Assessing the most effective and efficient solutions for noise control in a complex workplace

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ABSTRACT

When looking to mitigate noise levels in the workplace, the obvious solution is not always the most effective. Many questions arise from the initial assessment that may not be easily answered and solutions can sometimes appear to be counterintuitive. The noise exposure assessment will determine whether noise exposures are above the regulatory limits, but will not explain how these exposures may be mitigated. Sometimes the solution is obvious, particularly in simple scenarios, but it may not be so simple to be sure that any specific area, task or item of equipment is the cause of the problem. Even when the most significant source of the exposure is known, knowing which solution in the hierarchy of controls meets the As Low As Reasonably Practicable (ALARP) principle is essential. Even if an engineering or administrative solution is favoured, the effects of the final solution need to be determined if the solution is to be efficient and effective.

The following paper presents a case study and lessons learned when determining noise exposure in a complex workplace. Analyses determined not only which employees were receiving the highest noise exposure levels, but which areas/tasks/equipment are contributing most significantly to those exposures. Discussions include the expected effects of various mitigation measures and their application to the noise exposure of those employees. Further analysis demonstrates the importance of producing a tangible benefit when looking at cost-benefit analyses. The approaches used allowed specific methods of mitigation to be modelled and decisions to be made which were considered to be ALARP, be they engineering or administrative controls. By taking this approach the importance of producing a coherent noise action plan, which adhered to the hierarchy of controls is also discussed.

The study demonstrates how the processes used met the required noise exposure levels for the most affected employees. It was considered that the results of the study met ALARP, produced an auditable trail for the decision making process in achieving ALARP, and produced the most effective solution at the optimum cost.

INTRODUCTION

The premise behind this paper was the replacement of a power generation module on an offshore oil and gas production platform. Two existing gas turbine generators were to be replaced with three gas fuelled Caterpillar drive units (G3516 LE).The impact of the replacement on the platform noise exposure risk had to be determined. Should it be shown that the risk would be increased, it would be necessary to ensure that the risk was reduced to be As Low As Reasonably Practicable (ALARP).

This paper demonstrates a process for determining the impact of the power generation module replacement on the platform noise exposure risk and the subsequent processes for ensuring the new design achieved its requirements with respect to noise exposure ALARP.

This project was undertaken in the United Kingdom and was subject to the legislation within that country.

NOISE EXPOSURE ASSESSMENT

Background

The nature of the design of any oil and gas production platform requires a large amount of industrial processing plant to be located across a relatively small surface area, often over several decks. Depending on the particular platform design, it is common to find decks separated by steel grills as well as steel plate. In some instances, the disparate processes are located in individual modules separated by distinct bulkheads, though this is not a common occurrence. The consequence of these highly reverberant designs is that noise generated by neighbouring plant, be it above, below or adjacent, can pervade the space occupied by relatively quiet equipment. Subsequently, any employee working in what should be a quiet area can receive a high noise exposure from the noise generated by equipment from neighbouring areas. It is considered that this acoustic environment is highly complex and that the control of noise exposure risk can be a difficult process. In addition to these complications, it is possible for up to 350 personnel to be working on a platform at any one time. The determination of what the noise exposure levels each of these personnel receive, and what the cause of this risk is can be problematic.

In order to make a complex situation as simple as possible, a method has been derived which divides complex areas and variable personnel work patterns into more simple work areas and tasks. Using this information in more manageable subdivisions it is possible to attribute noise exposure risk to specific jobs or work tasks, and identify which areas of the platform are generating the highest exposure risk.

For this particular project, a full noise exposure risk assessment had been undertaken for the whole platform. The assessment was undertaken against the United Kingdom Control of Noise At Work Regulations 2005 (CoNAWR) though the premise behind this paper can be applied to any regulatory requirements. The power generation module was a specific enclosed module with steel plate deck, deckhead, and bulkheads containing two Rushton gas turbines and electrical generators.

Assessment Summary

Based upon the last exposure assessment undertaken for the platform, and following conversations with the platform regarding the validity of the assessment, the contribution of the power module to the platform noise exposure risk on significant platform trades was determined to be as shown in Table 1. A benchmark system used by the United Kingdom Health and Safety Executive (HSE), highlights the level of exposure experienced by various trades in the UK offshore industry and this information has been statistically analysed. Using this system, the level of exposure received by the significant trades that work within the existing power module on this particular platform has been assessed against the benchmark.

Table 1. Noise exposure risk for 5 most affected employee groups

Trade	Exposure Level $L_{Aeq, 8h}$ dB	Benchmark Semantic
Roustabout	100	Above Upper Quartile
Scaffold Team Leader	99	Above Upper Quartile
Operation Technician	96	Upper Quartile
Painter	95	Above Upper Quartile
Electrician	92	Upper Quartile

The average sound pressure level measured in the power module was found to be 93dB(A) L_{eq}. The average noise exposure level for the platform was found to be 94dB(A) and the contribution of the power generation module to the platform noise exposure risk was 4%.

Impact of Proposed Changes

In order to determine the impact of the proposed changes it was necessary to remove the influence of the existing gas turbine generators. As the power module was to be completely stripped of internal equipment, this process became simple. The gas engine manufacturer was able to supply sound pressure level data at set distances. Assuming hemispherical propagation in a free field environment, this data allowed the sound power level of the engines to be calculated. By defining the power module internal material characteristics (steel plate decks and deckheads, steel engines, and steel bulkheads lined with perforated steel sheet with a Rockwool insert) and known dimensions, the reverberant sound levels within the power module could be calculated.

The data presented in Figures 1 and 2, was obtained from manufacturers and reference information. It was subsequently determined that the internal sound pressure level for the operation of three engines would be 112 dB(A).

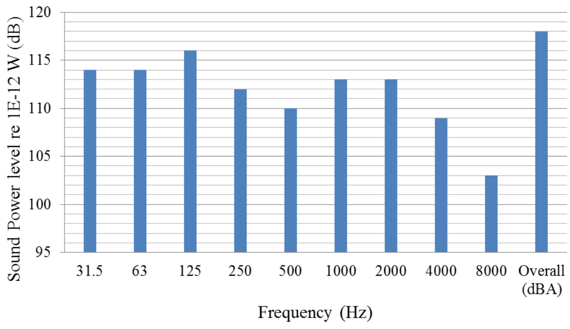

Figure 1. Calculated Sound Power Level Spectrum of one Gas Engine

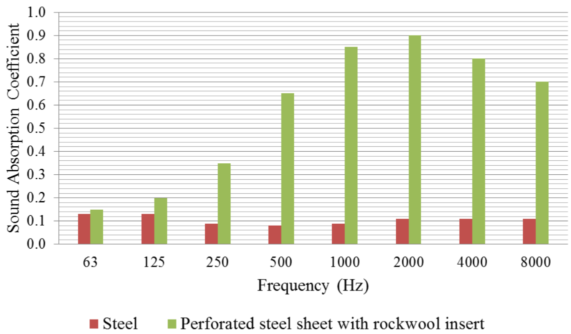

Figure 2. Sound Absorption Coefficients for Power Module Internal Materials

A direct comparison of the existing power module average sound pressure level and the expected average sound pressure level reveals an increase from 93 dB(A) to 112 dB(A). As the module was fully enclosed, the effect on the areas surrounding the power generation module from the engines was predicted to be negligible (existing noise levels surrounding the module ranged from 78 to 91 dB(A) and the predicted contribution from the power module was 55 dB(A)). However, the increase in risk for personnel requiring access to the module will be high with those persons receiving a much more significant noise exposure. Following discussions with platform operations and maintenance teams, it was also understood that more access to the module may be necessary due to an increase in maintenance requirements for the new units. Such a situation would further increase risk, though the degree of this risk could not be predicted as exact work pattern information was not available.

Although noise breakout from the module to external deck areas was predicted to be negligible, it was understood that the engine exhaust system would be ducted out of the module but will not be silenced at source. Engine exhaust silencers were to be located 2/3 along the exhaust duct length of 30m, placing them 20m downstream of the engine exhaust outlet. Conservative estimates of the impact of the noise transmitted by the exhaust duct onto the walkway next to the power generation module indicated that noise levels may increase by around 3 dB(A) to 81 dB(A). Although this impact would have a negligible effect on the platform noise exposure risk, such an increase did not represent 'good practice' with regards to controlling noise levels.

In addition to the exhaust noise, three axial fan cooler units were proposed to be installed on a new cantilever platform adjacent to an external walkway, next to the power generation module. Predictions for 3x100 kW units operating, indicated sound pressure levels on the immediate walkway could rise to 100 dB(A) which would increase the platform noise exposure. Such high noise levels on walkways are also not recommended as communication, either locally, or over the platform public address system becomes increasingly difficult. By applying this information into the platform noise exposure model, the effect on the platform noise exposure risk became apparent. Table 2 highlights these effects.

Table 2. Effect of proposed changes to power module on platform noise exposure risk

Trade	Exposure Level $L_{Aeq,\ 8h}$ dB	Difference in Exposure Level dB(A)	Benchmark Semantic
Roustabout	103	+3	Above Upper Quartile
Scaffold Team Leader	100	+1	Above Upper Quartile
Operation Technician	100	+4	Above Upper Quartile
Painter	99	+4	Above Upper Quartile
Electrician	102	+10	Above Upper Quartile

As well as an increase in average area sound pressure level of 19 dB(A), all of the most significant trades had an increased noise exposure risk (varying from between 1 to 10 dB(A)) and all of these trades were considered to be in the Above Upper Quartile benchmark semantic. The average platform noise exposure level rose from 94 dB(A) to 98 dB(A) and the significance of the power module on the overall platform noise exposure risk rose from 4% to 65%. It was therefore concluded that the proposed replacement of the gas turbine generators with gas engines would require significant noise control measures to be implemented in order for the project to be considered to be ALARP and to be considered to be acceptable by the HSE.

FRONT END ENGINEERING DESIGN

The noise exposure assessment and impact of the proposed changes to the power module were undertaken during the Front End Engineering Design (FEED) phase of the project. At this stage of the project work was undertaken with the project engineering contractor on behalf of the platform operator. Discussions were held with both the engineering contractor and the platform operator to discuss the feasibility of various noise control options. The following measures were presented to the project engineering contractor for discussion:

Table 3. Noise control options

Noise Control Option	Feasibility at FEED Stage
Replace old gas turbine units with new gas turbine units	Best solution with negligible impact on platform noise exposure risk, and may even reduce risk if quieter units were purchased. CoNAWR recommends this approach wherever possible. However, it was understood that over the lifetime of the project, a significant reduction in operating costs and in environmental emissions could be achieved by using a gas fuelled engine system. For these reasons, the operator felt this option would not be feasible.
Use quiet gas engines	In order to meet the operating requirements, only two engine manufacturers could meet the necessary specifications. Of these manufacturers, only one would be willing to supply the project. Consequently, the Caterpillar G3516 LE unit was selected.
Acoustic enclosures	Acoustic enclosures were considered to be the most effective option for reducing the noise exposure impact of the new engines; however, the power module did not seem to lend itself to accommodating such a measure. The presence of equipment pipework, an access hatch, an airlock, and a crane support stantion negated the possibility of incorporating engine enclosures.
Remote monitoring	By removing the need for personnel to access the power generation module the noise exposure risk would be reduced as no-one would be exposed. This could be achieved by locating any equipment monitoring gauges or indicators in a remote location (such as the neighbouring control room). As the engines required a regular visual inspection and oil checks, the scope for remote monitoring could be limited. Video camera technology has been discussed; however, platform operators have felt that this may not be a practicable solution.
Acoustic absorption	The power generation module is a highly reverberant environment. By applying acoustic absorption to the walls of the module the reverberant noise level in the module would be significantly reduced.
Minimise structure borne noise	The chosen engines are of a high vibration design. In order to minimise vibration transmission into the surrounding equipment skid and module, bespoke anti vibration engine mounts could be utilised to ensure a minimal vibration transmission to the equipment skid. It would be imperative that this solution was rigorously checked to ensure the solution will be effective. Further to this, all rigid connections to the engine should be replaced with resilient connections to remove any structure borne transmission.

Acoustic screening curtains	It is possible that retractable noise control curtains could be incorporated into the power generation module and may allow screened maintenance work to be undertaken. Unused curtains could be stored along the side of the module by using a curved track.
Portable acoustic screens	For any maintenance work, portable screens could be used to screen the operator from the other engines.
Screen walkway	To reduce the noise levels on the walkway adjacent to the power module, due to noise generated by the cooler fan units, it would be considered necessary to screen the walkway from the units. This could be achieved using steel plate covering the full area between decks.
Exhaust duct lagging	The exhaust duct for the engines would not have a silencer immediately after the engine exhaust outlet, but would instead be located 20m downstream. As it was not possible to move the silencer closer to the engine units (due to backpressure) it was likely to be necessary to apply an acoustic lagging to the exhaust duct to reduce noise levels on the nearby walkways.

All of the options in Table 3 were put forward to the project engineering contractor for discussion. However, it became apparent at this stage that the project engineering contractor had not considered the potential adverse effect in noise exposure risk. Due to cost implications the contractor felt that the only possible options were the use of acoustic absorption to be applied to the bulkheads, and for the use of acoustic screens/noise control curtains to be used for maintenance work. Despite repeated warnings to the contractor that the solutions selected would not reduce noise exposure risk to an acceptable level on their own, and that the ALARP requirements would not be met, the FEED stage concluded with these solutions used to take the project forward.

It is not uncommon for this scenario to arise. Often, within the scope of a large engineering project, the effect of noise exposure risk is all too easily neglected. It is usually an afterthought from the engineering team to include a noise exposure assessment or impact study. When the study finds a problem, the engineering team can find that this information is unwelcome, unexpected and often too late to do anything about.

DETAILED DESIGN PHASE

As the project entered the Detailed Design Phase, the platform operator had had a chance to appreciate the noise exposure risk. The operator's engineering team had the wherewithal to refer the issue to their health and safety team, with whom our consultancy had a good working relationship. Following the review it was felt by the operator that project engineering contractors FEED study conclusions in relation to noise exposure risk had not been sufficiently explored. It was felt that the options put forward for noise control during FEED should be re-explored and a more robust solution found.

The option of replacing the old gas turbine units with a like for like replacement continued to not be considered to be financially viable, as the expected life left for the platform operations was limited. The option of sourcing quiet equipment was also not possible due to the power requirements and supplier limitations. The next significant option was that of acoustic enclosures. This option was always considered by the project engineering contractor to be an engineering improbability due to the limited space available, and due to the complex safety environment that would be required to operate gas engines in an enclosure.

For this option to work, the solution would require three separate acoustic engine enclosures to be located in a space (L)14m x (W)9m x (H)4m. The power module would require sufficient space to allow operations and maintenance personnel to move around, and in between each enclosure. Visual inspections of each engine would be required on a regular basis. Each engine would need to be fuelled by its own supply, and each unit would require its own air intake and exhaust. In addition, each engine would need to be kept sufficiently cool, and would require its own fire and heat alarm system and fire suppression system. On top of this, each engine would require the ability to allow a full maintenance and repair schedule, which would require each enclosure to be fully modular and demountable and replaceable. From an ALARP perspective, the combination of all of these factors, plus the cost of undertaking these options had been considered to be impracticable, particularly from a retrospective noise control perspective. However, the complete redesign of the power module had presented a different perspective and in analysing the options at hand, the operator considered that these solutions, whilst being challenging, where practicable within the design project and represented the best possible solution for protecting the aural health of their workforce.

The Solution

Having selected a preferred method of noise control, it became necessary to select the best possible solution within the design parameters, time and financial constraints. Three potential vendors were chosen to present designs and work plans for delivering a solution that would meet a power module acoustic requirement of an average internal reverberant sound pressure level for three engines at 100% load of 83 dB(A). During this process, each design was assessed for its acoustic performance and opinion presented to the project engineering contractor and platform operator engineering team. Using this information in conjunction with operational considerations, financial implications and timescale requirements, one vendor design was selected.

The final design comprised a modular system which could be erected and dismantled over a basic steel frame. As the engine would be mounted on steel skid, there was a basic requirement that the enclosure should encompass the skid as well as the engine and ancilliary equipment. The frame incorporated the fire control and detection systems. Ducting was provided to allow air to be drawn and extracted through the enclosure to a degree that allowed the engine to be sufficiently cooled. Further ducting was included to allow air intake for the engine combustion system and for the exhaust. Observation windows and internal lighting were included for visual inspections to be undertaken from outside each enclosure. All engine operational switches and instrumentation were located within the engine control room located outside of the power module. It should be noted that the sound pressure levels on the deck below were particularly high. Although the engine was mounted on standard manufacturer's anti-vibration mounts, any structureborne noise transmitted to the deck below was not condidered to be significant. An example of the proposed design is presented in Figure 3.

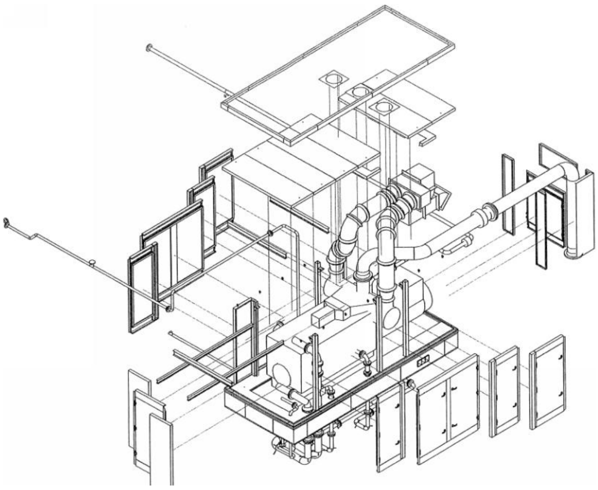

Figure 3: Engine acoustic enclosure design

By working closely with the acoustic enclosure supplier, and with the project engineering teams it was possible to identify potential problems within the project as they occurred. This approach allowed problems to be corrected as they happened rather than at the end of the project when it would have been too difficult to rectify any such problems. For example, during one project meeting it became apparent that the engineer responsible for the air intake and extract for each enclosure, and for the power module was not focused on the acoustic aspect, nor were they able to understand the principles behind acoustics or noise control. Though the project had an acoustic design specification of meeting 83 dB(A) within the power module during the operation of all three engines at 100% load, this particular engineer had located each enclosure air intake and air extract fan on top of each enclosure, within the power module, a total of six fans. The sound pressure level at 1m for *each* fan unit was 85 dB(A).

Within the design requirements of the project, such an oversight by one individual or discipline within an engineering team could be considered to be usual. Available space within the power module was minimal and this particular engineer was under pressure to find a solution for locating these particular fans. Acoustics was the least of their concerns. Fortunately, because this problem was identified immediately, it was possible to change the ducting designs and locate all of the fans outside the power module, solving what would have been a significant problem from the acoustics perspective of the project. It should not be forgotten however that the whole purpose of undertaking this project was to reduce the noise exposure risk this project was going to present. Such problems occur with a high degree of frequency and only vigilance throughout the project can prevent such errors occurring.

Equipment vendors often quote the acoustic performance of equipment to be 85 dB(A) at 1m. Whether such performance has been measured, modelled or guessed is often a point of conjecture. Similarly, some noise control vendors may claim certain degrees of attenuation performance, but unless the vendor is proven to be reputable, such claims should be treated with at least some degree of scepticism.

As the project progressed, acoustic measurements were undertaken during the equipment testing programme. It was possible to measure the sound intensity of each of the engines and the transmission loss performance of a completed enclosure. Measurements of sound intensity were undertaken on each of the three engines during various degrees of loading, without any acoustic enclosures. Such measurements allowed an average sound power level and frequency spectrum to be obtained. Knowing the enclosure characteristics it was possible to determine the average sound pressure level inside the enclosure. One of the engines measured is presented in Figure 4.

Figure 4: Gas engine during operational testing

Similarly, measurements were undertaken for the transmission loss of the acoustic enclosure. By placing a pink noise generator and appropriate loudspeaker system inside the enclosure, and measuring the sound pressure levels inside the enclosure, and at fixed points outside the enclosure it was possible to understand the actual source sound pressure level and the expected transmission loss of the control method. By understanding these parameters, it was possible to determine the expected sound pressure levels in the power module. The results are presented in Figure 5.

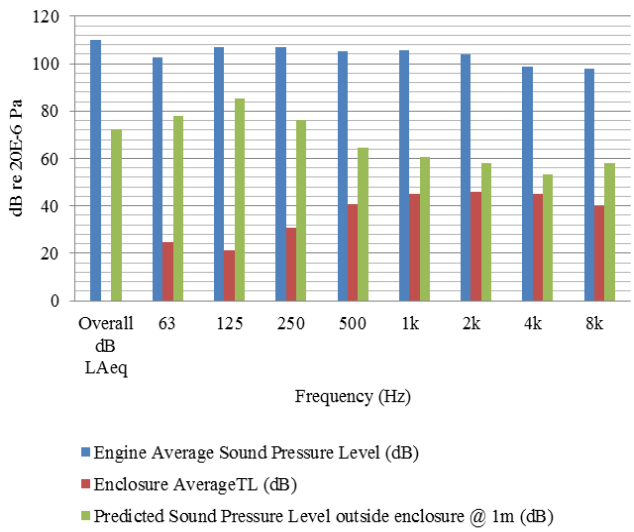

Figure 5: Expected engine sound pressure level attenuated by acoustic enclosure

From the results in Figure 5 it could be seen that a sound pressure level of 73 dB(A) at 1m from the enclosure was being predicted.

CONSTRUCTION PHASE

As the acoustic behaviour of the engines and of the acoustic enclosure was understood, and the performance of each of these components was within the design parameters for the project, the engineering teams had confidence that the project would meet its acoustic requirements.

In order to ensure that the performance is not compromised, it was necessary to ensure that the construction process followed its requirements, and that no corners were cut with respect to construction methods or materials. Often the reality of the construction site can be very different from the engineering drawings. Under such circumstances the construction team, particularly if they are comprised of a third party contractor, may not fully appreciate the design brief. This can lead to incorrect decisions being made to resolve site specific problems. In turn this can lead to the project becoming compromised.

To negate such problems, the worksite was visited midway through the construction phase. The construction was observed and construction workpacks were interrogated to ensure that the build was following the design and that no problems were being encountered. For this project, no problems were found and the construction was correctly following the design.

COMMISSIONING PHASE

On completion of the project it was necessary to undertake a check out survey to ensure that the project had met its objectives. Mobilising to the platform, tests were scheduled to operate all three engines under full load (100%), during which, sound pressure level measurements would be undertaken within the power module, and on the walkway around the fan coolers. Pictures of these areas are presented in Figures 6 to 8.

Figure 6: Fan coolers on cantilever platform

Figure 7: Between acoustic enclosures

Figure 8: Acoustic enclosure and access walkway

The viewing windows for inspection can be seen in Figures 9 and 10.

Figure 9: Inspection windows

Figure 10: Inspection window

The steel wall separating the fan coolers from the walkway can be seen in Figure 11

Figure 11: Steel wall screening access walkway from fan coolers.

The acoustic lagging on the exhaust duct can be seen in Figure 12

Figure 12: Engine exhaust duct acoustic lagging

The results can be seen in Figure 13.

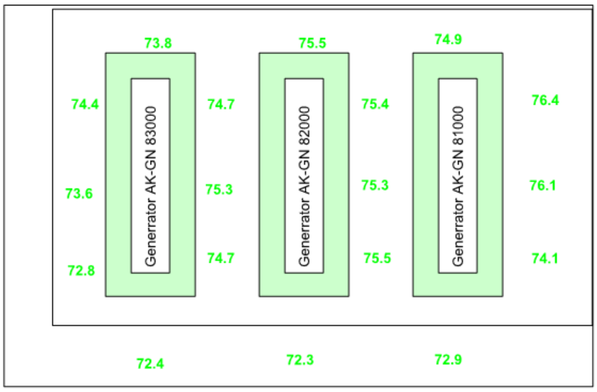

Figure 13: Sound pressure levels dB(A) re 20E-6 Pa measured around three generators operating at 100% load

It can be seen that all measured sound pressure levels with all of the units in operation are below the requirement of 83 dB(A) for the power generation room. The maximum L_{eq} was found to be 76.4 dB(A) with the room average found to be 74.6 dB(A). It can be seen that the measured levels compared favourably with the expected level of 73 dB(A) predicted from the transmission loss measurements and sound power calculations during the detailed design phase.

Whilst the three units were operating, measurements were also undertaken around the coolers and adjacent to the exhaust ducting on the cellar deck. Sound pressure levels around the coolers varied between 83 and 85 dB(A) L_{eq} with the sound pressure level in the middle of the cooler units measured to be 88 dB(A) L_{eq}. The walkway between the coolers and the power generation room was found to have a sound pressure level of 85 dB(A) L_{eq}. Sound pressure levels on the cellar deck by the exhaust ducts were measured to be 80 dB(A) L_{eq}.

Table 4. Effect on noise exposure risk after project was completed

Trade	Exposure Level LAeq, 8h dB	Difference in Exposure Level dB(A)	Benchmark Semantic
Roustabout	100	0	Above Upper Quartile
Scaffold Team Leader	99	0	Above Upper Quartile
Operation Technician	96	0	Upper Quartile
Painter	95	0	Above Upper Quartile
Electrician	91	-1	Upper Quartile

The contribution of the power module on the overall platform noise exposure risk was reduced from 4% to less than 1%. It should also be remembered is that the potential increase from 4% to 65% was hugely significant and this was avoided. Of further note is that the exposure level of the electrician trade was reduced from 92 dB(A) to 91 dB(A). This exposure level remains high, but some reduction was observed. The key for this particular platform will now be to investigate other, more significant areas of noise exposure and implement suitable control measures.

SUMMARY

This paper has presented a case study of a noise control project which aimed to reduce noise exposure risk on an oil and gas production platform resulting from an engineering project to replace the platform power generation module. The process for evaluating the platform noise exposure risk has been discussed and the benefit of producing a detailed risk assessment as well as an exposure study has been shown.

By following the process of providing detailed acoustic consultancy to the engineering teams throughout the life of the project, from FEED to commissioning, the pitfalls and the benefits of providing pro-active ongoing advice throughout the project has been presented.

By keeping a close watch upon the project development it has been demonstrated that potential problems can be avoided or contained, and that as a result of maintaining a positive working relationship with the engineering teams, the sometimes difficult objectives of a detailed noise control project can be achieved.

This particular project has also shown that despite the many obstacles that may be placed in the way of achieving suitable noise control, the use of acoustic enclosures in complex, difficult areas that utilise minimal space is a feasible and practicable method of mitigation. It is considered that this project sets a potential benchmark for similar projects when considering the feasibility of such projects.

REFERENCES

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