

# Efficiency In The Round

Originally published in October 2015 issue of Engineered Systems

According to a study conducted by Lawrence Berkeley National Laboratory for the Department of Energy (DOE), duct leakage is the leading cause of energy inefficiencies in commercial buildings. On average, duct leakage wastes 28.6 billion kw-hrs of electricity per year and costs U.S. building owners nearly \$3 billion annually. These startling statistics make it imperative that duct systems move air to every VAV box quietly and efficiently to reduce energy consumption and leakage rates.

One of the best ways to reduce duct leakage and improve energy efficiency in VAV systems is to move from rectangular ductwork to spiral round — sometimes referred to as spiral — ductwork. In addition, ASHRAE guidelines continue to drive the industry towards spiral round ductwork because:

- Spiral round ductwork can be designed to operate more efficiently and quieter than rectangular ductwork.
- Static regain computer modeling can help design a more balanced system using spiral round duct, which has the ability to deliver air to every VAV box quietly.
- Dampers, which cause noise and waste fan energy, are frequently used in rectangular ductwork. These dampers can be eliminated in a static regain spiral round duct system.
- Spiral round ductwork requires significantly less duct sealing than rectangular ductwork, which reduces duct leakage and helps reduce the installed cost of the ductwork.

Based on these specification guidelines, spiral round ductwork is rapidly gaining popularity in the HVAC industry.

## Static Regain

In order to deliver air to every VAV box quietly and efficiently, it is ideal to have a system that provides just enough static pressure to the most demanding VAV box and no more. Spiral round ductwork systems designed using a static regain duct design can help do just that.

Understanding how static regain works starts with the fundamentals found in the Bernoulli's Principle, which states:

$$Tp = Vp + Sp - hf$$

(Total pressure = Velocity Pressure + Static Pressure – Friction in moving from point to point)

It is important to understand that velocity, and its related velocity pressure, and static and static pressure can be interchanged. For example, when air is blown into a deflated balloon, the sound of the wind blowing into the entrance of the balloon is caused by the velocity of the air — hence it has velocity pressure. Once this pressure slows down in the balloon, it is changed into static pressure. It is this static pressure that keeps the balloon inflated. When the balloon is released, the static pressure jets out the balloon's entrance and is converted back to velocity and velocity pressure.

Friction is what causes resistance to air movement and must be taken into consideration when designing any duct system. There are two kinds of friction: 1) the friction in the straight section of ductwork and 2) the dynamic losses (air tumbling losses) in the fittings, elbows, etc. In any given system, there is "X" amount of total pressure at the start of each section of ductwork. If the system is designed correctly, the velocity of air can be slowed down so that just enough velocity pressure is changed into static pressure to offset the straight section and dynamic friction losses of that section of ductwork. If this is achieved, the static pressure at the beginning of each section of ductwork remains close to the same, and the system becomes more balanced. A balanced system helps achieve the original goal of delivering air to every VAV box quietly and

In a rectangular duct system, the maximum air velocity in comfort cooling applications recommended by ASHRAE and the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) is limited to 2,000 ft/min or less because of the potential for "oil canning." This oil canning effect can be compared to a base drum and can produce significant noise problems.

Rectangular duct systems, especially with higher aspect ratios, have a maximum airflow of about 2,000 ft/min. When the air moves at 2,000 ft/min, the system produces .25 in of velocity pressure, which is not enough velocity pressure to offset the friction losses of typical duct systems. Therefore, the system cannot take advantage of a static regain design. If the system cannot use the velocity pressure to move air from Point A to Point B, it has to use static pressure instead of converting velocity pressure to static pressure. This configuration causes higher static pressure near the fan and lower pressures as it approaches the end of the duct system.

In static regain duct systems, static pressure is more equal throughout the system and it becomes self-balancing. To achieve these results, the system must have enough velocity pressure. Spiral round duct systems can be designed to higher velocities without noise problems. For example, ASHRAE design guides allow air flow up to 4,000 ft/min in 25,000-cfm duct systems. This 4,000 ft/min results in 1 in of velocity pressure, which is sufficient to offset duct friction losses in a typical duct system.

Even with higher air velocities in round ductwork, the system uses the same or lower fan static pressure — total fan pressure — than rectangular systems. Why? While the air movement will typically be slower in rectangular ductwork, which helps reduce friction losses, the fittings and elbows have higher friction losses than round ductwork — even with higher velocity. This is because air moves through the curved turns in round duct systems more easily. For example, think of a slide on a playground. Children can quickly and easily travel to the bottom of a curved tube slide, but if the slide was designed at a 90-degree angle, children would lose momentum when they reached the wall and tried to turn.

## Installed and Operating Costs

To determine which type of ductwork is best for the system, building owners should consider both installed and operating costs. Round ductwork can normally save money on both. For example, round ductwork can save building owners \$0.25–1.00/sq ft on installation costs alone. While this can vary widely from job to job, frequently, rectangular ductwork can be installed for about .50 lb. of ductwork/sq ft and costs about \$3–3.50/sq ft. On the

other hand, round ductwork can be installed for about .25 lb. of ductwork/sq ft and costs about \$2–2.50/sq ft. To put this in HVAC terms, round ductwork can save building owners between \$100–400/ton — which is comparable to the cost of some centrifugal chillers.

The primary reason round ductwork costs less is because it takes less time, i.e. labor, to install than rectangular ductwork. Unlike rectangular ductwork, round does not require a series of connections every 4 to 5 ft. In addition to using fewer connectors, the fittings are easier to install and seal. This is especially true with fittings that have factory-installed gasketing.

However, there is a common misconception that round ductwork simply cannot be used because it takes up too much space. In reality, space challenges can typically be resolved by installing multiple round ducts, and when the project is done right, these ducts can be installed cheaper and in equal or less space than rectangular ductwork.

Making the switch to spiral round ductwork also helps building owners reduce operating costs because spiral round ductwork has lower duct heat pickup. Since the air is typically moving at twice the rate and there is much less surface area, duct heat pickup can be cut nearly in half.

More importantly, spiral round ductwork helps building owners reduce operating costs because it has lower leak rates than rectangular ducts. In the past, rectangular ductwork experienced leak rates of over 10%, causing the significant energy waste highlighted in the DOE report referenced at the beginning of this article. Today's rectangular ductwork can be designed to achieve less than a 3% leakage rate. However, spiral round ductwork can be designed to leak less than 1%, and frequently lower than 0.5%.

To understand the effect leak rates have on fan energy consumption, consider a rectangular duct system with a 3% leakage rate and a spiral round duct system with a 1% leakage rate. Using the following fan law equation, one can see that a building owner will save at least 6% on fan energy by using spiral round ductwork.

$$\frac{1.03 \text{ rectangular minimum leakage rate}}$$

$$1.01 \text{ round minimum leakage rate})^3$$

$$= \text{potential for fan energy savings}$$

In many situations, the fan energy can approach — or in some cases exceed — the refrigeration energy, meaning this 6% savings in fan energy represents a significant reduction in operating cost.

## Applications Best Suited for SPIRAL Round Ductwork

Spiral round ductwork is ideal for VAV systems and even many constant volume applications. Currently, K-12 and higher education buildings represent an important segment of the U.S. market.

In these applications, as well as health care and commercial real estate settings, it is important to move air quietly and efficiently. Done right, spiral round duct offers an additional advantage — better acoustics.

In rectangular duct systems, sound attenuators may be required. Many times, these attenuators have pressure losses of .50 in or more, which increases fan energy consumption. In addition, this configuration adds acoustic energy into the system which has to be removed.

In spiral round duct systems, acoustic attenuation can be handled by using double-wall, perforated ductwork to produce the same sound attenuation without the .50-in pressure loss. This perforated duct only has to be used for the first 10 to 20 ft in the straight sections coming off the fans. This configuration minimally increases pressure loss but offers a significant potential for sound attenuation.

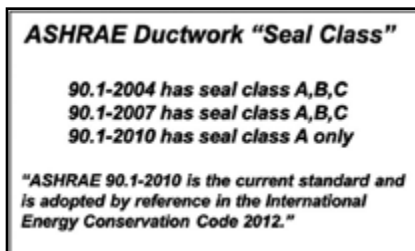
The key to maximizing operating efficiencies using spiral round ductwork is to get the air out of the air handler effectively. The duct system should be designed to minimize the number of turns used to get air out of the VAV box or equipment room. Older HVAC technologies relied on a fan paired with a rectangular duct to move the air over, up, and then out of the equipment room. All those turns increased friction and reduced air flow in the system. Today, direct drive plenum fans can be used to pressurize a plenum, and multiple ducts with bellmouth fittings can be connected to eliminate turns and can result in getting the air out of the air handler more quietly and efficiently.

## Regulations & SPIRAL Round Duct

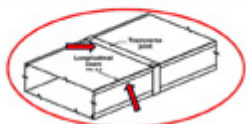
Driven by the importance of minimizing duct leakage, ASHRAE has introduced more stringent sealant guidelines.

ASHRAE Standard 90.1-2010 changed its “Seal Class” requirement to Seal Class A, as did Standard 90.1-2013, meaning that all duct seams and penetrations must be sealed.

These standards have also been accepted — by reference — by the International Energy Conservation Code 2012. State and local building codes are expected to adopt the new ASHRAE standards and model energy code(s) in the next one to three years, if they haven't done so already. Once this occurs, the round duct savings of \$100-400/ton will get even larger.



Seal Class	Sealing Requirements	Applicable Static Pressure Construction Class
A	All Transverse joints, longitudinal seams, and duct wall penetrations	2" eq and up (1000 Pa)
B	All Transverse joints and longitudinal seams only	2" eq and up (750 Pa)
C	Transverse joints only	2" eq and up (500 Pa)



## Software & Support

High-velocity, static regain spiral round duct designs do require a computerized duct design program. However, these programs and experienced design consultants are readily available to help educate and guide specifying engineers and D/B contactors in the transition to spiral round duct system design.

By making the switch to static regain spiral round duct systems, designers can spec VAV systems that are quieter, less expensive, more efficient, and have lower leak rates than VAV systems utilizing rectangular ductwork. The combination of these benefits is why all system designers are encouraged to explore higher velocity, static regain spiral round duct design on one of their next jobs. Find more information about static regain at [www.staticregain.net](http://www.staticregain.net).

*Eugene Smithart, P.E., LEED-AP, is the director of systems and solutions at Trane. He has more than 40 years of experience in the HVAC industry and is the proud recipient of a U.S. EPA Climate Protection Award.*