Module 2
Heat and Cold Energy Demands of Buildings

Part of the SHaKE Educational Package on District Heating and Cooling Systems

Exercise

Engineering exercise for teaching and applied learning

Developing institution: Mines Paris – PSL
Erasmus+ KA220-HED Cooperation Partnerships in Higher Education
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https://www.shakeproject-dhc.eu/

The purpose of this exercise is to size the heating systems for a building located in the Paris region connected to a district heating network.
This study will be carried out in three stages:

- Calculation of the heating power required for each room in the building in question
- Sizing the heating emitters
- Sizing of the hot water network
- Sizing the substation

The building has an area of 250 m² et 3 floors. The building is rectangle with 41.5x6x9m dimensions. The ground floor is composed of 2 premises, a shop and an office. The first floor is composed of 2 apartments, and the second floor has 3 appartements (see Figure 1). The dimensions of all the premises are given in the Table 1.

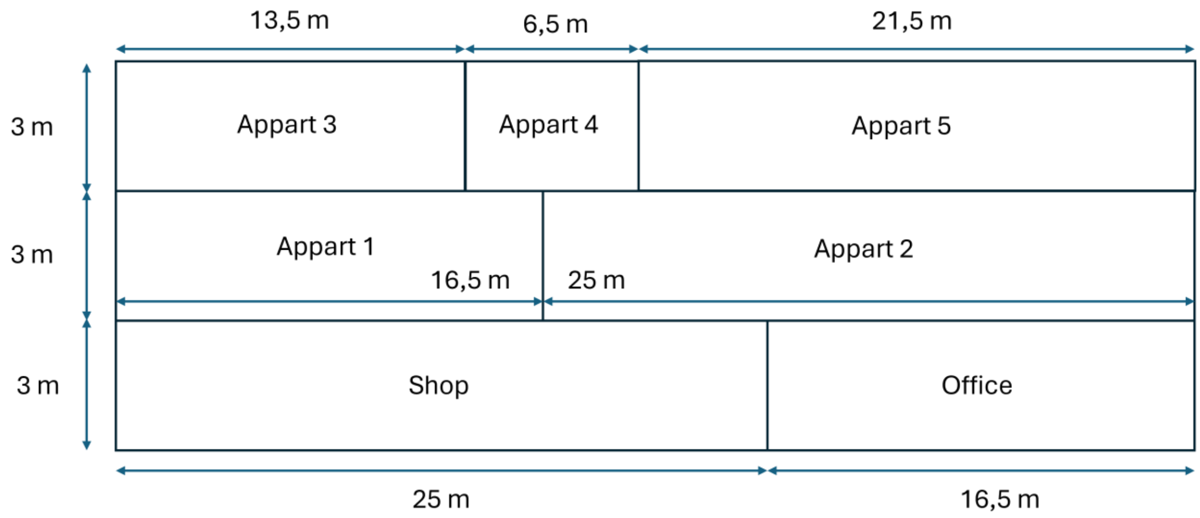

Figure 1 Building dimension

Table 1 Building data

		Length (m)	Width (m)	Height (m)	Area (m²)	Windows area (m²)	Number of rooms
Ground floor	Shop	25	6	3	150	67.2	1
	Office	16.5	6	3	100	46.8	1
1st floor	Apartment 1	25	6	3	150	42	4
	Apartment 2	16.5	6	3	100	23.4	3
2nd floor	Apartment 3	13.5	6	3	81	19.2	2
	Apartment 4	6.5	6	3	40	7.8	1
	Apartment 5	21.5	6	3	130	29.4	4

The composition of the walls is:

- Vertical walls: Cinder block (λ= 1.5 W/K.m) 20 cm, extruded polystyrene (λ= 0.034 W/K.m) 4 cm & plaster 1.3 cm (λ= 0.04 W/K.m)
- Floor: Concrete (λ= 2 W/K.m) 20 cm & extruded polystyrene (λ= 0.034 W/K.m) 2 cm
- Roof: Concrete (λ= 2 W/K.m) 20 cm & extruded polystyrene (λ= 0.034 W/K.m) 1 cm

The windows used are double gazed 4/16/4 with wood frame. The glass and air thermal conductivity are respectively equals 1 W/K.m and 0.023 W/K.m. The frame represents 15% of the windows total area with a thermal transfer coefficient of $U_f = 2.88\ W/k.m^2$.
The ventilation flow rate of the shop and office is equal to 0.5 vol/h.
The nominal outdoor temperature is -7°C, the inside temperature is 20°C. The ground temperature is supposed to be equal to 10°C.
The space heating systems and their characteristics are given in Table 2.

Table 2 System data

		System	$Tw_{in}(°C)$	$Tw_{out}\ (°C)$	$Tair_{out}\ (°C)$
Ground floor	Shop	Fan-coil unit	65	55	35
	Office	Heating floor	35	30	
1st floor	Apartment 1	Radiator	65	55	
	Apartment 2	Radiator	65	55	
2nd floor	Apartment 3	Radiator	80	60	
	Apartment 4	Radiator	80	60	
	Apartment 5	Radiator	80	60	

The Figure 2 show the hydraulic networks in the buildings.

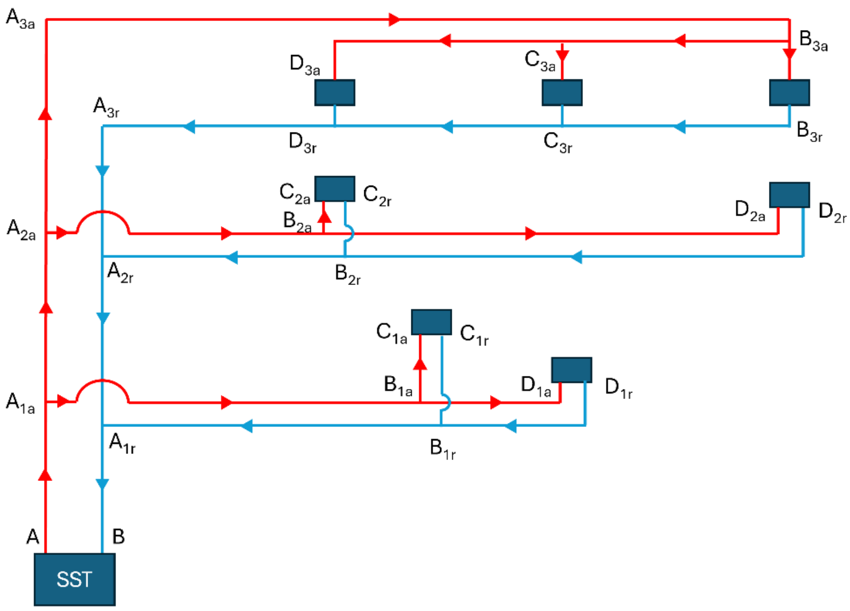

Figure 2 Hydraulic scheme

The length of each pipe is given in Table 3.

Table 3 Pipes size

	AA_{1a}	$A_{1a}A_{2a}$	$A_{2a}A_{3a}$	$A_{1a}B_{1a}$	$B_{1a}C_{1a}$	$B_{1a}D_{1a}$	$D_{1r}B_{1r}$	$C_{1r}B_{1r}$	$B_{1r}A_{1r}$
Length (m)	3	3	3	24	2.5	6	6	2.5	24

	$A_{2a}B_{2a}$	$B_{2a}C_{2a}$	$B_{2a}D_{2a}$	$D_{2r}B_{2r}$	$C_{2r}B_{2r}$	$B_{2r}A_{2r}$	$A_{3a}B_{3a}$	$B_{3a}C_{3a}$	$C_{3a}D_{3a}$
Length (m)	24	0.5	16	16	0.5	24	40	21	8

	$B_{3e}C_{3r}$	$C_{3r}D_{3r}$	$D_{3r}A_{3r}$	$A_{3r}A_{2r}$	$A_{2r}A_{1r}$	$A_{1r}B$
Length (m)	21	8	12	3	3	3

Part 1 Space heat demand

Q1- calculate the heat transfer coefficient U (W/m²/K) of the opaque wall and the windows.
Q2- For each premises, calculate the global heat transfer coefficient for all the different types of surfaces (horizontal wall, roof, floor and windows). Same question for the heat losses.
Q3 – Calculate the heat losses through ventilation
Q4- Calculate the total heat losses for all the premises. What are the major sources of heat losses? How can you reduce them?

Part 2 Sizing of heat emitters

Q1- Calculate the water mass flow rate needed for all the equipment
Q2- For the radiators, calculate the global transfer coefficient and the radiators area needed
Q3- For the fan-coil unit, calculate the air flow rate needed, the heat exchanger efficiency and the exchange surface. How is it possible to improve the fan-coil unit efficiency? What are the consequences?
Q4 – For the heating floor, calculate the position in the concrete floor of the hot water pipes to respect the temperature constraint. Recalculate the power needed to fulfill the needs and then the water mass flow rate needed.
Q5– What is the share of the heat supplied by the heating floor loose into the ground? Comment. Propose a solution to reduce the heat losses from the heating floor.

Part 3 Sizing the hot water network

Q1- Calculate the theoretical diameter of all the pipes described in Table 3 and give the diameter of the corresponding

Q2- For each pipe calculate the pressure losses.
Q3- Which pressure losses must be overcome by the pump?

Part 4 Sizing of the substation

Q1- Size the substation heat exchanger allowing to supply the building