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Smart Designs for Science Research Buildings

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Abstract
Science research laboratory buildings often contain noise and vibration sensitive equipment that may be impacted by common vibration and noise sources inside and outside of the building. This presentation discusses the importance of space planning with noise and vibration control in mind from the beginning. Cost effective methods of noise and vibration control are discussed, as well as general HVAC planning in a laboratory building. Noise and vibration control of special spaces such as magnetic resonance imaging (MRI) and vivarium are also discussed.

<u>Control of Footfall-Induced Vibrations – (without extra tons of steel)</u>

- Locate the spaces housing the most senstive equipment on grade rather than on upper floors of buildings.
- Identify special, concise zones where particularly senstive equipment will be located so that large areas of the building do not need to be designed to such a stringent standard.
- Keep main corridors in structural bays that are separate from bays that house vibration senstive equipment. If corridors are in bays with senstive equipment, locate them along column lines; avoid center bay locations.
- Avoid long span structures for spaces that house vibration senstive equipment. Note, however, that it can be acceptable to have transfer girder cases without much penalty from the vibration control case – such as if the upper floors of university laboratory are to be labs with relatively close column spacing and the first floor is to have larger lecture spaces that need to be column free. The transfer girder is generally so stiff for structural reasons that this is not material to the vibrations in the lab floor. So, if this is what is necessary for programmatic reasons, there is no reason to fear this from the vibration control standpoint.

<u>Environmental Vibration</u>

- Locate spaces housing particularly vibration sensitive equipment or activities far from sources of vibration like trains or busy roadways.
- Identify specific sources of vibration nearby like a utility plant or specific piece of machinery and keep the sensitive equipment far away.
- Avoid discontinuities in the pavement near a building such as pot holes and speed bumps and have traffic near a building move only quite slowly.

Building Equipment Vibration Control

- Locate major mechanical equipment plant rooms well away from areas housing vibration senstive equipment or activities.

- Well conceived, well specified and well installed vibration isolation systems for mechanical equipment and systems are essential. With reasonably good planning, conventional isolation systems are usually sufficient; exotic isolation schemes and equipment are not usually needed.
- Vibration isolation is cheap at the time of initial installation and should not be omitted. The cost to retro-fit vibration isolation systems later if they are not installed initially and are later found to be needed, will be many times the cost for initial installation.

Architectural Acoustics

- Separate noisy mechanical equipment rooms and program spaces from occupied spaces, especially program spaces that have greater than nominal sensitivity to noise. This will help minimize the need for particularly massive constructions and/or fussy details to address sound isolation issues.

- Need to plan on equipment like fan coil units and terminal boxes/valves not to be exposed in virtually all spaces. These need to be at least above mineral fiber panel ceilings. They could also be located outside the space or in an enclosed soffit. Even if the soffit has a mineral fiber acoustical panel ceiling, this is typically sufficient to reduce the noise to be acceptable.

- Use equipment rooms for noisier laboratory equipment to get these items out of the basic lab so that they do not contaminate the noise environment in the labs.

- Laboratory spaces and most spaces in general need to include a reasonable level of sound absorption to control activity noise, control laboratory equipment noise, and make the spaces feel acoustically comfortable. This could be provided with a conventional acoustical panel ceiling. Perhaps this is one of the most straight forward and simplest approaches to provide the desired level of sound absorption, but this is not the only way to accomplish the goal. It can be accomplished with exposed ceiling schemes, but acoustical solutions in these cases are typically harder to come by and are more expensive.

- Be extremely careful with the use of glass fiber ceiling panels. While they are highly sound absorptive, which is good for controlling the loudness of sounds in the occupied space, they are acoustically transparent and sound will go right through them. Unless special care is taken in other aspects of construction and to achieve the necessary sealing of sound isolating constructions, there can be significant sound isolation problems. Glass fiber ceilings also do not stop the transmission of mechanical systems noise from above the ceiling. Use of a mineral fiber ceiling that has an NRC of at least 0.70 will barely reduce the sound absorption that is available to the occupied space, but will provide significantly more sound transmission loss to address the concerns identified above.

<u>Internal Mechanical System Noise Control</u>

Main systems

- Use a header system with multiple drops or main branches into the building to create a consistent and only moderately long duct run to feed the spaces rather than one large and long main duct. This will minimize the energy that the fan needs to deliver the air in overcoming the pressure loss of the long run (thus reducing the noise that the fan develops) and it will reduce the pressure arriving at the closest terminal boxes which means that they will not have to do as much throttling to control the air flow, thus reducing the noise that they generate.

- Use of a loop duct for supply or exhaust is very favorable because this lowers the pressure loss in getting to the farthest points of the building – This lowers the pressure and noise of the fans and reduces the differential in pressure that arrives at the terminal boxes

- Consider the friction rate and velocities at which the main (medium pressure) duct systems are designed. Again, the goal is to reduce the friction in the main systems and the pressure that it takes to get air to the far ends reaches of the system.

- Slowly reduce the friction rate at which the medium pressure ducts are designed as the duct sections get closer to the ends of the system. For instance, the initial duct sections might be deigned at a friction rate of 0.15"/100 ft of duct run up to a maximum velocity of about 2,000 fpm, and as the ducts get closer to the end of the run, the friction rate might progressively drop to 0.08"/100 ft of duct run. Again, the idea is to lower the system resistance. The lower the system pressure drop from beginning to end, the lower the total system pressure, the lower the fan noise, and the lower the noise that is generated by terminal boxes. Typically, if the building system integration scheme is set up to accommodate the largest ducts, having somewhat larger, "over designed", ducts toward the end to lower the resistance of the system can be accomplished easily with little impact on other systems and without requiring more space in the building.

- Use constant size header ducts where practical.

- Attenuation is typically needed to control the fan noise transmission to the occupied spaces via the duct system and to avoid break-out noise issues. Often it is a good approach to have this attenuation in the casing of the main unit, where it typically only needs to be 3 ft long and the pressure loss can be quite low. But if the unit length needs to be limited and especially if there is ample straight duct length, duct silencers can be fine as well. Elbow silencers are available for modest premium cost and these are very helpful in resolving attenuation needs where there is little straight duct length. It is always better to use an elbow silencer rather than to poorly apply a straight silencer. If the geometry of the system is particularly poor from the aerodynamic standpoint for incorporation of silencers, it may be better to simply use double wall duct construction with a perforated inner face to provide the necessary attenuation with minimal pressure loss. The aerodynamic impact of the attenuation treatment is a key issue to watch for.

- Check the pressure on the various main branches to be sure that one or a couple of branches do not unduly control the pressure the system needs to develop. To the extent that noticeably more resistance exists on one branch, this should be addressed (branch resistance lowered) so that the entire system is not burdened by the need for this one branch.

- If there are only a few particular devices in the air system that have a higher pressure requirement than most of the other system devices (such as a bio-safety cabinet) consider having a local booster fan to provide that pressure rather than burden the entire system with the extra pressure.

- Balance and set-up the system to achieve the desired flow with the minimum pressure that is required to achieve the design flow under a simulated design flow scenario. All too often we are called in to address noise concerns only to find that the system pressure has been left unnecessarily high. Typically, the fan design flow is a diversified flow and is not the sum of the flows of the various terminal boxes. The systems cannot be properly set by commanding all the boxes open and see if there is sufficient flow at all the boxes. This is not a design condition.

Final Distribution Systems

- Terminal box/valve noise is somewhat a function of flow, but is primarily a function of the pressure loss that occurs across the box/valve. This pressure varies throughout the system, but is naturally greater near the beginnings of the systems than at the ends of the systems.

- Attenuation is often (in most practical systems) needed on the room sides of terminal boxes/valves to control the noise that is produced in throttling for control. The attenuation does not always need to be provided with a prefabricated silencer in the ductwork on the room side of the box, but for many (most) laboratory applications this is the appropriate solution. For offices, typically the box manufacturer’s attenuation section, 5 to 6 ft of lined duct or 5 to 6 ft of flexible duct of the plastic-covered wire helix variety will provide the necessary attenuation. Corrugated aluminum flexible ducts and film faced lining do not provide suitable attenuation.

- If the mechanical systems can be designed so that the pressure loss across the terminal boxes is lower than about 1.0” to 1.25”, for many applications it is marginally possible to get away without attenuation for lab applications, but it is often difficult to guarantee that such a desirably low pressure can be achieved, and identifying where this low level of pressure can be achieved is not always a sure thing. Even with careful planning, things often result in the field that require higher pressure than anticipated and this increases the need for silencing on the terminal boxes/valves. Without attenuation on the room sides of boxes there is precious little room for error. Given the risks involved, and the small margin for error, I suggest that the risks associated with not having attenuation are too large to take. The cost to fix this after the installation is complete will be very high.

Issues Specifically Related to Vivariums

- Sound isolation for small animals is rarely a concern and relatively ordinary construction can be acceptable.

- Sound isolation for large animals is usually the greatest concern. Different species typically need to be highly isolated from one another and the closer these are placed to one another in a facility the greater the construction needs to be to separate them. These are best separated in there own suites with buffer spaces used to help control sound transmission between holding rooms.

- Cage-wash equipment and operations can be structureborne noise issues that have to be addressed. It is best that these be located on grade, in which case not too much that is special needs to be done regarding noise and vibration control. Where these are located on above grade structures there is a real concern for vibration control due to motors and pumps associated with the washing equipment and for impact noises that are sometimes related to the operation. It is usually almost impossible to address these when the space is located over other noise sensitive spaces. Planning is essential to avoid significant problems and substantial constructions.

Issues Related to Special Equipment

- Locate ultra-senstive equipment on slab-on-grade conditions rather than structures above grade. The cost to accommodate these on above grade structures may be very substantial and may involve limited flexibility in their location.

- MRIs are both vibration sensitive pieces of equipment and noise/vibration sources of concern. Locate these away from other occupied spaces as much as possible and provide the vibration isolation mounting accessory that is typically available from the manufacturer. To the extent that no isolation is provided, a structural break in the floor around the unit or around the room will be needed. This is hard to do on an above grade floor.

Exterior Noise Emission Control

- Strobic fans are commonly found in research building projects and these are a common source of outdoor noise concerns. If there are residential neighbors nearby, it may be a good idea not to use this sort of fan and to use alternate fans that can be applied in an enclosed mechanical penthouse. For all but projects with no concern for exterior noise, you need to avoid the use of Strobic fans operating at 3,600 rpm. 1,800 rpm is nominal, but there are even slower fans that will typically operate at lower noise emission levels. The slower fans will typically be larger for a given application and you will need to plan appropriate space.

- A number of systems, such as cooling towers operate on VFDs and/or have a redundant unit. For equipment like cooling towers it is best to operate all the cells at reduced speed rather than to operate only a few of the cells at full speed because noise is a strong function of the speed of the equipment and is a much smaller function of the number of units operating. For exhaust fans, if there is a redundant fan, consider using this along with the other fans for normal operation with all the fans operating at reduced speed; with the emergency back-up position being to operate one less than all fans at full speed. To the extent that exhaust systems can operate at reduced flow and speed at off-peak times, this is very favorable way to operate the system to reduce noise. Often off-peak demand corresponds with nighttime when community noise requirements are more stringent that during the day, so this naturally goes together to create a potentially favorable noise emission condition.

- Air-cooled equipment (especially air-cooled chillers) is a common source of community noise concerns and these should be used with great care where there are residential neighbors nearby.