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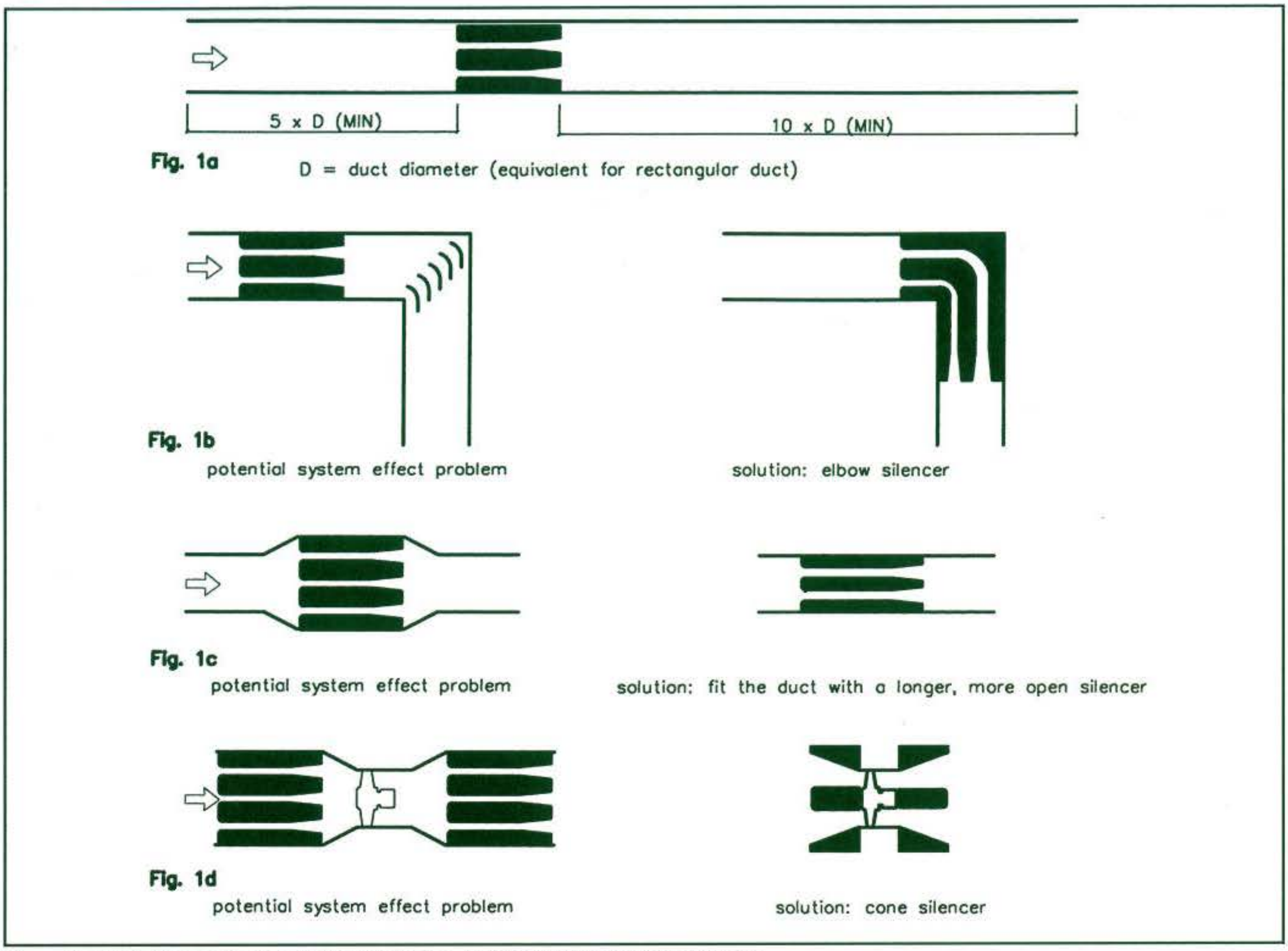

Figure 1: Ideal silencer test configuration and commonly found installations.

Duct Silencer Aerodynamic System Effects

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When a duct silencer is inserted into a typical system, the pressure drop and resulting energy consumption of the system increases by an amount greater than the silencer's ideal aerodynamic performance rating. Similar to system effects from fans and other duct components, this increase can be quite substantial — even several times the silencer rated pressure drop. The aerodynamic system effect depends upon the internal geometry of the silencer, the geometry of the duct system, and the installation condition itself.

Duct Silencer Ratings

It is essential to understand the ideal conditions under which silencers are tested. The applicable test standard, ASTM E477-99, requires five diameters of straight duct upstream of the silencer and 10 diameters downstream as shown in *Figure 1a.* The former ensures a well-established uniform airflow profile into the silencer and the latter provides adequate length following the silencer to achieve as much static pressure recovery as possible.

This laboratory test method is used to produce a catalog performance rating, and offers the direct comparison of silencer products. Further, the ratings derived from these ideal test conditions used for their specification in contract documents. However, designers must remember that the silencer pressure drop in this ideal duct system is commonly lower than in real-life duct system installations.

To estimate total duct system energy losses, aerodynamic system effects must be added to the silencer catalog pressure drop rating. These system effects result from the increased unsteady, non-uniform airflow profiles commonly present in lengths of duct that include bends, transitions and branches.

Fitting Silencers Into Duct Systems

Installing silencers too close to duct fittings such as elbows and transitions, and too close to fan inlets and discharges, are the most common sources of system effect problems. The ASHRAE publication, *A Practical Guide to Noise and Vibration Control for HVAC Systems,* provides guidelines to minimize silencer system effects. They include minimum spacing requirements between the silencer and the elbow fitting, and maximum allowable converging and diverging angles for transitions. Often these guidelines are difficult or even impossible to achieve. For example, space constraints may force the system designer to use multiple bends closely spaced or large angle transitions and offsets, leaving insufficient lengths of straight duct in which to locate a silencer.

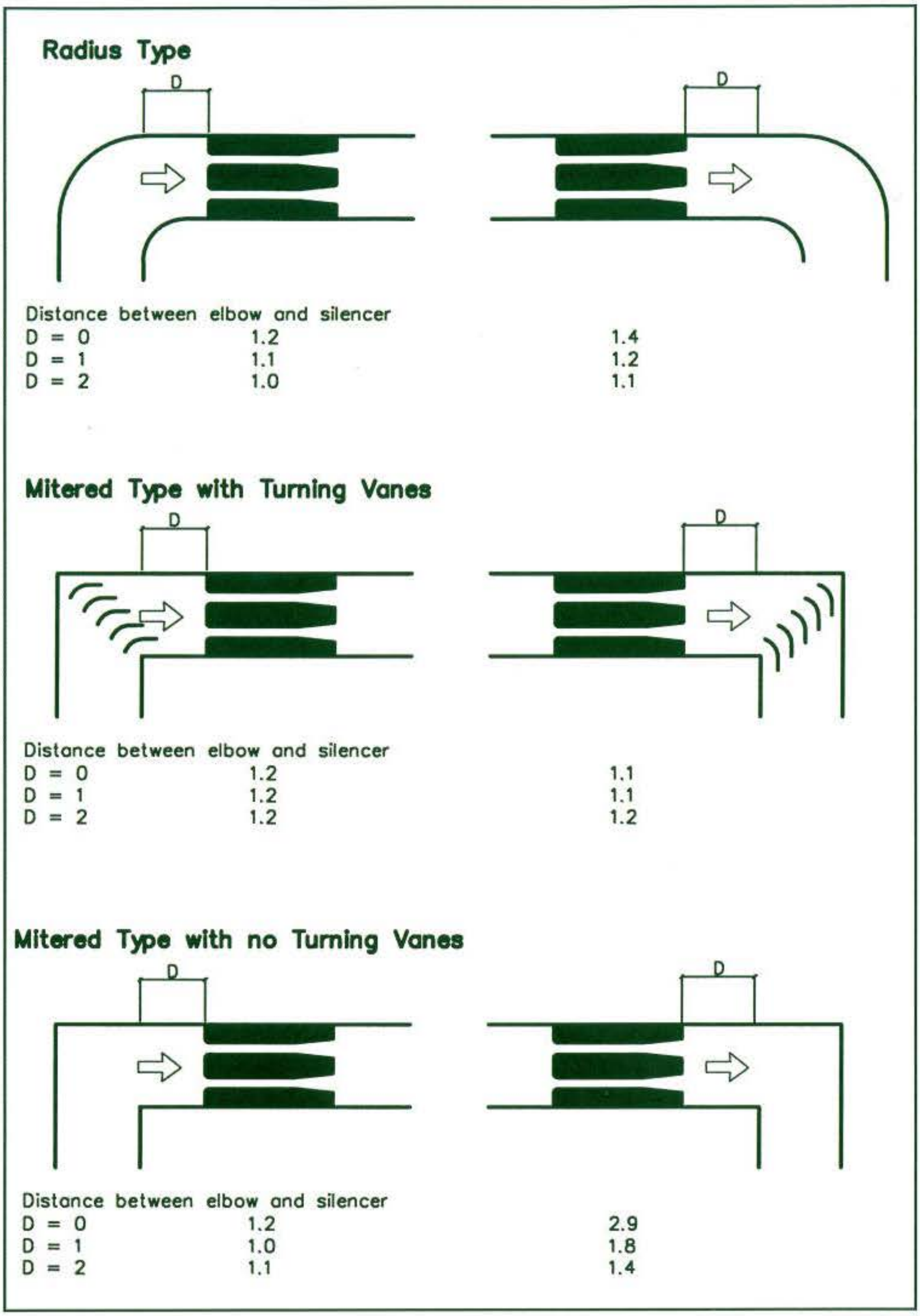

Figure 2: Inlet and outlet system effect factors for various elbow duct installations

However, silencers built into fittings can reduce or even eliminate system effects. Selecting elbow silencers when there is insufficient straight length of duct, as per the ASHRAE publication, is an excellent example of a practical solution. Elbow silencers effectively attenuate noise with splitters that aerodynamically turn the air to produce less pressure drop than a straight silencer installed in close proximity to an elbow duct fitting, as shown in *Figure 1b.*

To obtain lower pressure drops, engineers occasionally select larger silencers having duct connection sizes considerably greater than duct system sizes. This results in a theoretically lower air velocity at the silencer. However, for this type of selection, there is usually insufficient space to stay within the ASHRAE maximum transition angle guidelines (7.5° to 15° per side). In such cases, the connecting transitions introduce excessive turbulent effects due to velocity and momentum changes over a relatively short distance. These are created by a sudden expansion just before the silencer, a contraction into the air passages of the silencer, an expansion discharging the silencer, and finally a contraction back to the system duct size.

A more ideal design, yielding a lower pressure drop for the same acoustic performance, is the selection of longer silencers that have slightly larger air gaps and

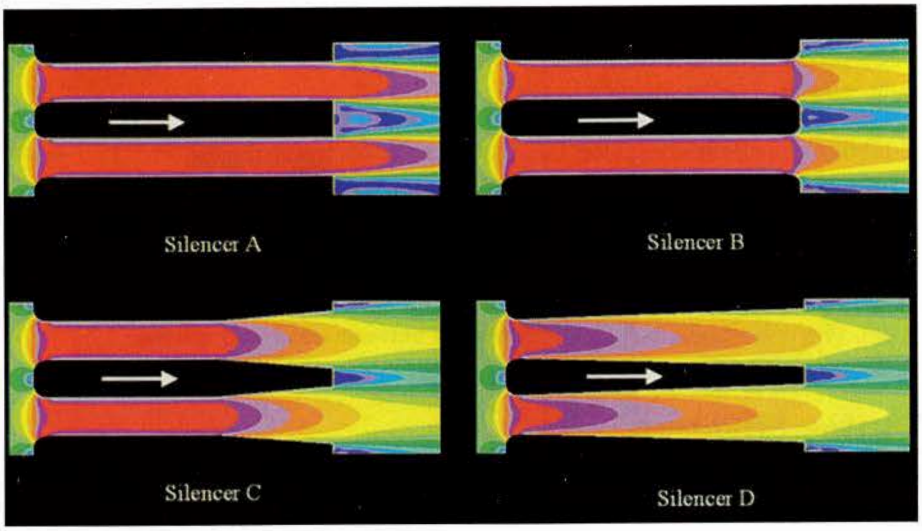

Figure 3: Silencer D has the lowest and Silencer A has the highest outlet velocity for identical airflow capacities and pressure drops, as shown in the velocity contour plots generated using computational fluid dynamics.

match the duct system sizes. As shown in *Figure 1c,* they effectively use the length of duct no longer required for the transitions, while avoiding the adverse system effects.

Silencers installed at duct entrances and duct endings are less frequent examples of system effects. Adding flanges or curvatures to standard silencer inlets for the former and static pressure regain devices to the outlets for the latter, are both effective methods of reducing system effect energy losses.

Fan-Silencer Systems

A complex system case is the direct connection of a silencer to a fan when it is beneficial to contain the noise at the source. This introduces a compounding of fan and silencer system effects that alter the performance of each individually.

Special designs of fan inlet and discharge silencers that minimize aerodynamic system effects include axial fan cone silencers (*Figure 1d*) and inlet box silencers for centrifugal fans. In some cases, if a silencer is carefully designed and applied, it can actually improve airflow conditions at the fan. For optimum results and/or accurate performance ratings, fan-silencer testing as systems are often required.

Quantifying System Effects

The current *ASHRAE Handbook — HVAC Applications* recommends that silencer pressure drops, including system effects, not exceed 87 Pa (0.35 in.w.g.),which may avoid installation problems. Good design based on value engineering and energy conservation should set a maximum at 62 Pa (0.25 in.w.g.) or lower. On some installations, it is economically feasible to achieve less than 25 Pa (0.10 in.w.g.) for both silencer and system effect.

The ASHRAE publication, *Application of Manufacturers' Sound Data,* provides approximate silencer system effect factors. Some common elbow duct fitting factors are given in *Figure 2.* They are applied to the silencers' ideal pressure drop data (catalog data) to predict the resulting silencer pressure losses including system interactions (i.e., Silencer Pressure Drop with System Effects = Inlet System Effect Factor × Outlet System Effect Factor × Silencer Catalog Pressure Drop).

This approach is based upon average silencer internal designs, and does not take into account the silencer's effect on the system. For example, the silencer discharge velocity depends upon the air passage profile. If a static pressure regain device is built into the silencer's discharge side, the system effect will be reduced. Some typical internal silencer designs are shown in *Figure 3.* Therefore, a more exact determination of system effects will depend upon the actual internal design of the silencer selected and the details of the ducted system. Where greater accuracy is needed, consult the silencer manufacturer that has accumulated physical test data. For extremely critical installations, actual mock-up tests may be very beneficial.

In conclusion, many duct systems consume more energy and have less airflow capacity than predicted. A few have serious aerodynamic and generated noise problems. To avoid problems, it is essential to be constantly aware of potentially excessive system effects from all duct system components including fans, duct fittings, and silencers. Do not compromise the best system design by using the lowest first-cost silencing package. Instead, select and specify silencers that best fit your duct systems for lowest energy consumption. Specify the ideal performance rating as tested in accordance with ASTM E477-99. Finally, pressure drops from system effects must be included in duct system calculations to ensure design airflow capacities are achieved.