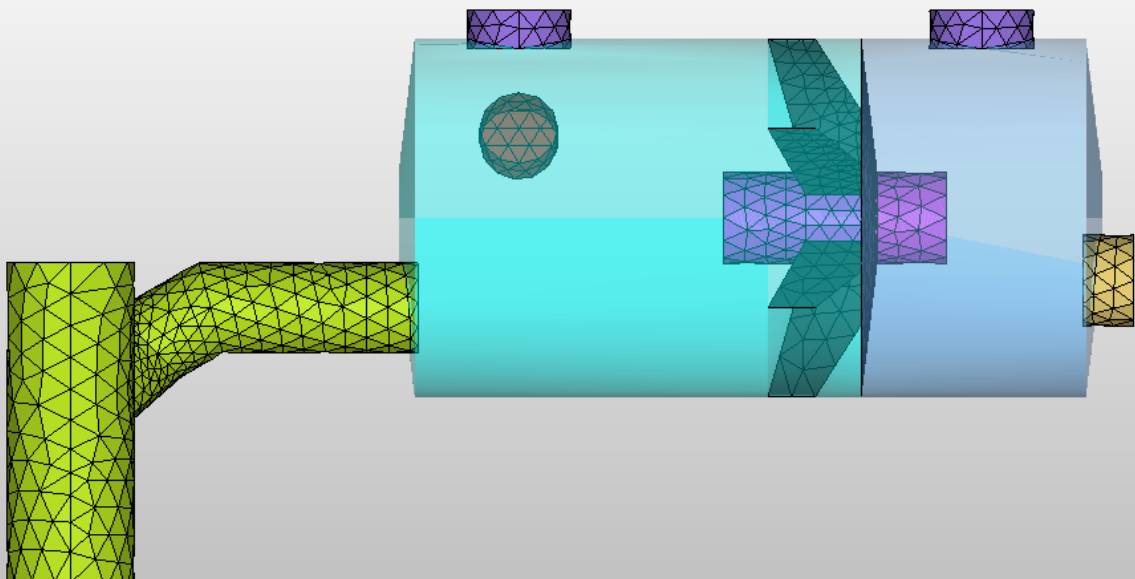


VTT technical research centre of Finland

Finding the solution to a noise problem



With the help of Actran, it was possible to completely understand this particular noise problem, which resulted in a simple and effective solution.

A night time noise complaint was issued from the residential area near one of Wärtsilä's main large 4-stroke medium speed engine factories located in downtown Vaasa. This factory produces the Wärtsilä 32 ship engine which provides higher unit power, enhanced fuel consumption, significantly reduced componentry and integral computer control to a fiercely competitive sector of the engine business.

The Wärtsilä facility produces about 500 engines per year and every engine is subjected to a test run. An investigation found that the likely source of the intolerable noise was from the exhaust from a W6L32E engine 1000 hour endurance test which was running continuously at 750 rpm and full load.

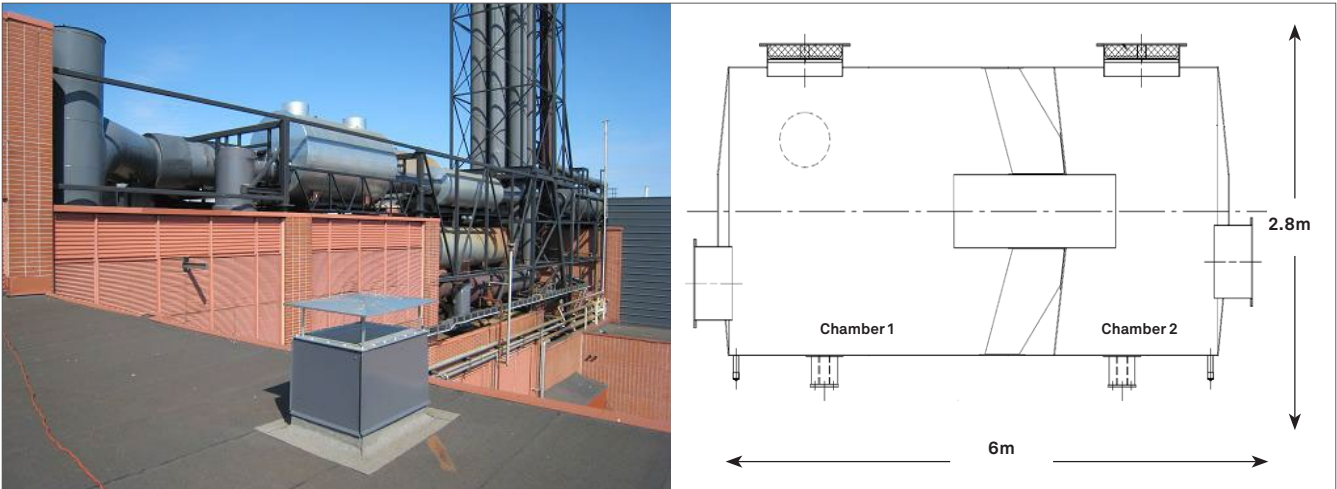


Figure1: 1st stage exhaust silencer

Challenge

An environmental noise study was conducted in the middle of the night when the test engine was running, with measurements taken at three locations between the test facility and the nearby residential area. Sound pressure level measurements indicated a peak in the sound spectrum at the 100 Hz 1/3 octave band at approximately 94 Hz in narrowband, which corresponds to the crankshaft rotation frequency (CRF) order of 7.5. Typically, the exhaust noise of the W6L32E engine should have the highest peaks at CRF orders 3 and 4.5. The measured noise was found to be well under the night time environmental noise limit. The annoyance levels were presumed to be high because of the dominant half order modulated low frequency noise components.

The exact cause of the 100 Hz 1/3 octave band noise was investigated by additional measurements taken near the engine exhaust system, located on the factory roof. High noise levels were noted near the 1st stage silencer (Figure 1) which is a double expansion chamber reactive silencer. Measurements were taken at several points at a distance of 1 m from the silencer surface. It was discovered the noise peak in the 100 Hz 1/3 octave band dropped more than 10 dB when the engine load went from 100% to 75% while the total noise level dropped by nearly 8 db. Speed sweeps were performed under varying loads to determine the resonances of the entire exhaust system. The primary peak in the measured sound pressure curves occurred at 94 Hz for 100% engine load and 90 Hz for 75-80% load.

Solution/validation

“Wärtsilä requested that we use Actran to address this problem because they wanted to evaluate the software’s effectiveness in solving vibro-acoustic problems,” said Erin Komi, Research Scientist for VTT Technical Research Centre of Finland who performed the simulation. Actran software was used to create a vibro-acoustic model of the silencer (Figure 2) including both internal and external air volumes as well as infinite elements for sound radiation computations. The mesh had 23.4k nodes. Either unit velocity or realistic pressure excitation was applied at the silencer inlet and a non-reflecting infinite duct boundary condition was applied at the silencer outlet. A zero-admittance boundary which characterizes the surface as a rigid wall was applied at the laboratory roof. Field points were positioned in and around the silencer for comparison with physical measurements.

Initial simulation results indicated the occurrence of a longitudinal standing wave mode in the first chamber at 75 Hz and a cross-channel mode in both chambers at 106 Hz. The primary acoustic resonances predicted by the model matched theory extremely well but failed to explain the source of the 94 Hz noise (Figure 3). It was noted however that a curved duct leading to the silencer inlet was of a length that could potentially have a first axial resonant frequency near 94 Hz. The finite element model was thus expanded to include both a 4.2 m vertical duct and the bent inlet side ductwork (Figure 4). Sharp peaks were still seen at 75 and 107 Hz but now a peak at 94 Hz

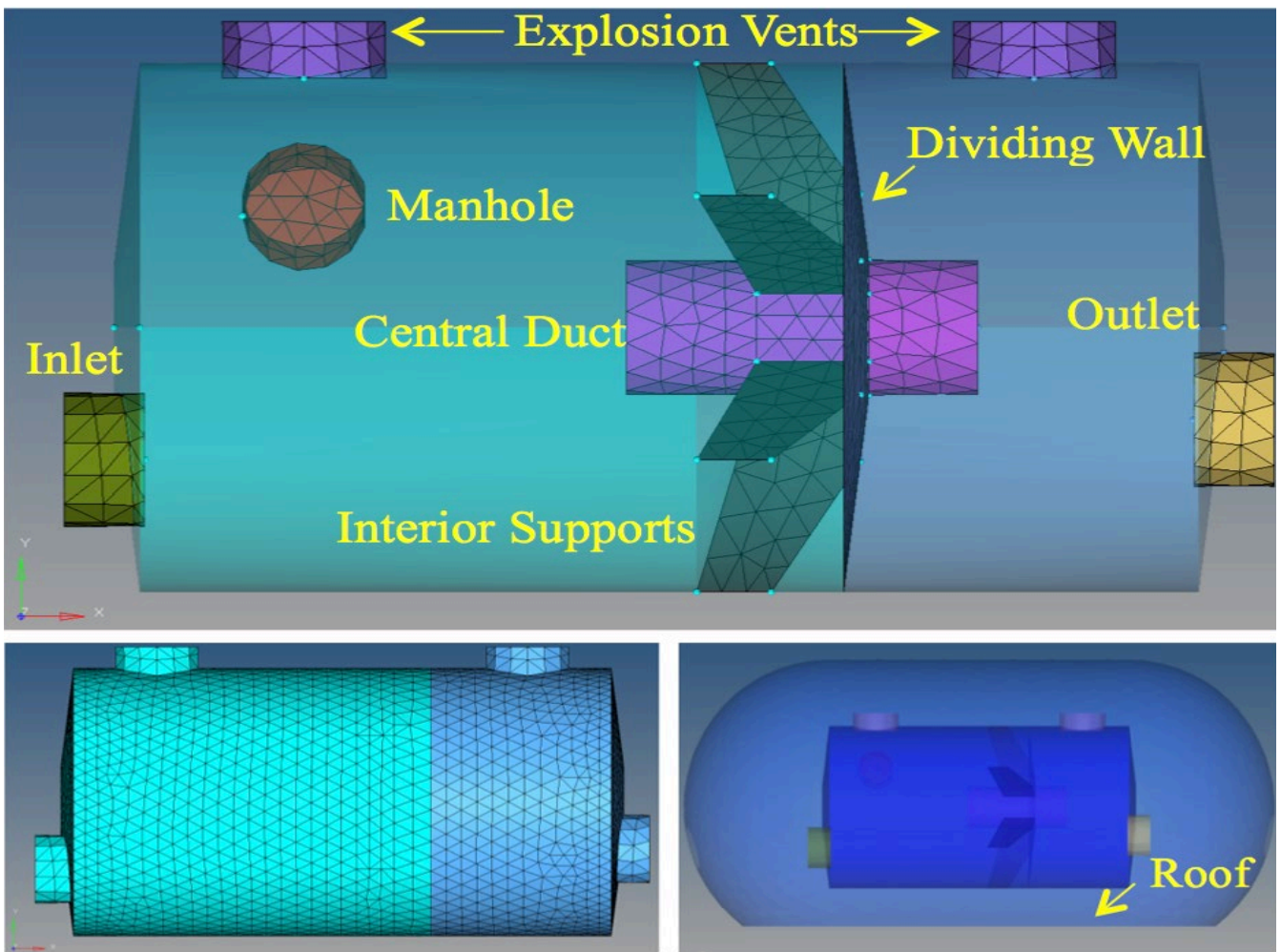


Figure 2: Original Actran vibro-acoustic model



Actran allows us to easily modify the model and re-run the analysis to determine the impact of a change .. when the original model did not shed light on the problem, we expanded the model to include the ductwork and quickly identified the root cause”

Erin Komi,
Research Scientist for VTT Technical Research Centre

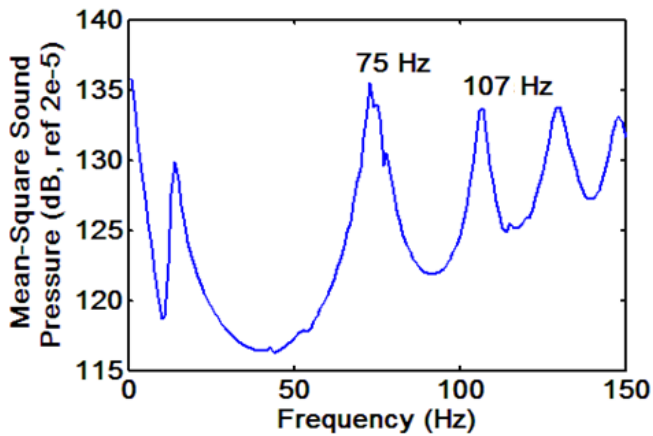


Fig. 3: Mean-square sound pressure in chamber 1

Key highlights:	
Product:	Actran
Industry:	Shipbuilding and Machinery
Benefits:	<ul style="list-style-type: none"> Accurate vibro-acoustic modeling of exhaust gas pipe system Reduction of environmental sound levels with minimal physical testing

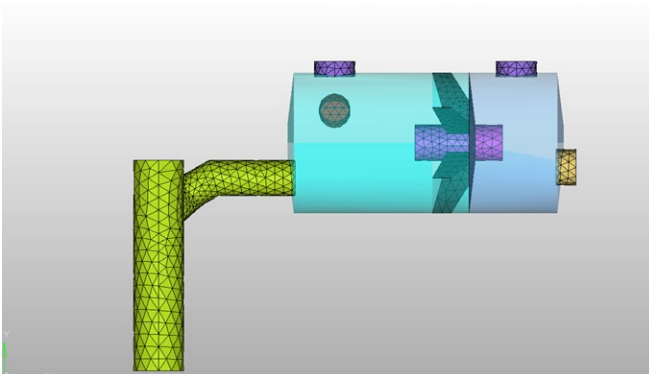
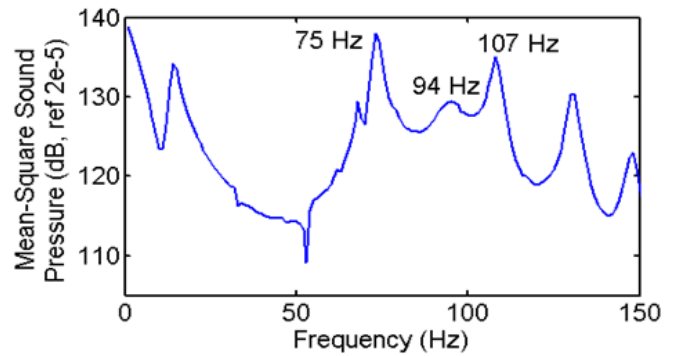


Fig. 4: Modified Actran model and mean square sound pressure in chamber 1



was also clearly visible (Figure 4). The peak at 94 Hz was not as sharp as those associated with the actual silencer resonance, most likely because the associated standing wave is strongly coupled to the vertical duct, causing higher apparent damping.

“While physical measurements only provide sound levels at a finite number of points, Actran provides detailed predictions throughout the simulation domain (Figure 5),” Komi said. “Actran also allows us to easily modify the model and re-run the analysis to determine the impact of a change. In this case, when the original model did not shed light on the problem, we expanded the model to include the ductwork and quickly identified the root cause.”

Extending the silencer inlet by 1.4 m to the centerline of the first chamber was proposed as a solution to the noise problem (Figure 6). Lengthening the horizontal ductwork leading to the silencer changes the resonant frequency so it no longer matches the engine order at 94 Hz. Second, the extended inlet lies at approximately the nodal line of the first longitudinal and cross-channel modes of the first chamber, substantially reducing the effects of both modes. The simulation predicted that this change would reduce the sound level at 94 Hz by 7 dB and that significant reductions would also be made at frequencies near 75 and 106 Hz (Figure 6).

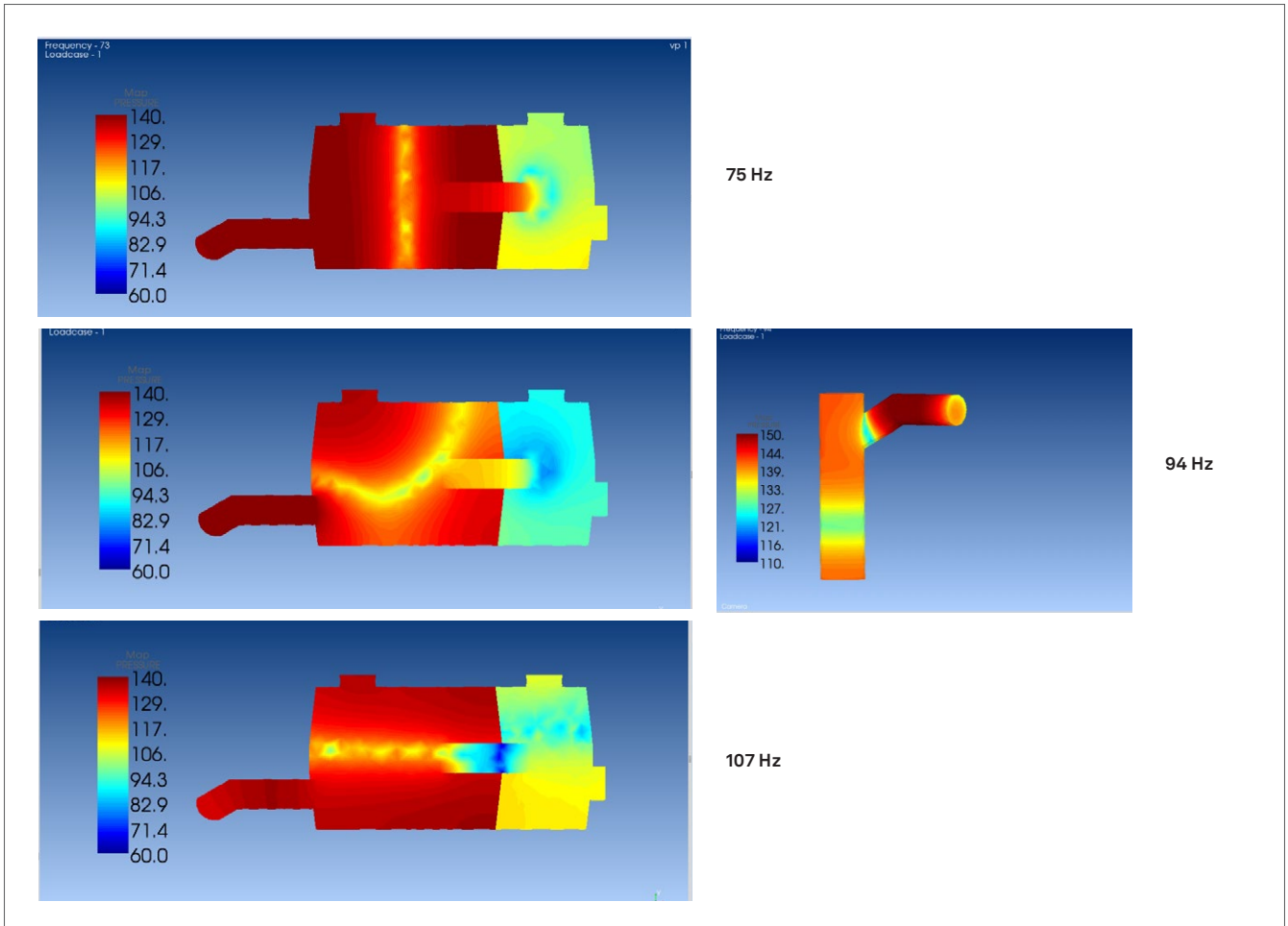


Fig. 5: Sound pressure colormaps (dB) showing pressure distribution inside the silencer at 3 frequencies

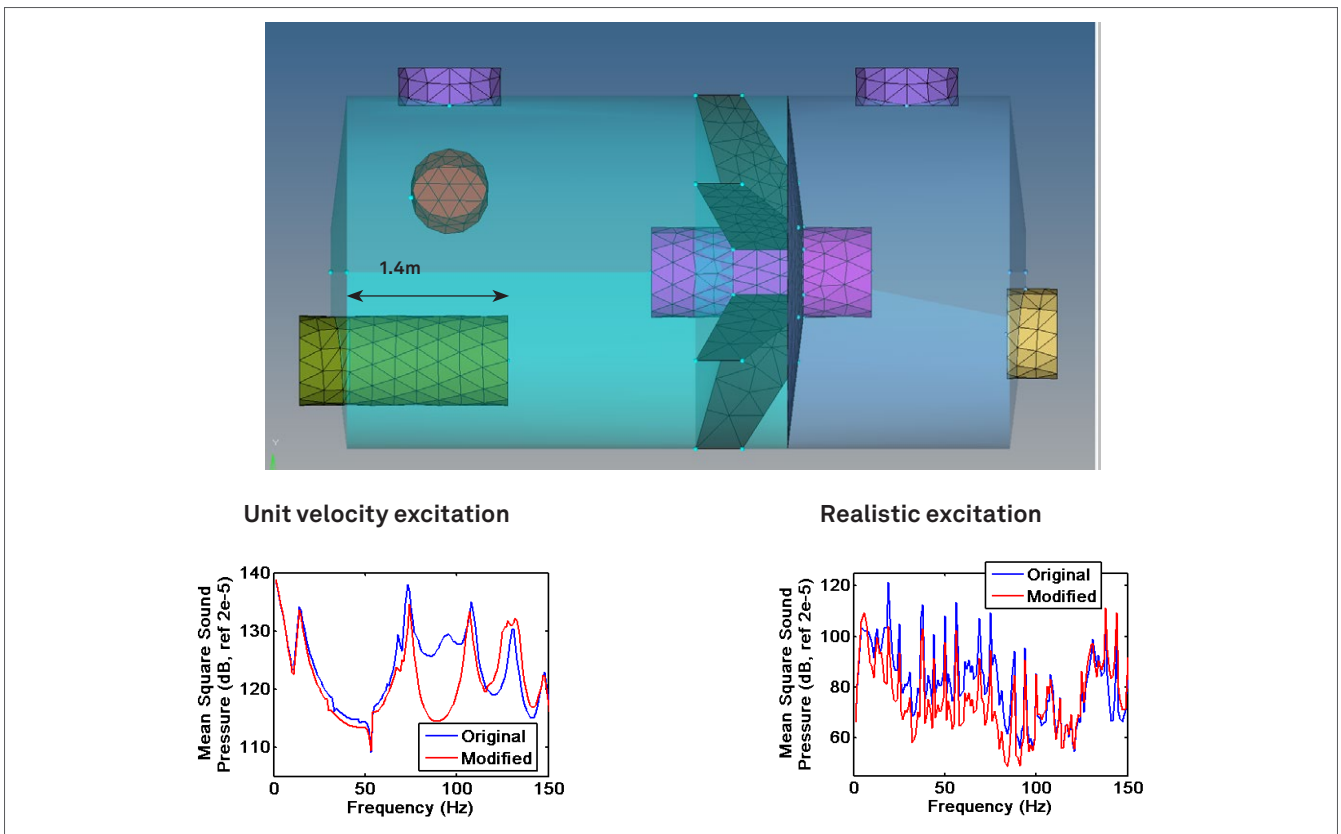


Fig. 6: Simple suggested silencer modification and simulated mean square sound pressure in first chamber for original and suggested design for applied unit velocity and realistic pressure excitations

Results

The physical silencer was modified to match the changes made to the Actran model and sound pressure level measurements were repeated. The final measurement results showed that the modified silencer reduced noise in the problematic 100 Hz 1/3 octave band by 20 dB and total noise was reduced by 10 dB (Figure 7). With the help of Actran, it was possible to completely understand this particular noise problem, which resulted in a simple and effective solution.

About VTT technical research centre of Finland

VTT Technical Research Centre of Finland is the biggest applied research organization in Northern Europe. VTT employs and combines a wide range of world class technologies and creates innovations in delivering applied research services that improve its clients' competitiveness and competence. VTT is a part of the Finnish innovation system under the domain of the Ministry of Employment and the Economy.

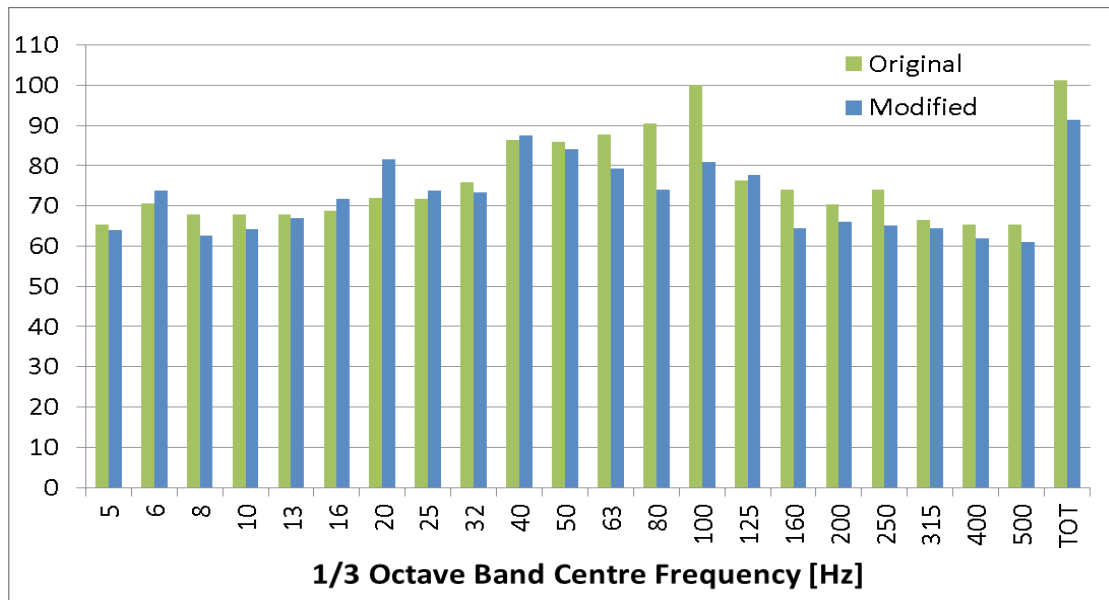


Fig. 7: Sound pressure measurements for original versus modified design



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