ICSV14
Cairns • Australia
9-12 July, 2007

14th International Congress on Sound & Vibration

DOLLARS AND DB. THE COST OF CONSERVATIVE ACOUSTICS IN INDUSTRIAL NOISE CONTROL

Colin Speakman

Parsons Brinckerhoff Australia Pty Ltd, 12th Floor, IBM Centre, 348 Edward St
Brisbane, QLD 4001 Australia
cspeakman@pb.com.au

Abstract

The objective of this paper is to demonstrate the costs involved in industrial acoustic projects and in particular the additional costs due to conservative acoustic assumptions made at various stages of the project. Industrial noise control projects are typically made up of a number of stakeholders such as; legislators, plant operators, equipment suppliers, acoustical consultants and noise control manufacturers. A typical industrial acoustic project will involve input from each of these stakeholders. All stakeholders have an interest in ensuring that the project, either, does not exceed the legislated limits, meets the specification or simply performs as expected. Commonly, conservative assumptions made by one stakeholder are not communicated to the various other stakeholders leading to compounding conservatism. The process of compounding conservatism and its effect on the final project cost is discussed. This paper uses a number of examples to demonstrate how the cost of a project can escalate due to each additional level of conservatism.

1. INTRODUCTION

Large infrastructure projects such as power stations, refineries, road construction, airports, tunnels, or building developments generally contain some industrial noise controls, particularly if the project is located in close proximity to residential property. In any such project there will be a number of stakeholders with input into the final design. A typical project could include the following stakeholders:

- legislators / government authorities.
- acoustic consultants.
- equipment suppliers.
- plant or site operators/owners.
- noise control manufacturers.
- affected residents.
- politicians / government representatives.

When the project exceeds the legislated limits each stakeholder faces the possibility of negative consequential actions. These may include:

- The particular government body will be criticised if a project produces excessive noise in the community.
- Acoustic consultants may face litigation if their design or acoustic modelling is inaccurate.
- Equipment suppliers will not sell equipment that exceeds specification.
- Plant operators and owners face expensive shutdowns and delays if community complaints are received or if legislated limits are not met.
- Noise control manufacturers face expensive rectification costs if their products fail to meet specification.
- Residents may lose value in their property or the standard of living.
- Politicians will face an election backlash if the community are dissatisfied with the resulting infrastructure.

To offset the risk of exceeding the legislated limits, each stakeholder is generally conservative in their calculations, approximations or goals for the project.

- Legislators will apply the most stringent of criteria.
- Consultants will adopt conservative assumptions and safety factors.
- Equipment supplier will give the upper limit of the noise emissions of their equipment.
- Plant owners will contractually ensure that the noise specification is met.
- Noise control manufacturers will over-design noise controls to ensure compliance with the contract.
- Residents will lobby politicians to ensure the best outcome for their area
- Politicians will put pressure on the authorities to ensure the best outcome for their constituents.

Problems and over conservatism can result if, as often is the case, the various stakeholders do not communicate. The results can be 'multiple layers of conservatism' [1] that add together to result in increased costs and physical magnitude of the resulting noise controls.

2. INDUSTRIAL NOISE CONTROL

2.1 Types of industrial noise controls

Industrial noise controls generally involve some combination of dissipative silencers, reactive silencers, enclosures or noise barriers. Active noise control has not been considered as it is currently not widely used in industry in Australia. The examples discussed in this paper will concentrate on noise abatement enclosures and dissipative (splitter) silencers as these are highly relevant industrial noise control techniques use widely throughout Australia.

2.2 Splitter Silencers

Splitter silencers are widely used for noise control in applications that require air flow (Figure 1). Typical construction involves a metal frame, a perforated metal facing and sound absorptive infill material (normally glasswool). The splitters are spaced across a duct cross-section with an air-gap between each splitter.

The acoustic and mechanical performance of the silencer is affected most commonly by changes in the silencer geometry (ie splitter spacing, splitter thickness etc), changes in the materials used for infill and changes in the facing materials. Typical design considerations could include the following.

- Insertion loss requirements
- Pressure loss
- Internal material selection
- Facing material selection
- Mechanical / Temperature effects
- Structural design

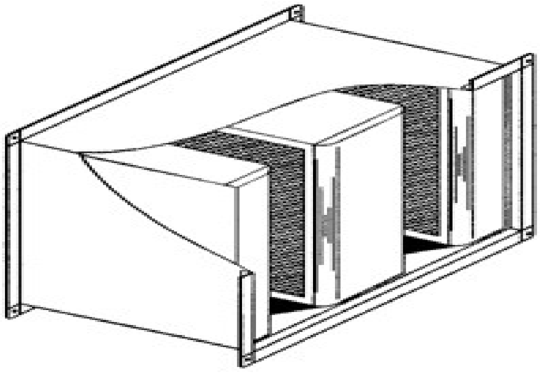

Figure 1. Typical splitter silencer arrangement

Assuming that the facing material, the internal material and the construction method are similar in most projects then the geometry and hence the cost will be a function of insertion loss and pressure loss requirements for the silencer.

2.3 Acoustic Enclosures

Industrial acoustic enclosures are installed to reduce noise emissions from industrial machinery (Figure 2). Typically a noise enclosure will have a heavy outer wall, an internal absorptive lining, doors, windows, exhaust ducts, ventilation fans and silencers on ventilation openings. A typical industrial noise enclosure is shown in Figure 2.

Typical design considerations for an industrial noise enclosure could include the following:

- transmission loss requirements
- internal absorption requirements / materials
- sealing of doors, window etc
- ventilation requirements
- internal pressure
- mechanical / size constraints.

Assuming that the construction material/method is similar then the transmission loss requirements and the ventilation requirements will decide the configuration and hence the cost of the enclosure.

Figure 2. Typical industrial noise enclosure

3. COST VERSUS PERFORMANCE

3.1 Splitter Silencers

As discussed, the cost of a splitter silencer is strongly related to the pressure loss and attenuation requirements for the silencer. The attenuation of a splitter silencer for a given fixed duct opening can be increased in a number of ways:

- Reduce the open area of the silencer.
- Increase the length of the silencer.
- Stagger the splitters.
- Change the facing material.
- Change the infill material.

If the construction materials, manufacturing method and the duct cross section are considered to be constant, then any increase in the insertion loss requirement for the silencer will result in either an increase in the length of the silencer or a reduction in the open area of the silencer. Figure 3 shows the insertion loss and splitter cost per decibel for a 1m long, 50% open area silencer with 300mm thick splitters. The 'critical design frequency' refers to the frequency band at which the required insertion loss is ultimately deciding the physical dimensions of the splitter.

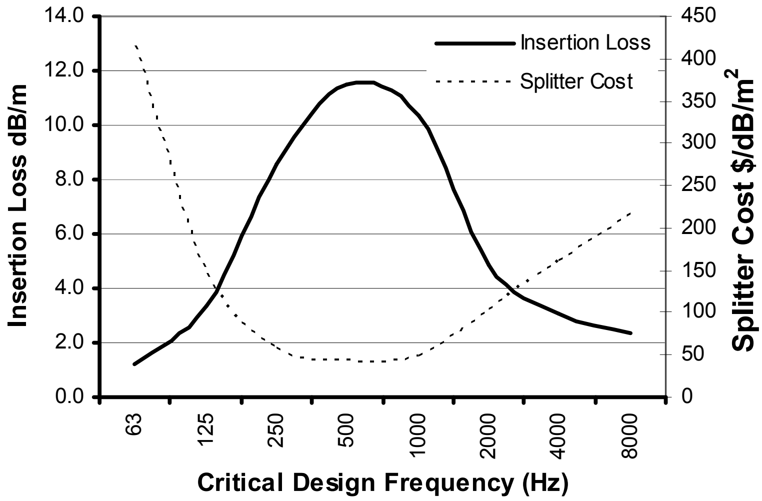

Figure 3. Insertion Loss and Splitter Cost vs Frequency for a 50% open area silencer with 300mm thick splitters

If the open area of the silencer is decreased then more splitters will be required to cover the same duct area and the pressure loss through the silencer will increase. Alternatively, if the length of the silencer is increased then the size and cost of each splitter is increased and the pressure loss through the silencer will also increase.

If the pressure loss becomes excessive then the cross-sectional area of the silencer must be increased and hence the cost of the silencer will increase further.

3.2 Acoustic Enclosures

If the materials and the construction method remain the same then the cost of an acoustic enclosure is largely dependant upon the transmission loss requirement for the walls and the size and insertion loss requirements of ventilation ducts. As the acoustic performance requirements are increased, the cost of an enclosure can increase significantly. The cost of ventilation noise treatments will also increase as discussed in the previous section. The transmission loss of the walls can be increased in a number of ways:

- Increase the mass of the wall.
- Increase damping in the wall structure.
- Increase the complexity of the wall ie using multiple non-homogeneous materials.
- Provide multiple separated walls.

Figure 4 shows the cost and transmission loss for 1mm thick sheet steel assuming a mass law relationship for the transmission loss. Increases in mass can also result in an increase in labour cost due to handling difficulties during construction. Increases in the complexity of the structure also result in increased labour costs as well as increased material costs.

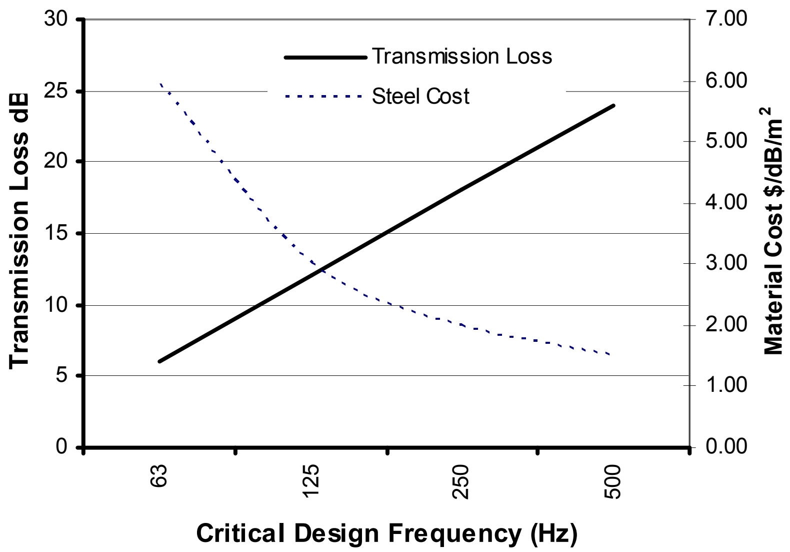

Figure 4. Transmission Loss and Material Cost vs Frequency for 1mm sheet steel

4. EXAMPLE INDUSTRIAL NOISE CONTROL PROJECTS

Examples of projects that have involved significant cost increases due to conservative assumptions and specifications are now presented. Some aspects of the project have been altered to prevent identification.

4.1 Industrial ventilation tunnel

Six large axial fans delivering 500m^3/s of air were to be installed at the upstream end of a 350m ventilation tunnel, the discharge of which was located only 50m from two semi-rural residential dwellings. The cross-section of the tunnel was 8m wide and 6m high and the walls were hard rock face and concrete. The project was unpopular with the local community and noise became a target for community concerns. The noise criteria for the project stated that the noise level should not be tonal or impulsive and should not exceed 35dB(A) at the nearest residential boundary. The maximum allowable pressure drop across the silencer was 150Pa.

The project management engaged an acoustic consultant to deliver a specification for the noise control of the tunnel fans. In order to be sure of meeting the strict criteria the target noise level was reduced to 30dB(A).

A noise model was prepared and the following silencer specification (Table 1) was put forward by the acoustic consultant to his client.

Table 1. Calculations for silencer specification.

Octave Band Centre Frequency (Hz)	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**Overall**
Fan sound power	117	118	123	125	131	123	120	117	134
Total sound power with six fans operating	125	126	131	133	139	131	128	125	142
A-weighting	-26.2	-16.2	-8.7	-3.2	0.0	1.2	1.0	-1.1	
Total A-weighted sound power level	99	110	122	130	139	132	129	124	142
Total system losses	60	61	62	63	64	65	67	72	
Predicted sound pressure level at receiver	39	49	60	67	75	67	62	52	77
Required level at boundary	20	20	20	20	20	20	20	20	29
Required insertion loss	19	29	40	47	55	47	42	32	

The specification stated that the manufacturer *"must guarantee the octave band insertion loss stated in Table…."*. In order to ensure that the insertion loss was achieved the manufacturer designed a silencer that would exceed the specification by at least 2dB in each octave band.

The final silencer dimensions were 7.2m high, 8m wide and 7.5m long. The silencer was manufactured from stainless steel and the final quoted cost of the silencer was over $420,000.00 and this did not include the earthworks to expand the tunnel or the installation of the silencer.

Some key points with regard to this project were as follows:

- The project management did not inform the consultant that they had applied a 5dB(A) safety factor to the target noise level.
- The consultant did not include any acoustic losses for 350m of tunnel.
- The consultant applied a final target noise spectrum that resulted in unnecessary attenuation at low and high frequencies.

The following example (Table 3) uses the same calculation method, however, attenuation for the tunnel has been included [2] and the target level has been increased to the original 35dB(A). The required spectrum has also been adjusted such that the lower and higher frequency requirements are less stringent than the mid frequencies.

The attenuation calculated by removing the conservatism can be achieved with a silencer 6m high, 8m wide and 2.4m long the approximate cost of this silencer would be $120,000.00 and no additional earthworks are required. The cost saving by removing the conservatism is approximately $300,000.00 plus earthworks.

Table 3. Alternative calculation for the silencer configuration

Octave Band Centre Frequency (Hz)	**63**	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	**Overall**
Fan sound power	117	118	123	125	131	123	120	117	133
Total sound power with six fans operating	125	126	131	133	139	131	128	125	141
A-weighting	-26.2	-16.2	-8.7	-3.2	0.0	1.2	1.0	-1.1	
Total A-weighted sound power level	99	110	122	130	139	132	129	124	140
Total system losses	60	61	62	63	64	65	67	72	
Tunnel attenuation	5	5	7	10	12	15	18	25	
Predicted sound pressure level at receiver	34	44	53	57	63	52	44	27	64
Required level at boundary	30	28	26	23	23	22	24	25	35
Required insertion loss	4	16	27	34	40	30	20	2	

4.2 Industrial noise enclosures

A large industrial plant was reviewing their heath and safety plan. After consulting with the relevant government authority it was decided that a noise audit of the plant was required in order to identify areas within the plant that exceeded 85dB(A).

An acoustic consultant was engaged to produce a noise map of the entire plant. This identified two areas where the measured noise levels were 93dB(A) and 88dB(A) at 1m respectively. The consultant was further commissioned to provide a concept design for noise enclosures for the machinery with the aim of reducing noise levels to below 83dB(A) at 1m.

The concept design was provided with a request for quotation to a number of manufacturers. The specification read *"must guarantee a noise level of less than 83dB(A) at 1m for any part of the noise enclosure"*. The manufacturer designed noise enclosures to achieve 78dB(A) at 1m in order to ensure that the specification was achieved.

Some key points about this project are as follows:

- The machinery in question was located in an uncovered area 50m from the nearest work area.
- The noise level in the nearest work area was less than 75dB(A)
- One machine operated for only $1^1/_2$ hours each day.
- When maintenance was performed the machinery was shut down.
- The plant management had a poor understanding of the occupational noise legislation.
- The final cost of the noise attenuation exceeded $60,000.00

In this case there was no legislative obligation to reduce the noise level from this machinery as there were no workers exposed to noise levels in excess of 85dB(A) LAeq,8hr [3]. Even if there were an obligation to reduce noise levels, a number of levels of conservatism were applied to the project:

- The government authority gave an unclear picture of the obligations with regard to noise legislation.
- The acoustic consultant did not fully inform their client.
- The plant management arbitrarily reduced the noise target by 2dB(A).
- The manufacturer applied a further 5dB(A) reduction to the already conservative target.
- There was no communication between the manufacturer and the acoustic consultant.

5. CONCLUSIONS

The use of conservative assumptions and adoption of conservative noise targets can significantly increase the overall cost of an industrial noise control project. Conservatism applied by various stakeholders involved in a project can lead to multiple levels of conservatism and further increases in cost.

The major problem is not conservatism, but the lack of communication between project stakeholders. Conservatism applied by one stakeholder is not communicated to all parties involved and hence further conservatism is applied resulting in significant over-design of some industrial acoustic projects.

REFERENCES

[1] F. H. Brittain, "Issues in designing energy facilities to meet noise limits", Bechtel Corporation

[2] K. M. Li and K. K. Iu, "Full-scale measurements for noise transmission in tunnels", *Journal of the Acoustical Society of America* **117**, 1138-1145 (2005).

[3] "National Code of Practice for Noise Management and Protection of Hearing at Work" *[NOHSC: 2009(2004)] 3rd Edition*