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A Practical Guide to Noise and Vibration Control for HVAC Systems

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RP-526

A Practical Guide to Noise and Vibration Control for HVAC Systems

SECOND EDITION

Mark E. Schaffer



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Preface

Since the publication of the 1991 edition of this guide, building owners and managers have been paying more attention to occupant comfort, and municipal codes have become more attentive to property-to-property noise emissions. As a result, the HVAC community has become much more sensitive to the acoustical design of its products and systems. Many equipment manufacturers are producing quieter products and sometimes use the acoustical benefit as the primary marketing feature. Increased attention to product acoustical performance is evidenced by the fact that the number of HVAC acoustical testing laboratories has almost doubled since 1991. Also, increased internationalization has permitted access to low-noise HVAC products from Europe and Asia.

System designers are paying closer attention to the acoustical performance of the products and systems that they specify, and many building owners now require acoustical consultants on project design teams.

Unfortunately, not all industry changes have been for the quieter. Energy-efficient screw (rotary) compressors have been the source of many noise and vibration complaints, and the momentum to remove internal acoustical liner from ductwork, or to cover it with solid sheet metal in air-handling units and terminal boxes, has reduced the palette of noise reduction strategies that can be used in system designs. These and other factors increase the importance of *system* design in the form of more careful attention to vibration isolation and the airflow aerodynamics in air distribution systems. Therefore, the main theme of this guide has not changed over the past 14 years—that is, most HVAC system noise and vibration problems are *system* problems that are due to the improper selection, design, or installation of the components into a complete *system*. More careful attention to these factors will greatly reduce the number and severity of noise and vibration complaints.

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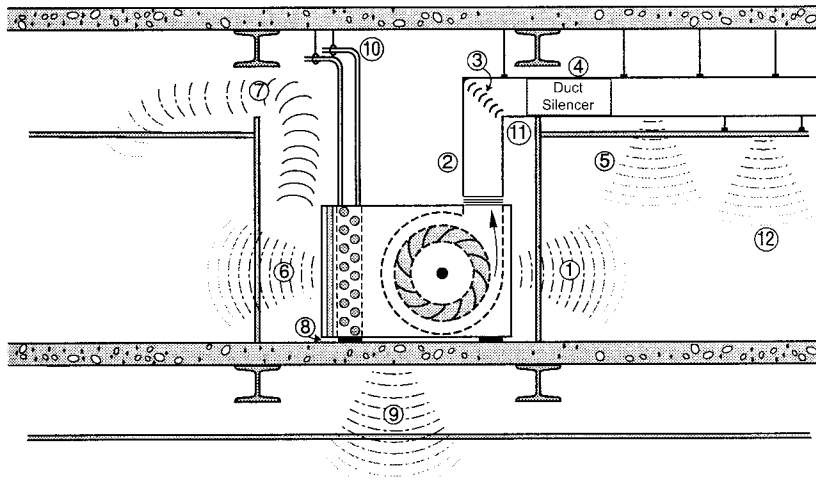
Introduction

Over the past few decades, building design teams have become more aware of the potential noise and vibration problems from HVAC systems. Mechanical engineers are specifying sound traps (duct silencers), acoustical louvers, sound-absorbing duct liners, and vibration isolators, while architects are designing mechanical room walls and slabs with high sound transmission class (STC) ratings. Despite the addition of these noise and vibration control features in more and more building designs, complaints of excessive HVAC system noise and vibration are still common. Investigations into these complaints by acoustical professionals have found that, in many cases, the correct equipment and materials were used, but they were not properly integrated into a *quiet system*, or some seemingly insignificant detail was omitted that negated the expected acoustical benefit.

A TYPICAL APPROACH

Figure A shows a typical air-handling unit (AHU) mechanical room in which some of the most common system-related acoustical faults are noted. Of the 12 faults noted, very few have to do with the specific equipment or materials used. Most of the faults are *system* related; that is, the individual components are not designed and installed as if they were part of a whole system. Airflow through the AHU/ductwork layout shown in the figure would generate excessive turbulence, noise, and rumble. The small mechanical room would have restricted airflow in places, resulting in locally turbulent airflow and unexpected noise and rumble in the tenant space. The vibration isolators would not perform as expected because they are resting on a flexible floor structure. The designers of this hypothetical system did not consider all of the *system (interactive)* effects of the various components and how they would control the amount of noise and vibration that enters the building's occupied spaces.

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1. AHU panel vibration "couples" to the lightweight, flexible gypsum wall just a few inches away. This coupling lets low frequency noise pass easily through the wall.
2. The counterclockwise rotation of the fan's discharge airstream is forced to change its spin direction at the downstream elbow. The turbulence generatred at the change can produce unstable flow with a very high, fluctuating pressure drop, thereby resulting in fan instability that is heard as rumble.
3. Problem 2 is aggravated if the elbow's turning vances do not have long trailing edges to straighten the airflow and control the turbulence.
4. The duct silencer is too close to the elbow. This compounds the turbulence problem.
5. Rectangular ductwork and duct silencers do not control the rumble produced by turbulent airflow.
6. The AHU's air inlet is too close to the wall. This causes two acoustical problems: unstable fan operation leading to surge and rumble, and direct exposure of the inlet noise to the mechanical room wall.
7. The lack of a duct silencer in a mechanical room return air opening allows fan noise to travel into the ceiling cavity, then through the lightweight acoustical ceiling into the occupied space.
8. The unit is resing on thin cork/neoprene isolation pads that are too stiff to adequately isolate the fan vibration.
9. The poorly isolated unit is resting on a relatively flexible floor slab without sufficient structural support. This arrangement allows unit vibration to enter the slab.
10. The chilled water piping is rigidly attached to the slab above, thereby letting unit vibration enter the slab.
11. Ductwall vibration in the duct silencer (or any other part of the trunk duct system) touching the drywall partition can cause the partition to act as a sounding board and radiate low frequency noise into the occupied space.
12. Suspending ceiling from supply duct causes ceiling to be a sound radiator.

Figure A Example of an air-handling unit room with several acoustical problems.

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A BETTER APPROACH

Correcting a noise or vibration problem usually costs much more than preventing one. The real costs include not only the direct payments to the retrofitting contractor but also the time required to coordinate the investigation and retrofit and the loss of goodwill from the complaining tenants. Therefore, in most cases the slight extra cost for prevention (usually about 1% to 2% of the total HVAC system cost) is money well spent.

Specifying quiet equipment and adding noise control materials to an HVAC system design are necessary initial steps of the design process. Calculations during the initial steps can be used to estimate the sound levels in a room or to select noise control materials to achieve a design goal. Comparing equipment sound data for competing products can help in the selection of quiet equipment. However, design decisions based on such work lose their value if the equipment and materials are not integrated into a properly designed *system* or if certain system detailing is ignored.

Figure B shows one version of a typical AHU room in which basic construction materials are integrated into a quiet system. The AHU and ductwork are selected and laid out for the best aerodynamics possible (this also reduces pressure drop and, therefore, fan horsepower). The AHU room is large enough for good aerodynamics in the room and for adequate clearance between the unit and the walls. The supporting structure has been stiffened with a housekeeping pad and beam to permit better vibration isolation.

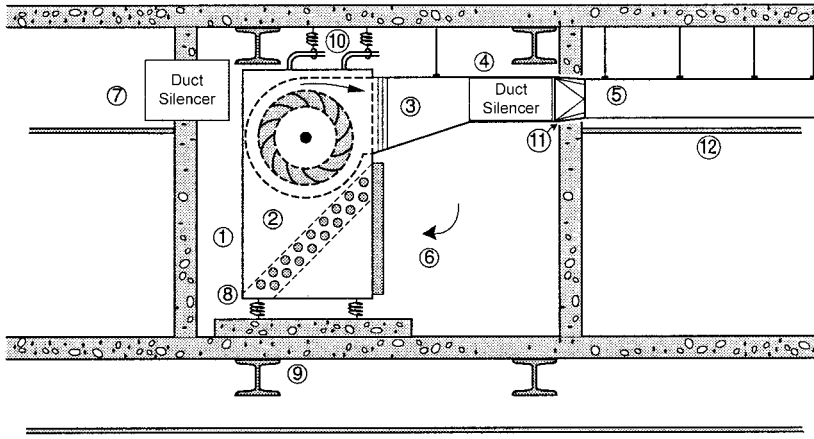
SUMMARY OF THIS GUIDE

This guide presents information that will help engineers, architects, contractors, and others with little acoustical experience to develop project designs that avoid the kinds of problems shown in Figure A. Chapter 1 includes general noise control design guidelines to be addressed during the various design phases and includes some information on the architectural and structural aspects of HVAC system design. Chapter 2 addresses the selection and use of airside system components. Chapter 3 looks at the selection and use of waterside and central plant equipment.

Packaged and unitary equipment are addressed in Chapter 4. Guidelines for selecting and using vibration isolation systems are included in Chapter 5. Sample specifications for acoustical materials and the acoustical performance of HVAC equipment are given in Chapter 6, along with some examples of poorly written specifications. Reviewing submittals and making site inspections are addressed in Chapter 7. Chapter 8 gives suggestions for troubleshooting HVAC noise and vibration complaints.

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The appendices present background information, including some basics of HVAC system acoustics, the use of criteria and manufacturer's published sound data, and how to make sound level measurements. Appendices with definitions of acoustical terminology, abbreviations, and addresses of relevant agencies and associations are also included.



1. Keeping a minimum 2 ft clearance reduces coupling between AHU and wall. Masonry wall provides excellent low frequency sound isolation.
2. Use of a horizontal discharge AHU eliminates the need for a turbulence-producing airflow.
3. Gradual transition at AHU outlet minimizes turbulence.
4. Duct silencer is far enough away from AHU outlet to avoid excessive regenerated noise and turbulence.
5. Circular ductwork controls the transmission of low frequency noise and rumble into the occupied space.
6. The large clearance at the AHU inlet keeps the unit away from the wall and avoids excessive inlet turbulence.
7. The return air duct silencer controls AHU noise via the return air path.
8. The unit is resting on high-deflection, steel spring vibration isolators.
9. The floor assembly supporting the unit has a housekeeping pad and at least one major beam under the unit. Additional stiffness and mass help to control the transmission of unit vibration into the slab.
10. The chilled water pipes are suspended by vibration isolation hangers.
11. The supply trunk duct does not touch the wall. A 1/2 in. gap surrounding the duct is filled with a non-hardening sealant.
12. Ceiling not suspended from supply duct.

Figure B Example of an air-handling unit room with optimal acoustical features.