receiving room. This is of particular value in dealing with what is referred to as the coincidence effect, where the coupling of incoming acoustical waves with the partition structural waves is particularly good, and as a result, a dramatic reduction in the transmission loss of a panel can occur in a particular frequency range. In practice, this frequency range is within the range of importance to humans.*
- *Increasing the depth of the wall cavity between wall panels in each of the two living spaces, thus increasing the thickness of the overall partition, and potentially enhancing the lower frequency performance of a partition.*
- *Increasing the amount of sound-absorbing material such as acoustical insulation inside the wall cavity. Greater depths of acoustical blanket tend to provide better performance at low-and mid-frequencies as well as higher frequencies. Acoustical blanket in wall cavities should fully fill the available volume with no voids but not be compacted.*
- *Increasing the amount of flexibility in the wall assembly to structurally decouple its various components can enhance the transmission loss of typical partitions over the frequency range that is important to people. Replacing wood studs with more flexible metal studs is one example of increasing flexibility in a partition. In other solutions, this may be accomplished by using resilient channels or resilient clips. Alternatively, employing two separate stud walls eliminates any direct mechanical connection between the two sides of the wall.*

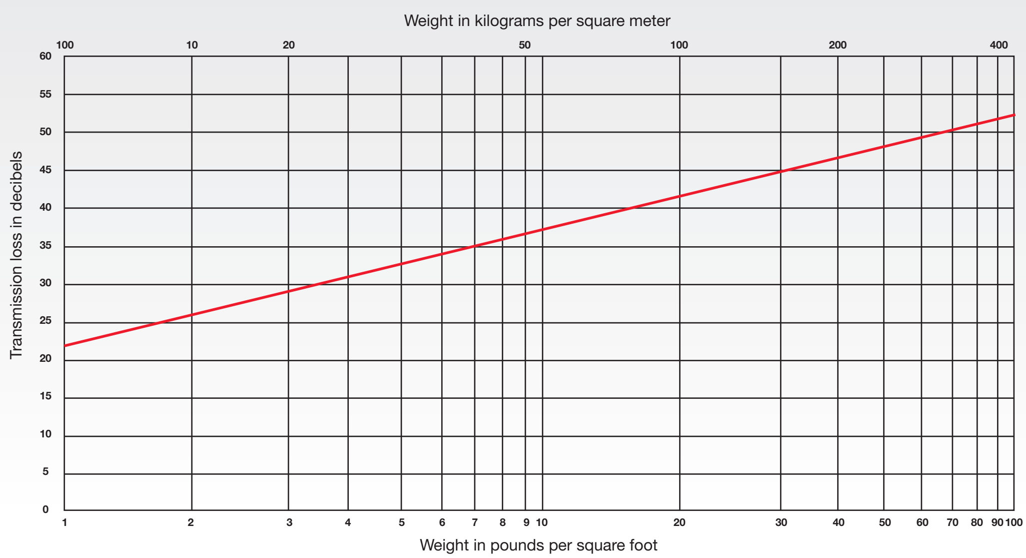
The Mass Law relation between average sound transmission loss and mass per unit area of partition

Mass Law – The noise-isolation potential of a given barrier or enclosure can be approximated initially if the weight per unit area is known. The following equation can be used for this estimate:

$$TL = 23 + 14.5 \log_{10} m$$

Where:

- TL is the sound transmission loss through the barrier in dB.
- m is the "mass" of the partition in psf.



Source: Leo L. Baranak, Noise and Vibration Control, McGraw Hill, 1971.

One existing solution that incorporates several of these design considerations – resilient channels – relies on a flexible metal channel that eliminates a direct rigid pathway for the transmission of noise and vibrations from the adjoining room. This solution, which has been employed since the 1960s, requires extra labor and material costs, but can effectively improve the STC rating of a partition by several – generally 3-5 – dB if installed correctly. More recently, resilient clips employing rubber as well as flexible metal components have been introduced for the same purpose. In any approach, as one seeks to achieve higher performing partitions, the attention to detail becomes increasingly important if design goals are to be realized.

Finally, installation details including proper sealing must be considered in order to avoid the likelihood of leaks or flanking paths. Inspection as construction proceeds is a requirement. Thus it is important to prepare a design with a view to its constructability and inspectability. All things being equal, keeping the construction process as straightforward as possible is to be recommended.

Thus, reliability of performance can be an important issue with many existing solutions. Unfortunately, what tests well in the laboratory may not perform up to the expected STC rating in the field. In fact, a key issue for project owners in noise-complaint litigation has been the gap between lab results and the performance of the solution in the real world. In the case of resilient channels, installation can be complicated and prone to mistakes as compared to other noise-reduction solutions. For example, the key to ensuring that resilient channels perform up to the STC rating is making sure that no "hard" connections exist between the gypsum board and studs, such as screws or nails driven through the gypsum board and contacting a stud. When this happens the flexibility that is key to the success of the system is lost, and the promised benefit of sound transmission loss can be virtually eliminated. It is also important to ensure that the selected resilient channels have been sound tested, as not all channels perform the same even under laboratory conditions.

Additionally, even if the system is installed correctly, the potential exists for the integrity of the solution to be unintentionally compromised post-construction by the dwelling's inhabitants. Something as simple as putting a nail for a picture hanger into the wall can "short-circuit" the channels if the nail creates a direct contact between the gypsum board and a stud.

Other existing solutions rely on adding multiple layers of gypsum board in an attempt to increase mass, building out the depth of the wall cavity so that it can be filled with extra insulation. This increases the low frequency performance of a partition assembly. Using staggered-stud or double-stud wall assemblies to eliminate the hard connection (through the stud) from the gypsum board on one side of the partition to the gypsum board on the other is another approach that also can provide a deeper wall cavity.

These approaches involve extra material and labor costs and result in deeper wall cavities, thus using valuable floor space. A typical wall assembly using resilient channels might be as much as 6-1/2" thick, while a double-stud assembly can be 9" or deeper. It is easy to see that valuable square footage used for noise reduction can add up quickly.

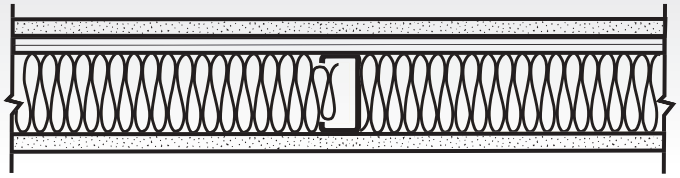
An Emerging Alternative for Reducing Sound Transmission

Project owners have borne the expense of higher labor and material costs in the name of achieving noise reduction, though in some cases the investment has not paid off. In fact, so prevalent have noise-complaint lawsuits become that many developers of multifamily projects have actually begun to build the cost of expected litigation into their financial models. These actions speak volumes about the need to incorporate reliable, cost-effective noise reduction solutions into building designs.

A new approach in noise reduction is represented by a new kind of acoustically enhanced gypsum board introduced by National Gypsum. Gold Bond® BRAND SoundBreak™ Gypsum Board incorporates increased mass by using gypsum board panels with a high-density core. Additionally, a new form of noise reduction for construction materials known as "constrained-layer damping" is achieved through the use of a board configuration with a middle layer containing a viscoelastic polymer. The polymer layer is located in the middle of the board thickness and absorbs and dissipates noise-producing vibrational energy by converting structural vibrational energy into negligible heat. The entire gypsum board panel is produced in the same thickness (most commonly 5/8") as a typical panel of gypsum board.

Because the solution incorporates constrained layer damping in a conventional board thickness, no additional depth in the wall cavity is required as is the case with the use of resilient channels, resilient clips, or additional layers of conventional board. For project owners, architects, specifiers and residents, this conveys the obvious benefit of being able to maximize floor space in each unit. As it can be installed and finished just like traditional gypsum board, requiring no extra labor or materials, it can be a cost-effective solution for reducing sound transmission. Its similarity to traditional gypsum board also greatly reduces the possibility of improper installation and compromised integrity. It is also immune from the effect of in-service actions of unit residents that can compromise resilient channels and clips. However, test information indicates that SoundBreak can provide sound attenuation enhancements on the order of those achieved through the use of resilient channels, resilient clips, or additional layers of gypsum board.

One-hour metal stud wall design
STC 57 (3-5/8" metal studs - 24" o.c. - 3-1/2" FG)



In one common wall assembly (unbalanced 2+1 layers of 5/8" board, with one layer being SoundBreak) featuring a one-hour metal stud design using 3-5/8" metal studs spaced at a maximum 24" and 3-1/2" of insulation, the incorporation of SoundBreak achieves an STC rating of 57. This particular design results in a wall that is only 5-1/2" thick, a relatively thin wall compared to other existing solutions designed for an STC rating of 57. This one-hour fire wall would be acceptable for consideration as a demising wall between high-rise residential condos or hotel rooms, as a corridor room in these same applications, or as a high-STC wall in a commercial office setting, as well as in an educational setting.

Although the building code minimum in many areas specifies an STC rating of 50 at the design stage, most people, as the above-mentioned survey results show, are seeking enhanced noise reduction levels such as the performance of not less than an installed STC-55 rated wall. The SoundBreak wall in the STC-57 design provides an extra 2-dB margin above this already recognized performance level. Designs with higher performing test data are also available.

SoundBreak can also be used as an additional layer in all UL fire-rated assemblies, adding margins to the STC rating without compromising the fire rating. Wall designs using SoundBreak were tested by Riverbank Acoustical Labs and the National Research Center of Canada using full ASTM E 90 testing protocols.

As with any product, it could be asked whether SoundBreak offers any advantages over other noise-reduction solutions in living up to its lab-tested STC ratings. From one perspective, the SoundBreak test data indicates that the introduction of the constrained layer damping provides an amount of additional sound transmission loss that is on the same order of magnitude as provided by resilient attachments or by an additional layer of gypsum board. If simplicity of installation is a key to ensuring the reliability of any solution, SoundBreak may represent a breakthrough in terms of its ability to deliver consistent STC ratings in the field. As a result of its reliance on constrained-layer damping, SoundBreak is not susceptible to any of the potential “short-circuit” events that can happen with resilient channels or resilient clips.

As with all solutions, following the manufacturer’s installation recommendations will be important to ensure that the product performs up to expectations. In the case of SoundBreak, these recommendations are relatively simple, such as staggering board joints from one side of the wall to the other, limiting necessary wall penetrations to one per stud cavity, and using ASTM-conforming practices for acoustic sealants, caulk or putty pads.

In closing, surprises are for birthday parties, not construction projects. Architects, engineers, builders and owners need noise-reduction solutions they can rely on, not ones that will produce surprises and result in noise-complaint litigation going to trial. In point of fact, the goal is that noise should not rise to that level of concern in the first place. The ready availability of reliable products and wall components to the supply chain, combined with ease of installation, high reliability, and cost-effectiveness, make SoundBreak a product that architects and builders should consider when working on projects that require enhanced noise reduction.

Stanley E. Dunn Jr., PhD, PE is an acoustical consultant with more than 30 years of experience in acoustical and vibration control engineering and consulting. His capabilities include a wide range of analysis, measurement and design functions in the area of surface transportation noise control, airport noise control, commercial property development, industrial noise control, and interior architectural acoustical design for office, school, church and theater projects. Clients have included architects, developers, condominium associations, engineering firms, and industrial organizations, as well as the City of West Palm Beach, Fla., the City of Ft. Lauderdale, Fla., and the Florida Department of Transportation. In addition, he has served as an expert witness in numerous cases involving litigation prompted by noise complaints. He is a member of ASME, IEEE, INCE, NCAC and ASA.

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111035 Rev. 1/08