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Ductwork Leakage & Leak Testing

(Part 1 of 2)

"How much does ducting leak? Where does ducting leak? How much should it leak? What are the applicable standards? How to use them? How to set up a leakage target - and, stay within it? What is a Leak Testing Rig and how does it help test and measure the leaks? These are some of the questions addressed in this two-part article."

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Testing ductwork for leakage in HVAC systems is not a new concept. Visual inspection with particular attention to flanges and longitudinal joints, for example, is supposed to be regular and routine work for site engineers and supervisors. Visual inspection of escaping smoke from leaky ductwork propelled by the fan of the system has been in vogue for quite some time. However, all these "tests" are qualitative and subjective and are often carried out in a perfunctory manner. They do not conform to any specific standard; nor do they lend themselves to quantification of the leakage.

The question as to why duct leakage should be quantified or for the matter, why ductwork should be even tested at all, could be raised and therefore needs to be answered. Leaky ductwork has many consequences:

- Stipulated airflow rates will not be achieved

- Design conditions (DB & RH) may not be achieved
- Room air movement suffers
- Diffusers & terminals - particularly those at the tail end of long ducts - won't get adequate air
- Pressurization may not be achieved
- Air lost represents energy lost
- Room cleanliness may not be achieved
- Leakage air could be noisy
- Duct insulation could get blown

Besides, the designer needs to know whether the system performance complies with the design goals. It is important for him to know whether the conditioned space is getting the air it was supposed to and whether it is being exhausted at the rate, it was supposed to be. Tests help in diagnosis and rectification of deficient performance.

How much does ductwork leak ?

It is not that engineers are totally unaware that ducting does leak and that allowance is to be made for such leakages in design calculations. It has been customary to allow a leakage of 10% in day-to-day design calculations in conventional comfort applications (as all such applications usually employ low pressure ducting). In practice however, leakage varies a great deal depending on – amongst other things – workmanship. The range of leakage variation encountered is as large as 5 to 15%; infact, ASHRAE observes that it could be as high as even 30%, as can be seen from the extract below from ASHRAE Fundamentals Hand Book - 2001 (pages 29.29 & 29.30)

"*Poorly designed or installed duct systems can have leakage rates of 10 to 30%. Leakage from low-pressure lighting troffer connections lacking proper taping and sealing can be 35% or more of the terminal air supply. Improperly sealed high-pressure systems can leak as much as 10% or more from the high pressure side alone. Such extremes destroy the validity of any load calculation. Although leaks do not always affect overall system loads enough to cause problems, they will always adversely impact required supply air quantities*".

Data in the following standards may be regarded as authentic:

DW/143 - A practical guide to Ductwork Leakage Testing	Heating and Ventilating Contractors Association(HVCA), UK
HVAC Air Duct Leakage Test Manual - 1985	Sheet Metal and Air Conditioning Contractors National Association,Inc

(SMACNA) USA.

Given below are the leakage rates from the above standards:

Low Pressure Ducting (This is according to SMACNA, while DW indicates only 6%)	- 5–15%
Medium Pressure Ducting	- 3%
High Pressure Ducting	- 2 to 0.5%

It will be noticed that while leakage can be upto 15% (in Low Pressure Ducting), it can be as low as 0.5% for High Pressure Ducting.

Is it possible then to achieve lower leakage rates and perhaps, even aim at zero leakage ?

It turns out that, achieving even lower leakage rates and for that matter, even zero leakage, is indeed possible, but from a practical standpoint, it is not necessary to aim for zero leakage. The reasons are simple enough – it is not necessary in the first place – and then it is too expensive.

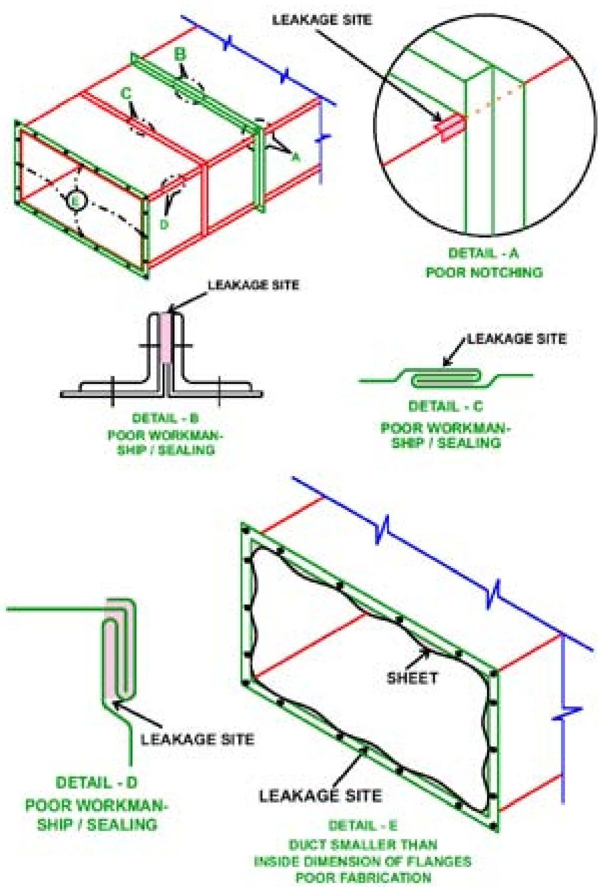


Figure 1 : Common duct leakage sites

Elements of leakage from ductwork

We shall now take a look at the different ways that ductwork can leak.

1. **Pressure/leakage relationship**. The fundamental relation is that leakage in ducting is proportional to the static pressure (in the duct) raised to the power of 0.65. This is the basis adopted in both DW & SMACNA Standards. This is in fact but a re-statement of the oft-quoted power law equation :

   $$Q = c(\Delta p)^n$$

   Where

   Q = air flow rate

   c = flow co-efficient

   Δp = pressure difference

   n = pressure exponent, dimensionless- In our case, the value of n = 0.65.

   Please see 2001 ASHRAE Fundamentals Handbook, Chapter 26, Ventilation and Infiltration, page 26.12.
2. **Leakage related to duct area**. Leakage can also be taken as proportional to the surface area of the ductwork, even though there may be considerable variation in different sections of a complete system because of the changing pressures and sizes of the ducts and the number and variety of the fittings. The surface area is easily calculable as part of the design procedure.
3. **“The weak points" in duct work**. Air leakage in installed ductwork occurs almost entirely at the longitudinal seams and the cross joints, particularly at the corners, and at the intersection of the seams and crossjoints (See **Figure 1**). The specifications adopted for the joints, methods of fabrication adopted, material and thickness stipulated - all have a bearing on the leakage rate. The last but not the least, the workmanship of ductwork - especially, in our country - is also obviously a key factor, which influences the leakage.

Ductwork classes & leakage limits

It has already been noted that leakage is proportional to the pressure raised to the power of 0.65, duct area and that “the weak points” is a major player where leakage matters are concerned. This is reflected in the categorization of ductwork classes, leakage limits, etc. in the paragraphs and tables that follow :

DW Standards

Ductwork classes, permissible leakage limits, applicable pressure limits and leakage flow rates at the same pressure (250 Pa) are furnished the **Table 1**.

Table 1 : Air Leakage Limits (DW/144)

Ductwork Classes	Leakage limit – l/s per m² of duct surface	Static Pressure limit - Pa		Leakage flow rate at a static pressure of 250 Pa
		Positive	Negative	
Low Pressure - Class A	$0.027 \times p^{0.65}$	500	500	0.977
Medium Pressure – Class B	$0.009 \times p^{0.65}$	1000	750	0.326
High Pressure – Class C	C $0.003 \times p^{0.65}$	2000	750	0.109

It may be noted that even though the static pressure limit is above 250 Pa for all the classes, leakage shown is for this value. This is with a view to provide a level playing ground for all the ductwork classes for a comparative assessment of their leak tightness.

Earlier DW142 had included a Class D also (with a leakage flow rate limit of 0.036 l/s per sqm), but DW144 has subsequently omitted this high pressure class, the reason adduced being - "in order to conform to European practice".

SMACNA Standards

The permissible leakage limits according to SMACNA are shown in **Table 2** for duct types and for sealed and unsealed ductwork.

Table 2 below corresponds to **Table 1**, (which contains DW values), even though the two tables are not strictly identical. Thus, **Table 2** also deals with duct type and the corresponding predicted leakage rates for several kinds of ductwork. In this table also, the pressure considered is 250 Pa. It will be appreciated, that this permits a direct comparison of DW and SMACNA Standards. In this case also, the pressure considered is 250 Pa. A cursory glance shows that the permissible leakage rate for almost all ducting is higher than in DW standards, in other words, DW ducts are tighter.

Tables 3A & **3B** show the sealing requirements for various ductwork locations.

Table 2 : Recommended Ductwork Leakage Class by Duct Type (SMACNA)

Duct Type	Leakage Class	Leakage Rate, l/s per m² at 250 Pa

Metal		
Round	4	0.14
Flat Oval	4	0.14
Rectangular	8	0.29
Flexible	8	0.29
Fibrous glass		
Round	4	0.14
Rectangular	8	0.29

This Table does not contain any values for unsealed ducting - evidently because the predicted leakage rates are far too high.

Table 3A : Recommended Duct Seal Levelsa (SMACNA)

	Duct Type			
	Supply			
Duct Location	**≤500 Pa**	**>500 Pa**	**Exhaust**	**Return**
Outdoors	A	A	A	A
Unconditioned spaces	B	A	B	B
Conditioned spaces (concealed ductwork)	C	B	B	C
Conditioned spaces (exposed ductwork)	A	A	B	B

Table 3B : Duct Seal Levels (SMACNA)

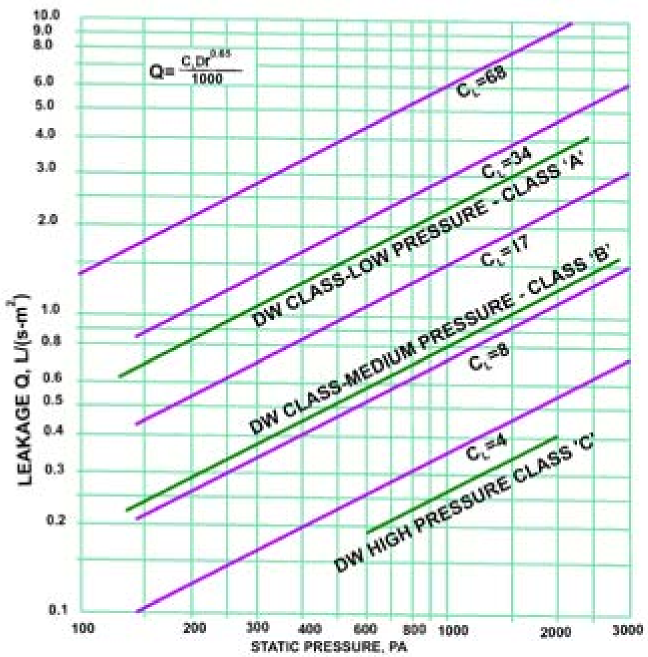
Seal Level	**Sealing Requirementsa**
A	All transverse joints, longitudinal seams and duct wall penetrations
B	All transverse joints and longitudinal seams
C	Transverse joints only

[a] Transverse joints are connections of two ducts or fitting elements oriented perpendicular to flow. Longitudinal seams are joints oriented in the direction of airflow. Duct wall penetrations are

openings made by screws, non-self-sealing fasteners, pipe, tubing, rods, and wire. Round and flat oval spiral lock seams need not be sealed prior to assembly but may be coated after assembly to reduce leakage. All other connections are considered transverse joints, including but not limited to spin-ins, taps and other branch connections, access doorframes, and duct connection to equipment.

DW & SMACNA compared

We are now in a position to juxtapose and compare DW & SMACNA Standards as shown in **Table 4**. This comparison is shown graphically in **Figure 2**. It will be readily seen that DW's Class A & Class C ductwork are tighter than the corresponding SMACNA classes C_L34 & C_L4



SMACNA & DW COMPARED

Figure 2

Table 4 : Comparision of DW & SMACNA

Class		**Pressure Classification – Pa**	**Leakage @ 250 Pa**		**Remarks**
DW	Equivalent. SMACNA		Equivalent. SMACNA	DW	
A	C_L34	250	1.3	0.95	DW Class A is more stringent
B	C_L8	1000	0.72	0.8	SMACNA C^L8 is more stringent
C	C_L4	2000	0.55	0.41	DW Class C is more

stringent

Table 5 : Leakage as Percentage of Airflowa,b (SMACNA)

Leakage Class	System leakage l/s per m² Duct Surface[c]	Static Pressure, Pa 125	250	500	750	1000	1500
68	10	15	24	38	49	59	77
	12.7	12	19	30	39	47	62
	15	10	16	25	33	39	51
	20	7.7	12	19	25	30	38
	25	6.1	9.6	15	20	24	31
34	10	7.7	12	19	25	30	38
	12.7	6.1	9.6	15	20	24	31
	15	5.1	8.0	13	16	20	26
	20	3.8	6.0	9.4	12	15	19
	25	3.1	**4.8**	7.5	9.8	12	15
17	10	3.8	6	9.4	12	15	19
	12.7	3.1	4.8	7.5	9.8	12	15
	15	2.6	4.0	6.3	8.2	9.8	13
	20	1.9	3.0	4.7	6.1	7.4	9.6
	25	1.5	2.4	3.8	4.9	5.9	7.7
8	10	1.9	3	4.7	6.1	7.4	9.6
	12.7	1.5	2.4	3.8	4.9	5.9	7.7
	15	1.3	2.0	3.1	4.1	4.9	6.4
	20	1.0	1.5	2.4	3.1	3.7	4.8
	25	0.8	1.2	1.9	2.4	3.0	3.8
4	10	1.0	1.5	2.4	3.1	7.4	4.8
	12.7	0.8	1.2	1.9	2.4	5.9	3.8
	15	0.6	1.0	1.6	2.0	4.9	3.2
	20	0.5	0.8	1.3	1.6	3.7	2.6
	25	0.4	0.6	0.9	1.2	3.0	1.9

1. From HVAC Air Duct Leakage Test Manual (SMACNA 1985, Appendix A).
2. Percentage applies to the airflow entering a section of duct operating at an assumed pressure equal to the average of the upstream and downstream pressures.
3. The ratios in this column are typical of fan volumetric flow rate divided by total system surface. Portions of the systems may vary from these averages.

Leakage as percent of airflow

The designer understandably – finds it convenient to think of leakage values as percent of system flow also. This is presented in **Table 5**. In this table, percent leakage is related to leakage class, system flow rate in terms of l/s per sqm of ducting and the static pressure.

The table and the underlying concepts are best understood by looking at an example.

Consider a 60 TR Plant for which the following typical values can be assumed :

Supply air flow rate – 13640 l/s

Supply air ducting area – 555 sqm

System - l/s / sqm – 13640 ÷ 555 = 24.58 l/s/ sqm.

From **Table 5** read, leakage as 4.8% of air flow at the intersection of system l/s / sqm of 25 at a static pressure of 250 pa.

Now consider the effect of ducting the return air also.

Return Air duct area – 665 sqm

Total duct area – 1220 sqm

System - l/s / sqm – 13640 ÷ 1220 = 11.18 l/s / sqm.

This is the same thing as saying that for the same flow rate, the leakage increases as the area of ducting. The larger the area of ducting (for the same flow rate), the tighter it needs to be to stay within a stipulated maximum permissible leakage rate – whether in terms of l/s per sqm or per cent of air flow.

Next Issue : *Part 2 leakage budget & AHU leakagev*