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NOISE CONTROL FOR A BETTER ENVIRONMENT

# Noise control: a holistic approach to resolving challenging problems – a review

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**ABSTRACT**

**Noise control can be highly varied and sometimes complex. The result of any mitigation will depend upon many factors; from correct understanding of the problem, to managing technical and commercial expectations. 'Off the shelf' solutions can be effective for some noise problems, but the parameters need to be fully understood. Handled incorrectly, results can lead to dissatisfaction, financial penalties, an unhappy client and mistrust. This can ultimately lead to a reluctance of the client to invest in future noise control activity.**

**Continual engagement and education throughout the project, provides the client with a better understanding of the noise issue and enhanced awareness of the solutions that meets expectations. By taking responsibility for the delivery and execution of the chosen solution, noise control providers can ensure that that full client satisfaction is achieved.**

**This paper presents case studies showing how noise problems can be overcome through continual engagement, understanding and good acoustic engineering. Moreover, it presents the case for a total engineering approach, combining detailed consultancy, design, delivery and execution of the noise mitigation from a single provider. Furthermore, it describes how non-acoustic professionals can be educated through this process to better understand noise issues now and for the future.**

**Keywords:** Noise Control, Education, Solutions
**I-INCE Classification of Subject Number:** 30

## 1. INTRODUCTION

Following many years of providing recommendations and solutions to various noise problems experienced by owners, operators and designers of industrial plant, it has become apparent that there can be a significant disconnect between the client and the solution provider. This can lead to, not only an unsatisfactory solution to a problem, but to the disengagement of the client to any form of noise control. This can place all

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interested parties (operators/employees/residents etc.) at an un-necessary disadvantage. This disconnect often arises from a lack of understanding of the problem and the potential solution, often exacerbated by poor communication. It is considered that the use of a single provider using a defined whole project approach, from material manufacture, through assessment and provision of solutions can alleviate these issues.

This paper sets forward a series of case studies where an over-reaching, holistic approach, supplied by a single service provider, to ensuring these issues do not hamper any solution, has resulted in the correct noise control solution being applied, and subsequently educated clients to openly embrace the correct processes to ensure future noise issues are resolved in a timely and efficient manner. Where this approach has failed, or could not be utilised, the consequences have been presented.

## 2. Philosophy

Preventing noise using controls at either the source/transmission path/receiver remain the key aspects of noise control provision. The determination of which method can be used often depends on the physical, regulatory, operational, and financial restraints placed by the client. It is imperative first to understand the physical problem and to frame any solution with those restraints. Failure to do so will result in a poor/failed project. Secondly, by engaging with the client at an early stage, educating them, and using an ALARP (As Low As Reasonably Practicable) approach, often leads to the best possible solution for all parties. The ALARP approach allows a project to consider the possible benefits against all aspects of implementing the solution and having to work with the solution. These aspects can take on the form of cost, operability, inspection, and maintenance, amongst others. A range of solutions can be implemented over time to allow the site operator to practicably implement the solution over a short, medium and long term, according to the lifetime of their asset.

Finally, the ability to present the solution with tangible benefits, in a simplistic manner that is straightforward to understand allows the client to feel empowered and develop confidence that their challenges are being dealt with in a professional manner. This approach creates a positive experience that the client is actively willing to repeat should the need arise.

Historically, the scope of the noise consultant is limited to the identification and quantification of the noise issue. More recently however, there are a number of acoustic solution providers who now offer a holistic service, including both the capability to recommend, supply and qualify the adopted mitigation measures, thereby delivering a total engineering approach to the client. It is through the implementation of a total engineering solution model that clients will develop confidence as the provider adopts a responsible, supportive role for the duration of the project.

### 2.1 Understanding the Problem

Within a project, understanding can take many forms. Initially, it is common for the client to have a 'Noise Problem' but to be ignorant of the details surrounding this problem. Similarly, the cause and effect of this noise problem is also not fully understood in the wider context of the project. Noise can be a symptom of wider problems or be caused by actions made by other parties.

It is often the role of the noise control engineer to understand the whole nature of the problem; the cause of the problem; the financial restrictions imposed by the client; and their expectations on the deliverables for the project. If none of these aspects are fully understood it is practically impossible to achieve a mutually beneficial solution.

### 2.2 The Process

Ultimately the client will need to be educated to allow them to understand the issues they face; what solutions are available to them; and what the end state of the project can look like. The complexity of this journey will depend on the interest and capability of the client to grasp the issues. Some clients can be eager to fully participate in the process, whilst others just want a particular outcome and will not be interested in how that is achieved as long as the financial budget is met. Understanding the most effective way to engage the client is a key skill of the noise control engineer. Above all, transparency of the process and the simplicity of the presentation of this information allows a client who may have little understanding of acoustics to feel comfortable that their budget is being effectively spent.

Where problems are encountered, the trust that has been engendered through the process should ensure the client is able to comprehend the further issues and be more capable of allowing the noise control engineer to resolve these problems, even if the solution is more expensive. An uninformed, uninterested client is less likely to be receptive to changes on scope or cost.

### 2.3 The Solution

Using an ALARP approach, it is often necessary to provide a series of potential solutions to a problem. All solutions will be defined as a source, transmission or receiver solution, or a combination of these, as well as elimination or low noise replacement. As the physical problem should have been defined at the start of the project, the solutions should be presented as an ALARP framework. Depending on the limits of the project, it may be necessary to provide a short, medium and long term noise control strategy as well.

Regardless of the nature of the solution, be it simple or complex, it is unlikely that the client will appreciate the true nature or elegance of the solution beyond whether it has solved the problem. The solutions should be defined simply in a benefit-cost format to allow the client to make an informed decision.

The following section presents a series of case studies where some or all of the philosophy described here was used, and the positive and negative outcomes respectively.

## 3. Case Studies

### 3.1 Offshore Produced Water Injection Pump

Offshore oil and gas project required an existing Seawater Water Injection Pump to be converted to re-inject produced well water. The pump originally had an acoustic enclosure, but this was to be removed to permit service with produced water, which could still contain residual hydrocarbon gas.

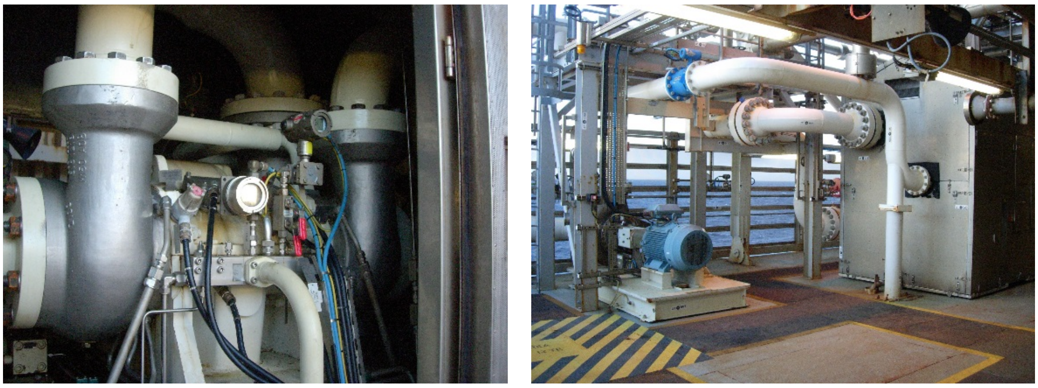

Figure 1: Water injection pump and pipework prior to noise control measures

Noise control measures were recommended and comprised the implementation of full pipework acoustic insulation, and a 3m high, 'L' shaped screen between the pump and the adjacent walkway. Upon receiving recommendations, client decided to save costs by applying the mitigation independently, halting the process that had been started.

Upon completion of the installation works, the client proceeded to complain that the project had not only been unsuccessful, but had exacerbated the situation and that noise had increased in level. Upon re-attending site and investigating the situation, it soon became apparent that following the decision to complete the project independently, the client was not able to execute the project due to a complete lack of understanding of how noise control worked. To confound this situation the higher noise being reported was found to be primarily due to the noise competent person on board the platform comparing $L_{Aeq}$ with $L_{Cpeak}$ sound pressure levels, showing a breakdown in acoustic education.

Figure 2: Incorrect noise control applied to pipework and water injection pump

Only a small part section of the pipework had been insulated. The insulation comprised a thermal low density mineral wool and a barrier layer and did not conform to the classification of ISO15665[1] that had been recommended. The materials used had been selected as they had been found in a storage unit. The L barrier was able to mitigate noise levels on the walkway but had only partially been treated with an acoustically absorbing inner layer, creating a higher reverberant level around the pump itself.

$L_{Aeq}$ sound pressure levels were measured to be between 91 and 108 dB. These sound pressure levels represented an increase in the original sound pressure levels, prior to equipment conversion, of up to 14 dB. These sound pressure levels were broadly in line with the sound pressure levels measured following removal of the pump enclosure, prior to the ‘noise control’ being installed. Essentially, the noise control that had been installed was totally ineffective.

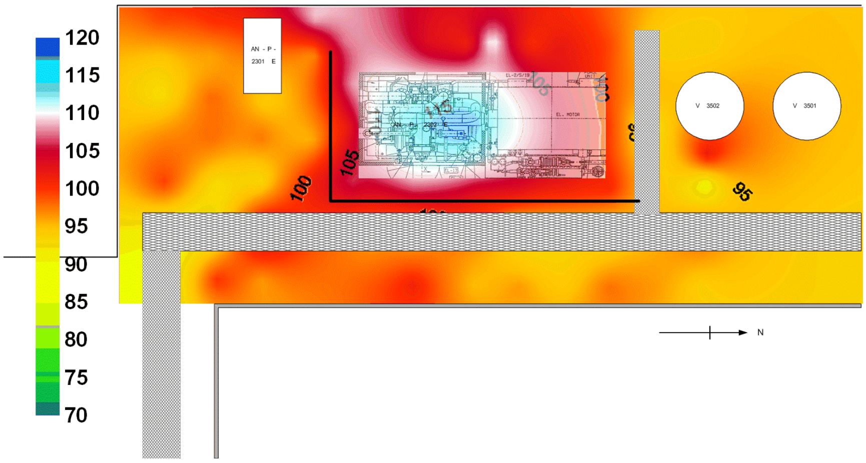


Figure 3: Measured sound pressure levels around partially mitigated water injection pump and pipework

Recommendations were re-made to apply acoustically absorbing lining to the interior of the barrier to reduce reverberation levels. In addition complete insulation of the water injection pump pipework was recommended using an ISO15665 Class C insulation. Unfortunately, the client had lost complete confidence in the use of noise control and decided to abandon the project without implementing further recommendations. This was considered to be a combination of financial restraints, political wrangling between the owner and 3$^{rd}$ party insulation contractor, and a general loss of faith in the process.

Though the problem had been fully understood, the education of the client had not been successful and resulted in disengagement with the noise control engineer in this particular instance. The result was that the process fragmented and too many third parties became involved. The result was unsatisfactory for all parties involved. Penalties imposed on the project could not be ascertained but the result of the conversion was in contravention of the local Health and Safety Authority requirements.

## 3.2 Offshore Power Generation

An offshore oil and gas project required replacement of a power generation module on an off-shore oil and gas production platform. Two existing gas turbine generators were to be replaced with three gas fuelled Caterpillar drive units. 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 ALARP as a minimum to ensure the project was approved by the Health and Safety Authority.

During the Front End Engineering Design (FEED) stage of the project, it was determined that the replacement drive units would significantly increase the platform noise exposure risk. Recommendations for a variety of noise control options were proposed and discussed at length with the design company. Unfortunately, as the design company had not foreseen this issue arising, it was decided to only apply minimal noise control to reduce reverberant levels in the power module. This was emphasised as being unlikely to be acceptable for the project but was ignored.

Figure 4: Gas engine during sound power determination

As the project entered the detailed design phase, the platform operator became more involved and insisted that the design house selected solution was unacceptable and that the final design incorporated more stringent mitigation. By selecting a low cost noise control solution during FEED, this placed heavy financial implications on the design house as they had not budgeted for a more stringent solution.

In this instance, the use of acoustic enclosures were advised with a remote start up sequence and use of viewing windows to remove the need for personnel to be directly exposed to the noise generated by the power units. Resistance continued to be applied by the design house and some elements of the operator. It became apparent that the guidance of experienced noise control engineers would be needed throughout the project to reassure all parties that the functionality and operability of the selected solution would meet all project requirements as well as providing the correct degree of noise mitigation. This was achieved via continual engagement, to approve any changes to the design, and provide verification of milestones as the project progressed.

Figure 5: Engine enclosure highlighting observation and inspection windows

During the design phase a number of mistakes were found to have been made by the design house, primarily around the placement of intake and extract fan units, but due to the collaborative nature of the project, these could be found quickly and corrected. Upon completion of the design, reviews of the construction work-packs were undertaken to ensure translation from design was correct, and a site inspection was organised to ensure these work-packs were being implemented correctly.

During commissioning, a check out survey was undertaken and the project was found to have exceeded expectations. A target area $L_{Aeq}$ of 82 dB was significantly bettered and an average area $L_{Aeq}$ of 78 dB was measured.

The result of the project was to have a very satisfied owner and a client that was now educated in how to undertake a noise control engineering project; why the collaboration was necessary, and with a good understanding of some of the basics of acoustics. This was confirmed when the same client returned for their next project at a very early stage to engage noise control services.

Although the problem was understood, the failure to keep the client educated regarding the benefits and requirements of project penalties almost let to a breakdown of the process. Once this issue had been resolved, the continual collaboration of all interested parties throughout the remainder of the project ensured that the project was highly successful and met and exceeded its targets. It should be noted that small, apparently inconsequential decisions can have the ability to completely undermine the project goals. These actions can only be prevented through continual engagement and vigilance throughout the whole process. Anything less can result in the project failing its aims.

### 3.3 Pressure Reduction Station

Part of a network of natural gas Pressure Reduction Stations comprising a major infrastructure project required new pipework and valves to be incorporated into existing facilities. Due to possible generation of high noise levels from the new pipework, it was necessary to predict the impact of the new works. These predictions were assessed against a noise limit provided by the client and found to significantly exceed this limit. Designs and pipeline elements could not be altered due to process requirements. Subsequently, it was advised that acoustic insulation would be required. Due to concerns over Corrosion Under Insulation issues that may arise from fibrous materials, an ArmaSound Industrial Systems (ASIS) Class C (to ISO 15665) insulation system from Armacell was recommended.

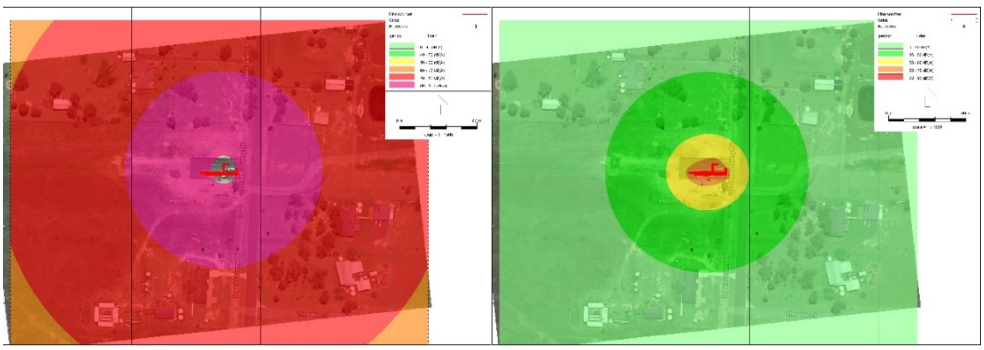

Figure 6: Predicted acoustic propagation before and after acoustic insulation

Figure 7: Acoustically insulated PRS pipework

A verification survey was undertaken to confirm project limits and it was found that although the insulation provided the expected noise level reduction, the client had used the incorrect limit. The true limit was 10 dBA lower than had been provided. Unfortunately the construction phase of the project initiated immediately after the survey and could not be altered. The situation was discussed with the client who decided that the project would continue and the end state would be considered following commissioning.

Following completion of the construction phase, a check out survey of the new plant operation was undertaken. The predicted, mitigated sound pressure levels were broadly met, however, as expected, the limit was confirmed to have been exceeded.

Figure 8: Predicted effect of application of acoustic barrier & Applied barrier

Working with the client, a further detailed assessment of the new plant items characterised the elemental sound power levels. These were applied to an acoustic propagation model and calibrated against the wider survey data. It was then possible to apply the performance of various noise control measures to the model to identify the likely impact of applying these measures. By being able to graphically indicate the likely impact of each mitigation measure and provide a typical expected cost for each measure, the client was able to decide which additional measure to employ with the most efficient cost-benefit. Further, by using a single supply company approach, for both assessment and material provision in this instance, the client was able to make their decisions in a fast and effective way as all necessary data and information was easily at hand from one source. It should be noted that this process only worked as the provider is able to demonstrate continuous integrity and transparency, breeding the necessary trust between parties.

The overall result of the project was to ensure that the client met the necessary limit and the project was deemed successful. The client was suitably educated to subsequently rely on the provider for other projects requiring acoustic understanding and noise mitigation.

The project problem was understood and the client fully engaged at each step of the process. This allowed the client to make continual, informed decisions, even when the project faced apparent failure. The solutions to all problems were presented in an easy to understand and simple manner, which was appreciated by a client with little or no acoustic knowledge or understanding. That the client was fully satisfied with the outcome and returned for further projects demonstrated that the holistic approach taken was justified.

### 3.4 LNG Plant

A client reported that they had high noise levels in a particular area of an LNG plant. No specific limit was requested but it was known that the issue was related to employee health and safety, indicating that the area limit would likely be between 82 and 88 dBA. Current noise levels were reported to be in excess of 110 dBA. The client initially requested that a standard pipework acoustic insulation material should be supplied.

Discussions with the client highlighted that they did not really understand the issue at hand and that they would welcome further assistance. It was agreed that a site survey would be beneficial and was subsequently undertaken. During the survey, further discussions were held. These discussions revealed that the client required the area noise level to be below 100 dBA which would classify the area as ‘Single Hearing Protection’. This represented a significant reduction in the degree of mitigation required.

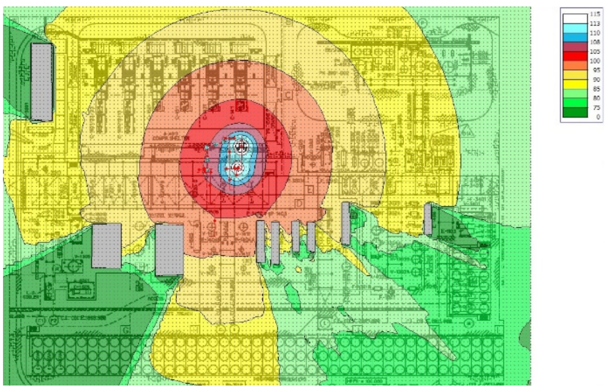

Figure 9: Influence of pipework noise on LNG plant

The measurement survey determined that a second area demonstrated equivalent high noise levels and a number of lines of pipework had had their acoustic insulation removed due to concerns over Corrosion Under Insulation (CUI). CUI refers to the general corrosion event occurring beneath an insulation system, typically on pipework, vessels or equipment. It is a huge issue for oil and gas, chemical process and other related heavy industries. CUI is estimated to represent between 40-60% of pipe maintenance costs and 10% of annual maintenance costs are attributed to repairing damage from CUI[2-3]. In extreme cases, significant risk to injury and death of site personnel is possible.

In order to prevent/mitigate CUI it is necessary to prevent/reduce the ingress and passage of liquid or vapour from external environments to the pipe surface. With traditional insulation systems, the barriers against such ingress is the external cladding itself, along with any additional vapour barriers placed within the system construction. Under perfect conditions, such a construction would be wholly suitable for preventing water ingress and CUI. Unfortunately, damage to the cladding is very common and breaks in seals and punctures in vapour barriers are often widespread. The fibrous nature of traditional materials, in particular mineral wool, ensures that water is easily transferred to the pipe wall via capillary action or a wicking effect.

In addition to the CUI challenges the ingress of water/water vapour brings, the retention of water between the fibres reduces the acoustic performance of the construction which can lead to a permanent change in material properties (such as sagging and consolidation) which effects both thermal and acoustic performance even after the removal of any moisture from the system.

By determining the sound power of the pipework it was possible to build an acoustic model of the plant and apply noise control reductions to the sources. By re-running a number of control scenarios, the client was able to understand which solutions would best suit the needs of the project and make an informed selection of the final solution.

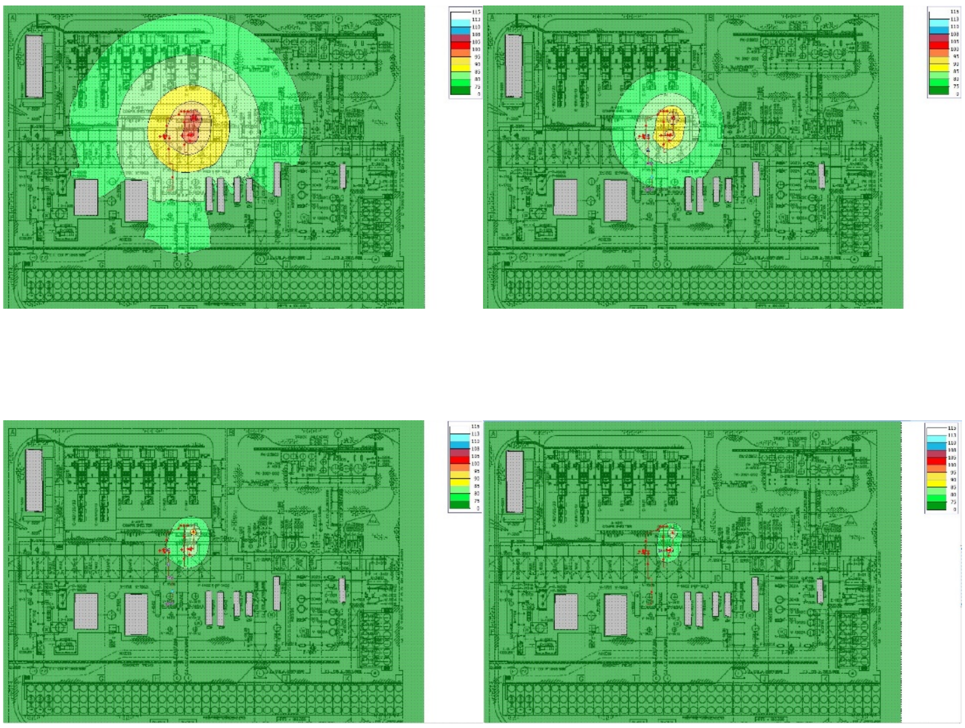

Figure 10: From top left, clockwise, predicted mitigation provided by ArmaSound Industrial Systems MC Class A-C (ISO15665) and Class D (Shell DEP #31)[4]

Delving further into the problem, it was revealed that the whole plant had an ongoing CUI issue and inspection and maintenance programs required removal and replacement of all pipework every 3 to 5 years. Consequently, the client had decided to not replace some acoustic insulation for a number of lines, helping the CUI issue but generating noise levels that were unacceptable to employee health requirements. Though noise needed to be reduced, the problem that needed to be solved was one of CUI mitigation/protection. Any solution had to balance the risk of CUI against the requirement to reduce noise exposure risk of employees.

Had the client insisted on an off-the-shelf solution, without investigating further, it is likely that unsuitable materials which offer little or no protection against CUIwould have been provided and the problem of CUI would have remained an ongoing concern. Fortunately, by taking a more detailed approach and understanding the problem, an Armaflex / ArmaSound Industrial system was proposed and accepted. Such a system was able to provide the necessary acoustic mitigation as well as reduce the risk associated with CUI which was required by the client.

Though it took some time and effort to fully understand the problem, the ability to fully understand all the issues facing the client, aside from just the acoustic problem at hand, allowed the correct control measures to be provided. Had this effort not been made, it is very likely that the client would have received the wrong solution in the long term. Continual effort was needed to educate and engage the client into the benefits of changing a long established technology. Once completed however, the client could fully appreciate the success of the process and project as a whole.

## 4. Lessons Learned

Though the case studies highlighted in this paper are a small number of examples of how and where noise control projects were successful or unsuccessful, it is imperative that lessons, both positive and negative are learned.

The initial phase of any project should be to fully understand the problem presented by the client; what is driving the problem, is it just noise, or are other factors such as CUI, excessive vibration, or public perceptions of wider developments; limits or constrictions, be they regulatory, operational or financial; what the clients' expectations for the project are; and how engaged the client is likely to be.

Once the problem is satisfactorily understood, it is necessary to begin the process of educating the client. Often this achieved by keeping the technical aspects of the process simple, unless the client is motivated and educated sufficiently to appreciate the more complex aspects. If the client is adequately educated they are more likely to be fully engaged and feel as though they are a key stakeholder in the project process. This will allow them to make better, more rational judgements, even if setbacks or problems develop, and maintain trust in the noise control provider.

By being able to simply demonstrate the benefits of the noise control solutions available, an educated client should be able to find concurrence with the thoughts and ideas of the experience noise control engineer. Using the ALARP approach enables the client to develop a workable noise control plan that can be implanted over a sensible period of time, resolving the problem at hand.

Consultancies and solution providers that maintain a collaborative approach, working with integrity and transparency throughout the entire process, builds ongoing trust with the client. Failure to manage the relationships at any stage in the process described above is likely to lead to errors, misunderstandings, unbudgeted costs and even total project failure in some cases. The holistic approach described is considered key to establishing and delivering a successful noise control project.

Further, it is considered that the use of a single service provider to deliver all aspect of the noise control project, from concept, assessment, material manufacture and supply through to ongoing support and project verification allows the possibility of communication breakdown and errors to be minimised. Such an approach is considered to be highly beneficial.

## 5. REFERENCES

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