STØYVURDERING

FOR

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Acoustical assessment of a coastal research vessel

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Task and objective: Assessment of underwater noise radaition for a coastal research vessel

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Reference to part of this report which may lead to misinterpretation is not permissible.

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Table of contents

1 INTRODUCTION

A new coastal research vessel is to be designed for the Institute of Marine Research in Norway by LMG Marin. The preliminary design of the vessel is assessed and discussed with particular focus on underwater noise radiation. The assessment is based on arrangement drawings, a specification (funksjonell kravspesifikasjon) an operational profile, a basic technical description of machinery and propeller as well as a selection of stream lines and pressure distributions derived by CFD.

Achievable underwater noise radiation levels have been assessed based on the early design proposal. Structureborne noise source criteria to match the achievable underwater noise radiation levels have been proposed.

Detailed hydro-acoustic analysis has not been performed, but the results should be sufficiently reliable to evaluate approximate noise emission levels if proper actions are taken during the detailed design process.

A noise control strategy outlining recommended analyses and working procedures is proposed.

This is a first preliminary evaluation without consideration of the actual propeller design. An updated assessment will be carried out when more data are available on the actual propeller design.

2 VESSEL PARTICULARS

Ship type	Coastal Research vessel
<u>Hull</u>	
Length, o.a. abt.	35.00 m
Length, p.p.	32.20 m
Beam moulded	10.00 m
Depth moulded	4.60 m
Draught (max.)	3.50 m
Frame spacing approx.	500 mm
Ship speed (maximum)	11.3 kts
Ship speed (service)	11.0 kts
Ship speed (eco sailing)	7.0 kts
Slow sailing	4.0 kts
Flag	NOR – Liten kystfart
Tonnage	< 499 GRT
<u>Main Diesel Engine</u>	
Make	TBD
Number of sets	1
Power	~749 kW
PTO/PTI	350 kW
Speed	1600 - 1800 rpm
Mounting	Resilient
<u>Gear</u>	
Type	2 speed , 244 rpm and 175 rpm on propeller shaft
<u>Diesel Generator</u>	
Make	TBD
Number of sets	1
Power	350 kW
Mounting	Resilient
<u>Harbour Generator</u>	
Make	TBD
Number of sets	1
Power	70 kW
Mounting	Resilient
<u>Propeller</u>	
Make	TBD
Number of	1
Number of blades	5
Type	Ducted CPP
Diameter	2100 mm
Speed	175 rpm / 244 rpm

3 NOISE & VIBRATION REQUIREMENTS

3.1 General

No concise requirements have been stated in the initial preliminary specification. It is, however, stated that the vessel should have as low as possible underwater noise radiation in the frequency range 20 Hz – 1 kHz by mounting rotating machinery resiliently. In addition, it is mentioned that the vessel should have low self-noise in the frequency range 1 kHz – 100 kHz for speeds up to 7 kts by ensuring that the propeller is kept cavitation free at least up to this speed.

"Fartøyet bør ha lavest mulig utstrålt støy til vann i området 20Hz til 1kHz, ved at roterende maskineri, pumper og lignende settes på dempere for å unngå overføring av vibrasjoner til skrog og bærende struktur.

Fartøyet bør ha lav egenstøy i frekvensområdet fra 1kHz og opp til 100kHz med inntil 7 knop hastighet for å få best mulig signal/støyforhold for egne hydroakustiske instrumenter, blant annet ved bruk av kavitasjonsfri propell.»

It is quite common that research vessels are required to have controlled noise radiation in the mentioned frequency ranges for several reasons, e.g.:

- Preventing disturbance to the natural distribution of fish.
- Preventing disturbance to sea mammals in the vicinity of the Vessel.
- Ensuring that acoustic instruments can be used to their maximum capability.

Generally, there are two types of formal requirements that may be applied to this type of vessel in addition to owner specified requirements as stated above. Viz. the ICES 209 recommendation and various voluntary class notations issued by the major classification societies, such as DNV GL. The latter type of recommendations has several levels of strictness that may be combined to suit special vessels not falling directly into one of the vessel groups that the requirements were developed for.

The most relevant SILENT requirements are shown and discussed below:

SILENT-R. This is the strictest set of requirements for a research vessel. The requirements are equal to the ICES 209-recommendations from the 25 Hz 1/3 octave band and upwards in frequency. Note that the ICES 209 requirements are stated in nominal 1 Hz bandwidth but are otherwise equal to the DNV GL SILENT-R requirements. These requirements were derived to primarily ensure comparative research results from different fishery research vessels. However, the strictness of the requirements is demanding and can only be achieved through use of dedicated noise reduced machinery such as double resiliently mounted diesel generators, direct drive noise controlled electric propulsion motors and highly tip offloaded propellers.

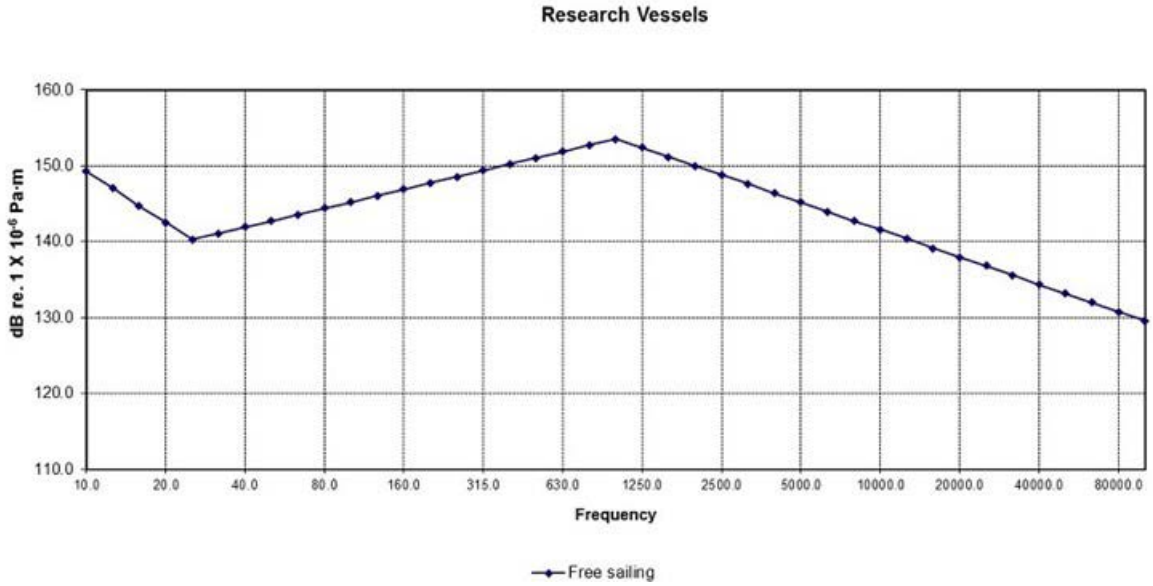

Figure no. 1, The DNV GL SILENT-R recommended max. noise levels presented graphically.

SILENT-A. This is a set of high frequency requirements which were derived to ensure good operational capability of acoustic transducers. The requirements are hence only covering the high frequency range between 1 kHz and 100 kHz. Since it only covers the high frequency range, it will mainly require a moderately noise-controlled propeller design. Ordinary resilient mounted diesel engines, generators and gears with tooth passing frequencies below 1000 Hz will normally be able to meet SILENT-A requirements. The requirements have been derived for two operational modus, but will only require the normal transit requirements to be satisfied unless thrusters will be required for acoustic operations.

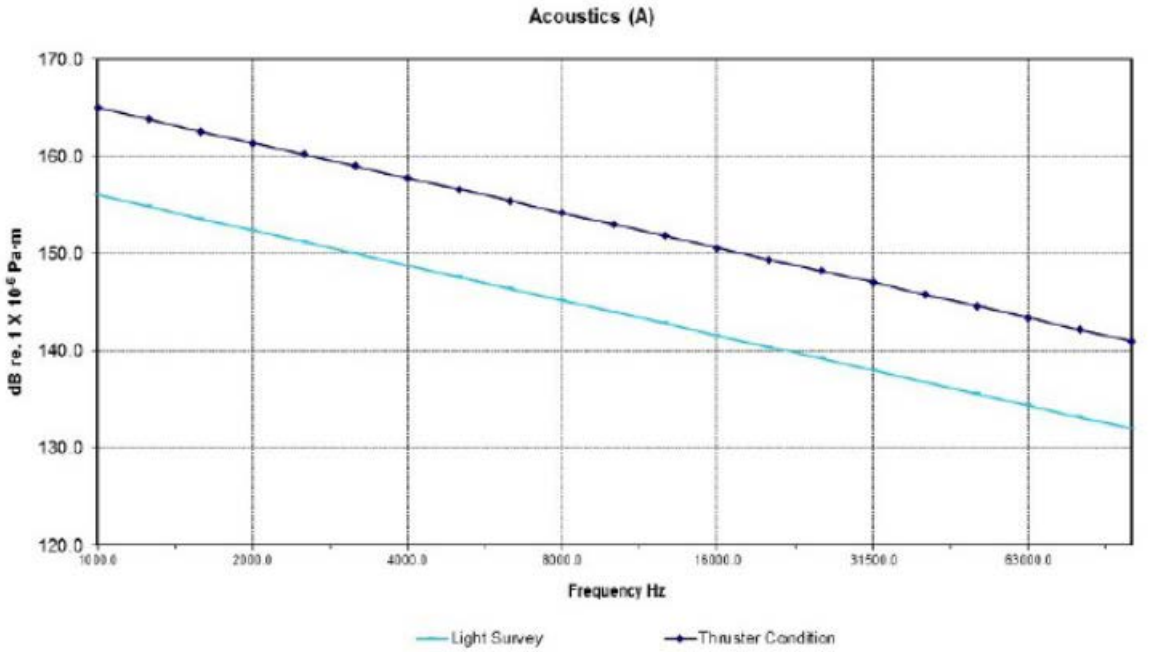

Figure no. 2, The DNV GL SILENT-A recommended max. noise levels presented graphically. Side thrusters condition (upper) and normal transit (lower)

SILENT-A requirements have been applied to many research vessels not directly engaged in fishery research. Often in combination with the SILENT-S requirements to ensure that excessive machinery noise radiation is avoided in the low frequency range.

SILENT-S. The purpose of these requirements is to ensure that seismic vessels towing heavy streamers are not emitting excessive low frequency noise and hence disturb recording of signals from their air guns. Hence, only the low frequency range is covered.

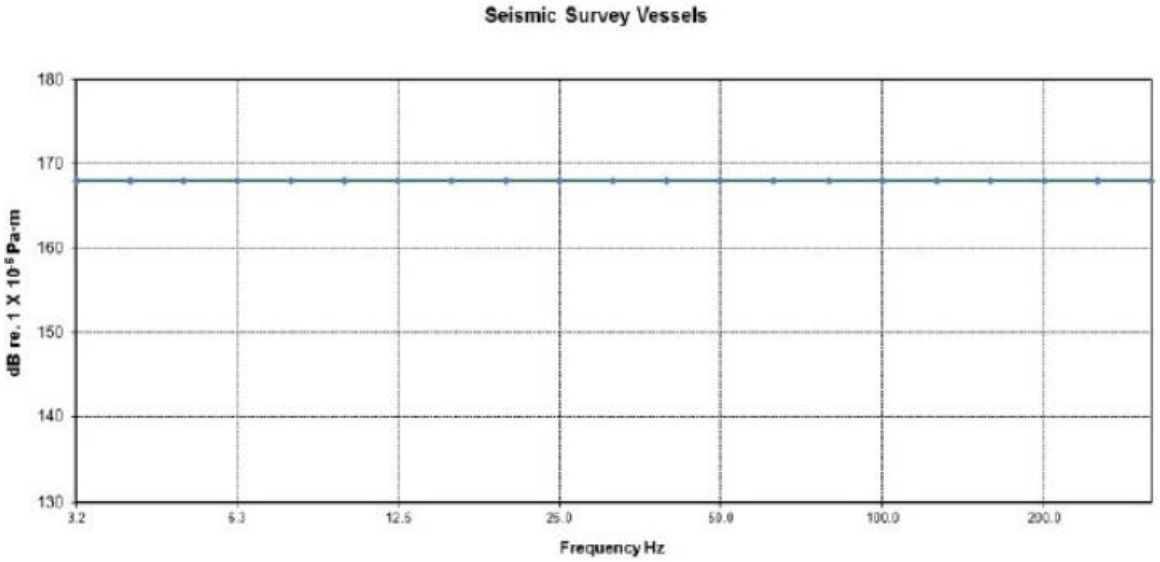

Figure no. 3, The DNV GL SILENT-S recommended max. noise levels presented graphically. In addition the overall rms noise level in the frequency range 3 – 300 Hz should not exceed 175 dB re. 1µPa·m

SILENT-F. Contains requirements aiming to ensure undisturbed catch for vessels engaged in fishery. The notation consists of two sets of requirements, one set for a light search condition and one set for heavy trawl towing. These requirements require noise-controlled propellers and otherwise normal resilient mounting of most mechanical machinery.

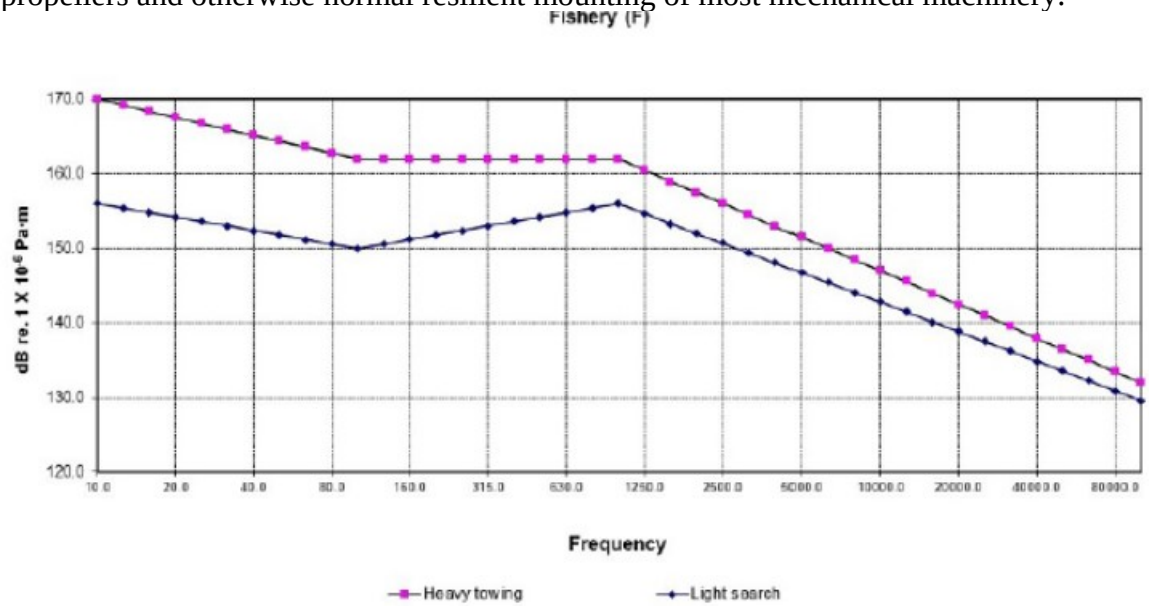

Figure no. 4, The DNV GL SILENT-F recommended maximum noise levels

3.2 Onboard noise and vibration

It is recommended that the onboard noise and vibration should comply with the requirements of the DNV GL Comfort Class COMF-V(3) sub notation Pt. 6 Ch 8 Sec. 1 on a voluntary basis. These requirements are equivalent to the IMO MSC 337(91) requirements which are mandatory for vessels of a gross tonnage of 1 600 and above. Even if these requirements are not mandatory for a vessel of the size considered here a good noise and vibration environment is important for crew recreation, communication, safety and general health considerations.

The Comfort Class noise requirements are shown in table no. 1 presented on the next page. Table no. 2 shows the noise requirements from IMO MSC 337(91), Code on noise levels. Vibration levels are recommended to be in compliance with the Comfort Class requirements shown in table no. 3.

The onboard noise and vibration requirements may be regarded as common requirements for this type of vessel. The noise and vibration reducing features which have to be integrated in the design for controlling underwater noise radiation will have a favourable influence on the onboard noise and vibration levels. Also, the layout of the vessel is favourable with respect to noise and vibration. Hence, it is expected that rather limited local noise and vibration control measures will be necessary to ensure compliance with the recommended Comfort Class requirements. Local situations that may require noise and vibration control are:

- Cabins or other low noise areas in the vicinity of machinery rooms
- Cabins or other low noise areas close to the exhaust casing
- Noise on open decks
- Vibration due to local resonance
-

Necessary treatment will be determined through airborne noise analyses and local vibration calculations (natural frequencies of deck plates).

Table: Cargo ships < 10 000 GT [1)] - Crew Accommodation Noise levels in dB(A)

Locations	*Comfort rating number (crn)*		
	1	*2*	***3***
Wheelhouse	~~60~~	~~60~~	**65**
Radio room	~~55~~	~~55~~	**60**
Crew cabins	~~50~~	~~55~~	**60**
Crew public spaces	~~55~~	~~60~~	**65**
Hospital	~~55~~	~~55~~	**60**
Offices	~~60~~	~~60~~	**65**
Engine control room	~~70~~	~~70~~	**75**
Open deck recreation	~~70~~	~~70~~	**75**

1) For working areas and engine room it is referred to IMO MSC 337(91) Code on noise levels onboard ships.

Table no. 1, The DNV GL Comfort Class noise requirements

Designation of rooms and spaces	Ship size	
	1,600 up to 10,000 GT	≥10,000 GT
4.2.1 Work spaces (see 5.1)		
Machinery spaces[5]	110	110
Machinery control rooms	75	75
Workshops	85	85
Non–specified work spaces[6] (other work areas)	85	85
4.2.2 Navigation spaces		
Navigating bridge and chartrooms	65	65
Listening posts, incl. navigating bridge wings[7] and windows	70	70
Radio rooms (with radio equipment operating but not producing audio signals)	60	60
Radar rooms	65	65
4.2.3 Accommodation spaces		
Cabin and hospitals[8]	60	55
Messrooms	65	60
Recreation rooms	65	60
Open recreation areas (external recreation areas)	75	75
Offices	65	60
4.2.4 Service spaces		
Galleys, without food processing equipment operating	75	75
Serveries and pantries	75	75
4.2.5 Normally unoccupied spaces		
Spaces not specified	90	90

Table no. 2, Extract from the MSC 337(91) Code on Noise Levels

5 – If the maximum noise levels are exceeded when machinery is operating (only permitted if dispensation is granted by the administration) stay should be limited to very short periods or not allowed at all. The area should be marked with appropriate warning signs according to section 7.4 of MSC 337(91).
6 - Examples are open deck work spaces that are not machinery spaces, and open deck work spaces where communication is relevant.
7 Reference is made to the *Recommendation on methods of measuring noise levels at listening posts* (resolution A.343(IX)) which also applies.
8 Hospitals: treatment rooms with beds.

Table: Cargo ships Crew Accommodation and Work Places			
Frequency weighted r.m.s. values in mm/s from 1 Hz to 80 Hz			
Locations	**Comfort rating number (crn)**		
	1	***2***	***3***
Cabins	~~2.0~~	~~3.0~~	4.0
Mess/recreation rooms	~~2.0~~	~~3.0~~	4.0
Offices	~~2.0~~	~~3.0~~	4.0
Navigation Bridge	~~2.0~~	~~3.0~~	4.0
Control rooms	~~3.0~~	~~4.0~~	5.0
Work places	~~3.0~~	~~4.0~~	5.0

Table no. 3, The DNV GL Comfort Class vibration requirements

3.3 Sound Insulation requirements

The Comfort Class contains the following requirements to sound insulation:

Table: Sound Insulation Indexes R'w (ISO 717-1:1996/Amd:2006			
Locations	*comfort rating number (crn)*		
	1	*2*	***3***
Cabin to cabin (crew)	~~38~~	~~35~~	32
Cabin(crew) to corridor or cabin with communicating door	~~37~~	~~32~~	28
Cabin(crew) to messrooms, recreation rooms, public spaces and entertainment areas	~~50~~	~~47~~	43

Notes:

- The laboratory measured sound insulation (R_W) for the bulkheads and decks shall at least be 3 dB higher than the field measured (R'_W) values.

Table no. 4, The DNV GL Comfort Class sound insulation requirements

The MSC 337(91) also contains requirements to sound insulation, but these will be satisfied if the Comfort Class requirements are met.

4 DESIGN REVIEW

4.1 Underwater Noise

4.1.1 General

The arrangement of the vessel is shown on figures 6 – 11, the main points from the discussion below are indicated on the figures.

4.1.2 Underwater noise

The vessel will have several operational modes. The actual operating condition is very important for underwater noise radiation. Hence, we have considered the stated main operating scenarios independently below.

Operational mode	Daily percentage	Propeller loading (Pd)	Machinery configuration
1. Transit 10-11 knop	15 %	10.5 kts - 666kW	Main diesel + Genset for hotel load
2. ECO transit 5-7 knop	20 %	7 kts – 98kW	Main diesel + PTO for hotel
3. Slow sailing 1-4 knop	25 %	4 ts – 19 kW	Genset + PTI for propulsion
4. Stationary DP	15 %		
5. Light trawling/ towing	5 %	4 kts – 540kW	Main diesel + PTO for hotel
6. Heavy trawling	5 %	4 kts – 725kW	Main diesel + Genset for hotel
7. Stationary moored	15 %		
Harbour full day	100 %		

Table no. 5, Expected operational modes of the vessel

Conditions nos. 2 & 3 will be the main operating scenarios for low noise radiation. Of these, mode no. 3 the slow sailing is expected to be the least noisy mode with very low power requirements and propulsion through a diesel electric system with power supplied from the diesel generator. However, all the modes will involve the gear which therefore will be an important element with respect to noise radiation. In addition, it will be important to be able to vary the speed of the propeller to avoid pressure side cavitation for the lightly loaded slow sailing condition no. 3. In addition, a good resilient mounting system on well stiffened foundations will be critical for the diesel generator. For the ECO transit condition, the mounting of the main diesel engine, a good resilient coupling between the diesel engine and the gear as well as a propeller design avoiding pressure cavitation for the low speed gear rpm of the propeller will be the most important items for a low noise radiation.

For the high-power conditions, like condition nos. 1, 5 and 6, significantly higher broad band noise levels may be expected as tip vortex cavitation and other types of propeller cavitation probably will occur at these conditions. Hence, these conditions will be less suited for low noise research activities.

4.1.3 Statistical noise levels

Figure no. 5, below shows data from similar size vessels with gears and electric propulsion motors. Noise levels may depend on a range of different variables and in particular on the noise control effort integrated in the designs, but the data give a fair indication of achievable noise levels.

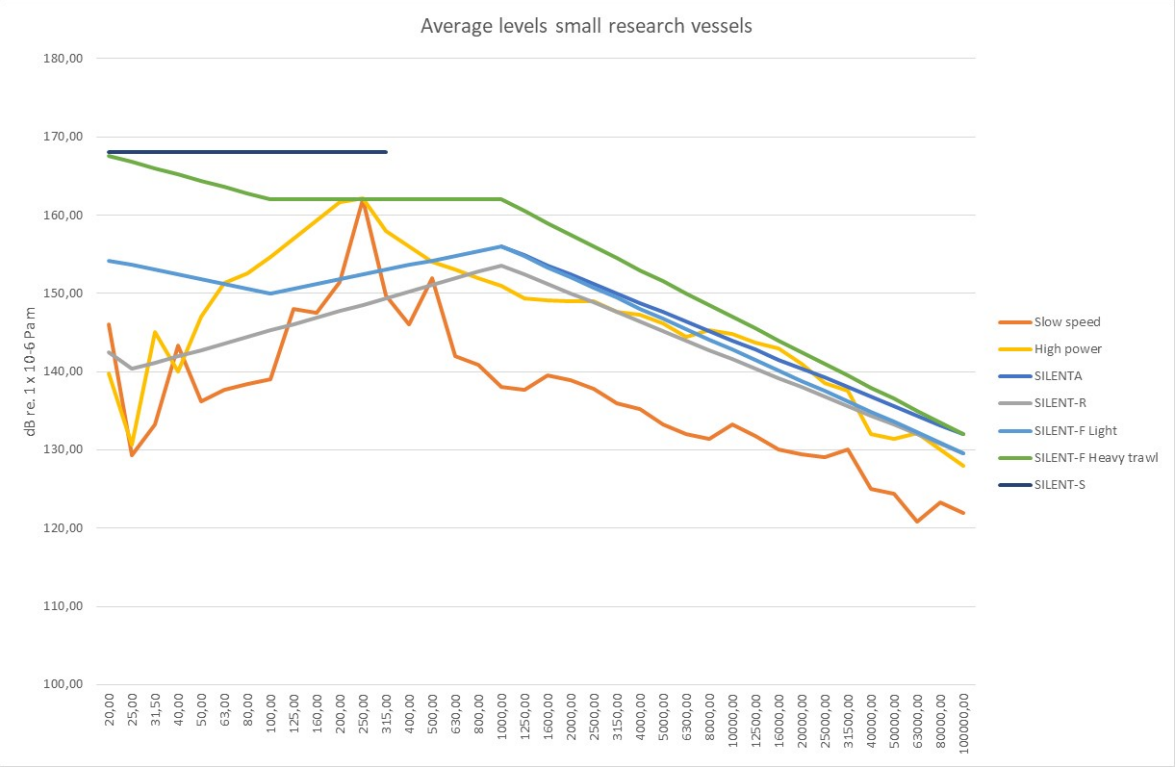

Figure no. 5, Average underwater noise levels for small research vessels compared to different DNV GL SILENT requirements. (a larger print of this figure is attached at the end of the report)

The vessels in the database are quipped with geared propulsion systems and electric propulsion motors powered by resiliently mounted diesel generators. Mechanical noise from the geared propulsion systems is the main source for the elevated noise levels in the 125 – 500 Hz range. For the high-power condition, cavitation noise from the propeller(s) dominates. This gives a broad band radiation with a maximum level in the frequency range 80 – 300 Hz depending on the actual loading of the propeller.

4.1.4 Realistic underwater noise requirements

Based on the proposed design with a geared propulsion system it appears difficult to expect lower noise levels than the SILENT-F heavy trawl requirements. Alternatively, it is possible to aim for a combined SILENT-A + S requirement. The specified slow sailing condition may potentially generate somewhat lower noise levels, but sometimes gear noise increases slightly at very low power due to backlash between the gear teeth. Hence, we recommend aiming for noise levels in line with or lower than the SILENT-F or alternatively the SILENT-A + S requirements. In order to achieve such requirements, the following constructional considerations will be necessary:

- The propeller needs to be designed with the noise level requirements in mind. For the two noise-critical operating conditions the required power is moderate and it should not constitute too much of a challenge to reach the SILENT-A+S requirements. In fact, the propeller should be able to meet the stricter SILENT-R requirements at these moderate power conditions provided pressure side cavitation is avoided. Due to the balancing between potential pressure side cavitation and inception of tip-vortex cavitation a further propeller assessment should be carried out once the details of the propeller design are known. The supplied stream lines indicate a normal wake for a single screw vessel. However, the wake and the propeller geometry should be evaluated further when the propeller design has been established.

For a SILENT-A + S requirement almost any normally working marine gears should be able to comply, provided the gear tooth frequencies are below 1000 Hz. The same applies to the resiliently mounted diesel engine, the diesel generator and the PTI / PTO.

If the SILENT-F requirements are aimed for, the gear including the PTO / PTI unit should be constructed for low noise emission and should comply with the maximum structureborne noise levels stated in table no. 6.

	1/3 Octave band velocity levels, dB re 5 * 10^{-8} m/s								
Centre frequency (Hz)	20	25	32	40	50	63	80	100	125
Max.foundation level	78	78	77	75	73	70	70	70	72

	1/3 Octave band velocity levels, dB re 5 * 10^{-8} m/s								
Centre frequency (Hz)	160	200	250	315	400	500	630	800	1000
Max.foundation level	73	74	78	76	76	78	73	70	65

	1/3 Octave band velocity levels, dB re 5 * 10^{-8} m/s								
Centre frequency (Hz)	1250	1600	2000	2500	3150	4000	5000	6300	8000
Max.foundation level	61	58	55	52	49	46	43	40	37

Table no. 6, Maximum structureborne noise levels on the gear foundations

The following low noise constructional features should be considered for the gear noise design. Alternatively, it may be considered if it is practically possible to mount the gear resiliently.

Solutions	Features
Use of high precision gears	Minimizes errors of pitch, tooth profile, runout and lead error. Grind teeth for improving the accuracy and the surface finish.
Good surface finish on gears	Methods of lapping, grinding and honing of the tooth surface improve the overall smoothness of tooth surface and can reduce noise
Lubrication	High viscosity lubricants can reduce gear noise
High rigidity gear teeth and gear box	Full face tooth rigidity and rigid support of gear shafts reduces gear noise
Backlash	Small backlash reduces pulsations of gear teeth and reduces noise
Proper tooth contact	Reduces effect of tooth surface impacts

Table 7, Gear noise control techniques

The diesel generator and the diesel engine need to be proficiently mounted on proper rubber isolators supported by stiff foundations. The maximum structureborne noise source strength need to comply with the requirements stated in table 8.

Centre Frequency [Hz]	Guarantee based (Trawl) dB re. $5x10^{-8}$m/s	Typical shipboard foundation mobility dB re. 1m/Ns
20	75.0	(-120)
25	74.0	(-119)
31.5	74.4	(-118)
40	73.8	(-117)
50	73.2	(-116)
63	72.9	-115
80	72.7	-114
100	71.1	-113
125	71.0	-112
160	72.3	-111
200	72.0	-110
250	72.0	-109
315	72.1	-108
400	71.9	-107
500	71.6	-106
630	70.8	-105
800	69.0	-104
1000	62.2	-103
1250	58.7	-102
1600	54.4	-101
2000	50.8	-100
2500	47.8	(-99)
3150	45.6	(-98)
4000	43.8	(-97)
5000	41.4	(-96)
6300	39.5	(-96)
8000	38.3	(-96)

Table 8 Maximum structureborne noise levels on the Diesel Engine and Diesel Generator foundations, as well as nominal foundation mobility levels

The source levels in table no. 8 may be used as guarantee levels towards suppliers of the diesel engine and the diesel generator if required. The exhaust, fuel oil, lubrication oil and cooling water systems for the diesel generators will require resilient mounts and/or accumulators or silencers in order to avoid flow of acoustical energy through these paths. The fuel system for the diesel engines should be equipped with pressure-pulse reducing accumulators unless the manufacturer of the diesel engines can prove that such accumulators are not needed.

All other auxiliary machinery should aim at lower source levels than stated in table no. 8. In practice this means that all mechanical equipment needing to operate during the low noise operating conditions should be resiliently mounted.

The requirements may be used as guidance for the yard when performing FAT tests at a customer's test facility or for onboard evaluation of equipment during start-up testing.

The limits apply to structureborne noise and mobilities measured in 1/3-octave bands and in all three orthogonal directions (vertical, transverse, longitudinal). Limiting levels are only stated up to 8000 Hz due to practical difficulties and inaccuracies associated with measuring structureborne noise at higher frequencies. The manufacturers should nevertheless endeavour to avoid significant excitation at higher frequencies. Some of the mobility levels in the low frequency range and in the high frequency range are bracketed. This is due to practical difficulties associated with mobility measurements in the low and high frequency range. Corrections at the bracketed frequencies should only be done if satisfactory mobility measurements can be carried out at these frequencies.

If the test bed foundations are stiffer or softer than the nominal mobilities given in Table 8, the measured structureborne noise levels on the test bed foundations should be corrected to values that would have been achieved on a foundation just satisfying the nominal ship mobilities.

If the ship foundations are less stiff than the nominal mobilities given in Table 8 for the respective foundations, the measured structureborne noise levels on the ship foundations should be corrected to values that would have been achieved on a foundation just satisfying the nominal ship mobilities.

Corrections will be done on a basis of:

Measured velocity level – 20 log10 (measured mobility (m/Ns)/ “Nominal shipboard mobility” (m/Ns))

Measurements are to be taken in at least 8 positions on the foundation as close as practically possible to the machine feet in all three orthogonal directions. For resiliently mounted machinery, the limits are to be satisfied on the foundation at positions as close as practically possible to the rubber isolators.

The energy-averaged level from all positions should be computed for each of the three orthogonal directions. The energy-averaged levels for each direction should be compared to the limiting levels stated in respective tables.

Introducing guarantee requirements toward the suppliers of auxiliary equipment may be cost increasing and is not considered necessary in order to satisfy the underwater noise requirements. Local treatment of these sources by the shipyard in cooperation with the acoustical consultant will usually be a more cost-efficient approach than strict guarantee requirements for this type of equipment / machinery.

The noise level from the vibrating shell plates into the water depends on the steel structure as well as the magnitude of the forces introduced by internal noise sources and the transmission through the ship structure. However, the possibility of noise control in this path is limited due to constructional restraints and the underwater noise requirements must be achieved through source control, viz. propeller design, construction and mounting of gear, diesel engine, diesel generator and the PTO / PTI. Natural frequencies of hull plates corresponding to the rotational frequency, the first harmonic of this frequency and the firing frequency of the diesel engines should be avoided.

A low underwater noise requirement is an excellent basis for a comfortable interior of a vessel as the control measures for the main sources also will influence the comfort onboard the vessel in a favourable way. It may still be a need for interior noise reduction measures, but to a lesser extent than for an ordinary vessel.

4.1.5 Other control measures

The machinery ventilation fans will have to be resiliently mounted and will most likely need to be equipped with silencers in order to limit external noise from the vessel during harbour stops. The steering gear pumps should be acoustically isolated from the structure and preferably be frequency controlled. It is important to focus on good resilient mounting systems for possible chilled water plants with integrated compressors or any hydraulic power packs that may be used during the low noise operating modes.

The rudder design should be considered for the possibility of vortex shedding and all links and mechanically moving parts should be controlled such that possible impact noise due to backlash is avoided. All other underwater appendices, including the drop keel and side thrusters openings should have smooth trailing edges and otherwise have a good hydrodynamic design. If equipped with bilge keels, these should be well stiffened and equipped with smooth trailing edges.

All foundations for resiliently mounted machinery should be sufficiently stiff and avoid natural frequencies close to operational speeds of the machinery.

The high airborne noise levels expected within the diesel generator room will not require additional acoustic insulation with respect to waterborne noise unless stricter requirements like the SILENT-R requirements are aimed at.

4.2 Airborne noise

Airborne noise from the main propulsion machinery will have its highest impact in the locations closest to the main propulsion machinery, i.e. the cabins directly forward of the machinery room and the wet laboratory on main deck. For good resiliently mounted diesel engine / diesel generator and good resilient mounting on most pumps, compressors, fans etc., only moderate machinery noise is expected. However, in the two aftmost cabins there is a risk that the noise level may exceed 60 dB(A) moderately. This risk may be eliminated by installation of a floating floor in these two cabins, e.g. consisting of 50 mm mineralwool approximately 140 kg/m^3 covered by 2 mm + 3 mm steel plates with a thin viscoelastic glue between them. In addition, the lining of the aft bulkhead facing the machinery room should have no fixed connection to the bulkhead structure. It is recommended to allow a distance of at least 100 mm between the bulkhead structure and the lining panel. The void should be equipped with a layer of light mineralwool.

It is important that the exhaust system is resiliently mounted to stiff attachment positions to avoid elevated noise levels in the aft port cabin and the wet lab on the deck above.

In the wet lab noise levels in the range 63 dB(A) – 68 dB(A) may be expected. The noise levels may be reduced by 2 – 3 dB(A) by installing a constrained viscoelastic damping layer on the deck, i.e. 1 - 2 mm viscoelastic material covered by 2 mm steel or aluminium tiles and deck levelling compound. The bulkheads of the exhaust / ventilation casing

should be covered by resiliently mounted lining panels located at least 100 – 150 mm from the casing structure and with a layer of light mineral wool in the void.

Thruster noise during dynamic positioning and manoeuvring will be significant in the lower forward areas, as it is on all vessels with bow thrusters and accommodation in the foreship. The influence of this noise may be reduced, but not removed by installation of floating floors.

4.3 Vibration

The most important excitation sources for vibration will be the main propeller when sailing in the high power conditions. In addition, the diesel generators and the exhaust systems may excite low frequency vibration locally around the casing area. A local vibration calculation, i.e. a calculation of natural frequencies of plates, stiffeners girders with the aim of avoiding resonant conditions, may be carried out to ensure that local vibration problems are avoided. For a compact size vessel with controlled noise and vibration sources no global vibration problems are expected. Hence global vibration calculations are not considered necessary.

5 SUMMARY OF RECOMMENDATIONS

Due to the aim for low underwater noise, it may be worthwhile to include concise requirements in the specification. Based on the preliminary design, two alternative sets of requirements seem feasible:

DNV GL SILENT-A+S which will ensure a low high frequency noise level in the range above 1000 Hz and which will accept normal, but not excessive noise levels in the low frequency range. This combination of voluntary class notations has been used for a range of different research vessels worldwide. Compliance with these requirements will require a noise-controlled propeller design and normal shipboard propulsion machinery with resiliently mounted diesel engine and diesel generator.

DNV GL SILENT-F (trawling) will require somewhat lower noise in the frequency range below 1000 Hz. For these requirements it will be important to restrict the gear noise to the maximum levels stated in this report in addition to then same considerations as would apply for the SILENT – A+S alternative.

Regardless of chosen formal requirements the following control measures are recommended:

- All sub-suppliers of major machinery items (propeller, diesel engine, diesel generator, gear, PTI / PTO) should be made aware of the low noise aim of the project. For the diesel generator, diesel engine and gear it may be considered to impose acoustical guarantees for their equipment, such as presented in chapter 4.1.4 of this report. Suppliers of auxiliary components may also be made aware of the requirements, but should not need to be involved in the same way as the main suppliers.
- A more detailed propeller assessment should be carried out once the actual propeller design has been established. Particular focus should be given to the possibility for pressure side cavitation for the ECO transit condition no. 2.
- Airborne noise in the accommodation may require limited use of floating floors and damping layers in order to secure a good environment for the crew.
- Natural frequencies of local structure are recommended to be calculated in order to avoid noise amplification due to resonance of bottom and hull side panels near machinery as well as possible vibration problems in the accommodation and in the working areas.

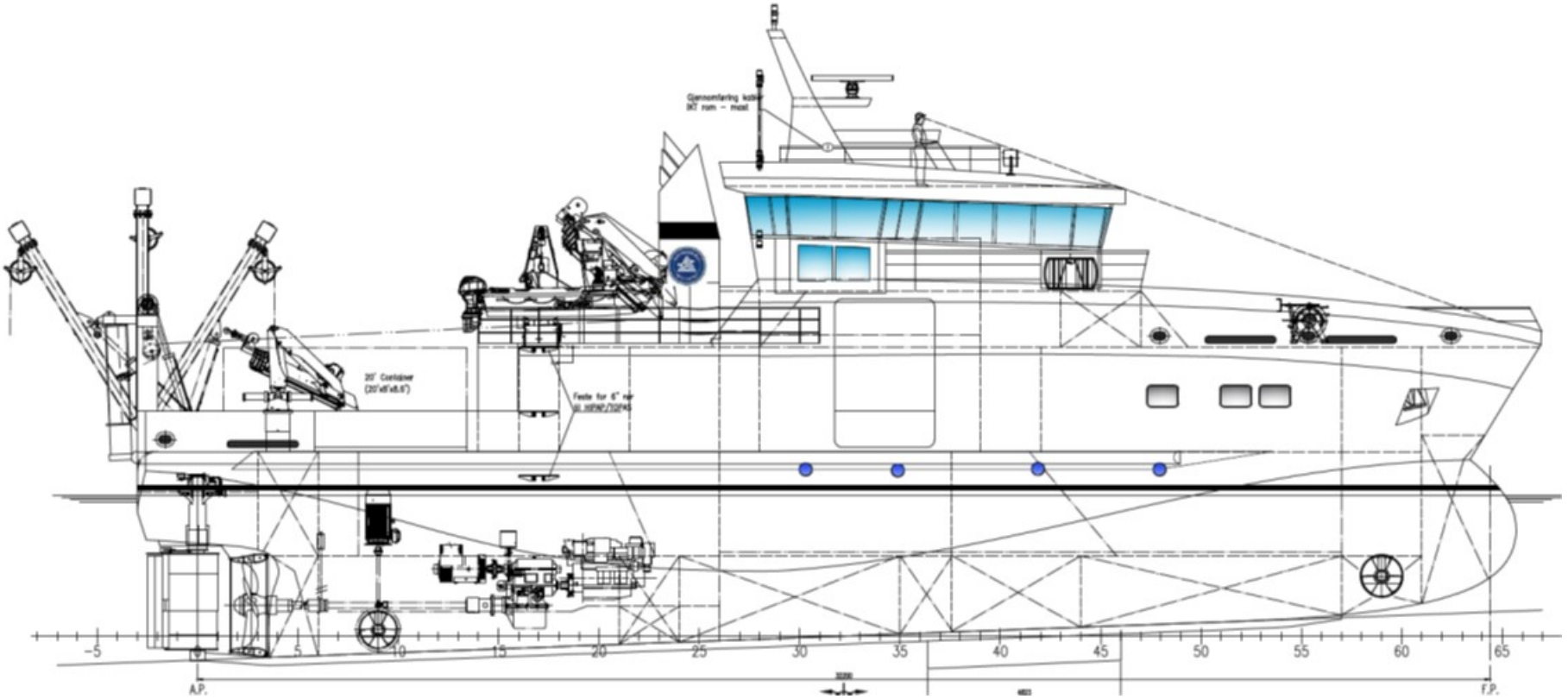

Figure no. 6, The ship in profile

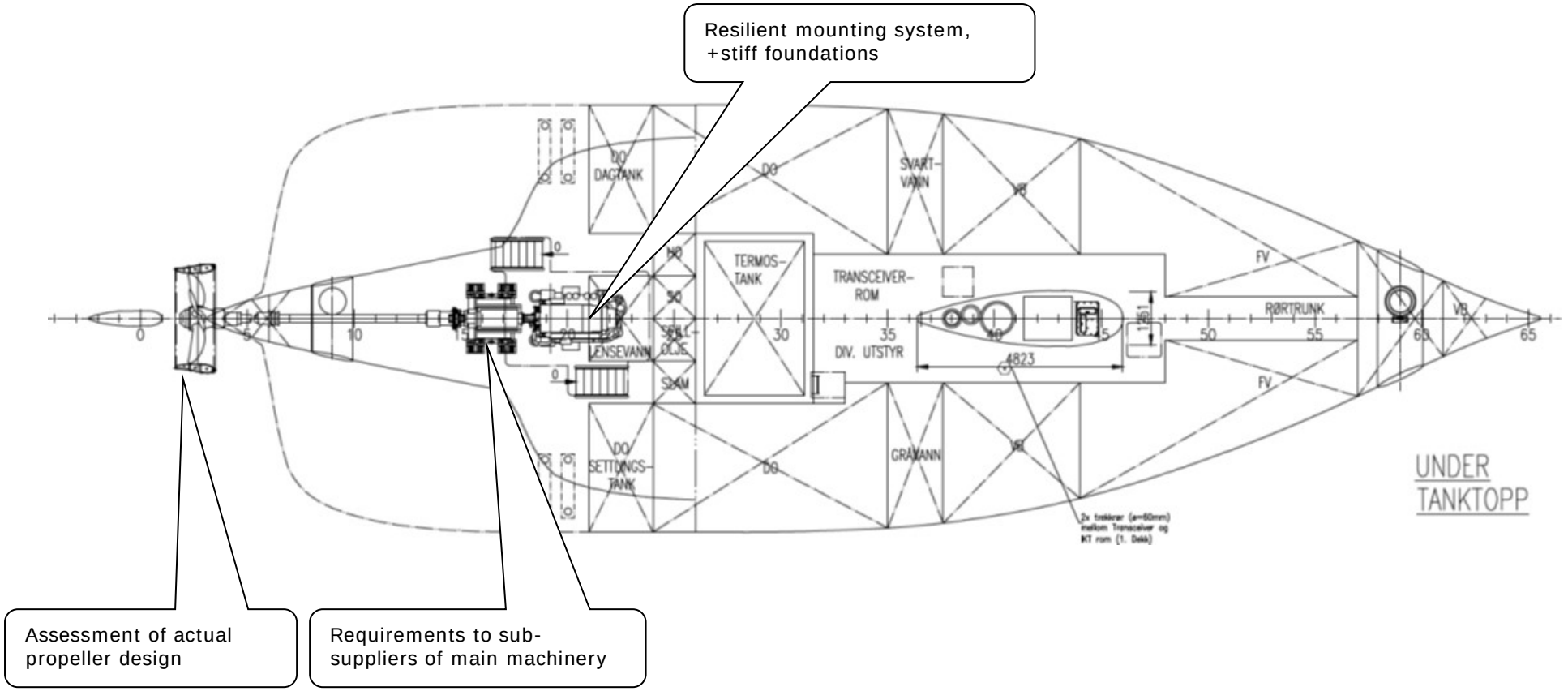

Figure no. 7, Deck 1

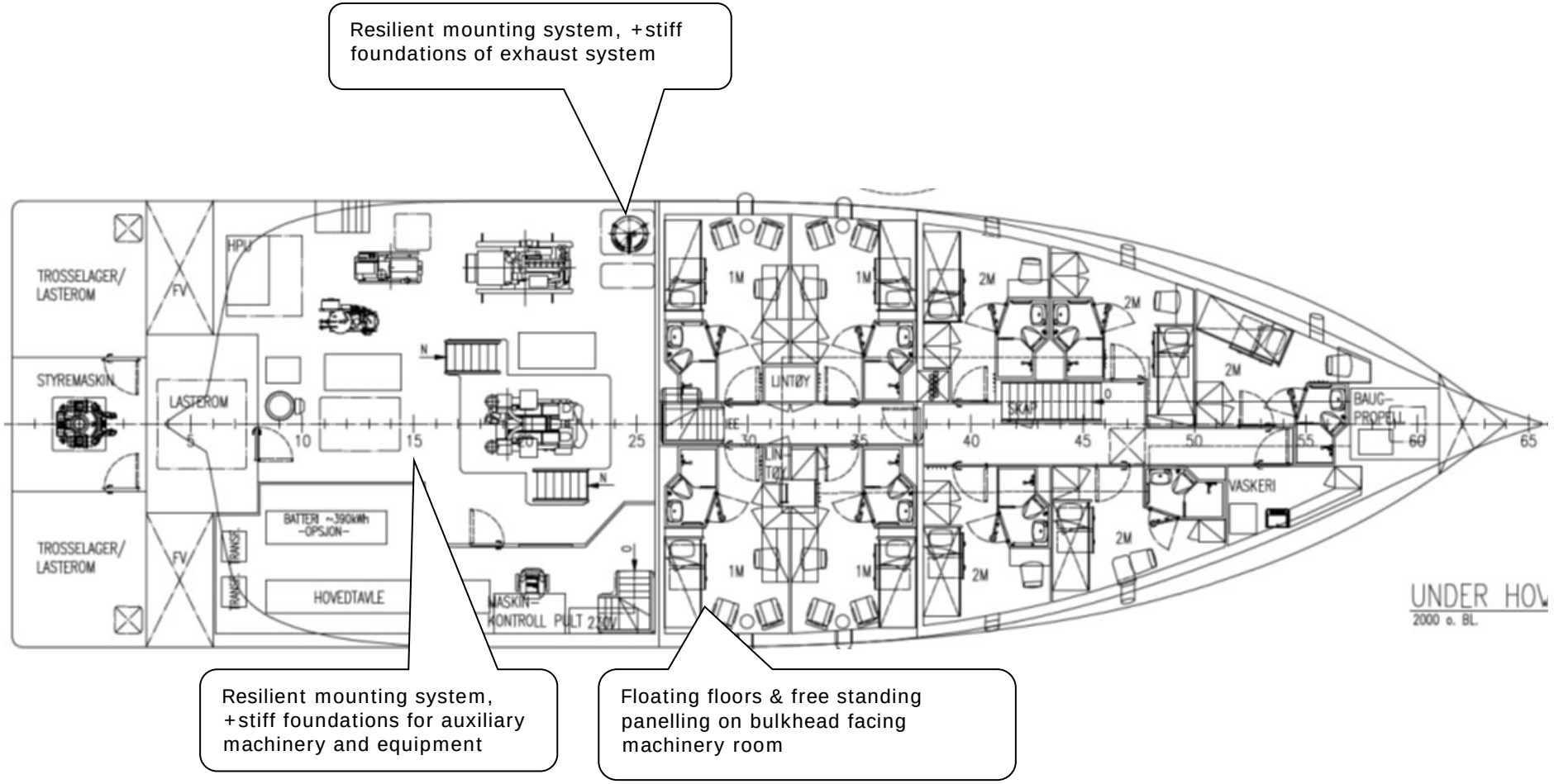

Figure no. 8, Deck 2

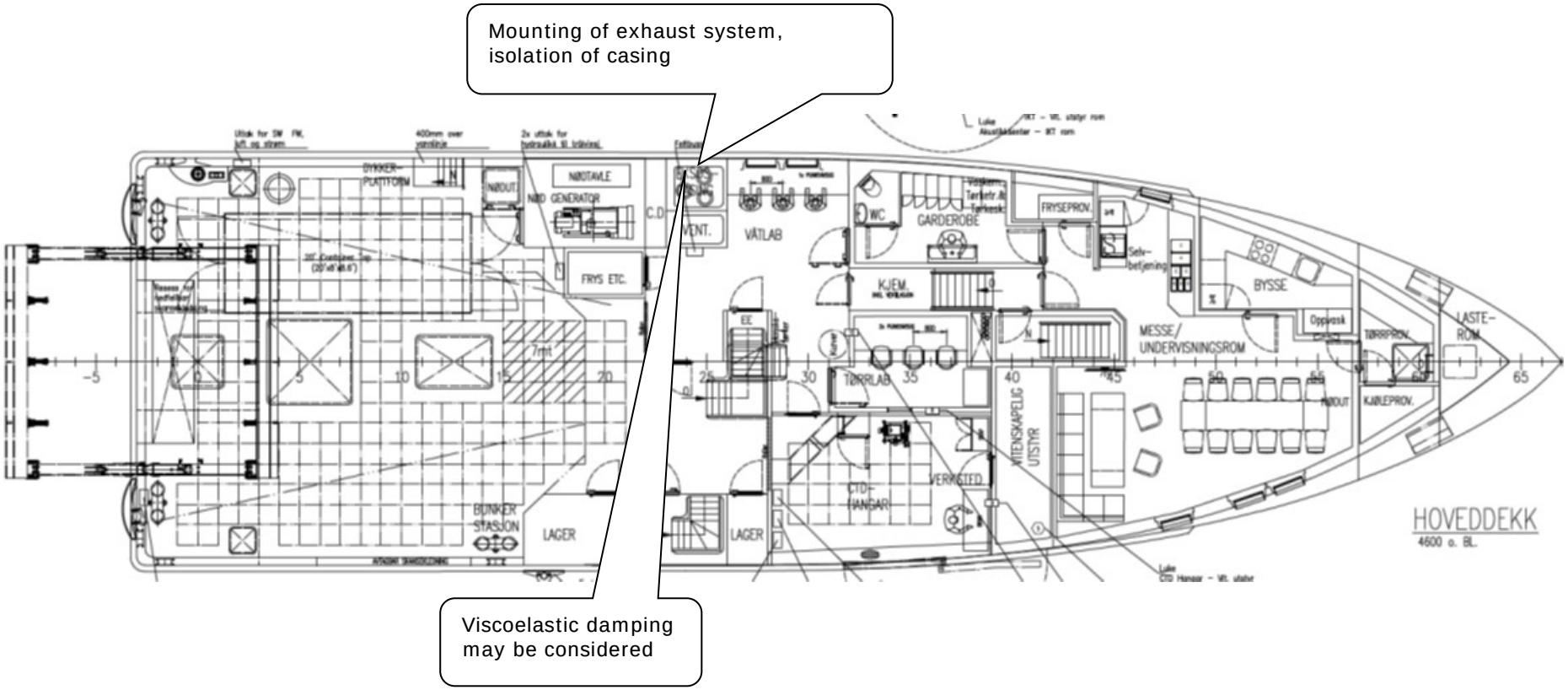

Figure no. 9, Deck 3

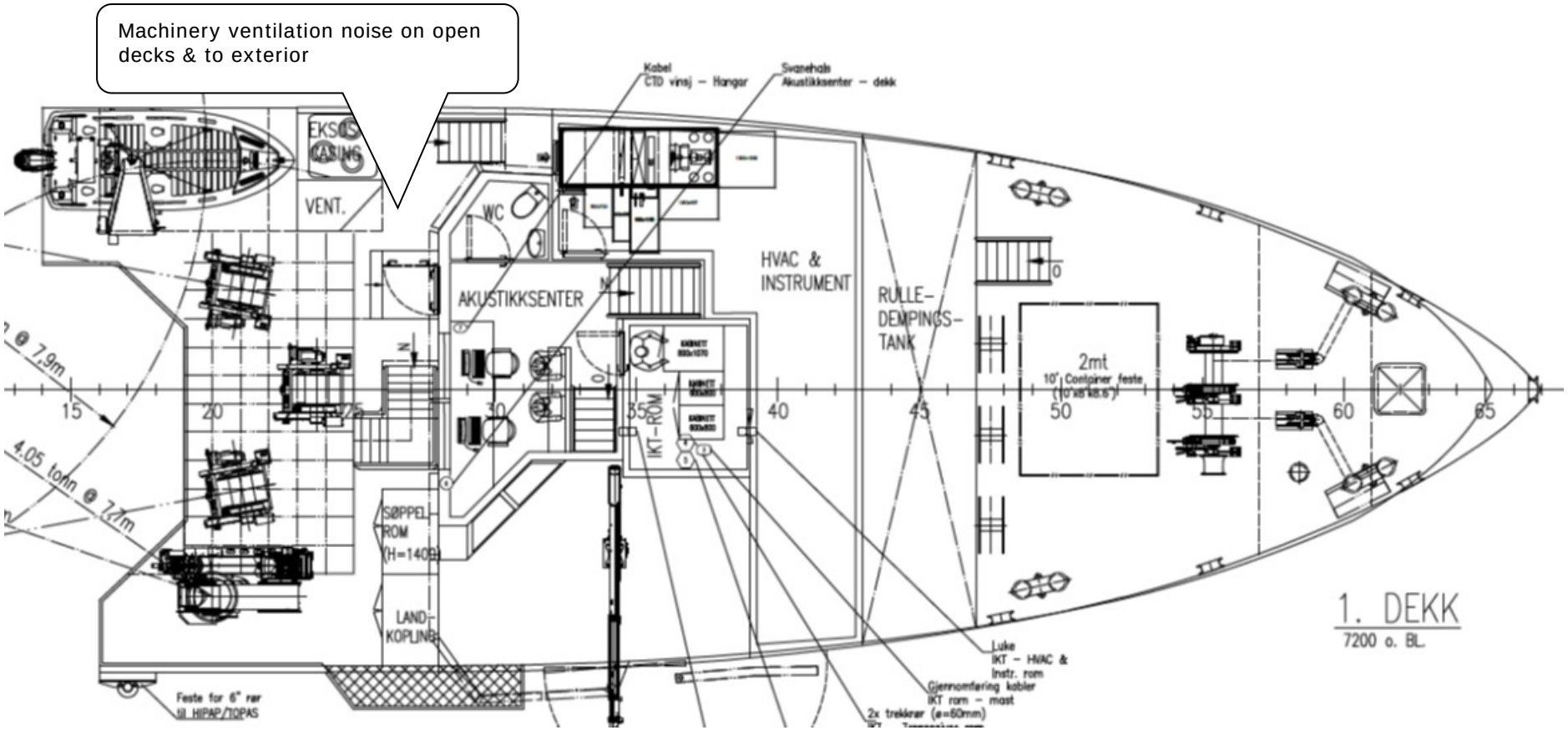

Figure no. 10, Deck 4

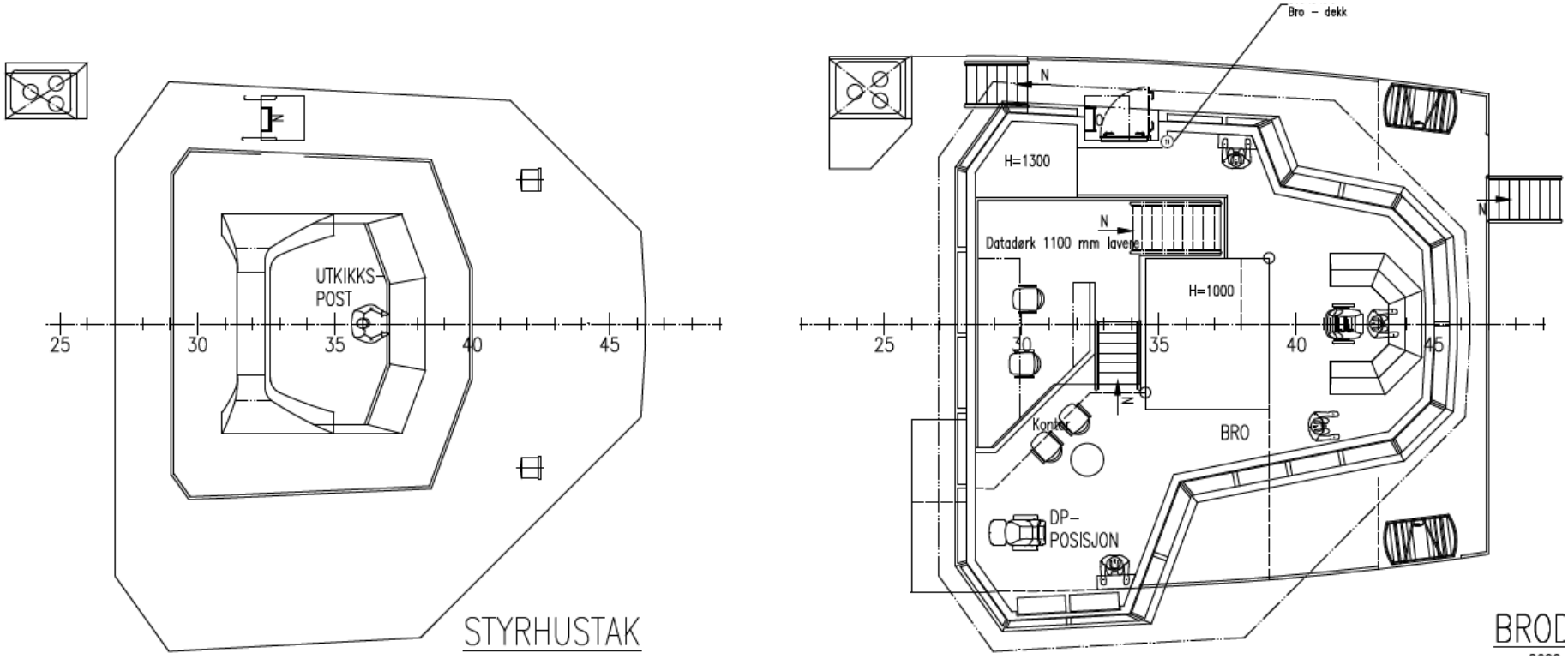

Figure no. 11, Deck 5

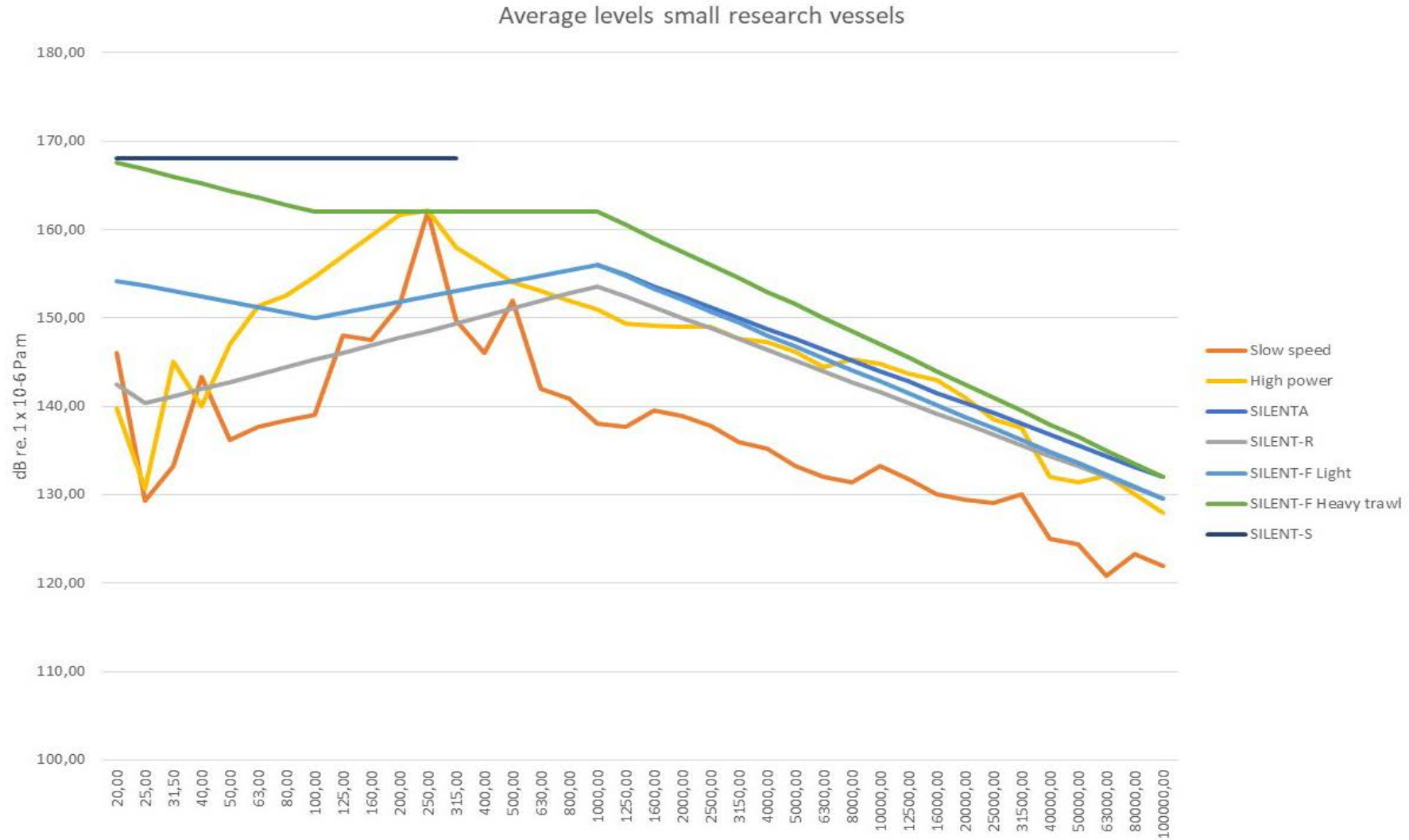

Figure no. 5, Average underwater noise levels for small research vessels compared to different DNV GL SILENT requirements.

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