Noise and the Mechanical System Design Process

Common Acoustical Pitfalls, Misconceptions, and Problems in Mechanical System Design

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Noise and the Mechanical System Design Process

Common Acoustical Problems in Mechanical System Design

• Presenting four issues:
  – Duct Layout and Design
  – Diffusers and Dampers
  – Overlooked Vibration Isolation
  – Vertical Heat Pumps
**Duct Layout and Design**

- Do design ducts to be self-regulating, i.e. reduce duct sizes to maintain constant velocity and pressure in the mains instead of using a single duct size with dampers at each branch take-off to regulate flows.

- Don’t rely on volume dampers as the main devices to regulate flows. Dampers produce static pressure losses and noise.
  - The system should be designed so that dampers are used only for minor trimming and should be avoided at locations directly behind diffusers.
  - Fans should be run at the lowest speed to achieve the minimum pressure for the farthest outlet in the system.

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Poor Duct Design Example: The main branch is the same size throughout. Volume dampers are needed to equalize the pressure and get the proper air flows through each branch.

This is a cheap, easy-to-build design. But, it uses more energy, more sheet metal and results in a potentially noisy installation.

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**Duct Layout and Design - Examples**

Proper Duct Design Example: The main branch reduces in size as it goes along. Thus the system becomes self-regulating and the volume dampers are only needed as trim devices to get the proper air flows through each branch.

While this is a more labor intensive design. It is more energy efficient, uses less sheet metal and results in a quieter installation.

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Another example of poor duct design: Diffusers right at the underside or side of a duct.

This design is a noise problem because of the pressure loss at the damper creates noise right in the room. Naturally the higher the air velocities and pressures the worse the noise becomes.
Duct Layout and Design - Examples

The Proper Duct Design, shown below in plan, is to place diffusers in a take off from the side or bottom of a duct.

It would be even better to have a self-regulating main duct, but this configuration is less likely to be a problem because the noise from pressure loss at the damper can be dissipated in the duct and the elbow before the diffuser into the room.

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Diffusers and Dampers

- It is a particularly bad situation to have a damper directly behind a diffuser. This is because the inherent air turbulence downstream of a damper, even opposed blade types, causes excessive noise generation across the face of a diffuser.

- Another factor that must be considered is the uniformity of the air flow into the throat of a diffuser. See the examples from Chapter 47 of the ASHRAE Guide:
Diffusers and Dampers

- The way to avoid these problems is through tight specifications regarding the use of flexible duct in terms of minimum radius of the turn and requiring proper support of the flexible ducts. Then following up by continual inspection of the work as it proceeds.
Flexible Ducts

- Here is a brief example of the problems that improperly installed flexible ducts can cause.

- Small College in upstate NY had a Featured Auditorium/Lecture Hall in a laboratory building.

The Design was NC-30

With the kinks shown here the levels were NC-40

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Flexible Ducts

- Straightening out the kinks in the flexible ducts made all the difference.

The resulting NC levels at maximum air flows dropped below the NC-30 design goal.
Overlooked Vibration Isolation

Most of you know to place rotating equipment on vibration isolation systems.

But what about all that non-moving equipment attached to the rotating machinery.

Things like the first elbows off a centrifugal pump or a water-to-water heat exchanger.

Anything that is connected within 50’-0” or 100 pipe diameters to a rotating piece of equipment must also be vibration isolated.
Poor Vibration Isolation of Pump and Pipe Elbows

Pipe Elbow Short Circuits Pump Isolation

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Proper Vibration Isolation of Pump and Pipe Elbows

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Overlooked Vibration Isolation

Electrical Conduit — Should be in a flexible conduit in a half loop so there is real flexibility.

Piping — Should be a vibration isolated for a distance of 50’-0” from the rotating equipment, within the equipment room, or for the first 100 pipe diameters, whichever is largest. Don’t rely on so-called flex connectors they are never flexible enough and certainly not in all three degrees of freedom.

Don’t forget Thrust restraints!— This is particularly a problem for suspended fans and fans with seismic restraint. Without a thrust restraint the fan will move, tilt and short out the seismic restraints or the flexible connectors between the duct and the fan.
Overlooked Vibration Isolation

- Read through and refer often to the vibration isolation sections of the ASHRAE Guide Book.

- Many people have worked long and hard to present good information in a fairly accessible manner.

- Use it!
Vertical Heat Pumps

• Three basic configurations:
  – In a wall niche using manufacturer’s discharge plenum and standard return access door
Vertical Heat Pumps

– In a wall niche with ducted supply duct system and standard return access door

– In a closet with ducted supply duct system and with an attenuated return path
Vertical Heat Pumps

Chief problem that we’ve seen are specifying these units for medium or high speed to minimize the sizes of the units and save on first costs.

With the short discharge plenum in a standard unit there is insufficient time for the air flow to become uniform before reaching the diffuser.

This results in high air velocities, in excess of 1000 fpm at the top of the discharge diffuser. And 300 fpm or less at lower portion of the diffuser.

There used to be a benefit to all this fan air noise. It masked, or covered over the pure tones from the built-in compressor system. Manufacturers’ have gotten much better at isolating compressors and containing their noise.
In this photo we see how close the fan is to the discharge in a typical vertical heat pump unit.

Fan Location.

Compressor compartment and coils

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Vertical Heat Pumps

Fan Noise Control
We have found that the main cause of the excessive fan related noise is uneven flow distribution across the face of the discharge diffuser. Note that most of the air comes off the top of the fan. It takes at least two duct diameters for the air to even out to smooth flow. The primary cause is the short distance between the fan discharge and the louver opening. When air leaves a centrifugal fan the velocity profile is very uneven as shown in the Figure 1 below:

![Figure 1: Airflow at Fan Outlet](image)

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**Vertical Heat Pumps**

In the typical factory unit the discharge louver opening is much less than two duct diameters from the fan discharge. In addition in the units where the discharge is split between two rooms, the flow conditions are worse due to the location of the “vision shield” because the shield puts most of the air on one side when air needs to be split between two sides.

After two fan diameters the air has a more uniform flow, as shown here in Figure 2:

This permits a more uniform flow across the discharge diffuser reducing fan and air flow noise.

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**Figure 2: Smooth Even Flow After Two Fan Diameters**

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Vertical Heat Pumps

The second issue is the compressor noise emanating from the return inlet opening and maintenance access door.

Typically there is only a small overlap of the access door beyond the inlet air opening. Less than 1”. This doesn’t stop much of the 60 and 120 Hz tonal noise from the compressor.

With the newer R-410 Refrigerant units. The compressors operate at higher pressures and are more tonal at higher frequencies. This requires more attention to the inlet air details as well as internal vibration isolation of the compressor systems.

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**Vertical Heat Pumps**

It is a small premium to fix the non-uniform discharge condition. Merely Extending the Discharge Plenum to permit two fan diameters downstream of the fan does the trick.
**Vertical Heat Pumps**

The second area of additional noise control is the return air path / maintenance access doors. The typical door overlaps the inlet opening by ½” to 1”. While this limits pressure loss on the return side, it does little to stop the tonal noise.