Topical session: Ductwork Air Tightness: Ongoing works in some European countries.

Duct leakage testing in Portugal, a consulting engineer view and experience

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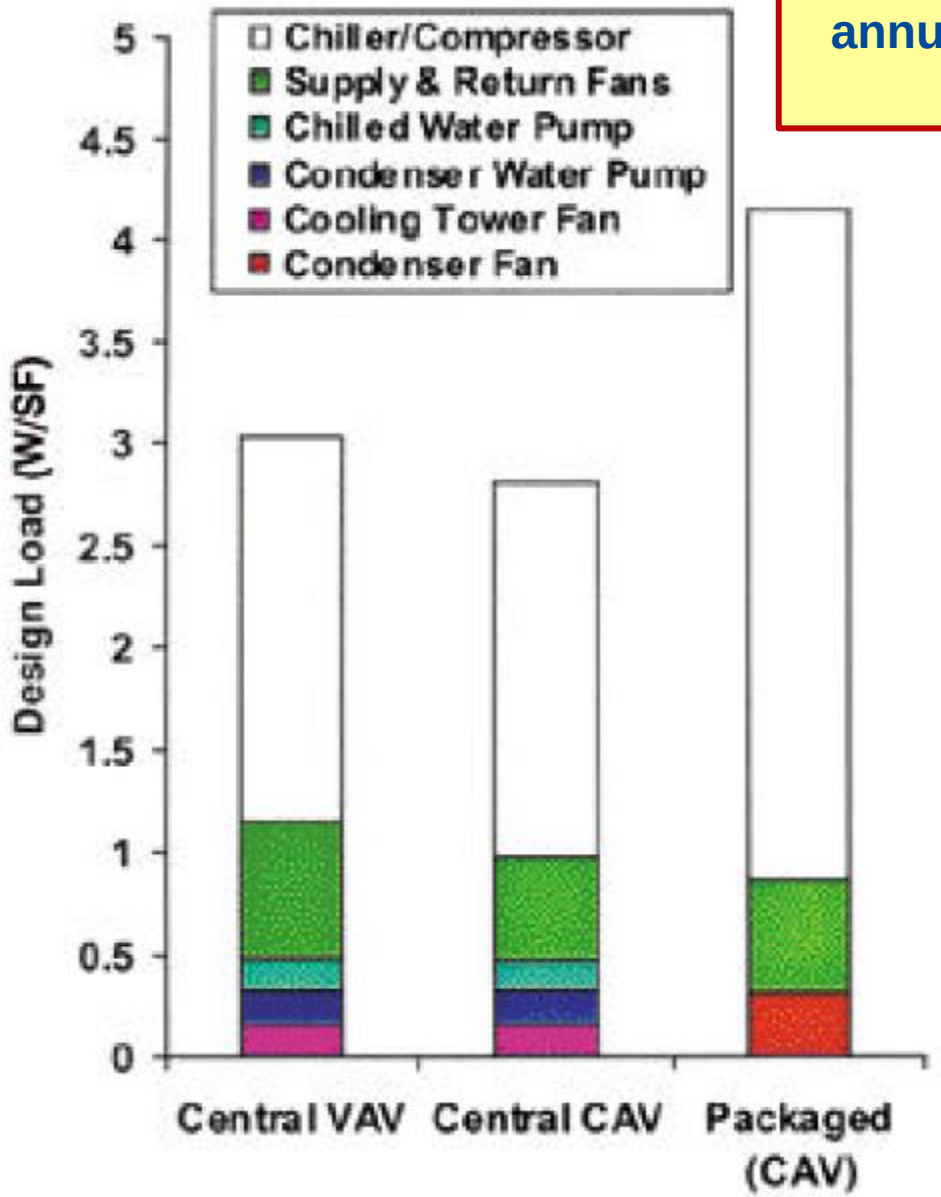
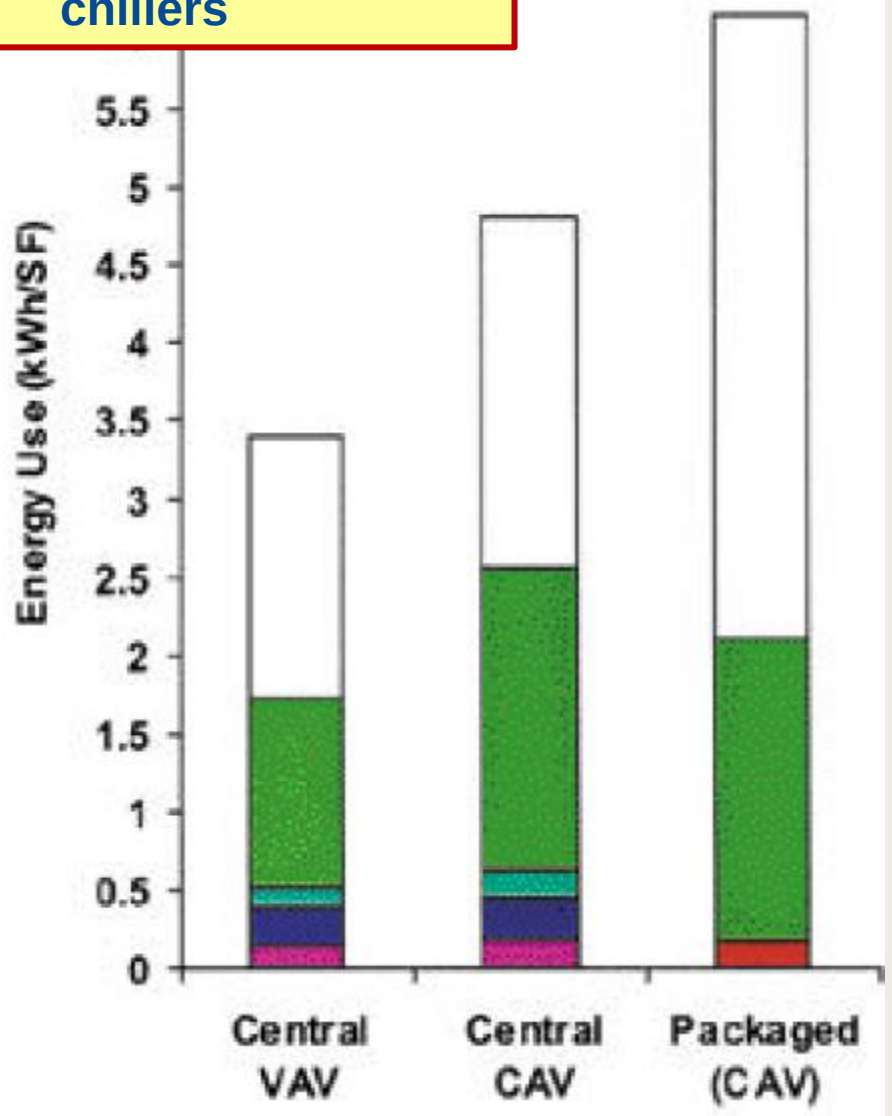
Learning objectives:

- Ductwork air tightness importance;
- Values of air leakage rates measured in existing air duct systems;
- Ductwork air leakage testing, technical standards;
- Ductwork air leakage testing, legal requirements;
- Ductwork air leakage testing, practice;
- Conclusions and recommendations.

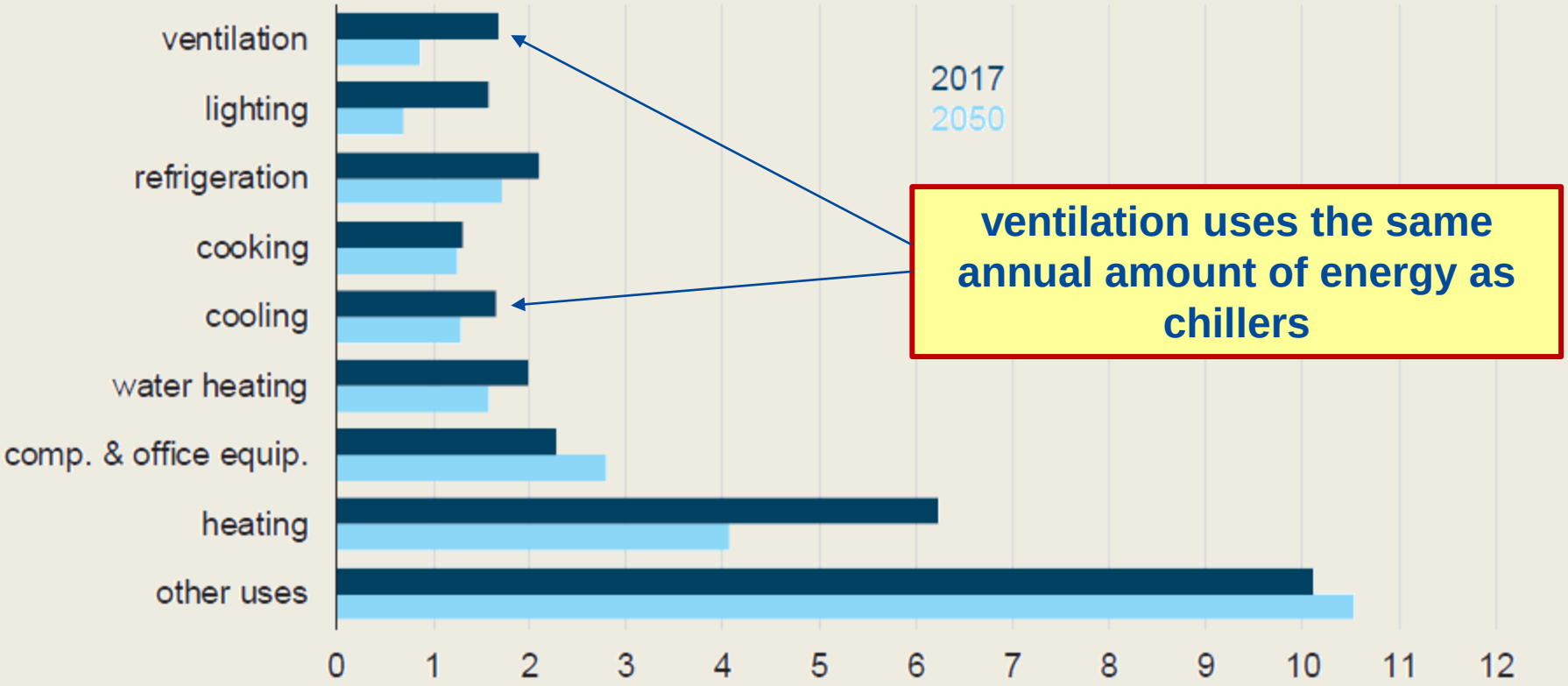
fans&pumps use the same annual amount of energy as chillers





*USA Department of Energy (DOE). Annual Energy Outlook **1998**.*

Use of purchased electricity per square foot of commercial floorspace
thousand kilowatthours per billion square feet



*USA Department of Energy (DOE). Annual Energy Outlook **2018**.*

ASHRAE Handbook – System&Equipment

- *Depending on HVAC system type, the relationship between fan power and airflow lays between a quadratic and cubic function (Sherman and Wray 2010).*
- *Filed measurements show that a system with 10% leakage, uses 25 to 35% more fan energy tan an system with 2,5% leakage, (Diamond et al. 2003).*
- *Increasing AHU airflow to compensate for airflow leakage significantly increases fan power usage.*

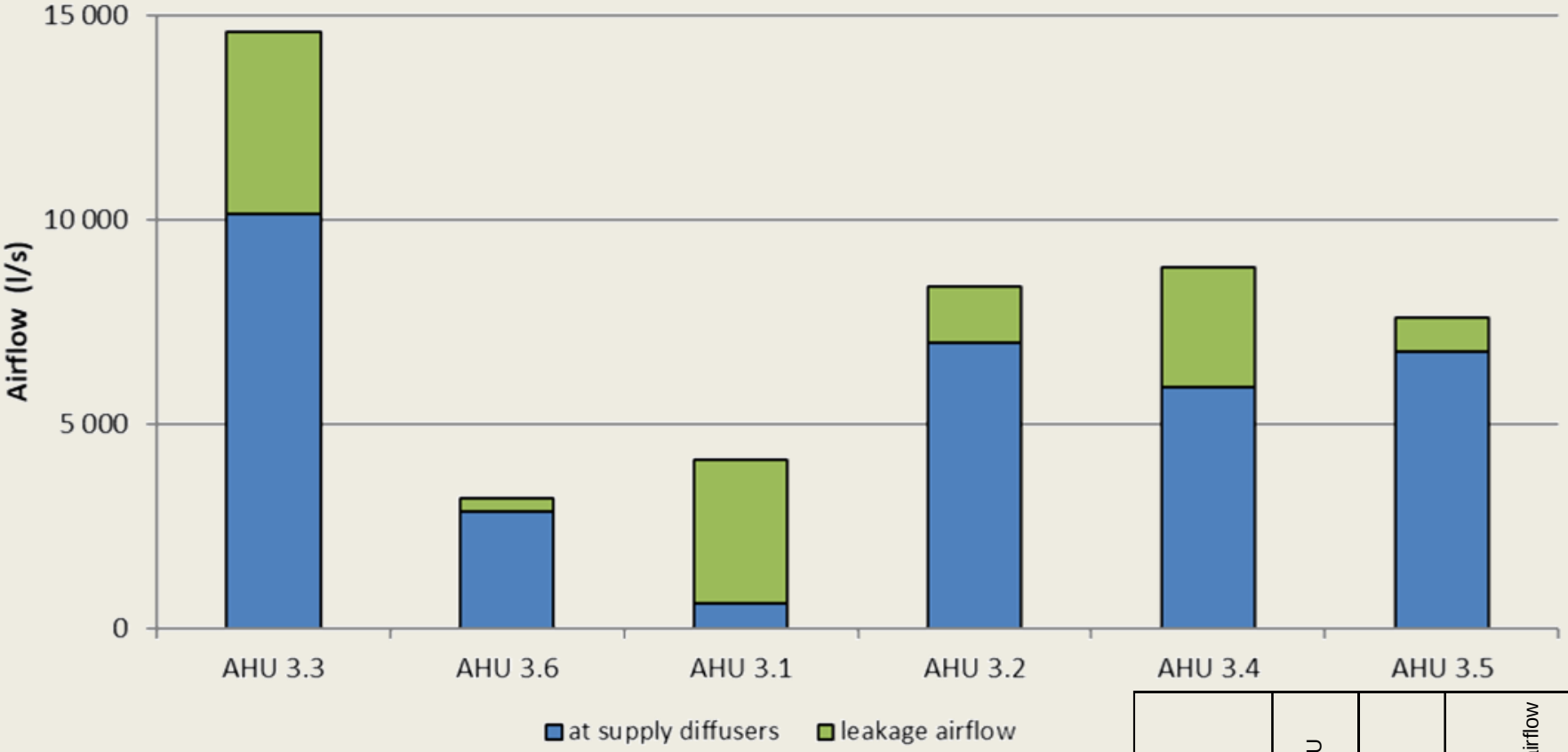
ASHRAE Handbook – System&Equipment, Chapter 19 – Duct Construction.

Required fan energy to deliver 1.000 W sensible cooling using air

ref.	description	symbol	value	units	formula/source
1.	air density	ρ	1,2	kg/m3	
2.	air specific heat	cp	1,0	kJ/kg.K	
3.	delta T	ΔT	10	K	typical value
4.	cooling per (m^3/s)	cap	12	kW	1 (m^3/s) . ρ . cp . ΔT
5.	airflow per 1 kW cooling	q	0,083	m^3/s	1 / cap
6.	fan pressure	P	1.500	Pa	typical value (SUP + ETA)
7.	fan efficincye (global)	η	0,58	-	ηv x ηt x ηm
7.1	fam mechanical efficiency	ηv	0,68	-	big centrifugal fan
7.2	VFD efficicincy	ηc	0,95	-	typical value
7.3	motor efficincy	ηm	0,90	-	big motor
8.	**Fan power**	**E**	**215**	**W**	q (m^3/s) . P(Pa) / η

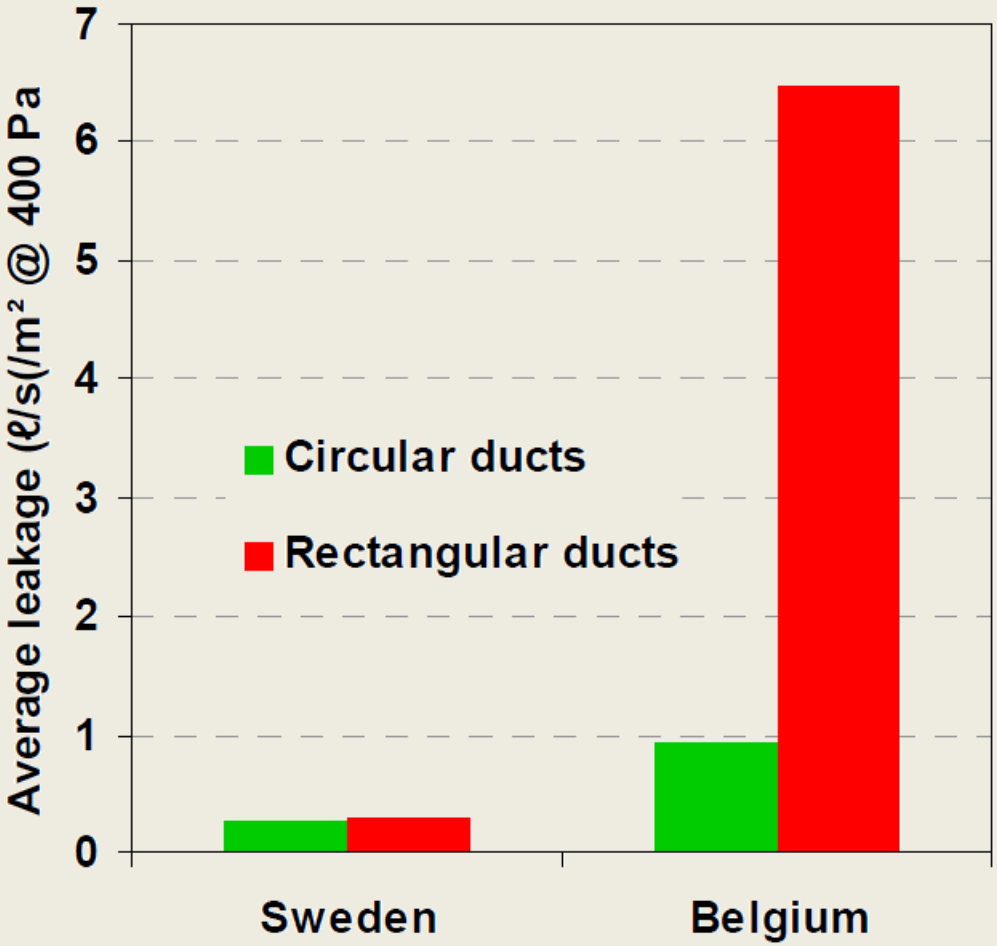
To deliver 1.000W of sensible cooling, using air, with a zero leakage ductwork, fans use around 215W of electrical energy, this fan energy adds to the sensible cooling energy.

Measured airflows in existing building. At the AHU and in terminal diffusers.



AHU	at the AHU	at supply diffusers	leakage airflow	
	l/s	l/s	l/s	%
AHU 3.3	14 601	10 136	4 465	31%
AHU 3.6	3 175	2 873	303	10%
AHU 3.1	4 120	602	3 518	85%
AHU 3.2	8 369	6 969	1 400	17%
AHU 3.4	8 837	5 913	2 924	33%
AHU 3.5	7 589	6 772	817	11%

Existing ductwork systems can have huge leakage rates



In Belgium, where there are no regulatory requirements for ductwork thightness, neither mandatory leakage testing, square section ductwork have a very high lekage rate.

A big improvement in ductwork air thightness can be achieved by the adoption of circular ducts.

(P187 report extract)

ASIEPI Project. P187. Duct system air leakage. How Scandinavia tackled the problem. 2009.

"In practice a whole different theory applies ☺ "

When, in practice, real world systems move away from ideal conditions unexpected results happen, compromising the established objectives, regarding efficiency and effectiveness.

To have efficient buildings, with nearly zero energy usage (NZEB), we need to have air ductworks with a very high tightness level.

EN 12237: 2003 - Ductwork strength and leakage of circular sheet metal ducts

4 Classification

The air tightness classes shall be as specified in Table 2.

Table 2 – Ductwork Classification

Air tightness class	Static pressure limit (p_s) Pa		Air leakage limit (f_{max}) $m^3 \cdot s^{-1} m^{-2}$
	Positive	Negative	
A	500	500	$0{,}027 \cdot p_t^{0{,}65} \cdot 10^{-3}$
B	1 000	750	$0{,}009 \cdot p_t^{0{,}65} \cdot 10^{-3}$
C	2 000	750	$0{,}003 \cdot p_t^{0{,}65} \cdot 10^{-3}$
D [a]	2 000	750	$0{,}001 \cdot p_t^{0{,}65} \cdot 10^{-3}$

[a] Ductwork for special applications.

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Table 3 - Leakage as Percentage of Flow

Class	Q_{fan}/A_S	Static Pressure, Pa								
L/s per 10 m^2 per $Pa^{0.65}$	*L/(s · m2) Duct Surface Area*	125	250	500	750	1000	1250	1500	2000	<>
K (0.81)	10.2	18,4	28,9	45,3	58,9	71,1	82,2	92,5	100	100
	12.7	14,7	23,1	36,2	47,2	56,8	65,7	74	89,2	100
	15.2	12,3	19,2	30,2	39,3	47,4	54,8	61,7	74,3	85,9
	20.3	9,2	14,4	22,6	29,5	35,5	41,1	46,2	55,8	64,5
	25.4	7,4	11,5	18,1	33,6	28,4	32,9	37	44,6	51,6
A (0.27)	10.2	6,1	9,6	15,1	19,6	23,7	27,4	30,8	37,2	43
	12.7	4,9	7,7	12,1	15,7	18,9	21	24,7	29,7	34,4
	15.2	4,1	6,4	10,1	13,1	15,8	18,3	20,6	24,8	28,6
	20.3	3,1	4,8	7,5	9,8	11,8	13,7	15,4	18,6	21,5
	25.4	2,5	3,8	6	7,9	9,5	11	12,3	14,9	17,2
B (0.09)	10.2	2	3,2	5	6,5	7,9	9,1	10,3	12,4	14,3
	12.7	1,6	2,6	4	5,2	6,3	7,3	8,2	9,9	11,5
	15.2	1,4	2,1	3,4	4,4	5,3	6,1	6,9	8,3	9,5
	20.3	1	1,6	2,5	3,3	3,9	4,6	5,1	6,2	7,2
	25.4	0,8	1,3	2	2,6	3,2	3,7	4,1	5	5,7
C (0.03)	10.2	0,7	1,1	1,7	2,2	2,6	3	3,4	4,1	4,8
	12.7	0,5	0,9	1,3	1,7	2,1	2,4	2,7	3,3	3,8
	15.2	0,5	0,7	1,1	1,5	1,8	2	2,3	2,8	3,2
	20.3	0,3	0,5	0,8	1,1	1,3	1,5	1,7	2,1	2,4
	25.4	0,3	0,4	0,7	0,9	1,1	1,2	1,4	1,7	1,9
D (0.01)	10.2	0,2	0,4	0,6	0,7	0,9	1	1,1	1,4	1,6
	12.7	0,2	0,2	0,4	0,6	0,7	0,8	0,9	1,1	1,3
	15.2	0,2	0,2	0,4	0,5	0,6	0,7	0,8	0,9	1,1
	20.3	0,1	0,3	0,3	0,4	0,4	0,5	0,6	0,7	0,8
	25.4	0,1	0,1	0,2	0,3	0,4	0,4	0,5	0,6	0,6

*Airtightness classes K and D are not EUROVENT 2/2 (1996) designations, but are used by some countries in Europe.

ASHRAE Handbook – System&Equipment, Chapter 19 – Duct Construction (excluding color formating)

Legal requirements in Portugal

Dispatch (extract)-15793-G/2013. Test and provisional acceptance of systems. Maintenance plan.

- Leakage tests are mandatory except when the construction works contract explicitly excludes them;
- Ductwork must have a leakage rate of less than 1,5 l/s/m^2, when tested at a pressure of 400Pa;
- The sample to be tested shall be, at least, 10% of the ductwork;
- If the test fails a second test covering 20% of the ductwork must be performed;
- If the second test fails, the full ductwork must be tested.

Legal requirements in Portugal

- EN 12237: 2003, Class A, at 400Pa, establishes a leakage airflow limit of 1,33 l/s/m^2;
- **The requirements** of the portuguese law, 1,5 l/s/m^2, when tested at a pressure of 400Pa **are under Class A**;
- The Portuguese law does not refer to the European standard EN 12237: 2003;
- Ductwork leakage tests are mandatory by law since 2006.

Situation in Europe

- In Sweden leakage tests are a normal practice for over three decades.
- In Sweden new ductwork systems, although not mandatory by law, usually comply with lekage class C.
- In most European countries measures are being taken to improve air ductwork leakage performance, following Sweden's example.
- In Portugal leakage testing is mandatory by law since 2006.
- Portuguese legal requirements (1,5 l/s/m^2, at 400Pa) are less demanding than Class A (the less demanding class in the European standard).

Lekage test specification

After static works completion, and before system start-up, the following checks must be done:

- Correct duct work installation according to manufacturers requirements.
- Correct duct work installation according to contractual BIM model.
- Installation of all specified components (balancing dampers, access door, fire dampers, sound attenuators, etc.).

Before connecting all terminal componentes (grilles and diffusers) leakage testing shall be done according to EN 12237.

Leakage test specification

Test shall be done to a representativ part of the ductwork system. For this purpose one system is defined as one AHU and it's associated ductwork. The part to be tested must comply with the following:

- Ductwork surface area of at least 10% of the total system área.
- Ductwork surface area of at least $10m^2$.
- Ductwork surface area compatible with the testing equipment capacity (airflow).
- Ratio "L/A" between the total joints lenght, L(m), and the total duct area to be tested, A(m^2),between 1 m^{-1} e 1,5 m^{-1}.

Leakage test specification

- The part of the ductwork to be tested must representative of the system, i.e., must include typical components namely;
  - Terminal branches of smaller diameter.
  - Main branches of bigger diameter.
  - Tees and branch tap offs.
  - Bends.
  - Balancing dampers.
  - Fire dampers.
  - etc.

Leakage test specification

- If na higher than specified leakage airflow is measured the following must be done:
  - Leakage areas identified using coloured smoke.
  - Leakage areas corrected/sealed.
  - Repeat leakage test on the same part of the system.
  - Repeat teh leakage test in a second part of the system with a similar area as the first tested part.
  - If the second tested part still shows excessive leakage, the full ductwork system must be tested.

Leakage test equipment

Test report ID# 1524

Leakage test report of air ducts in accordance to EN12237, EN1507 and EN12599

Test object information

Surface area	119.4	m²
Tightness cl.	B	
Adapter type	W/o	
Rate factor	91/s	l/m²
Pressure	400	Pa
Testpressure	406	Pa
Leakage rate	18.43	l/s
Endurance	300	sec
limit at A	159.92	l/s
limit at B	53.30	l/s
limit at C	17.76	l/s
limit at D	5.92	l/s

Result:
Test object OK

Date: ____.____._____

Time: ____:____

Signature.

Ductwork air leakage testing, practice in Portugal

The practicing experience in our company, on design and field inspection works, shows that:

- When forced to comply with the design specification, of ductwork leakage testing according to EN 12237: 2003, achieving a minimum performance of Class B, the reaction of the contactor is always surprise and lack of experience in performing the test;
- We need to guide the contractor on the test procedures;
- We have never worked with a contractor that owned the leakage test equipment. They either rent it or propose a test with a custom made equipment;
- Our general feeling, based on conversations with other professionals, in the market, is that very few leakage tests are performed.

Ductwork air leakage testing, practice in Portugal

- Class B ductwork can easily be achieved in ductworks of circular cross section if adequate installation procedures are met and adequate duct joining accessories are applied;
- The test itself takes around 10 minutes to perform, after correctly preparing the duct sample to test;
- Avoiding ovalization due to incorrect handling of ducts, namely transport or storage of straight duct sections in the horizontal position, stacked or not, without adequate rigid circular end caps. When rigid end caps are not used, to prevent ovalization, straight ducts must be transported and stored in the vertical position;
- The first part of the installed ductwork must be immediately tested to identify and correct possible inadequate installation procedures that, otherwise, would be repeated in subsequent parts of the ductwork

Ductwork air leakage testing, practice in Portugal

When using 3D BIM models of the ductwork, with adequate level od detail, prefabrication of ductwork can be done, increasing quality of the finished job and decreasing installation time. Using this method, in a recent job, the majority of the tested samples reached leakage class C, and, in one of the last duct samples even reached class D.

Ductwork air leakage testing in Portugal. Survey.

In order to have a more objective information on ductwork air leakage testing, we performed an **online survey** on the biggest contractors in the market. The survey sample was:

- 15 contractors;
- Total of nearly 180 M€ of sales (2016) for the 15 contractors;
- Answers are anonymous;
- Only 11 contractors answered the survey questions.

Ductwork air leakage testing in Portugal. Survey.

How many ductwork air leakage tests has your company performed in the last five years?

range	answers
0	0
< 5	1
6 to 10	0
11 to 50	6
51 to 100	2
> 100	2

Ductwork air leakage testing in Portugal. Survey.

What kind of test equipment do you use?

type	answers
custom made	2
test equipment conceived for leakage testing, rented	5
test equipment conceived for leakage testing, owned	4

Ductwork air leakage testing in Portugal. Survey.

The survey results confirms that leakage tests, in Portugal, are seldom performed, since:

- 64% of contractors performed, yearly, from 1 to 10 leakage tests;
- 82% of contractors performed, on average, at most, 20 leakage tests per year;
- Only four contractors own leakage test equipment, which confirms that the remainder seven performed a small number of tests per year.

Conclusions and recommendations.

- Duct leakage can be relevant, undermining efficiency and effectiveness of HVAC systems.
- Duct leakage testing is a simple procedure and should be systematically done preventing leaky duct systems.
- The use of BIM procedures, and duct prefabrication, increases the final quality of ductwork systems and should be strongly promoted.
- Ductwork should be built to comply, at least, to leakage class B, according to EN-12237;

Conclusions and recommendations.

- Legal requirements should be updated and merely state a minimum leakage class, according to the European standard EN 12237;
- Although mandatory by law, leakage tests are not performed in most installations;
- Inspections or other procedures should be implemented in order to ensure that all installations comply with the law requirements;
- Actions should be taken to increase awareness of the importance of tight ductwork systems and of leakage test procedures.

References

- EN 12237: 2003 – Ductwork strength and leakage of circular sheet metal ducts;
- EN 1507: 2006 – Sheet metal air ducts with rectangular section - Requirements for strength and leakage;
- EN 13403: 2003 - Non-metallic ducts - Ductwork made from insulation ductboards;
- ANSI/ASHRAE 215-2018 – Method of test to determine leakage of operating HVAC air distribution systems;
- ANSI/ASHRAE 90.1- 2016 – Energy Standard for Buildings Except Low-Rise Residential Building - 6.4.4.2 – Ductwork and plenum leakage;

Questions?

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