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What is an Allowable Duct System Leakage Specification?

What is an Allowable Duct System Leakage Specification? It is a written specification noting how much air is acceptable to leak from a duct system while maintaining optimum occupant comfort at minimum owner expense. Leakage reduces the amount of heated or cooled air that arrives at a work area. This can lead to a loss in the occupants' comfort level, reducing productivity and increasing labor costs. Increasing the fan speed to offset leakage may improve occupant comfort, but results in increased operating and maintenance costs; and sealing the ductwork during installation increases construction costs. No matter how you examine it, leakage, or the steps required to prevent it, results in increased costs. The underlining goal is to determine how much leakage is too much and to specify an appropriate leakage rate that results in minimal leakage at minimal expense. The designer should carefully consider the following information in establishing allowable leakage specifications.

Does Table 1 look familiar? It is Table 4-1 on page 4-3 in the *1985 SMACNA HVAC Air Duct Leakage Test Manual* and Table 1-1 on page 1.11 in the *2005 SMACNA HVAC Duct Construction Standards.* This table is not an allowable leakage specification, but is often used as one. McGill AirFlow receives many inquiries each year from contractors, who are performing leak tests in the field, wanting to know how to use this table to test to as a leakage specification. McGill AirFlow often gets specifications stating that the leakage class for rectangular and round ductwork will be in accordance with the SMACNA Table 4-1 for a 3-inch water gauge (wg) supply duct system, thus allowing the rectangular duct leakage class to be 12 and the round and flat oval duct leakage class to be 6. What the table actually shows is that for the same seal class, rectangular ducts leak at least two-times more than round and flat oval, so where they are installed can have a significant impact on the overall system performance and associated operating costs. It should be further noted that SMACNA states if the designer does not designate pressure class for duct constructions on the contract drawings, the basis of compliance is as follows: 2-inch wg

Table 1: Applicable Leakage Classes

Duct Class	½-, 1-, or 2-inch wg	3-inch wg	4-, 6-, or 10-inch wg
Seal Class	C	B	A
Sealing Applicable	Transverse Joints Only	Transverse Joints and Seams	Joints, Seams, and all Wall Penetrations
Leakage Class			
Rectangular Metal	24	12	6
Round Metal	12	6	3

Table 2: Leakage as Percent of Airflow in System

		Static Pressure (inch wg)					
Leakage Class	**Fan Airflow (cfm prorated/sq ft)**	**½**	**1**	**2**	**3**	**4**	**6**
48	2	15.0	24.0	38.0			
	3	10.0	16.0	25.0			
	5	6.1	9.6	15.0			
24	2	7.7	12.0	19.0			
	3	5.1	8.0	13.0			
	5	3.1	4.8	7.5			
12	2	3.8	6.0	9.4	12.0		
	3	2.6	4.0	6.3	8.2		
	5	1.5	2.4	3.8	4.9		
6	2	1.9	3.0	4.7	6.1	7.4	9.6
	3	1.3	2.0	3.1	4.1	4.9	6.4
	5	0.8	1.2	1.9	2.4	3.0	3.8
3	2	1.0	1.5	2.4	3.1	3.7	4.8
	3	0.6	1.0	1.6	2.0	2.5	3.2
	5	0.4	0.6	0.9	1.2	1.5	1.9

for all ducts between the supply fan and variable volume control boxes and 1-inch wg for all other ducts of any application. According to Table 1, this requires a seal class C, which means rectangular ducts can leak up to a leakage class of 24 and round ducts can leak up to a leakage class of 12. What system can afford that?

Actually, this table is very helpful in providing the designer with some insight as to the expected leakage rates for rectangular and round duct sealed in accordance to a seal class based on operating pressure. The designer can estimate how much more horsepower the fan requires to compensate for lost energy due to leakage, and hopefully material and operating costs can be compared at the design stage and not after the system is installed.

Although specifying a higher duct class does yield a lower leakage class, it is a poor means to select allowable leakage. Table 2 is an abridged version of Appendix A from the *SMACNA HVAC Duct Leak Test Manual* comparing common prorated leakage {cubic feet per minute (cfm)/square feet (sq ft) of surface area} to the "older" percent by system volume allowable leakage specification. The percent by volume method is by far the more accurate means of specifying leakage in that at the completion of the system installation, the air testing and balancing agencies can quickly, and easily, determine how close the airflow discharged by the fan compares to the airflow entering the conditioned space through prescribed registers. The increased costs associated with higher duct leakage are quickly realized when accounting for the increased fan horsepower required to overcome the leakage in order to obtain the designed airflow, a cost increase that is continually paid out to the utility company.

The popular "old" specification was 1 percent (approximately a leakage class 3) allowable leakage for medium- and high-pressure systems and 5 percent (leakage class 6 to class 12) for low-pressure systems. Leakage specifications are less stringent today yet more complicated to figure out. It is a fact that spiral round and flat oval systems did, and still can, meet or exceed ½ of 1 percent leakage by volume when properly sealed under seal class A. For the most part, many spiral manufacturers have softened their positions and given in to unsubstantiated or unqualified industry claims that those leakage specifications are too stringent, too expensive, and too difficult to achieve; and forfeited the fact that spiral round and flat oval systems easily meet or exceed the lowest published leakage class 3 (see Table 5). With the present energy cost/crisis, spiral ductwork with leakage rates of less than 1 percent may again have to be considered for pressures of 1-inch to 10-inch wg.

Table 3 is an abridged version of Appendix E from the *SMACNA HVAC Duct Leak Test Manual* that quantifies the amount of leakage by pressure for each duct class. The *engineer* can use this table to determine the expected total leakage of the system designed prior to selecting the fan and associated costs for increased horsepower to compensate for leakage. The *contractor* can use this table in conjunction with the capabilities of the leak testing equipment to determine how large a system they can pressure leak test.

Table 4 depicts Table 7 about duct design from the *2005 ASHRAE Handbook* – "Fundamentals"(refer to page 35.15, Chapter 35). ASHRAE also presents a duct leakage classification table, similar to Table 1, which includes the seal classes and *predicted* leakage classes for the additional duct types presented in Table 2. ASHRAE further provides an extremely helpful recommended duct seal levels table noting how the seal class should be adjusted to account for duct location and application. Although several duct construction types show leakage classes greater than 6, the ASHRAE Recommended Ductwork Leakage Specification in Table 4 maintains a maximum allowable leakage class 6 for all duct types regardless of seal class or application. This table is presented as an allowable leakage specification but it is still based on SMACNA leakage classes. The designer should consider the total ownership cost, which is the sum of the first cost plus the sum of the operating cost over time. What may have a lower first cost for a rectangular system will have much higher operating costs. Round and flat oval systems that have much lower leakage rates will end up costing much less over time since the higher operating costs of rectangular systems will continue to accumulate due to increased leakage. Unfortunately, there are no guidelines in helping the designer to establish what combination of construction types may

Table 3: Leakage Factor (F) in cfm/100 sq ft

		Static Pressure (inch wg)					
Leakage Class	**½**	**1**	**2**	**3**	**4**	**6**	**10**
48	30.6	48.0	75.4	98.0	118.1		
24	15.3	24.0	37.7	49.0	59.0		
12	7.6	12.0	18.8	24.5	29.5		
6	3.8	6.0	9.4	12.2	14.8	19.2	26.8
3	1.9	3.0	4.7	6.1	7.4	9.6	13.4

Table 4: Recommended Ductwork Leakage Specification

Duct Type	Leakage Type (cfm/100 sq ft at 1-inch wg)
Round Metal (including metal flexible)	3
Flat Oval Metal	3
Rectangular Metal	6
Round Flexible	6
Round Fibrous Glass	3
Rectangular Fibrous Glass	6

Table 5: McGill AirFlow Allowable Leakage Specification 1985

System (Static) Pressure (inch wg)	Allowable Leakage (cfm/100 sq ft)
0 - 0.99	3.0
1 - 1.99	4.6
2 - 2.99	6.0
3 - 3.99	7.4
4 - 5.99	9.6
6 - 10.00	13.5

Table 6: Allowable Leakage Rates		
Type of System	**Minimum Test Pressure[5]**	**Maximum Allowable Leakage**
Fractional horsepower fan system; fan coils, small exhaust/supply fans	0.50-inch wg	2%
Small systems; split DX systems – usually under 2,000 cfm	1-inch wg	2%
VAV and CAV boxes and associated downstream duct[1]	1-inch wg	2%
Single zone, multi-zone, low pressure VAV and CAV systems[2], return ducts and exhaust duct systems	2-inch wg	2%
All constant volume ducts in chases and concealed spaces, main return ducts on VAV and CAV systems, main ducts on exhaust or supply systems	3-inch wg	1%
Supply ducts for VAV and CAV systems	4-inch wg[3]	1%
High-pressure induction system	6-inch wg[4]	0.5%

Notes:

1. It is assumed that the box damper is on the inlet side of the box. If the box damper is on the outlet side of the box, then the box should be included in the upstream leakage testing. Series boxes should not be included in the test since they operate at neutral pressure.
2. When low-pressure VAV and CAV systems are used, the total allowable leakage should not exceed 2 percent, including the box and downstream ductwork. The box and downstream ductwork should be tested at the lower 1-inch wg static. This is the minimum for most systems currently used in today's design practices.
3. It is recommended that the pressure rating of the duct be equal to the fan shut-off pressure if the possibility of fan shut-off exists either in the VAV systems or in systems with smoke/fire damper control. In a VAV system, the pressure may be selected at the intersection of the minimum box total cfm and the maximum fan RPM.
4. Large induction systems may have higher-pressure requirements, i.e. 10-inch wg.
5. Test pressure should not exceed the pressure rating of the duct.

give the lowest operating cost. *Technical Bulletin (3-2), System Leakage Comparison* due out this fall will provide further insight in this area.

Consider what happens in those instances where the engineer specifically designs spiral round and flat oval trunk duct systems between the fan and variable air volume boxes for their low-leakage characteristics, then allows these to be changed at the last moment to rectangular for an assumed first cost reduction and equal airflow performance. As shown in comparison Table 4, there is still two-times more leakage in the rectangular duct system. Before basing a decision on just doubling the allowable leakage, review Table 2. Does replacing a duct system that leaks less than ½ of 1 percent, with a rectangular system even at a leakage class 6 make good economic sense? Consider the following example; for a 4-inch wg duct supply system with a fan cfm prorated for 3 cfm per square foot of duct surface, the allowable leakage for a leakage class 6 product is 4.9 percent. This is almost ten-times the leakage of a properly installed round or flat oval spiral duct system. Therefore, most would not consider this an acceptable allowable leakage specification.

Table 5 is the Allowable Leakage Specification that has appeared as Table N in the McGill AirFlow *Recommended Specification for Commercial and Industrial Round and Flat Oval Duct Systems* and as Table 1 in the *System Pressure Testing For Leaks Manual* for over 20 years. McGill AirFlow has realized the importance of the development of the SMACNA's leakage class methodology in 1985 and thereby constructed Table 5, McGill AirFlow Allowable Leakage Specification. However, McGill AirFlow based the allowable leakage on SMACNA class 3 for all duct types, regardless of seal class, duct class, or application. McGill AirFlow has been the number one manufacturer of round and flat oval spiral duct for over 50 years and has stated that properly sealed round and flat oval spiral duct systems will not leak more than ½ of 1 percent air leakage by system. McGill AirFlow still stands behind that statement today. If an inexpensive yet tight duct system is desired, specify McGill AirFlow spiral ductwork.

Table 6 is extracted from the *2002 National Standards for Total System Balance* – "Duct Leakage Testing" (refer to Chapter 35), published by the Associated Air Balance Council (AABC). The minimum test pressures are established based on an objective type of system rather than subjective duct class or seal class; and the maximum allowable leakage rates are based on the simple, more accurate, percent of total cfm rather than cfm/sq ft. The test section surface area prorated to system total surface area allows for manageable testing of smaller sections for conformance to the percent total cfm maximum allowable leakage rate. This allows for lower operating costs resulting from the lower percentage allowable leakage rates as presented by AABC than any other specification previously discussed. Lower material and installing costs result from specifying spiral ductwork since little time and sealant is needed to seal spiral systems and achieve lower leakage rates compared to rectangular systems.

Summary

The designer is responsible for establishing an allowable leakage specification and should take into account the leakage variation associated with different duct types and applications. The designer should be reminded that rectangular and other available duct systems cannot be as tightly or economically sealed as round and flat oval systems, and therefore should not be accepted in low leakage applications without due consideration. Allowable leakage must be considered when selecting a fan with the highest operating efficiency associated with long-term operating cost. The greater the leakage the more energy is required to overcome leakage and obtain the designed volume flow rates and proper airflow distribution. The designer must specify where, when, and how leakage testing is required and what leakage testing procedures are to be used in order to ensure the duct construction and leakage specifications are met. With skyrocketing energy costs, reducing leakage is now more important than ever before.

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