



Mitigation of Residential Air-Conditioning Condenser Noise

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Abstract - The mitigation of residential air-conditioning condenser noise can be a very difficult problem to solve. Often situated at the side or rear of residences where there is limited access and low background noise levels, it is necessary to engineer a solution that achieves a noise reduction in excess of 30 dB. Finding an acoustician or specialist contractor to mitigate the noise can be difficult, as the design requirements for residential air-conditioning condensers are usually stricter than those of commercial air-conditioning condensers, with the solution being expensive compared to the original cost of the air-conditioning system. In this paper, the factors influencing residential air-conditioning condensers noise control are discussed to allow an engineering design methodology to be derived. In addition, alternative approaches that could potentially be used by residents and local authorities to manage residential air-conditioning condenser noise without implementing expensive noise control measures are presented.

1 INTRODUCTION

The amelioration of noise from residential air-conditioning condensers has always been a challenge. When a complaint situation arises, acousticians frequently have to deal with unrealistic compliance criteria, lack of room to acoustically treat an air-conditioning condenser, limited or no options to relocate the condenser, restricted budget, irate neighbours, emotional homeowners and air-conditioning contractors who do not understand acoustics.

The creation of suburbs containing small lots as shown in Figure 1 has made the mitigation of air-conditioning noise nearly impossible. The close proximity of the residences means that natural ventilation is limited and the residences require air-conditioning to ensure amenity for the occupants. The background noise levels in the absence of air-conditioning noise can be very low at all periods of the day, as the closely located residences act like a large acoustic barrier to noise sources such as road traffic. The proximity of the residences to the side boundaries and small front and rear yards limit where an air-conditioning condenser can be located, with every location on the lot affecting surrounding residences.

Finally, all of the above issues are further compounded by the change in society where more businesses operate 24 hours per day, requiring shift workers to sleep during the daytime, where previously noise from air-conditioners was not considered to be much of a problem.

2 THE PROBLEM

2.1 Noise Emission Criteria

Noise emission criteria based upon a measured 5 dB or 3 dB exceedance of the background noise level, as set by many local authorities in Australia, does not account for the close proximity of required mechanical plant to residences. A combination of low background levels and the close proximity of mechanical plant and equipment to neighbouring residences frequently results in emission limits being exceeded by more than 30 dB.



Figure 1 – A small lot residential subdivision where controlling air-conditioning noise is nearly impossible (Google, 2024)

Pool pumps, water tank pumps, heat pump hot water systems and air-conditioners are the most common noise sources complained about in residential situations. While pool and water tank pumps have minimal ventilation requirements and can be easily enclosed and hot water systems can be limited to operate during the daytime only to reduce their impact, air-conditioners need to be able to operate 24/7 to provide amenity to the occupants inside the residence it services.

2.2 Dwelling Design and Air-Conditioning System Capacity

The use of dark colours for roofs and walls leads to an increase in heat load. While there has been an improvement in the thermal efficiency of dwellings in many instances, the large size of dwellings compared to the overall lot size has limited opportunities for natural ventilation occur as windows and curtains need to be kept closed to achieve acoustic and visual privacy and any breeze, when it occurs, is disrupted by intervening buildings. When selecting the capacity of the required air-conditioning unit, air-conditioning contractors apply rules of thumb and the philosophy that the cost to increase unit size to provide additional capacity is negligible, with the installation cost remaining identical. These factors, combined with an expectation that when the air conditioning is running, no matter the temperature outside, the inside of the dwelling should be kept at 24°C has led to air-conditioning unit capacities increasing.

2.3 Lot Size

Figure 2 shows a typical air-conditioning condenser installation on a small lot and the associated problems. The condenser is located near-to the boundary of the lot only 4.5 m from the neighbouring residence. The neighbouring residence is two storey and overlooks the condenser, which means acoustic barriers will be ineffective and a full acoustic enclosure around the condenser will be required if left at that location. However, there is a retaining wall immediately adjacent to the condenser, a 340 mm gap between the condenser and boundary fence and the eaves of the residence are located 1 m above the condenser. There is insufficient space to construct an acoustic enclosure.



Figure 2 – A typical problematic residential air-conditioner installation

2.4 Home Owners and Cost

Imagine purchasing a brand new car from a dealer, driving it around for a month or two, then being told it is not roadworthy and cannot be driven any more, and it will cost two or three times the original purchase cost of the car to make it roadworthy. This analogy is similar to that experienced by homeowners with have received a breach notice or direction notice from their local council for air-conditioning noise. It is not possible to purchase an off-the-shelf solution to attenuate noise from a residential air-conditioning condenser. The large number of different condenser models, limited site access, the need to provide access for maintenance and varying levels of noise amelioration require a bespoke approach, where the cost of the acoustic treatment is much more than the air-conditioning system.

With the design and implementation costs being high, desperate home owners grasp onto anything inadvertently said by council compliance offices or consultants, scour online forums for answers and perform Internet searches for solutions that are likely to be inappropriate for their situation. Figure 3 presents several examples of homeowners solutions to attenuate air-conditioning noise. None of those solutions were successful in achieving the required level of noise amelioration, with most of them adversely impacting upon the operational efficiency of the condensers, potentially voiding the manufacturer's warranty. The loaded vinyl "treatment" in Figure 3(a) was done by the homeowner on the advice of the council compliance officer, where in reality, a properly engineered solution was necessary.



Figure 3 – Homeowner “solutions” to attenuate air-conditioner noise

2.5 Air-Conditioning Condenser

The main source of noise complaints in modern air conditioning units centres around the condensers fan or fans. Modern compressors are relatively quiet and the increase in noise levels between minimal load and full load is relatively small whereas the increase in noise levels for the fan(s) between low load and full load is substantial. Once the units are operating around 50% capacity the compressor noise is dominated by the condenser fan(s).

To demonstrate the importance the selection of the air-conditioning systems has on the radiated sound power level, data from over 400 domestic air-conditioning condensers have been extracted from the websites of 15 different suppliers in the Australian market. Data have been sourced from ActronAir (ActronAir, 2024), Braemar (Seeley International, 2024), Daikin (Daikin, 2024), Fujitsu (Fujitsu, 2024), Hisense (Hisense, 2024), Hitachi (Hitachi, 2024), Kelvinator (Kelvinator, 2024), LG (LG, 2024), Mitsubishi Electric (Mitsubishi Electric, 2024), Mitsubishi Heavy Industries (Mitsubishi Heavy Industries, 2024), Panasonic (Panasonic, 2024), Rinnai (Rinnai, 2024), Samsung (Samsung, 2024), TECO (TECO, 2024) and Toshiba (Toshiba, 2024). As shown in Figure 4, the (maximum) radiated sound power level varies for different cooling capacities amongst the different manufacturers.

Figure 5 shows the impacts of different types of air-conditioning systems and discharge direction on the radiated sound power level and cooling capacity.

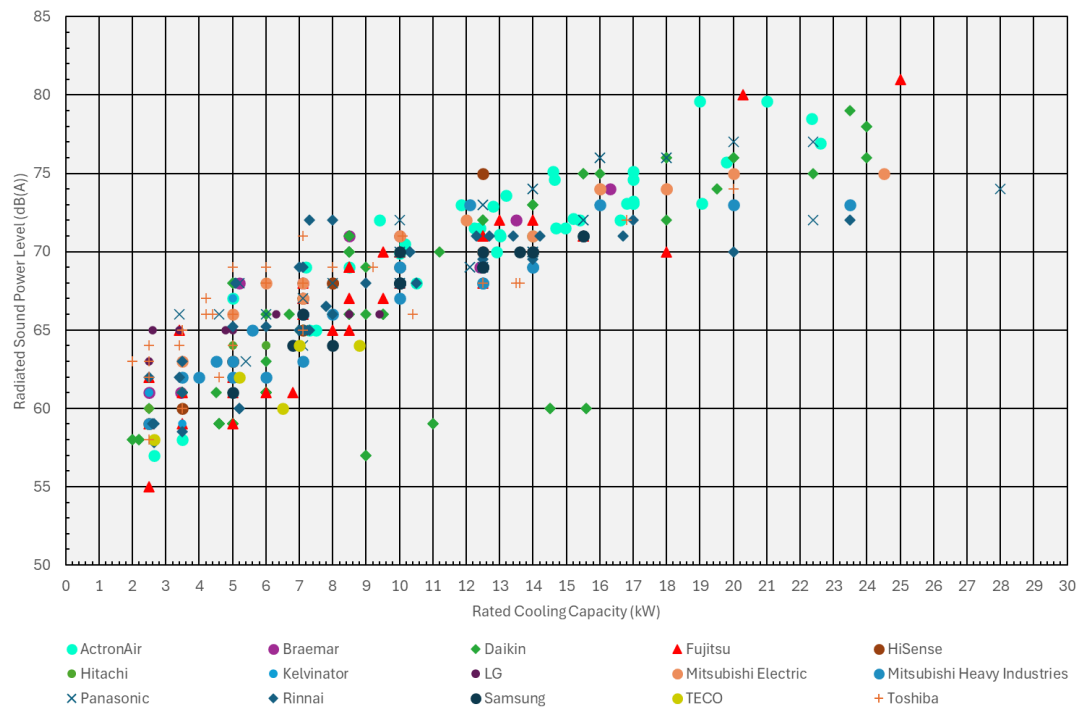
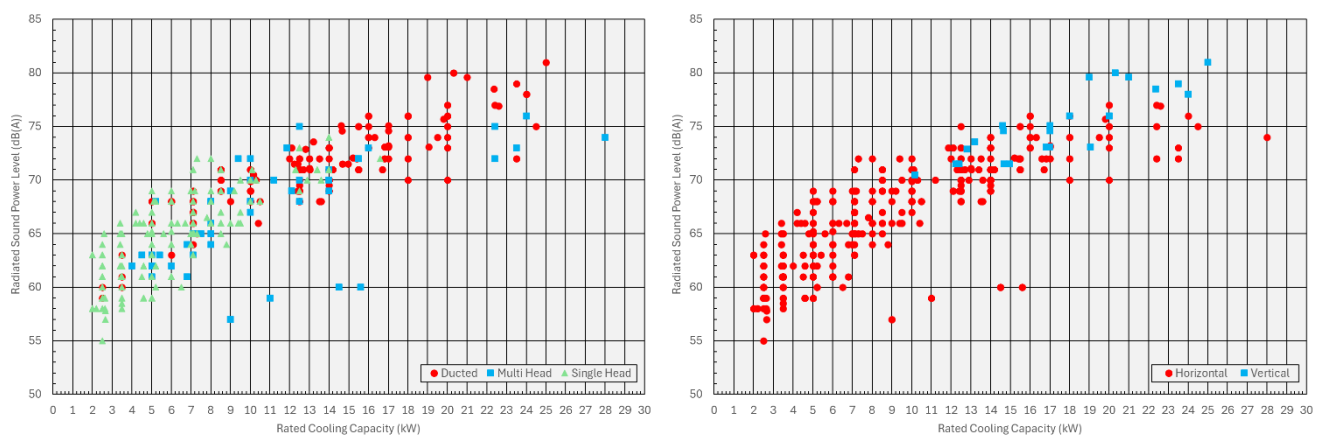


Figure 4 – Comparison of different air-conditioning condenser radiated sound power levels



(a) Different types of air-conditioning systems

(b) Discharge direction

Figure 5 – Impact of different design parameters on rated cooling capacity and radiated sound power levels

In Figure 5(a) the different types of air-conditioning systems are:

- Single head: An external condenser connected by refrigerant pipework to a single wall mounted, ceiling cassette, under ceiling or floor mounted fan coil unit inside the dwelling.
- Multi Head: An external condenser connected by refrigerant pipework to multiple wall mounted, ceiling cassette, small in-ceiling ducted, under ceiling or floor mounted fan coil units inside the dwelling.
- Ducted: An external condenser connected by refrigerant pipework to a single in-ceiling ducted fan coil unit. For larger systems, the dwelling is usually zoned to allow dampers within the flexible ductwork to open and close as necessary to cool or heat different parts of the dwelling.

One difference between the three types of air-conditioning system is the allowable maximum length of refrigeration pipework. This must be considered when evaluating potential locations for a condenser.

The differences between the horizontal and vertical discharge condensers shown in Figure 5(b) is illustrated in Figure 6. For domestic air-conditioners, one or two fans are used in either configuration depending upon the cooling/heating capacity of the system. Vertical discharge condensers are used for 10 kW systems and above.



Figure 6 – Examples of horizontal discharge (left) and vertical discharge (right) condensers (Fujitsu, 2024)

The condensers in Figure 4 and Figure 5 are an inverter type, where the speed of the compressor motor to drive variable refrigerant flow in an air conditioning system is controlled to regulate the conditioned-space temperature. The fans are also speed controlled to meet cooling needs, with some units having three fans speeds (low, medium and high) and other having a DC motor to allow infinite speed control.

It is common practice for a manufacturer to market their condenser as being “low noise”. Several manufacturer’s also offer “low noise” or “night-mode” options that limit the speed of the fan(s) and compressor, or turn off the outdoor condenser during the night-time and just use the fan coil unit to circulate air through the dwelling. However, implementing these additional features rarely removes the need for additional acoustic amelioration measures.

3 DESIGN INFLUENCES

The purpose of an acoustic enclosure is to ameliorate the noise emitted by the air-conditioning condenser while ensuring adequate airflow through the condenser coils and access is maintained for maintenance. While this appears to be relatively straightforward, residential condensing units are not designed to be in an enclosure nor have their airflow restricted.

Airflow restrictions occur when the static pressure losses (or impedance) imposed by an enclosure and acoustic treatments overwhelm the static pressure that can be produced by the fan. There is a negative correlation between the airflow and static pressure of a fan. When airflow increases, static pressure decreases; when static pressure increases, airflow decreases. It is therefore critical to keep the cumulative additional static pressure losses as low as possible, with 20 Pa being the typical adopted upper limit for domestic air-conditioning condensers.

The requirement to keep static pressure losses low can be seen in Figure 7, which presents the static insertion loss and air pressure drop data for four 27 % open area rectangular sound attenuators ranging from 900 mm to 2,400mm long.

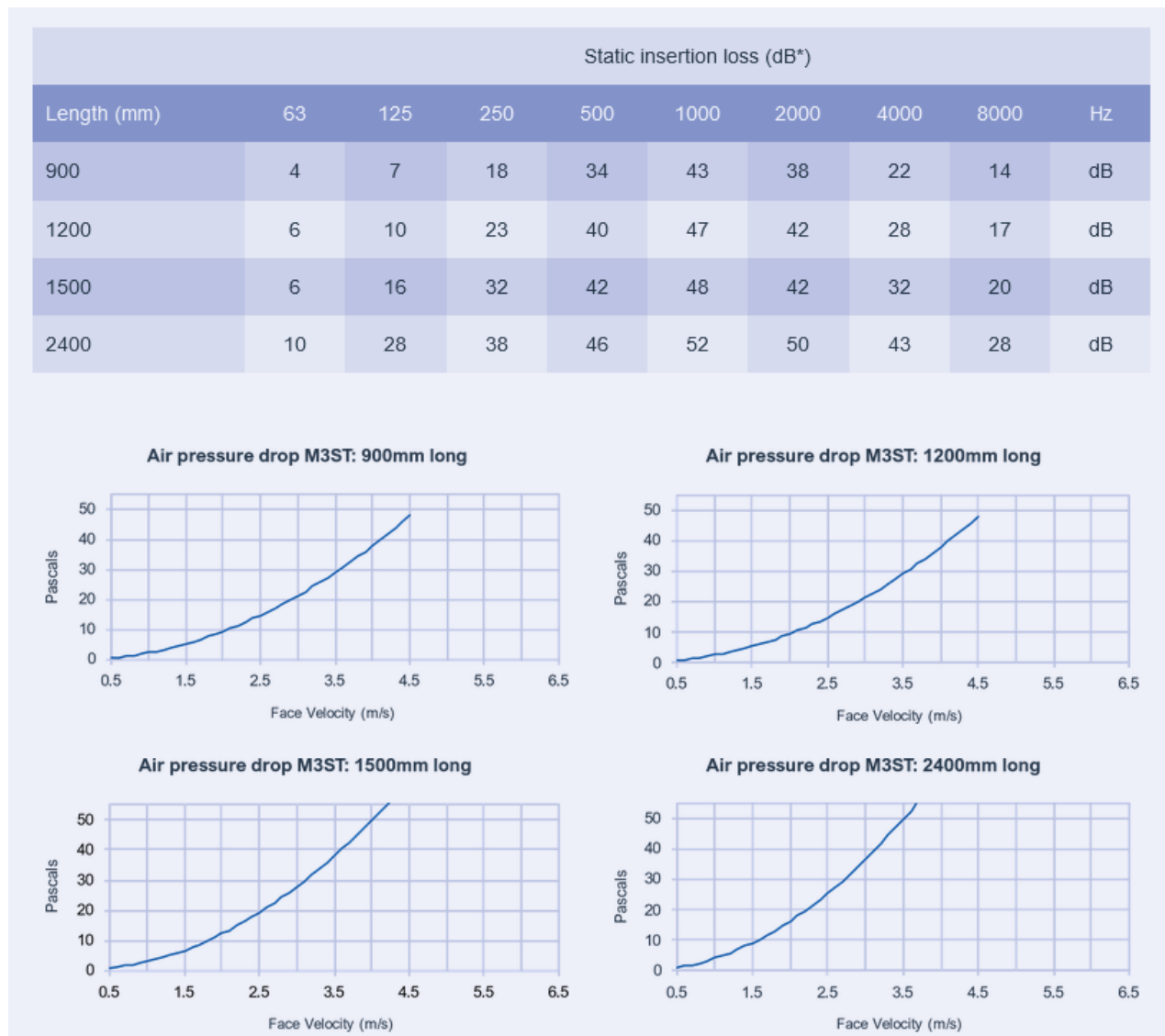


Figure 7 – Static insertion loss and air pressure drops for different 27 % open area attenuators (Acran Noise Control, 2024)

For the condenser shown in Figure 2 the required maximum airflow is 2,583 L/s (Fujitsu General, 2022). For a maximum pressure drop of approximately 8 Pa (remembering attenuators are required on both the inlet and discharge air paths), the air pressure drop graphs in Figure 7 indicate that the minimum face area of each attenuator needs to be 1.7 m² for attenuators up to 1,500 mm long. For the 2,400 mm long attenuator, the minimum face area will need to be approximately 2.1 m².

The attenuator face areas, necessity to size the enclosure to minimise additional airflow impedance and maintenance access results in the acoustic enclosure being significantly larger than the condenser. Acoustic louvres are not viable for the treatment of domestic air-conditioning condensers due to the extremely low face velocities that are required to meet air pressure drop requirements.

4 VIABLE SOLUTIONS

4.1 Pre-Installation Design

Where there is acceptance from the designer and owners that the air-conditioning condenser(s) will be a noise issue, there is the opportunity to design an effective solution. Installation of equipment in the garage of the dwelling, with internally lined ducts and somewhat torturous duct paths provide a method to reduce the noise

levels externally. This approach does take up space within the garage and might necessitate reconfiguration of the dwelling design to allow the necessary duct runs as shown in Figure 8. This option is typically suited to larger dwellings with multiple air conditioning units and sufficient space. It also requires some design thought at the beginning to ensure that the condenser(s) can operate effectively with the increased static pressure losses from the ductwork. This type of installation needs an inlet to allow air into the garage and potential upgrading of internal walls, floors and doors within the dwelling to contain the noise. An added benefit of the type of installation is that the condenser unit is not visible and hence is unlikely to be a “beacon” to any noise-sensitive neighbours.



(a)



(b)



(c)



(d)

Figure 8 – Internally installed condenser units ducted to outside

4.2 Post Installation Treatment

For post installation of an air-conditioning condenser, the most economical method is to relocate the offending equipment to a new part of the dwelling where the noise generated is no longer an issue at surrounding noise-sensitive receivers. Often this is to the detriment of the amenity of the homeowner in question, requiring some compromise. For small lots such as those shown in Figure 1, relocating the unit becomes part of a strategy to reduce the magnitude of the acoustic amelioration rather than a solution in itself.

Where the exceedance is less than 5 dB, there is scope for installing an acoustic screen and utilising sound absorption treatments. The efficacy of this approach depends upon the geometry of the nearby noise sensitive receiver(s). If the receiver is located at a higher level than the offending condenser, an acoustic screen will be ineffective.

For exceedances greater than 5 dB or where the noise-sensitive receiver(s) overlooks the condenser(s), the solution is to enclose the equipment in a purpose-built acoustic enclosure as shown in Figure 9.



(a) 18 kW condenser untreated



(b) 18 kW condenser with enclosure



(c) 25 kW condenser untreated



(d) 25 kW condenser with enclosure

Figure 9 – Examples of purpose-built acoustic enclosures to achieve a 20 dB noise reduction

As described in Section 3, constructing acoustic enclosures as shown in Figure 9 creates its own problems as the equipment is not designed to be enclosed, requiring the inlet and discharge air pathways for the enclosure to be large. This in turn takes up a significant amount of area, which is a problem on small residential lots.

In addition, Figure 9 shows that as cooling capacity increases from 18 kW to 25 kW, there is a large increase in the required amelioration for two condensers that both needed a nominal 20 dB of noise reduction. In addition to the larger attenuators, the transitions and baffles needed to prevent reticulation of air within the enclosure can increase in size and complexity.

The acoustic enclosures can consist of pre-fabricated acoustic panels as shown in Figure 9, or else an architecturally designed enclosure to match the adjacent residence can be constructed with acoustic attenuators installed to the inlet and discharge airflow paths. Whichever option is used, it is important to ensure that the internal surfaces of the enclosure are lined with sound absorption, all penetrations are acoustically treated to avoid sound leakage, the attenuators and enclosure are supported independently of the condenser, the condenser is resiliently isolated from the enclosure and access doors and panels fitted with perimeter acoustic seals are provided where necessary to facilitate maintenance access.

5 CONCLUSION

This paper has presented a brief overview of the problems, design influences and viable solutions associated with the mitigation of residential air-conditioner noise. Residential air-conditioning condenser noise is complex, involving a number of factors over which an acoustician has little or no control.

Given the right circumstances, there are viable options to treat an air-conditioning condenser. However, when the mitigation requires locating the condenser in the garage or within a purpose-built enclosure, the acoustic mitigation cost will be several times the original cost of the air-conditioning system.

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