

of 5-10 dB(A). This is very challenging and cannot be reached without extensive improvements to the engine, as well as to the engine room.

Another complication with regard to noise limits is the fact that many yards and/or shipowners express the noise specification for the engine in terms of sound pressure level. If the verification of the sound pressure level is carried out by measurements in a test cell, the sound pressure level in the actual engine room may, because of differences in the acoustical properties of the test cell and the engine room, be considerably higher. Differences of up to 3-5 dB(A) have been observed.

Prediction of noise levels

The noise level is dependent on a number of factors, such as the strength of the noise source(s) and the acoustic properties of the room. The mechanisms are very complex, but traditional room acoustics theories give some illustrative, simple, and useful formulas.

One of the most well known theories determines the relationship between the noise level in a room (L_p), the sound power (L_w) of the source(s), the reverberation time (T) of the room, and the volume of the room (V):

$$L_p = L_w + 10 \log(T) - 10 \log(V) + 14 \text{ dB}$$

- L_p = sound pressure level (dB, re 20µPa)
- L_w = sound power level (dB, re 10⁻¹² W)
- T = reverberation time (seconds)
- V = volume of room (m³)

The noise level is directly proportional to the *sound power* of the source(s). Furthermore, the noise level decreases with a shorter reverberation time and a larger volume. The reverberation time is a measure of the absorption in the room, where a room with lots of absorption has a short reverberation time.

The above formula is based on the diffuse field theory (i.e. the noise level is the same in all positions and directions within the room) and contains a number of assumptions. As such, it can give useful information on the average noise level in a room, but is too simplified

to accurately predict the noise from an engine in a realistic engine room scenario.

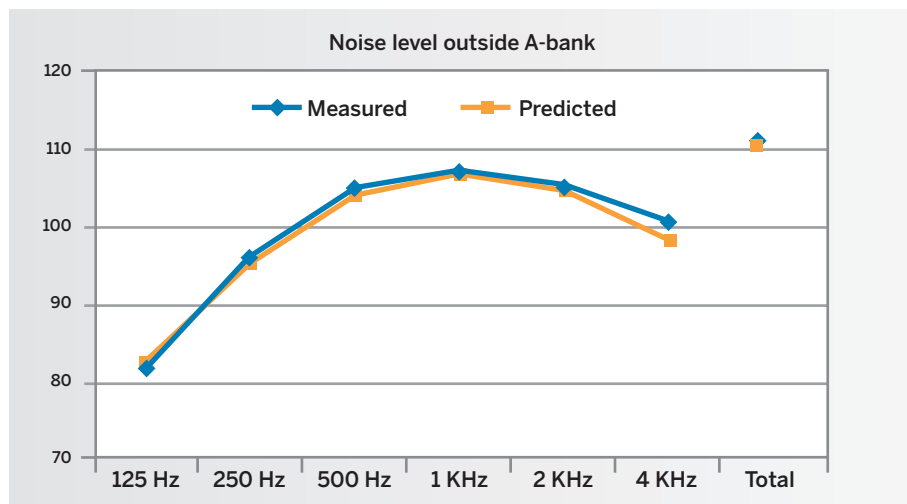
A more advanced method for studying noise in engine rooms is *the ray tracing method*. A large number of rays are sent out in various directions from each source and “traced” around the room as they are reflected against the surfaces in the room. Each time a ray is reflected, it loses energy according to the absorption coefficient of the surface. Additionally, the “roughness” of the area determines how the ray is reflected. The sound pressure level at any position in the room is estimated by a summation of the energy levels of the rays passing close to the receiver.

In the present study, various aspects of engine noise in engine rooms have

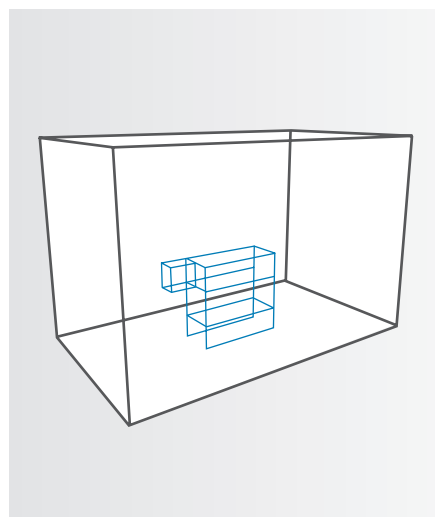
been studied using the prediction tool Odeon¹, which is based on the ray-tracing theory combined with image-source techniques. An accurate 3D model is made of the engine and the room. Each area is described by absorption properties, as well as by scattering coefficients. The engine is modelled as several area sources, where each area of the engine is assigned an outgoing sound power level. Calculations are carried out in 125-4000 Hz. octave bands.

Verification of model

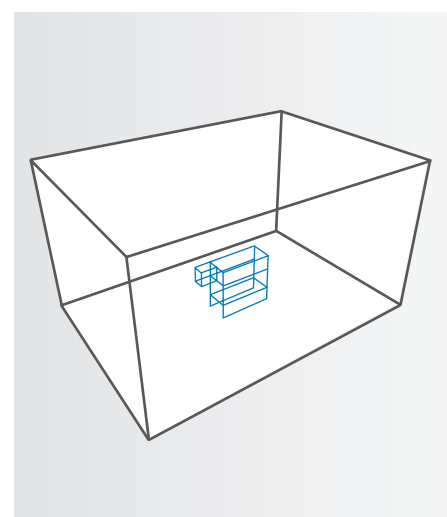
To verify the prediction strategy, a model was made of a 16-cylinder in-line Wärtsilä 32 engine installed in a test cell, as shown in Figure 1. →



■ Fig. 2 – Verification of prediction method.



■ Fig.3 – Model of engine in a “small room”.



■ Fig. 4 – Model of engine in a “large room”.

¹ Odeon has been developed by Acoustic Technology at Denmark Technical University. The company Odeon A/S is owned by 5 consulting companies including ØDS.

For the selected engine, detailed measurements of the sound power from various parts of the engine were made. The obtained sound power levels were then used as input to the Odeon model exactly as measured. All areas of the test cell and engine were assigned realistic absorption coefficients.

In order to verify the model, the predicted sound pressure levels were compared to actual measured sound pressure levels in the test cell. An example of a comparison of the noise level outside the A-bank is shown in Figure 2.

For the shown position, excellent results were obtained. In general, it was found that satisfactory results were obtained for noise levels as well as for the reverberation time. The situation in the test cell is very similar to an engine room onboard ship. It can thus be concluded that the used prediction strategy can accurately model the noise from an engine in an engine room.

Study of effect of volume and absorption

The developed prediction model was used to study the effect of the volume and absorption properties of the engine room. The same engine (with the same sound power) was modelled in a “small” engine room ($V \approx 1000 \text{ m}^3$) and a “large” engine room ($V \approx 3000 \text{ m}^3$) as shown in Figures 3 and 4. To illustrate the effect of the absorption of the room, simulations were made with absorption applied to the two largest walls parallel to the engine. Measured absorption coefficients for a material consisting of 60 mm absorption behind a perforated steel panel, as is typical in a ship’s engine room, were used.

Results

The results are shown in Table 2, where the effect of the volume and the applied absorption on reverberation time (T) and noise level (L_{pA} , dB re $20 \mu\text{Pa}$), is shown. The indicated noise level is the noise level outside the A-bank.

The results clearly demonstrate that the noise level in the engine room varies considerably with volume. The difference in noise level between the small engine room ($V \approx 1000 \text{ m}^3$) and the large engine room ($V \approx 3000 \text{ m}^3$) is 4 dB.

For the absorption, the prediction shows that a reduction of between 4-7 dB(A) can be obtained by the use of additional absorption. It should be noted that the studied case is optimistic since 100%

	T	L_{pA}
Small room No absorption	$\approx 2 \text{ s}$	112 dB(A)
Large room No absorption	$\approx 3 \text{ s}$	108 dB(A)
Small room Absorption on 2 walls	$\approx 0.8 \text{ s}$	105 dB(A)
Large room Absorption on 2 walls	$\approx 1.3 \text{ s}$	104 dB(A)

■ Table 2. – Simulated effect of volume and absorption on noise level in engine rooms.

of the two largest walls were covered by highly absorbing material. For a more realistic case with only partial coverage, the reduction will be significantly less.

Reducing noise by engine modifications

Wärtsilä has several internal R&D projects where possible measures to reduce the noise from the engine are being studied:

- Use of low-noise components
- Use of low-noise engine types (gas)
- Reduction of internal noise mechanisms
- Improved design of engine covers
- Enclosure of top part.

Reducing noise by modifications to the room

A detailed investigation of noise reducing measures applied to the engine room itself is beyond the scope of the present study. However, the predictions that were carried out clearly identify a number of promising measures that are proposed for further investigation:

- Optimizing the design of the engine room (volume)
- Application of absorption materials
- Optimizing the location of “working areas”.

CONCLUSION

It has been concluded that a noise reduction of 5-10 dB(A) is necessary in order to meet the current strictest noise limits for engine rooms. In general, the noise level in the engine

room is strongly dependent on:

- Sound power of the engine
- Measurement position in the room
- Volume of the room
- Absorption properties of the room.

The sound power of the engine is the only parameter that can be influenced directly by engine manufacturers. As such, it is preferable to specify the allowable noise level of an engine in terms of sound power, and not in terms of resulting sound pressure level, since this is dependent on the engine and the properties of the engine room in which it is installed.

It is foreseen that by modifying the engine only, the noise level in the engine room can be reduced by 5 dB(A).

To achieve further reductions, noise-reducing measures must also be applied to the engine room.

It has been demonstrated that the noise level from the engine in an engine room can be accurately predicted using state-of-the-art prediction tools. This gives new opportunities to understand the cause, for example, of high noise levels in certain areas, as well as being able to determine the improvements necessary to the room in order to meet a specified noise level. The numerical examples shown on expected noise reduction as a result of increasing the volume and/or adding absorption, can hopefully serve as a starting point for future discussions on necessary modifications.●