Sprinkler System Design Considerations

A review of the basics

By CRAIG STUDER, PE, CIPE
Operations Manager
Fire Protection Management Inc.

There are several aspects that must be addressed in the design of a sprinkler system. Some are obvious; some are not, so it's essential that all the right questions be asked and answered before beginning a basic system design.

WHAT IS MOST IMPORTANT? COST OR...

You, as the design engineer, have to answer this fundamental question some time during the design process. Normally, the earlier you can answer it, the less you need to alter the design.

If cost is most important, you may be looking at using Schedule 5 or Schedule 7 pipe, which is thinner and lighter than Schedule 40, and is easier to handle, and less costly. There are also alternate joining methods that have been developed for lighter-schedule pipes, in lieu of threaded or grooved fittings. You may also want to use pendent sprinklers with adjustable escutcheons, which are less expensive than concealed or recessed pendent sprinklers. Sometimes, you can save money by running the piping exposed, if aesthetics is not a factor. You will also want to maximize sprinkler spacing.

The downside to this approach is you may be sacrificing system longevity, aesthetics, and flexibility.

Flexibility may be an important factor. Some companies will relocate personnel and functions and increase or decrease the size of departments. The sprinkler system design may need to be "modular" to allow the relocation of walls to accommodate company changes without significantly changing the sprinkler system.Whatever it is, you need to identify the important aspects that will drive the type of sprinkler system you design. Once you have done that, you can proceed with all the other issues that will affect your design.

Craig Studer, PE, CIPE, is the operations manager for the Chicago office of Fire Protection Management Inc. (FPM). He has more than 34 years of experience in the design, installation, and maintenance of fire-protection systems, and is a member of NFPA 13. To learn more about FPM visit its website at www.rjagroup.com.

Although an atrium can present its own set of design issues due to height and possible smoke migration, the contents of this atrium illustrate a light-hazard condition.

WHAT IS BEING PROTECTED?

Before you can proceed, you need to determine the types of occupancies that the system is to protect. Occupancies such as offices typically have less concentrated amounts of combustible material than, say, a paint shop or even a library. NFPA 13, *Standard for the Installation of Sprinkler Systems*, provides hazard classifications that should be assigned for each type of occupancy. These vary from "Light Hazard" (light fuel load, minimal storage) to "Extra Hazard, Group 2" (areas with flammable liquids, and airborne combustible dust).

Each hazard classification has a corresponding minimum water density the sprinkler system must produce. Our sprinkler system water supply requirements will be based on what we determine to be the most hydraulically demanding area of the building.

IS YOUR WATER SUPPLY ADEQUATE?

NFPA 13 limits the use of pipe schedule systems, typically requiring the designer to hydraulically calculate the sprinkler system based on a minimum flow rate and pressure

The conditions in both warehouses pictured on this page demonstrate a potential hazard. There is a large quantity of combustible material concentrated together, both in height and area, providing a substantial fuel load in the event of a fire.

at the most remote sprinkler, plus pressure loss due to friction and elevation difference from the remote area of the sprinkler system to the source of the water supply. Calculating sprinkler-system demand is similar to calculating air-supply systems, gas-piping systems, or other fluids.

Every sprinkler system must have an adequate water supply to allow the sprinkler system to perform properly. If there is a municipal water supply, it must have both an adequate flow rate, as well as adequate pressure to handle the calculated sprinkler-system demand. The designer must obtain current water-supply information to determine its compatibility with the design water supply.

If the municipal water supply is not very robust, the designer may be able to adjust the design pipe configuration or sizing to better accommodate the available water supply. If the municipal water supply is still not adequate, a fire pump may need to be added to provide additional pressure, and a storage tank may need to be added to provide enough water.

The height of your building also will affect the adequacy of your water supply. Sprinkler systems for high-rise buildings are the same as those used for single story buildings. But the challenge between the two buildings is getting an adequate supply of water with the proper pressure to the top floor of the high-rise building. Most municipal water supplies have sufficient pressures to serve only two or three floors of a multi-story building. After that, a fire pump would need to be added for additional pressure.

If a fire pump is included, the designer must verify that system pressures do not exceed 175 psi, normally the maximum pressure allowed on sprinkler system components. If pressures do exceed 175 psi, the designer must either provide pressure-reducing valves or provide heavy-duty fittings, valves and special high-pressure sprinklers whose rating exceed the system pressures. As an alternative option, the designer may provide a multi-zone pumping arrangement so that either zone has less than 175 psi maximum pressure.

OTHER CONDITIONS TO ACCOUNT FOR

Designers also must be aware of special conditions that could affect the design. One condition is seismic zones severe enough to require special bracing. Another condition is occupancies that are mandated to have quick-response sprinklers by the Life Safety Code or local code. Hospitals and nursing homes are examples of this condition.

Environmental or process conditions may also require special equipment. Sprinkler systems subject to freezing (either due to climactic conditions or processes similar to cold storage warehousing) will require a dry pipe sprinkler system. This type of system consists of empty sprinkler piping charged with compressed air and provided with standard upright or pendent sprinklers. The piping is connected to a dry pipe valve, which releases water into the system if one of the sprinklers fuses (activates).

Many computer personnel are wary of installing standard wet pipe sprinkler systems in computer rooms due to the perceived possibility of an accidental sprinkler activation, or a legitimate activation, which would likely damage sophisticated and costly electronic equipment, and result in lost data and downtime. For these instances, a pre-action sprinkler system can be substituted, either by itself or in conjunction with a gaseous suppression system. A pre-action sprinkler system is similar to a dry-pipe sprinkler system in that it is empty. The pre-action valve, however, does not release water into the system if a sprinkler fuses. The valve must be released by activation of a smoke or heat detection system.

Other occupancies may also require special equipment. Warehouses with rack storage may require in-rack sprinklers or early suppression, fast response (ESFR)) sprinklers with high-density discharges.

ALARMS

Virtually every sprinkler system must provide an alarm when it activates. The designer must determine whether this will be accomplished by providing flow switches connected to a new or existing fire alarm system, by providing an alarm check valve with water motor gong for local alarm, or by electronic activation. Local code requirements and the type of project will likely dictate the alarm method and whether the alarms must be received at the local fire department.

A WORD ABOUT MAINTENANCE

While designing the sprinkler system, the designer must remember that someone will eventually have to maintain the system. Too many times, valves are designed to be installed in areas difficult to reach; or inspector's test connections are located where test water cannot be easily drained away. Sprinkler system equipment must be inspected, tested, and maintained on a regular basis, just like any other building system. The designer needs to take location and accessibility into account during the design.

VAV Diffusers: Issues of Design

Important design considerations for new construction and retrofits

By **EDWARD BARBIERI, PE**
Senior Vice President
Cosentini Associates

VAV diffusers are air diffusers with VAV dampers. Design with VAV diffusers is commonly considered instead of VAV boxes because of their enhanced air-distribution characteristics at low flows, as well as their increased zone-control capabilities. In evaluating construction costs, we find that we get up to five times the number of zones (where integral thermostats are used) at a total installed cost competitive with one VAV box zone. Additional benefits include ease of reconfiguration and minimal maintenance. Some types of VAV diffusers require either wall-mounted room thermostats or they can be provided with integral thermostats built into the diffuser. Thermostats can be either electrically or thermally powered. Space temperature control is accomplished by sensing temperature at a location near to the diffuser.

Our firm has used thermally powered VAV diffusers regularly for over 15 years. We specify them for both retrofit and new construction. Examples of new construction projects include a large animation studio in Burbank, Calif., and a large auction house headquarters in New York City. Retrofit projects include numerous financial, publishing and education facilities. In such projects, there are several important design considerations including diffuser selection, system supply air temperature, and system static pressure.

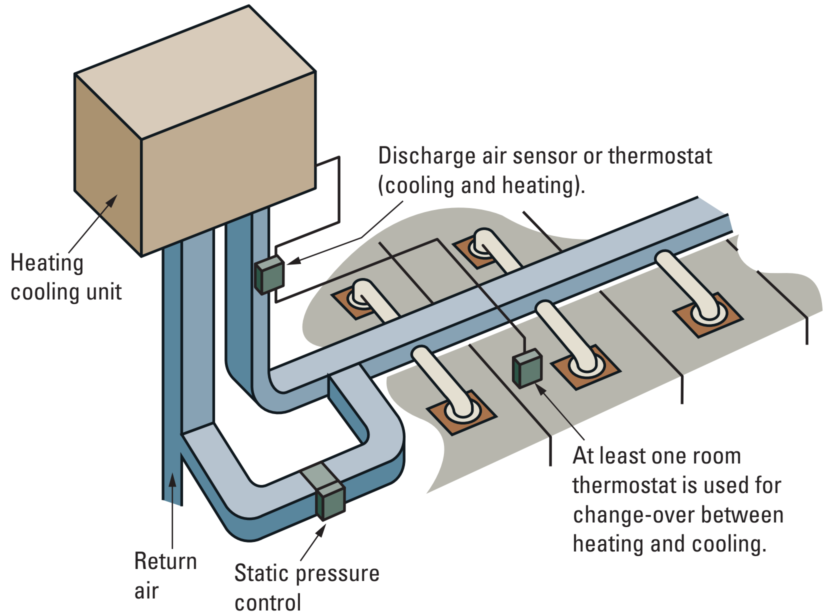

FIGURE 1. Supply-air temperature control

DIFFUSER SELECTION

VAV diffusers should be designed for the maximum air volume required using the manufacturer's published performance guide. A larger inlet size should be considered with lower static pressure availability, or when lower sound or NC levels are required. VAV diffusers cannot be oversized. They will simply turn down air flow to match the space load. Unlike the fixed diffusers with VAV boxes, variable-opening VAV diffusers will not dump with reduced air flow.

VAV diffuser placement design is the same as standard diffuser placement. Spacing is determined by the largest air volume and throw expected, usually the maximum cooling volume. Most guidelines suggest placing diffusers so that the 50-to-100 fpm velocity contour just reaches the wall, with the maximum velocity at the wall being 150 fpm.

Standard guidelines should also be followed when putting multiple diffusers in the same room. When possible, the diffusers should be no closer together than twice the throw at the 150 fpm level. Ideally, they should be located at somewhere twice the 50 fpm and 100 fpm levels.

SUPPLY AIR TEMPERATURE

VAV diffusers control air volume. During times of the year with cold outdoor temperatures, heating may be required in portions of the building and cooling in others. Therefore, it is necessary to design the system with separate capabilities of heating and cooling on each building exposure, as well as the building interior. This can be accomplished with a single air-handling unit with building perimeter heat (such as radiation) for colder climates or duct-mounted perimeter-zone heating for milder climates.

Two supply air temperature goals for VAV systems are to provide a nearly constant supply air temperature and to limit the supply air temperature. The cooling air supply temperature low limit is usually 50 F. The heating supply temperature should be high enough to cause the VAV diffusers to change over into the heating mode, usually 80 F, and for reduced stratification the limit should be no higher than necessary to satisfy the design load. These supply-air goals are best satisfied by using supply-air temperature sensors to control the sources of cooling and heating.

Systems with duct heat coils will need heating and cooling changeover capabilities. This can be simply done with control from a

Edward Barbieri, PE, is senior vice president of Cosentini Associates and is responsible for design and project management for a wide variety of projects, including data centers, co-location and related mission-critical facilities,corporate headquarters, and tenant interiors. Mr. Barbieri has been with Cosentini since 1984. He holds a Bachelor's degree in mechanical engineering from the Polytechnic Institute of New York, is a licensed professional engineer in the state of New York, and is a member of ASHRAE.

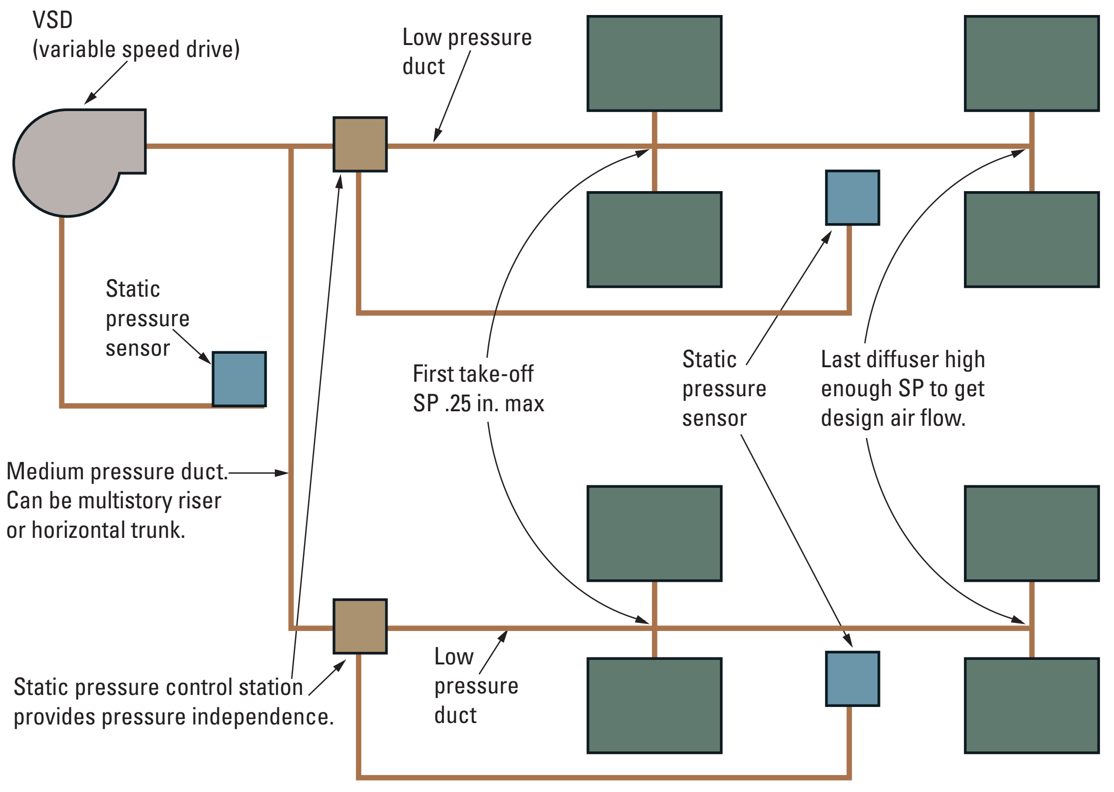

FIGURE 2. Static-pressure control

room sensor or thermostat. Where temperature control zones are provided with multiple sensors for temperature monitoring, control logic can be applied to determine heating or cooling priority by utilizing either a majority rule or cooling dominant (heat only when there is not a call for cooling) approach. Diffusers with VAV heating are necessary in these systems to avoid overheating.

STATIC PRESSURE

VAV diffusers, like most diffusers, get noisy (NC-35) above .25 in. WG static pressure. Design objectives include limiting static pressure to .25 in. WG at both full flow and turndown, while providing high enough static pressure at the last diffuser for design air flow. Pressure independence must also be designed into the system.

While a low-pressure ductwork distribution system is preferred, as a practical matter most of our larger jobs use medium pressure trunks or risers due to space constraints. Static-pressure stations are used to reduce static pressure and to provide pressure independence. Static-pressure stations consist of a damper, actuator, controller, and transducer package. The transducer is connected to a static pressure sensor located ⅔ to ¾ of the way downstream between the first and last diffusers. For constant-volume fan systems, the static-pressure stations could also be a bypass damper controlled from downstream static pressure (Figure 1). Variable-air volume fan systems should incorporate a variable-speed drive at the fan. This is essential for for proper central-fan static pressure control (Figure 2).

Proper duct design is critical to insure low pressure drop, and, as a result, reduced noise and energy consumption. The ducts downstream of the first takeoff on each low-pressure leg must be designed for a pressure drop that is the difference between .25 -in.-WG static pressure at the first takeoff and the static pressure required for design air volume at the last diffuser. If the last diffuser requires .15- in.-WG static pressure, the pressure drop downstream from the first takeoff should not exceed .10-in. WG. If this duct length is 100 equivalent ft, the duct can be sized for .10-in WG per 100 ft, however it is desirable to design as low as .04-in. WG per 100 ft. to insure a quiet system in longer runs. It is also acceptable to consider designs with higher pressure drops in the upstream portion of the duct run to reduce duct size and compensate with lower pressure drops and larger ducts in the downstream portion so that the overall pressure drop remains the same.

While a low-pressure ductwork distribution system is preferred, as a practical matter most of our larger jobs use medium pressure trunks or constraints.

CONCLUSION

Over the years, we have designed many successful jobs with VAV diffusers by applying the fundamentals described for selection, system supply-air control, and system static pressure control. If you would like more design information, refer to the design manuals provided by VAV diffuser manufacturers.

Designing without noise

Steps to mitigate a potential noise problem

By **ROBERT W. TINSLEY, PE, CFPS**
P2RS Group Inc.

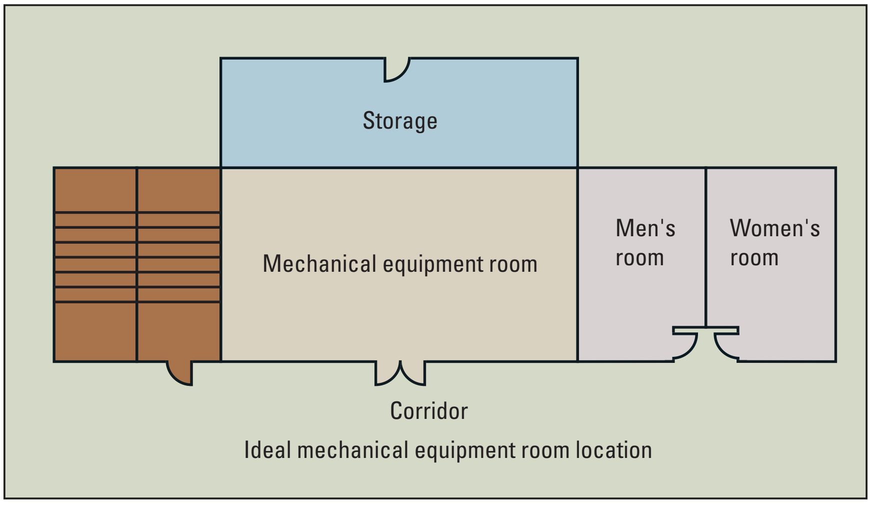

FIGURE 1. Using non-critical areas as sound buffers.

Back in the days of my adolescence, my parents would occasionally complain about my choice of music. I would reply, usually with unwarranted arrogance, "One man's noise is another man's music." Unfortunately, this saying doesn't apply to HVAC noise. Unless, of course, you're an acoustical consultant called in to fix a noisy building.

Fortunately, ASHRAE provides enough information to allow a designer to keep the acoustical consultants at bay in most applications, at least until your pristine drawings start getting translated into the real world. Don't get me wrong! Acoustical consultants are fine, useful people, particularly when designing performing arts centers and recording studios. I even have some friends who are acoustical consultants. But for most applications, a little common sense and ASHRAE are enough to keep you out of hot water.

SOME BASICS

There are six related issues regarding noise in HVAC systems: airborne equipment noise, equipment vibration, duct-borne fan noise, duct breakout noise, flow-generated noise, and duct-borne crosstalk.[1] Common sense is a big help in controlling noise. For instance, keep noisy equipment far away from sensitive areas such as offices, conference rooms and classrooms, and make the equipment room walls as heavy as possible, taking them up all the way to the deck above. Most architects are sensitive to this, locating equipment rooms such that non-critical areas such as stairwells, restrooms, storage rooms, and other similar rooms buffer them (Figure 1) Locate things such as VAV boxes, in-line fans and high-velocity ductwork over corridors, not over the rooms they serve.

Select fans on the right side of the fan curve, well away from the stall region. The closer to peak efficiency you select, the quieter the fan. On smaller fans, such as exhaust fans and in-line fans, go for lower rpm and larger outlet areas to keep them quiet.

Isolate all rotating equipment from the building structure. Provide vibration isolators: spring-type on larger-horsepower motors and neoprene on the smaller ones. And don't forget flexible connections: canvas or elastomeric fabric as the duct connection to a fan. On pumps, I prefer to use the rubber or neoprene sphere-type isolators between the pump and piping. I have had the braided-metallic and metallic-bellow types transmit high-frequency whines into the piping.

Duct conditions at the fan outlet comprise another family of noise-avoidance opportunities. Don't try to bend the air the "wrong" way. Don't make abrupt transitions. Keep all transitions at least three fan-diameters downstream of the fan outlet. Both ASHRAE and AMCA Publication 402 are chock-a-block with illustrations of the right and wrong ways of fan ducting.

These are all things that everyone knows and does all the time. There are other things that can be done that aren't so obvious or well known or have a certain controversy attached to them.

FIBERGLASS DUCT LINER

Fiberglass duct liner is one of the cheapest, most effective ways of providing sound attenuation in an HVAC system.[2] The most common application is downstream of VAV boxes and fans and in short return duct runs. Situations where crosstalk can occur, such as where there are short, direct runs of ductwork between rooms, are another good application. It has been documented in ASHRAE literature and elsewhere that sheet-metal ductwork lined with 1-in. acoustical liner will show a duct-noise attenuation reduction of 5.3 dB per foot of length in the 1,000 Hz octave band and 4.8 in the 2,000 Hz octave band.[3]

While 1-in.-thick acoustical liner works well with the higher frequencies, it doesn't do much for you in the lower frequencies. If you are expecting rumble from fans or regenerated noise, you'll have to go to 2-in. or 4-in. thickness.

Lined elbows are particularly effective. A lined elbow can have the same acoustical effect as 2 to 8 ft of straight lined duct or 100 ft of unlined duct.

Health issues with fiberglass continue to be an issue. Airborne fiberglass fibers have been shown to be non-carcinogenic. However, one study has indicated that when fiberglass has been improperly installed or maintained, some people complain of skin irritation and occasional respiratory-tract irritation.[4] I use duct liner all the time

Robert Tinsley, PE, CFPS, is with the P2RS Group in Colorado Springs, Colo. Some of his projects include Sun Microsystems, Broomfield, Colo.; Embassy Suites Hotel, Denver, Colo.; and the American Numismatic Association Museum, Colorado Springs, Colo. He can be reached at btinsley@p2rscos.com.

without problems unless I am specifically asked not to. Some institutions, such as hospitals, consider the possibility of having airborne fiberglass fibers in their facilities not worth the potential risk and thus will not allow the use of fiberglass duct liner. He who pays the piper calls the tune. There are some steps that can be taken to mitigate this perceived danger.In low-to medium-velocity systems, fiber erosion can be minimized by specifying a liner with an acrylic surface treatment and factory-applied edge coating. Fabrication cuts and handling damage may be repaired with proprietary sealers. In high-velocity systems, double-wall ductwork with a perforated metal interior should be specified. In any lined ductwork system, humidity control is essential. The manufacturer may have treated the duct liner surface with a biocide, but the core will eventually suffer the effects of moisture damage.

DUCT CHASES AND SHAFTS

Duct chases and shafts are often sources of rumble and air noise. The first course of action goes back to our old friend, common sense. Locate the things so restrooms, storage rooms, and corridors surround them.

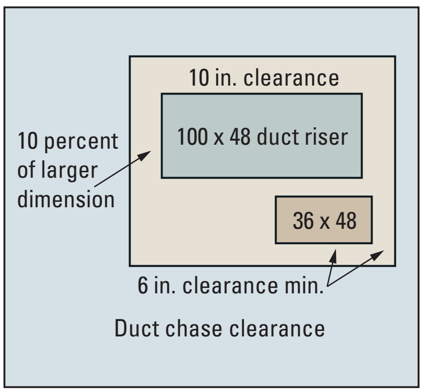

FIGURE 2. Keep ducts clear of chase walls.

Once you've done that, take a close look at the size of the chase. Keep the ducts away from the sides of the chase. Ducts should be located so that they are clear of the chase walls by 10 percent of the larger dimension or a minimum of 6 in., whichever is greater (Figure 2). Any closer than this and vibrations in the duct could be transmitted through the air to the chase walls and thus to the surrounding space.[5]

Return-air shafts that contain supply-air ductwork need special attention. Velocities in the chase should be held below 1,000 fpm. This doesn't mean that you subtract the area of the supply riser and size the remainder of the shaft for 1,000 fpm or less. You have to consider the size of your largest supply-air takeoffs. Don't take the section through the riser; take it through the supply-air takeoffs (Figure 3) and size the remainder of the shaft at less than 1,000 fpm.[5]

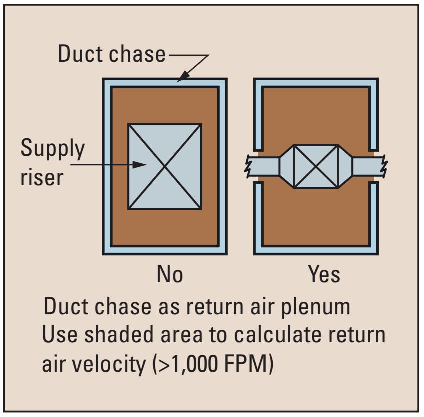

FIGURE 3. Calculating chase area.

REGENERATED NOISE

Velocity equals noise whether in ducts or pipes. Regenerated noise is caused by turbulence when medium- to high-velocity air impinges on obstacles such as dampers, turning vanes, elbows, and even sound traps. It can also occur at abrupt duct transitions. As far as noise in ductwork is concerned, 2,000 fpm to 3,000 fpm is medium velocity, while 3,000 fpm and up is high velocity.

Regenerated noise, usually a low-frequency rumble that breaks out of the ductwork, is one of the most difficult types of noise to deal with after construction is complete, thus it's most important to try to eliminate it during design. The easiest way to eliminate regenerated noise is to keep velocities below 1,800 fpm. If you must use medium- to high-velocity air, strictly follow SMACNA duct design and construction standards and choose fittings with the lowest possible pressure drop.

If you know that there will be some places where it will be impossible to follow good design practice to the letter, there are still some things you can do to head off trouble at the pass.

Mass is the best attenuator for low-frequency sound, so anything you can do to increase the mass of the ductwork in a problematic area will help.[6] The SMACNA-recommended gauges for sheet-metal ductwork are about the lightest available you can use without popping the duct apart. If you know you have to have an abrupt transition, call for the following 10 to 20 ft of ductwork to be a couple of gauges heavier than what SMACNA recommends for that size. Then apply some external angle bracing and internal liner. This kind of treatment won't increase the cost of the job significantly—as long as you keep it to a minimum.

DIFFUSER NOISE

The last line against objectionable noise is in and above the room itself. In our case, that means the air devices. As a good designer, you should have a target number for the NC rating of the room you are designing. If you have a classroom where your target NC is 30 with four diffusers, don't pick a diffuser with an NC of 30! Diffuser manufacturers rate their products with the idea that there will only be one diffuser in a room, no other noise sources exist, and the listener isn't close to the diffuser. Diffuser noise is additive with other diffusers, any breakout noise from the duct, and any other noise source in the room.

A good rule of thumb for one diffuser in a room is to select it at a NC 3 dB lower than the room NC. For two diffusers select them at a NC 6 dB lower. In our example classroom with four diffusers, select them at a 21 NC, 9 dB lower than the room criteria. Every time you double the number of diffusers, lower the selection NC by 3 dB.[7]

Three other things you can do to reduce diffuser noise are keeping the balancing damper as far from the diffuser as possible (back at the takeoff from the main duct is best), use 4-to-6 ft of acoustical flex duct as opposed to regular flex, and keep the flex duct straight for at least three duct diameters back from the diffuser. That last point is often hard to achieve in the field, but if it is not, it can increase the noise by as much as 10 to15 dB, depending on the location of the bend and the angle.[7]

REFERENCES

1) Yerges, J.F. and J.R. Yerges. October 1997. "Noise and vibration control for HVAC and piping systems." *HPAC Engineering*.

2) Tinsley, R.W. May 1998. "Duct liner: problem or solution?" *HPAC Engineering*.

3) ASHRAE. 1999. Handbook, Applications. ASHRAE, Atlanta, GA.

4) Horvath, E.P. 1995. "Health effects of man-made mineral fibers." *Cleveland Clinic Journal of Medicine.*

5) Schaffer, M.E. 1991. *A practical guide to noise and vibration control for HVAC systems*. ASHRAE, Atlanta, GA.

6) Cerami, V.J. March 1996. "HVAC equipment and noise." *HPAC Engineering*.

7) Lilly, J. G. February, 2000. "Understanding the problem; noise in the classroom." *ASHRAE Journal*.