Working with Acoustic Products and Mechanical Services

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ABSTRACT
Mechanical Services have become an essential part of modern building design. The acoustic design requirements for a building's Mechanical Services form a significant portion of the overall building acoustic design package and are often a main driver for end-user amenity. This paper examines some of the issues encountered and options to assist in the mitigation of the risks to acoustic professionals.

1. INTRODUCTION

The design of acoustic products for Mechanical Services can present issues to acoustic professionals. While in many applications the required products can and are selected from a catalogue, instances occur where the design work is circumvented accidentally by the mechanical services contractor or the project's Main Contractor.

While these issues can be caused by "value engineering" more often they are caused by a contractor's lack of awareness of the overall design or alternatively a combination of the contractors good intentions mixed with a lack of understanding of the test method used to present the acoustic data.

While it is not the role of the acoustician to necessarily inspect each and every part of a design they are involved with, the reduction in issues towards the end or at the completion of a project. This improves the outcome for the client while also increasing the profitability for all involved.

2. COMMON NOISE GENERATING MECHANICAL SERVICES ISSUES

There are regularly very similar acoustic issues encountered in projects and awareness of these allows them to be addressed during the construction phase.

The major airborne noise sources in a mechanical services installation are typically compressors, fans, chillers, and cooling towers. The major structure-borne noise is generally generated by rotating or moving machinery or transmitted through pipework. Each of these items can be treated effectively with a correctly engineered approach and can equally create acoustic issues if sufficient care is not taken by the relevant contractors.

2.1 Ventilation Fans

The selection of fans in mechanical services systems often creates issues due in part to the number of fans that are incorporated in modern buildings.

Higher speed fans are the default selection for contractors as 4 pole motors are cheaper than 6 or 8 pole motors. Typically a fan with a 4 pole motor is physically smaller and hence cheaper to manufacture, deliver to site and move into its final location. A secondary cost saving measure is to install axial fans with less blades however while these fans are less expensive to purchase, axial fans with less blades generally create more acoustic energy at low frequency noise.

The data outlined in Table 1 is for a 900mm dimeter fan operating at nominally 5,000 litres per second at a static pressure of 100Pa and a speed of 1440 RPM.

Table 1: Axial Fan Sound Power Levels – 3 & 6 Blades

Fan Type	63	125	250	500	1000	2000	4000	8000	Hz	Outlet SPL	
3 Blades	95	87	84	84	83	81	80	75		68 @ 3m	dB(A)
6 blades	85	89	87	86	87	85	84	76		71 @ 3m	dB(A)

The fan with more blades produces 85dB at 63Hz while the fan with less blades produces 95dB at 63Hz. The reduction of 10dB will have a substantial impact on any attenuation selection and would offset the cost reduction associated with using a fan with less blades.

The noise control solution for a project is regularly driven by lower frequencies. Hence the use of a fan with more blades can often increase the frequency driving the acoustic solution which in turn will reduce the cost of the attenuation. A reduction in noise levels of 2-4dB at low frequencies will often achieve a halving of the length of attenuator required.

A two-pole fan (2880RPM) is so rarely an acceptable solution to an air movement problem in a building that we should always heavily question the use of 2 pole fans in a design. A two pole axial fan is often used where higher static pressure is required and a better solution acoustically is normally a backward curved fan of similar diameter running at much lower speeds.

Table 2: Fan Sound Power Levels – 2 Pole Axial vs Backward Curved Fan

Fan Type	63	125	250	500	1000	2000	4000	8000	Hz	Outlet SPL	
2 Pole Axial	95	87	84	84	83	81	80	75		68 @ 3m	dB(A)
Backward Curved	85	89	87	86	87	85	84	76		71 @ 3m	dB(A)

2.2 Commissioning Issues

Is it not unusual for issues to arise from poor or incomplete commissioning. Acoustic issues stemming from commissioning will typically be associated with:

- Excessive airflow within ductwork system or through louvres doors for air conditioning return air;
- Excessive water flows in chilled water or condenser water pipework;

The solution for excessive airflow is either adjustment of dampers or reduction in fans speeds. Reducing fan speed is a better solution as closing dampers to reduce airflow can lead to further noise issues due to the turbulence created by the damper throttling the air.

The solution for excessive waterflows is often adjustment of valves. It should be noted that valves used to eliminate excess flow often become sources of noise themselves and hence then require lagging of pipework or adjustment of mounting brackets.

2.3 Equipment Selection & Placement

It is important to ensure that the equipment selected by the mechanical contractor or builder is suitable for the application. Developments that are close to residential properties or other noise sensitive receivers should try to avoid using industrial type equipment.

Common issues that can be addressed by equipment placement are:

- Roof mounted refrigeration equipment for cold rooms and freezers rarely comply with local council regulations. A well designed and efficient refrigeration system for commercial applications will cycle many times per hour and the stop/start action will generate annoyance with receivers;
- A residential property with air conditioning capacities above 25kW will likely generate noise complaints if the equipment is not acoustically treated;

- Exhaust fans attached to kitchen exhaust hoods operate with relatively high airflows and static pressures. This often requires 700-800mm dimeter fans which operate at 4 pole speed. Typically these backward curved fans have noise levels exceeding 75dB(A) when measured 3m from the fan and 1m above the roof.
- Air cooled chillers for commercial building will often have capacities in excess of 300kW. These units are designed to be installed on a roof and typically are fitted with 800mm dimeter fans fitted with speed controllers to ramp the fan speed according to the required cooling capacity. The compressors operate at part load and this regularly generates tonal noise in the 125-250Hz range. It is not unusual for the low load noise levels to exceed 65dB(A) at 3m. Where the equipment continues to operate into the evening it is important to be aware that while the fans noise drops substantially inline with the ambient temperature, it is not unusual for the partly loaded compressor noise to be dominant.

2.4 Lack of Knowledge or Understanding

Mechanical services contractors will rely on the noise data provided by equipment manufacturers. With much of the technical data being highly qualified, when a problem occurs after installation the technical data is queried in detail and can show misunderstanding of the application of the data.

An excellent example of how data can be misinterpreted is fan data. The fan data presented by most manufacturers includes sound power details plus an overall sound pressure level at a particular distance.

A typical Sound Power spectrum for an axial fan may look as follows:

Table 3: Typical Fan Sound Power

63	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Hz**
87	84	82	75	73	71	65	61	dB

The fan will then be listed with an overall Sound Pressure Level of 58dB(A) @ 3m. This figure is achieved using the inverse square law where:

$$L_p = L_w - 20\log R - K$$

The stated figure of 58dB(A) @ 3m is only achieved if K equals 11. This equates to spherical propagation which in most instances for a fan, is not realistic. When combined with connecting the fan to reverberant ductwork the issue is further exacerbated. While in many cases acousticians will undertake calculations from the spectrum data, it is important to understand a cursory glance at the overall sound pressure data could be problematic.

2.5 Air Cooled Condensers

Air cooled condensers are often placed on roof tops or in back of house areas. While these locations often avoid the ire of their own internal noise sensitive receivers the back of house areas are often are near boundaries with adjacent properties. The addition of speed controlled fans has assisted in reducing the noise levels when operating at full load but they can still generate complaints.

As with air cooled chillers, where the equipment operates into the evening it is important to be aware that while the fans noise drops substantially as the ambient temperature reduces it is not unusual for the compressor noise to become dominant.

Table 3: Typical Small Air Cooled Chiller Sound Power @ 1m – High Fan Speed

63	125	250	500	1000	2000	4000	8000	Hz	Overall
32	45	54	60	59	55	47	36	dB(A)	64dB(A)

The additional data below for the same unit operating with very low fan speeds shows how the compressor noise becomes dominant at the lower frequencies.

Table 4: Typical Small Air Cooled Chiller Sound Power @ 1m – Low Fan Speed

63	125	250	500	1000	2000	4000	8000	Hz	Overall
31	40	51	49	49	46	39	30	dB(A)	55dB(A)

While there has been a 10dB reduction in overall noise level the dominance of the lower frequency compressor noise has become more noticeable both in the data and to the ear.

2.6 Percentage Open Area

Many acoustic products and especially acoustical louvres are susceptible to design issues when their selection is based upon percentage open area. It is not unusual for an acoustic louvre to have open areas in the order of 15-25% while many mechanical consultants specify louvres with 50% open area.

The 50% open area is often a rule of thumb figure that has been used for many years in relation to single stage weather louvres. The requirement often comes from a design where weather louvres are replaced with acoustic louvres once detailed acoustic design have been undertaken. When the question is asked about airflow performance of the newly specified acoustic louvre the initial response regularly is “just make sure it 50% open area”.

A request for a 50% open area acoustic louvre, when the acoustic requirements are quite low, can be farcical as show in Figure 1 below.

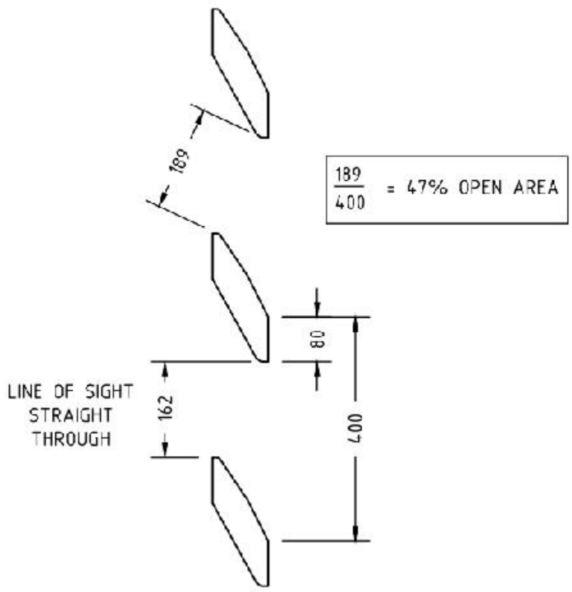

Figure 1: Large Open Area

In applications such as smoking areas where specific open areas are required the thickness of the louvre mush be increased to overcome the larger percentage open area.

The design of modern acoustic louvres is such that the lower percentage areas do not impact on the pressure drop through the louvres. Hence if the louvres sizes are generated based from an open area calculation typically the louvre size is much too large. The added issue is that increased acoustic performance may well be specified unnecessarily simply due to the area of louvre. Where a louvre open area is specified the correct approach is to determine from the louvre manufacturer the correct louvre size based upon the required airflow and the maximum pressure drop, not the open area.

With the construction of more naturally ventilated buildings there has been an increase in requests from mechanical consultants for openings in buildings to allow air entry where the openings are detailed as a percentage open area. In many instances this is due to the limitations on some of the modeling software used to determine how the buildings will operate under different ambient conditions.

2.7 Natural Ventilation

The inclusion of natural ventilation in modern building provides acoustic challenges. As designers we need to ensure that the inclusion of operable windows or screens does not impact the acoustic amenity within the building. It is common to find buildings that meet the thermal and comfort design criteria with windows open however the acoustic amenity is poor due to the impacts from birds and other external activities.

While there is no easy solution to the ingress of sound through an operable window it is important that we flag these items to architects and where possible, the end user. All parties need to be aware of the outcome when a crow or similar sits on a tree branch outside the window.

3. SOLUTIONS FOR REDUCING AIRBOURNE NOISE

Reduction in airborne noise from Mechanical Services is typically undertaken using a combination of absorbent surfaces, attenuators, acoustic louvres, barriers and enclosures.

3.1 Line of Sight

The removal of line of sight between noise sensitive receivers and mechanical plant will often assist in areas with higher background noise levels. While installing a barrier to visually screen the plant is not a solution to equipment that exceeds the relevant regulations or standards, locating the equipment such that it may be within a quasi plant area and ducting ventilation air to outside is always a better solution. Often the reasoning for not installing mechanical equipment in a plant area relates to a perceive lack of suitable airflow paths to outside however with good engineering design most equipment can be installed in enclosed spaces.

3.2 Acoustic Louvres

Acoustic louvres can be installed as part of the external building fabric to allow air movement through the façade while providing a suitable transmission loss.

They are typically accepted by architects as an option for noise control however they tend to have a larger face area for a given volumetric flow rate than attenuators. When working with acoustic louvres it should be noted that the use of percentage open area “rules of thumb” will regularly lead to an oversized opening during initial designs undertaken by the mechanical consultants. This in turn can impact calculated overall noise levels as the louvre typically has lower acoustic performance than the adjacent façade with the outcome of the calculations suggesting a louvre with a higher transmission loss is required for the large opening.

Figure 2: Acoustic Louvres

3.3 Attenuators

Attenuators, unlike acoustic louvres, are not a solution often accepted by architects as a façade element. They are well suited to plantrooms, ductwork and industrial environments and if fitted to the façade will normally have another louvre installed in front of the attenuator to improve the aesthetics.

The advantage of an attenuator over an acoustic louvre is that you can achieve a greater reduction in noise levels for a given flow rate with a smaller face area. The downside is that the attenuator is often deeper than the acoustic louvre which may require more real estate within a plant area.

Figure 3: Attenuator

3.4 Acoustic Barriers

Acoustic barriers are well suited to situations where noise reductions up to 10dB are required. In practice it is difficult to achieve larger noise reductions due to reflections from other surfaces along with the limitations associated with geometry and the path of sound over the barrier. Reductions greater than 10dB can however be achieved if the noise sensitive recipient is at a lower RL compared to the barrier.

Figure 4: Acoustic Barriers – Before & After

The barriers are typically absorbent on the noise source side with a solid surface on the noise sensitive receivers side. It is important to determine, when another structure forms one or more sides of the barrier, whether the existing structure also needs an absorbent lining. Reflections from an existing building façade can halve the overall noise reduction achieved by the barrier.

Barriers can easily incorporate sections of, or be fully constructed, using acoustic louvres to allow greater airflow for air cooled equipment and reduce recirculation. The addition of the low level louvres provides an air entry path at low level which will coincide with the air inlet into the equipment.

3.5 Roof Top Acoustic Screens

Where mechanical plant is situated on roof tops it is important that the overall performance is not degraded due to grid mesh floors or plant decks being raised above adjacent parapets. Where plant deck screens do not extend to roof level either the floor needs to be constructed from solid material such as FC sheet or there must be additional features such a parapets available to achieve the required acoustic screening.

Given roof top plant is often above the noise sensitive receivers the noise reductions achievable can exceed 10dB which makes the choice of floor material more important to ensure the floor performance does not adversely impact on the screen performance. Where solid floors are installed it is important to ensure the airflow to the equipment is acceptable.

Figure 5: Full Height Roof Top Acoustic Louvred Screen - Before & After

3.6 Acoustic Enclosures

Acoustic enclosures are installed for equipment where noise reductions greater than 15dB are required. The enclosures are typically constructed from a combination of acoustic panels, louvres, doors and attenuators and can be built to accommodate all types of equipment.

Figure 6: Acoustic Enclosures – Before & After

There is always a concern about the use of enclosures from Mechanical Consultants and contractors who are concerned about the impact in the equipment operation however good engineering practices and solid design philosophies can ensure any concerns are allayed. It is not unusual to install booster or exhaust fans with temperature or sped controllers to ensure operational issues with the enclosed equipment.

4. CONCLUSION

Mechanical Services in buildings will always provide acoustic challenges for designs in relation to occupants and adjacent properties. The development of designs that inherently provide reduced noise levels and reduce noise issues at the end of a project should provide for buildings that operate more harmoniously while also increasing the profitability for all involved.