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ACOUSTIC TRANMISSION LOSS AND STRUCTUREBORNE NOISE TRANSMISSION TESTS ON A LASCOR AND A REFERENCE STEEL PANEL

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C. NORWOOD

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Acoustic Transmission Loss and Structureborne Noise Transmission Tests on a LASCOR and a Reference Steel Panel

C. Norwood

MRL Technical Note
MRL-TN-623

Abstract

LASCOR is a laser welded corrugated steel sandwich developed as a lightweight construct for ship superstructures. Tests were performed to measure acoustic transmission loss and structureborne noise transmission for both a LASCOR panel and a reference conventional rib-stiffened steel panel. This report outlines the test methods used and compares the results for the two panels.

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Acoustic Transmission Loss and Structureborne Noise Transmission Tests on a LASCOR and a Reference Steel Panel

1. Introduction

In recent years there have been several examples of crippling fires on warships where aluminium superstructures have been perceived to exacerbate rather than limit the severity of damage. These include the loss of HMS Galahad in the Falklands and the USS Stark in the Persian Gulf. The very high thermal conductivity and low melting point and softening temperatures of aluminium alloys are now regarded as unacceptable trade-offs for the advantages of low density and high stiffness per unit weight which provide a strong lightweight superstructure, even though the blame for the very extensive damage lies far more with the large amount of combustible material packaged in the superstructure.

Following these incidents a collaborative program was established to develop alternative ship superstructure materials. Information Exchange Program (IEP) ABC-36 Ship Structures, is a collaborative research program between USA, UK, Canada and Australia, which is working on the development of lightweight, laser welded ship structural panels. Other materials being investigated are glass reinforced plastics (GRP) and GRP-foam sandwich constructions.

LASCOR is a laser welded corrugated steel sandwich construct, designed to combine the features of low density of aluminium alloy with the perceived advantages of traditional steel superstructures, and is being evaluated as part of ABC-36. Australia's contribution to the program is to undertake the noise attenuation testing of the candidate constructs. MRL was asked to devise and carry out a series of tests to measure the acoustic transmission loss and structureborne noise transmission characteristics of a representative LASCOR panel and compare these with those of a reference, conventional rib-stiffened steel panel of the same overall dimensions.

Two tests were undertaken, these were:

(i) acoustic transmission loss
(ii) structure borne noise transmission.

2. Panel Details and Construction

Both panels tested measured 2.44 m x 1.22 m. The detailed geometries of the panels are given in Figures 1 and 2.

The LASCOR panel is a US manufactured corrugated steel/steel sheet sandwich construction. The face sheets are 2 mm thick steel and the corrugated centre is 1 mm thick. The face sheets are 75 mm apart and the pitch of the corrugations is 80 mm. The panel is constructed by laser welding the two face sheets to the core.

The conventional steel panel is 5 mm thick and has tee-section stiffening ribs at approximately 685 mm centres. The ribs are welded using conventional techniques.

3. Test Descriptions

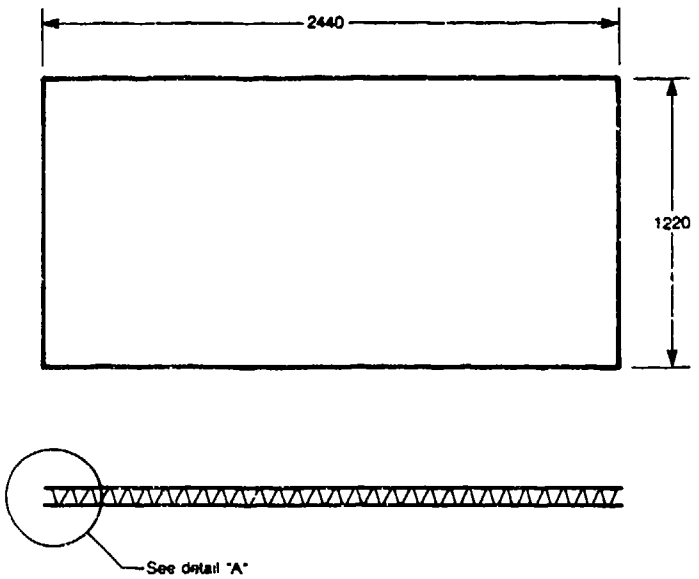
3.1 General

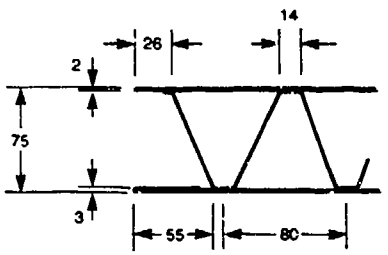
MRL was asked to develop tests to determine the acoustic transmission loss and structureborne noise performance of the LASCOR panel.

The term acoustic transmission loss is used to describe the reduction in sound that is transmitted through a panel or partition. It is therefore used as a measure of how effective a panel or partition will be in preventing the transmission of noise between adjoining rooms. The higher the acoustic transmission loss the more effective the prevention of noise transmission. This is important in preventing noise transmissions between accommodation spaces and adjacent machinery spaces in ships. The most commonly accepted method of determining transmission loss is in a two-room transmission suite, where the test panel is used to separate the two rooms and the difference in sound levels in the two rooms is measured [1].

Structureborne noise is the term given to the transmission of vibrational energy through structures. The input of vibrational power, and the transfer of power through the structure are dependent on the structural mobilities, both driving point and transfer, of the structure. For a given input force the power transferred into the structure is a function of the driving point mobility, while the transfer mobility gives an indication of levels produced at stations remote from the source [2]. Hence for comparative purposes the measurement of driving point and transfer mobilities for the panels provides an indication of the relative structureborne noise transmission.

The details of the two tests are described below.





Detail "A"

Figure 1: LASCOR panel.

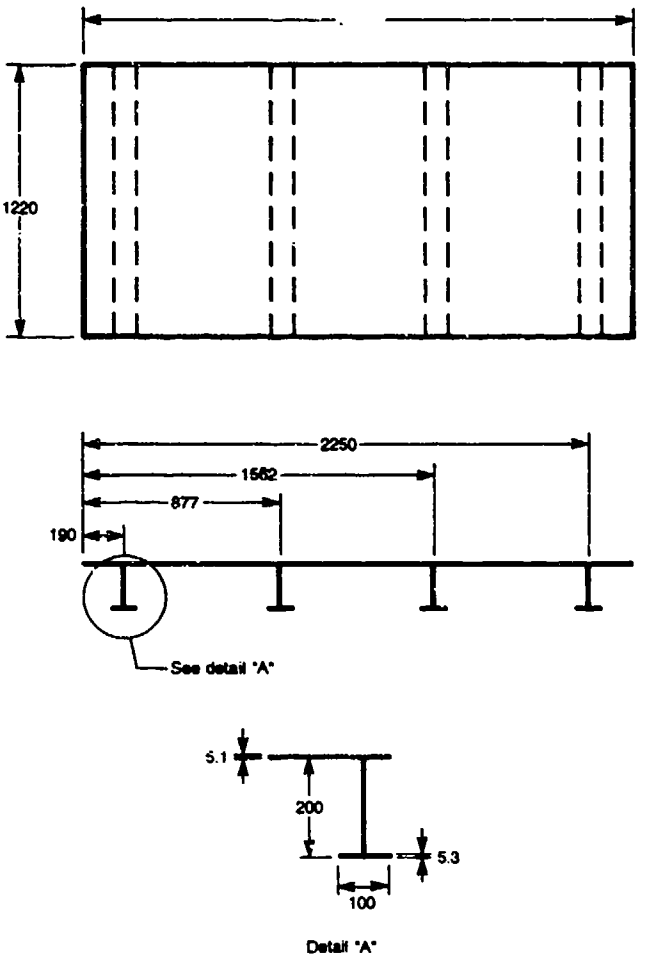


Figure 2: Reference panel

3.2 *Acoustic Transmission Loss*

The acoustic transmission loss test was carried out at the Department of Applied Physics, Royal Melbourne Institute of Technology in a two-room transmission suite, consisting of a pair of reverberant rooms with an aperture between. The rooms are constructed of 305 mm reinforced concrete, supported on laminated-rubber isolators and acoustically decoupled from one another by a layer of 50 mm thick cork. The source room has a volume of 115.49 m^3 and the receiving room a volume of 120.14 m^3. The rooms comply with the requirements of AS 1191-1985 [1].

The opening between the two rooms is 10.69 m^2 compared with the panel area of 2.98 m^2. A filler wall consisting of a double layer of clay bricks with 10 mm mortar between was used to reduce the aperture size. The samples were placed in the aperture and sealed around the edge with silicone sealant on both sides. The effect of the filler wall is taken into account in the determination of the panel acoustic transmission loss. After the panels had been tested the aperture in the filler wall was bricked in and the acoustic transmission loss of the filler wall was measured. The results for the panels were then corrected using these data in accordance with AS 1191.

The transmission loss was determined in accordance with AS 1191 over 18 contiguous third octave bands, centre frequencies from 100 Hz to 5000 Hz.

The acoustic transmission loss (R) is given by the expression

$$R = 10 \log_{10} (P_1 / P_2)$$

where P_1 = the sound power incident on the panel
P_2 = the sound power transmitted through and radiated by the panel.

The sound fields within both the source room and the receiving room were diffuse. As the sound power cannot be measured directly in this experimental set up, an indirect method of determination was adopted, as follows. The acoustic transmission loss can be defined in terms of measurable quantities [1] and is expressed as

$$R = D + 10 \log_{10} (S/A)$$

where D = average sound pressure level difference in dB
S = area of partition under test in m^2, in this case 2.98 m^2
A = equivalent absorption area in the receiving room in m^2

The average sound pressure level difference (D) is given by

$$D = Lp_s - Lp_r$$

where Lp_s = average sound pressure level in the source room in dB
Lp_r = average sound pressure level in the receiving room in dB

3.3 *Structureborne Noise Transmission*

As a comparative measure of the structureborne noise transmission performance of each panel the driving point and transfer mobilities were measured at a number of locations on the panels.

Mobility is a complex quantity which is a function of frequency and is defined as

$$M_{ij} = \frac{V_j}{F_i}$$

where F_i = the applied force at point i
V_j = the response velocity at point j
for $i = j$ it is the driving point
$i \neq j$ it is the transfer mobility

Each panel was suspended by light cable, which provided an easily repeatable support condition, and was excited using an impact hammer. The input force was measured using a force transducer and accelerometers were used to measure the panel response at various locations. The data were collected and processed using an HP 3566A 8 channel analyser.

Each panel was excited at four different locations, in turn, and the response measured at the driving point and six other locations. The LASCOR panel was excited near the centre, both over a corrugation rib and between ribs; and off centre again both over a rib and between ribs. The reference panel was excited in the centre of the panel, on one of the stiffeners, off centre between two stiffeners and on the back of one of the stiffeners. Locations for excitation points and response points for each panel are shown in Figures 3 and 4.

4. *Results*

4.1 *Acoustic Transmission Loss*

The measured airborne acoustic transmission loss, R expressed in dB, at each one-third octave bandwidth centre frequency for both panels is given in Table 1, and is plotted in Figure 5.

The acoustic transmission loss for the reference panel is in general greater than that for the LASCOR panel. The LASCOR panel only has a value of R higher than the reference panel in the 2500 Hz to 4000 Hz range. In this frequency range there is a pronounced peak in the LASCOR panel R, while the reference panel shows a dip, which is associated coincidence affects. At other frequencies the R of the reference panel is up to 10 dB higher.

Wave coincidence occurs when the trace wavelength of an incident plane sound wave is such that $\lambda/\sin\theta$ is equal to λ_b, the wavelength of a free bending wave in the panel, Figure 6. When this occurs the intensity of the transmitted wave approaches the intensity of the incident wave.

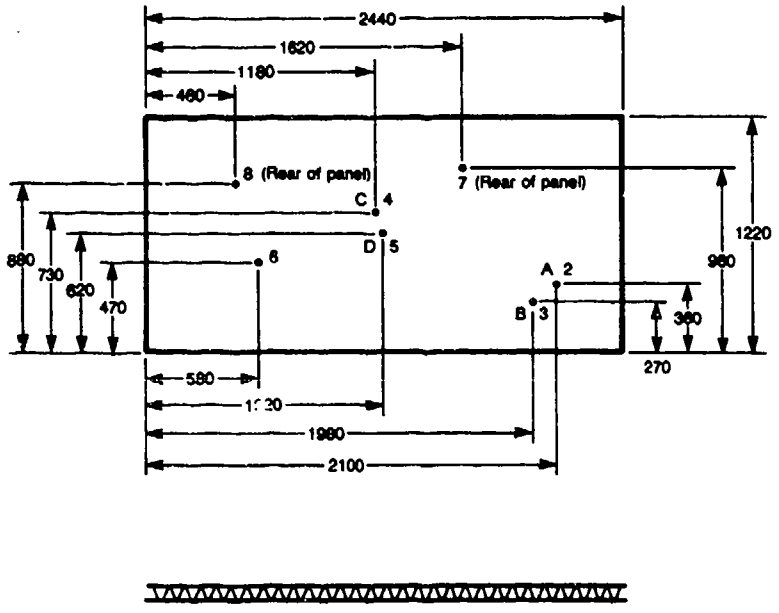


Figure 3: LASCOR panel showing excitation and response points for structureborne noise test.

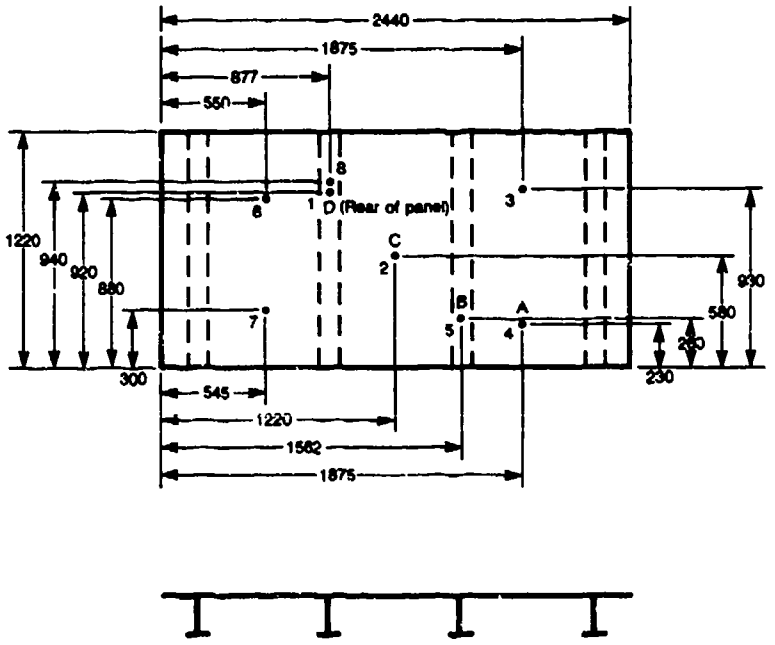


Figure 4: Reference panel showing excitation and response points for structureborne noise tests.

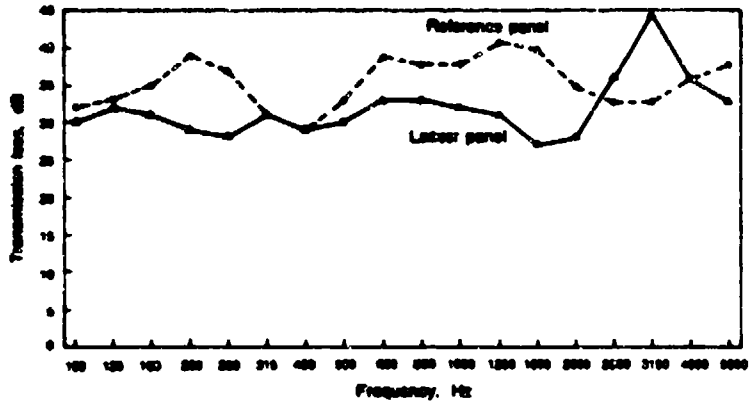


Figure 5: Sound transmission loss.

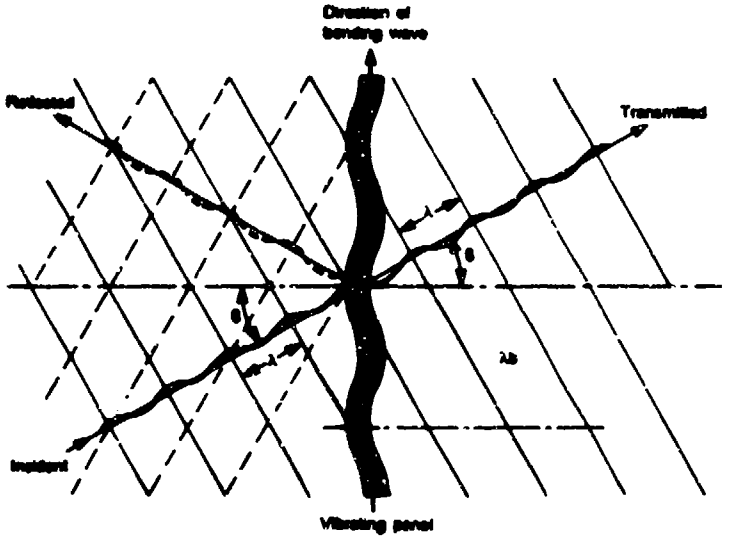


Figure 6:

Table 1: Acoustic transmission loss, R dB

One-Third Octave Band Centre Frequency (Hz)	Reference Panel Transmission Loss (dB)	LASCOR Panel Transmission Loss (dB)
100	32	30
125	33	32
160	35	31
200	39	29
250	37	28
315	31	31
400	29	29
500	33	30
630	39	33
800	38	32
1000	38	32
1250	41	31
1600	40	27
2000	35	28
2500	33	36
3150	32	45
4000	36	36
5000	38	33
Equivalent STC	36	31

The equivalent Sound Transmission Class (STC) [3], of the LASCOR panel is 31 while the STC of the reference panel is 36. This difference is of a similar order to that between single and double glazed windows. The STC provides a single number rating that can be used for comparing partitions for general building design purposes. It is useful when designing walls that provide insulation against sound sources such as speech, music, radio. It is not valid for noise sources with spectra that differ markedly from these such as industrial machinery and power transformers.

For a stiffened panel, with the stiffeners in one direction only, the general form of the acoustic transmission loss curve is shown in Figure 7a [4]. A straight line estimation method, or plateau estimate, for that part of the curve in the frequency range above the first panel resonance including the mass law, coincidence and damping controlled regions is shown in Figure 7b [5].

The first panel resonance of the reference panel was calculated using finite element analysis to be 41 Hz, so the straight line approximation is valid for the frequency range covered in the acoustic transmission test. The upper frequency of the coincidence range, B, was calculated to be 2400 Hz [5], giving the lower frequency of the range, A, as 220 Hz. The plateau estimation for the reference panel using these values is compared to the measured R values in Figure 8. The curves show that the reference panel acoustic transmission loss closely follows the behaviour outlined in [4], and can be closely approximated by the plateau method, indicating a high degree of confidence in the test results.

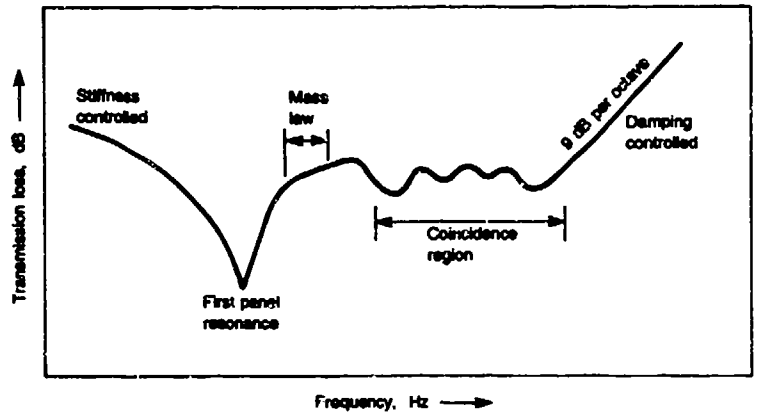


Figure 7a: Typical orthotropic panel transmission loss.

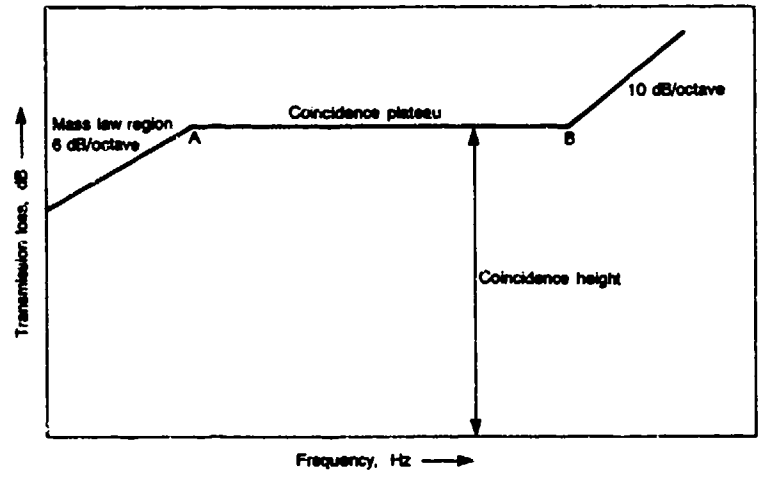


Figure 7b: Plateau approximation for acoustic transmission loss.

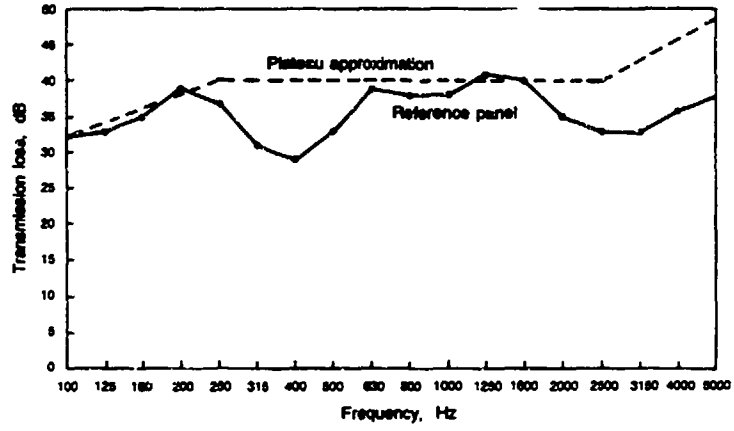


Figure 8: Transmission loss for reference panel and plateau approximation.

Panel size and aspect ratio will only affect the results if edge effects become important. The resonant frequencies of the panels will change, depending on size and shape. However the coincidence frequencies of the panels should remain constant, unless the panels become small enough for the edge effects to dominate. For the reference panel the lower coincidence frequency was 220 Hz, and the wave length approximately 0.5 m, so for the panel size tested edge effects would not have been important.

4.2 *Structureborne Noise Transmission*

Plots of the magnitude of typical driving point mobility and transfer mobilities for each excitation point for the LASCOR panel are shown in Figures 9 and 10 and for the reference panel in Figures 11 and 12. Table 2 summarises the average mobility level magnitudes for the two panels.

For both panels the mobility levels for excitation between ribs are higher than when for excitation on a rib. This is because the local panel stiffness is lower between ribs, and the driving point mobilities are primarily dependent upon the local structure around the excitation point. Both panels showed similar differences in driving point mobilities for excitation on a rib and excitation between ribs.

The magnitude of the driving point mobilities between the ribs for the reference panel approximate to a straight line, Figure 11, equivalent to the driving point mobility of an infinite plate of the same thickness [6].

When comparing the driving point mobilities of the LASCOR panel with those of the reference panel it can be seen that the LASCOR panel mobility is higher for the corresponding location (Table 2). The results in order of increasing mobility may be generalised as reference panel on a rib, LASCOR panel on a rib, reference panel between ribs and LASCOR panel between ribs.

For the reference panel the transfer mobilities within the same section are higher than those across one or two rib stiffeners. The transfer mobility across two ribs was similar to that across a single rib. Similarly the transfer mobility to a point on an adjacent rib was similar to that for a non-adjacent rib.

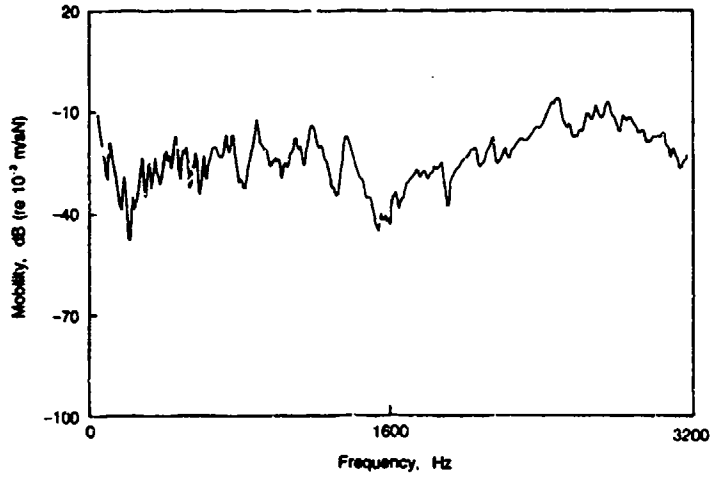
For the LASCOR panel the transfer mobilities to locations between ribs were higher than for locations on ribs. The transfer mobilities decreased as the response location moved away from the excitation point, so those locations furtherest away from the source were slightly lower than those at a corresponding location near the source. Additionally, the transfer mobilities when the panel was excited on a rib were lower than when excited between ribs.

The magnitude of the transfer mobilities of the two panels was similar for corresponding locations.

The higher driving point mobilities of the LASCOR panel mean that for a given excitation a higher power will be transmitted in to the structure since the input power is given by [2]

$$P = \frac{< V_f^2 >}{Re\,(M_f)} = < F_f^2 > Re\,(M_f)$$

where F_f is the excitation point force
$<V_f>$ is the excitation point velocity
$Re\,(M_f)$ is the real part of the driving point mobility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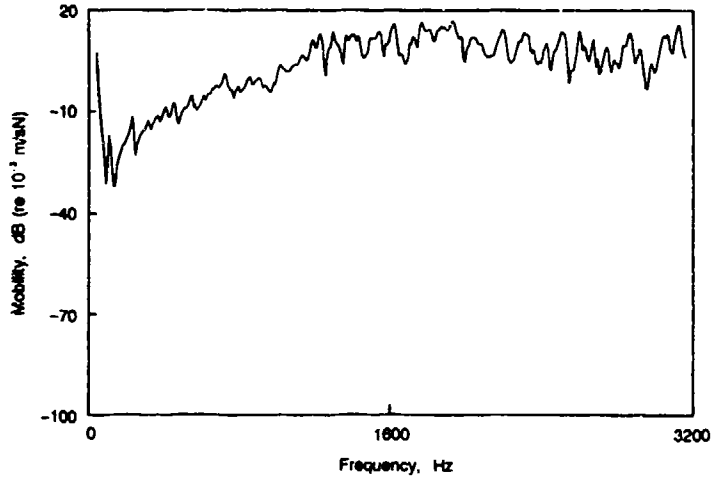
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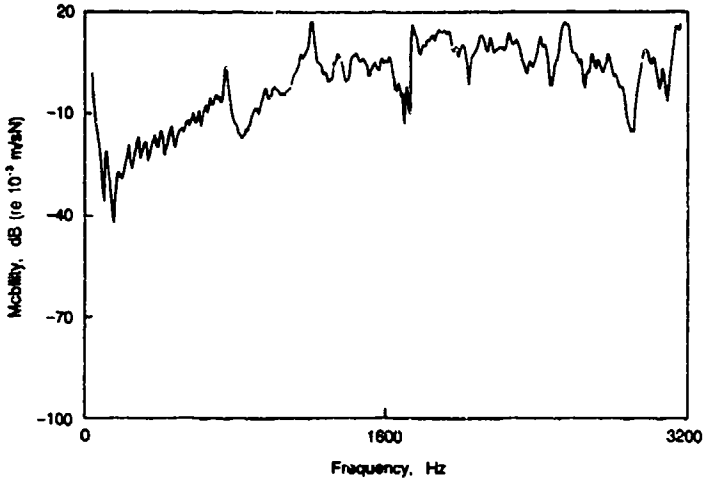
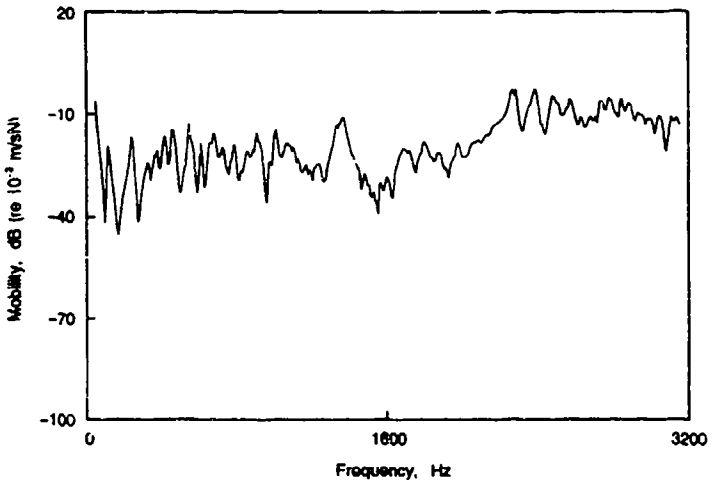
Figure 9:





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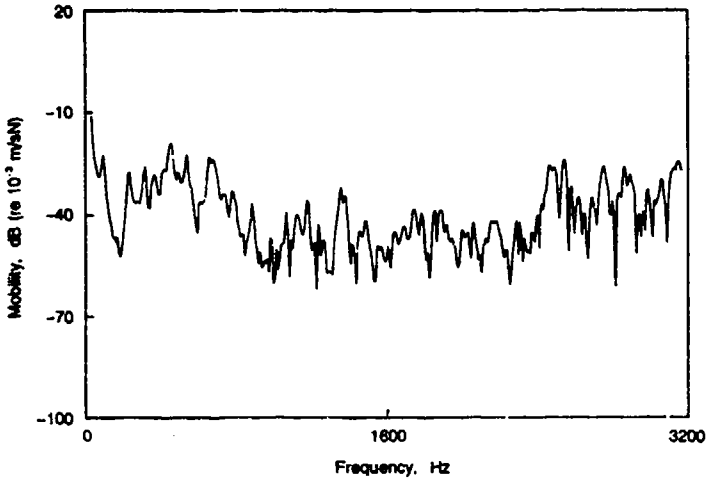
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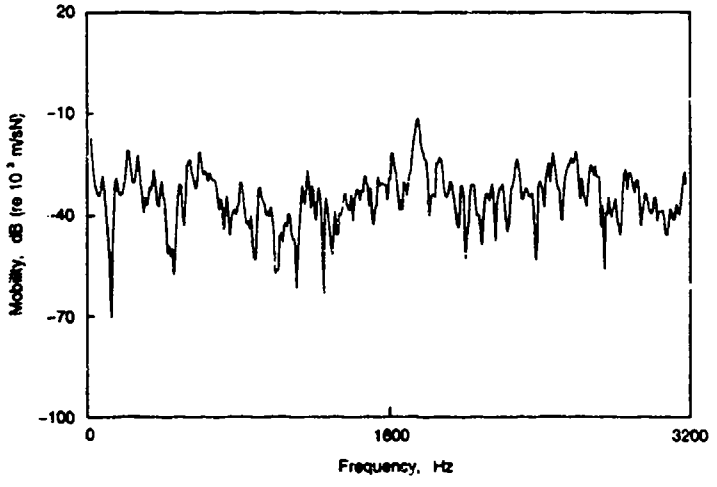
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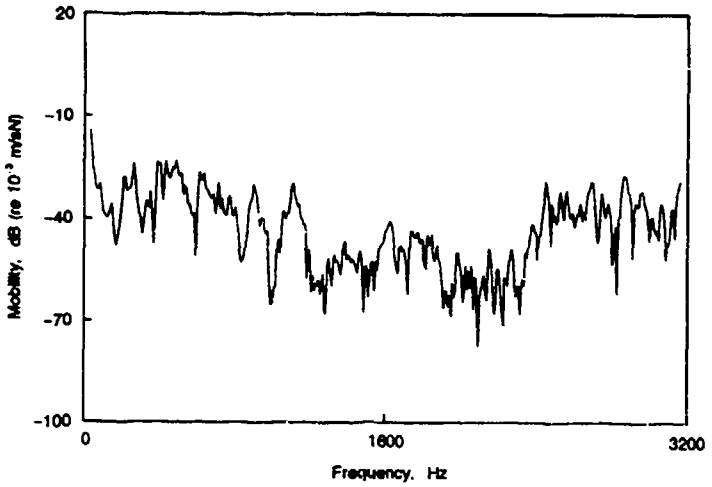

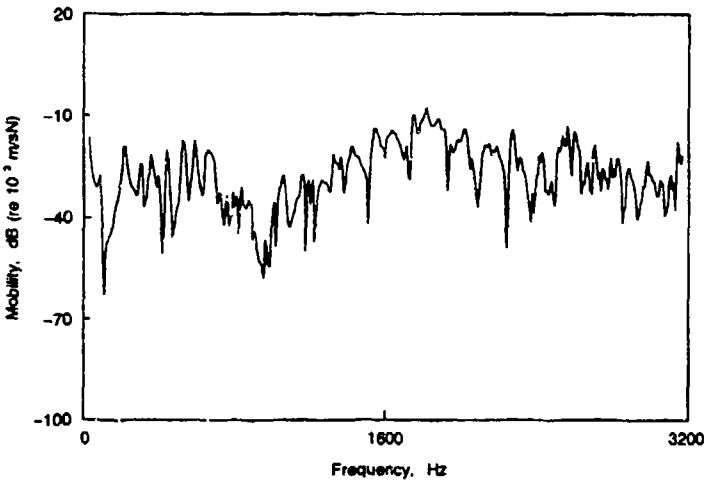

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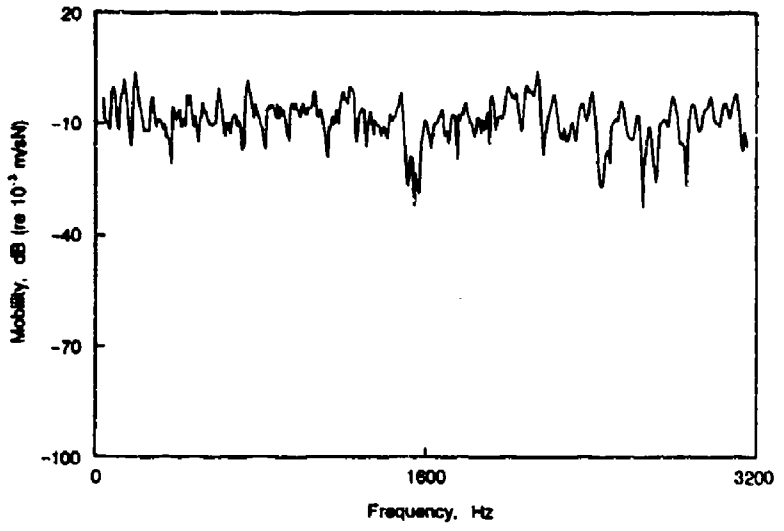
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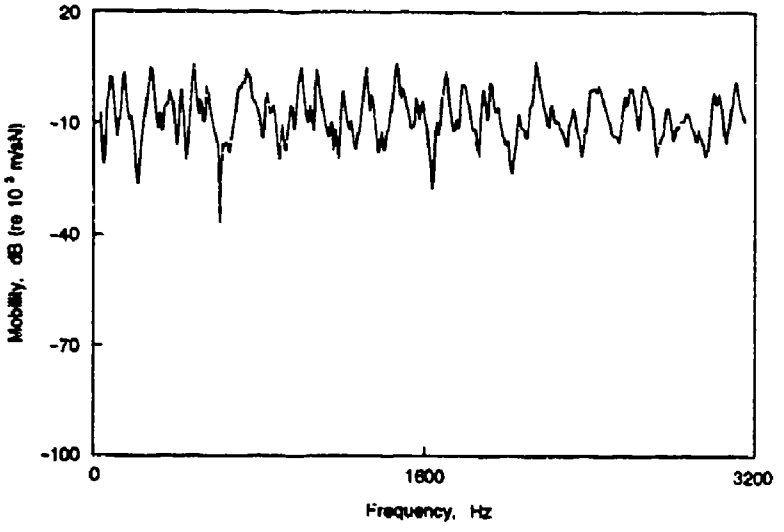
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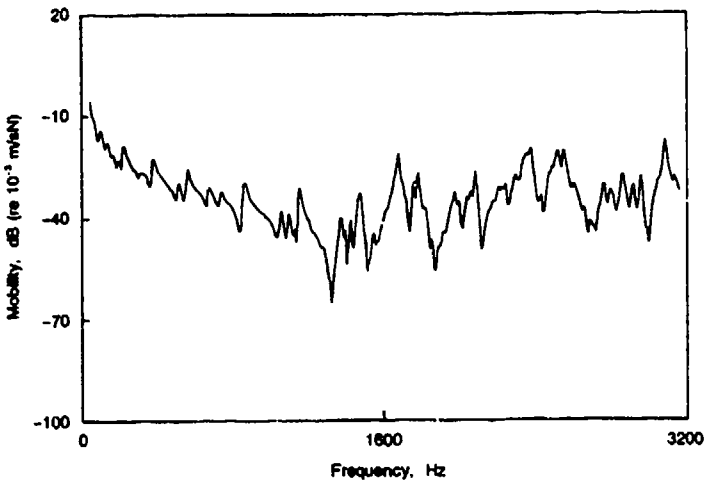
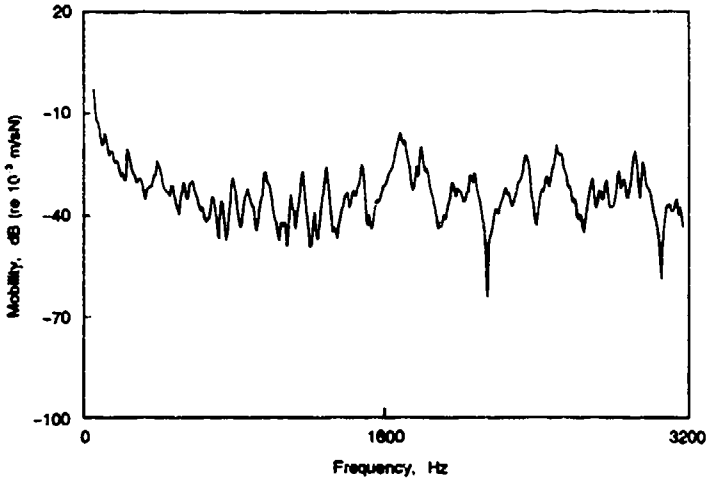
Figure 11:





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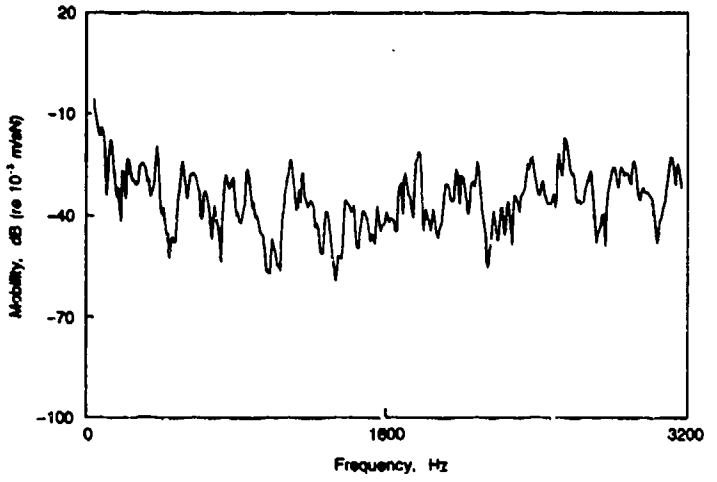
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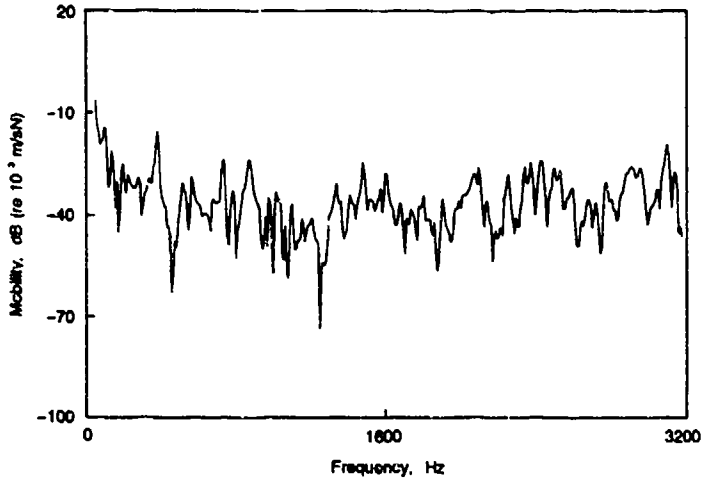
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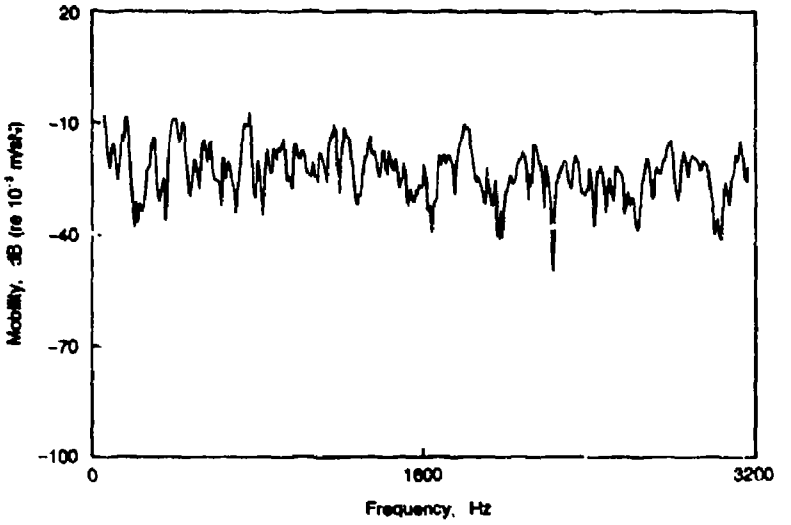

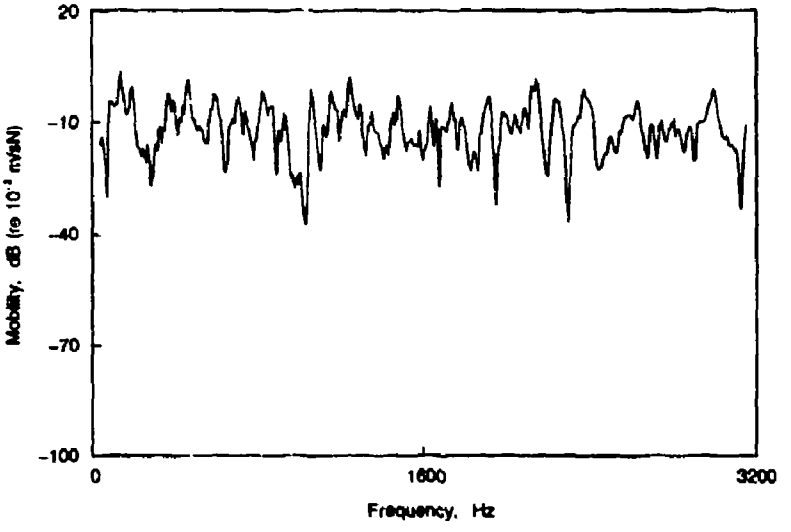

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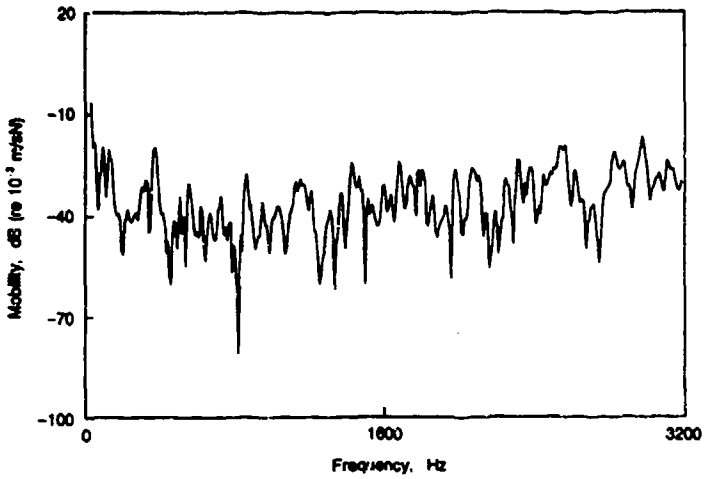

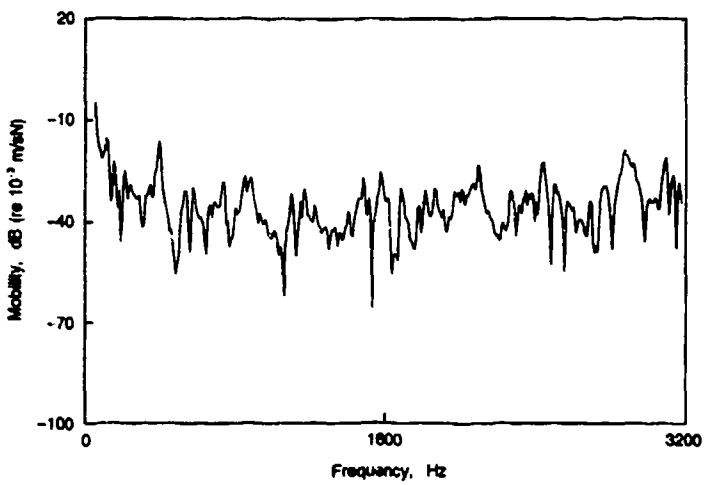

Figure 12 (Contd):

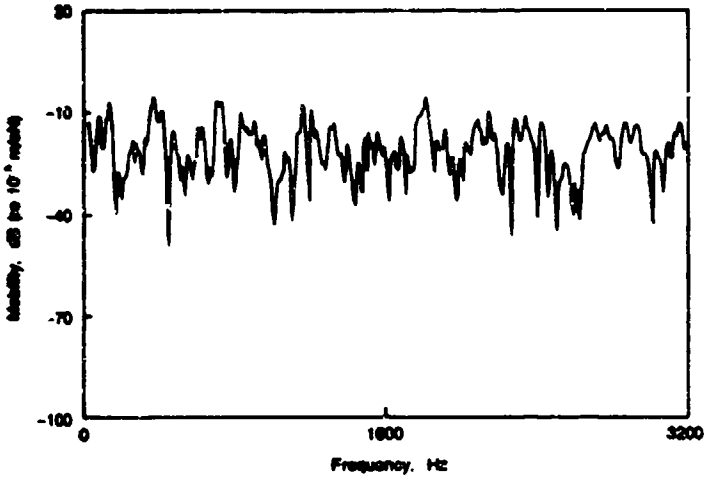

Figure 12 (Contd):

Table 2: Average mobilities of the two plates for different excitation and response locations (dB levels re 10^{-3} M/SN)

Location	LASCOR Panel Mobility	Reference Panel Mobility
Driving point over rib	- 25 dB	- 40 dB
Driving point over a gap	5 dB	- 10 dB
Transfer gap-rib	- 35 dB	- 40 dB
Transfer gap to gap	- 25 dB	- 25 dB
Transfer rib to gap	- 40 dB	- 40 dB

Both panels have a low loss factor which means that the real part of the mobility is approximately equal to the magnitude of the mobility. Thus, the LASCOR panel will have higher structureborne sound transmission than the reference panel when excited in a corresponding location.

The driving point mobility for the LASCOR on a rib is lower than for the reference panel between ribs so that the structureborne noise will be lower in LASCOR when comparing these excitation points. Looking at the cross-sections of the two panels, the LASCOR has a greater area of directly stiffened plate (ribbed) than the reference panel, thus the relative structureborne noise performance depends upon the exact mounting locations.

Panel size and aspect ratio will only affect the results at lower frequencies, where panel resonances are important. At higher frequencies the mobilities are dependent on the local panel stiffness and approximate to the mobilities for an infinite panel.

5. Conclusions

1. The LASCOR panel has a lower transmission loss than the reference panel except in the 2500 Hz and 3150 Hz centre frequency, one third octave bands, and the equivalent STC of the LASCOR panel is 5 dB lower than for the reference panel. This means that there will be higher acoustic transmission between compartments separated by LASCOR partitions than by standard partitions.

2. The LASCOR panel has higher driving point mobility and similar transfer mobilities compared with the reference panel, for corresponding excitation location. This means that there will be higher structureborne noise transmission with the LASCOR panel for the same excitation location.

6. Acknowledgements

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AUTHOR(S)
C.J. Norwood

CORPORATE AUTHOR
DSTO Materials Research Laboratory
PO Box 50
Ascot Vale Victoria 3032

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KEYWORDS

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ABSTRACT

LASCOR is a laser welded corrugated steel sandwich developed as a lightweight construct for ship superstructures. Tests were performed to measure acoustic transmission loss and structureborne noise transmission for both a LASCOR panel and a reference conventional rib-stiffened steel panel. This report outlines the test methods used and compares the results for the two panels.

Acoustic Transmission Loss and Structureborne Noise Transmission
Tests on a LASCOR and a Reference Steel Panel

C. Norwood

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