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Temporary Living Quarters Ekofisk Field

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1 Introduction

Figure 1, “Haven” during outfitting in Eydehavn, Norway, 2011

The vessel later known as “Haven”, to be used as accommodation structure on Ekofisk Field in the Norwegian North Sea, was contracted as Building Number 205 at the Drydocks World Graha yard in Batam, Indonesia. The original class for the ship was ABS ship class. Because of the specific requirements applying to the Norwegian continental shelf (contained in NORSOK S-002), extensive redesign was necessary. Stricter standards applied to most aspects of the vessel, including sound and vibration levels in accommodation and work spaces, as well as sound insulation requirements between cabins.

Sound levels were calculated and later verified as part of the NORSOK requirements. The final results were in most respects successful. This paper describes the main acoustical features of the vessel, as well as some lessons learned.

2 Vessel Description

2.1 General Layout

The original design was a self-propelled, self-elevating crane ship, with a nine storey superstructure in the front part and a rear poop deck. The central loading deck has dimensions of about 50 x 50 metres. There are four legs of about 130 metres length, so as to accommodate a water depth of 70-80 metres. A helicopter deck is located in the front part of the vessel. Two 750 ton cranes were planned on the port side (not visible in the picture). The main generators are located on Main Deck level in the rear part. Other machinery rooms are on two levels between the legs, both fore and aft.

The machinery rooms contain pumps for ballasting, fire protection and general cooling and circulation purposes. The forward machinery room (AMS) includes also cooling machinery for the forward superstructure (PLQ) and fresh water equipment. Ventilation of the hull (original design) is made by distributed above-deck axial fan systems. Other ventilation, designed as part of the modifications, is accomplished by packaged units placed where needed.

After receiving the contract for Ekofisk Field, the vessel was modified as follows:

- An additional 390 bed living quarter unit (ALQ) was placed on the load deck.
- An additional 157 cabins were accommodated in the original fore superstructure (R in picture) and
- A four storey Office Module (OFM) placed on the aft deck (hardly visible L in picture).
- The rear crane was removed, the forward crane replaced by a smaller (75 ton) utility crane. Both crane pedestals were maintained as designed for the higher load.
- The propulsion/positioning equipment (six thrusters) was removed
- The number of generators was reduced from nine to six, and projected running time reduced.

2.2 Gaps Between ABS and NORSOK Requirements

The original requirements included noise limits of 55 dBA in accommodation, 85 dBA in work spaces, and I_a 30 dB between cabins. The NORSOK S-002 limits include levels as low as 40 dBA in cabins, R_w (I_a) (field measured) at minimum 45 dB, additionally limits for corridors and walkways (80 dBA exterior). A complete acoustic re-evaluation of the design was required.

With time being very limited and commercial relations strained between owner and ship yard, it was very limited what was possible to achieve at the yard in Indonesia. Sound traps were added by the yard for control of outdoor ventilation noise and, almost by mistake, for the emergency generator. Otherwise most of the modifications (and several changes) had to be accomplished during the outfitting period in Norway.

2.3 Calculations

Advance calculation of noise levels was difficult, since much of the equipment on board was ordered without noise specifications. Noise data sheets were not possible to obtain. Some equipment could never be tested before departure to the North Sea. This made the work frustrating at times, and some sources could not be modified due to practical and contractual limitations.

Noise calculations had to be made using experience data. Later, measurements were used to verify and adjust the calculations for documentation purposes. Air borne noise was calculated using standard procedures. Structure borne noise is determining of the environment in much of a marine structure. Structure borne noise was calculated using a proprietary, empirically based model. This model considers the steel structure (bulkheads, decks, frames) and vibration input data measured on available occasions, such as previous projects, FAT tests and even during pre-commissioning and commissioning, which continued over a long time period due to the challenging nature of the project.

Correlation of calculated and measured structure borne noise turned out to be surprisingly good. The model is not, by its nature, highly scientific, but reasonably controlled tests of crane and main engine noise showed agreement within a 5 dBA range.

3 Sound Reduction Features Achieved

As in all project organizations, the sound reduction features that can be built in are a result of both good ideas and practical possibilities, but also on the political acumen available to the difficult disciplines. The work is often more political in nature than technical. With noise being defined as a high priority by the Operator (ConocoPhillips) and the Norwegian Petroleum Safety Administration (PSA), it was possible to achieve a number of effective sound reduction features. These are listed in the following paragraphs.

3.1 Flexible Support of ALQ and OFM

The noise of both generators and other machinery was identified as critical for the lower elevations in all the accommodation and office spaces. It was possible to introduce flexible supports for both the main accommodation structure (ALQ), delivered by Markhus in Norway, and the office module on the aft deck (OFM), designed and delivered by Hertel Defense and Offshore (HDO) in the Netherlands. For both systems, the owner assumed the responsibility for the noise control performance.

For the ALQ, steel wool pads were used for all the support points and distributed according to a loading analysis made by the structural engineers. Side and uplift support (important for transit) was done by snubbers and specially designed clamps, also including steel wool pads. It was practically impossible to find pads that could take all loads during transit, and a test was made, overloading them to see what this would do to the structure. It turned out to be unproblematic. The pads recovered their original dimension and were used despite the possibility of overload.

For the OFM, the system was designed using prefabricated cassettes. Most of the horizontal load had to be taken by two points, where special reinforcements were made, both of foundation and cassette structure.

Both systems proved effective, with acceptable noise levels being achieved throughout these structures.

3.2 Floating Accommodation Systems

Floating floor systems have been well developed in the Scandinavian offshore industry over the past 40 years. They are used throughout the accommodation of this vessel; in offices, cabins and messes/recreation facilities. They proved to be well suited to their purpose. Without them, significant excess noise would have been likely in parts of the PLQ (rear part, above the machinery spaces) and OFM (mainly related to crane hydraulics). Only in wet rooms the floating interior was omitted. As expected, the floating interior proved challenging during construction and commissioning, with some parts having to be replaced more than once due to flooding. Piping leakages are very common during MC and commissioning. From the acoustician's viewpoint it is good to see that the floating interior is still acceptable to the Owners, as it is, despite all its practical challenges, the only effective solution to many on-board noise problems.

3.3 Ventilation Silencers for Exterior Locations

Silencers for exterior areas were generally built in by the Drydocks World engineers. The axial fans are relatively noisy. Cylindrical silencers with a centre bullet were used in most cases, sometimes with one duct diameter length, some systems with double length. These were effective.

In some cases silencers had to be retrofitted. This included the ventilation openings from the main machinery rooms. The intake openings had silencers from the yard, but the natural exhaust was untreated. Here custom designed, baffle based silencers were added below the fire dampers. In some cases, new systems were crammed into the vessel during outfitting. Here the supplied silencers were marginal and space for improvement limited. Replacements were recommended, but the vessel left before this could be achieved.

3.4 Ventilation Silencers for Interior Spaces

Due to miscommunication, the yard did not consider sound reduction in interior hull areas, i.e., machinery spaces, walkways and stores. In all critical spaces, silencers had to be added. This was done by a sheet metal contractor, who manufactured and inserted baffle silencers in the large intake ducts. These turned out very effective.

In some cases the structure borne noise from the axial fans was transmitted with unacceptable levels through the ducts. Especially where these transited through quieter stores or corridors, extra cladding was necessary. This was done with mineral wool and sheet metal covering.

In some cases it was not possible to adequately reduce noise before departure of the vessel. This was mainly where space was very limited, especially in the workshop. The contractor ran out of time due to other priorities. This may have to be addressed off shore.

3.5 Noise Control for Interior Ventilation

The systems, designed and installed mostly by Novenco, were generally outfitted with enough silencers of good quality that there were few problems with noise in the interior. There were some exceptions where silencers had either been forgotten in the design or installation or did not function as expected. In these cases there were problems with excessive system noise (fans, regenerated sound) and crosstalk between cabins or between corridors and cabins. Not all these problems could be resolved before departure.

The main systems for the PLQ (fixed accommodation) were placed in containers on the superstructure. The structure borne noise did not prove to be a problem. Only the fans were vibration isolated from the system frames.

3.6 Corridor through Machinery space

The 1400 or so Leave Lockers (where the crew members leave their belongings during leave) had to be accommodated in a walkway running below the load deck. The only practical access was through a machinery space with service air compressors immediately adjacent and the PLQ chillers somewhat farther away.

To maintain the required 80 dBA on this walkway and still have adequate access to the machinery space, a divider was constructed using a combination of fixed wall (up to the level of the A60 insulation – more was considered unnecessary) and a mineral wool based curtain below. The curtain was fastened to the drip trays at floor level and from panel to panel by means of Velcro strips. The results were entirely satisfactory, with a noise reduction of about 10 dBA.

3.7 Noise Attenuation between Cabins

This proved to be a larger issue than expected. Mock-up testing had only included the smallest of the partitions between cabins. The R'_w index, which is used in NORSOK context, uses as transmitting surface area the actual area or 10 m^2, whichever is greater. Therefore there is a "bonus" for all partitions smaller than 10 m^2, in practice all cabin walls. With three different partition sizes, it turned out that the wall design was generally inadequate for all but the smallest walls.

This necessitated an extensive testing program where most cabin partition walls on board were tested eventually. In addition to careful caulking of all walls (which brought up to 3 dB improvement in some cases), extra sheet metal with project standard foil facing was glued to one or both sides of identified walls and brought all partitions above the required 45 dB attenuation.

The walls used for the project were 50 mm thick and had been lab tested to R_w = 47 dB. The experience in this project confirmed the old rule of thumb: that a field installed partition can lose some 5 dB compared to the lab tested value. With the large number of tests performed, it was possible to see variations, in some cases systemic due to installation practices, or material based variations, (mostly visible through mid-frequency weakness). For the most part, the panel performance was relatively consistent.

The cabins all had an "ante room" between cabin and corridor, typically serving two cabins. Thus, the 40 dB R'_w requirement between cabin and corridor was not a problem. It was established early on that this limit should not apply between the ante room and each cabin.

3.8 Structure Borne Sound Levels

Structure borne sound control is important throughout the vessel. The control measures adopted have proved adequate for the most part. In the PLQ cabins closest to the machinery rooms, levels marginally above 40 dBA were measured. These were caused mainly by the screw compressors of both the main chillers and the fresh water generators, located 2 and 3 decks lower, respectively. These are both systems that could not be specifically addressed during the project work. Better installation would probably have been possible with more access to the design and purchasing process. You can't win them all...

Structure borne noise in the workshop, which is close to the main generator rooms, proved to be acceptable.

Structure borne noise from crane operations had been a focus during design, and with the vibration levels measured during the main crane FAT, levels in the closest cabins was calculated to about 35 dBA. Field tests during commissioning confirmed a value in this range. Other sources were more dominant, with levels close to 40 dBA, but the varying crane operations led to variations of 1-2 dBA in overall measured levels.

An auxiliary crane on the OFM had also been the focus of much attention. The hydraulic system noise in the end exceeded 50 dBA in a stair well near the offices, but noise levels in the offices themselves did not exceed 40 dBA. This is thought to be mostly because of the floating interior. The hydraulic line mounting brackets were on the exterior wall between offices and stairwell. The supply lines had firm, but flexible bracket inserts.

4 Helicopter Noise Issues

The vessel, as well as its later replacement, the Ekofisk L (EKOL) platform, will be the locus of much helicopter traffic. NORSOK S-002 includes a requirement that helicopter noise levels not exceed 55 dBA. We have adopted the policy that this means either measured with "slow" response or as a one second L_{eq}.

The exterior wall construction of the PLQ is typically 8 mm stiffened steel plating with thermal insulation and an interior liner similar to the cabin walls: a sandwich panel with steel sheets on each side and a core of mineral wool. The ALQ has a similar construction, but with 4 mm steel/mineral wool sandwich exterior wall. The PLQ thus has a heavier wall, but is also much closer to the helicopter deck. The helicopter noise has been the subject of much analysis both in this project and for the EKOL

The A-weighted sound attenuation of an exterior wall such as on the "Haven" is dependent on the spectral content of the exterior sound. The official test method for helicopter noise includes direct flyover for the landing situation. In this position the available tests made for the Sikorsky S-92 aircraft show strong components at 100 and 125 Hz. These make prediction of effective sound reduction to a level of 55 dBA almost impossible.

However, for a platform, a direct flyover at low elevations is unlikely. The helicopter is almost universally seen more from the side, where the high frequency components are much more prominent and the low frequency ones less pronounced. To find a more typical spectrum for an offshore situation, tests were made aboard the EKOH platform (the old hotel structure) for several arrivals and departures of both S-92 and Aerospatiale Super Puma helicopters. The resulting average spectrum is shown in Figure 2. The differences between take-off and landing spectra showed up for both types of helicopters, and the differences between the two helicopter types for each operation was not large enough to warrant separate representation for each aircraft.

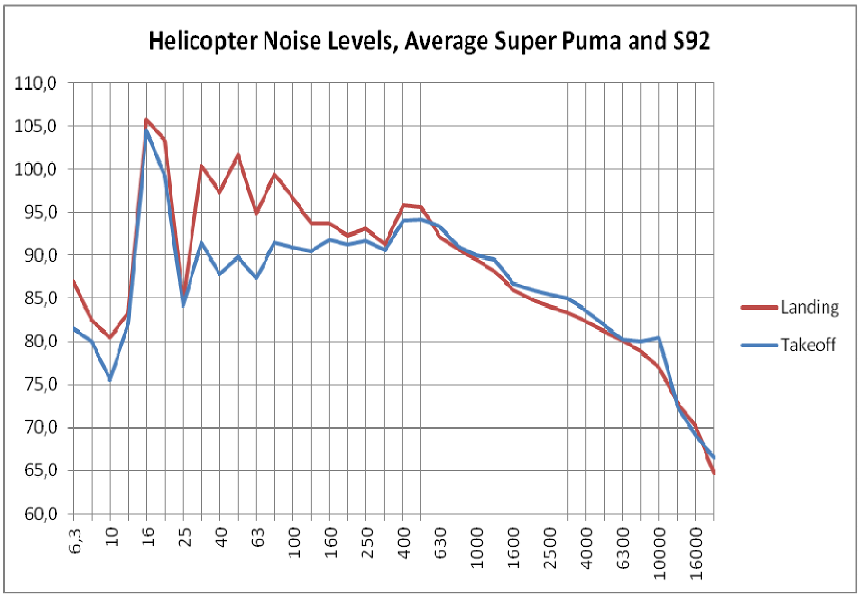

Figure 2: Practical Offshore Helicopter Noise Spectrum

The establishment of these spectra removed much of the fear of the helicopter as a noise source. Subsequent tests on board the "Haven" showed the highest measured values in the PLQ to be 53-54 dBA, with most helicopter events registering less than 50 dBA.

The strong low frequency (blade passage) components can account for the feeling that one can have off shore, that one "feels" the helicopter approaching as much as one hears it. This component does not affect the A-weighted levels and is not considered strong enough to cause infrasound problems indoors.

5 PAGA Performance Evaluation

Multiconsult was given the task of validating the performance of the PAGA system. During design this was done using the Odeon room acoustics modeling program. This program is very useful for this application and could be used to show both projected sound levels within a room and the Speech Transmission index (STI) in a room, for the system with a given background sound levels. Figure 3 shows a graphic representation as produced by Odeon, for a certain deck area. The illustrations are meant to be representative only, and are not from the "Haven" project, where similar studies were made.

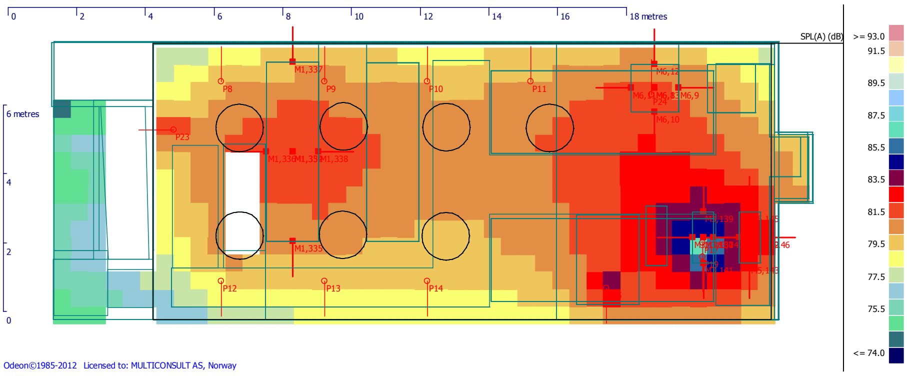

Figure 3, Odeon presentation of sound levels

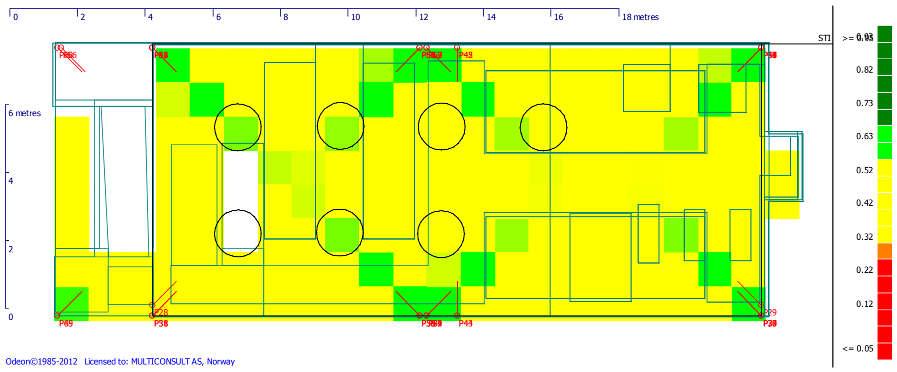

Figure 4, Odeon presentation of STI

PAGA performance was also verified during commissioning, including STIPA measurements in selected cabins.

6 Summary

The "Haven" project provided the opportunity to try a wide selection of acoustical engineering practices. Multiconsult was able to use and verify the results of their structure borne noise calculation program, which is in further development on other projects.

The "Haven" project started as a huge challenge, but thanks to the strong focus on noise of the Norwegian PSA, and to a vessel owner pressed to perform, it has turned out a success.

At the time of this writing it is in operation in the North Sea with no known complaints regarding noise.