Air Duct Leakage

INTRODUCTION

Air duct leakage should be a concern to the consumers, contractors, designer and the building owner because of its impact on energy usage, quality of air and system performance.

Pressure in a duct, the movement of air over or through the resistance elements and forces of airflow is a function of air pressure. Nevertheless the size, the total benefit of the duct system is based and measured on the peak fan efficiency for that system.

BACKGROUND

Small commercial buildings typically use a packaged air-handling unit where all of the supply and return air ductwork is in the conditioned space. If the design airflows are not properly delivered to the building HVAC loads, the occupants will respond with corresponding higher or lower temperature settings to meet their comfort requirements. The end result is higher energy costs.

Typically "…one third of the total annual energy consumption is related to HVAC (heating, ventilation, and cooling). In addition, 39 percent of this HVAC consumption is associated with fan operation."[2]

DUCTWORK

The key elements influencing ductwork leakage start with the very basics — size, shape, and construction materials. Ductwork is made from a wide range of materials — galvanized steel, carbon steel, aluminum, stainless steel, fiberglass, polyvinyl chloride (PVC), polyvinyl steel (PVS), duct board, and others. Perhaps the most common material used is galvanized steel. Ductwork is available in rectangular, round, and flat oval geometric shapes. The particular shape that is selected for a specific system should adhere to minimizing the initial installed cost and annual operating costs, as well as conform to the constraints of the building envelope.

There are many reasons why the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) HVAC Systems Duct Design Manual recommends the following:

1. Use the minimum number of fittings;

2. Consider the use of semi-extended plenums;

3. Seal ductwork to minimize air leakage;

4. Consider using round duct; and

5. When using rectangular ductwork, maintain an aspect ratio as close to 1-to-1 as possible.

Air Duct Leakage

There are several reasons for specifying round ductwork versus rectangular ductwork:

1. Lowest possible duct friction loss for a given perimeter;

2. Lowest weight based upon the same airflows, pressures, and friction loss rates;

3. Requires less supports per running foot;

4. Handles negative pressures with less weight and reinforcement;

5. Handles higher air velocities than rectangular ductwork while achieving the same acoustic design criteria;

6. Least expensive to seal for air leakage.

DUCTWORK SEALING

The engineering community has traditionally specified SMACNA's three distinct duct sealing classes (A, B, or C), which differ in their requirements for sealing the transverse joint, longitudinal seams, and duct penetrations. Typically the designer will specify a Seal Class and a percentage of the design airflow as an acceptable air leakage rate.

As reported in the SMACNA 1990 HVAC Systems Duct Design Manual, duct leakage previously specified as an arbitrarily established percentage of the airflow was impossible to attain by the installing contractor. Joint research conducted by SMACNA and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has since developed a methodology used to relate the amount of ductwork leakage to the ductwork surface area and the design static pressure independent of the actual airflow in the ductwork.

SMACNA publishes a table (Table 1) that correlates the Seal Class (A, B, or C) and the Leakage Class (typically 3, 6, 12, or 48). Obviously, this assumes a superior application of sealants to the ductwork system.

Seal Class	A	B	C
Leakage Class – Rectangular	24	12	6
Leakage Class – Round	12	6	3

Table 1

ASHRAE's Energy Standard 90.1 recognizes the Leakage Class method for

$L_{max} = C_L P$

where:

L_{max} = maximum permitted leakage in cfm/100 ft^2 ductwork surface area

C_L = duct leakage class, cfm/100ft^2 at 1 inch water gauge

P = test pressure, which shall be equal to the design duct pressure class rating in inches water column

In addition, the leakage class recognizes that under the best conditions, rectangular ductwork will leak air at a rate twice greater than round.

SEALING DUCTWORK

Various recognized methods of sealing ductwork also vary in degrees of cost, quality, visual appearance, and performance. Choices range from various types of flanges, to slip fit connections that require liquids, mastics, tapes, or heat-applied materials to seal the joints. In addition, several ductwork manufacturers offer a factory-applied gasket with self-sealing characteristics that do not require the field application of external sealants.

ENERGY COSTS

A typical response to unanticipated ductwork air leakage has been:

1. Increased design airflows which increase the initial construction costs for equipment and ductwork;

2. Increased fan energy;

3. Increased energy for heating, cooling, and dehumidifying the air stream;

4. Increased difficulty in air balancing the system airflows;

5. Impacts on indoor air quality (IAQ); and

6. Compromised occupant comfort.

Computer simulations previously reported through PIER[1] and confirmed by actual field measurements found the impact of air duct leakage on the total energy used to condition the occupied space as follows:

• "…the increase in total annual HVAC site energy is 2 percent – 14 percent" and this

For a less complex constant volume system, the annual increase in energy consumption for the supply fan alone (Table 2) ranges from 4 percent for a Leakage Class 6 system to 101 percent for a Leakage Class 48.
Leakage Class 3 is the tightest leakage class currently recognized by SMACNA and ASHRAE.

A Leakage Class 48 is what one may expect with unsealed rectangular ductwork and is the highest recognized leakage class. This table represents what would be expected in an actual operating system based upon: changes in the system delivered cfm (CFM_2) due to air leakage; revised system total static pressure (TSP_2) as calculated using established fan laws; and the actual required fan brake horsepower (BHP_2) using the published fan performance data from a nationally recognized fan manufacturer.

Air Duct Leakage

Leakage Class	CFM Leakage	CFM_2 (iwg)	ISP_2 (iwg)	ESP_2 (iwg)	TSP_2 iwg	BHP_2	Total Dollars per Year	% Increase from Class 3 per Year
3	143	20,190	2.04	2.04	4.08	16.70	$8,465	0%
6	291	20,482	2.10	2.10	4.19	17.40	$8,820	4%
12	605	21,087	2.22	2.22	4.45	19.03	$9,646	14%
24	1,309	22,395	2.51	2.51	5.02	22.79	$11,552	36%
48	3,098	25,493	3.25	3.25	6.50	33.60	$17,031	101%

Table 2

Assumptions:

20,000 design cfm
2.00 iwg ISP_1 (internal static pressure loss: air handler cabinet, filters, heating coil, and cooling coil
2.00 iwg ESP_1 (external static pressure or friction losses in ductwork)
4.00 iwg TSP_1 (total static pressure or TSP = ISP + ESP)
3,000 ft^2 exposed ductwork
Greenheck 44-AFSW-21 fan and Greenheck's CAPS program (ver 2.6.2.1)
90% motor efficiency, 70% run time, $0.10 per KWh, PF=1.0

CONCLUSIONS

HVAC systems account for upwards of 40 percent of a building's annual energy usage. High efficiency equipment is one way to reduce annual utility costs; however, understanding the different styles of duct systems and the impact of duct leakage is key to realizing maximum system efficiency.

References

1. The Public Interest Energy Research (PIER) Program, "Duct Leakage Impacts on VAV System Performance in California Large Commercial Buildings," Contract Number 400-99-012-1, conducted by the Energy Performance of Buildings Group, Environmental Energy Technologies Division of the Lawrence Berkeley National Laboratory (Published October 2003)
2. California Energy Commission Year 2000 Energy Estimates
3. SMACNA HVAC Duct Construction Standards
4. SMACNA HVAC Systems Duct Design
5. ASHRAE 90.1
6. ASHRAE 2003 HVAC Applications Chapter 17 Sound and Vibration Control