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AEREAULIC PLANT PRESSURE LOSSES AND PLANT SIZING

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INTRODUCTION

Which is the scope of an air system installed in an environment? Full-air and primary air systems.

FULL-AIR SYSTEMS



- Fulfillment of IAQ and thermal requirements
- No coupling with other systems
- High air volumes to be treated
 - ➔ Higher energy, higher noise
- High volumes required (system)
- Challenging system control

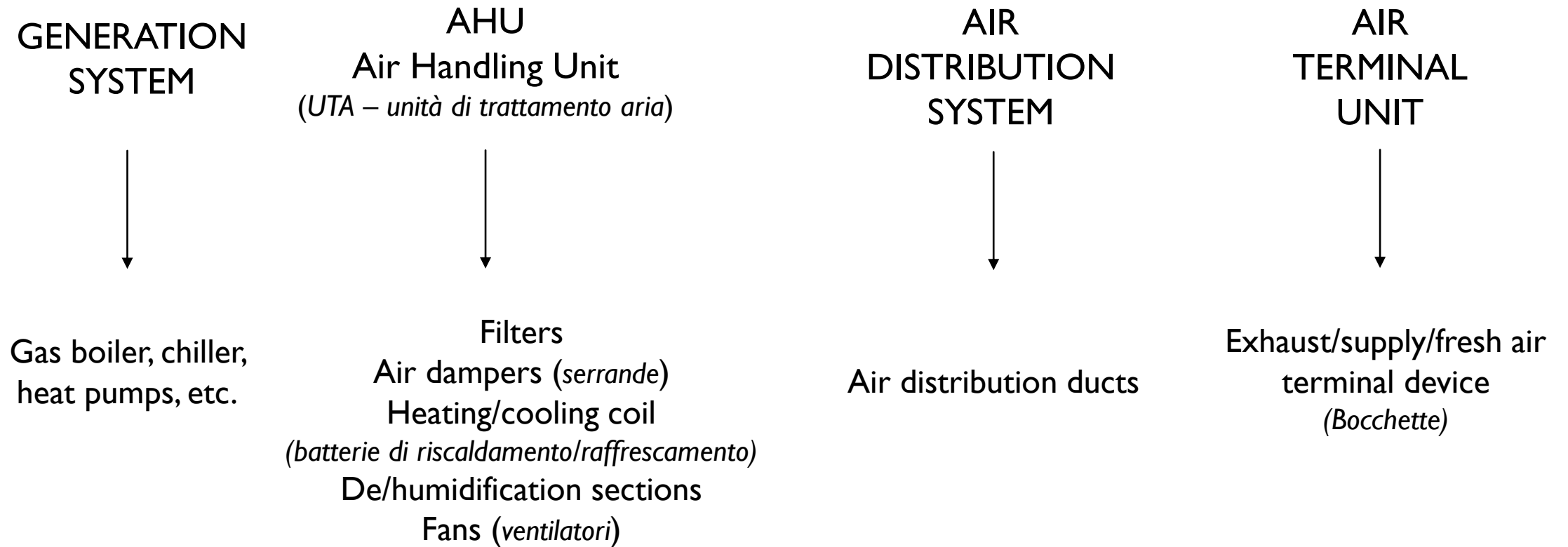
PRIMARY AIR SYSTEMS



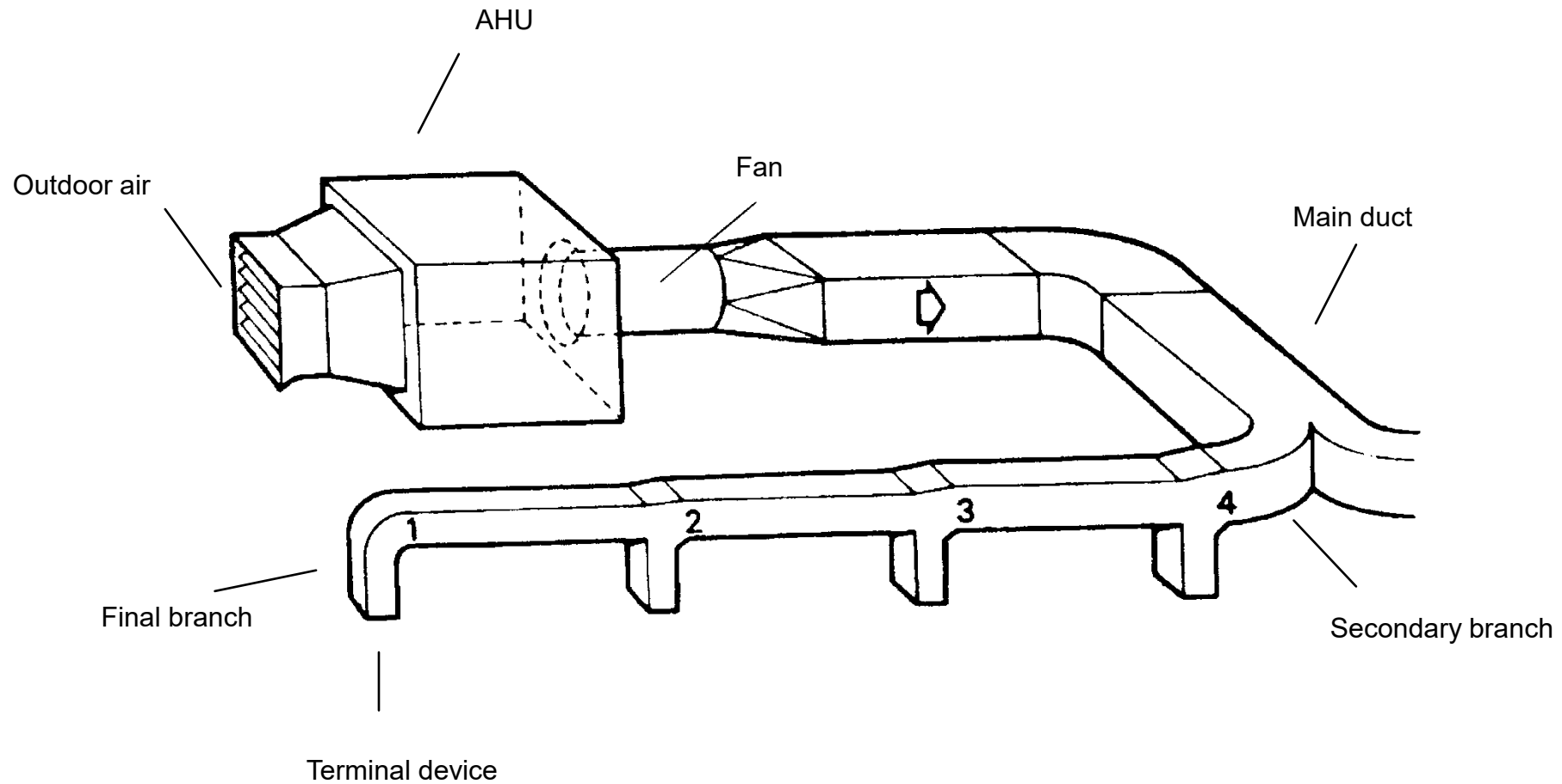
- Low air volumes to be treated
- Presence of an alternative heating/cooling system
- More compact systems
- Split IAQ and thermal requirements control

INTRODUCTION

Main elements of a full-air conditioning system



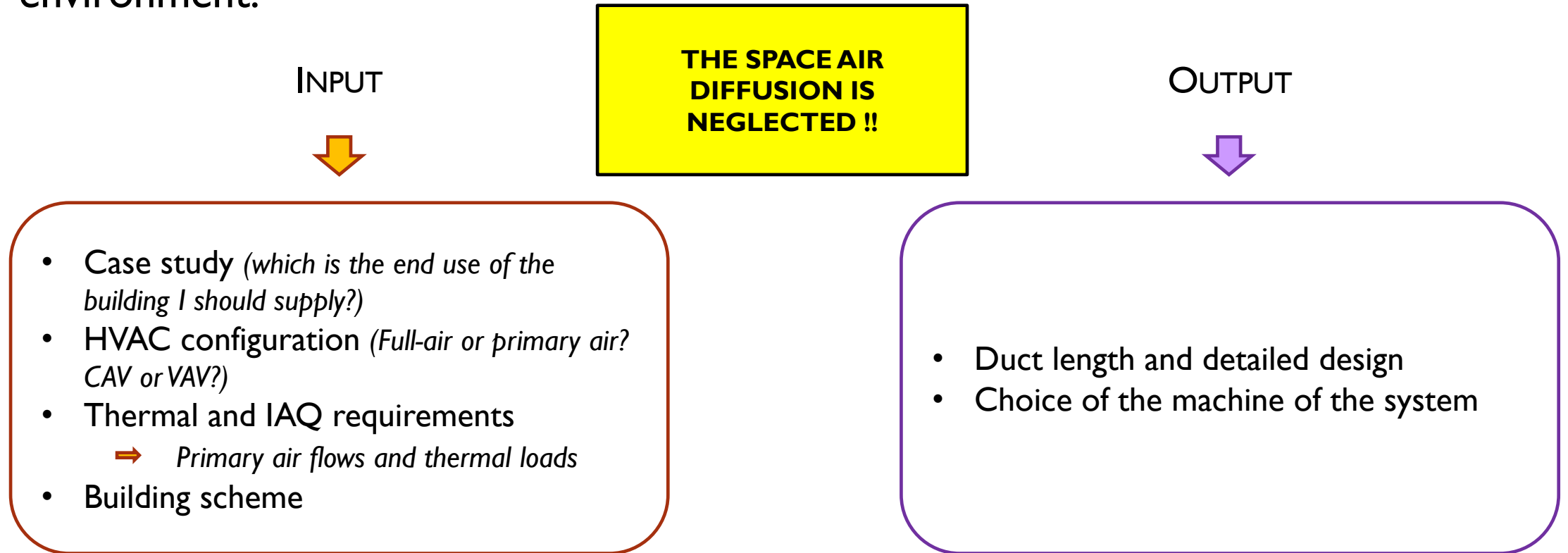
INTRODUCTION



SIZING AN AIR SYSTEM

What does it mean to size an air system?

It consists of the definition of the system layout and the choice of components for the proper supply of the air flow to fulfill the thermal and IAQ requirements of the environment.



SIZING AN AIR SYSTEM

What does it mean to size an air system?

ASHRAE Handbook of Fundamentals (english)
Manuale del termotecnico – Nicola Rossi (italian)

1. Define the **thermal loads** (Q_i - [W]) of the building in the heating and cooling season and the **IAQ requirements** ($V_{req,i}$ - [m³/h])
2. Define the **air flow rate** to supply to each environment ($V_{prog,i}$ - [m³/h])
3. Chose the **vents** for each air inlet and outlet
4. Sketch the system on the case study (main ducts, risers, branches)
5. Determine the airflow in each part of the system, starting from the outlets and acting backwards
6. Set the in-duct velocity, define the ducts section (shape and dimension) and their length
7. Calculate the **pressure losses**
8. Choose the appropriate **machine** (adequate flowrate and enough prevalence!)

1 - IAQ REQUIREMENTS: THE VENTILATION RATE

STANDARD EN 16798-1 (ANNEX B)

- Definition of **fresh air** flow rates to size the ventilation system;
- Minimum flow rate: 4 L/(s person).

Category	Level of expectation	
I	High	⇒ High level for specific cases (elderly, sick people)
II	Medium	⇒ Medium/average value
III	Moderate	⇒ Lowest admissible value
IV	Low	⇒ To be avoided. Tolerated for limited time

For healthy reasons. **the minimum flow rate** in occupied rooms **should never go below 4 L/(s px)**

$$4 \text{ L/(s px)} = 14.4 \text{ m}^3\text{/(h px)}$$

1 - THERMAL REQUIREMENTS: HEATING AND COOLING LOADS

HEATING (q_H) AND COOLING (q_C) LOADS
CALCULATED ACCORDING TO THE METHODS
SHOWN IN THE PREVIOUS LECTURES

How to convert a **load** to an **air flow**?

STEP 1: Define environment setpoint

WINTER		SUMMER	
Humidity φ_A [%]	Temperature t_A [°C]	Humidity φ_A [%]	Temperature t_A [°C]
50	20-21	50	26

STEP 2: Define the limit supply temperature (t_s)

WINTER
 $|t_s - t_A| \leq 12 \div 20 \text{ } ^\circ\text{C}$

SUMMER
 $|t_A - t_s| \leq 8 \div 12 \text{ } ^\circ\text{C}$

STEP 3: Calculate the air flow rates (V_{load}) according to:

$$q_i = \rho_{air} V_{load} c_p (|t_s - t_A|)$$

NOT NECESSARILY
FRESH AIR!!

2 - DEFINITION OF THE DESIGN FLOW RATE

The design flow rate (V_{prog}) is the maximum value of the flows calculated in all the previous steps:

$$V_{prog} = \max(V_{req}; V_{load,H}; V_{load,C})$$

EXAMPLE: Case study with 3 (j) rooms

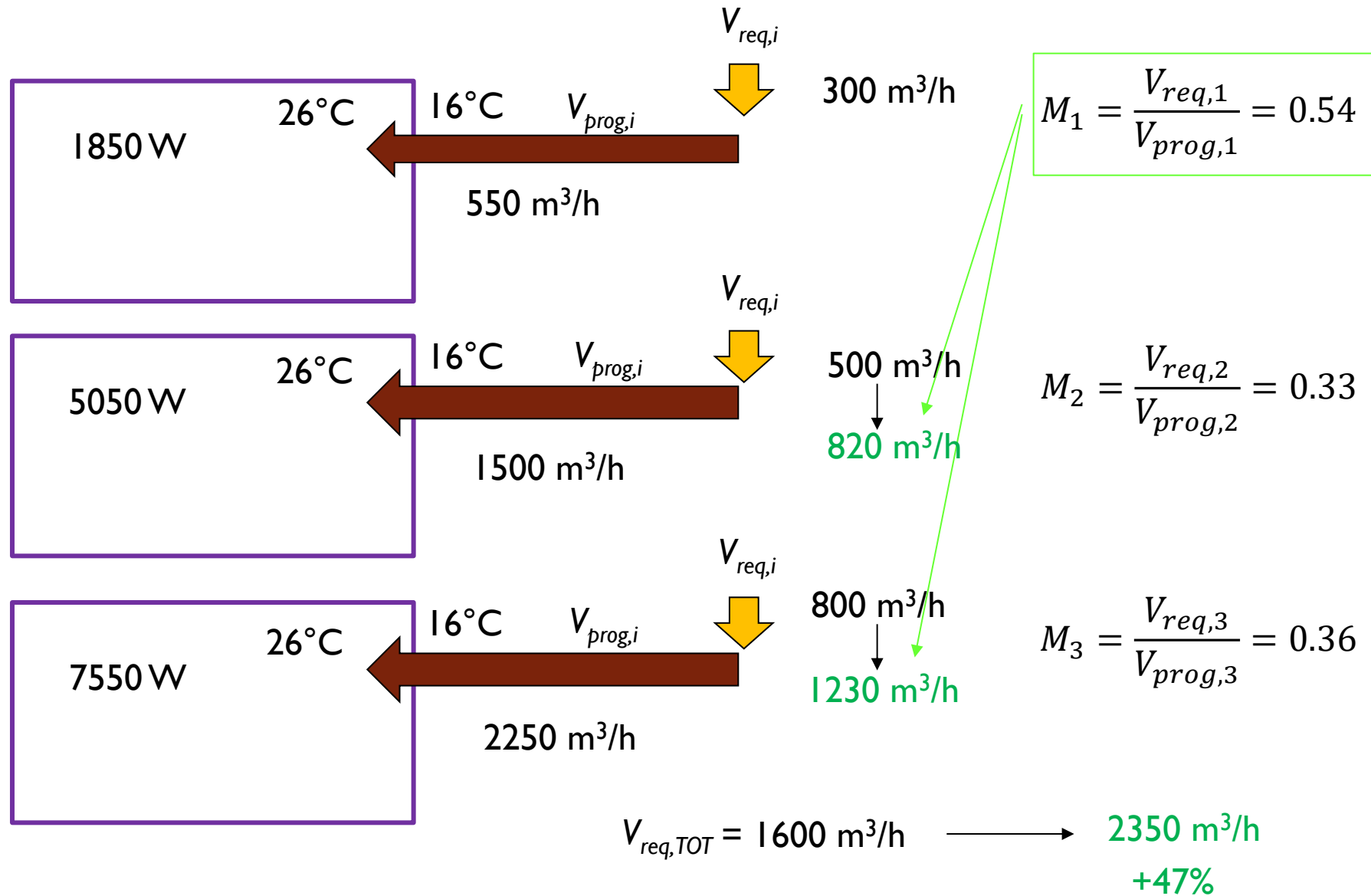
$$V_{prog,TOT} = \sum_j V_{prog,j}$$

The share of the **fresh air** over the **total** should be calculated room-by-room to determine the ratio (M). To simplify the sizing process, the maximum M -value will be assumed for all the environments

$$M_j = \frac{V_{req,j}}{V_{prog,j}}$$

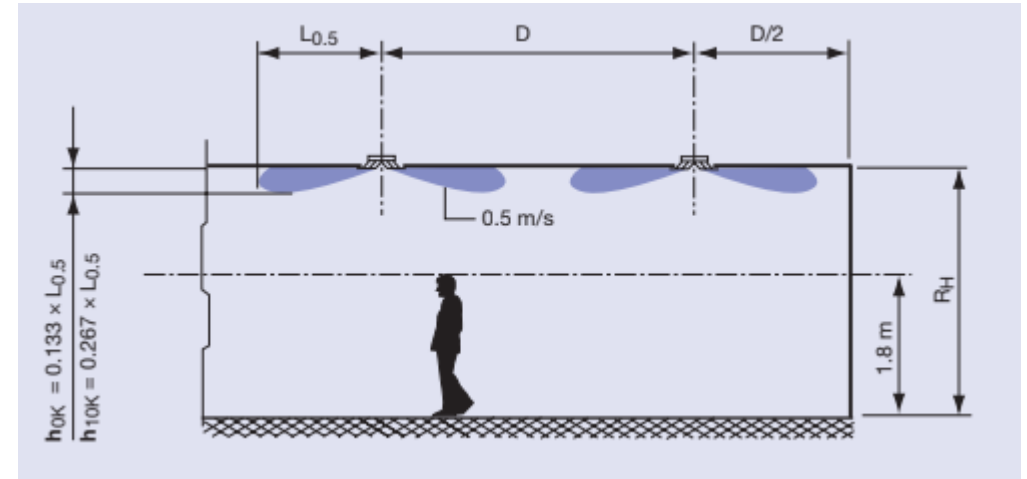
$$M_{TOT} = \max_j(M_j)$$

2 - DEFINITION OF THE DESIGN FLOW RATE - EXAMPLE

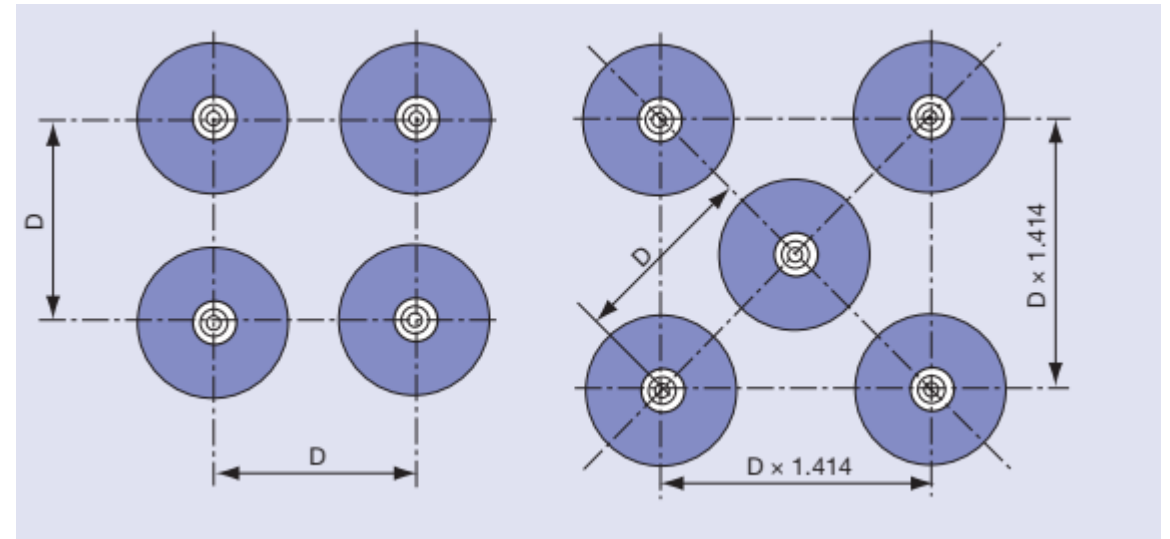
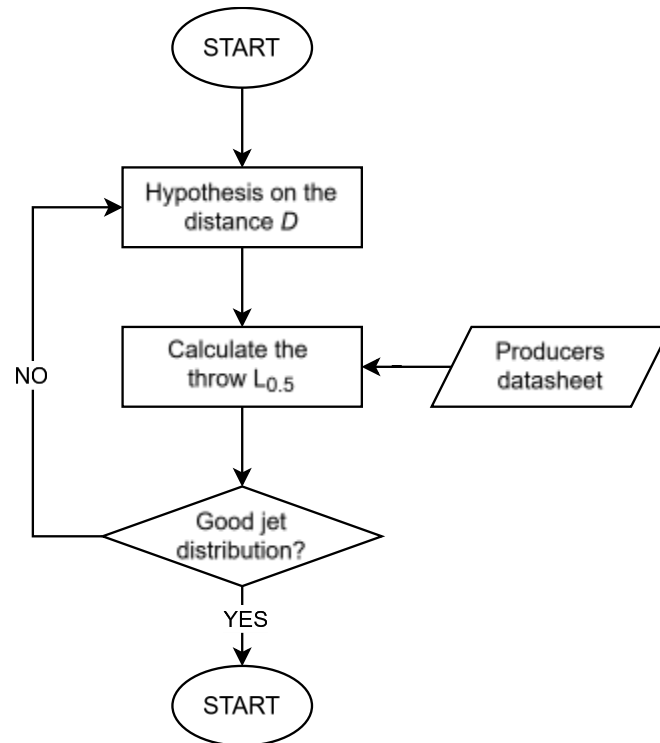


3 - VENT CHOICE

The choice of the vents starts from the discretization of the room into a “grid” where the vents can be placed. According to the vent shape, different grids can be created.



The choice of the vent is iterative!



CHECK AIR VELOCITY!

Air velocity [m/s]

	Main ducts	Secondary ducts	Air inlet	Air outlet
Residential	4 - 5	3 - 4	2 - 3	1,5 - 2
Public buildings, schools	5 - 8	4 - 6	3 - 5	2 - 3
Offices	8 - 11	6 - 8	5 - 8	3 - 4
Industrial buildings	8 - 15	6 - 10	5 - 10	4 - 10

The diagram illustrates an Air Handling Unit (AHU) system. Air flows from the AHU through main ducts, then through secondary ducts, into air inlets, and finally through air outlets. The flow is indicated by blue arrows for supply and red arrows for return. The table above provides the recommended air velocity ranges for each component in different building types.

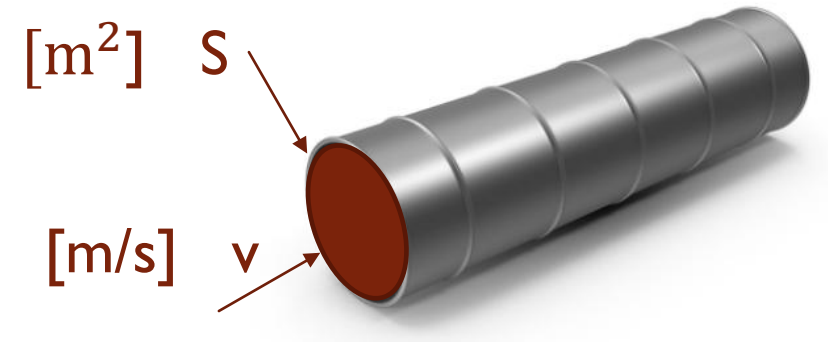
6 - AIR VELOCITY AND DUCT SHAPE SELECTION

The two widespread ducts are the **round** and **rectangular** ductworks.

- When there are no space constraints, round ductwork is preferable: they have lower mass, lower perimeter, the flow inside is more regular, they rarely have problems with rumble and present an excellent resistance to low-frequency break-out noise.
- When the space constraint is important, you can find in the literature graphs for the choice of the duct shape, according to the available space, the design flow rate and the acceptable pressure losses. (ASHRAE Handbook of Fundamentals, Chapter 21: Duct design)

The ducts' section should be chosen (in each branch) considering the in-duct air velocity limits for the acoustic requirements.

$$[\text{m}^3/\text{s}] \quad V = S \cdot v$$



7 - PRESSURE DROP

To guarantee the fluid motion inside a duct, a pressure difference between inlet and outlet sections must be supplied by a fan, which should fill the fluid pressure losses:

$$\Delta P = \Delta P_k + \Delta P_p + \Delta P_f$$

ΔP_k : kinetic energy variation

ΔP_p : potential energy variation

ΔP_f : friction pressure loss


$$\Delta P_f = \Delta P_{f,C} + \Delta P_{f,L}$$

Friction pressure loss (or pressure loss) is due to two components:

- Localized pressure drop: occurs whenever flow meets discontinuity in its path
- Continuous pressure drop: occurs because of fluid-wall interactions

7 - CONTINUOUS PRESSURE DROP

$$\Delta P_{f,c} = f \frac{\rho v^2 L}{2 D} \quad [\text{Pa}]$$

- ρ : fluid density $\left[\frac{\text{kg}}{\text{m}^3}\right]$
- v : mean fluid velocity $\left[\frac{\text{m}}{\text{s}}\right]$
- f : friction factor [-]
- L : pipe length [m]
- D : pipe diameter [m]

The friction factor f is determined either analytically or via appropriate diagrams.

It depends on:

- Fluid density, viscosity and velocity → Reynolds Number (Re)
- Duct diameter and roughness

7 - CONTINUOUS PRESSURE DROP

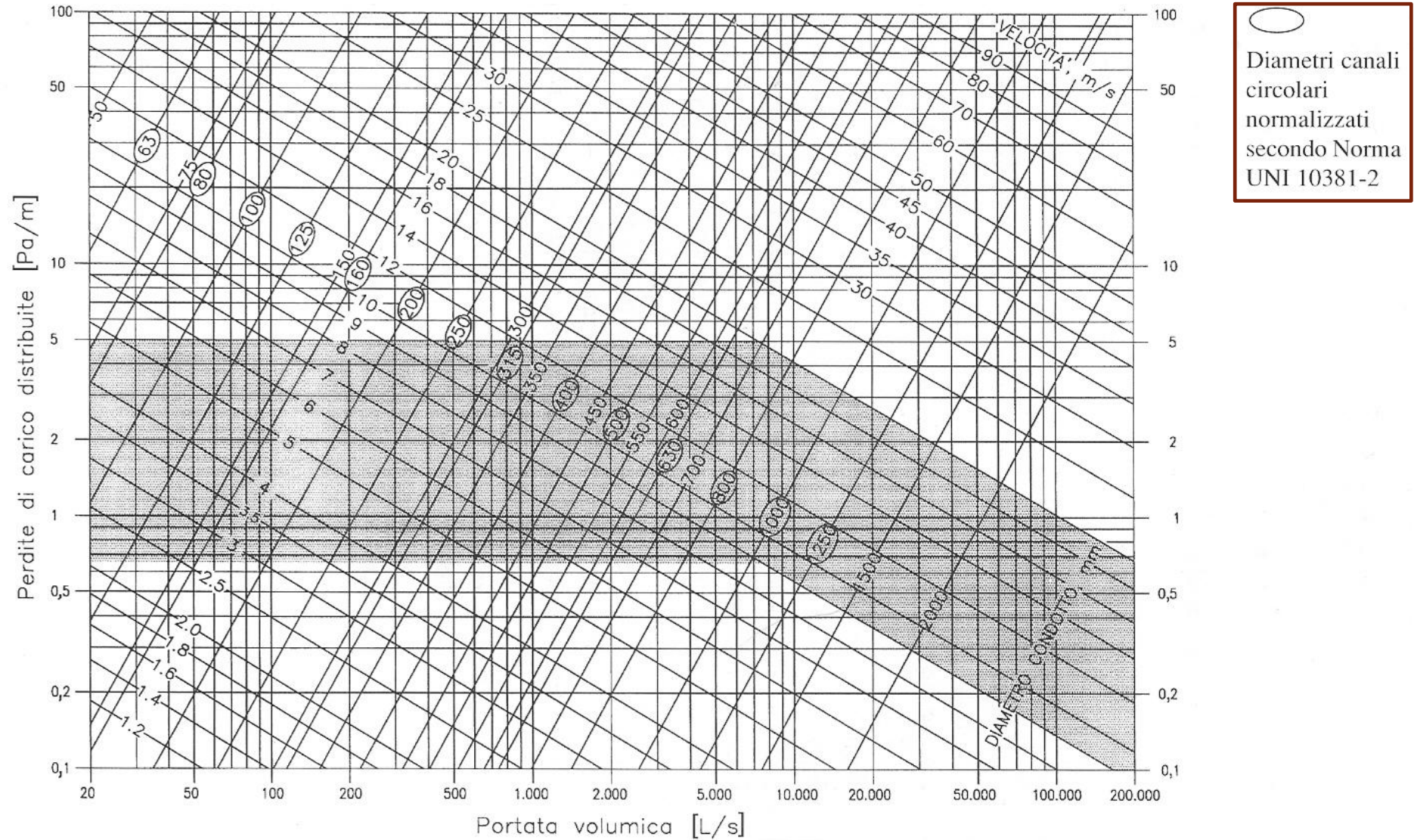


Fig. 1 - Abaco per la determinazione delle perdite di carico distribuite (massa volumica $1,204 \text{ kg/m}^3$, rugosità $\varepsilon = 0,09 \text{ mm}$)

7 - LOCALIZED PRESSURE DROP

$$\Delta P_{f,L} = \xi \frac{\rho v^2}{2} \quad [\text{Pa}]$$


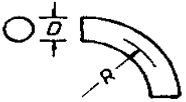
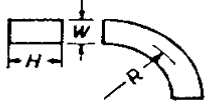
- ρ : fluid density $\left[\frac{\text{kg}}{\text{m}^3}\right]$

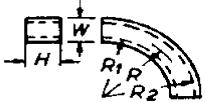



- v : mean fluid velocity $\left[\frac{\text{m}}{\text{s}}\right]$

- ξ : localized pressure drop coefficient [-]

ξ coefficient is established on the basis of the particular type of loss, usually tabulated for the most common circuit elements (curves, branches etc.)

7 - LOCALIZED PRESSURE DROP - 1

TIPO	FIGURA	CARATTERISTICHE	PERDITA DI PRESSIONE			
			C	L/D	L/W	
CURVA A N°		RETTANGOLARE O ROTONDA; CON O SENZA ALETTE	N°/90 x PERDITA DI UNA CURVA UGUALE A 90°			
CURVA A 90° SEZIONE ROTONDA		GOMITO	1,30	65		
		R/D = 0,5	0,90			
		0,75	0,45	23		
		1,0	0,33	17		
		1,5	0,24	12		
		2,0	0,19	10		
CURVA A 90° SEZIONE RETTANGOLARE		H/W	R/W			
		0,25	GOMITO	1,25	25	
			0,5	1,25	25	
			0,75	0,60	12	
			1,0	0,37	7	
			1,5	0,19	4	
		0,5	GOMITO	1,47	49	
			0,5	1,10	40	
			0,75	0,50	16	
			1,0	0,28	9	
			1,5	0,13	4	
		1,0	GOMITO	1,50	75	
			0,5	1,00	50	
			0,75	0,41	21	
			1,0	0,22	11	
1,5	0,09		4,5			
4,0	GOMITO	1,38	110			
	0,5	0,96	65			
	0,75	0,37	43			
	1,0	0,19	17			
	1,5	0,07	6			

CURVA A 90° SEZIONE RETTANGOLARE CON DEFLETTORI		R/W	R1/W	R2/W	0,70	28	
		GOMITO 0,5	0,5				19
		0,5	0,4				12
		0,7	0,6				7,2
		1,0	1,0				0,13
GOMITO CON ALETTE		GOMITO 0,3	0,5		0,12	22	
		0,5	0,2	0,4	0,45	16	
		0,75	0,4	0,7	0,12		
		1,0	0,7	1,0	0,10		
		1,5	1,3	1,5	0,15		
GOMITO A T CON ALETTE		C = 0,10 ÷ 0,35 SECONDO LA COSTRUZIONE					
T CURVILINEO		CONSIDERARLO UGUALE AD UNA CURVA ANALOGA. PERDITA BASATA SULLA VELOCITA' IN ENTRATA					

HOW TO USE THE TOOL - INPUT/OUTPUT

INPUT

Number of secondary branches → Number of final branches

Final branches air flow

Size of the ducts

Materials of the ducts

Lengths of the ducts

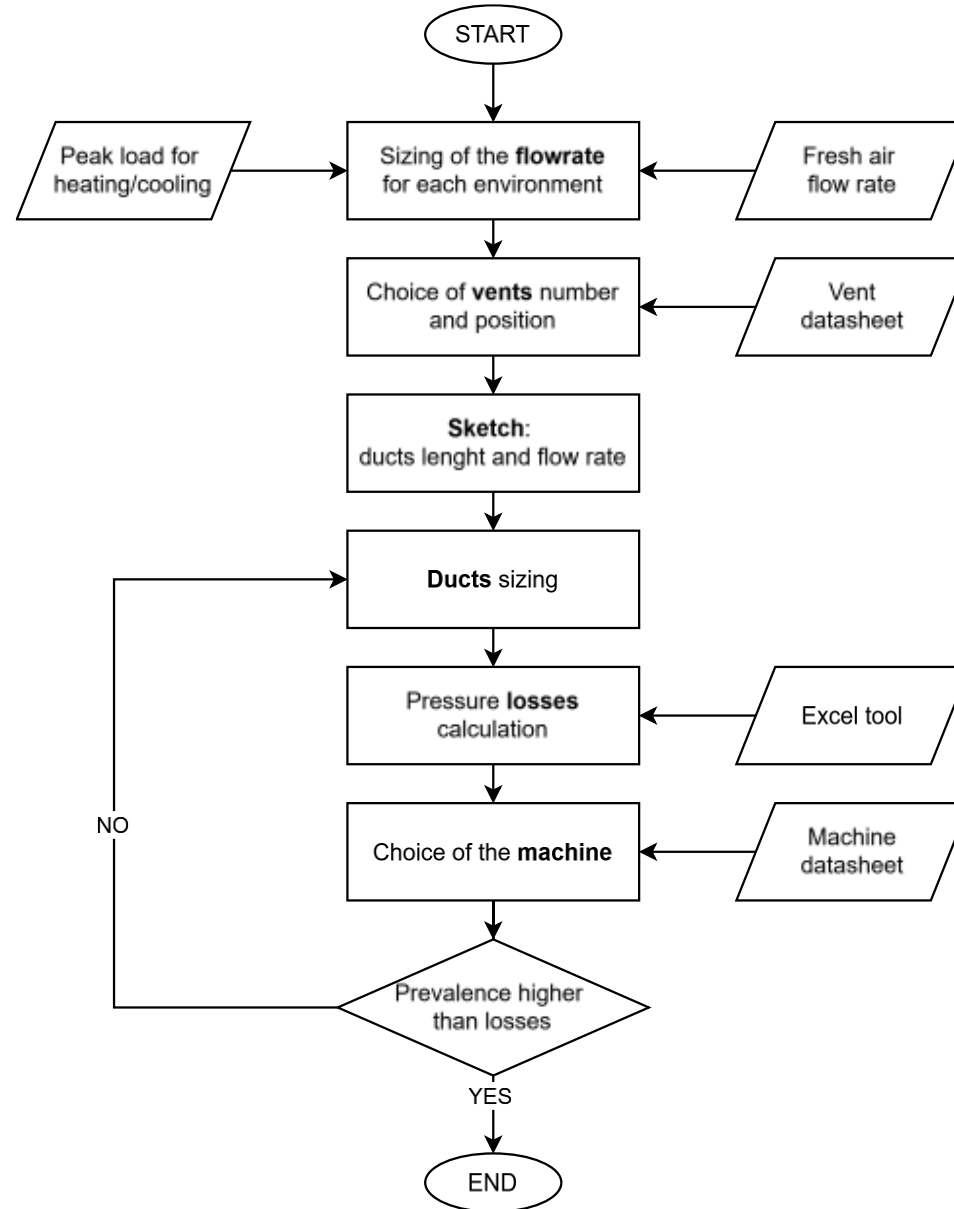
Particular circuit elements (curves, collars, etc.)

The Tool does not substitute the sizing process: it only helps in the pressure loss calculation

OUTPUT

Pressure losses of the circuit

SIZING GENERAL PROCEDURE



INSTRUCTIONS FOR THE REPORT

For this part of the project, you will be divided into groups of 3 people. Each group will receive a specific case study

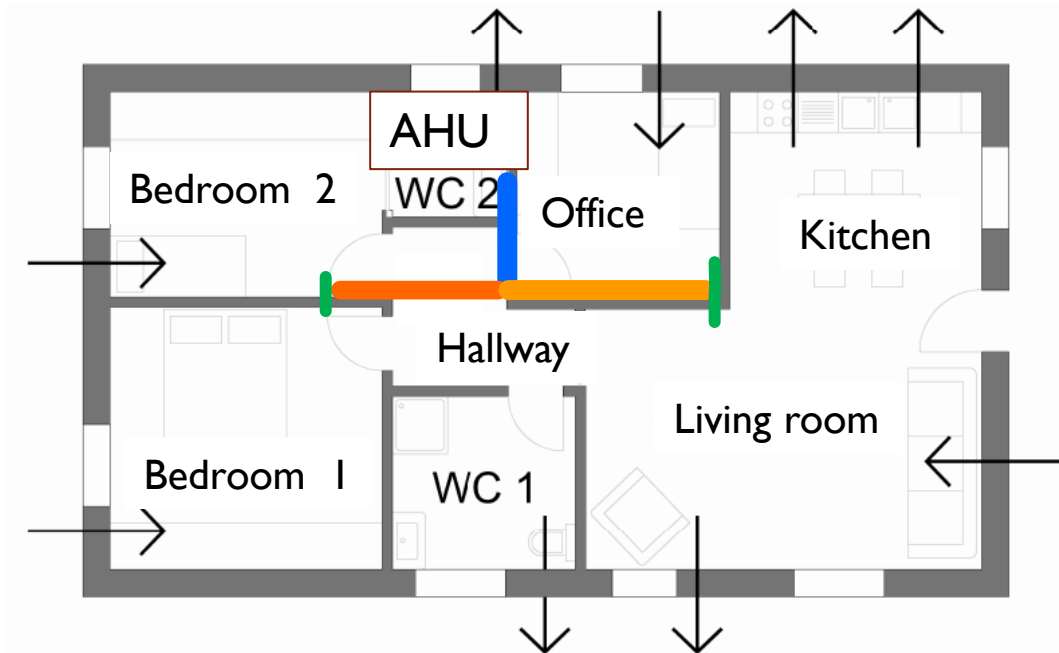
You are asked to provide the **sizing** of a **full-air system with recirculation** for your case study.

In the report you should submit, the information to provide are as follows:

- Calculation of the design and fresh-air flow rates: methodology and results (*)
- Choice of the vents, their number and position
- Schematic layout of the air distribution system, position of the AHU, duct sizing.
- Calculation of the continuous and localized pressure losses for all the ducts (*)

(*) for these sections, it is compulsory to provide the excel with the calculations!

CASE STUDY



In this example, we **NEGLECT** the presence of thermal loads to be fulfilled and we only size the supply path.

N.	Name	Area [m ²]	Volume [m ³]
1	Living room	22.7	61.3
2	Office	9.0	24.3
3	Kitchen	11.0	29.7
4	Bedroom 1	15.4	41.6
5	Bedroom 2	12.0	32.4
6	Bathroom I	6.8	18.4
7	Bathroom 2	3.2	8.6
8	Hallway	5.0	13.5
	Total	85.1	229.8

ALERT!! Do not forget to verify the air flow mass balance!!

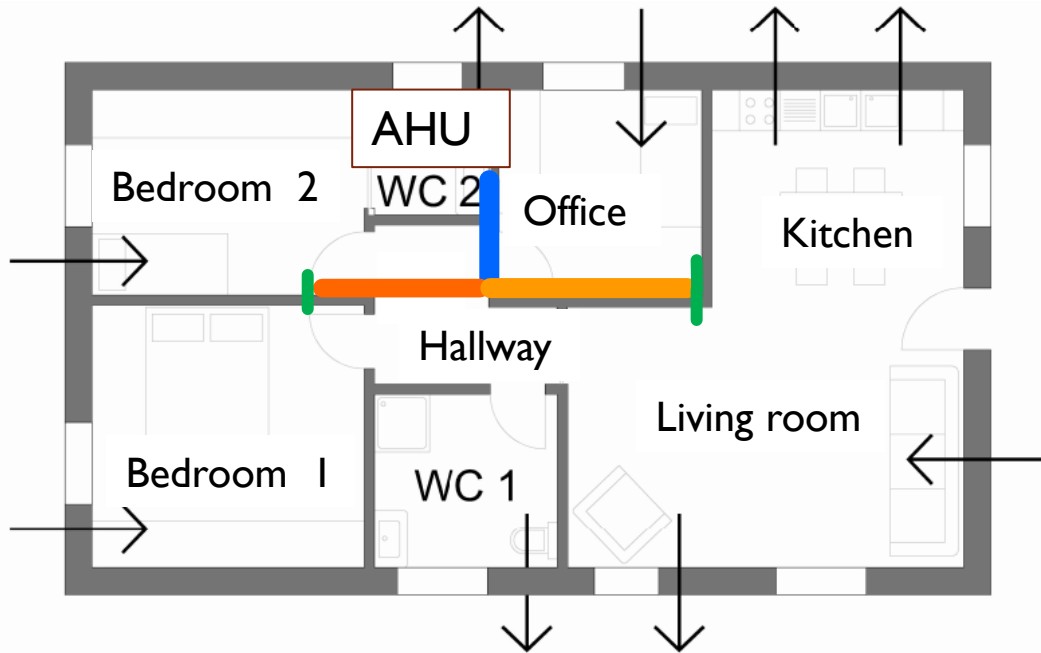
CASE STUDY

Level	L/(s m ²)	h ⁻¹ (ACH)
I	0.49	0.7
II	0.42	0.6
III	0.35	0.5
IV	0.23	0.4



Level	Resulting flow rate	
	m ³ /h	
I	150	161
II	129	138
III	107	115
IV	70	92

$$q_{i,C} = q_{i,H} = 0 \Rightarrow V_{des,TOT} = V_{IAQ,TOT}$$



Name	Area [m ²]	Volume [m ³]	V _{prog,i} [m ³ /h]
Living room	22.7	61.3	55
Office	9.0	24.3	20
Kitchen	11.0	29.7	-
Bedroom I	15.4	41.6	35
Bedroom 2	12.0	32.4	30
Bathroom I	6.8	18.4	-
Bathroom 2	3.2	8.6	-
Hallway	5.0	13.5	-
Total	85.1	229.8	140.0

Some examples for the definition of the ventilation flow rate can be found on EN 16798 – 2, Annex B, Section B.3.2.5