

IDENTIFYING NOISE CONTROL STRATEGIES FOR VARIABLE AIR VOLUME (VAV) BOXES IN ACUTE CARE HOSPITAL DESIGN

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1 Introduction

Variable air volume (VAV) boxes are frequently used as the final temperature/airflow control at each room-space in new acute care hospitals. The project requirements for specific background noise levels are often necessarily onerous and require significant acoustical design measures to mitigate unwanted noise effects in patient rooms.

Noise control in the design of heating, ventilation and air conditioning systems (HVAC) for hospitals in Canada is regulated by multiple healthcare standards, such as Canadian Standards Association (CSA) Z8000 *Canadian Health Care Facilities – Planning, Design and Construction*; the Canada Green Building Council (CAGBC) Leadership in Energy and Environmental Design (LEED) *Building Design and Construction (BD+C)*; the Facilities Guidelines Institute - *Guidelines for Design and Construction of Hospitals* and other provincial technical guidelines. In most cases, each project will define background sound ratings from combined HVAC systems within each space of the hospital design for specific project specifications and sound ratings that are typically quantified under a Noise Criterion (NC) standard.

The requirements to achieve NC 25-30 ratings within noise-critical spaces are technically challenging due to both acoustical and non-acoustical factors. A significant number of treatments and controls for acoustical, architectural and mechanical operations are necessary to achieve NC 25-30 ratings. Notable factors that materially affect background sound ratings from HVAC systems include room dimensions and shape, ceiling assemblies and room finishes, distances from noise sources to receivers, mechanical equipment type (VAV size, model and type), airflow (operating conditions and duct velocities), pressure drop, and ductwork types and layout arrangements.

Additionally, CSA-Z317.2 *Special Requirements for Heating, Ventilation, and Air-conditioning (HVAC) Systems in Health Care Facilities* [3] outlines certain mechanical requirements that inadvertently place limitations on the noise control measures, such as the limitation of flexible duct applications outlined in Sections 6.9.4 *Duct Surfaces* and 6.9.5 *Lining of HVAC Elements*.

2 Method of Determining Sound Ratings

Calculations of noise from mechanical systems are routinely performed using the formula derived from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) *Handbook - HVAC Applications* Chapter 49 Noise and Vibration guidelines,

while VAV sound power data are obtained from published commercial sources [4]. Calculations are performed by combining certain scenarios with multiple elements configured to achieve the target design sound ratings of NC 25-30.

3 Result and Discussion

Radiated Casing Noise and Duct Rumble

Often the Design-Builder or Mechanical Consultant will want to assess the potential for locating VAV boxes above the ceiling assembly within the NC 25-30 rated spaces. Based on the published radiated sound data for VAV boxes, certain VAV units with discrete sizing and operating conditions appear capable of maintaining sufficiently low radiated sound ratings. The VAV boxes that typically achieve this rating category rely on the VAV units with attenuators, discrete unit sizing (i.e., size 4 to size 24x16), VAV operating conditions (lower airflow velocities and/or pressure differential) as well as sound isolating ceiling types.

Transmission loss provided by gypsum wallboard ceilings is much higher than mineral fibre tiles and allows a greater variety of VAV boxes to be located above the NC 25-30 rated spaces. According to ASHRAE experiments, leakage between the mineral ceiling tiles and the T-Bar grid is the major noise transmission path where penetrations from light fixtures is present. Diffusers have only a localized effect [1,7]. However, in practice, the use of solid gypsum board as a ceiling would be challenging where other stringent room acoustic criteria are present. For example, in most cases, patient rooms with an NC 25-30 rating will also have an onerous reverberation criterion that will be difficult to achieve since a gypsum wallboard ceiling does not have a high sound absorption capability when compared to mineral ceiling tiles. In addition, where flexible duct designs are introduced, gypsum wallboard ceilings cannot be used as per the CSA-Z317.2-15 Section 6.9.4 requirements.

Selecting VAV boxes with in-line attenuators has been found to improve the potential for placing the VAV boxes above the NC 25-30 rated spaces without incurring significant cost uplifts. However, the magnitude of radiated noise is significantly affected by the VAV boxes' operating conditions (airflow and pressure differential) and, as such, in practice is only possible to implement where the VAV boxes system is being upsized and operated at a very low design airflow condition.

Discharge/ Inlet Noise

The main challenge to achieving the NC 25-30 rating in critical room-spaces is the level of noise emitted from the discharge and inlet terminals. In a case where VAV boxes are

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located near the spaces they are serving, there is limited ductwork treatments that can be introduced to attenuate the noise from the VAV boxes. In these cases, operating the boxes at a very low design airflow conditions are also not possible.

While the lengths of the flexible ducts are regulated and limited as per CSA-Z317.2, the introduction of a wire-reinforced plastic inner duct surrounded by a plastic-faced layer of flexible fibreglass insulation flexible duct can attenuate sound emitted from the VAV boxes in a cost-effective manner. The use of the flexible ducts in the system aides the attenuation of sound at the higher octave band frequencies (500 Hz-4 kHz). Without the use of flexible ducts, VAV boxes would typically need to be located further away from the spaces they are serving in order to provide more ductwork attenuation, operated at a very low design airflow or a combination of both methods.

VAV Distribution and Air Circulation

In acute care hospitals, two different VAV system strategies are typically presented that include either supplying one VAV box for each room against another which includes one centralized VAV box to serve multiple rooms.

Supplying an individual room with its own dedicated VAV box has both advantages and disadvantages in terms of the final sound ratings. The advantages are that the significant potential to upgrade the capacity of the airflow in the individual spaces, since these VAV boxes will be running at a low operating condition (normally below 50%) and individual temperature control. The disadvantages are that VAV boxes are being located closer to or directly above the noise-critical spaces due to a large number of VAV boxes required. This can lead to overcrowding within the busy ceiling plenum of the circulation corridor, which can inadvertently force some of the VAV boxes inside the spaces. This is less of an issue in the NC 35 or above rated spaces. However, additional treatments are typically required to control the radiated noise from the large number of VAV boxes located within the space. Where the VAV boxes need to be located above critical spaces (i.e., NC 25-30), then architectural solutions such as gypsum wallboard ceilings and flexible ductwork would need to be introduced.

Better noise control could be achieved by selecting larger VAV box units and running longer ductwork with mitred elbows or bends to multiple spaces. NC 25-30 spaces should be located at the end of the ductwork branches to provide the maximum attenuation. To a certain extent, this could reduce the need for flexible duct in the systems.

Similarly, centralized VAV boxes serving multiple spaces also have advantages and disadvantages in terms of the potential noise control treatments. The advantages of increased space availability for longer ductwork with more elbows and less radiated noise to be controlled is a significant cost benefit. Additionally, large VAV boxes can be relocated or situated in less noise-sensitive areas (NC 35 and above) such as corridors, building services, and storage areas to minimize the potential noise impacts. The disadvantage of such a system is that the VAV boxes that are serving multiple spaces are more likely to operate under larger airflow design

conditions with greater system inefficiencies. This results in higher sound power data for the radiated noise at the VAV box location and the discharge/inlet at the closest path.

4 Conclusion

The success of acoustical treatments for air distribution systems using VAV boxes relies on a combination of acoustical, mechanical, and architectural design factors. Wholesale positioning VAV boxes above the ceilings within noise-sensitive (NC 25-30 rated) spaces is not typically considered suitable without the inclusion noise control measures. The discharge and inlet noise from VAV boxes to the noise-sensitive (NC 25-30 rated) spaces could be mitigated by either the use of flexible duct or VAV boxes with attenuators, trunking longer ductwork lines with additional mitred elbows or bends, and introducing branches, as well as by upsizing the VAV boxes and operating the units at lower pressure differential and airflow velocities.

References

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