PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Evaluation of range standards for underwater radiated noise in beam aspect

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ABSTRACT

The underwater radiated noise levels of a small naval vessel were measured at the Heggernes deep water sound range. The data evaluation and analysis were performed in accordance with the NATO standard STANAG 1136 and the ISO 17208-1 standard. Both standards describe procedures for the determination of underwater radiated noise levels of ships in beam aspect on a deep water sound range.
To assess and compare the results of both standards, the hydrophone configuration at the Heggernes range was utilized at various depth settings. Measurements were made of the ship in two different ship conditions (machinery states) and a variety of sailing speeds. Some of these measurements were repeated a large number of times. The resulting 3rd octave based spectra are used to compare the two procedures.

Keywords: Underwater Sound, Ship Noise, Acoustic Signature

1. INTRODUCTION

The ISO 17208-1 (1) is a relatively new standard for measuring the underwater sound of ships. The standard describes the Underwater Acoustics Quantities, the required hydrophone layout, the measurement procedures and the analysis specifications. The standard is developed for the determination and evaluation of the underwater radiated noise levels of ships in relation to sea life which is jeopardized by increasing world-wide ship traffic and noise pollution. Accurate measurement procedures are needed to compare the noise levels produced by ships.
In addition to the ISO standard, there is the STANAG 1136 standard for measuring the radiated noise levels in beam aspect of naval platforms in relation to sonar detection.
This paper is meant to investigate the practical and technical use of the ISO 17208-1 in comparison with the STANAG 1136 (2), evaluated and compared to the actual procedures and available infrastructure at the Heggernes deep water sound range.
For this evaluation, the acoustic data of a measurement trial with a small naval vessel at Heggernes was made available. A number of runs with speeds of 5 and 12 kts were carried out in accordance with the requirements of the different procedures.
Only the main differences with respect to the hydrophone layout and the data window length (DWL) for the determination of the radiated underwater noise levels will be addressed here.

2. SOUND RANGE

The Heggernes sound range is situated in Norway near the city of Bergen. The main objective of the range is to determine the underwater radiated noise levels as function of all relevant ship parameters, such as speed and diving depth without the interference of background noise and reverberations due to reflections of walls and the sea bottom. An evaluation of the performance of the range can be found in (4). The Herdla fjord was chosen as a suitable location to fulfil these requirements. The fjord has a depth of almost 400 meters and a width of more than 1200 meters at the measurement location. The

length of the Herdla fjord is about 16 km. The wet end of the range equipment consists of three cables operated by individual winches. Each cable is equipped with 3 hydrophones at fixed positions. The depth of the hydrophones is adjustable by the hydraulic winch system ashore. The hydrophones are connected through a junction box to the range house by fiber and copper cables. The cables are kept vertical by a main buoy and small buoys between the hydrophones.
One of the cables is positioned at the track line and is used to measure the radiated noise levels under the ship in keel aspect. The other cables are positioned North and South from the track at a distance of approximately 100 meters. These hydrophones are used to measure the radiated noise levels in beam aspect.
The ranging can be performed in two directions (East and West). A Differential Global Positioning System (DGPS) is used for the determination of the exact position of the ship in relation to the track line and the hydrophones.

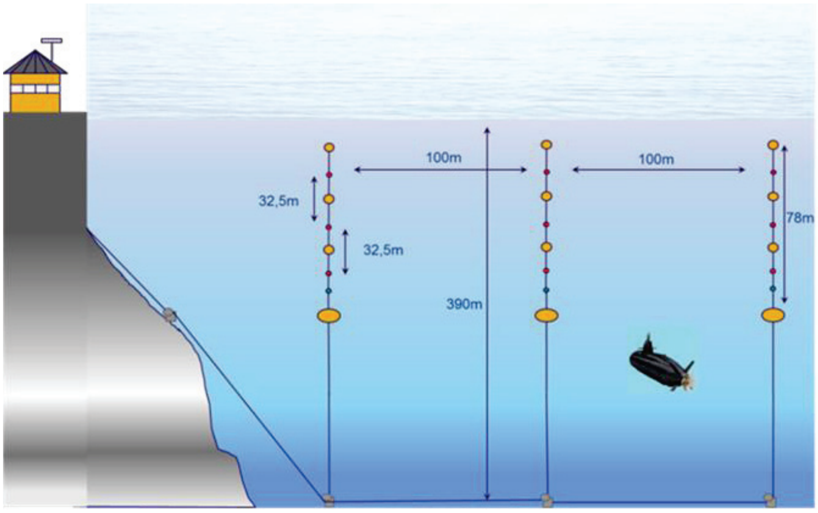

Figure 1: Sound range hydrophone configuration

3. STANDARDS VERSUS HEGGERNES

Both standards describe a procedure to measure the 1/3 Octave Root Mean Square Sound Pressure Level re 1 µPa, measured in the far field and normalized to a reference distance of 1 m by means of spherical propagation correction. The results of these measurements is called 'Radiated Noise Levels' (RNL).

3.1 Hydrophone configuration

The standards require that only calibrated omnidirectional hydrophones are to be used. The Heggernes sound range is equipped with regularly calibrated hydrophones according to IEC 60565:2006 (5).
According to the ISO standard, the passing distance between the ship and the hydrophone at the Closest Point of Approach (CPA) should be at least 100 m, in order to realize far field conditions which assumes that the radiating sound sources on the ship can be considered as a point sources. The beam aspect hydrophones deployed at the Heggernes sound range are positioned at 100 meters from the track line.
The STANAG 1136 requires only one hydrophone at a depth between 9-36 m. The underwater radiated noise levels in accordance to ISO 17208-1 should be measured at 3 different aspect angles which means that the required water depth of the range location is determined by the lowest hydrophone at a nominal depth of 100 meters. The required minimal water depth is then 150 meters.
For the measurement trials the South and North hydrophones were positioned at a depth of 30, 62.5 and 95 meters. This is almost exactly in line with the requirements of both standards.
Table 1 shows that the differences between the required and realized hydrophone configurations are less than 5 meters for the ISO standard.

Table 1: main differences between different standards

Topic	ISO 17208	STANAG 1136	Heggernes
Number of hydrophones	3	1	3x3
Hydrophone depth	@ 15° = 27 m @ 30° = 58 m @ 45° = 100 m	Between 9 m - 36 m	H-up = 30 m H-mid = 62.5 m H-low = 95 m
Data window angle (*Data window length*)	± 30° (*121 m*)	± 45° (*209 m*)	Ship length (*56 m*)
Distance correction at CPA	Sea surface	Nearest point on the hull	Nearest point on the hull

The results of the three hydrophones are averaged in order to smooth the variability caused by Lloyd's mirror surface image coherence effects. Figure 2 shows the ISO hydrophone specification along with the prescribed averaging equation (1).

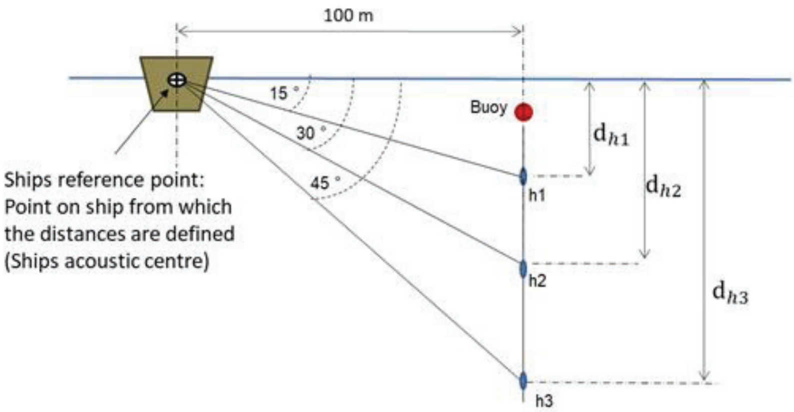

Figure 2: ISO hydrophone layout

$$L_{RN}(r) = 10log_{10}\left(\frac{10^{L_{RN}(r,h_1)/_{10\,dB}} + 10^{L_{RN}(r,h_2)/_{10\,dB}} + 10^{L_{RN}(r,h_3)/_{10\,dB}}}{3}\right) \quad (1)$$

Figure 3 shows the influence of Lloyd's Mirror on the radiation of a point source (180 dB) in a water depth of 4 meters for the different hydrophone depths at the sound range. The average of the three hydrophones in different depths is comparable with the levels at a hydrophone depth of 60 meters. Calculations are done by assuming a constantly moving point source near an ideal pressure release boundary, according to [3].

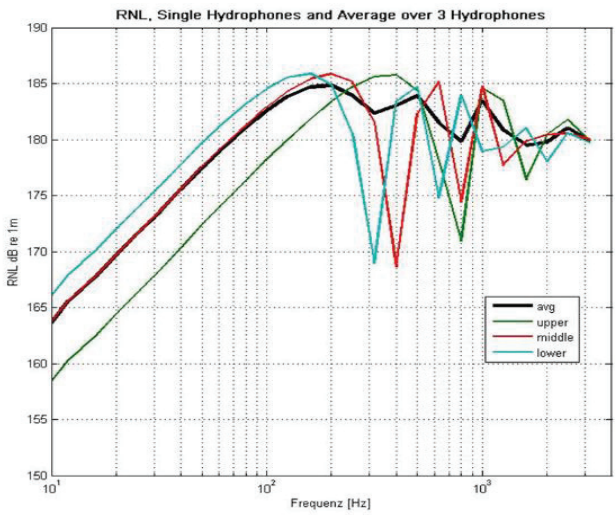

Figure 3: Influence of the "Lloyd's Mirror-Effect"

3.2 Data window length

The data window length (DWL) is defined by the distance at CPA and the data window angle (DWA) of ± 30°. Port and Starboard aspect underwater RNL are the energetic levels of all samples within DWL during CPA of the ship reference point. The ships reference point is located at ¼ ship length in front of the ship's stern.

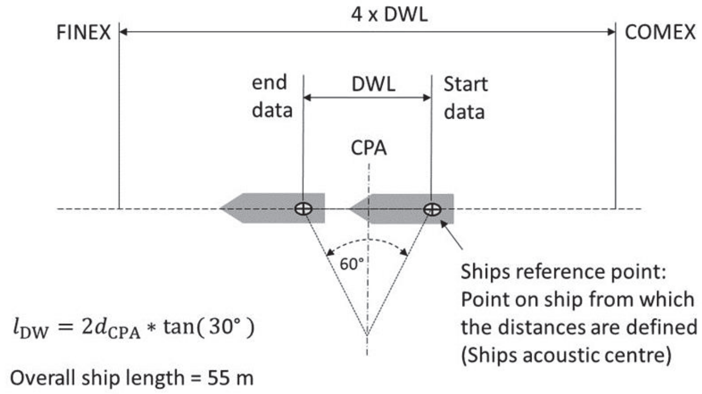

Figure 4: DWL

The STANAG 1136 does not clearly define a DWL. The radiated underwater noise levels should be analyzed over a DWA of ± 45° arc, with a passing distance of 100 meters this results in a DWL of approximately 209 meters. This large DWL is not useful for ships with an overall length between 50 and 150 meters. Range experiences have shown that a large DWL can lead to an underestimation of the RNL. The results of the RNL calculated with different DWL's for the hydrophones at a depth of 30 meters showed that a DWL related to the length of the ship is more suitable. The average differences calculated over the complete frequency range between the RNL on the basis of STANAG and the procedure at Heggernes or ISO is approximately 1 dB, see Figure 5.

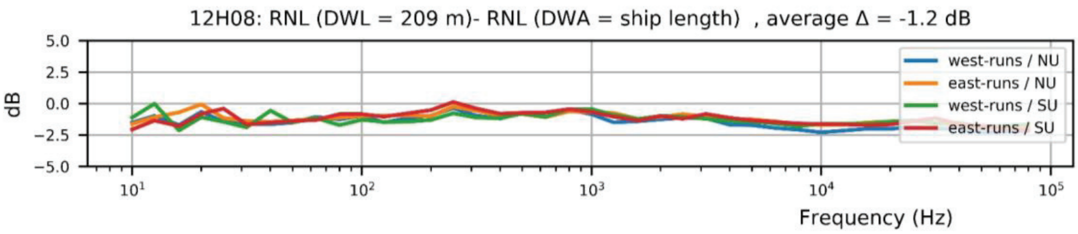

Figure 5: effect of DWL

3.3 Noise measurements

The available naval vessel carried out a large number of runs in the east and west directions with fixed operational conditions at 5 and 12 kts. The number of runs, average speed and track deviation are presented in Table 2. The average (ground) speed in the west direction was slightly higher for both conditions due to the local current and wind direction and influenced the radiated noise levels. Thus, average noise levels for port and starboard aspect where determined for both headings, respectively. The average track deviation was approximately 2.5 meters for the two conditions and headings.

Table 2: Run statistics

Heading	Run statistics	5H01	12H08
East runs	Number of runs	6	9
	Average speed (kts)	4.6	11.8
	Average track deviation (m)	2.4	2.9
West runs	Number of runs	7	10
	Average speed (kts)	5.9	12.4
	Average track deviation (m)	1.9	2.3

The sea state and background noise levels were sufficiently low during the trial program. The signal to noise ratio in most frequency bands was at least 10 dB.

On-board sensors located near the main machinery and hydrodynamic noise sources of the ship confirmed steady state and repeatable conditions for all runs in east and west directions. Also, the underwater noise data at the different single hydrophones show repeatable results with an average standard deviation of 2 dB.

The noise distribution during the track shows that the maximum levels are reached inside all used DWL's. Starting recording at a large distance before CPA is useful to confirm that a sufficient signal to noise ratio was established as shown in Figure 6.

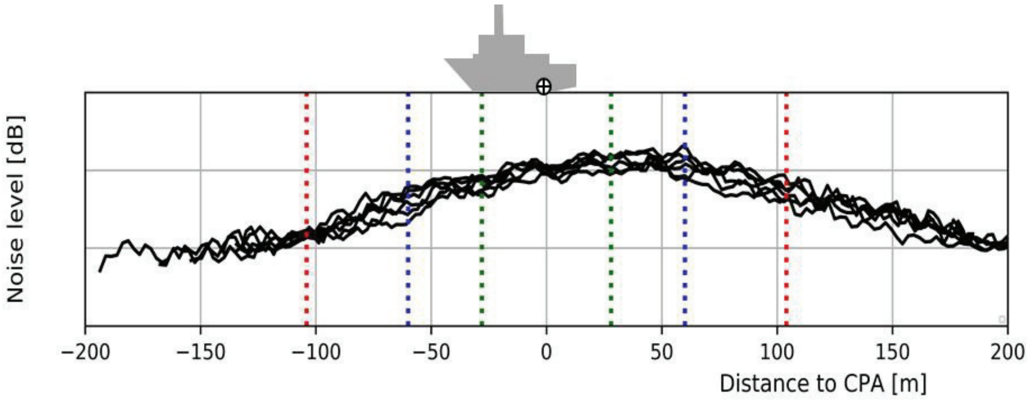

Figure 6: Used DWL's and noise distribution during runs with 12 kts

3.4 Evaluation and comparison

Table 3 gives an overview of the hydrophone settings of the range in relation to the different procedures and DWL's used for the determination of the RNL's

Table 3: used hydrophone depth and DWL's

	Hydr depth (m)	DWL (m)
ISO	30 / 62.5 / 94	121
STANAG	30	209
Heggernes	30	56

The differences between the RNL based on ISO and STANAG are presented in Figure 7. The ISO average RNL levels of 3 hydrophones are in all frequency bands higher compared to the RNL of a single hydrophone based on the STANAG standard. In the lower frequency bands this difference is related to the Lloyd's mirror effect and in the higher frequency bands only to the large DWL in STANAG.

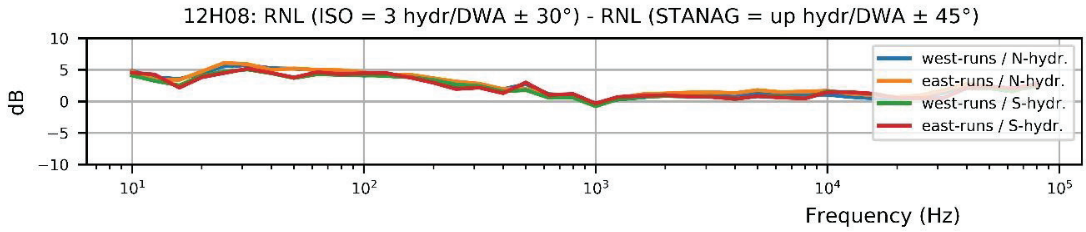

Figure 7: RNL differences between ISO and STANAG

These differences reduce to almost zero (see Figure 8) when measurements are carried out with a single hydrophone at a water depth of 60 meters, which corresponds to an aspect angle of 30° , and a smaller DWL conforming the ISO standard or the procedure used at Heggernes.

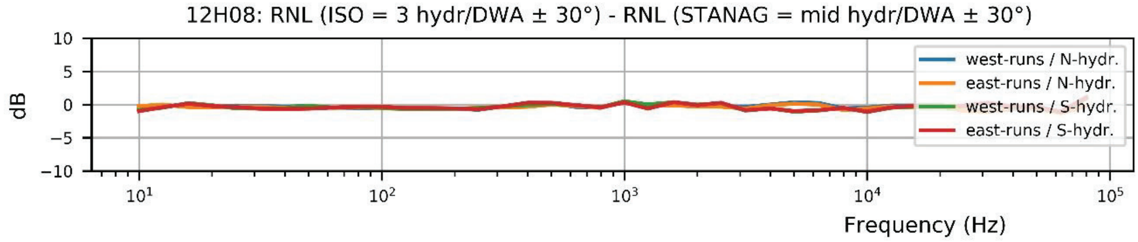

Figure 8: RNL differences between ISO and modified STANAG procedure

4. CONCLUSIONS

The Heggernes sound range has a hydrophone layout which complies with the specifications of the relatively new ISO 17208-1 standard for vessels up to an overall length of 100 meters.

The DWL suggested by STANAG is too large for small ships and leads to 1 dB lower RNL compared to the DWL defined by ISO and used at Heggernes. Thus, for small ships, the DWL should be related to the ship length.

RNL measured with a single hydrophone at shallow water depths, as specified by STANAG are lower, compared to the ISO 17208 standard due to the Lloyd's Mirror effect. RNL measured with a single hydrophone at 60 meters depths are comparable to the RNL of ISO.

Both, the ISO and STANAG procedures should be reconsidered with respect to the definition of the DWL for small ships. A DWL related to the ship length, especially for small ships, is a more suitable approach. In order to achieve comparable RNL with ISO, measurements with a single hydrophone should be carried out at an aspect angle of 30° which corresponds to a measurement depth of circa 60 meters at a CPA distance of 100 meters.

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