The noise of cloud computing

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ABSTRACT

With Cloud computing and Cloud data storage being sold as the way of the future for storing and accessing our digital information, we are seeing an increase in data centre developments in metropolitan areas throughout the world. However, given their complex building services' and high power requirements, there is potential for significant noise emissions to impact the surrounding area. This paper explores the operational noise emission challenges associated with designing acoustically sound data centres and draws on recent project experience from the development of new data centres in Australia's major cities. Included in the discussion are various power and cooling options, unique noise emitting equipment, building layouts, types of operation and rigorous testing schedules, all of which can significantly affect the environmental noise impact assessment of sensitive receivers in the vicinity of the centre.

INTRODUCTION

In today's world cloud computing is being marketed as the way we will be accessing and using our data in the future. For this to occur the associated infrastructure, in the form of data centres, has to be built to host all of our online personal and business information so that it can be available to us 24 hours a day, 7 days a week.

Data centres must be built in areas that have a guaranteed high bandwidth uninterrupted Internet pipeline, high quantities of civil infrastructure such as electricity, gas as well as water connections. Predominantly these conditions occur within industrial and commercial areas of urban cities. As these buildings start getting built closer to and nearby mixed use and residential areas the acoustic impacts from the associated noise emissions have to be assessed.

Working on a data centre (like other industrial buildings) is a unique process for consultants in the buildings market, where the design is driven by engineering function rather than architectural design compared to commercial and residential developments.

This paper discusses the various types of acoustic impacts associated with predominately Tier 3 data centre developments as well as a case study on the design of a data centre and how the acoustic design complimented the operational conditions.

What is a data centre?

A data centre is facility used to hold computer servers, telecommunication equipment and storage systems. The facility is required to provide uninterrupted access to the computer servers housed within. This requires the building to contain numerous redundancy systems for power supply, heating and cooling needs, data communication along with physical security and natural disaster requirements.

The extent of these systems is dependent on the size and class (Tier) of the data centre.

In commercial data centres the owner usually does not provide the actual data storage facilities and IT setup (that is the computer servers themselves and associated setup). Instead the data centre owner provides technical space for rent where clients can install their own servers and associated accessories using their own IT resources. The data centre then guarantees uninterrupted power supply and Internet access, optimum internal operating conditions as well as physical security of the facility.

Types of Data centres

Data centres are classified in Tiers in accordance with ANSI/TIA-942 (ADC, 2004). The tiers generally refer to the required system redundancy and expected availability of the data. This is summarised in Table 1 below:

Table 1. Data centre Tier levels

Tier 1	Basic plant room with no redundancy. Expected data availability - 99.671% Annual down time of 28.8 hours e.g. Server rooms
Tier 2	N+1 redundancy on critical site infrastructure. Expected data availability - 99.741% Annual down time of 22 hours e.g. Individual dedicated large company data storage facilities
Tier 3	N+2, +3 redundancy on critical site infrastructure. Co-current maintenance can be carried out on all components. Expected data availability - 99.982% Annual down time of 1.6 hours e.g. Large high-end commercial data centres in Australia
Tier 4	N+N redundancy. Two parallel complete building infrastructure systems. Expected data availability - 99.995% Annual down time of 0.4 hours e.g. Government department high security data storage facilities, Large high-end commercial data centres in Asia.

This paper discusses acoustical impacts of large commercial Tier 3 type data centres. In a lot of cases in Australia, large commercial data centres are designed and built with the intent to satisfy ANSI/TIA-942 Tier 3 requirements however they are never actually certified.

LOCATION - PLANNING

Data centre clients that are from large businesses located within central business districts require good access to data centres so that their IT staff can efficiently perform required maintenance on their IT infrastructure. This means it is a benefit for the data centre to be located close to business centres, especially the central business districts of cities.

This requires appropriate site planning to choose the correct location to eliminate or minimise current and future noise emission issues. The following areas are most practical and common for the location of data centres:

- Industrial zones
- Business/commercial zones
- New industrial/business parks
- High noise residential / mixed use zones

Industrial zones

Industrial zones provide the best noise environments with high ambient and background noise levels during all times of day and reduced consideration for nearby neighbours due to their non-sensitive nature. The separation distances between site boundaries and adjacent receivers are usually quite small especially in inner city industrial areas. The probability of complaints from adjacent receivers is low.

Business/commercial zones

Business/commercial zones require more strict noise emission criteria compared to an industrial zone. The ambient and background noise levels are increased however they are typically lower than in industrial zones and predominantly consist of general building services hum. The probability of complaints from the neighbours is slightly increased especially if the adjacent receivers comprise office space where the occupants require relatively low internal noise levels. Minimal complaints are likely to occur during evening and night times.

Business/Industrial parks

Modern industrial/business parks provide good locations for data centres as these areas are usually quite spaced out and provide a large separation distance between adjacent developments. Noise criteria would be similar to that of traditional commercial zones. Complaints are less likely to occur from adjacent developments as typically they are relatively newer buildings with higher quality façade construction which would provide sufficient sound insulation performance should any small exceedances of the noise emission criteria occur thus reducing internal disturbance.

Mixed use zones

Data centres are also appearing in more prime real estate in inner city mixed use zones with adjacent or nearby residential residents, usually with medium to high ambient noise levels from other sources such as traffic or other infrastructure. These areas may have been rezoned over time into mixed used areas, and provide potential operational risks for data centre operators.

There is a higher potential for noise complaints especially during night times where the masking background noise levels can drop due to reduced traffic volumes, thereby exposing sensitive receivers to constant noise emissions from the data centre. Much higher levels of sound insulation have to be incorporated into the building design to provide noise mitigation.

This risk is shared with other inner city industrial and commercial zones where there is potential for progressive rezoning in the future to accommodate "inner city living" which then increases the potential for complaints from residents and stricter criteria for noise emissions from data centre operations and future upgrades.

It is important to take into consideration that unlike in some other industrial developments; complete temporary shutdowns are not practical due to contract restrictions and are detrimental to business for the data centre operator. Partial equipment shutdowns can be scheduled (especially for Tier 3 data centres) to implement additional acoustic treatment however major retrofitting is, in a lot of cases, not practical due to the requirement for a complete site shut down.

EXTERNAL NOISE SOURCES AND ACTIVITIES

Data centres contain a large amount of building services equipment to ensure uninterrupted operation of its facilities. Most of this plant equipment contributes to the noise emission from the site and includes:

- Power generating equipment
- Cooling systems
- Electrical distribution and storage
- Testing
- Auxiliary equipment.

Power generation

Power generation at a data centre can vary depending on the intended design of the building. This can range from:

- Standby power capacity
- Ongoing power generation – partial or complete
- Co-generation/Tri-generation systems.

Standby generation requires the use of multiple generators to provide sufficient power capacity in the event of a complete power shortage from the external source. Usually this occurs with the use of multiple generators.

The generator plant rooms generally have sufficient construction to satisfy the airborne sound insulation requirements through the use of either block work or precast concrete walls and concrete slab flooring. Depending on the location of the plant room the ceiling could be of lightweight fire rated construction hence sufficient acoustic performance is required through this noise path.

The main noise emission path relates to the generator air intake. Large quantities of air are required to feed the engines which in turn means a large air intake opening usually in the façade. A high performance noise attenuator is required, however in a lot of cases there are limitations on its length while still maintaining a large cross sectional area. Designing a more intricate internally lined air path to complement the sound transmission loss of the attenuator is key to achieving the desired externally radiated sound power level.

The outlet air discharge from the generator can also have a high sound power level. Since this air path is usually fan driven, there are more options to duct the air to a more suitable discharge location, usually away from the perimeter of the building and on its roof top. The additional internally lined duct length, lower specification noise attenuator, discharge position and directivity satisfy the sound power emission requirements.

An appropriately selected industrial silencer can provide adequate attenuation of the engine exhaust from an engine generator. The position and directivity of the stack mouth away from the development boundary also reduces its noise contribution.

Correct vibration isolation of the generators from the structure is very important to minimise structure-borne noise transmissions to the adjacent spaces, especially when the generator plant rooms are not at grade and there are occupied spaces below.

Based on the intended power generation operation the extent of the generator room attenuation would be dependent on what is considered “normal operation”. That is a data centre with standby power generation would require less attenuation then the equivalent data centre with an ongoing power generation system.

Cooling systems

The cooling system plays an important part in the operation of a data centre. It is required to provide optimum operating conditions within the technical spaces where the computer server racks are stored. With its high heat loads and unique heat flows it is critical for the cooling system to maintain the required thermal and climatic conditions. Usually a traditional HVAC system is used which comprises:

- Cooling towers
- Chillers
- Air distribution systems via Air Handling Units (AHU) and Computer Room Air Conditioners (CRAC) Units.

This arrangement places most of the equipment within the data centre where the noise emissions can be controlled through the construction of the associated plant rooms. The major external noise emitting equipment is the cooling towers which are usually located on the roof top.

The AHUs can be located within individual plant rooms where the air path can be treated to control both external and internal noise emissions. The AHUs would service predominately the occupied spaces within the data centres such as office areas and control rooms.

The CRAC units are specifically designed to provide sufficient airflow into the technical spaces. These units are usually located in the corridors adjacent to the technical spaces They pump cool air through a perforated raised floor into “cold” rack aisles while simultaneously pulling exhaust air from adjacent “hot” rack aisles. This provides constant airflow through the technical space environment. Given the large number of CRAC units required to sufficiently service a technical space, it is not possible to completely isolate them and so can lead to increased noise levels within the access and service corridors.

An alternative option for a cooling system involves the use of Indirect Evaporative Coolers. This system removes the need for Cooling Towers, CRAC units and Chillers and replaces them with an Indirect Evaporative Cooler and pressurisation AHUs. This option places all cooling equipment in a single plant room with the air supply and return then directly ducted into the technical spaces. From a noise perspective the intake and exhaust air paths have to be treated with low pressure drop systems however the internal noise level within the Evaporative Cooler Plant Rooms are below those in the Generator Rooms.

Smaller cooling system components that can also contribute to the noise emission from the data centre development, depending on the design, are the generator radiators. These can either be packaged as part of the generator equipment and placed within the generator room, or be remotely located (usually as part of the rooftop plant). The external location of the radiators then contributes to the overall noise emission from the site, whereas being located with the generator the noise emissions are controlled by the plant room.

Electrical distribution and storage

The equipment associated with the distribution of the electrical power and its storage is usually not a major noise concern for a data centre development. The equipment usually consists of:

- Transformer: High and Low voltage (depending on design)
- Uninterruptible Power Supplies (UPS)
- Associated electrical switch equipment.

Depending on the design and building layout, the transformers can be located within the building envelope or placed externally. From a noise perspective it is preferable for the transformers to be located internally however due to space restrictions this is not always practical. A noise barrier is usually sufficient to control the noise emissions from the transformers.

The UPSs are located within the core of the building so that any noise emissions are controlled through correct wall specification. For rotary UPSs correct vibration mounts are required (especially if there are occupied spaces below) to minimise structure borne noise transfer.

Electrical switch equipment is located with individual rooms and generate limited amount of noise impacts.

Testing and auxiliary equipment

Each data centre requires regular maintenance and testing of all of its redundancy systems to ensure correct operation. Depending on the size of the data centre the noise associated with the testing schedule and procedure can become sufficiently regular to warrant assessment as part of the regular noise emissions from the site.

This involves testing the backup generators and redundant cooling equipment. In an emergency situation all (or most) of the generators would be operational, however under regular testing conditions simulating emergency loads and assessing all of the systems can become impractical while still maintaining operations of the data centre and providing redundancy. As such, typically generators are tested individually or in pairs.

To provide a test electrical load simulating the power requirements of the technical spaces, a load bank is used. This piece of equipment is only utilised during the testing procedure. Noise emissions from the load bank can be quite considerable and its location on site is required to provide sufficient sound attenuation to the adjacent receivers. The load bank can be located as part of the roof top plant or in an isolated outdoor location of the site.

CASE STUDY

Overview

This case study examines the acoustical design and subsequent compliance of a large data centre located in an inner city industrial area in NSW. The data centre consisted of:

- The retrofit of an existing industrial building
- Multiple stand-by generators with remote roof mounted radiators
- Roof mounted plant including multiple wet and dry cooling towers, remote generator radiators and testing load bank
- Chiller plant room
- Transformers and UPSs located within the building envelope.

The external noise emission criteria were determined in accordance with the *NSW Industrial Noise Policy* (EPA, 2000) based on an environmental noise survey carried out on site. The driving assessment criterion for the project was L_{eq} 68 dBA at the development boundary.

Each generator plant room contained a pair of diesel engines in stand-by mode with a weekly testing schedule for each individual unit. The expected operations of the diesel engines consists of day time testing of individual engines for approximately four hours total daily operation (i.e. the equivalent of one engine running for four hours during each day). This meant that the testing of the generators had to be assessed as a regular noise source and no duration modifying factors could be applied to the criteria.

Noise emissions from the generators were of greatest concern because the generator air intakes were located towards the back of the building approximately six metres from the development boundary.

Other major noise sources consisted of the roof mounted plant which included multiple wet cooling towers, two dry fan cooling towers, generator radiators, load bank and the generator air outlet and exhaust discharges.

The main plant room, on the western façade of the building, comprised of multiple large water-cooled centrifugal liquid chillers with over 3500 kW cooling capacity as well as smaller water-cooled helical-rotary liquid chillers and 24 various pumps. A worst case simultaneous operation would consist of four centrifugal chillers, one helical-liquid chiller and all 24 pumps operating.

Power storage and distribution equipment were all located within the envelope of the building with no externally placed transformers.

The layout of the major noise sources in the data centre are shown in Figures 1 and 2.

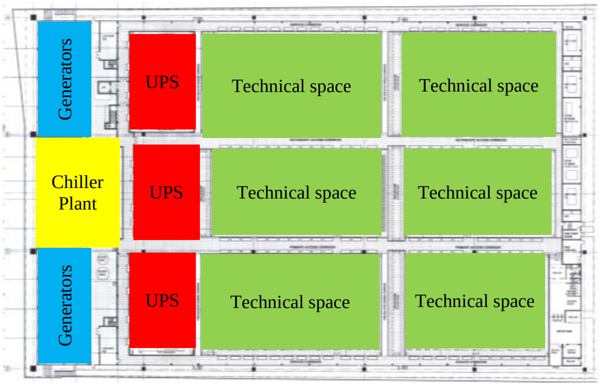

Figure 1. Plan view of the major plant rooms

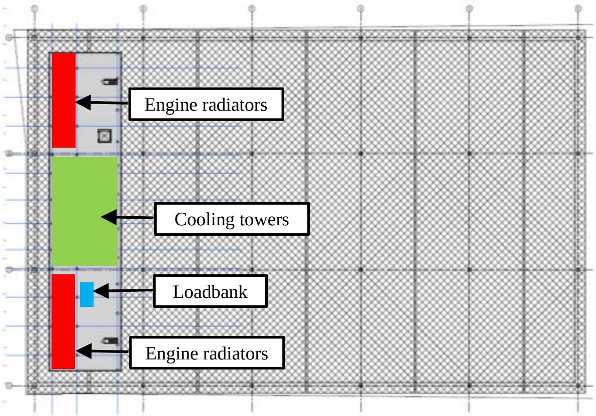

Figure 2. Plan view of the roof top plant

Generator rooms

The generator rooms with their reduced space and high airflow requirements limited the maximum lengths of the attenuators that could be used for the air intake. To complicate matters further, the external wall of the plant room had to be removable for future access to potentially replace large equipment such as the generators. The section layout is shown in Figure 3.

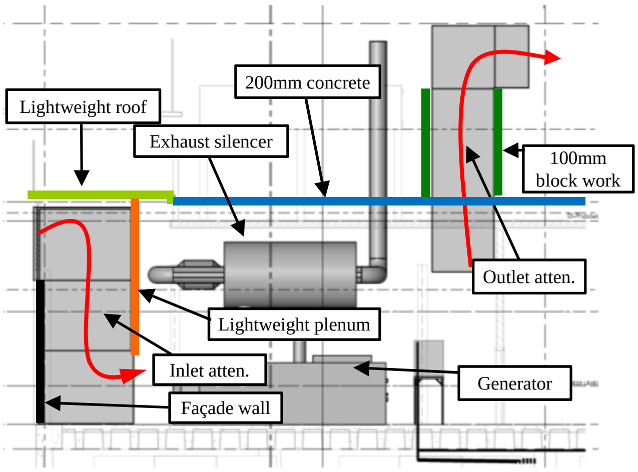

Figure 3. Section view of the generator room design showing the inlet and outlet air paths

The following noise attenuation measures were implemented into the design of the data centre:

Break-out noise control

Lightweight plenum wall

- Plenum walls consisted of 50 mm Kingspan composite panel with 1x9 mm compressed fibre cement sheet attached /92 mm steel stud with 75 mm 24 kg/m^3 insulation/ 3x13 mm fire rated plasterboard.

Plant roof

- 2x12 mm compressed fibre cement/200 mm air gap with 100 mm insulation 32 kg/m^3 /2x16 mm fire rated plasterboards on resilient mounts
- Remainder of roof 200 mm precast concrete.

External plenum wall/ facade

- Western plenum wall consisted of 100 mm precast /50 mm steel stud with 50 mm 24 kg/m^3 insulation/ 1x6 mm compressed fibre cement sheet.

Outlet air outlet

- 100 mm block work encasing the outlet air duct.

Internal finish

- Perforated metal absorptive panels (NRC 0.9) to 60% of total surface area.

Down-duct noise

- Intake air plenum in “S” shaped air path with 1500 mm long attenuator, turning vanes and internal lining
- Air outlet – dual axial fan driven with a 900 mm rectangular attenuator, remainder of duct lined internally. Discharge directed away from boundary
- Industrial exhaust silencer of “critical” rating. Discharge directed away from boundary.

In addition, some office space was located directly below the generator rooms. A vibration isolated ceiling had to be mounted to the existing waffle slabs along the ribs to minimise and structure borne noise:

- 2x16 mm fire rated plasterboard on resilient mounts with a layer of insulation in the cavities

Chiller plant room

The chiller plant room construction was a “light weight” version of the generator rooms due to the lower internal noise levels predicted:

External wall

- 100 mm precast concrete walls
- 600 mm attenuator required for the exhaust system
- 12 mm compressed fibre cement sheet/ 50 mm void with insulation/ 12 mm compressed fibre cement sheet construction to block out the architectural louvered opening along the whole extent of the plant room.

Plant roof

- 1x16 mm Fire rated plasterboard/200 mm air gap with 100 mm insulation 32 kg/m^3 /1x16 mm Fire rated plasterboard.

Electrical distribution and storage

All of the electrical distribution and storage equipment such as the transformers, UPS systems and associated switch boards were located within the building envelope minimising and external noise emissions. The high voltage transformers were located along the building façade away from the building boundary.

Roof top plant

The roof top plant will consist of the following equipment:

- 12 x Single fan wet cooling towers
- 2 x Triple fan dry cooling towers
- 16 x Horizontal remote engine radiators
- 1 x Load bank.

The worst case operation consisted of the simultaneous use of eight wet cooling tower units, two dry cooling towers, one set of radiators and the load bank. Exhaust risers and air outlets from the generator rooms below also discharged at the roof level.

Limited mitigation measures could be applied to the operating equipment, besides equipment selection and layouts. The set down location of the roof top plant deck provided some barrier shielding to the adjacent receivers at ground level. Limited barrier effect was experienced at adjacent properties at roof height.

The load bank was located along the southern end of the roof top plant, away from the roof level accessible area of the neighbouring property.

Compliance noise measurements

Compliance measurements were carried out during Stage 1 of the commissioning of the data centre, which included a reduced rooftop plant. As part of the noise survey, noise levels within some plant rooms and emissions from the load bank were measured. These are shown in Table 2 and Figure 4 below.

Table 2. Measured equipment sound pressure levels (dB)

Source	Sound pressure levels (dB) in Octave bands (Hz)								Total (dBA)
	63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**	
Generator Room (Lp rev)	73	95	100	102	101	97	93	85	**102**
Chiller room (Lp rev)	60	74	78	78	76	71	74	67	**81**
Load bank (Lp @ 2m)	89	91	91	92	88	82	77	69	**92**

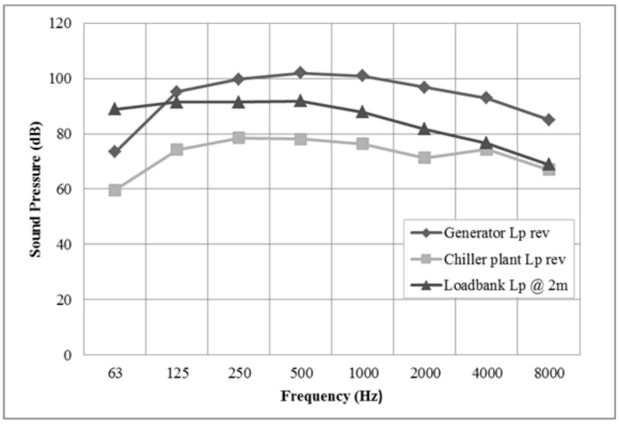

Figure 4. Equipment noise emissions

Noise measurements were carried out at three locations on the development boundary and are shown in Figure 5. Table 3 shows the results of the compliance measurements.

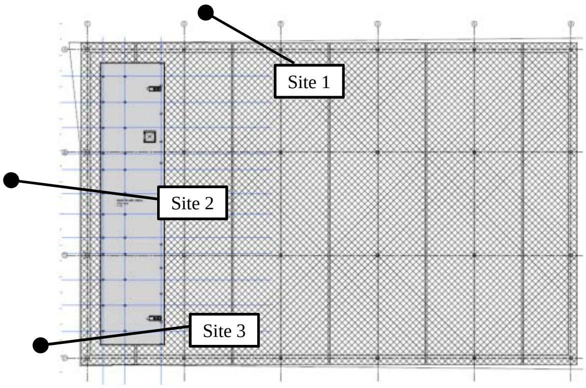

Figure 5. Compliance noise measurements

The compliance noise measurement sites were as follows:

- Site 1 – Accessible area of the neighbouring property at the roof height of the data centre, approximately 50 m away from closest currently operating roof plant
- Site 2 – Ground level at the boundary adjacent to the chiller plant room façade, 12 m away
- Site 3 – Ground level at the boundary adjacent to the generator room façade, 6 m away

Table 3. Outdoor compliance noise measurements

Location	L_{eq} (dBA)	L_{90} (dBA)	Criteria (L_{eq} dBA)
Site 1	54	52	68
Site 2	56	54	68
Site 3	55	53	68

Site 1 noise comprised of the rooftop plant noise emissions from the development and adjacent sites. Site 2 and 3 noise emissions consisted of audible generator and chiller plant noise. Rooftop plant noise was not audible at these locations. Based on the measured noise levels and noise survey observations, it is expected that the noise emissions from site will not increase significantly for subsequent construction Stages 2 and 3 and therefore satisfy the L_{eq} 68 dBA criteria

Figure 6 shows the one-third octave noise data from the measurements at Site 2. As can be observed there are small tonal peaks at 25 and 100 Hz, however based on the tonality criteria outlined in the *NSW Industrial Noise Policy*, no tonal penalty had to be applied. The low frequency modifying correction was also not applicable since the difference between the dBC and dBA levels was 12 dB, which is below the 15 dB threshold in the *NSW Industrial Noise Policy*.

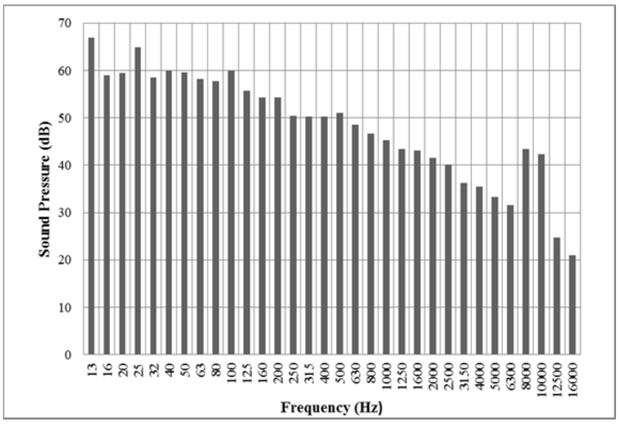

Figure 6. Spectral noise data at Site 2

Through the successful design and implementation of acoustic attenuation measures within the data centre, the noise emissions from the site complied with the development conditions (L_{eq} 68 dBA).

CONCLUSION

During the design and planning processes for a large data centre it is important to understand the noise environment that the building will be located amongst, along with the operating conditions of the building itself. It is also essential in the early planning phases, to understand what type of testing schedule the operator is likely to implement in order to identify how it will affect the general noise emissions from the site.

To accurately predict noise emissions from a data centre site, a comprehensive list and location of the various building systems are required and should take into account:

- Power generating equipment
- Cooling systems
- Electrical distribution and storage
- Testing
- Auxiliary equipment.

By breaking down the noise emissions of each individual system, appropriate and practical noise mitigation measures can then be developed and incorporated into the building design. Individual problem areas can be highlighted early on in the design process to ensure they do not develop into major issues during the detailed design or construction stages.

Obtaining the correct noise emission data from equipment suppliers forms an important base to achieving accurate predictions that can be relied on to reduce the risk of major issues during the construction and compliance stages of the project. By taking these steps, engineers can ensure the sound radiated by data centres will be below prescribed noise limits and help clients to maintain good relationships with their neighbours.

REFERENCES

NSW Industrial Noise Policy, 2000, Environment Protection Authority, Sydney Australia.

TIA-942 Data Centre Standards Overview, 2006, ADC Telecommunications Inc., Minnesota USA.