CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF MECHANICAL ENGINEERING
DEPARTAMENT OF ENVIROMENTAL ENGINEERING

DESIGN OF HEATING SYSTEM IN A FAMILY HOME

BACHELOR THESIS

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BACHELOR'S THESIS ASSIGNMENT

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II. Bachelor's thesis details

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Design of Heating System in a Family House

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Guidelines:

Make a design of building´s envelope and its opening fillings. Calculate heat losses according to EN 12831-1 and design a suitable heating system for this building. Calculate heat and fuel needs.

Bibliography / sources:

Supporting documents will be provided as the thessis progresses.

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Date of bachelor's thesis assignment: **29.04.2022** Deadline for bachelor thesis submission: **29.06.2022**

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III. Assignment receipt

The student acknowledges that the bachelor's thesis is an individual work. The student must produce his thesis without the assistance of others, with the exception of provided consultations. Within the bachelor's thesis, the author must state the names of consultants and include a list of references.

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SOUHRN

Cílem této bakalářské práce je zpracovat tepelně technický návrh pláště budovy a jejích otvorových výplní. Dále stanovit tepelné ztráty podle normy EN 12831-1 a návrh vhodné otopné soustavy pro tuto budovu. Rovněž bude stanovena potřeba tepla a paliva. Tento projekt poskytuje technické informace o tom, jak implementovat otopnou soustavu do vytápěného prostoru, ať už jde o obytnou budovu nebo kancelářskou budovu nebo školu atd., ale pro účelem této práce je návrh vytápění pro rodinný dům.
Popisuje konkrétní typy otopných těles, které lze použít tak, aby zajistila obyvatelům v otopném období vhodné tepelné prostředí uvnitř domu.

SUMMARY

The goal of this bachelor thesis is to make a design of a building's envelope and its opening fillings. Calculate heat loss according to standard EN 12831-1 and design a suitable heating system for this building. And also calculate heat and fuel needs.
This project provides a technical insight on how it is to implement a heating system in a space being it a home or an office building or a school, etc. But for the soul purpose of our work we will be focusing on a residential home.
It details specific types of radiators that can be used for the same purpose to provide a warm and suitable climatic environment inside the house for the residents during heating period.

DECLARATION

I declare that this Diploma thesis entitled "Design of Heating System in a Family House" is my own work performed under the supervision of Ing. Jindřich Boháč, Ph.D., with the use of literature presented at the end of my diploma thesis in the list of references.

In Prague 08.06.2022 Marton Guedes

Acknowledgment

I would like to express my deepest thank you to my supervisor Ing. Jindřich Boháč, Ph.D., for his guidance and mentoring throughout the elaboration of my Bachelor Thesis for his patients and availability for consultations with the soul intent of helping me understand what I need to do for the moment I choose him as my mentor. And also, a thank you to my friends and family that helped me see this bachelor degree till the very end especially my Mother who has had a huge impact on my mental state and as giving me so much strength.

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LIST OF USED SYMBOLS

$\Phi_{HL,i}$	Total design heat load (total) for heated space (i)	[W]
$\Phi_{T,i}$	Design transmission heat loss of the heated space (i)	[W]
$\Phi_{V,i}$	Design ventilation heat loss for the heated space (i)	[W]
$H_{T,ie}$	Heat transfer coefficient from the heated space (i) to exterior (e)	[W/K]
$H_{T,ia}$	Heat transfer coefficient from the heated space (i) to an adjacent heated space (a)	[W/K]
$H_{T,ig}$	Heat transfer coefficient from the heated room (i) to the ground (g)	[W/K]
$\theta_{int,i}$	Internal design temperature	[°C]
θ_e	External design temperature	[°C]
A_k	Surface area of the building element (k)	[m^2]
U_k	Thermal transmittance coefficient of the building element (k)	[$W/m^2.K$]
ΔU_{TB}	Blanket additional thermal transmittance for thermal bridges	[$W/m^2.K$]
f_{UK}	Correction factor for the influence of building part qualities and meteorological conditions not considered in the calculation of the respective U-values; for central Europe, i.e. CZ too, substitute = 1	[-]
$f_{ie,k}$	Temperature adjusment factor (for $H_{T,ie}$ equals 1)	[-]
R_{int}	Internal heat transmission resistance	[$m^2.K/W$]
R_{ext}	External heat transmission resistance	[$m^2.K/W$]
λ	Thermal conductivity	[w/m.k]
d	Thickness of the wall	[m]
f_{ia}	Temperature adjustment factor (for $H_{T,ia}$)	[-]
θ_{ia}	Temperature of the adjacent space ia (...)	[°C]
$f_{\theta ann}$	Correction factor considering the annual variation of the external temperature =1,45	[-]
A_k	Area of the building element (k) in contact with the ground	[m^2]
$f_{GW,k}$	Correction factor taking into account the influence of ground water $f_{GW,k}$ = 1,00 if the distance between assumed water table and floor slab is > 1m & $f_{GW,k}$ = 1,15 if the distance between assumed water table and floor slab is ≤ 1m	[-]
$f_{ig,k}$	Temperature adjustment factor	[-]
$U_{equiv,k}$	Equivalent thermal transmittance coefficient of the building element (k) in contact with the ground	[$W/m^2.K$]

$\theta_{e,m}$	Mean external temperature in heating period	[°C]
B'	Geometric parameter of the floor slab	[m]
A_G	Area of the floor slab	[m]
P	Expose periphery of the floor slab	[m]
ρ	Density of air is 1,2	[kg/m^3]
c_p	Specific heat capacity of air is 1010	[J/Kg.K]
$q_{V,min,I}$	Minimum air volume flow of room (i)	[m^3/h]
$n_{min,I}$	Minimum air change rate of the room	[h^{-1}]
V_i	Internal volume (air volume) of the room (i)	[m^3]
w	With of the room	[m]
l	Length of the room	[m]
h	Height of the room	[m]
Q	Real radiator power	[W]
Q_N	Nominal (known) radiator power (by 75/65/20 °C)	[W]
$f_{\Delta t}$	Correction factor for temperature difference	[-]
Δt	Temperature difference	[K]
Δt_N	Nominal temperature difference	[K]
c	Temperature ratio factor	[-]
t_{w1}	Flow water temperature	[°C]
t_{w2}	Return water temperature	[°C]
t_i	Indoor air temperature	[°C]
$\dot{m}$	Mass flow rate	[kg/h]
Q	Real heat output of the radiator	[W]
c	Specific thermal capacity is 4187	[J/kg.K]
d_{opt}	Optimal diameter of section	[mm]
ρ	Density of water is 1000	[kg/m^3]
w_{opt}	Optimal wter flow velocity 0,6 (most cases in CZ)	[m/s]
d_{real}	Real diameter section	[mm]
w_{real}	Real water flow velocity	[m/s]
Δp_F	Friction pressure loss	[Pa]
Δp_L	Local pressure loss	[Pa]
λ	Dimensionless friction factor	[-]
L	Length of pipe	[-]

d	Inner diameter of pipe	[m]
w	Water flow velocity	[m/s]
ζ	Local loss coefficient	[-]
R	Specific pressure drop	[Pa/m]
$\dot{V}$	Volume flow rate of water	[m^3/h]
Δp	Pressure loss difference	[kPa]
K_v	Nominal volume flow rate (K_v-value)	[m^3/h]
TRV	Thermostatic Regulation Valve	[-]
RV	Regulation Valve	[-]
V_{EV}	Volume of Expansion Valve	[liters]
V_o	Volume of Water in Heating System	[liters]
n	Expansion Coefficient	[-]
η	Degree of utilization of closed Expansion vessel	[-]
Δt_{max}	Maximal temperature difference	[-]
$P_{d,dov,A}$	The lowest allowed pressure	[kPa]
P_d	The lowest operation pressure	[kPa]
$P_{h,dov,A}$	The highest allowed pressure	[kPa]
P_h	The highest operation pressure	[kPa]
Q_{TH}	Theoretical need of heat	[J/Heat Per.]
d	Number of days in the heating season	[days]
t_{is}	Average internal temperature of object	[°C]
t_{es}	Average outdoor temperature for heating season	[°C]
t_e	Outdoor area calculated temperature	[°C]
e_i	- Correction factor of non-concurrence of surcharges (according to ČSN 06 0210)	[-]
	- Correction factor for non-concurrence heat lost through ventilation and permeation (according to ČSN EN 12 831-1)	[-]
e_t	Correction factor for temperature reduction (with intermittent heating)	[-]
e_d	Correction factor for shortening the operation time (system speed during the intermittent heating)	[-]

Q_{real} Real need of heat [J/Heat. Per]

η_R Heat distribution efficiency - considers the quality of insulation and the method of heat distribution. (from 0.85 (remote heating) to 0.95 or 0.98) [-]

η_O Efficiency of heat source operator, resp. today regulation - considers the type of regulation of the given heat source (equity, zone, etc.). (from 0.9 (solid fuel boiler) to 0.99 for gas boiler) [-]

η_K heat source efficiency (boiler) - considers the type of heat source, approx. 0.68 to 0.8 - solid fuel boilers, approx. 0.83 to 0.96 - boilers for liquid and gaseous fuels, approx. 0.95 to 0,98 - for electric boilers [-]

F Fuel need [MJ/m^3]

H_u Calorific value of fuel used, eg natural gas (Russian transit) = 35,9 MJ/m^3, Firewood = 14,6 MJ/kg, brown coal (Most) = 17,2 MJ/kg, black coal (Ostrava region) = 29,3 MJ/kg [MJ/m^3]

1 INTRODUCTION

We all know the thematic problem of having to ensure thermal comfort during the cold periods and that is no secret. Having it being in Apartments, Family houses, an Office building or a School, is not as simple as just install the radiators in all the comportments of that place and hope that all the rooms will achieve the required temperature to ensure thermal comfort. It requires calculations special selection of the various materials that will go in the construction of this pipe system.

From the selection of the tubes to the selection of thermostatic valves every component on this assembly in carefully selected to ensure maximum efficiency and comfort and also to ensure the economic demand that will come with build such a system for complex unit. We know that calculations of total heat loss of the space is the first step to ensure a functional heating system because we need to know how much heat is for each room to ensure that the radiators that we are selecting can cover for those losses.

Then we design the heating appliances and pipe system, here we will be looking on the selection of the radiators based on the calculations of heat losses and choose the most appropriate one for our network system of course there are various types so careful selection of the ones that we are important because we are not only have into account the design of it but also the cost factor that comes with it. It is important to know that our costumer will not want to pay a lot but they will demand high efficiency and quality at the same time and it is our job as the persons who are design it to provide the right information so that our job is less demanding.

The last part is the design of pipe system here we will be looking at calculations of pressure losses and balancing of the system, we know that there will be losses on our system and due to elbow bends, T-bends, expansion, valves and radiators, once we have calculated all of that we have to ensure that our system is in Hydronic balancing, Why you ask?

Because the system network when not in balancing state it will not function properly in most cases and common ones what happens is the thermal comfort inside all the rooms is not achieved because the system is not balanced so flow of water usually goes to the path that is the closest to the water source, and the radiators which are furthest from the heating source can’t get enough hot water to be able to heat up the radiator and what we usually end up with are Overheated and under-cooled rooms, one way we could try to correct this is by increasing the flow of water in the pipes so that the system can try and compensate for the flow of water that is not reaching the furthest radiators but in doing so we risk a high consumption of energy from the heating source and the flow noise at the valves will increase. So that’s why we need to ensure Hydronic Balancing because when the system is perfectly balanced we get save energy form the heating source as there is not a big demand to ensure that all radiators are heating properly, we achieve optimum room temperatures, we completely eliminate flow noises in the valves and we get a good regulation behaviour of the system.

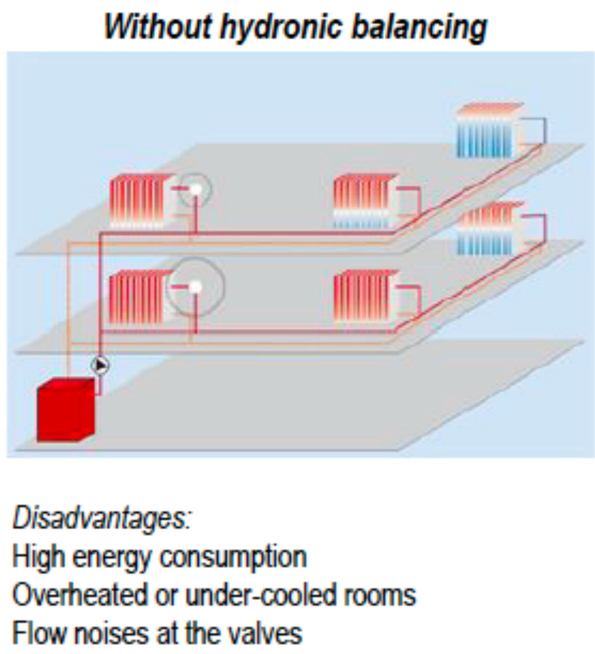

Figure 1. Heating System without Hydronic Balancing. [1]

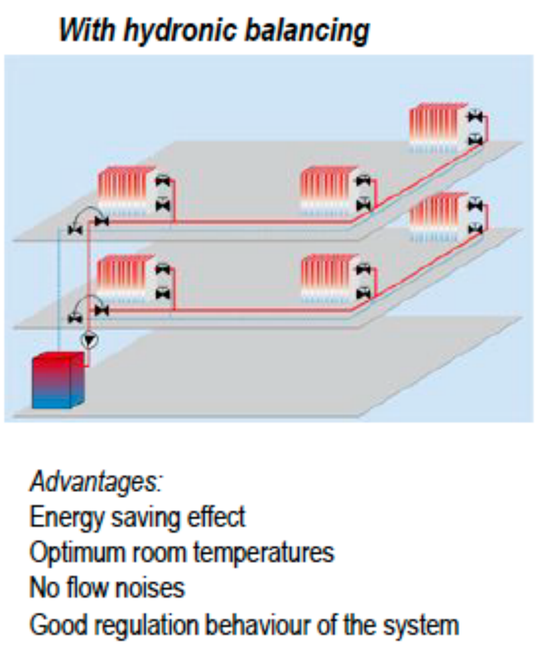

Figure 2. Heating System with Hydronic Balancing. [1]

2 CALCULATION OF TOTAL DESIGN HEAT LOSS FOR HEATED SPACE (EN 12 831-1)

This European Standard covers methods for calculation of the design heat load for single rooms, building entities and buildings, where the design heat load is defined as the heat supply (power) needed to maintain the required internal design temperature under design external conditions. [2]

The total heat load is calculated from all transmission heat losses to the exterior (direct and indirect), the ventilation heat loss of the building and, if any, an additional heating up power. [2]

First, I design the model of the house on CAD program in which I would be performing the installation of the radiator and also to have a layout of the situation helps a lot to visualize what calculations are being performed where inside our model house.

I performed calculations on the Excel spread sheet for determination of all the losses in the space for better understanding of how it works when trying to perform the installation of this system in building.

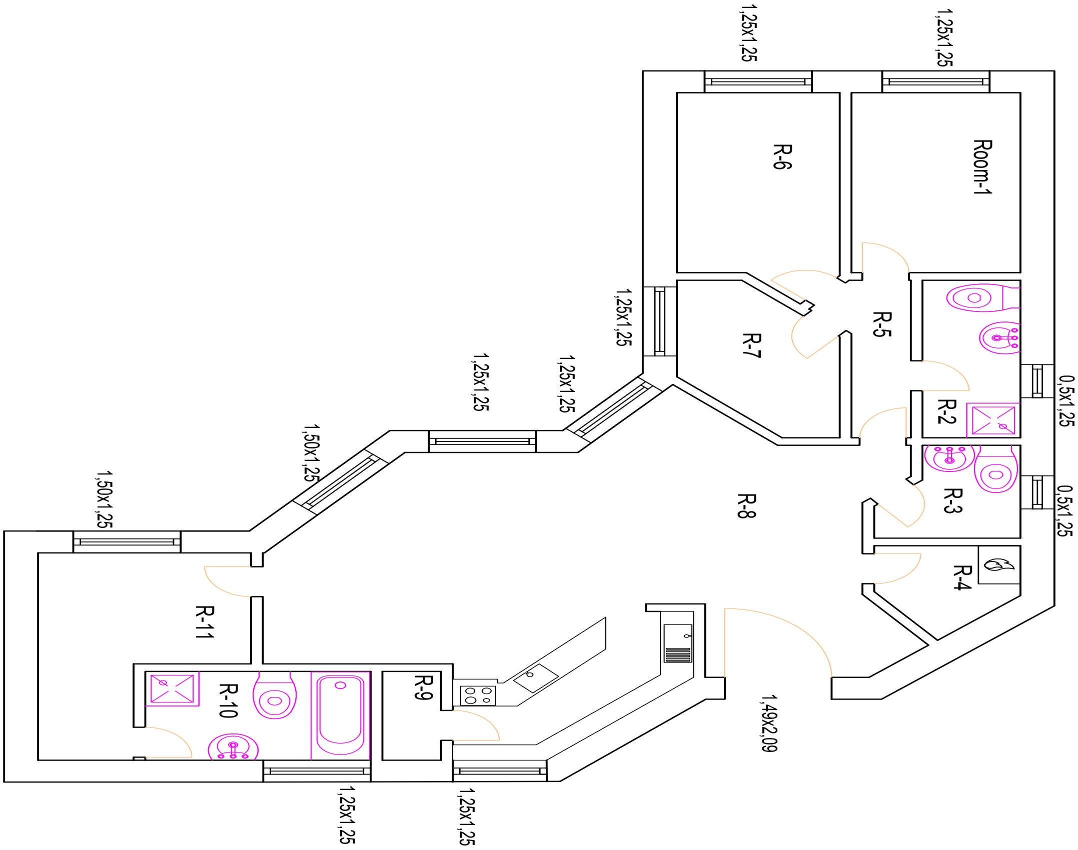

Figure 3. Model Drawing on CAD Program of the house which I will be using to perform installation of Radiator network system.

2.1 DESIGN TRANSMISSION HEAT LOSSES OF A HEATED SPACE (i).

After, preparations of the CAD model then I have to analyse the materials in which will compose the building because depending on the different materials used it will have different impact on heat losses in each room that composes the house, and it may either increase or reduce significantly the losses on them. I first went and determine the design transmission heat losses of a heated space given by the equation.[2]

$$(1)\ \Phi_{T,i} = \left(H_{T,ie} + H_{T,ia} + H_{T,iae} + H_{T,iaBE} + H_{T,ig}\right).\left(\theta_{int,i} - \theta_e\right) = \left(H_{T,ie} + \sum H_{T,ia(\dots)} + H_{T,ig}\right).\left(\theta_{int,i} - \theta_e\right)$$

We do not require the heat transfer coefficient from the heated space (i) to the exterior (e) through an adjacent unheated space or a neighbouring building because there is no such room in the house that falls under this condition. And we do not heat transfer coefficient from the heated space (i) to an adjacent building entity (aBE) because there is also no room in our building that falls under this condition. So, we are left with final equation shown above.

2.2 HEAT TRANSFER COEFFICIENT FROM THE HEATED SPACE (i) TO EXTERIOR (e)

We start first by calculating the Heat lost coefficient from the heated space to the exterior of our house. And we use the formula describe under to do so.

$$(2)\ H_{T,ie} = \sum_k [A_K \,.\, (U_k + \Delta U_{TB}).\, f_{U,k}.\, f_{ie,k}]\ [2]$$

Now certain parts of the equation describe individual components that must the in order to get the results of our calculation, the surface area of the building element simple describe the part of the space (in our case the room in which we need to determine the area from).

$$(3)\ A_k = (w + l).\,h - (\text{window area})\ [2]$$

Now depending if our room as a window in it or not it significantly after our calculations because we have to take into that most the heat that will be lost in the room will be throughout that window so it is important that we count it out formula

Now thermal transmittance coefficient of building elements considers the materials used in the construction of our building, these materials will have different types of thermal conductivity, thicknesses and internal and external transmission resistance and are calculated by the formula under

$$(4)\ U_k = \frac{1}{\frac{1}{\alpha_{iny}} + \sum \frac{d}{\lambda} + \frac{1}{\alpha_e}} = \frac{1}{R_{int} + \sum R + R_{ext}}\ [2]$$

The internal heat transmission resistance will be of all rooms in horizontal direction of heat flow and it is provided by the standards. But we will also use the upwards and downwards direction of heat flow for calculation of heat losses though ceiling and ground respectively. [2]

Heat transmission resistance [$m^2.K/W$]	Direction of heat flow		
	Upwards	Horizontally	Downwards
R_{int}	0.1	0.13	0.17
R_{ext}	0.04	0.04	0.04

Table 1. of heat transmission resistance values for different Heat flow directions.

And materials that compose the external wall are given on the table below. [2]

Material Composition of external wall	Thermal Conductivity λ (W/m.K)	Thickness of the wall (m)
Brick	0.15	0.1025
Thermal fiber glass insulation	0.043	0.075
Plaster light	0.2	0.0125

Table 2. Materials that compose the external wall of the House.

Values obtained from the calculation of thermal transmittance coefficient must fulfil requirements according to ČSN 730540-2, designated Thermal protection of buildings – Part 2: Requirements. And on the picture, we can see under which values they need to fall under. [2]

Construction	Overall coefficient of thermal transmittance U [$W/m^2.K$]		
	Required $U_{N,20}$	Recommended $U_{K,20}$	Recommended d for passive houses
external	0,30	Heavy: 0,25 Light: 0,20	0,18 to 0,12
Pitched roof over 45º	0,30	0,20	0,18 to 0,12
Roof. Pitched roof to 45º	0,24	0,16	0,15 to 0,10
Ceiling and floor over outdoor area	0,24	0,16	0,15 to 0,10

Table 3. Different types Overall coefficients of thermal transmittance. [2]

Additional thermal transmittance for the thermal bridge can be selected from the table, depending on the building selection criteria it will one the values in it.

Selection of criteria	Additional thermal transmittance
	ΔU_{TB}
	[W/m^2.K]
New buildings with a high level of heat insulation and attested of minimization of thermal bridges that exceeds generally recognize rules of practices.	0,2
New buildings in compliance with generally recognized rules of practice regarding minimization of thermal bridges.	0,05
Buildings with mainly internal heat insulation broken by solid ceilings (example reinforced concrete)	0,15
All other buildings	0,10

Table 4. Additional thermal transmittance for thermal bridge. [2]

The last two components of the equation describe some correction and adjustment factor the first is the correction factor for the influence of building part qualities and meteorological conditions not taken into account in the calculation of the respective U-values; for central Europe, i.e C.Z and is equal to 1. The second is the temperature adjustment factor (for Heat transfer coefficient from the heated space to the exterior) and is also equal to 1.

2.3 HEAT TRANSFER COEFFICIENT FROM THE HEATED SPACE (i) TO ANADAJECENT HEATED SPACE (a)

Heat transfer coefficient to adjacent spaces refers to the part of the equation that determines the amount transferred from a room or space with a higher temperature to another usually rooms or spaces that are not temperature regulated by some radiator or that we don’t have a need to maintain under the same temperatures as the common rooms. The formula for its calculation is give as.

$$(5)\ H_{T,ia} = \sum_k (A_k . U_k . f_{ia(\dots),k})\ [2]$$

I will not talk about the first two components of the equation as they have already been discussed in the previous equation and their method of determination is the same, but for the second component I will mention that the inner composition of the walls is made out different materials then the outer walls and its composition is.

Material Composition of Inner wall	Thermal Conductivity λ (W/m.K)	Thickness of the wall d (m)
Plaster light	0.2	0.0125
Bitumen	0.17	0.1

Table 5. Materials that compose the inner wall of the House

And different from the External Thermal transmittance coefficient of building elements calculation for the internal wall we only use the internal heat transmission resistance on both sides of the equation.

And the last component is of the equation describes the temperature adjustment factor where the internal design temperature of the consider heated space, temperature of the adjacent space (i) and external design temperature play their part into its determination.

$$(6)\ f_{ia(\ldots)} = \frac{\theta_{int,i} - \theta_{ia(\ldots)}}{\theta_{int,i} - \theta_e}\ [2]$$

2.4 HEAT TRANSFER COEFFICIENT TO THE GROUND.

Now we calculate the heat transfer coefficient to the ground ana the equation for it is give as.

$$(7)\ H_{T,ig} = f_{\theta ann} \cdot \sum_k (A_k \cdot U_{equiv,k} \cdot f_{ig,k} \cdot f_{GW,k})\ [2]$$

The first component represents the correction factor considering the annual variation of the external temperature and its equal to 1.45. the area is already a known factor on how to be determined.

The equivalent thermal transmittance coefficient of the building element (k) in contact with the ground is determined using the fallowing formula.

$$(8)\ U_{equiv,k} = \frac{a}{b + (c_1 + B')^{n_1} + (c_2 + z)^{n_2} + (c_3 + U_k + \Delta U_{TB})^{n_3}} + d\ [2]$$

Where the variables are given by a table of values for us to insert in the equation under. [2]

	a	b	c_1	c_2	c_3	n_1	n_2	n_3	d
Floor	0.9671	-7.455	10.76	9.773	0.0265	0.5532	0.6027	-0.9296	-0.0203

Table 6. Values of variables in Equivalent Thermal transmittance coefficient of the building

The letter z on the formula represents the depth of the top of the floor slab below ground level, but since we don’t have any underground rooms in our house we can discard z from our formula.

The correction factor considering the influence of ground water is equal to 1 if the distance between assumed water table and floor slab is > 1 meter, and its equal to 1.15 if the distance between assumed water table and floor slab is ≤ 1 meter. Which for our case it will be equal to 1 because the distance between assumed water table and floor slab is > 1 meter.

U values of Residential house	Uk [W/m^2.K]
Uk for external walls:	0.22
Uk for wall between rooms:	1.03
Window	1.40
Door	1.80
Floor	0.15
Ceiling	0.13

Table 7. All values for Thermal transmittance coefficients that I used in the process.

The most crucial element would be B´, because depending on geometric parameter of the floor slab for each room we will have different value results for B´
And this will influence the results of our equivalent thermal transmittance coefficient of the building.

$$(9)\ B' = \frac{A_G}{0.5.P}\ [2]$$

Geo parameter floor slab	
# of Room	B´
Room 1	1.79
Room 2	1.67
Room 3	2.49
Room 4	2.49
Room 6	1.75
Room 7	2.78
Room 8	1.59
Room 9	2.35
Room 10	2.35
Room 11	1.56

Table 8. Calculation of geometric parameter of floor slab.

The temperature adjusting factor is calculated using almost the same formula with the exception of the mean external temperature in heating period which is a part of the formula.

$$(10)\ f_{ig,k} = \frac{\theta_{int,i} - \theta_{e,m}}{\theta_{int,i} - \theta_e}\ [2]$$

And we get that values for the equivalent thermal transmittance coefficient for each room that we will use to calculate the heat coefficient though the ground of each room.

Heat transfer coefficient to the ground	
# of Room	$U_{equiv,k}$
Room 1	0.23
Room 2	0.23
Room 3	0.22
Room 4	0.22
Room 6	0.23
Room 7	0.22
Room 8	0.23
Room 9	0.23
Room 10	0.23
Room 11	0.23

Table 9. Equivalent thermal transmittance coefficient of each room.

2.5 DESIGN VENTILATION HEAT LOSSES OF HEATED SPACE (i)

And now I calculate the element of the determination of the total heat losses in each room of the house and it is the design ventilation heat loss of heated spaces given by the equation.

$$(11)\ \Phi_{V,i} = \rho . c_p . q_{V,min} . (\theta_{int,i} - \theta_e)\ [2]$$

First element of the equation refers to the density of air which common value s 1.2 kg/m^3. The second element of the equation the specific heat capacity of air which normally in any rooms or spaces on the house its common value is 1010 J/kg.K.

The third element of the equation the minimum air volume flow of the room can be determined using the simple formula

$$(12)\ q_{V,min,i} = n_{min,i} . V_i\ [2]$$

The minimum air change rate in the room can be determine using the table below.

Room type	n_{min} [h^{-1}]
Permanent dwelling areas; e.g living rooms, offices	0,3 – 0,5
Kitchens, bathrooms, wcs, etc (with windows)	0,5
Secondary rooms, internal rooms	0,0 – 0,3

Table 10. Determination of minimum air change rate in room. [2]

Most common value in Czech Republic is 0.5 h^{-1} so we divide this value by 3600 which is minimum of air exchange in the room per hour. And the reason for this is because the minimum air volume flow of the room needs to be recalculated to (m^3/s)

And the internal volume (air volume) of the room is determined buy the product of height, length and width of the room.

$$(13)\ V_i = w.l.h\ [2]$$

Number of Room	q_(V,min,i) values
Room 1	0.0019
Room 2	0.0029
Room 3	0.0026
Room 4	0.0009
Room 6	0.0018
Room 7	0.0010
Room 8	0.0075
Room 9	0.0002
Room 10	0.0038
Room 11	0.0028

Table 11. Minimum air volume flow rate of the room values.

Now we will have a look of the table on excel with all the calculations performed with all the final results

Room #	U_k [W/m^2.K]	Width [m]	Length [m]	Height [m]	A_k [m^2]	H_{Tie} [W/K]	H_{Tia} [W/K]	H_{Tig} [W/K]	$\Phi_{T,i}$ [W]	$\Phi_{V,i}$ [W]	$\Phi_{HL,i}$ [W]
Room 1									250	74	324
Through Wall	0.22	1.44	2.38	4	13.73	4.45					
Through window	1.40	1.25	1.25	4	1.56	2.34					
Through Ground	0.13	1.44	2.38	4	3.43			0.57			
Through Ceiling	0.13	1.44	2.38	4	3.43		0.45				
Room 2									197	126	323
Through Wall	0.22	0.83	2.09	4	11.05	3.58					
Through window	1.40	0.50	1.25	4	0.63	0.94					
Through Adjct Ro.	1.13	0.83	2.09	4	1.74		0.22				
Through Adjct Ro.	1.13	0.83	2.09	4	1.74		0.22				
Through Ground	0.13	0.83	2.09	4	1.74			0.29			
Through Ceiling	0.13	0.83	2.09	4	1.74		0.23				
Room 3									166	111	277
Through Wall	0.22	1.25	1.23	4	9.28	3.00					
Through window	1.40	0.50	1.25	4	0.63	0.94					
Through Adjct Ro.	1.13	1.25	1.23	4	1.53		0.19				
Through Ground	0.13	1.25	1.23	4	1.53			0.27			
Through Ceiling	0.13	1.25	1.23	4	1.53		0.20				
Room 4									118	34	152
Through Wall	0.22	1.25	1.25	4	10.00	3.24					
Through Ground	0.13	1.25	1.25	4	1.56			0.25			
Through Ceiling	0.13	1.25	1.25	4	1.56		0.20				
5*											
Room 6									246	71	318
Through Wall	0.22	1.39	2.38	4	13.52	4.38					

Through window	1.40	1.25	1.25	4	1.56	2.34					
Through Ground	0.13	1.39	2.38	4	3.31			0.55			
Through Ceiling	0.13	1.39	2.38	4	3.31		0.43				
Room 7									185	38	223
Through Wall	0.22	1.39	1.27	4	9.0815	2.94					
Through window	1.40	1.25	1.25	4	1.5625	2.34					
Through Ground	0.13	1.39	1.27	4	1.77			0.28			
Through Ceiling	0.13	1.39	1.27	4	1.77		0.23				
Room 8									2383	291	2675
Through Wall	0.22			4	16.71	60.29					
Through window	1.40	1.25	1.25	4	1.56	0.51					
Through window	1.40	1.50	1.25	4	1.88	2.81					
Through M.Door	1.80	1.49	2.09	4	3.11	5.92					
Through Ground	0.13			4	16.71			2.78			
Through Ceiling	0.13			4	16.71		2.17				
Room 9									75	8	82
Through Wall	0.22	0.50	1.18	4	6.7	2.17					
Through Ground	0.13	0.50	1.18	4	0.59			0.09			
Through Ceiling	0.13	0.50	1.18	4	0.59		0.08				
Room 10									246	164	410
Through Wall	0.22	1.92	1.18	4	10.82	3.50					
Through window	1.40	1.25	1.25	4	1.56	2.34					
Through Adjct Ro.	1.13	1.92	1.18	4	2.26		0.28				
Through Ground	0.13	1.92	1.18	4	2.26			0.40			
Through Ceiling	0.13	1.92	1.18	4	2.26		0.29				
Room 11									307	107	414

Through Wall	0.22	1.81	2.74	4	16.36	5.30					
Through window	1.40	1.50	1.25	4	1.88	2.81					
Through Ground	0.13	1.81	2.74	4	4.98			0.83			
Through Ceiling	0.13	1.81	2.74	4	4.98		0.65				

Table 12. Performed calculations for all Loss.

3 DESIGN OF HEATING APPLIANCES AND PIPE SYSTEM.

After calculations of all losses we can move to the design and of the heating appliances (Radiators) and how we are going to place them in each room, as well as the calculation of pipe system and there design how we will be placing them inside the house as well as their respective diameters and lengths.

This part is very import because once we have the pre-calculations already done we need to start thinking of what type of radiators we will use and their respective sizes the placing of them inside the room and how many Watts should it produce to compensate for the amount that is already been lost by the rooms in the house itself.

3.1 RECALCULATION OF HEAT OUTPUT.

We are going to identify some of the ways that we can calculate the heat output of the of house appliances:

1. find out how much heat is produced inside the space. There may be a need for approximations. For instance, if you are aware of how much power is produced inside the device, estimate that 10% of that energy is lost as heat. [3]
2. Calculate the area that is exposed to the outside, except the top of the panel, in order to account for heat transfer from the outside. [3]
3. Choose the inside temperature you want and the difference in temperature between it and the anticipated highest outside temperature. [3]

So now we start by recalculating the heat output of the radiators under real conditions and formula we will use for it is the following:

$$(14)\ Q = Q_N . f_{\Delta t} . f_m . (f_{\delta t}) . f_x . f_o . f_n . f_p \ [4]$$

The first component describes the real radiator power, on the right side of equation we start out with nominal (know) radiator power (by 75/65/20ºC) and right after we have the correction factor for temperature difference. The other components are not use in my calculation so I will not be discussing them.

Now the most significant correction factor is that for temperature difference.

$$(15)\ f_{\Delta t} = \left(\frac{\Delta t}{\Delta t_N}\right)^n \ [4]$$

After defining all the components from the equation we can, proceed to selection the radiators of both (bathroom and rooms), based on the recalculation of real heat output of the radiators in each room and the radiators catalogue is provided by Korado company where we can find on their website the panel radiators for rooms in the catalogue (Radik steel panel radiators)[5], and bathroom radiators in catalogue (Koralux towel rail radiators)[6].

Under we will find the table with all the radiators determination based on the real recalculation of heat output of the radiators.

# of Room	c	Δtln [°C]	ΔtlnN [°C]	fΔt	QN [W]	Real Q [W]	Calculated Q [W]
Room 1	0.714	30	50	0.507	772	392	324
Room 2	0.677	26	50	0.434	991	430	323
Room 3	0.677	26	50	0.429	749	321	277
Room 4	—	—	—	—	—	—	152
Room 5	—	—	—	—	—	—	20
Room 6	0.714	30	50	0.507	772	392	318
Room 7	0.714	30	50	0.507	515	261	223
Room 8 for 1st Radiator	0.714	30	50	0.507	1373	697	
Room 8 for 2nd Radiator	0.714	30	50	0.507	1201	610	
Room 8 for 3rd Radiator	0.714	30	50	0.507	1201	610	
Room 8 for 4th Radiator	0.714	30	50	0.507	772	392	
—	—	—	—	—	—	2308	2675
Room 9	—	—	—	—	—	—	82
Room 10	0.677	26	50	0.429	1332	571	410
Room 11	0.714	30	50	0.507	1373	697	414
Total Heat of space from Calculated and selected of radiators from standard comparision:						5372	5218

Table 13. Recalculation of real heat output of radiators in each room of the house.

The correction factor for temperature difference as a condition in other for its calculation and it depends on temperature ratio factor.

$$(16)\ c = \frac{t_{w2} - t_i}{t_{w1} - t_i} \ [4]$$

Now if result from c is ≥ 0.7, then we will arithmetically determine the temperature difference.

$$(17)\ \Delta t = \frac{t_{w1} + t_{w2}}{2} - t_i \ [4]$$

And if the result from c is ≤ 0.7, then we will logarithmically determine temperature difference. Which is going to be the case from my calculations.

$$(18)\ \Delta t_{ln} = \frac{t_{w1} - t_{w2}}{ln\frac{t_{w1}-t_i}{t_{w2}-t_i}}\ [4]$$

Parameters	Given [°C]	Nominal [°C]
t_{w1}	55	75
t_{w2}	45	65
t_i for bathroom	24	20
t_i for toillet	24	
t_i for rooms	20	

Table 14. Real and Nominal parameters of heating system.

And we implemented all this information and calculated the real heat output of the radiators. And we can see from the figure below that that some of the radiators have a slightly bigger heat output then the required by the rooms demand.

And after all the calculations we can select the radiators for each room in the house. And we will show them in the table below with type length and height.

Room	Type	Length [mm]	Height [mm]
1	11 VK	900	500
2	KLM 1820.600	600	1810
3	KLM 1820.450	450	1810
6	11 VK	1400	500
7	11 VK	600	500
8 for 1st Radiator	11 VK	1600	500
8 2nd & 3rd Raditor	11 VK	1400	500
8 for 4th Radiator	11 VK	900	500
—	—	—	—
10	KLM 1820.750	750	1810
11	11 VK	1600	500

Table 15. Radiator Models and specific dimensions.

And from the from the table 15 we can then select the temperature exponents of each radiator. According to the catalogues that where already mention in previously.

Room #	Temp exp (n)
1	1.3123
2	1.2592
3	1.276
6	1.3123
7	1.3123
8	1.3123
10	1.2762
11	1.3123

Table 16. Temperature exponent of radiator. [5] [6]

3.2 DESIGN OF PIPE SYSTEM

There are four basic methods in which we can use for the design of pipe system. [1]

- Preliminary specific pressure loos method
- Method of pump pressure direct choice
- Economical specific pressure loss method
- Economical velocity method (w_{opt})
-

We will be using the using the economical velocity method for design of our pipe system.

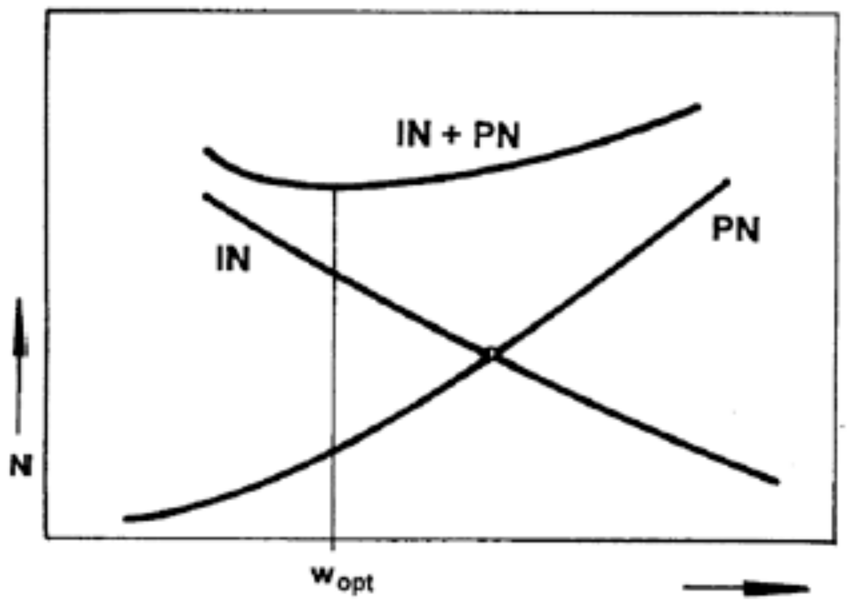

Figure 4. Economical velocity method diagram showing relation between IN (investment costs) and PN (operating costs). [4]

Based on the pipe and pumping system, the graphical approach for calculating ideal conditions. Consider the situation where the ideal pipe diameter required to handle a particular flow, fluid density, and viscosity, cost of power, and pump efficiency as a pumping cost were calculated. However, authors have established an optimization approach for turbulent flow of conduit size using pipe density and wall thickness, which may be estimated by piping specification, in order to take piping cost into consideration. [7]

To select recommended optimal velocity suitable for type of our heating system we don't have to calculate any costs of course, we can simple selected directly from table. [1]

Pipe net	Velocity w [m/s]
Inside of buildings	0.3 to 0.7
Inside of buildings – horizontal feed pipes	0.8 to 1.5
District heating	2.0 to 3.0

For pump (forced), two-pipe system (most cases) optimal velocity is 0.6 m/s.

Now that we know how much is the typical optimal velocity we can start the calculations for our system.

3.3 DETERMINATION OF MASS FLOW RATE FOR EACH RADIATOR (IN KG/S AND KG/H).

We have to split the pipe system and number each section of the pipe system which differs with mass flow rate.

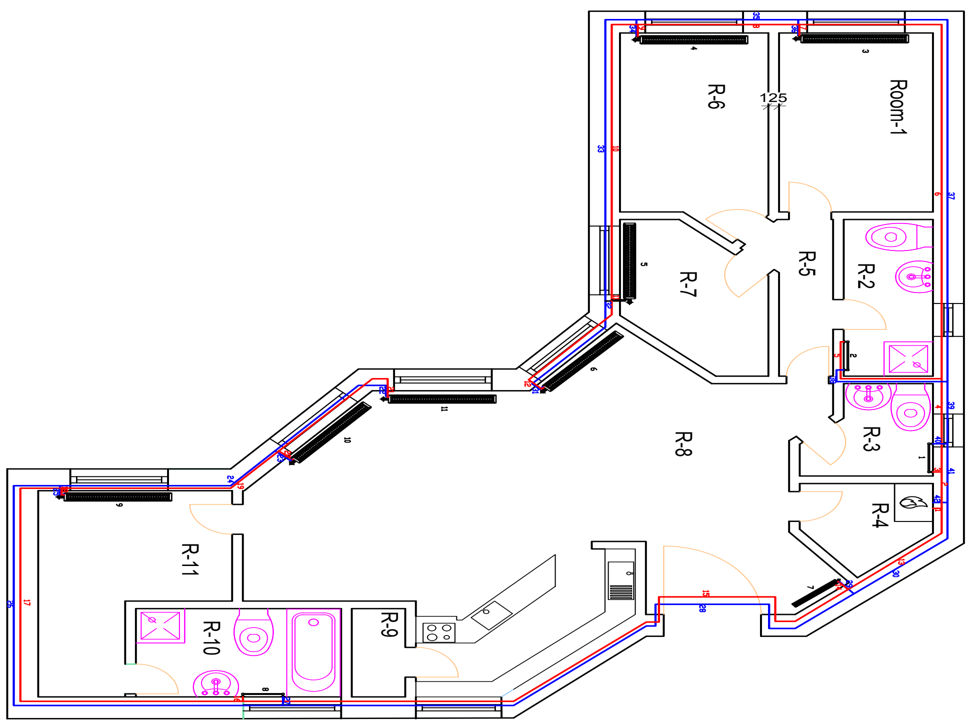

Figure 5. Top view of House showing sections of pipe distribution for calculation of mass flow.

And now we determine the mass flow rate of each section base on the formula given.

$$(19)\ \dot{m} = \frac{Q}{c.(t_{w1} - t_{w2})}\ [4]$$

The Q represents the real heat output of radiators that we already have calculated. The c specific thermal capacity is 4187 J/kg.K, and t_{w1} and t_{w2} are flow water temperature inlet and outlet respectively.

Number of Room	Q [W]
1	392
2	430
3	321
4	—
5	—
6	392
7	261
8 1st Radiator	697
8 2nd Radiator	610
8 3rd Radiator	610
8 4th Radiator	392
—	2308
9	—
10	571
11	697
Total of all heat outputs	5372

Table 17. Real Heat Output of Radiators.

3.4 DETERMINATION OF OPTIMAL AND REAL DIAMETER OF EACH SECTION.

After calculation of mass flow rate, we can we can now calculate optimal diameter and the real diameter of each section.

$$(20)\ d_{opt} = \sqrt{\frac{4.\dot{m}}{\pi.\rho.w_{opt}}} [4]$$

We already have mass flow rate, and for our system optimal velocity is 0.6 m/s (most cases in Czech Republic). Density of water is 1000 kg/m³.

Based on the results that we obtained for the optimal diameter, we didn't go to the table to select the nearest real diameter from real line according to the calculated optimal diameter. [4]

We will be using copper pipe for our heat system in the house. Not only are they one of the most widely used types on the market, offering outstanding flexibility and a more compact make-up than other galvanized steel rivals. Although it can be a little prone to corrosion, it typically corrodes less than other galvanized steel pipes.

Copper tubes are available in straight or coiled formats to fit any type of plumbing network. They are lightweight with thin wall sections. As a result, it may be used for any type of arrangement, whether it be a two-pipe household installation or a single pipe loop system for commercial use. And their sizes range from 4 mm to 54 mm. [8]

Figure 6. Copper pipe Image.

$d_{i,real}$ [mm]	4	6	8	10	13	16	20

Note: if possible, never use the meters smaller than 8 mm (pipes with these diameters are expensive and can cause pressure losses).

3.5 DETERMINATION OF REAL VELOCITY.

Once we have the real diameter of pipes, we can then proceed to calculate the real velocity flow in each section of our pipe system which will be given by the equation.

$$(21)\ w_{real} = \frac{4.\dot{m}}{\pi.\rho.d_{real}^2}\ [4]$$

After all the calculations are done, we can then proceed to create our table Where we will find all the results of our calculations from the formulas given above.

Section	m[kg/s]	m[kg/h]	dopt[m]	dopt[mm]	dreal[mm]	wreal[m/s]
1	0.128	462	0.017	17	16	0.64
2	0.128	462	0.017	17	16	0.64
3	0.008	28	0.004	4	8	0.15
4	0.050	179	0.010	10	10	0.63
5	0.010	37	0.005	5	8	0.20
6	0.040	142	0.009	9	10	0.50
7	0.009	34	0.004	4	8	0.19
8	0.030	109	0.008	8	8	0.60
9	0.009	34	0.004	4	8	0.19
10	0.021	75	0.007	7	8	0.41
11	0.006	22	0.004	4	8	0.12
12	0.015	52	0.006	6	8	0.29
13	0.128	462	0.017	17	16	0.64
14	0.009	34	0.004	4	8	0.19
15	0.061	221	0.011	11	13	0.46
16	0.014	49	0.005	5	8	0.27
17	0.048	172	0.010	10	10	0.61
18	0.017	60	0.006	6	8	0.33
19	0.031	112	0.008	8	8	0.62
20	0.017	60	0.006	6	8	0.33
21	0.015	52	0.006	6	8	0.29
22	0.015	52	0.006	6	8	0.29
23	0.017	60	0.006	6	8	0.33
24	0.031	112	0.008	8	8	0.62
25	0.017	60	0.006	6	8	0.33
26	0.048	172	0.010	10	10	0.61
27	0.014	49	0.005	5	8	0.27
28	0.061	221	0.011	11	13	0.46
29	0.009	34	0.004	4	8	0.19
30	0.128	462	0.017	17	16	0.64
31	0.015	52	0.006	6	8	0.29
32	0.006	22	0.004	4	8	0.12
33	0.021	75	0.007	7	8	0.41
34	0.009	34	0.004	4	8	0.19
35	0.030	109	0.008	8	8	0.60
36	0.009	34	0.004	4	8	0.19
37	0.040	142	0.009	9	10	0.50
38	0.010	37	0.005	5	8	0.20
39	0.050	179	0.010	10	10	0.63
40	0.008	28	0.004	4	8	0.15
41	0.128	462	0.017	17	16	0.64

42	0.128	462	0.017	17	16	0.64

Table 18. Calculations of Pipe System Design.

4 PRESSURE LOSSES OF HEATING SYSTEM.

The total pressure loss in the system consists of friction pressure loss and local pressure loss. Which we will be determining on our system.

The friction pressure loss is given by the fallowing equation.

$$(22)\ \Delta p_F = \lambda.\frac{L}{d}.\frac{w^2}{2}.\rho = R.L \ \ [1]$$

The λ on the equation represents the dimensionless friction factor, the L is the length of the pipe, d is inner pipe diameter, w is water flow velocity, ρ is fluid density, ζ is local loss coefficient and R is the specific pressure drop (stated in table of pipe material for Copper).

The local pressure loss is given by the fallowing equation.

$$(23)\ \Delta p_L = \sum \zeta.\frac{w^2}{2}.\rho = Z \ \ [1]$$

After we known the formula how to obtain the losses in the system we can then proceed to calculate them but for that we will need the table of pipe materials

Cu pipes	8 x 1 (d_i = 6 mm)		10 x 1 (d_i = 8 mm)		12 x 1 (d_i = 10 mm)		15 x 1 (d_i = 13 mm)		18 x 1 (d_i = 16 mm)		22 x 1 (d_i = 20 mm)	
M [kg/h]	***R*** [Pa/m]	***w*** [m/s]	***R*** [Pa/m]	***w*** [m/s]	***R*** [Pa/m]	***w*** [m/s]	***R*** [Pa/m]	***w*** [m/s]	***R*** [Pa/m]	***w*** [m/s]	***R*** [Pa/m]	***w*** [m/s]
50	805	0,50	155	0,28	43,5	0,18	13,0	0,11	5,70	0,07	2,35	0,04
71	1475	0,71	375	0,40	120	0,25	24,5	0,15	8,25	0,10	3,30	0,06
100			680	0,56	235	0,36	68,0	0,21	19,5	0,14	5,40	0,09
140			1225	0,80	420	0,50	120	0,30	45,0	0,19	14,5	0,12
200			2300	1,10	790	0,71	225	0,42	83,5	0,28	29,0	0,18
250					1170	0,90	330	0,53	125	0,34	42,5	0,22
320					1810	1,10	515	0,67	190	0,45	65,5	0,28
360					2235	1,30	630	0,75	235	0,50	80,5	0,32
400							760	0,85	280	0,56	97,0	0,36
450							940	0,95	345	0,63	120	0,40
500							1130	1,00	415	0,71	145	0,45

Table 19. Table of Pipe Material for Copper . [1]

We will not calculate the mass flow rate, diameter of pipes or water flow velocity of the system because we already calculated the them on the previous chapter of the thesis. The lengths of pipes are determined by ruff estimation in the CAD drawing because the dimensions are not so accurate.

Local losses can be determined from the local loss (coefficient)

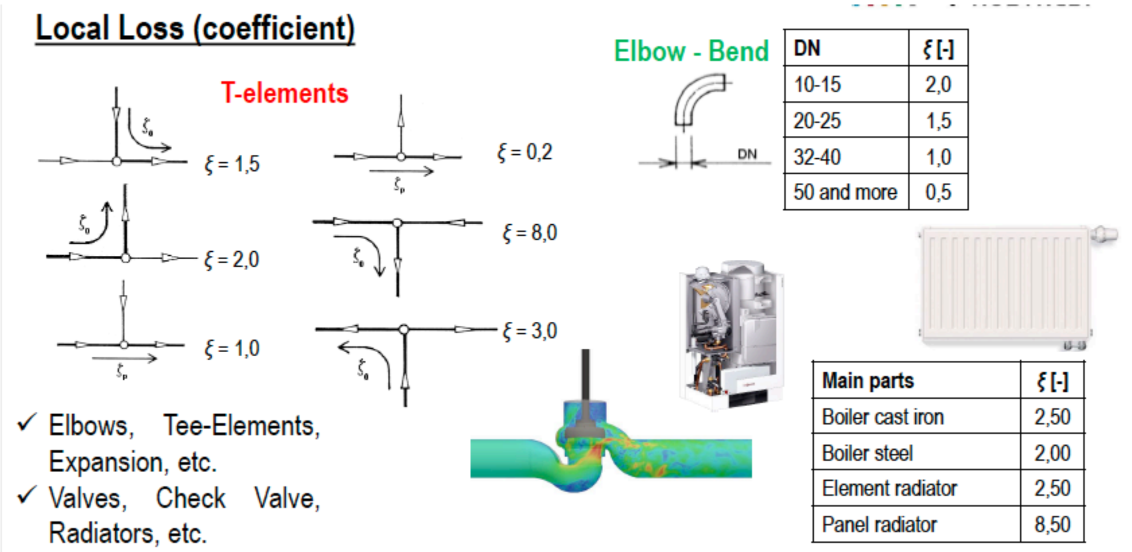

Figure 7. Local losses some examples provided by presentation of Heating Tutorial 3 2022. [1]

Section	m[kg/s]	m[kg/h]	d_{opt}[m]	d_{opt}[mm]	d_{real}[mm]	w_{real}[m/s]	L [m]	R [Pa/m]	ξ[-]	R.L [Pa]	Z [Pa]	R.L+Z [Pa]
1	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
2	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
3	0.008	28	0.004	4	8	0.153	0.5	155	1	77.5	12	89
4	0.050	179	0.010	10	10	0.634	1.2	615	1	738	201	939
5	0.010	37	0.005	5	8	0.204	1.5	155	4	232.5	83	316
6	0.040	142	0.009	9	10	0.503	6	424	2	2544	253	2797
7	0.009	34	0.004	4	8	0.186	0.5	155	2	77.5	35	112
8	0.030	109	0.008	8	8	0.600	1.5	682	1	1023	180	1203
9	0.009	34	0.004	4	8	0.186	0.5	155	2	77.5	35	112
10	0.021	75	0.007	7	8	0.414	4	379	3	1516	257	1773

11	0.006	22	0.004	4	8	0.124	0.5	155	1	77.5	8	85
12	0.015	52	0.006	6	8	0.290	1.5	162	3	243	126	369
13	0.128	462	0.017	17	16	0.638	1.5	376	2	564	407	971
14	0.009	34	0.004	4	8	0.186	0.5	155	1	77.5	17	95
15	0.061	221	0.011	11	13	0.463	8	246	7	1968	751	2719
16	0.014	49	0.005	5	8	0.272	0.5	155	1	77.5	37	114
17	0.048	172	0.010	10	10	0.609	5	595	2	2975	371	3346
18	0.017	60	0.006	6	8	0.331	0.5	263	1	131.5	55	186
19	0.031	112	0.008	8	8	0.621	2	690	3	1380	578	1958
20	0.017	60	0.006	6	8	0.331	0.5	263	1	131.5	55	186
21	0.015	52	0.006	6	8	0.290	1.7	164	3	278.8	126	405
22	0.015	52	0.006	6	8	0.290	1.7	164	3	278.8	126	405
23	0.017	60	0.006	6	8	0.331	0.5	263	1	131.5	55	186
24	0.031	112	0.008	8	8	0.621	2	690	3	1380	578	1958
25	0.017	60	0.006	6	8	0.331	0.5	263	1	131.5	55	186
26	0.048	172	0.010	10	10	0.609	5	595	2	2975	371	3346
27	0.014	49	0.005	5	8	0.272	0.5	155	1	77.5	37	114
28	0.061	221	0.011	11	13	0.463	8	290	7	2320	751	3071
29	0.009	34	0.004	4	8	0.186	0.5	155	1	77.5	17	95
30	0.128	462	0.017	17	16	0.638	1.5	376	2	564	407	971
31	0.015	52	0.006	6	8	0.290	1.5	162	3	243	126	369
32	0.006	22	0.004	4	8	0.124	0.5	155	1	77.5	8	85
33	0.021	75	0.007	7	8	0.414	4	379	3	1516	257	1773
34	0.009	34	0.004	4	8	0.186	0.5	155	2	77.5	35	112

35	0.030	109	0.008	8	8	0.600	1.5	682	1	1023	180	1203
36	0.009	34	0.004	4	8	0.186	0.5	155	2	77.5	35	112
37	0.040	142	0.009	9	10	0.503	6	424	2	2544	253	2797
38	0.010	37	0.005	5	8	0.204	1.5	155	4	232.5	83	316
39	0.050	179	0.010	10	10	0.634	1.2	615	1	738	201	939
40	0.008	28	0.004	4	8	0.153	0.5	155	1	77.5	12	89
41	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
42	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799

Table 20. Calculated Pressure Loss in Heating System.

From what we know are calculation are not finished yes, we did calculate all the pressure loss of the Heating System but we still haven't calculated the pressure losses in the radiators. And it is important that we do that because it is a crucial step to ensure that our system is balanced otherwise our radiators will be under performing or over performing which is not what we want.

$$(24)\ \Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 \ [5]$$

The first component on the equation Δp represents the pressure loss that is given in (Pa), the $\dot{V}$ is the volume flow rate of water that is given in (m^3/h) and k_V is the valve level setting also given in (m^3/h).

The value given by the volume floe rate of water is 0.1 m^3/h.

And the valve level setting can be read from the table under for thermostatic valves of both normal radiators (for rooms) and bathroom radiators, as well as the other regulation valves also for (normal rooms) and bathrooms.

Valve with thermostatic head

Level of valve setting	0,5	1	1,5	2	2,5	3	3,5	4	4,5	5	5,5	6	6,5	7	7,5	8
k_v [m^3/h]	0,05	**0,13**	0,18	**0,22**	0,27	**0,31**	0,35	**0,38**	0,42	**0,47**	0,52	**0,57**	0,62	**0,66**	0,71	**0,75**

Valve without thermostatic head

Level of valve setting	0,5	1	1,5	2	2,5	3	3,5	4	4,5	5	5,5	6	6,5	7	7,5	8
k_{vs} [m^3/h]	0,05	**0,16**	0,22	**0,27**	0,33	**0,38**	0,41	**0,43**	0,54	**0,65**	0,82	**0,98**	1,11	**1,23**	1,33	**1,43**

Table 21. Values of nominal volume flow rate for K_v, at different levels for Thermostatic valves in rooms. [5]

#	1	2	3	4	5	6	7	8	9
↻	1¼	1½	1¾	2	2½	3	3½	4	Max
Kv	0.14	0.20	0.31	0.43	0.60	0.79	1.00	1.20	1.35

Table 22. Values of nominal volume flow rate for K_v, at different levels for regulating valve in rooms. [9]

Nastavení	1	2	3	4	5	6 (otevřeno)
Hodnota Kvs	0,09	0,19	0,3	0,41	0,66	0,85

Table 23. Values of nominal volume flow rate for K_v, at at different levels for thermostatic valve in bathrooms. [10]

#	1	2	3	4	5	6	7	8	9
↻	1¼	1½	1¾	2	2½	3	3½	4	Max
Kv	0.14	0.20	0.31	0.43	0.60	0.79	1.00	1.20	1.35

Table 24. Values of nominal volume flow rate for K_v, at different levels for regulating valve in bathrooms. [11]

Now we can calculate the balancing of each radiator we first start by looking into our system and seeing the furthest radiator from water source which is going to the biggest losses and then we balancing the other radiators on the system based on the results of the calculation from that radiator.

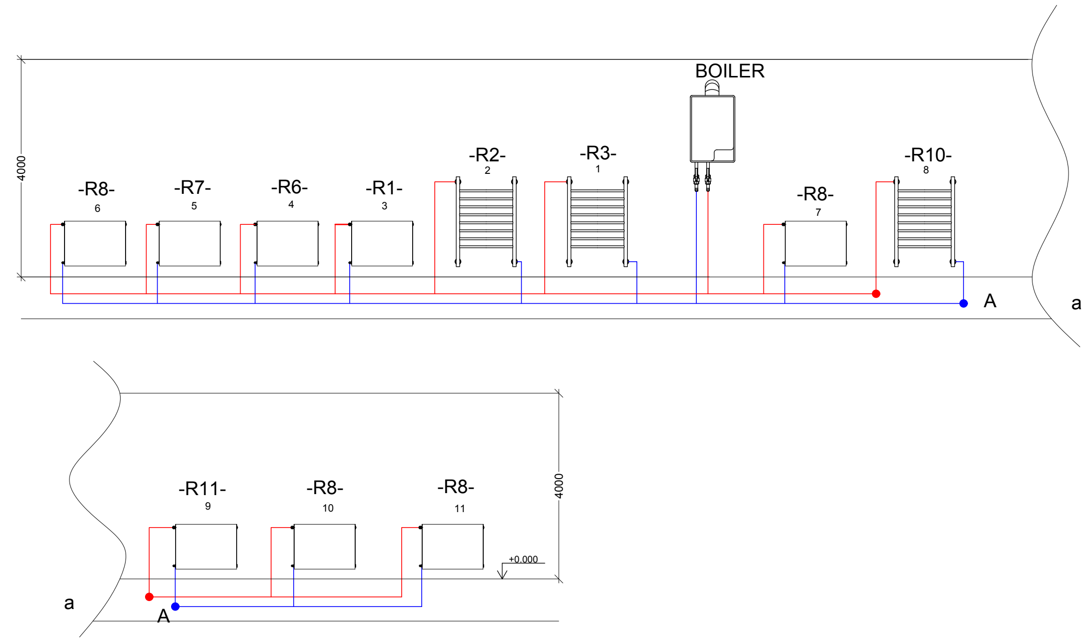

Figure 8. Circuit diagram of radiators in the household.

From the circuit diagram we can see that that the furthest radiator is the one labelled number 11 and we will start by calculating the losses of this radiator first.

Formulas and Calculations:

For Radiator 11

TRV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.75}\right)^2 .100 = 1.77\ kPa\ \rightarrow 1770\ Pa$$

RV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{1.35}\right)^2 .100 = 0.55\ kPa\ \rightarrow 550\ Pa$$

For Radiator 10

TRV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.71}\right)^2 .100 = 1.98\ kPa\ \rightarrow 1980\ Pa$$

RV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{1.2}\right)^2 .100 = 0.694\ kPa\ \rightarrow 694\ Pa$$

For Radiator 9

TRV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.52}\right)^2 .100 = 13.7\ kPa\ \rightarrow 3700\ Pa$$

RV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.6}\right)^2 .100 = 2.7\ kPa\ \rightarrow 2700\ Pa$$

For Radiator 8

TRV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.3}\right)^2 .100 = 11.1\ kPa\ \rightarrow 11100\ Pa$$

RV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.5}\right)^2 .100 = 4\ kPa\ \rightarrow 4000\ Pa$$

For Radiator 7

TRV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.31}\right)^2 .100 = 13.71\ kPa\ \rightarrow 13710\ Pa$$

RV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.43}\right)^2 .100 = 5.41\ kPa\ \rightarrow 5410\ Pa$$

For Radiator 6

TRV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.47}\right)^2 .100 = 4.53\ kPa\ \rightarrow 4530\ Pa$$

RV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{1}\right)^2 .100 = 1\ kPa\ \rightarrow 1000\ Pa$$

For Radiator 5

TRV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.42}\right)^2 .100 = 15.67\ kPa\ \rightarrow 5670\ Pa$$

RV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{1}\right)^2 .100 = 1\ kPa\ \rightarrow 1000\ Pa$$

For Radiator 4

TRV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.47}\right)^2 .100 = 4.53\ kPa\ \rightarrow 4530\ Pa$$

RV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.43}\right)^2 .100 = 5.41\ kPa\ \rightarrow 5410\ Pa$$

For Radiator 3

TRV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.38}\right)^2 .100 = 6.93\ kPa\ \rightarrow 6930\ Pa$$

RV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.43}\right)^2 .100 = 5.41\ kPa\ \rightarrow 5410\ Pa$$

For Radiator 2

TRV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.3}\right)^2 .100 = 11.1\ kPa\ \rightarrow 11100\ Pa$$

RV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.43}\right)^2 .100 = 5.41\ kPa\ \rightarrow 5410\ Pa$$

For Radiator 1

TRV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.3}\right)^2 .100 = 11.1\ kPa\ \rightarrow 11100\ Pa$$

RV Calculation

$$\Delta p = \left(\frac{\dot{V}}{k_V}\right)^2 .100 = \left(\frac{0.1}{0.31}\right)^2 .100 = 10.41\ kPa\ \rightarrow 10410\ Pa$$

We assume that the pressure of each radiator is 0 Pa, that comes manufactured company. And now that all the pressure losses are calculated we can then balance our system.

Section	m [kg/s]	m [kg/h]	d_{opt} [m]	d_{opt} [mm]	d_{real} [m]	w_{real} [m/s]	L [m]	R [Pa/m]	ξ[-]	R.L [Pa]	Z [Pa]	R.L+Z [Pa]
1	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
13	0.128	462	0.017	17	16	0.638	1.5	376	2	564	407	971
15	0.061	221	0.011	11	13	0.463	8	246	7	1968	751	2719
17	0.048	172	0.010	10	10	0.609	5	595	2	2975	371	3346
19	0.031	112	0.008	8	8	0.621	2	690	3	1380	578	1958
21	0.015	52	0.006	6	8	0.290	1.7	164	3	279	126	405
22	0.015	52	0.006	6	8	0.290	1.7	164	3	279	126	405
24	0.031	112	0.008	8	8	0.621	2	690	3	1380	578	1958
26	0.048	172	0.010	10	10	0.609	5	595	2	2975	371	3346
28	0.061	221	0.011	11	13	0.463	8	290	7	2320	751	3071
30	0.128	462	0.017	17	16	0.638	1.5	376	2	564	407	971

42	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
Total pressure loss of PIPE SYSTEM to Radiator 11												20747
Own pressure loss of the Radiator 11												0
Pressure loss of the Thermostatic Radiator Valve TRV11												1770
Pressure loss of the Regulation Valve RV11												550
TOTAL PRESSURE LOSS OF THE CIRCUIT FOR Radiator 11												23067

Table 25. Determination of pressure losses for Radiator 11.

Radiator 11 is the furthest from the heat source and is having for TRV (level setting of 8), and RV (level setting of 9).

Section	m [kg/s]	m [kg/h]	d_{opt} [m]	d_{opt} [mm]	d_{real} [m]	w_{real} [m/s]	L [m]	R [Pa/m]	ξ[-]	R.L [Pa]	Z [Pa]	R.L+Z [Pa]
1	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
13	0.128	462	0.017	17	16	0.638	1.5	376	2	564	407	971
15	0.061	221	0.011	11	13	0.463	8	246	7	1968	751	2719
17	0.048	172	0.010	10	10	0.609	5	595	2	2975	371	3346
19	0.031	112	0.008	8	8	0.621	2	690	3	1380	578	1958
20	0.017	60	0.006	6	8	0.331	0.5	263	1	132	55	186
23	0.017	60	0.006	6	8	0.331	0.5	263	1	132	55	186
24	0.031	112	0.008	8	8	0.621	2	690	3	1380	578	1958
26	0.048	172	0.010	10	10	0.609	5	595	2	2975	371	3346
28	0.061	221	0.011	11	13	0.463	8	290	7	2320	751	3071
30	0.128	462	0.017	17	16	0.638	1.5	376	2	564	407	971
42	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
Total pressure loss of PIPE SYSTEM to Radiator 10												20311
Own pressure loss of the Radiator 10												0
Pressure loss of the Thermostatic Radiator Valve TRV10												1980
Pressure loss of the Regulation Valve RV10												694

TOTAL PRESSURE LOSS OF THE CIRCUIT FOR Radiator 10	22985

Table 26. Determination of pressure losses for Radiator 10.

Radiator 10 is having for TRV (level setting 7,5), and RV (level setting of 8).

Section	m [kg/s]	m [kg/h]	d_{opt} [m]	d_{opt} [mm]	d_{real} [m]	w_{real} [m/s]	L [m]	R [Pa/m]	ξ[-]	R.L [Pa]	Z [Pa]	R.L+Z [Pa]
1	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
13	0.128	462	0.017	17	16	0.638	1.5	376	2	564	407	971
15	0.061	221	0.011	11	13	0.463	8	246	7	1968	751	2719
17	0.048	172	0.010	10	10	0.609	5	595	2	2975	371	3346
18	0.017	60	0.006	6	8	0.331	0.5	263	1	132	55	186
25	0.017	60	0.006	6	8	0.331	0.5	263	1	132	55	186
26	0.048	172	0.010	10	10	0.609	5	595	2	2975	371	3346
28	0.061	221	0.011	11	13	0.463	8	290	7	2320	751	3071
30	0.128	462	0.017	17	16	0.638	1.5	376	2	564	407	971
42	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
Total pressure loss of PIPE SYSTEM to Radiator 9												16395
Own pressure loss of the Radiator 9												0
Pressure loss of the Thermostatic Radiator Valve TRV9												3700
Pressure loss of the Regulation Valve RV9												2700
TOTAL PRESSURE LOSS OF THE CIRCUIT FOR Radiator 9												22795

Table 27. Determination of pressure losses for Radiator 9.

Radiator 9 is having for TRV (level setting of 5,5), and for RV (level setting 5).

Section	m [kg/s]	m [kg/h]	d_{opt} [m]	d_{opt} [mm]	d_{real} [m]	w_{real} [m/s]	L [m]	R [Pa/m]	ξ[-]	R.L [Pa]	Z [Pa]	R.L+Z [Pa]
1	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
13	0.128	462	0.017	17	16	0.638	1.5	376	2	564	407	971
15	0.061	221	0.011	11	13	0.463	8	246	7	1968	751	2719
16	0.014	49	0.005	5	8	0.272	0.5	155	1	78	37	114
27	0.014	49	0.005	5	8	0.272	0.5	155	1	78	37	114
28	0.061	221	0.011	11	13	0.463	8	290	7	2320	751	3071
30	0.128	462	0.017	17	16	0.638	1.5	376	2	564	407	971
42	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
Total pressure loss of PIPE SYSTEM to Radiator 8												9559
Own pressure loss of the Radiator 8												0
Pressure loss of the Thermostatic Radiator Valve TRV8												11100
Pressure loss of the Regulation Valve RV8												4000
TOTAL PRESSURE LOSS OF THE CIRCUIT FOR Radiator 8												24659

Table 28. Determination of pressure losses for Radiator 8.

Radiator 8 is having for TRV (level setting of 3), and for RV (level setting of 5).

Section	m [kg/s]	m [kg/h]	d_{opt} [m]	d_{opt} [mm]	d_{real} [m]	w_{real} [m/s]	L [m]	R [Pa/m]	ξ[-]	R.L [Pa]	Z [Pa]	R.L+Z [Pa]
1	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
13	0.128	462	0.017	17	16	0.638	1.5	376	2	564	407	971
14	0.009	34	0.004	4	8	0.186	0.5	155	1	78	17	95
29	0.009	34	0.004	4	8	0.186	0.5	155	1	78	17	95
30	0.128	462	0.017	17	16	0.638	1.5	376	2	564	407	971
42	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
Total pressure loss of PIPE SYSTEM to Radiator 7												3730
Own pressure loss of the Radiator 7												0
Pressure loss of the Thermostatic Radiator Valve TRV7												13710
Pressure loss of the Regulation Valve RV7												5410

TOTAL PRESSURE LOSS OF THE CIRCUIT FOR Radiator 7	22850

Table 29. Determination of pressure losses for Radiator 7.

Radiator 7 is having for TRV (level setting of 2,5), and for RV (level setting of 4).

Section	m [kg/s]	m [kg/h]	d_{opt} [m]	d_{opt} [mm]	d_{real} [m]	w_{real} [m/s]	L [m]	R [Pa/m]	ξ[-]	R.L [Pa]	Z [Pa]	R.L+Z [Pa]
1	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
2	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
4	0.050	179	0.010	10	10	0.634	1.2	615	1	738	201	939
6	0.040	142	0.009	9	10	0.503	6	424	2	2544	253	2797
8	0.030	109	0.008	8	8	0.600	1.5	682	1	1023	180	1203
10	0.021	75	0.007	7	8	0.414	4	379	3	1516	257	1773
12	0.015	52	0.006	6	8	0.290	1.5	162	3	243	126	369
31	0.015	52	0.006	6	8	0.290	1.5	162	3	243	126	369
33	0.021	75	0.007	7	8	0.414	4	379	3	1516	257	1773
35	0.030	109	0.008	8	8	0.600	1.5	682	1	1023	180	1203
37	0.040	142	0.009	9	10	0.503	6	424	2	2544	253	2797
39	0.050	179	0.010	10	10	0.634	1.2	615	1	738	201	939
41	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
42	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
Total pressure loss of PIPE SYSTEM to Radiator 6												16949
Own pressure loss of the Radiator 6												0
Pressure loss of the Thermostatic Radiator Valve TRV6												4530
Pressure loss of the Regulation Valve RV6												1000
TOTAL PRESSURE LOSS OF THE CIRCUIT FOR Radiator 6												22479

Table 30. Determination of pressure losses for Radiator 6.

Radiator 6 is having for TRV (level setting of 5), and for RV (level setting of 7).

Section	m [kg/s]	m [kg/h]	d_{opt} [m]	d_{opt} [mm]	d_{real} [m]	W_{real} [m/s]	L [m]	R [Pa/m]	ξ[-]	R.L [Pa]	Z [Pa]	R.L+Z [Pa]
1	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
2	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
4	0.050	179	0.010	10	10	0.634	1.2	615	1	738	201	939
6	0.040	142	0.009	9	10	0.503	6	424	2	2544	253	2797
8	0.030	109	0.008	8	8	0.600	1.5	682	1	1023	180	1203
10	0.021	75	0.007	7	8	0.414	4	379	3	1516	257	1773
11	0.006	22	0.004	4	8	0.124	0.5	155	1	78	8	85
32	0.006	22	0.004	4	8	0.124	0.5	155	1	78	8	85
33	0.021	75	0.007	7	8	0.414	4	379	3	1516	257	1773
35	0.030	109	0.008	8	8	0.600	1.5	682	1	1023	180	1203
37	0.040	142	0.009	9	10	0.503	6	424	2	2544	253	2797
39	0.050	179	0.010	10	10	0.634	1.2	615	1	738	201	939
41	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
42	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
Total pressure loss of PIPE SYSTEM to Radiator 5												16382
Own pressure loss of the Radiator 5												0
Pressure loss of the Thermostatic Radiator Valve TRV5												5670
Pressure loss of the Regulation Valve RV5												1000
TOTAL PRESSURE LOSS OF THE CIRCUIT FOR Radiator 5												23052

Table 31. Determination of pressure losses for Radiator 5.

Radiator 5 is having for TRV (level setting of 4,5), and for RV (level setting of 7).

Section	m [kg/s]	m [kg/h]	d_{opt} [m]	d_{opt} [mm]	d_{real} [m]	w_{real} [m/]	L [m]	R [Pa/m]	ξ[-]	R.L [Pa]	Z [Pa]	R.L+Z [Pa]
1	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
2	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
4	0.050	179	0.010	10	10	0.634	1.2	615	1	738	201	939
6	0.040	142	0.009	9	10	0.503	6	424	2	2544	253	2797
8	0.030	109	0.008	8	8	0.600	1.5	682	1	1023	180	1203
9	0.009	34	0.004	4	8	0.186	0.5	155	2	78	35	112
34	0.009	34	0.004	4	8	0.186	0.5	155	2	78	35	112
35	0.030	109	0.008	8	8	0.600	1.5	682	1	1023	180	1203
37	0.040	142	0.009	9	10	0.503	6	424	2	2544	253	2797
39	0.050	179	0.010	10	10	0.634	1.2	615	1	738	201	939
41	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
42	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
Total pressure loss of PIPE SYSTEM to Radiator 4												12890
Own pressure loss of the Radiator 4												0
Pressure loss of the Thermostatic Radiator Valve TRV4												4530
Pressure loss of the Regulation Valve RV4												5410
TOTAL PRESSURE LOSS OF THE CIRCUIT FOR Radiator 4												22830

Table 32. Determination of pressure losses for Radiator 4.

Radiator 4 is having for TVR (level setting of 5), and for RV (level setting of 4).

Section	m [kg/s]	m [kg/h]	d_{opt} [m]	d_{opt} [mm]	d_{real} [mm]	w_{real} [m/s]	L [m]	R [Pa/m]	ξ[-]	R.L [Pa]	Z [Pa]	R.L+Z [Pa]
1	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
2	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
4	0.050	179	0.010	10	10	0.634	1.2	615	1	738	201	939
6	0.040	142	0.009	9	10	0.503	6	424	2	2544	253	2797
7	0.009	34	0.004	4	8	0.186	0.5	155	2	78	35	112
36	0.009	34	0.004	4	8	0.186	0.5	155	2	78	35	112
37	0.040	142	0.009	9	10	0.503	6	424	2	2544	253	2797
39	0.050	179	0.010	10	10	0.634	1.2	615	1	738	201	939
41	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
42	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
Total pressure loss of PIPE SYSTEM to Radiator 3												10484
Own pressure loss of the Radiator 3												0
Pressure loss of the Thermostatic Radiator Valve TRV3												6930
Pressure loss of the Regulation Valve RV3												5410
TOTAL PRESSURE LOSS OF THE CIRCUIT FOR Radiator 3												22824

Table 33. Determination of pressure losses for Radiator 3

Radiator 3 is having for TRV (level setting of 4), and for RV (level setting of 4).

Section	m [kg/s]	m [kg/h]	d_{opt} [m]	d_{opt} [mm]	d_{real} [mm]	w_{real} [m/s]	L [m]	R [Pa/m]	ξ[-]	R.L [Pa]	Z [Pa]	R.L+Z [Pa]
1	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
2	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
4	0.050	179	0.010	10	10	0.634	1.2	615	1	738	201	939
5	0.010	37	0.005	5	8	0.204	1.5	155	4	233	83	316
38	0.010	37	0.005	5	8	0.204	1.5	155	4	233	83	316
39	0.050	179	0.010	10	10	0.634	1.2	615	1	738	201	939

41	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
42	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
Total pressure loss of PIPE SYSTEM to Radiator 2												5298
Own pressure loss of the Radiator 2												0
Pressure loss of the Thermostatic Radiator Valve TRV2												5950
Pressure loss of the Regulation Valve RV2												10410
TOTAL PRESSURE LOSS OF THE CIRCUIT FOR Radiator 2												21658

Table 34. Determination of pressure losses for Radiator 2.

Radiator 2 is having for TRV (level setting of 4), and for RV (level setting of 3).

Section	m [kg/s]	m [kg/h]	d_{opt} [m]	d_{opt} [mm]	d_{real} [mm]	w_{real} [m/s]	L [m]	R [Pa/m]	ξ [-]	R.L [Pa]	Z [Pa]	R.L+Z [Pa]
1	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
2	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
3	0.008	28	0.004	4	8	0.153	0.5	155	1	78	12	89
40	0.008	28	0.004	4	8	0.153	0.5	155	1	78	12	89
41	0.128	462	0.017	17	16	0.638	0.5	376	2	188	407	595
42	0.128	462	0.017	17	16	0.638	0.5	376	3	188	611	799
Total pressure loss of PIPE SYSTEM to Radiator 1												2966
Own pressure loss of the Radiator 1												0
Pressure loss of the Thermostatic Radiator Valve TRV1												11100
Pressure loss of the Regulation Valve RV1												10410
TOTAL PRESSURE LOSS OF THE CIRCUIT FOR Radiator 1												24476

Table 35. Determination of pressure losses for Radiator 1.

Radiator 1 is having for TRV (level setting of 3), and for RV (level setting of 3).

Number of Radiator	Total pressure loss of the circuit for given Radiator
Radiator 1	24476
Radiator 2	21658
Radiator 3	22824
Radiator 4	22830
Radiator 5	23052
Radiator 6	22479

Radiator 7	22850
Radiator 8	24659
Radiator 9	22795
Radiator 10	22985
Radiator 11	23067

All parts of the heating system are under almost the same pressure but there because we can have a. approximately +/- 10% difference in the values of losses found for each radiator.

-10% < Biggest Pressure lost on system > +10%

$$20760.3 < \quad 23067 \quad > 25373.7$$

5 CALCULATION OF VOLUME FOR EXPASSION VESSEL.

Most household pressurized heating systems use expansion vessels, also referred to as expansion tanks. An expansion vessel will be present if you have a combined boiler. The goal of this tank, which carries air and water from the central heating system, is to keep the system's pressure at the proper level. There are different types of expansion vessels.

- Open expansion vessels (for gravity system)
- Closed (pressure) expansion vessel
  - With half membrane (for small plants)
  - With full membrane
- Automatic expansion device

For the purpose of my work I will be using the closed expansion vessel with half membrane because. And the formula for its calculation is given under as.

$$V_{EV} = 1.3. V_o. n. \frac{1}{\eta} \ [12]$$

Where V_{EV} is the volume of closed expansion vessel given in [litres], 1.3 is the safety coefficient [-], V_o is the volume of water in the heating system [litres], n is the expansion coefficient [-] and η is the degree of utilization of closed expansion vessel [-].

We can determine n from the table provided under base on the max temperature difference. [12]

Δt_{max} [K]	20	30	40	45	50	55	60	65	70
n [-]	0,00401	0,00749	0,01169	0,01413	0,01672	0,01949	0,02243	0,02551	0,02863
Δt_{max} [K]	75	80	85	90	95	100	105	110	115
n [-]	0,03198	0,03553	0,03916	0,04313	0,04704	0,05112	0,05529	0,05991	0,06435

η can be calculated according to following formula:

$$\eta = \frac{P_{h,dov,A} - P_{d,dov,A}}{P_{h,dov,A}} \quad [12]$$

Where pressures have to be expressed like absolute pressures by adding up barometric pressure p_B = 100 kPa ($p_{h,dov,A} = p_{h,dov}$ + 100kPa)

Highest allowed pressure is equal to opening pressure of safety valve and it is $p_{h,dov,A} = p_{ot}$ = 350kPa.

The formula for lowest allowed pressure is.

$$p_{d,dov,A} = 1.1.\rho.g.h.10^{-3} + p_B \quad [12]$$

Now that we have all the formulas we can calculate the volume of expansion vessel.

$\Delta t_{max} = t_{max} - t_{min} = 55 - 45 = 10$ K

n = 0.00013 (from table)[13]

$p_{h,dov,A} = p_{ot,A} = 350 + 100 = 450$ kPa

$p_{h,dov,A} = 1{,}1.\rho.g.h.10^{-3}+p_B = 1{,}1.1000.9{,}81.1{,}5.10^{-3}+100 = 116$ kPa

$$\eta = \frac{P_{h,dov,A} - P_{d,dov,A}}{P_{h,dov,A}} = \frac{450 - 116}{450} = 0{,}74$$

$V_{EV} = 1{,}3.V_o.n.\frac{1}{\eta} = 1{,}3.250.0{,}00013.\frac{1}{0{,}74} = 0{,}06$ litres

6 CALCULATION OF THEORETHICAL AND REAL NEED OF HEAT AND NEED OF FUEL.

The last step is to calculate the theoretical and real need of heat as well as the Fuel need.

We first start by calculating the theoretical need of heat which is given by the simple formula. [14]. The type of house is a family house located in Prague and will have the fallowing values for calculation of Theoretical need of heat.

d (days)	225
t_{es} (°C)	4,3
t_e (°C)	-12
t_{is} (°C)	19

$$Q_{TH} = 24.3600.\Phi.\frac{d.(t_{is}-t_{es})}{(t_{is}-t_e)}.e_i.e_t.e_d = 24.3600.\Phi.\frac{225.(19-4,3)}{19-12}.0,6.0,9.1 = 2,59.10^{10} \text{ (J/ heating period)} \quad [14]$$

Now we can calculate the real need of heat.

$$Q_{real} = \frac{Q_{TH}}{0,98.0,99.0,95} = 2,81.10^{10} \text{ (J/heating period)} \quad [14]$$

And last, we can calculate the fuel need.

$$F = \frac{Q_{real}}{H_u} = \frac{28100}{35,9} = 782,71 \text{ (MJ/m}^3\text{)} \quad [14]$$

From the calculations we acquired we can select the optimum boiler for our heating system and ensure that it is enough to satisfy our needs and demands for the House. And I have chosen a combine boiler from my system in the house provided from a Czech Manufacturer the THERM PRO 20 LXZE.A5 which can used both for heating water for the central heating of the House and it can also provide hot water for showers and kitchen. [15]

Figure 9. Combined Boiler Therm 20 LXZE.A 5

It has a built-in storage tank and its recommended for heating hot water in a small-sized and medium -sized houses with insufficient space for the location of the boiler and the storage tank. But that is not our case because our storage space is more than big enough to accommodate our boiler.

Technical data	Unit	THERM 20 LXZE.A 5
Max.thermal input power	kW	22,2
Min-Max thermal output for heating	kW	8 – 20
Gas consumption- natural gas	m^3/h	0,9 – 2,3
Min-Max overpressure of heating system	bar	0,8 – 3,0
Maximum inout pressure of heating water	°C	80
Boiler efficiency	%	92
Volume of expansion unit	l	10
Volume of storage tank for water	l	55 (stainless)

Table 36. Technical description of boiler.

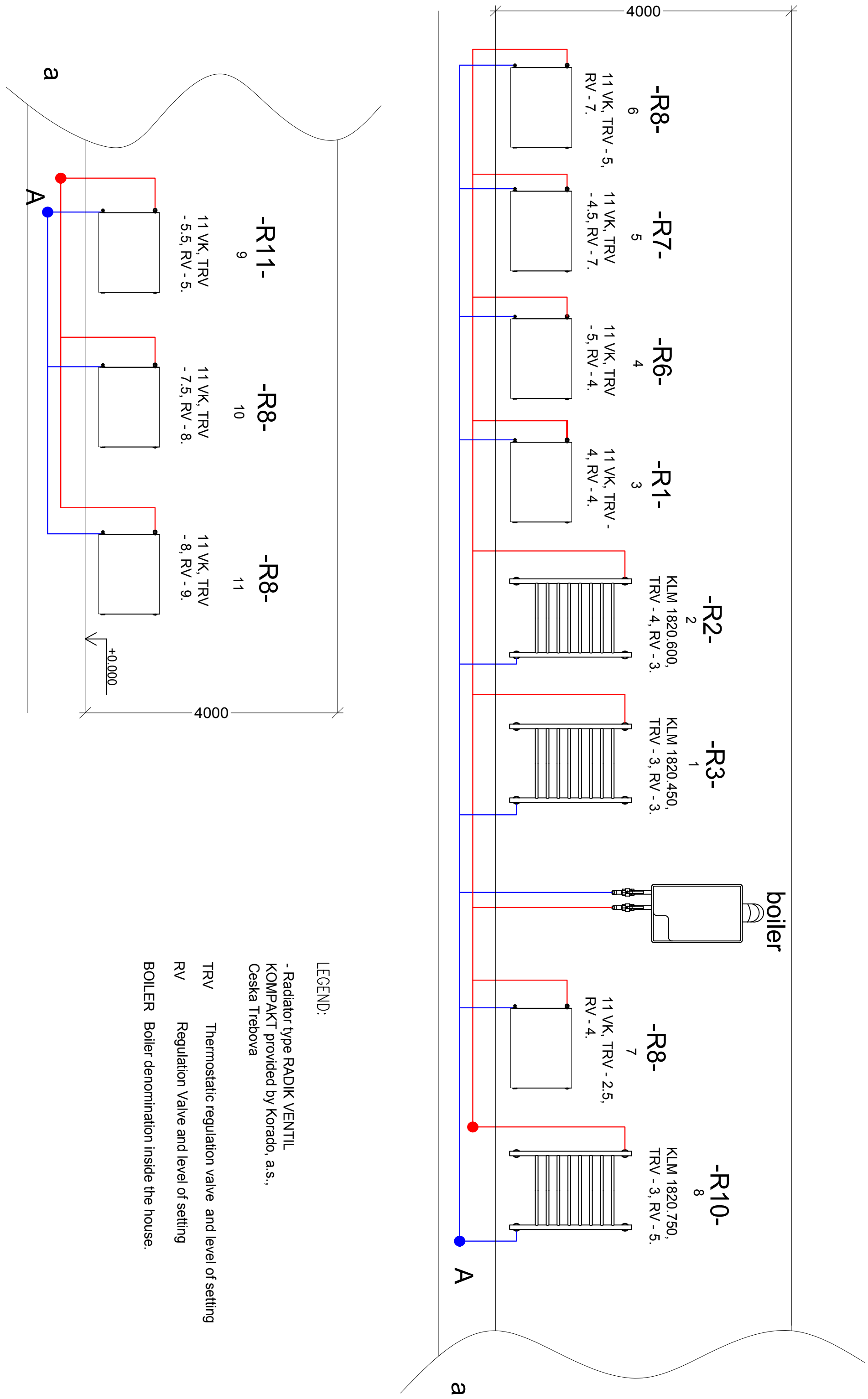

Figure 10. Unfolded View of Heating system inside the house.

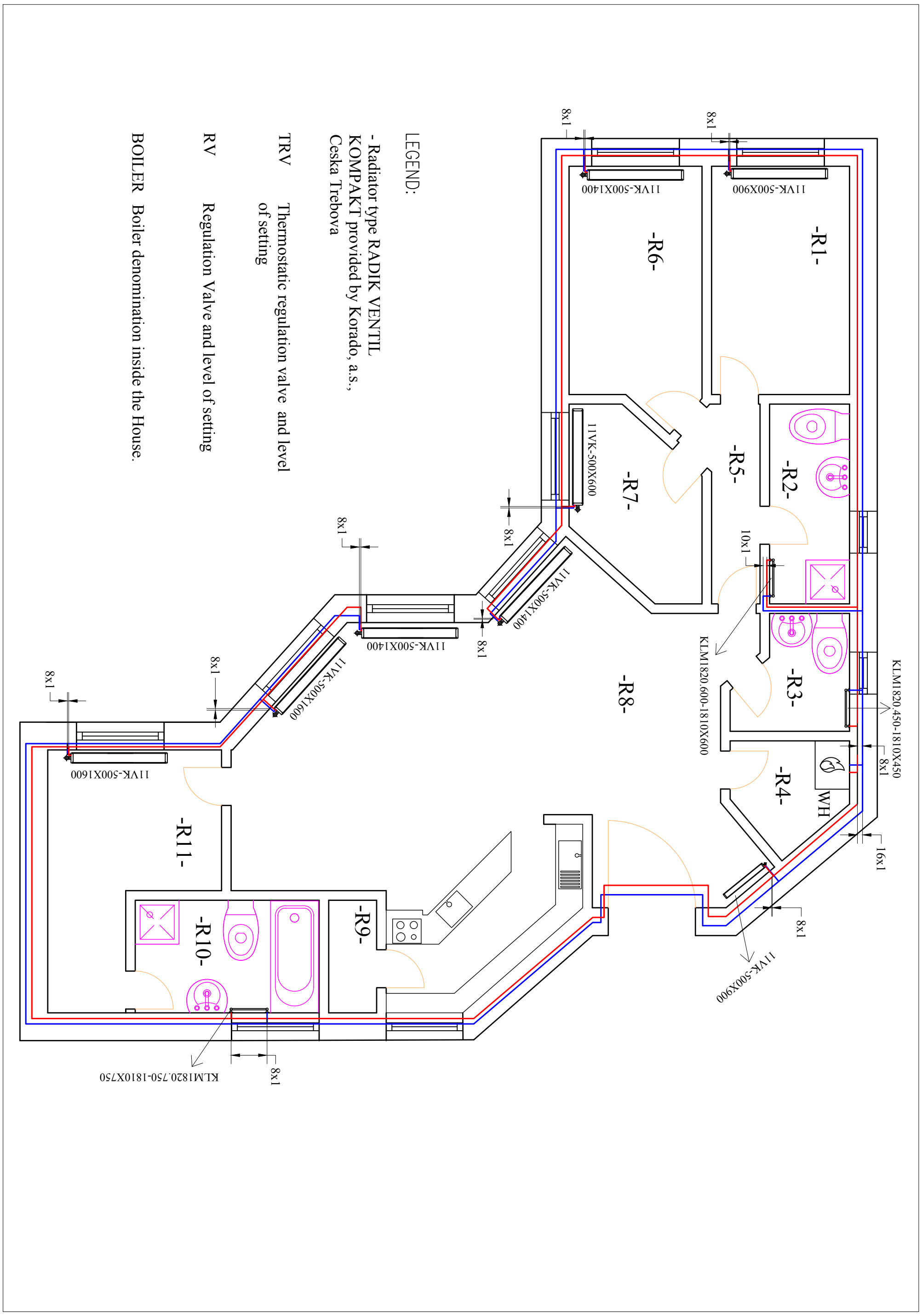

Figure 11. Top view of Family House with description

7 CONCLUSION

The goal of this thesis is to Design the heating system in family house, to see how one should approach this task in the best way possible and most efficient manner. From the selection of the right material for composition of the building to calculation of losses and many others to meet the criteria of acceptance for to be able to design and come up with solutions of the best possible scenario to implement our ideas on how it would be after all the calculation and analysis are done if we can move forward with proposal of construction, from selection of the windows to the doors and all the insulation materials that will be part of the construction this are some of the things we have to have in mind when performing this task.

I found that the most easy way to start is to first imagine how it would be to actually be inside the house so for that a plant based model of our building actually helps us visualize from where we can start or have a basic idea of it, the selection of materials is no easy task for that we have to combine a lot of materials that can give us the perfect thermal insulation so that our heat losses are not that large, like any other construction or design of anything we must always take into account the cost of our materials, we must keep this mind when design or projecting something. But the goal here is not cost analysis is to see how simple and effectively can we design the heating system of the house.

From the radiators to the thermostatic valves and regulating valves, to the pipes in length and diameter to the selection of the our water heating pump, all of them will have a great impact on how well our heating system will perform under certain conditions and it is our job to make sure that the implementation of this heating system is working perfectly and as it should, that's where the balancing of the heating system also comes into play to ensure that all our radiators are getting the right amount of water flow in them to be able to eat properly the rooms. On an article I read ¨**Challenges for the Transition to low-temperature heat in the UK: A Review**¨[16], it stated for the design engineer, over-sizing can present less risk than under-sizing, and there are no incentives to correctly size a system. During the design stage, components are usually selected to be larger than required to ensure safety margins, and during the procurement stage, the next size up is chosen because components are available in a limited number of sizes. [16], meaning when selecting the components, I went for larger sizes instead of smaller sizes then the required for our system to and what is written in the article has solid basis for the selection of the pipe diameters from the tables I took the largest unit close to the values found for each section of the pipe.

Knowing which type of water heating pump, you will need for your house of design is also important, it can happen that the installation is ok is running smoothly but the heating pump installed is not fulfilling the demands of our system and in this case there is no problem because we have calculations that show us how to avoid the wrongful selection of our heating pump and help us select the right one for our system. In reality the tools are all here one might get confused and lost during the process, so is good to create table of calculations excel sheets where you can mark and see all your calculations accordingly and monitor everything to see if its ok or not, that way you can avoid major errors while proceeding with next phases and even if you made a mistake you can always go back and view step by step where might the error be and correct it is also good if you can link your tables to make sure if by mistake put in a wrong number and the calculation are not adding up you can always correct and the link tables will update themselves because you made it so that way.

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