70-AA Silentex® Design Guide

Revision Level	Date	Changes
1	April 2004	
2	March 2006	

1.0 Introduction

Silentex®[1] system technology is a process for separating individual filaments of roving into a material that is an efficient sound absorber. Texturized material produced by this process can be directly injected into a silencer chamber, into a bag or into a mold to produce a preform. The texturized material can also be utilized in filament winding operations. Owens Corning offers two glass materials for the Silentex® system; Advantex®[2] glass that can operate at a maximum continuous glass temperature of ~740 ºC and ZenTron®[3] glass that can operate at a maximum continuous glass temperature of ~820-830 ºC.

In determining suitable use temperatures, the observation that glass temperatures are often 20-50 ºC lower than the maximum measured exhaust gas temperature at the silencer inlet needs to be considered. The temperature differential between the maximum glass and maximum exhaust temperatures is highly dependent upon the design of the exhaust system. Fiberglass roving is made of continuous fibers, literally miles long. Since these fibers are continuous, they are typically more resistant to particulate and short fiber blow out from the silencer than short fiber materials.

As with any exhaust system development program, it is best to consider Silentex® system technology early in the design phase. This allows the advantages of acoustic materials to be fully used while creating designs that can be filled in the most efficient manner that optimizes the cost/performance/weight opportunities.

2.0 Acoustics

Except for the lowest frequency ranges, as shown in Figure 1, the Silentex® system technology does an excellent job of absorbing sound over a broad frequency range. This provides a quality low frequency "performance sound" when desired. Low frequency attenuation can be addressed in a coupled reflective / absorptive system design when desired.

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[1] Silentex® is a registered trademark of Owens Corning
[2] Advantex® is a registered trademark of Owens Corning
[3] ZenTron is a trademark of AGY

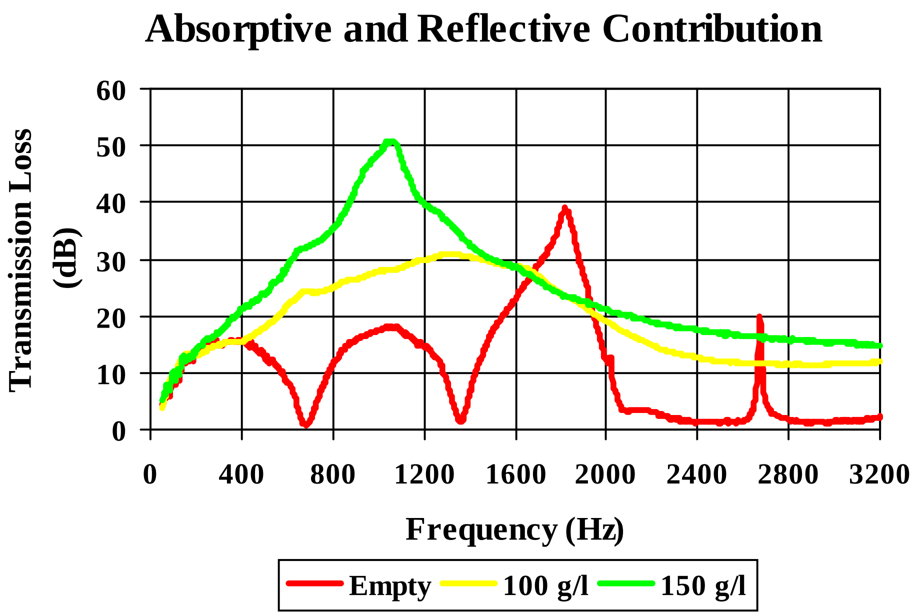

Figure 1: Acoustic transmission loss of a simple expansion chamber approximately 16 cm. in diameter and 25 cm. long containing a 5 cm diameter perforated tube with 8% porosity.

Best performance is normally seen with fill densities in the 100 to 150 gm/liter (kg/m3) range but specific fill density should be determined for each design. Filling densities of less than 100 kg/m3 can result in voids in the filling which can have an impact upon the thermal insulating value of the filling. It could also have a negative impact upon resistance to particulate blowout. However, optimum filling densities outside the 100-150 kg/m3 range are possible depending upon the actual silencer design.

Higher frequencies, often generated by high velocity exhaust gases, are typically well attenuated by absorptive materials. The absorptive materials are most effective in reducing flow-generated noise when the absorptive component is placed at the rear of the exhaust system. Furthermore, in many cases, shell ring is reduced in silencers with acoustic absorption materials such that single layer shell construction can be employed.

The Silentex® filling material process distributes the glass fibers in a random process in a silencer, bag, or preform mold. Thus, there are variations in the glass filling density over volumes of a few cubic centimeters. It has been shown4 that these density variations have no impact upon acoustic performance as long as a void is not located adjacent to the opening in a perforated tube.

3.0 Methods of Exposing Gas Flow to Roving

There are three methods of exposing roving to the gas flow, namely: perforations, louvers, and slots. However, in no case should absorption materials be placed in the system such that gas may flow unrestricted directly through the absorption material.

***3.1 Perforated Tubes* –** Good performance has been obtained with perforated holes of 3-5 mm. diameter. There is some indication that larger holes perform a little better acoustically, especially when the exhaust gases are flowing at a high velocity. Normally, 20-30% open area in the perforated tube will have better overall acoustic performance than a perforated tube with only a few percent open area. (The open area, or porosity, is defined as the sum total area of the openings divided by the total surface area of the tube including openings.)

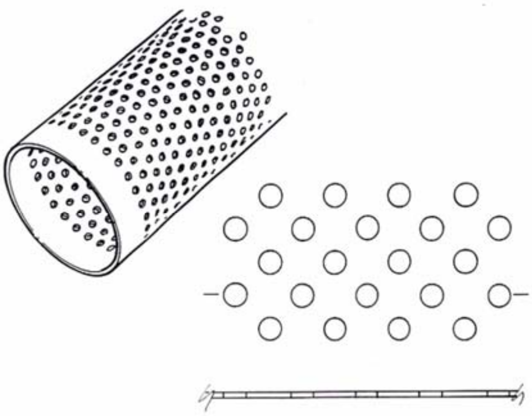

Figure 2: Perforations

[4] N. T. Huff "The Impact of Fiber Filling Density Variation on the Acoustic Performance of Silencers", *SAE Noise and Vibration Conference and Exposition*, May 16-18, SAE Paper 2005-01-2367

Table 1 Typical North American Perforation Patterns

Hole Diameter	Hole Center Spacing	% Open Area	IPA number
3.175 mm.	5.55625 mm.	29	114
3.175 mm.	6.35 mm.	23	115
4.7625 mm	7.9375 mm.	33	119

3.2 Louvers – Louvers can interfere with the ease of the filling operation for direct filling, bag filling, and preform filling. It is possible that louvers tend to reduce the amount of acoustic communication between the exhaust gases and the absorptive material. This could result in lower acoustic performance of the absorptive material.

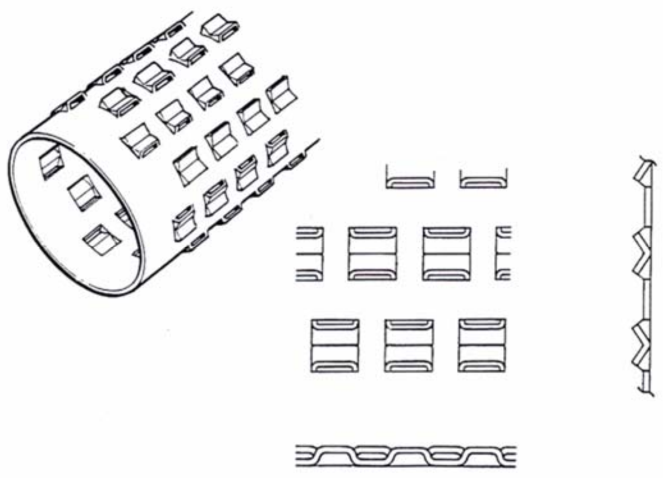

Figure 3: Louvers

***3.3 Slots* –** While slots are able to contain well texturized roving, they must be carefully designed. Depending on the location and orientation of the slots in the silencer design, wider and longer slots can be more susceptible to strand blowout in the silencer**.**

Figure 4: Slots

4.0 Design for Direct Fill

***4.1 Round / Oval Silencers* –** Direct filling of silencer chambers is normally possible regardless of chamber location. However, if an inner chamber is filled, fill holes in baffles / partitions between the chambers are required. Care must be taken in the placement of holes in the baffle with relation to the gas stream such that the gas flow will tend to push the roving inside the fill hole (see Figure 5) rather than pulling against it and dragging it out. In doing this, the design is de-sensitized with respect to strand blowout which may be caused by an improperly trimmed tail of roving left hanging out of the fill hole during filling. To allow for proper filling of inner silencer chambers, the minimum recommended clearance hole for the filling nozzle is 15-mm. diameter.

When direct filling (for either interior or exterior chambers) a minimum spacing of 20-mm. between silencer components (i.e. tube to tube and tube to shell distances) is recommended in order to obtain optimal roving texturization and filling,

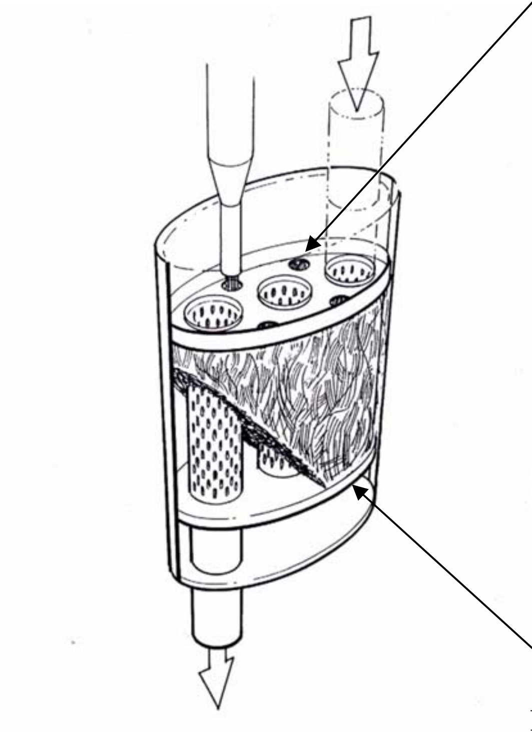

Figure 5: Placement of fill holes for direct fill of round and oval silencers

To obtain the best filling results, a vacuum is usually applied from the end opposite to the end through which filling is taking place. This method helps to pull the glass into the silencer thereby ensuring better texturized and more even filling. If the silencer is unable to be designed allowing for the vacuum to pull the roving evenly into the cavity, then expensive and complex tooling is required; otherwise bags or pre-forms or other filling methods become necessary.

For direct filling, there should be no rough projections inside the silencer which would interfere with the roving completely filling the cavity. Examples of possible protrusions are louvers, spot welds, or burrs on silencer components. Furthermore, heavy oil deposits can also impact the filling process. If end chambers (especially "shallow" end chambers) are to be filled to a relatively high density, sufficient vacuum must be applied and maintained until the end is capped to prevent the roving from "popping out" of the filled chamber. If this cannot be done, preforms or bags may be required.

4.2 Stamped Silencers **–** Direct filling of stamped silencers is not as straight forward as round or oval silencers. Owens Corning can assist in designing special machines and filling methods. If direct fill cannot be economically applied, then bag fill or pre-forms are recommended.

Factors to be considered when filling stamped silencers include production line rate, optimal filling density, fill-tooling design, and individual machine rates. Owens Corning develops direct fill tooling for each application as part of its range of services.

5.0 Bag Filling

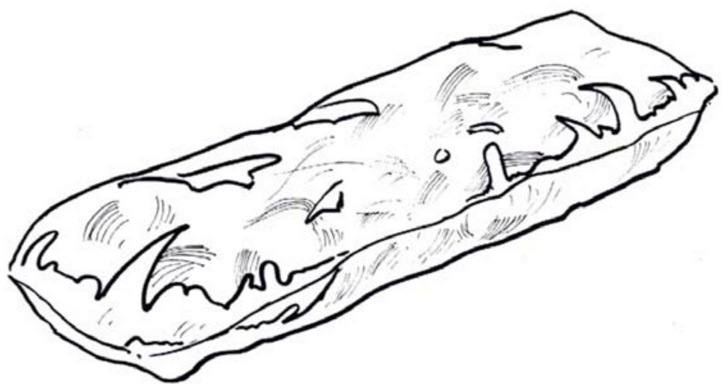

Figure 6: Typical Bag Configuration

Several types of bag material are available for bag filling of silencers. To minimize odors which might be noticeable in enclosed areas the first time hot gases flow through the silencer, a spun bond polypropylene material is recommended. This material will melt near 150 ºC and will completely decompose below 400 ºC. The primary decomposition products for this material are CO_2 and H_2O. It should be noted that maximum acoustic performance of the silencer will not be obtained until the plastic bag around the perf tube has melted or decomposed.

Fiberglass mesh bags are also available but at a higher cost. Mesh bags are made of glass fiber and sewn together with a cotton or polymer thread. Thus, there are minimal decomposition products produced when this bag is first heated. Depending on the type of glass used to make the bags and the silencer operating temperatures, the fiberglass mesh may remain essentially intact over the life of the silencer.

With any of these bag materials, the actual design of the bag for a given chamber can be specified with OC technical assistance. Proper bag design plays a major role in the ease of insertion of the bag into the silencer and upon roving texturization.

6.0 Failure Modes

The two types of failure modes are particulate blow out and strand blow out.

6.1 Particulate Blowout**—**Particulate blow out occurs when the glass filaments are broken into small pieces. These small pieces of glass fiber can then be drawn into the exhaust gas stream and blown out the tail pipe of the exhaust system. Particulate blow out typically occurs when the glass is exposed to temperatures above its time/temperature use limit. If exhaust gas temperatures entering the silencer are in excess of 740 ºC most of the time the engine is in operation, then measurements should be made of the actual temperatures achieved by the glass. Typically, the temperature achieved by the glass is significantly (as much as 20-50 ºC) below the maximum measured exhaust gas temperature.

In a properly designed silencer, the Advantex® glass should not have significant blowout if the continuous operating temperature **of the glass** remains below 740 ºC. However, if there is direct impingement of the gas flow into the fibers, blowout may occur at glass temperatures lower than 740 ºC. For example, in Figure 7, locating the roving between two down-pipes in the front part of the system where high temperatures and high instantaneous pressure pulses are encountered, particulate blow out may result. Under this combination of high temperatures and high gas flows, the fibers may break up below 740 ºC. Of note, when gas flows through the roving, much of the thermal insulating value of the roving to the outer shell is lost. This can be prevented with a design having no significant gas flow through the roving.

These fibers can maintain mechanical integrity for temperatures above their continuous operating temperature limit (740 ºC for Advantex® reinforcements, 830 ºC for ZenTron glass) for varying periods of time. To determine whether blowout might occur for particular time/temperature operating conditions, it is recommended that direct contact be made with OC Automotive for technical assistance.

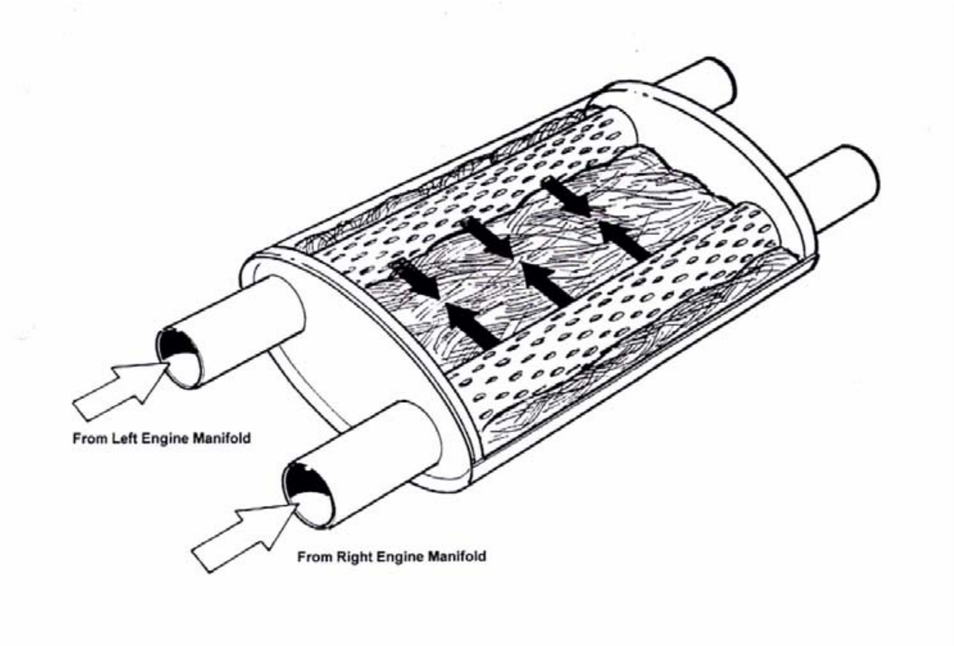

Figure 7: Particulate blowout from gas flow through the roving.

6.2 Strand Blowout**—**This phenomenon occurs when an entire strand is caught in an exhaust stream and pulled out of the silencer. This can occur if the end of a "long" strand is left hanging out of a fill hole, especially if the fill hole is oriented toward the down stream end of the silencer. Alternatively, if the openings in the perforations/slots are large, under some conditions a poorly texturized strand end can be caught in the exhaust stream and pulled into the gas stream. Following this guideline can largely eliminate this blowout mechanism.

In addition, strand blowout may occur when there is not a good seal between the ends of the chamber filled with fiberglass and the silencer shell. For example, in Figure 5, if there is a gap present and if there is sufficient pressure differential between the chambers on each end of the filled chamber, air flowing between the ends of the filled chamber and the silencer shell may be sufficient to pull fiber strands out of the filled chamber and into the exhaust gas stream.

7.0 Thermal Insulating Characteristics

Advantex® glass used between the perforated tube and the silencer shell reduces shell temperatures. The temperature decrease from the perforated tube to the shell is the order of 90 ºC/cm of glass material thickness if there is not significant flow of exhaust gases through the glass and the filling density is of the order of 100 g/l. Thus, the use of Silentex® material can result in the shell temperature being significantly lower than the exhaust gas temperature. *However, if there is significant exhaust gas flow through the Silentex® material or if the filling density of the Silentex® material is significantly less than 100 g/l, then the thermal insulating characteristics of the Silentex® material can be severely compromised.*

7.1 Thermal Management Design Considerations

Exhaust gas temperatures—Since less heat is lost from the walls of a silencer where Silentex® material is present, the result is that more heat will be carried out through the exhaust gas. This will result in somewhat higher exhaust gas temperatures coming out of the tailpipe. Although the increased exhaust gas temperature is not normally an issue, it needs to be considered in the exhaust system design phase.

Maintenance of thermal insulation properties throughout the life of the silencer—In some applications, the thermal insulation properties of Silentex® materials are required to be maintained throughout the life of the silencer. An example would be the elimination of a heat shield to protect underbody components. In such cases, special attention must be given to assure that the required thermal insulation properties of the Silentex® material will be maintained for the lifetime of the silencer. Among the items that must be considered (this is not meant to be an exhaustive list) are 1: the average filling density of the Silentex® material and 2: the variability of the filling density.

With respect to the average filling density, typically, if there is no direct gas flow through the filling material, a filling density of 100 g/l will sufficiently fill a chamber that the glass will not move during normal use. In addition, there will not normally be significant gas flow through the filling material at this filling density. If the average filling density is significantly less than 100 g/l, then after silencer is put into operation on a vehicle, there may be some movement of the material in the chamber which could produce void or near void conditions in the filling material. This might allow exhaust gases a nearly unrestricted path to the shell. This could then result in unacceptable heating of the shell in the area of the void. As long as a void is not adjacent to a perf tube, the impact upon the acoustic performance of the silencer due to the glass shifting during use will be negligible (see footnote 4 above).

With respect to variability in the filling density, again, conditions which would produce a low flow resistance path to the silencer shell must be guarded against. Low flow resistance or voids can be present in silencers filled by direct fill, bags, or with preforms. With proper filling techniques, the probability of there being a significant low flow resistance path from the perf tube to the silencer shell is minimized for direct fill and preforms. However, if improper filling techniques are utilized while direct filling a silencer or in the filling of a preform mold, voids or low filling density regions can be produced. These areas could provide low flow resistance paths to the silencer shell which could result in unacceptable heating of the shell in some areas.

For silencers filled with bags, even if proper techniques are followed in filling the bags, care must be taken in the installation of the bags in the silencer. If the bags are placed in the silencer cavity in such a manner as to leave a void or very low filling density in a region, then again, this could allow exhaust gases to easily access the silencer shell and thus cause a relative hot spot on the silencer shell. The possible movement of bags after their insertion in the silencer must also be taken into account. This is especially true if glass mesh bags are present because these types of bags typically remain partially in tact for extended periods during typical vehicular operations.

In any application where the thermal insulation properties of Silentex® materials are relied upon to keep the shell below a given temperature, sufficient testing on actual silencers needs to be carried out to assure that the required shell surface temperatures are attained. The tests should be carried out not only on freshly filled silencers but also on silencers that have been installed on test vehicles driven under conditions simulating the lifetime of the silencer. If “hot spots” are detected on the silencer after testing and improvements to filling techniques/methods cannot assure the absence of “hot spots”, then other methods of controlling the shell temperatures (e.g. dual wrap shells, providing an insulation material between the dual wraps) must be considered.

8.0 Corrosion Characteristics

The thermal insulating properties of the texturized roving keep the silencer shell cooler than silencers not using absorptive materials. This reduces the heat tint of the shell and thus its susceptibility to corrosion of both the inside and outside of the shell.

In addition, field studies have indicated that shells of Silentex® system filled silencers are protected on the inside from corrosive acids and salts in the areas adjacent to the glass filling. Exhaust gas condensates are largely trapped on the glass, thus reducing the amount of condensate contacting the silencer shell which is the primary cause interior shell corrosion. The behavior of the large diameter Silentex® filled systems is just the opposite of the behavior of systems filled with small diameter materials such as basalt wool. Capillary action in the small diameter densely packed fiber materials encourages the corrosive condensates to contact the silencer shell. Under some operating conditions, this will actually accelerate the corrosion of the silencer shells from the inside out. Thus, the corrosion characteristics of small fiber diameter basalt and needle felt filled silencers will be different than the corrosion characteristics of large fiber diameter texturized roving filled silencers. Advantex® glass and ZenTron® glasses themselves are chemically very resistant to exhaust gas condensates.

9.0 General References:

Physical Properties of Inorganic Fibrous Materials Used for Noise Absorption: Norman T. Huff; Inter-Noise 2002

Acoustic Characteristics of Perforated Dissipative and Hybrid Silencers: Ph. D. Dissertation of Iljae Lee, The Ohio State University, 2005

Corrosion Analysis of Eight Owens-Corning Fiberglass-Filled Stamped Mufflers from Canadian Field Exposure: Richard Strait, AK Steel Corporation, August 23, 1999