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OMICS Group International is a pioneer and leading science event organizer, which publishes around 400 open access journals and conducts over 300 Medical, Clinical, Engineering, Life Sciences, Pharma scientific conferences all over the globe annually with the support of more than 1000 scientific associations and 30,000 editorial board members and 3.5 million followers to its credit.

OMICS Group has organized 500 conferences, workshops and national symposiums across the major cities including San Francisco, Las Vegas, San Antonio, Omaha, Orlando, Raleigh, Santa Clara, Chicago, Philadelphia, Baltimore, United Kingdom, Valencia, Dubai, Beijing, Hyderabad, Bengaluru and Mumbai.

IMPROVEMENT OF THE HEAT AND SOUND INSULATION OF A BUS FOR COMPLIANCE WITH AMERICAN REGULATIONS

DR. KADIR AYDIN
PROFESSOR

AUTOMOBILE-2015
02.09.2015 VALENCIA/SPAIN

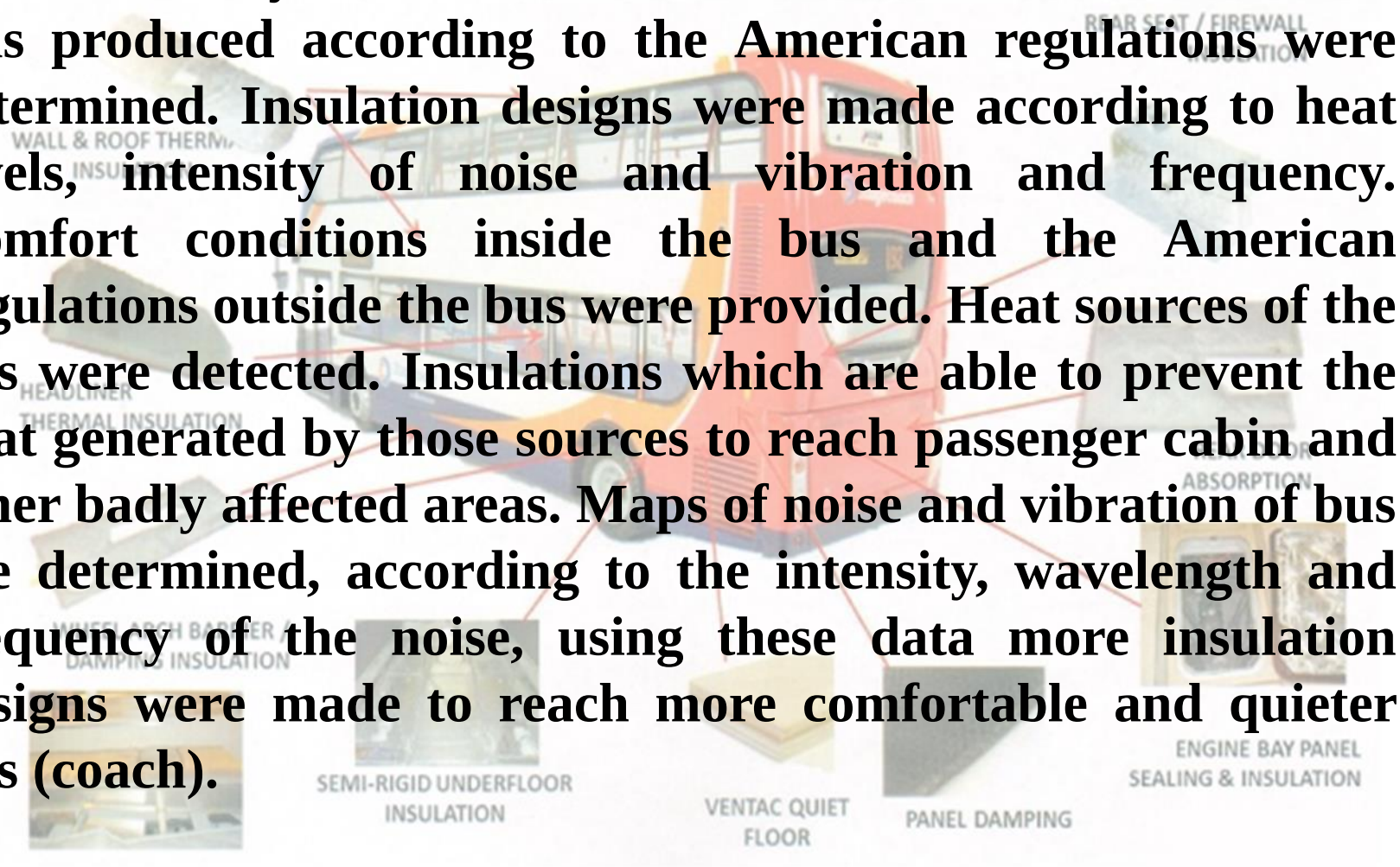
ÇUKUROVA UNIVERSITY
DEPARTMENT OF AUTOMOTIVE ENGINEERING

TEMSA Global has a total annual production capacity of 11.500 vehicles in one shift at its Adana Production Plant, comprised of 4.000 buses&coaches and 7.500 light trucks.

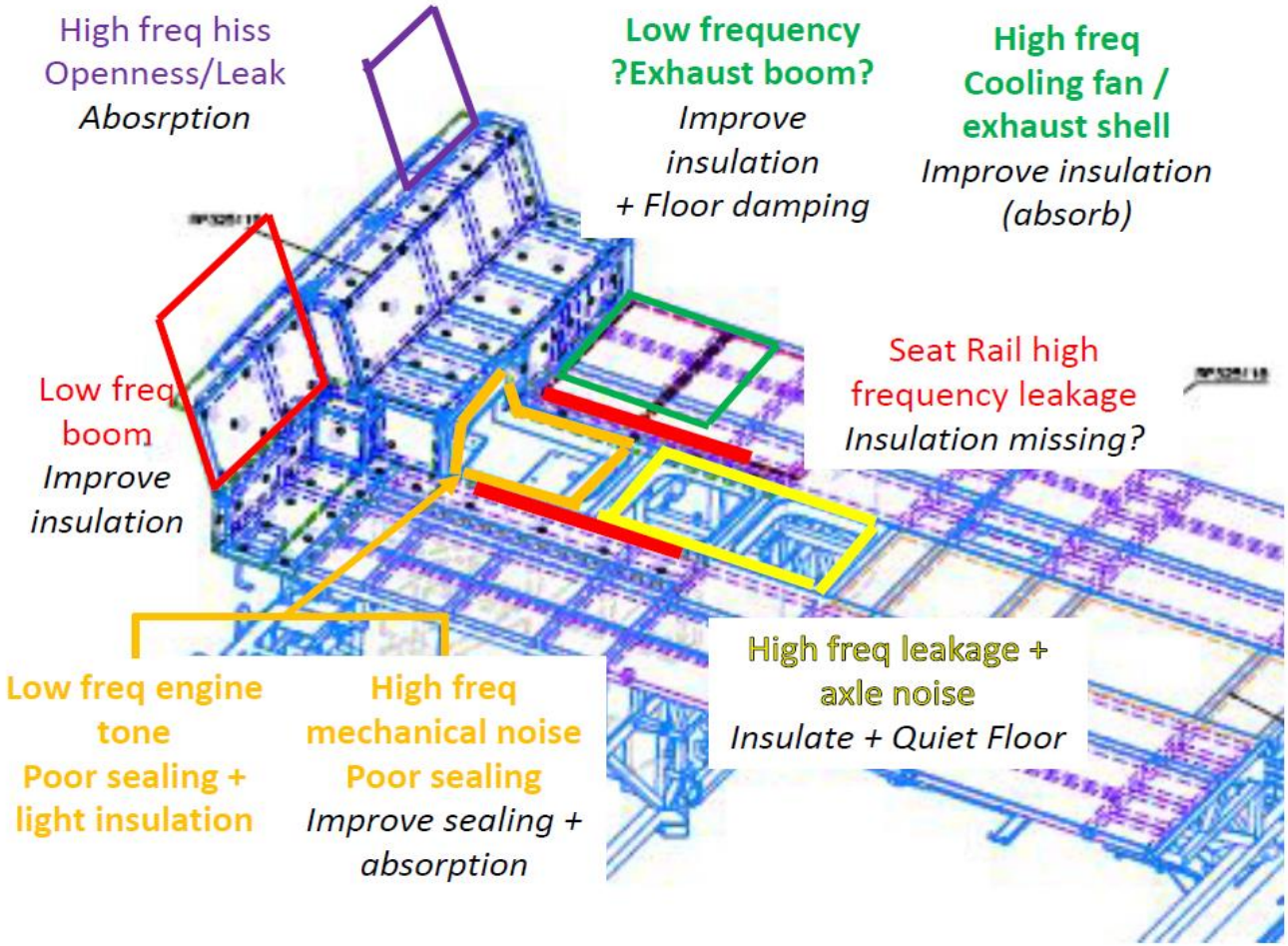
With a total area of 555.000 m^2, TEMSA's Adana Production Plant manufactures 11 different models for European market, 3 different models for American market and 8 different models for Turkish and Non-European markets.

Having significant competitive advantages in the industry, TEMSA sells its products to 64 countries in addition to Turkey. In France alone, more than 3.000 TEMSA branded buses are on the roads. The Company's major markets in Europe include Germany, Italy, Austria, Sweden, Lithuania and the Benelux region; meanwhile, TEMSA continues to strengthen its market share in the United States through increased product diversification.

In this study, heat, noise and vibrations of 3-axle bus which was produced according to the American regulations were determined. Insulation designs were made according to heat levels, intensity of noise and vibration and frequency. Comfort conditions inside the bus and the American regulations outside the bus were provided. Heat sources of the bus were detected. Insulations which are able to prevent the heat generated by those sources to reach passenger cabin and other badly affected areas. Maps of noise and vibration of bus are determined, according to the intensity, wavelength and frequency of the noise, using these data more insulation designs were made to reach more comfortable and quieter bus (coach).

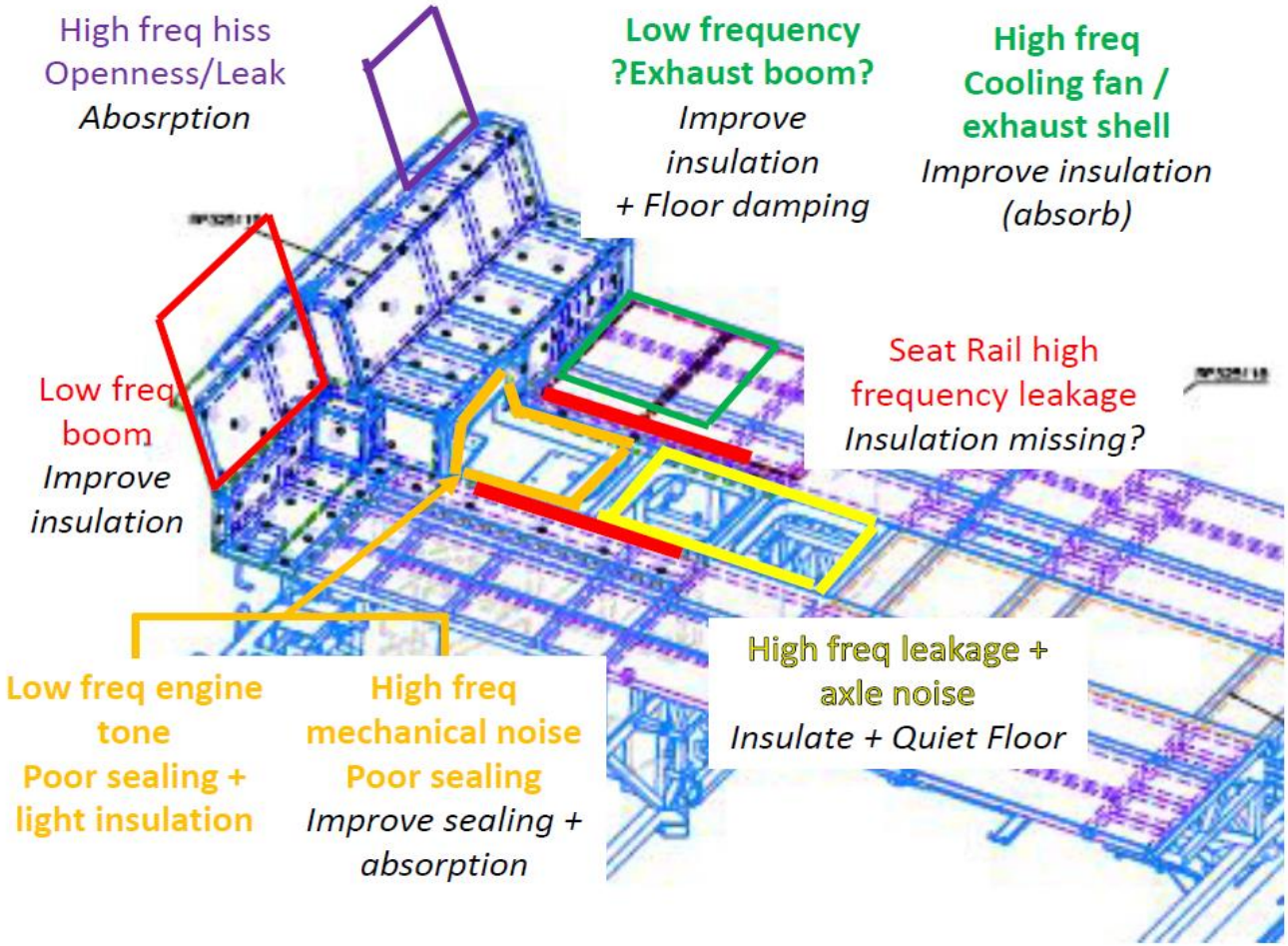


Initially there was heavy insulation across the rear seat and floor up to the rear axle with the exception of certain locations. These exceptions are acoustic weak points which allow high levels of noise to pass through. It is recommended to treat these weak points and reduce the mass of the acoustic insulation across the remaining areas of the floor to optimize the effectiveness of the treatment.



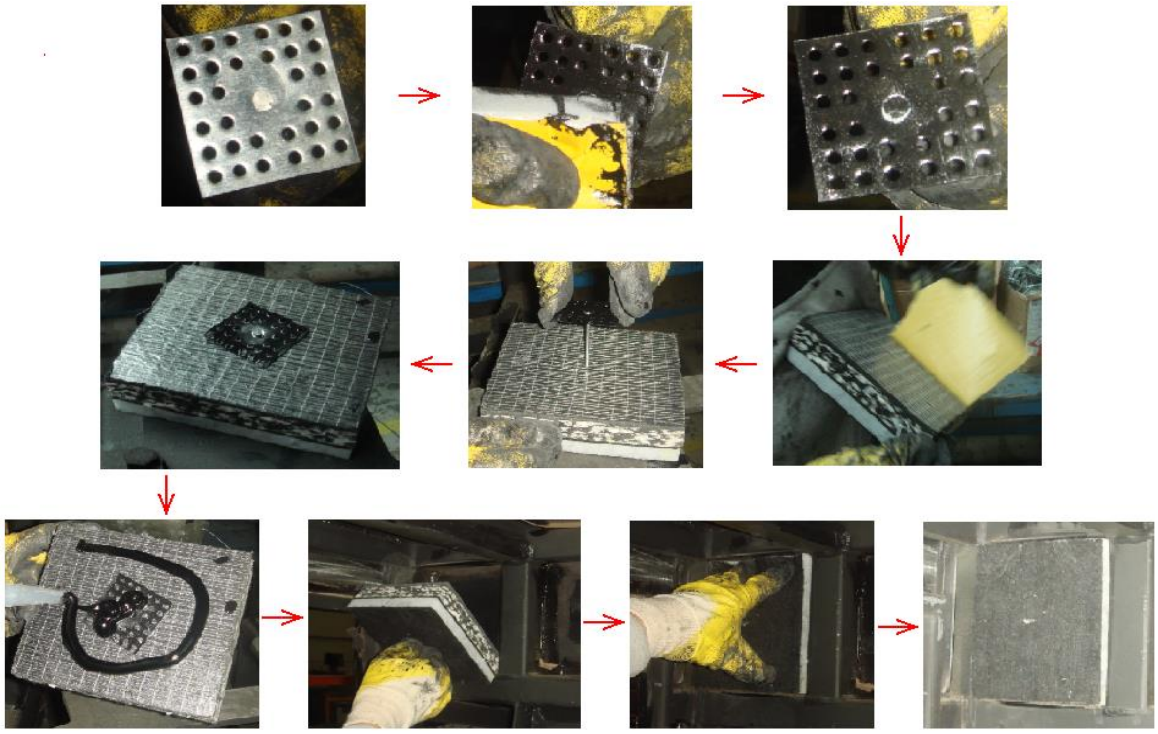
These weak points are;

- **The floor in front of the back seat on the left side of the bus,**
- **The engine bay access hatches**
- **The seat back of the rear seat and services running up the rear left corner.**

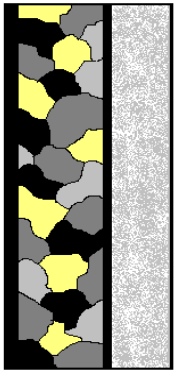


The previous insulating materials are;

- **Inefficient,**
- **Consist of several layers,**
- **Very complex design,**
- **Heavy,**
- **Difficult to assembly, we have to use insulating nail with adhesive material. Also Material's top surface is adhesive surface,**
- **Very expensive.**







Normally, evaporator units are on the roof of the buses according to European regulations. But according to American regulations, the evaporator units must be in the rack of the buses.

Because of this, the evaporator units for the air conditioning, the bus are a very important noise source in the passenger compartment. The ideal solution is to distribute the air more efficiently to each passenger location which would allow for the reduction of the fan speed. It is also possible to apply noise control measures to the evaporators.



Especially in the regions previously identified, measurements were taken for detect noise and vibration sources of the bus.

The measurements were taken with a sound level meter that was calibrated before testing and checked afterwards.

Three measurement locations were assessed:

- **1 m over the floor directly in front of the back row of seats, on the center axis of the bus**
- **1 m over the floor directly over rear axle, on the center axis of the bus**
- **1 m over the floor on the center axis of the bus in line with the 6th row of seats from the back of the bus**

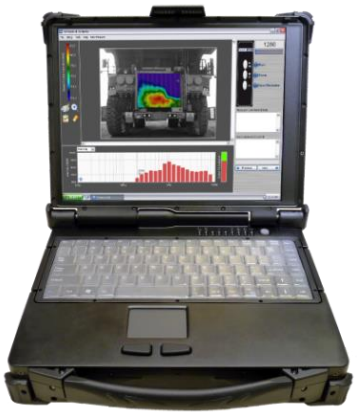


The measurements were taken in the following operating conditions for a period of approximately 25 seconds each:

- **Acceleration in third gear full throttle**
- **Acceleration in third gear partial throttle**
- **80 km/h Steady Speed**
- **100 km/h Steady Speed**
- **Stationary, Engine Speed Idle**
- **Stationary, Engine Speed High Idle**

MEASURING DEVICS

Conductor



The Conductor is a high-performance Laptop based analyzer. The Conductor provides a rugged platform for acoustics and vibration measurements. Mainly used for the I-Track sound intensity mapping system, it is also suitable for any other task encountered by a noise and vibration specialist.



The I-Track system is a powerful tool for fast, easy and accurate sound mapping. The maps are created by combining in real-time the acoustic data from a sound intensity probe with its position data from a position tracking device. The result is a high definition sound mapping performed in a few minutes and an automatic sound power calculation.

Sound Level Meter

An advanced, single-channel, hand-held analyzer and sound level meter that has everything needed to perform high-precision, Class 1 measurement tasks in environmental, occupational and industrial application areas.

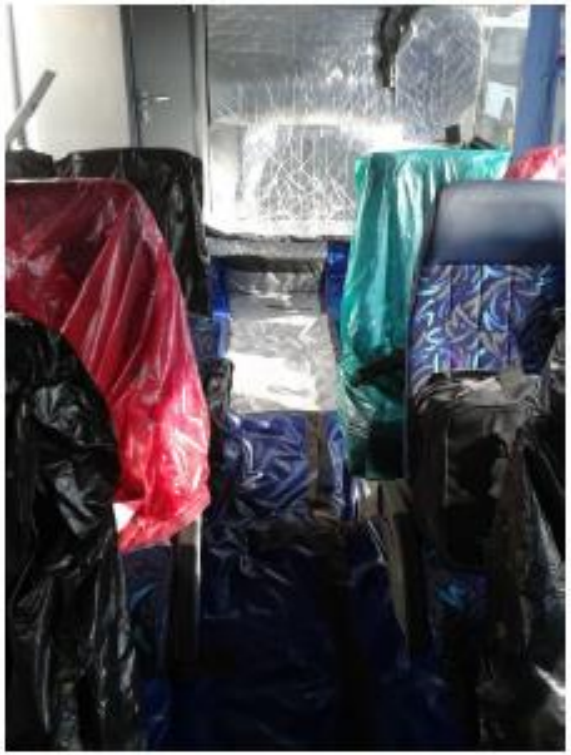


Uses;

- **General-purpose Class 1 sound measurements to the latest international standards**
- **Occupational noise assessment**
- **Environmental noise assessment and logging**
- **Product development and quality control**
- **FFT analysis of sound and vibration**
- **Sound power determination**

Coach Masking

- **To assist in prioritizing noise pathways into the passenger compartment, sections of the bus floor and rear of the bus were masked with sound insulations quilts.**
- **These quilts could be a removed from specific sections and the difference in noise levels was measured.**



Noise Measurements with the Evaporators Off

Operating Condition	In Front of Rear Seat	Over Rear Axle
	L_{Aeq} dB	L_{Aeq} dB
Acceleration in third gear full throttle	74.7	70.7
Acceleration in third gear partial throttle	70.6	66.6
Stationary, Engine Speed Idle	58.4	53.5
Stationary, Engine Speed High Idle	70	65.4

Noise Measurements with the Evaporators On

Operating Condition	In Front of Rear Seat	Over Rear Axle	6 rows of seat from the back seat
	L_{Aeq} dB	L_{Aeq} dB	L_{Aeq} dB
Acceleration in third gear full throttle	74	72.2	75.3
Acceleration in third gear partial throttle	71.6	71.4	
80 kph Steady Speed	69.7	71.2	74.3
100 kph Steady Speed	70.4	70.9	75.2

Table 5.3. Max Noise Levels Measured

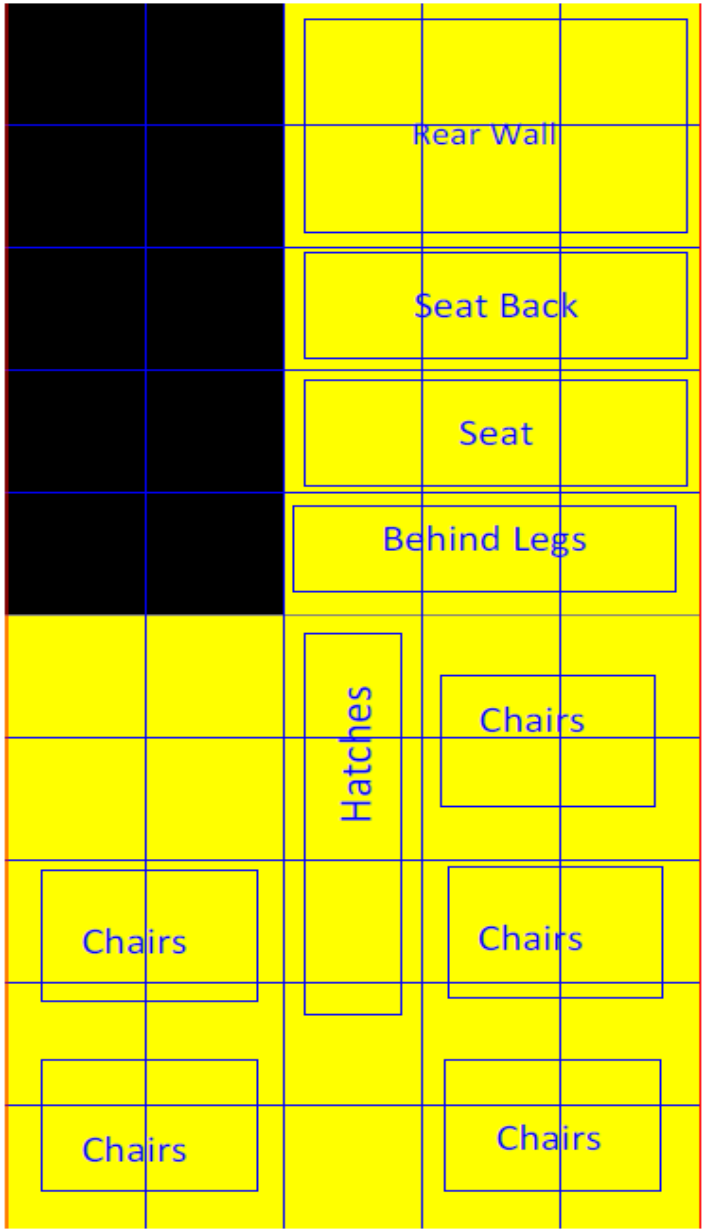
Operating Condition	In Front of Rear Seat	Over Rear Axle
	L_{Aeq} dB	L_{Aeq} dB
Evaporators Off		
Acceleration in third gear full throttle	76.2	73.1
Evaporators On		
Acceleration in third gear full throttle	77.1	73.7

Noise Measurements on Evaporator Treatment (One unit running)

Operating Condition	RecirculatedAir	Fresh Air
	L_{Aeq} dB	L_{Aeq} dB
Baseline	80.1	77.5
Splitters	78.6	76.2
Splitters + Masked Grill	75.3	73.8

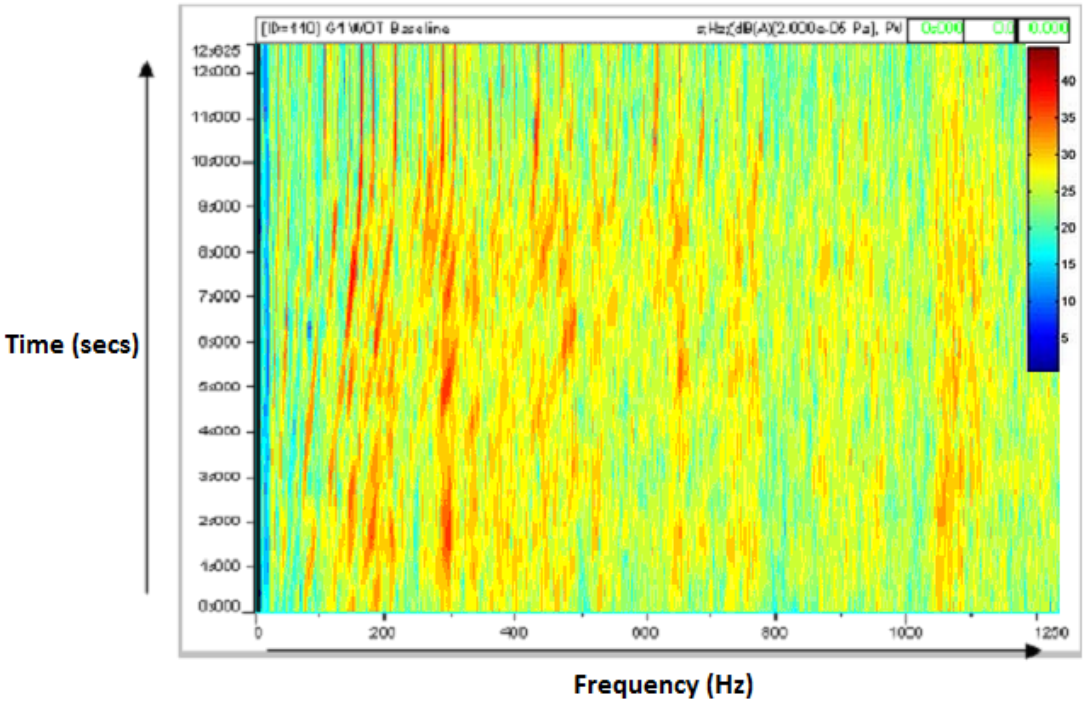
Noise Mapping

The use of a sound intensity probe with paired microphone arrangement allows for the measurement of the directionality of sound. By taking a series of measurements across a grid, a noise map can be generated that can indicate how the noise is traveling through a space. These noise maps can be used to identify the noise paths into the bus interior.

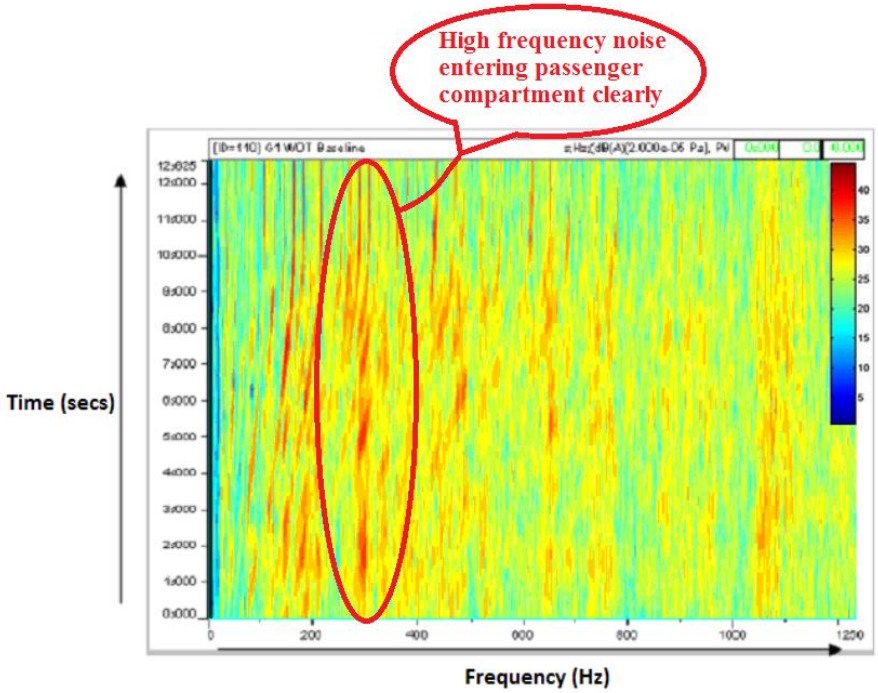


Digital recordings taken during the windowing process of the bus were post processed and presented as a sonogram.

A sonogram is a graph that presents the frequency vs time high levels are shown by yellow and red, lower levels are shown by green and blue. The time measured is as the vehicle is accelerating in the third gear both under wide open throttle and also partially open throttle.



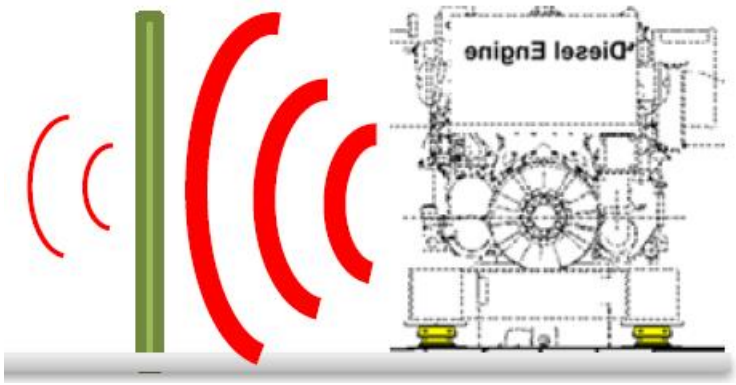
Resonance Map of Vehicle at Wide Open Throttle, Baseline

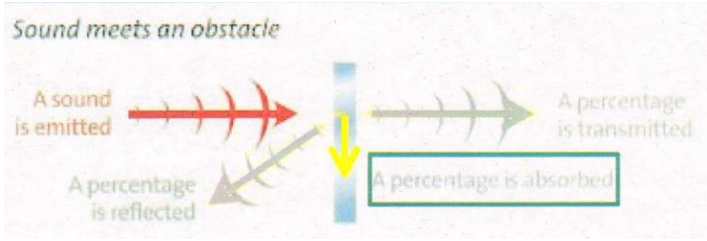


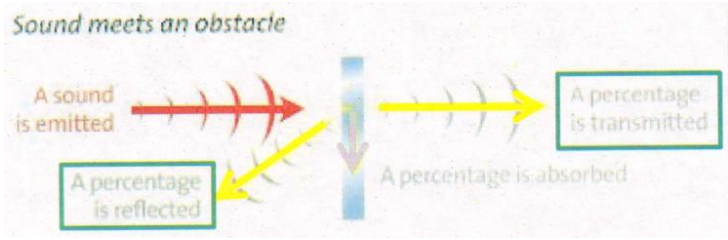
Resonance Map of Vehicle at Wide Open Throttle, Baseline

While the vehicle working on idle condition, increasing the engine speed results in increasing frequency. In addition, for every frequency range we identify the areas which resonate.

Noise which is revealed from ranges of frequency of resonance is measured. The resulting sound amplitude (wave length) are taken into consideration.







We determine whether to absorb or reflect the noise according to frequency of noise and wave length. For example; If the wave length of coming noise is too high wave length skips to material, can not be absorbed. So; the proper design is using the material which reflects the noise. If it is necessary to prevent penetration of noise, sound barriers must be created by using heavy layers.

Lastly, it must be noted that how much the insulation material can absorb noise and also in which frequency range. Frequency range of resonance in vehicle, frequency range which material is able to absorb must be noted and must be suitable with each other.

When the intensity measurements are broken into third octave bands it can be seen the hot spot over the floor section on the left side of the vehicle is strong in the mid frequency range particularly at 630 Hz and 500 Hz. The third octave band sound pressure measurements found this to be an important frequency range.



Floor Section on The Left Side

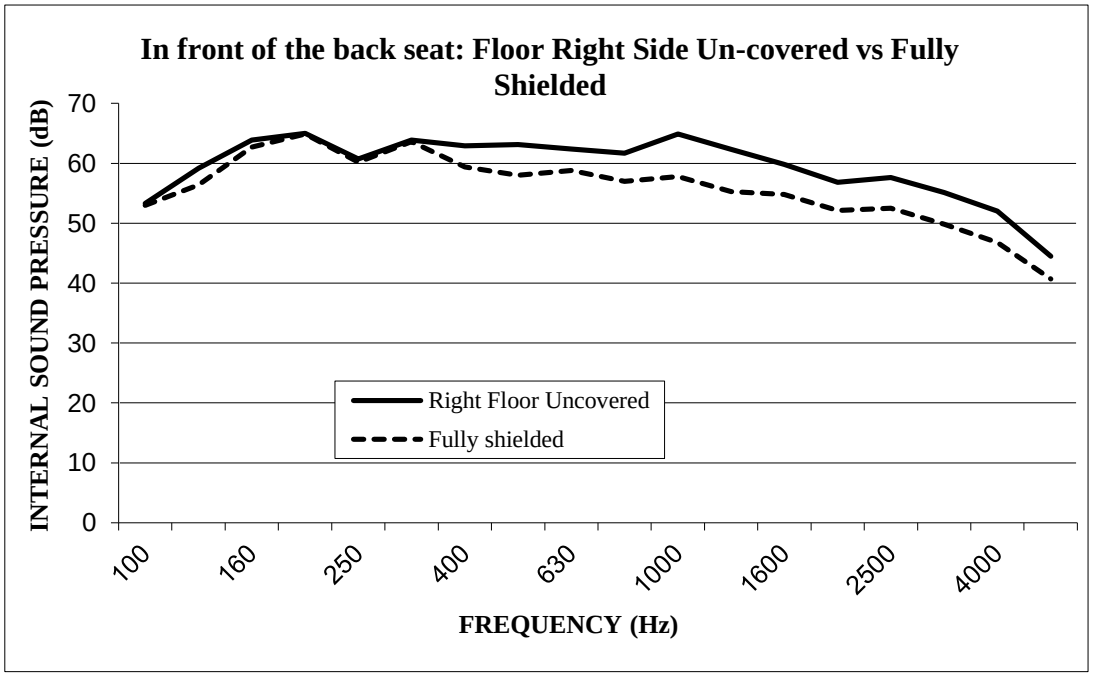
The floor section on the left side of the bus in front of the backseat was found to be an important route for the noise from the engine bay into the bus. The sound intensity noise mapping and the windowing exercise both identified this area as important. This area is particularly important for the mid frequencies of 500 Hz – 630 Hz.

Examination of the bus after testing found a section of the floor in this area was untreated and it is believed this may be the reason for the high levels in this area. It is recommended that this area should be treated but typically where there is a gap in the noise insulation there is a practical reason for it.



Floor Section on The Right Side

The floor section on the right side of the bus was found to be of less important than the left side. There was an indication of low frequency noise being radiated from this section. This was particularly found in the 200 and 315 Hz bands. This range of frequencies is of high importance to the overall sound pressure level of the bus but perhaps less important for the sound quality. It is also in a frequency region which suggests that it is structure borne.



Floor Hatches

Subjectively it was the impression that the engine noise was coming very clearly through the engine bay hatches. The noise has a harsh quality that indicates a large level of high frequency noise. High frequency noise has low energy so it can only penetrate where there are light weight materials or gaps.





Evaporators

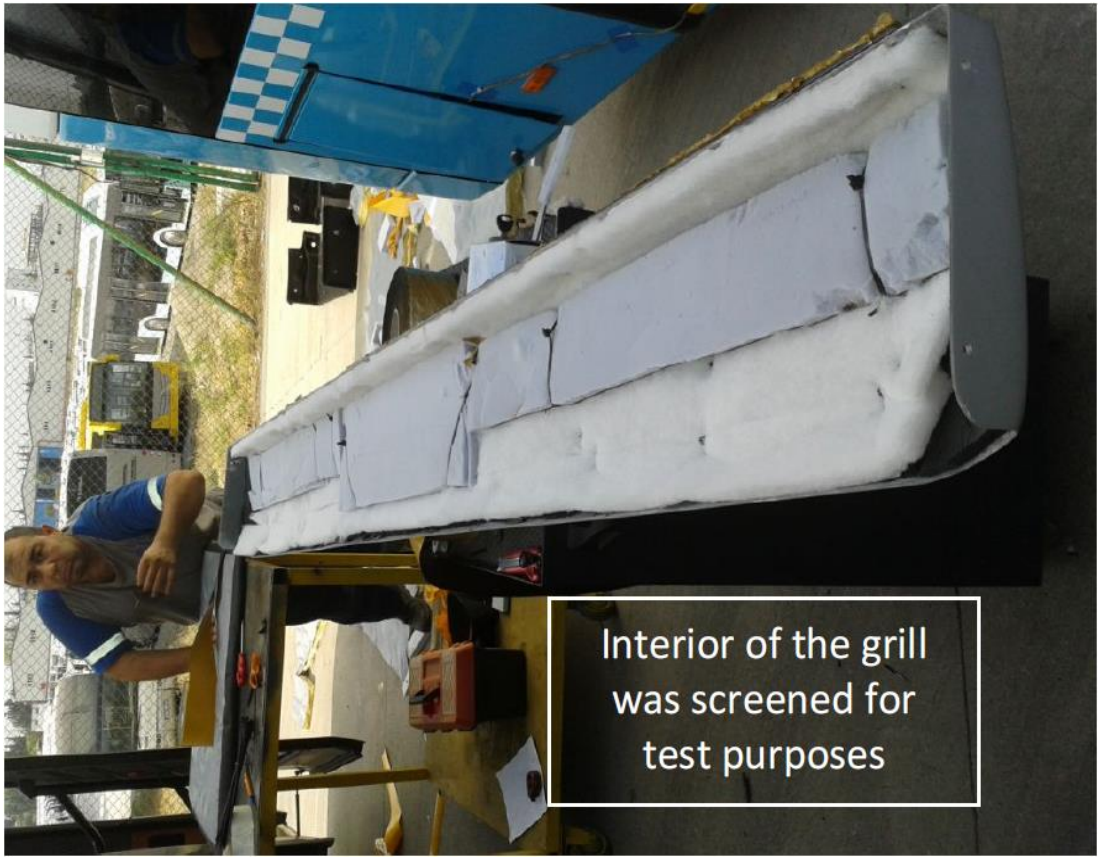
The four evaporator units mounted in the central section of the passenger compartment are a very significant noise source in the vehicle. These units are for the air conditioning and the high flow rate across them generate a significant amount of noise. A high flow rate is required to distribute the air effectively to the ends of the bus.

The optimal method for reducing noise from the unit is to improve the distribution of the airflow to all parts of the bus, either by restricting the airflow at vents closer to the evaporator and opening it up at further away locations or by ducting the airflow to a number of partitioned off compartments behind the outlet vents to allow for even air pressure.



The alternative solution or an option to use in combination with improving the ventilation system is to treat the evaporator. There are several points to consider when treating the noise from the evaporator unit.

- **Large covering grill on air inlet**

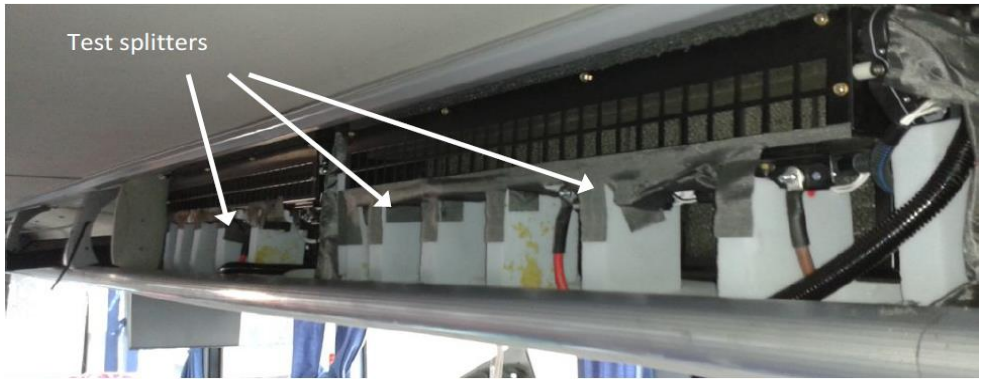


- **Sound treatment lining the unit has an impermeable facing – a porous sound absorption material will allow the sound energy to be absorbed before passing through the grill.**

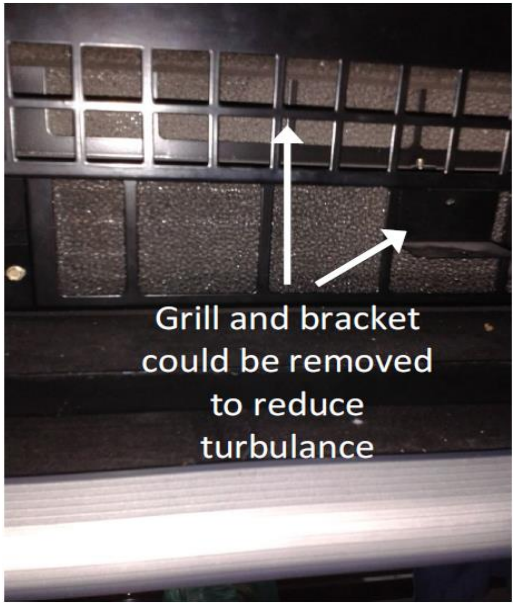


- **Large foam blocks are packed in round the sides of the unit**

- **Sound absorptive splitters are often used to absorb sound energy from the airflow**



- **The internal grill over the fresh air intake is a potential source of turbulence and therefore noise. It is recommended to remove as much of the grill as possible.**



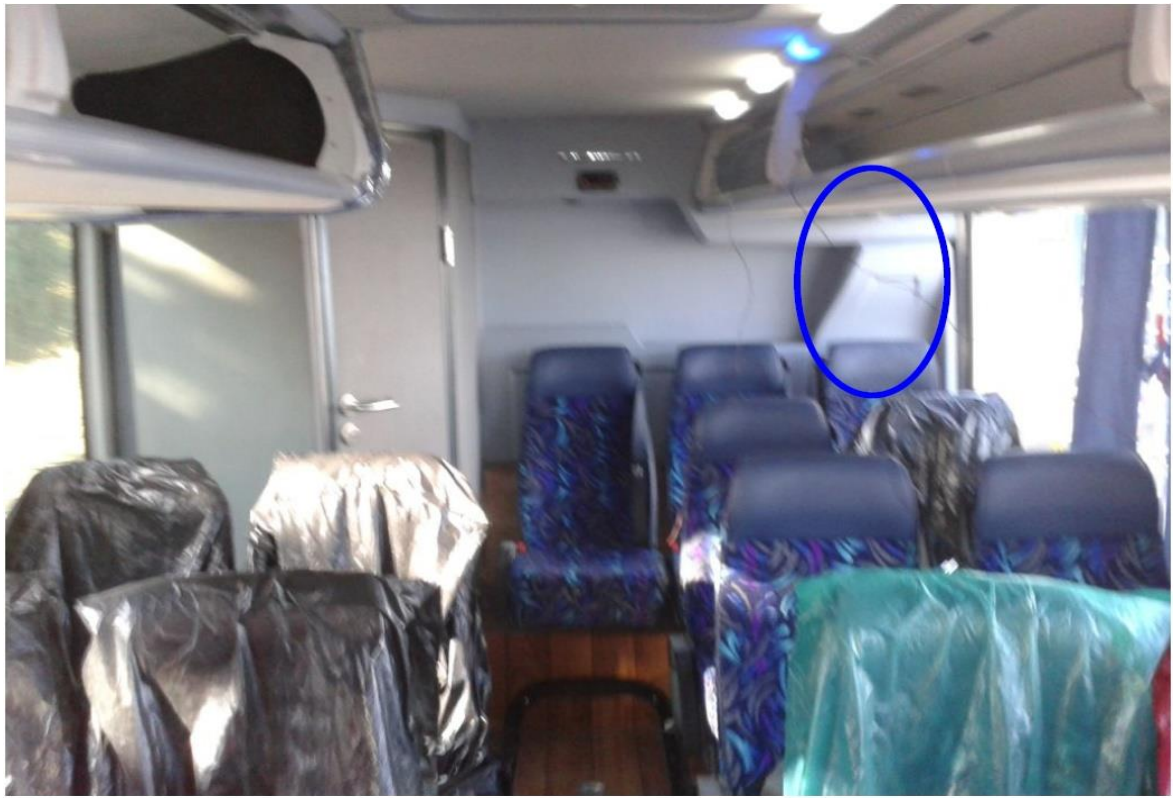
Rear Seat

The rear seat back was highlighted as a hot spot in the noise mapping. The windowing also indicated that this area is important. The frequency range this occurs in is 160 Hz – 315 Hz which suggests it is structure borne noise. This type of noise is best treated with a damping material or the Quiet Floor material (Insulating material) might be an effective measure for this type of noise.

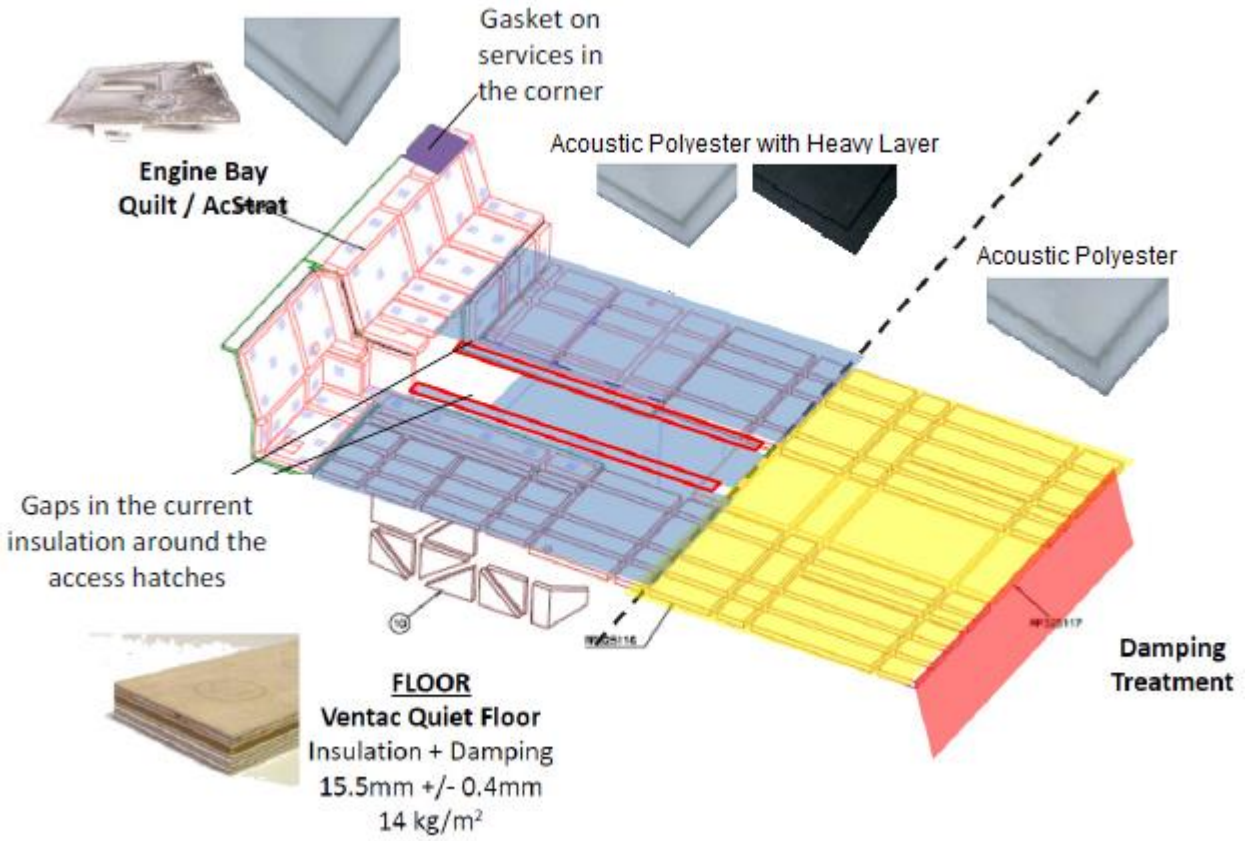


Services in rear corners

Services running from the engine bay to the passenger compartment enter along the rear left corner of the bus. This point is not effectively sealed for high frequency noise, because of the air compressor unit. Sound is traveling easily into the back seat area of the vehicle.



Summary Recommendations



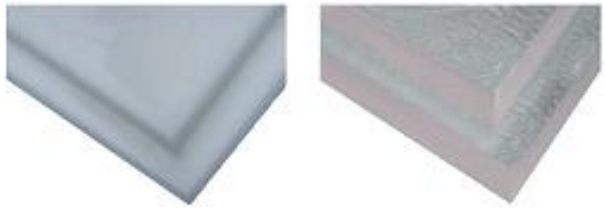
Using Material

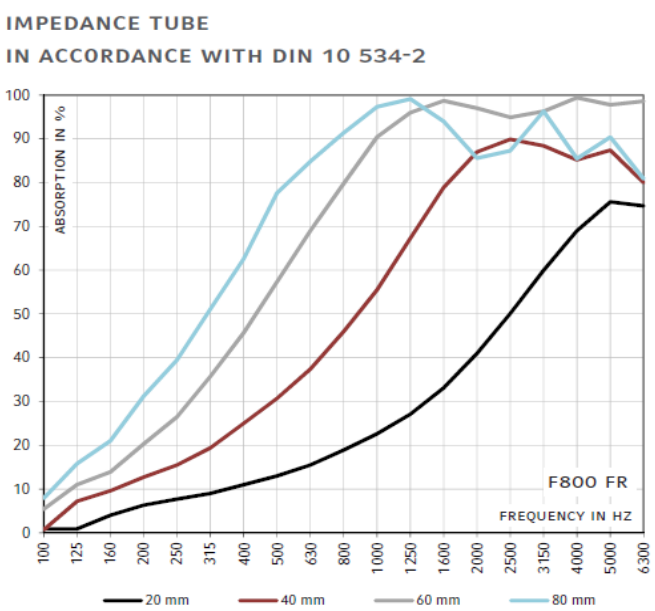
Products Based Aluminum Foil Coated Polyester

The material is made from a white pes non-woven that fulfills the highest requirements of diverse flammability tests optionally laminated with an embossed foil of highest-grade aluminum.

Material benefits are;

- Excellent sound absorption values,
- High temperature resistance,
- Fulfills high requirements regarding fire performance,
- In vibration tests, the fiber composite shows no tendency to break up,
- High shape stability,
- Aluminum foil for fulfillment of the highest hygienically requirements,
- The aluminum foil prevents the penetration of liquids.





Thermal conductivities of material are: 0.035 W/ (m.K)

Temperature Resistance is -50°C to +150°C

Product Based Heavy Foil

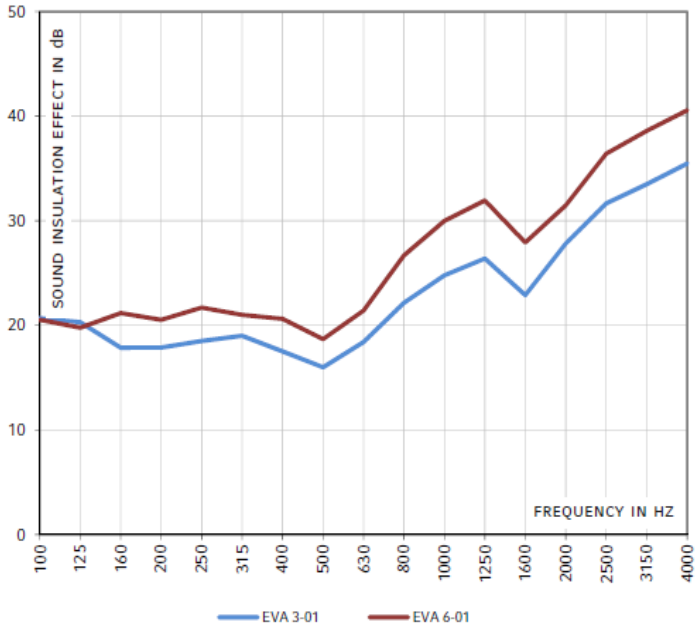


This heavy foil consists of a blend of synthetic materials on the basis of epdm/Eva polymers, with an admixture of special flame-retardant minerals.

Typical applications of material are; Machine and plant construction, construction machinery, utility vehicles, buses, rail vehicles, air-conditioning technology, solid borne noise damping of metal sheets.

Key benefits of material are;

- Excellent sound insulation values
- Very good flammability characteristics
- Higher temperature resistance as bitumen layer
- Odorless even when warmed
- Effortless to cut with a cardboard cutter or similar
- Easy and clean installation
- The material is flexible, not sensitive to pressure and does not emit particles or cause smudges.



Product Based Glass fiber mats



Glass material is a white glass fiber mat laminated with a high-temperature resistant aluminum foil. It is an ideal two-layer combination material for heat insulation and sound proofing. The upper layer is a top quality aluminum foil for reflection of heat radiation. The lower layer consists in a quilted glass fiber mat, which is responsible for the heat insulation effect as well as for the sound insulation properties.

Typical applications in high-temperature areas of: Machines and industrial plants, compressors, construction machinery, utility vehicles, buses, rail vehicles.

Key benefits;

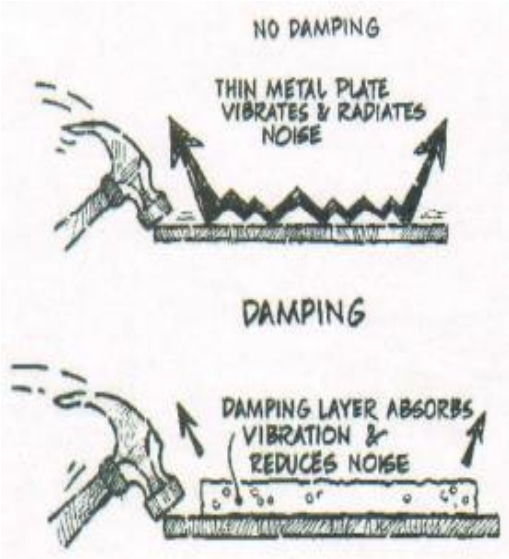
- High temperature resistance,
- Very high heat insulation effect,
- The aluminum foil completely prevents the penetration of dust, water, oil or other pollutants,
- Its low weight makes handling and processing easy.

Product Based Quiet Floor Material



Constrained layer damping acoustic flooring offering leading sound insulation in conjunction with improved low frequency damping control.

Functionality	Quiet Floor	15mm Ply
Insulation, Rw	34dB	26dB
200Hz		
Damping %	7,17	3,81
Noise Transfer (dB/N)	75	83
500Hz		
Damping %	4,92	2,1
Noise Transfer (dB/N)	73	75



Damping % measures ability of floor to dissipate vibration energy. Higher number is better as structural vibration in the structure is dissipated before being radiated.

Noise transfer measures amount of noise radiated from surface of board for every 1N dynamic force input. Lower number is better meaning less noise radiated.

Product Based Acquit 22x Turbo/VB



Front: Turbo facing + cross stitch	Reverse of quilt: vinyl black facing	Quilt with velcro slot for installation

Acquit Turbo/VB is an acoustic composite with fiber glass absorbent layers encapsulated between Turbo and Vinyl facing materials. The fiber Glass insulation provides excellent sound absorption and thermal insulation.

The inner surface of the composite is faced with black Vinyl (available grey also), a cloth coated in PVC rubber resistant designed for continuous use at temperatures up to 120 °C. The exposed face of the quilt is faced with T250 facing, a heat reflective aluminized glass cloth designed for continuous use at temperatures up to 250 °C. The cloth is coated with an aluminum sprayed polyester film which is laminated to one side of the cloth.

The fiber glass has a maximum service temperature of 350 °C, a thermal conductivity @ 24 °C mean temperature of 0.0383 W/mK and a thermal resistance @ 24° C mean temp of 0.65 m^2K/W.

Applications of material are;

A variety of vehicle applications including the engine bay and chassis' of buses, earth moving equipment and forklift trucks.

Results of New Developed Thermal and Acoustic Insulation

	REAR SEAT POSITION				REAR AXLE POSITION			
	Pilot (Last Design)	TARGET	Pilot 2 (New Design)	Change	Pilot (Last Design)	TARGET	Pilot 2 (New Design)	Change
FULL THROTTLE	74,7	70-72	69,6	-5,1	70,7	70-72	69,2	-1,5
WOT-LA F,MAX	76,2		73	-3,2	73,1		72,8	-0,3
PART THROTTLE	70,6	68-69	68,5	-2,1	66,6	68-69	68,7	1,1
CRUISE 80km/h	69,7	<67	66	-3,7	71,2	<67	65,3	-
CRUISE 100km/h	70,4	<67	67,6	-2,8	70,9	<67	66,9	-
IDLE A/C OFF	58,4		60,3	-1,9	53,5		56,3	2,8
HIGH IDLE A/C OFF	70		71,2	-1,2	65,4		66,3	0,9
IDLE A/C ON			68,7				65,7	

Results of New Developed Thermal and Acoustic Insulation

The measurements in these results were to assess the effectiveness of the heat and noise control kit on the TS 45 prototype bus.

The noise control kit did not produce the expected reduction in noise levels during vehicle acceleration for the following reasons,

- **No barrier in acoustic insulation over rear axle,**
- **Acoustic weak point in rear corner of bus where services enter cab,**
- **Acoustic weak point in rear seat due to rails,**
- **Cut outs in engine bay quilts for brackets and fixings,**

Sound quality improved in the vehicle due:

- **Structure borne booming noise from the floor removed by new insulating materials**
- **Acoustic hotspots around the hatches and across the floor were removed creating an even sound field.**

After this project, it is now a quarter, more comfortable bus,

- ✓ **Lower noise levels for increased comfort,**
- ✓ **Noise quality – vastly improved, less harsh,**
- ✓ **Rear seats are no longer 'noisy seats',**
- ✓ **Floor vibration is a lot less noticeable,**
- ✓ **Buzz through floor much subdued**

Cabin Insulation – Sound Quality;
✓Better sealed from engine bay noises
✓Tiring low frequency noise reduced

Quieter Cabin,

- ✓ **70 dB of target goal achieved**
- ✓ **Reductions of 3 to 5 dB**
- ✓ **Rear half of bus improved**

Floor Vibration Reduced;
✓4 dB reduction overall
✓Up to 13 dB off tactile buzz

Engine Bay Treatment





Material is a engine bay composite quilt, this material's function is thermal and tuned acoustic performance for engine bay.

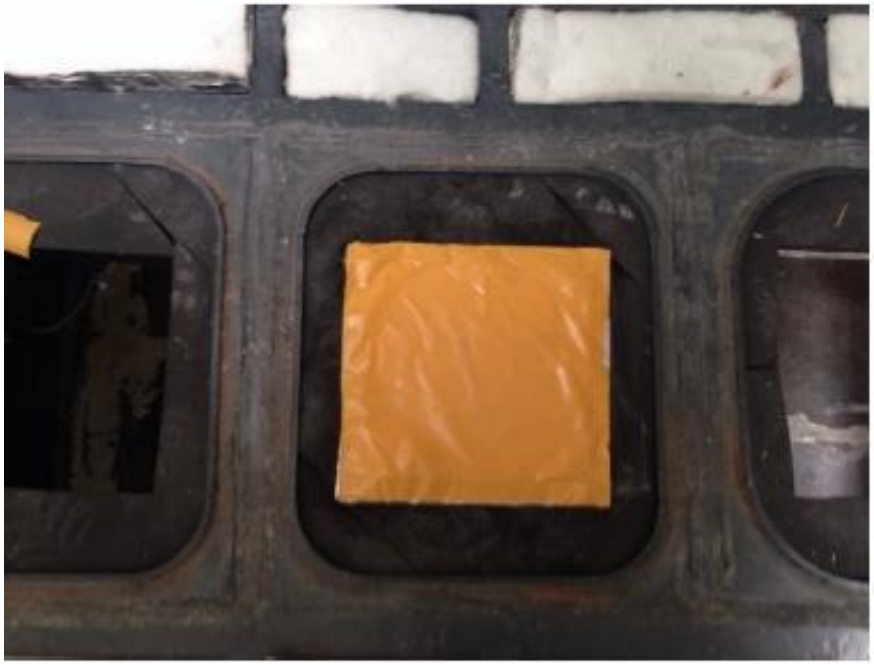
Under floor Treatment





Material is combination composites including acoustic polyester. It's function is thermal and acoustic performance at low weight engine bay noise, road noise, gear noise.

Hatches



Material is combination foam and barrier composites. The function is preventing noise leakage in through sensitive inspection hatches, engine high frequency noise.

Rear Module



Material is well developed acoustic polyester. Function of this material at this region is reducing rear openness and noise leakage from engine bay.


Thanksgiving