Noise Transmission Through an Acoustically Treated and Honeycomb-Stiffened Aircraft Sidewall

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The noise transmission characteristics of test panels and acoustic treatments representative of an aircraft sidewall are experimentally investigated in the NASA Langley Research Center transmission loss apparatus. The test panels were built to represent a segment of sidewall in the propeller plane of a twin-engine, turboprop light aircraft. It is shown that an advanced treatment, which uses honeycomb for structural stiffening of skin panels, has better noise transmission loss characteristics than a conventional treatment. An alternative treatment, using the concept of limp mass and vibration isolation, provides more transmission loss than the advanced treatment for the same total surface mass. Effects on transmission loss of a variety of acoustic treatment materials (acoustic blankets, septa, damping tape, and trim panels) are presented. Damping tape does not provide additional benefit when the other treatment provides a high level of damping. Window units representative of aircraft installations are shown to have low transmission loss relative to a completely treated sidewall.

Nomenclature

a	= length of (sub) panel, m
b	= width of (sub) panel, m
B	= bending stiffness, N-m
c	= speed of sound, m/s
d	= core thickness, m
E	= elasticity modulus, Pa
f	= frequency, Hz
f_c	= critical frequency, Hz
f_r	= resonance frequency, Hz
k	= wave number
m	= surface mass, kg/m^2
R	= flow resistivity, rayl/m
t	= thickness, m
t_1	= skin thickness, m
t_2	= thickness of face plate, m
TL	= transmission loss, dB
α	= propagation factor
η	= loss factor
θ	= angle of sound incidence, deg
ν	= Poisson's ratio
ρ	= gas density, kg/m^3
τ	= transmission coefficient
$\bar{\tau}$	= average transmission coefficient

Introduction

PROPELLER noise transmitted through the fuselage sidewall of a turboprop aircraft is a major contributor to the noise in the passenger cabin. Conventional sidewall acoustic treatment has been evaluated for a pressurized twin-engine turboprop aircraft for which acoustic measurements are available from flight test as well as laboratory simulation.[1,2] Flight measurements have indicated that interior noise levels during standard cruise flight conditions are high enough to benefit from improved sidewall treatment.

An improved acoustic treatment, developed through theoretical analysis,[3-5] has been designed to lower cabin overall sound pressure levels by 7 dB(A) or more compared with the conventional treatment. This advanced design utilizes a combination of honeycomb panels, constrained layer damping tape, absorptive acoustic blankets, and an isolated limp trim panel. The purpose of this paper is to evaluate and analyze the noise transmission loss characteristics of the advanced treatment as compared to a conventional treatment, and to consider some alternative noise control measures. The noise attenuation characteristics of the individual elements of the sidewall treatments are systematically investigated in the NASA Langley transmission loss apparatus. Measurements are made also of the transmission loss contribution of the window units relative to the total sidewall structure.

Noise Transmission Loss Apparatus

The aircraft sidewall panels are tested as a partition between two adjacent reverberant rooms, designated as source and receiving rooms. In the source room, which measures 3.35×3.66×3.94 m (11.0×12.0×12.9 ft), a diffuse field is produced by two reference sound power sources that generate random noise over a wide frequency range. Sound from the source room is transmitted into the receiving room only by way of the test panel. A space and time average of the sound pressure levels in each of the rooms is accomplished by means of a windscreen-covered microphone mounted at the end of a 0.91-m (3-ft) long rotating boom which has a rotational speed of 16^{-1} rev/s. The microphones complete two full rotations during the 32-s linear time-averaging analysis which is performed by a digital one-third octave band frequency analyzer. To obtain the noise reduction characteristics of the test structure in terms of transmission loss the "plate reference method" is employed.[2,6] The accuracy of the measurements is within 1.5 dB in the very low frequency bands (<200 Hz) and within 0.5 dB for the higher one-third octave bands.

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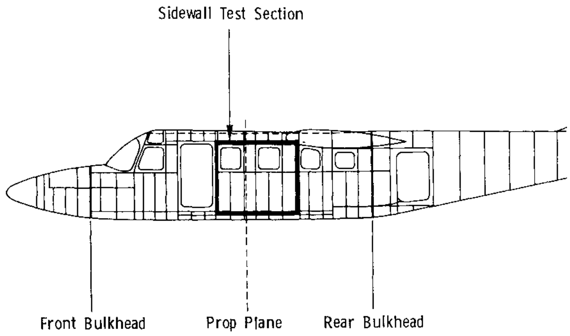

Fig. 1 Location of the sidewall test section on the fuselage of the light twin-engine turboprop.

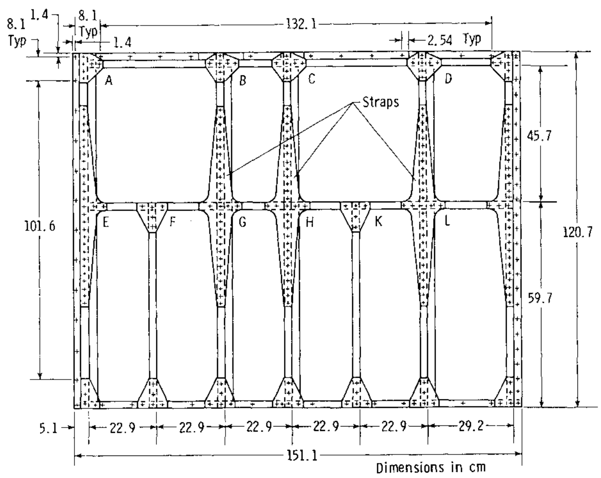

Fig. 2 Engineering drawing of the test structure.

Test Panel Structure

The test panel structure used in the laboratory measurements was designed after a part of the fuselage sidewall of a twin-engine turboprop aircraft. The cabin height of this high wing aircraft is 1.45 m (4.76 ft), while the length is 5.33 m (17.5 ft). The cabin sidewall includes five commercial transport-type double windows. The test panel structure was chosen to be modeled after a fuselage section around the propeller plane, including two windows (Fig. 1). Due to the very slight curvature of the actual fuselage and to allow for ease of construction and analysis, the laboratory model is flat and covers an area of 1.15 m (3.77 ft) (cabin height direction) by 1.46 m (4.79 ft) (length). In the aircraft, doublers were used to reinforce the structural members of the frame around the area of the propeller plane. In the laboratory panel structure this was achieved by the addition of solid straps with a thickness equal to the total thickness of the doublers (Fig. 2). The structural members of the test panel extend onto the supporting frame of the transmission loss apparatus, dividing the test specimen into 10 subpanels, each of them exhibiting its own resonances. The window units consist of two 6.35-mm (0.25-in.) thick plexiglass panes separated by a 12.7-mm (0.5-in.) spacer. The outer pane has a slightly outward curved surface with a maximum out-of-plane deflection of 25.4 mm (1.0 in.). Initially, windows were not installed, to simplify the study of the panel and treatment. In such a case, the window areas, subpanels A and C in Fig. 2, are considered part of a continuous fuselage and their aluminum skins are treated in the same manner as the other parts of the sidewall structure.

Advanced vs Conventional Treatment

The transmission loss characteristics of the conventional treatment package for the designated part of the aircraft fuselage sidewall may be found in Ref. 2. The different layers

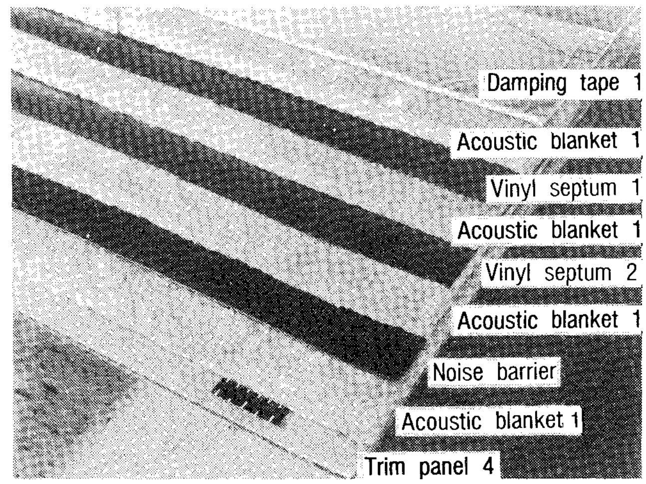

Fig. 3 Components of the conventional treatment package.

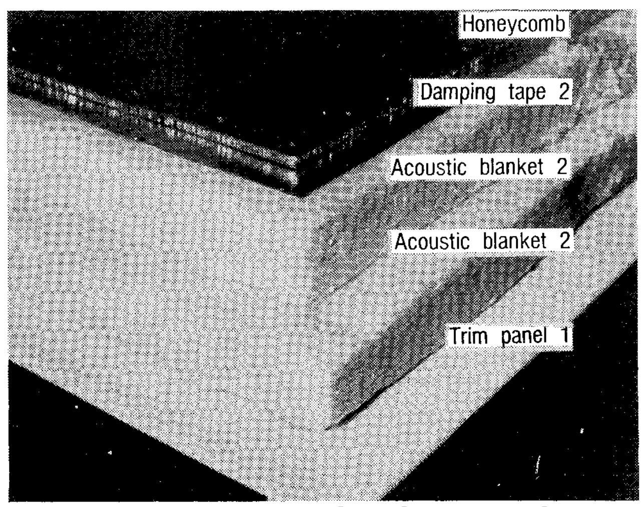

Fig. 4 Components of the advanced treatment package.

of treatment are shown in Fig. 3, where the first six layers are compressed into the space between the stiffeners which provides a total depth of 50.8 mm (2 in.). The analytically designed treatment is intended to give better transmission loss characteristics for less total added weight and is depicted in Fig. 4. The honeycomb, damping tape, and one acoustic blanket are positioned in the space between the stiffeners. The second acoustic blanket and the trim panel cover the entire area of the test structure. The thickness and surface mass of the components are tabulated in Table 1. Figure 5 shows the test panel structure viewed from the receiving room with the window units installed and the treatment in place in the area between the stiffeners. The different treatments and their properties are described later in this section and in more detail in Refs. 2 and 7.

The transmission loss of the sidewall test structure with the conventional and advanced treatments is shown in Fig. 6. Also indicated in this figure are the one-third octave bands in which the blade passage frequency (BPF = 75 Hz) and the first five harmonics occur. Highest excitation levels are experienced for these frequencies with the first harmonic (160 Hz one-third octave band) being most important for A-weighted interior noise levels.[1] Figure 6 shows that the transmission loss (TL) of the advanced treatment is as much as 14 dB higher (315 Hz) than the TL of the conventional treatment, with an average gain of 8 dB at the BPF harmonics. This result, combined with a surface mass reduction of 2.25 kg/m^2 (0.461 psf), makes the advanced treatment superior in terms of transmission loss to surface mass ratio. Two possible disadvantages are noted. At the BPF the transmission loss of the sidewall with the advanced

Table 1 Thickness and surface mass of panel and treatment components

Component	Thickness mm	Thickness (in.)	Surface mass kg/m^2	Surface mass (psf)
Skin	1.61	(0.063)	4.66	(0.954)
Honeycomb	28.2	(1.11)	3.31	(0.678)
Damping tapes				
1	6.35	(0.25)	1.54	(0.315)
2	0.40	(0.016)	1.16	(0.238)
Acoustic blankets				
1	25.4	(1.0)	0.24	(0.049)
2	76.2	(3.0)	1.92	(0.393)
Vinyl septa				
1	1.02	(0.040)	1.79	(0.367)
2	0.61	(0.024)	1.37	(0.281)
3	2.78	(0.109)	4.88	(1.000)
Rubber mass	6.35	(0.25)	8.13	(1.665)
Noise barrier	8.26	(0.325)	4.96	(1.016)
Trim panels				
1	1.42	(0.056)	2.49	(0.510)
2	2.79	(0.11)	4.88	(1.000)
3	6.35	(0.25)	.98	(0.201)
4	3.81	(0.15)	1.28	(0.262)
5	6.35	(0.25)	1.87	(0.383)
Treatments				
Conventional	87.9	(3.46)	11.9	(2.437)
Advanced	129.1	(5.08)	9.6	(1.966)
Alternative	133.4	(5.25)	9.7	(1.987)

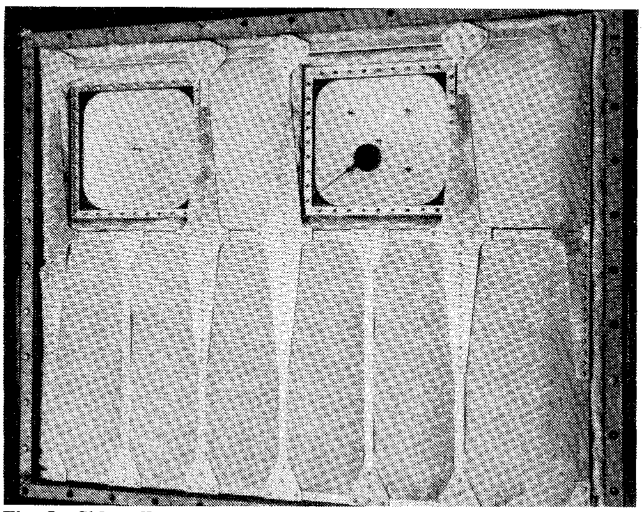

Fig. 5 Sidewall test panel showing partial fiberglass treatment (view from receiving room).

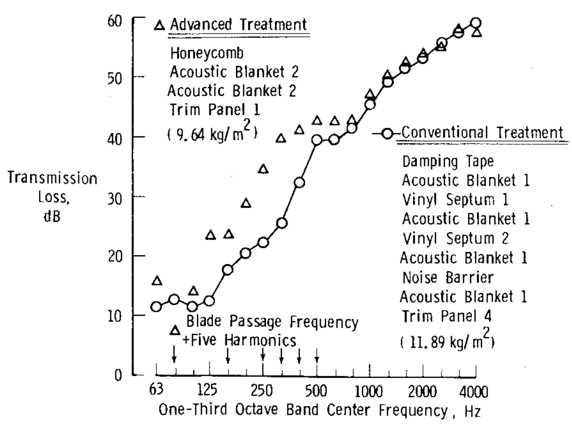

Fig. 6 Transmission loss of the conventional and advance treatment applied to the sidewall test panel.

Table 2 Resonance frequencies of the bare and honeycomb-treated sidewall structure

Subpanel	Bare Test	With honeycomb Theory	With honeycomb Test
A	72	307	330
B	155	1036	
C	71	307	
D	133	635	734
E	140	985	
F	140	767	
G	140	968	
H	141	1002	
K	142	756	
L	125	561	605
Sidewall	92, 185		
Critical frequency	7865	1115	1000

treatment is approximately 5 dB less than the transmission loss of the sidewall with the conventional treatment. Reasons for this will be examined later. Also, the advanced treatment is about 2 in. thicker than the conventional treatment due to the use of thicker acoustic blankets. In the following sections, the effect of each of the elements on the transmission loss of the treated sidewall will be discussed.

Honeycomb Treatment

High stiffness-to-mass ratio materials such as honeycomb are used to raise the fundamental frequency of a panel such that it will no longer coincide with frequencies of highest excitation.[3,5,7-9] Then treatments such as acoustic blankets can be used to control transmission more effectively at the higher panel frequencies.[2] The resonance frequencies of each of the 10 subpanels of the sidewall structure (Fig. 2) were established in Ref. 2 and are presented in Table 2. The resonance frequencies of the entire structure, including the skin, structural members, and supporting frame along with the critical frequency of the aluminum skin are also given in Table 2. Adhering the honeycomb [consisting of a 6.25-mm (0.25-in.) core with a 0.81-mm (0.032-in.) aluminum face plate] to the skin makes the area within the boundaries very stiff relative to the boundaries themselves (only aluminum skin). Therefore, it seems justified to assume simply supported edge conditions. The resonance frequency then is given by

$$f_r = \frac{\pi}{2}\left(\frac{1}{a^2}+\frac{1}{b^2}\right)\sqrt{\frac{B}{m}} \tag{1}$$

The critical frequency, which is the lowest frequency at which the acoustic wavelength matches the free bending wavelength in the panel, is defined by

$$f_c = \frac{c^2}{2\pi}\sqrt{\frac{m}{B}} \tag{2}$$

For a homogeneous panel the bending stiffness is given by

$$B = Et^3/[12(1-\nu^2)] \tag{3}$$

The bending stiffness of the honeycomb panel is, assuming the core has no flexural rigidity,

$$B = \frac{E}{1-\nu^2}\left[\frac{t_1^3}{12}+\frac{t_2^3}{12}+\frac{t_1t_2}{t_1+t_2}\left(\frac{t_1}{2}+\frac{t_2}{2}+d\right)^2\right] \tag{4}$$

These formulas have been shown to provide reasonable agreement with measured frequencies of honeycomb-stiffened panels similar to the panels of the present study.[10] The

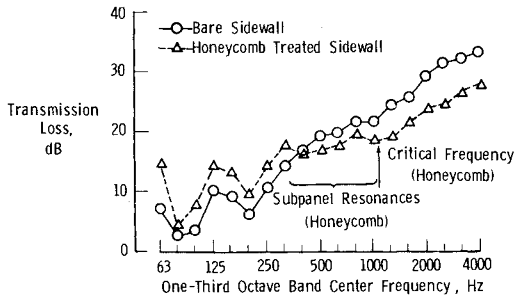

Fig. 7 Transmission loss of the bare sidewall test panel and the honeycomb-treated sidewall.

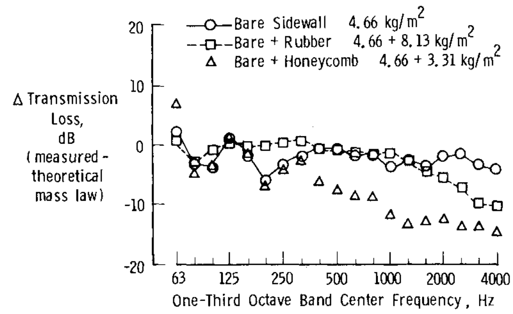

Fig. 8 Difference between measured transmission loss and mass law for the bare, rubber-treated, and honeycomb-treated sidewalls.

resonance frequencies and critical frequency are calculated for the honeycomb subpanels and tabulated in Table 2. To verify reasonable agreement with experimental values, transfer functions between acoustic input (microphone) and vibrational output (accelerometer) were obtained for three subpanels. Resulting experimental resonance frequencies are also tabulated in Table 2.

The transmission loss of the bare panel and the panel with the honeycomb applied are compared in Fig. 7. In the low-frequency region ($\leq$315 Hz), where the BPF and the strongest harmonics occur, an average increase in transmission loss of 4 dB is observed due to the honeycomb application. This increase in TL may not necessarily be due to an increase in the stiffness of the panels, but partly may be due to the mass of the honeycomb. To investigate the mass effect, the TL of each panel is compared to its mass law TL and the difference is plotted in Fig. 8. Mass law TL was calculated using the skin mass for the bare panel, and the mass of skin and honeycomb for the honeycomb-stiffened panel. Figure 8 shows that in the frequency region at and below the 315 Hz one-third octave band, the two sidewall configurations have the same deviation from mass law except for the 63 Hz one-third octave band, which shows a 5 dB larger TL for the honeycomb-stiffened panel. This suggests that the same increase in TL might be achieved by applying a limp mass to the skin of the sidewall. The ΔTL for the test panel with rubber panels attached to the skin is also plotted in Fig. 8. The test data are taken from Ref. 2. The ΔTL for the rubber-treated panel follows mass law much more closely at frequencies below 315 Hz than the ΔTL for the other two panels. This may be explained by the damping properties of the rubber which raises the ΔTL at the second structural resonance of the sidewall plus supporting frame (200 Hz) up to its mass law level. The first structural resonance (80 Hz) is lowered in frequency (opposite to the honeycomb application) and some damping is provided by the rubber. At the 63 Hz one-third octave band the rubber-treated sidewall provides the least TL of the three configurations but this frequency is below the BPF of the propeller. These results indicate that at least the same or more TL can be obtained with limp mass applications as with a honeycomb-treated sidewall in a laboratory environment using a diffuse source sound

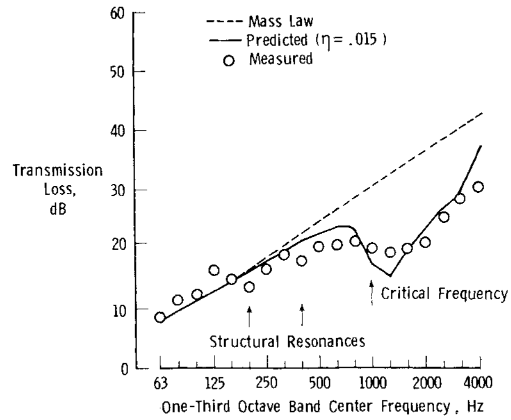

Fig. 9 Measured transmission loss of honeycomb-treated aluminum panel compared with theoretical prediction and mass law.

field. The mass-like behavior of the honeycomb at low frequencies ($\leq$350 Hz) may be explained by the hypothesis that it is applied to the sidewall skin, thus adding stiffness to the subpanels but not to the total sidewall panel. As no stiffness is added, the first structural resonance (80 Hz) will be only negligibly reduced by the effect of mass. In the 63 Hz one-third octave band, which is below the fundamental resonance frequency in the stiffness-controlled region, the honeycomb does add stiffness to the sidewall panel and thus raises its TL.

Previous tests of honeycomb stiffening used a horn noise source and an aircraft fuselage,[10] and showed that the honeycomb stiffening provided more noise attenuation than an equal weight of limp mass at low frequencies (<200 Hz). The effect of honeycomb may be associated with the nature of the source field, the dynamics of the sidewall structure, the method of gluing the honeycomb, or the attachment of the honeycomb to the skin only and not to the stiffening frames. Determination of the governing effects appears to be important, if the full potential benefits of honeycomb are to be realized.

Referring again to Fig. 7, it is shown that between the 315 and 1000 Hz one-third octave bands the TL of the honeycomb-treated sidewall is less than the TL of the bare sidewall structure. As shown in Table 2, the resonances of the subpanels of the honeycomb-stiffened sidewall fall in this frequency range. The critical frequency of the honeycomb-stiffened panel occurs in the 1000 Hz one-third octave band and coincidence resonances take place at this and higher frequencies as a function of the angle of sound incidence.

To investigate the effect of the honeycomb in the frequency region above 315 Hz, a 1.15$\times$1.46 m (3.77$\times$4.79 ft) unstiffened aluminum panel with the same thickness as the sidewall skin was treated with the same type honeycomb and tested in the TL apparatus. The measured results are compared with predictions in Fig. 9. The first two structural resonances now appear to occur in the 200 and 400 Hz one-third octave bands. This would imply that the honeycomb has stiffened the bare aluminum panel more effectively than the combination of frames and honeycomb-treated subpanels of the sidewall panel for which the first two structural resonances were found at 80 and 200 Hz (see Table 2 and Fig. 7).

The transmission coefficient of an infinite panel, taking into account coincidence effects, is given by[11]

$$\tau(\theta)=\left[\left\{1+\eta\left(\frac{\omega m}{2\rho c}\cos\theta\right)\left(\frac{\omega^2 B}{c^4 m}\sin^4\theta\right)\right\}^2 + \left\{\left(\frac{\omega m}{2\rho c}\cos\theta\right)\left(1-\frac{\omega^2 B}{c^4 m}\sin^4\theta\right)\right\}^2\right]^{-1} \tag{5}$$

Integrating over all angles of sound incidence up to a limiting

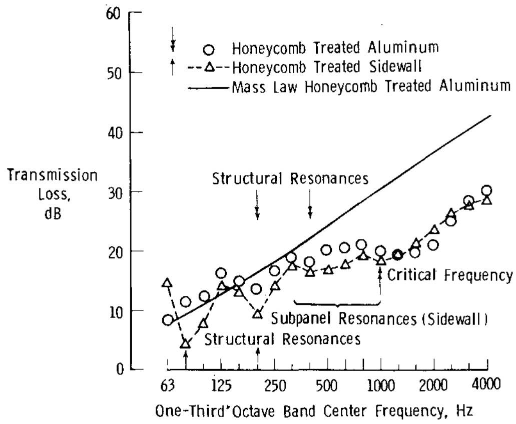

Fig.10 Transmission loss of honeycomb-treated aluminum and honeycomb-treated sidewall panel.

angle $\theta_{\lim}$ yields the average transmission coefficient

$$\bar{\tau} = \int_0^{\theta_{\lim}} \tau(\theta)\cos\theta\sin\theta d\theta \Big/ \int_0^{\theta_{\lim}} \cos\theta\sin\theta d\theta \tag{6}$$

The average transmission coefficient is related to the transmission loss by

$$\mathrm{TL} = 10\log(1/\bar{\tau}) \tag{7}$$

Using the surface mass and bending stiffness equation (4) of the aluminum/honeycomb combination and an estimated loss factor of $\eta = 0.015$, the TL is predicted for the 1.15×1.46 m (3.77×4.79 ft) panel and plotted in Fig. 9 along with its mass law. Reasonable agreement between measurement and prediction is obtained.

The TL of the unstiffened honeycomb-treated aluminum panel is compared with the honeycomb-treated aircraft sidewall panel in Fig. 10, where the important resonances are indicated. The shift in structural resonances (structure plus supporting frame) can easily be seen to result in different TL values at those frequencies. Between 315 and 1000 Hz the TL of the honeycomb-treated aircraft sidewall is lower due to the resonances of the subpanels. Above the critical frequency of 1000 Hz both TL curves are very close and thus can be compared favorably with the predictions of the basic theory.

Acoustic Blankets

Porous acoustic blankets are used to absorb acoustic energy. The sound waves passing through the blanket cause motion of the fibers and the air around the fibers. Acoustic energy is thus converted into heat. At low frequencies, for wavelengths greater than ten times the thickness of the blanket, the acoustic blanket will move as a whole following the movement of the panel to which it is attached, and the sound absorption mechanism described above cannot take place.[12] For calculating TL at these low frequencies it is therefore assumed that the sound attenuation by the acoustic blanket is zero. Reference 13 presents an empirical power law approximation for the propagation constant α which gives the sound attenuation in a semirigid material per unit thickness

$$\alpha = 1.64\, k\, (\rho f/R)^{-0.595} \tag{8}$$

The flow resistivity $R = 4.1 \times 10^4$ rayls/m for acoustic blanket 1 with a bulk density of 9.5 kg/m^3 (0.59 lb/ft^3). To include the viscous and inertial effects of the gas contained in a soft porous material an effective gas density has been used in the calculation.[13] The approximation in Eq. (8) is valid for values of $\alpha t > 9$ dB, where t is the total thickness of the blanket.[12] A prediction has been made for 76.2 mm (3 in.) of acoustic blanket 1 and is shown in Fig. 11 as a solid line. A smooth curve is faired between the zero attenuation at 315 Hz and the 10-dB transmission loss at 630 Hz. The TL shown by the data for frequencies below 315 Hz is thought to be due to damping of the second structural resonance by the acoustic blankets, which are pressed tightly against the skin of the panel. The acoustic blankets have been compressed into the 50.8-mm (2-in.) depth between the stiffeners. Reference 14 indicates the availability of acoustic blankets 2 with better sound-absorbing properties at the lower frequencies. Two thicknesses of this material are compared with acoustic blankets 1 in Fig. 11. From this figure it can be seen that at the BPF and harmonics acoustic blankets 2 perform better in terms of TL than acoustic blankets 1. As they are also more rigid, they are thought to provide more damping to the subpanels and the structure. In conclusion, it can be said that in addition to thermal insulation, the acoustic blankets provide sound absorption, sound transmission loss, and structural damping showing that they are a very important component for interior noise control.

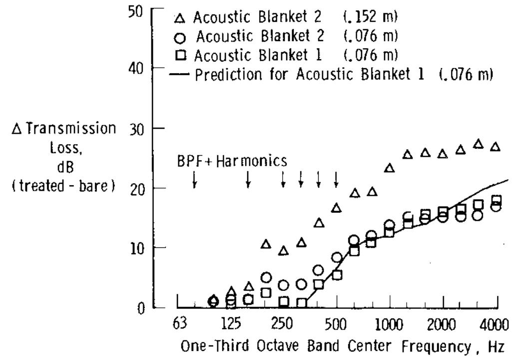

Fig. 11 Measured and predicted transmission loss of acoustic blanket 1 and transmission loss for two thicknesses of acoustic blanket 2.

Damping Tape, Septa, and Trim Panel

The purpose of the damping tape is to suppress the damping-controlled resonant structural vibrations of the sidewall structure and, thus, prevent reradiation of noise on the receiver side. Damping tape 1 is a pressure-sensitive, compounded polyurethane foam with an aluminum foil laminate backing. It has been shown[2] that damping tape 1, when applied directly to the subpanels of the structure, will effectively damp vibrational resonances except for the first structural resonance of the entire structure. The transmission loss curve of the sidewall structure then follows the mass law of the total surface mass of the skin and damping tape. Damping tape 2 is a constrained damping material consisting of an aluminum sheet with a pressure-sensitive backing. Measurements indicated that applying damping tape 2 on a sidewall with other acoustic treatments does not have a beneficial effect when damping is already provided by the other treatment components.

The vinyl septa are made of a mass-loaded vinyl fabric reinforced with fiberglass, while the noise barrier is a composite of a loaded urethane elastomer bonded to a decoupler foam. Their purpose is to provide additional transmission loss, using the double-wall effect, in a limp resonance-free panel and provide structural damping when applied to the sidewall. The beneficial effects of these noise control materials are discussed in Ref. 2.

Adding a trim panel to the basic treatment package serves the purpose of interior decoration, protection for treatment and aircraft skin, thermal insulation, and acoustic attenuation. Trim panels 1 and 2 are of the same material as the vinyl septa, while trim panels 3 and 4 are high strength-to-weight

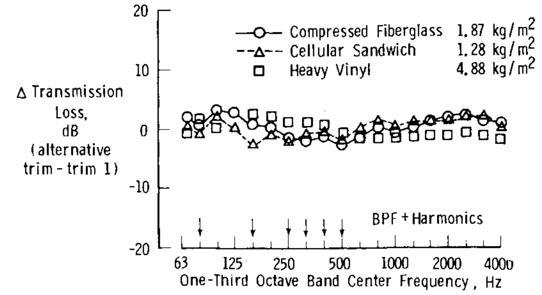

Fig. 12 Difference between transmission loss of three alternative trim panels and light vinyl trim panel 1.

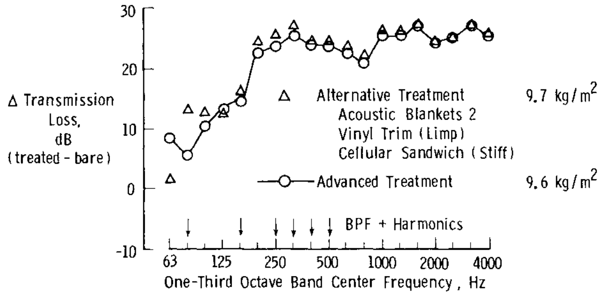

Fig. 13 Difference between transmission loss of alternative treatment and advanced treatment packages.

sandwich constructions with laminated fiberglass facings and a core of blended plastic resins. Trim panel 5 is a compressed fiberglass with a perforated, thin vinyl cover. The effect of adding a stiff trim panel to the conventional treatment was found to be of little benefit in terms of TL[2]. The advanced treatment was designed to have optimum acoustic attenuation characteristics with a light vinyl trim panel installed. Figure 12 shows the effect of alternative trim panels on the TL of the treated sidewall when compared with the light vinyl trim panel. The thickness and mass per unit area of the different trim panels are given in Table 1. At the BPF and first five harmonics only the heavy vinyl trim panel 2 shows an improvement in acoustic attenuation. However, the increase in TL/mass ratio is small at these frequencies and even shows a decrease for frequencies higher than 500 Hz.

Alternative Treatment

Analyzing the effects of the individual elements of the treatment packages, it appeared that the honeycomb could be replaced by a limp mass and still provide at least the same TL. At the same time, the limp mass would give better damping to the sidewall structure, helping to get a higher TL at the first structural resonance. From a practical point of view, this would simplify the installation of the treatment tremendously, especially when the aircraft skin is curved slightly. It was also found that the damping tape is not very functional, because the other treatment will provide similar damping characteristics. It has been shown that the alternative acoustic blanket 2 gives higher TL values in the low-frequency region and, because it is more rigid, provides better damping properties for the structure. Lightweight trim panels do not seem to have a great effect on the total TL of the sidewall structure. For practical reasons, a trim panel that can be molded to the contours required in the cabin would be most desirable. In Ref. 2 it was concluded that highest TL is achieved when a limp mass either is attached directly to the skin or as far away from the skin as possible in a double-wall configuration. Taking all of these considerations into account, an alternative treatment was designed with approximately the same surface mass as the advanced treatment. Measured TL is compared with the TL results of the advanced treatment in Fig. 13. This figure shows that the alternative treatment, consisting of two

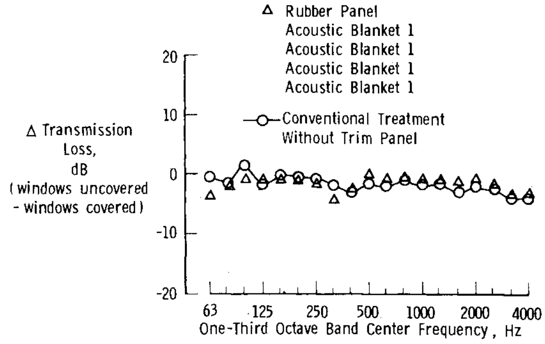

Fig. 14 Difference between transmission loss with and without the windows covered for two acoustic treatments on the sidewall panel.

acoustic blankets and two trim panels, gives an improvement in TL of 1.5-8 dB over the advanced treatment at the BPF and its first five harmonics. Application of mass rather than stiffness (similar to the honeycomb) shifts the first structural resonance down to the 63 Hz one-third octave band which is below the BPF. The two acoustic blankets 2 provide damping, absorption, transmission loss, and isolation of the trim panels. The first trim panel 2 is limp to provide mass and the second trim panel 3 has some rigidity so it can be molded to the shape requirements in the cabin.

Windows

To determine the effects of windows on the TL of the treated sidewall, two double-pane window units were installed in areas A and C (Fig. 2). These window units, which were modeled after the ones used in current flight configurations, were tested for two high transmission loss sidewall treatments (Fig. 14). The TL was measured for the sidewall with the windows left uncovered and when they were covered with two layers of heavy noise-barrier material (with higher TL than sidewall treatment). Differences for covered and uncovered windows are less than 4 dB, but as their area comprises only about 13% of the total sound exposed area, improvements in window design might be desirable. Window TL can be improved in a number of ways, including the use of thicker and/or curved panes, different distances between panes, smaller windows, vibration isolation, Helmholtz resonators, and depressurization of the air between the panes.[2,4,15-18]

Conclusions

The noise transmission characteristics of an aircraft test panel having a conventional, an advanced, and an alternative sidewall treatment were experimentally investigated. For the aircraft in consideration the highest excitation levels are generated at the propeller blade passage frequency (75 Hz) and its first five harmonics defining a critical frequency range from the 80 Hz band up to and including the 500 Hz one-third octave band. The results of the noise transmission loss tests showed that:

1) Honeycomb stiffening of the skin panels raised the subpanel resonance frequencies, but the increase of TL associated with honeycomb installation was close to the increase predicted by mass law for installation of an equivalent amount of mass.

2) Damping tape provided little beneficial effects when combined with other treatments that provide damping.

3) Highest transmission loss was achieved by attaching a limp mass directly to the skin or locating it as far away from the panel as possible in a double-wall configuration.

4) An alternative treatment, consisting of acoustic blankets, soft trim panel, and stiff trim panel performed better than the other treatments in terms of noise transmission loss.

5) In simulated flight configuration, double-pane window units exhibited less transmission loss than the treated sidewall.

The behavior of the honeycomb observed in these tests is thought to be associated with the application of the honeycomb directly to the skin without extending it to the framework. Improved low-frequency transmission loss might be obtained by rigidly coupling the structural frames of the sidewall to the honeycomb on the skin. The alternative treatment may be more practical than the advanced treatment since no honeycomb panels have to be adhered permanently to the skin, which is especially difficult when the skin is curved. The acoustic blankets and soft trim panel provide vibration isolation and the stiff trim panel can be molded to the specifications of the aircraft cabin.

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