The Current (2014) ***State of the Art*** for Air Leakage in Ductwork

Over the last five years there has been a major shift in the way ASHRAE has approached air leakage in ductwork. This is reflected in the latest revisions of the following ASHRAE Handbooks and Standards:

1. ASHRAE Standard 90.1-2010 Energy Standard for Buildings Except Low-Rise Residential Buildings
2. ASHRAE Handbook, HVAC Systems and Equipment (2012), Chapter 19, Duct Construction
3. ASHRAE Handbook, Fundamentals (2013), Chapter 21, Duct Design

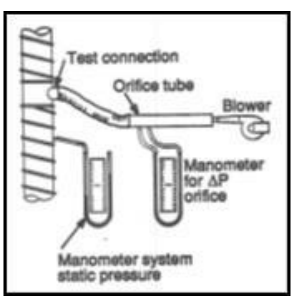
Background

It was reported by the Associated Air Balance Council (AABC) TAB Journal (Spring 2011) that a major manufacturer of ductwork ***"…maintains that a quality fabricated duct system, properly installed and sealed, can achieve (air) leakage rates as low as 0.5% ..."***

Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) states in its HVAC Systems Duct Design (2006), 4th edition, section 2.9 that ***"…1% air leakage rate for large HVAC duct systems is almost impossible to attain…"*** and that ***"…large unsealed duct systems may develop (air) leakage well above 30% of the total system airflow…".***

EHG, as well as other spiral duct manufacturers, has supplied self-sealing gaskets meeting Leakage Class 3 requirements for many years. Leakage Class 3 is equivalent to a range of 0.4% to 6.7% air leakage of system airflow at static pressures ranging from 0.5 to 10 iwg (ASHRAE 2012 Duct Construction Table 3); the range (0.4% – 6.7% air leakage) is dependent on the actual test pressure and fan cfm prorated per square feet of duct surface area.

The industry accepted method of air leakage field testing is well documented by the SMACNA Air Leakage Test Manual (2012) and the National Standards for Total System Balance (AABC 2002). The procedure is to partition off a section of ductwork (including duct-mounted equipment such as terminal units, reheat coils, access doors, and dampers) and using a blower and a calibrated orifice plate (illustrated below) to measure the airflow into the isolated ductwork and hence, the air leakage out of the sealed section of duct.



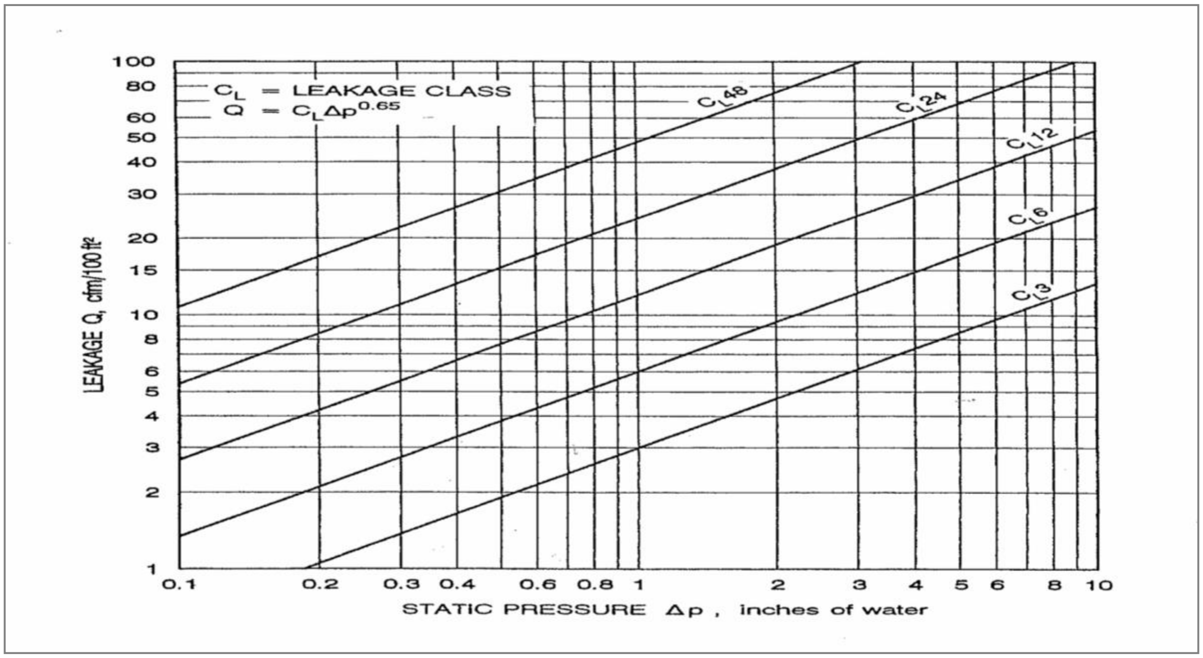
Courtesv of AABC

The Leakage Class (C_L) is determined using the following formula.

$$C_L = \frac{Q}{A\,P^{0.65}}$$

C_L = Leakage Class, cfm per iwg$^{0.65}$ per 100 ft^2 of duct surface area
Q = air leakage, cfm
p = test pressure, iwg
A = 100 square feet of surface area of duct tested, 100 x ft^2

Leakage data can also be plotted on the following graph to determine leakage class.



Prior to the 2013 version ASHRAE Standard 90.1 required Leakage Class 6 for rectangular metal and round flexible duct and Leakage Class 3 for round and flat oval metal duct.

Air leakage testing of 25% of the installed ductwork is required by the current ASHRAE Standard 90.1-2013, as well as the earlier versions for ductwork designed to operate at a static pressure in excess of 3 iwg. There is no requirement for air leakage for systems designed to operate at 3 iwg and lower.

ASHRAE Standard 90.1 prior to 2010 specified duct sealing requirements (Seal Class A, B, or C) depending on the pressure classification of the ductwork for supply air, exhaust air, or return air; as well as the ductwork location being outdoor, in unconditioned space, or the conditioned space.

It has become a generally accepted industry practice, as a pass/fail criterion, which incorrectly assumes ductwork sealed to a Seal Class A, B, or C is expected to achieve a corresponding Leakage Class under actual field conditions according to the following tables.

Seal Class	Sealing Required
A	seal all joints, seams, and wall penetrations
B	seal transverse joints and seams
C	seal transverse joints only

	Leakage Class		
Seal Class	**C**	**B**	**A**
Rectangular	24	12	6
Round & Flat Oval	12	6	3

The information presented in the above tables is reported by SMACNA in its "Technical Paper on Duct Leakage" (1992). In said document, it states "***…analysis of the available data allows for the estimation of a Leakage Class corresponding to a given Seal Class for both round and rectangular ductwork…. predictions are based on test research averages using SMACNA's standards for construction and skilled, trained workers."***

According to the current SMACNA HVAC Air Duct Leakage Test Manual 2nd edition (2012) the Leakage Class (A, B, and C) changes from 24/12/6 to 16/8/4 respectively for rectangular and from 12/6/3 to 8/4/2 respectively for round & flat oval. SMACNA's commentary in section 5.1 states, ***"Table 5-1 is the basis of evaluating duct conforming to the SMACNA duct construction standards unless a specifier gives other limits."***

Without air leakage testing, the actual Leakage Class achieved in the field has no correlation to the SMACNA Seal Class as stated above. This is substantiated by the fact that there is no currently available research that correlates Seal Class with Leakage Class under actual field conditions. This is further expanded upon in the following paragraphs.

A major shift

ASHRAE Standard 90.1-2010 was modified to require Leakage Class 4 for both round and rectangular ductwork. In addition, only Seal Class A is recognized for all HVAC duct systems. Ductwork air leakage testing is required for no less than 25% of the installed ductwork area for all systems operating in excess of 3 iwg and 100% of the ductwork located outdoors.

Due to ASHRAE Standard 90.1-2013 limiting fan horse power (Section 6.5.3.1), it is rare to encounter a system operating in excess of 3 iwg; and therefore, there is no regulatory mandate to conduct field verification for actual duct air leakage in the majority of ductwork systems.

Prior to the current ASHRAE Duct Design (2013), a similar table to the above SMACNA (1992) table was presented comparing Seal Class to Leakage Class; however, it was footnoted as representing the ***"predicted"*** ductwork air leakage, Leakage Class 6 for rectangular and Leakage Class of 3 for round with a Seal Class A. In addition, there is an additional footnote that ***"Leakage classes…are averages based on tests conducted by AISI/SMACNA (1972), ASHRAE/SMACNA/TIMA (1985), and Swim & Griggs (1995)."***

The AISI/SMACNA (1972) research included at most two test samples which were subsequently rolled into the work done by ASHRAE/SMACNA/TIMA (1985). This work generated a *predicted* air leakage per foot of transverse and longitudinal seam. Swim & Griggs (1995) did not generate any new testing, but reworked the previous research data.

The change to Leakage Class based upon the surface area as presented in the previous editions of the ASHRAE Duct Design was done without any documented or credible research. In the current ASHRAE Duct Design (2013), this table has been removed due to a lack of any technical basis and a change in focus of the ASHRAE Technical Committee moving from "predicting" ductwork air leakage to "operating system air leakage."

The current, ASHRAE (2012) Duct Construction, contains a commentary regarding a **major shift in direction** from leak testing ductwork to **"system air leakage testing."** The ductwork system includes the air handler, ductwork, and all duct mounted components; not just the ductwork! In addition, testing would be required to meet a maximum system leakage percentage at operating pressure versus a Leakage Class. This is supported by credible published research (refer to the ASHRAE Handbooks cited above) and the adverse economic impact of system air leakage on energy costs. Recommended maximum system air leakage percentages are found in the ASHRAE Duct Construction (2012, Table 2, page 19.4) which range between 1% and 5% at operating pressure depending of the type of system and system conditions.

This ASHRAE (2012) Duct Construction chapter elaborates on the responsibilities of the engineer, sheet metal contractor, and the testing contractor. Most importantly noted is that the engineer is responsible, in addition to other requirements, to ***"specify HVAC system components, duct mounted equipment, accessories, sealants, and sealing procedures that together will meet the system airtightness design objectives."***

ASHRAE (2013) Duct Design builds on the previous work of ASHRAE (2012) Duct Construction and expands the scope to include a recommendation to test 100% of supply air (both upstream and downstream of the VAV box primary inlet damper when used), return air, and exhaust air after construction at operating conditions. This is in addition to testing at least 25% of the ductwork during construction. The final testing after construction, at operating conditions, is required to ensure that good workmanship was performed and low air leakage components were used.

ASHRAE (2013) Duct Design also includes recommended specifications for low leakage duct mounted components and expands on the roles and responsibilities of the engineer, sheet metal contractor, and testing contractor as mentioned in ASHRAE (2012) Duct Construction.

What is the economic impact of system air leakage?

A "leaky" ductwork system ASHRAE (2012) Duct Construction states that ***"…air leakage 10% upstream of the terminal air units and 10% downstream will use 25-35% MORE fan horsepower than a tight system (2.5% upstream and 2.5% downstream)"***. For each 100 shaft horse power of fan energy running 24/7 equates to $22,840 wasted energy per year assuming energy cost is $0.10/kWh. Obviously this number is higher when the fan efficiency, fan belt drive efficiency, motor/VFD efficiency, and power factor are considered.

Duct air leakage, as reported by Mills (Building Commissioning, Public Interest Energy Research, July 2009), ranks air duct leakage as the #1 cause of energy inefficiencies in commercial building. In addition, Mills reports that 30% of the estimate of 1.0 Quad of annual energy wasted is due to duct air leakage and equates to approximately $2.9 billion per year in wasted energy.

SMACNA recently stated in the forward of the 2nd edition HVAC Air Duct Leakage Manual (2012), ***"SMACNA encourages designers to specify equipment (air) leakage control and to rely on prescriptive sealing ductwork as measures that will normally lead to effective control of (air) leakage without the need for extensive (air) leakage testing."***

Unfortunately, there is no credible research that will avoid the need for actual field testing.

What is required by the code?

The SMACNA (2012) HVAC Air Duct Leakage Test Manual clearly states that ***"specifications that read test per SMACNA or similar are invalid"*** and that ***"no leakage tests are require by the SMACNA HVAC Duct Construction Standards (2005) or by this test manual."***

The current ASHRAE Handbooks give clear and concise direction for allowable air leakage for ductwork systems (as a percentage of design airflow), the required test pressure, and how much and which systems to test. These requirements are neither mandatory nor required by any applicable codes. However, there is economic justification to substantiate testing which ultimately verifies the quality control exercised by the installing contractor and saves energy.

ASHRAE Standard 90.1-2013 does place mandatory code requirements on air leakage testing as previously stated.

Outside of any regulatory requirements to properly seal and test ductwork systems for air leakage over the last several years, the writer has seen:

1. An increase frequency of specifications requiring 25% to 100% of the ductwork systems (including access doors, volume dampers, relief air doors, smoke dampers, fire dampers, fire smoke dampers, and end caps used to seal ducts) to be tested,
2. Specifying air leakage rates not to exceed 5% (sometimes as low as 2.5%) of system design air quantity with test pressures equal to duct pressure class, and
3. Includes 10% of the ductwork downstream of the air terminal units to be tested.

What is next?

ASHRAE has formed a MTG.EAS (Multidisciplinary Task Group Energy-Efficient Air-Handling Systems for Non-Residential Buildings) with the purpose to coordinate the activities of related ASHRAE technical and standards committees to facilitate development of packages of tools, technology, and guidelines related to the design, operation, and retrofit of energy-efficient air-handling systems in new and existing non-residential buildings.

The ASHRAE technical committee for duct design (TC5.2) is working to put in place the research that will justify the economics of field testing along with new test procedures and methods for system air leakage testing on operating systems. The ultimate goal is to amend ASHRAE Standard 90.1 and then to incorporate these finding into the National Energy Codes.

Prepared by:
Larry A. Smith, P.E.
Engineering Manager
Gustafson/Linx Industries, Inc.
Larry.smith@li-hvac.com

Larry A. Smith, P.E. is the Engineering Manager for Gustafson which is a division of Linx Industries (formerly known as Lindab, Inc.). Smith is the current chairman for ASHRAE TC5.2 (Duct Design) and a voting member of ASHRAE MTG.EAS.