International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com

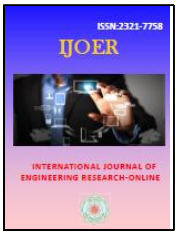
Vol.7., Issue.4, 2019
July-Aug

RESEARCH ARTICLE

ISSN: 2321-7758

DESIGN OF AIR-WATER HEAT PUMP HEATING SYSTEM IN COMBINATION WITH BIVALENT SOURCE

Dr. MOHAMED MUSTAFA ABDULGALIL[1], Dr. IMHAMED M. SALEH ALI[2]
[1]Higher institute of sciences and Technology, Sirte, Libya.
Email- alsewe7803@yahoo.com.
[2]Mechanical Engineering- Sirte University - Libya.
Email:isa6@su.edu.ly
https://doi.org/10.33329/ijoer.74.56



ABSTRACT

The work solves the complete reconstruction of the heating system, i.e., including the source of heat, piping and radiators, family house with higher heat losses. An air-to-water heat pump is selected as the heat source. With regard to minimal construction interventions, the system is designed with panel radiators. Calculation of the required output for hot water production and selection of a heat pump of the appropriate output series in combination with an accumulation tank with built-in hot water tank is performed. The point of bivalence is determined, the backup source is electric heating elements installed in the accumulation tank.

Keywords: Heat loss, heating, hot water heating, design of heating system, air-water heat pump, bivalent source, panel radiators, storage tank.

1.0 Introduction

Ensuring thermal comfort of the environment is one of the basic needs of man. The heat source and the heating system therefore belong to the necessary technical equipment of residential buildings. Along with the development of technology, the possibilities for ensuring this state of the environment are being expanded. For heat pumps, high investment costs are associated with lower operating costs. At the same time, it is a move away from traditional fossil fuel boilers or biomass occupying agricultural land, leading to a reduction in the extraction of firewood, gaseous and liquid fuels and other exhaustible resources.

Heat pumps use renewable energy sources. The air-to-water heat pump can be considered environmentally neutral in terms of heat removal from the environment, since the low-potential heat of the extracted air is returned to the outdoor environment in the form of heat losses of the building.

The aim of this work is to design a heating system and hot water for a family house and to determine the necessary heat pump performance in connection with a bivalent heat source, where the second source are used electric heaters located in the accumulation tank, and determination of bivalence point.

The work includes calculation of heat losses, design of radiators and piping dimensions, calculation of pressure losses and selection of suitable circulation pump. Further determination of the required output for hot water heating according to the heat supply and consumption curve, selection of a storage tank with built-in hot water tank. It also includes expansion volume determination, air-to-water heat pump selection and bivalence point determination.

International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com
Vol.7., Issue.4, 2019
July-Aug

1.1 Characteristics of the Family House (Subject)

The subject of this work is a proposal of reconstruction of heating of a family house in Tripoli (Libya) near Governmental hospital. The building is situated to the north-northeast. The house is two-generation, with one underground and two above-ground floors. The ground plan dimensions are 12 x 9.9 m. The total area of heated rooms is 194.95 m^2. Construction of the house began in 2013. The current picture of the building is in Figure. 1.

Furthermore, to replace original windows and doors with triple-glazed windows / doors, in the case of double-glazed roof windows. Expert energy assessment by PROST indicates that this adjustment reduced the specific heat demand for heating from 199.9 kWh / m^2 year to 139.0 kWh / m^{2}year, ie by 30.4%. Heating and hot water heating are provided by the original Destila DP 25Z natural gas boiler with a rated output of 25.0 kW with a production date of 1985. Due to boiler wear resulting in reduced efficiency (rated efficiency of 84.9%), non-insulated basement piping and rising natural gas prices do not generate the required savings. Due to the age of the building and hence the heating system, it was decided on its complete reconstruction, so the proposal includes replacement of heat source, distribution and radiators.

Figure. 1 Front view of the house

For illustration, Figure shows the layout of individual floors. The basement is heated up to one room. The hall on the 2nd floor (103_2) is heated by a radiator placed in the hall on the first floor (103) through a common staircase. The legend for room marking is given in Tab. 1.1.

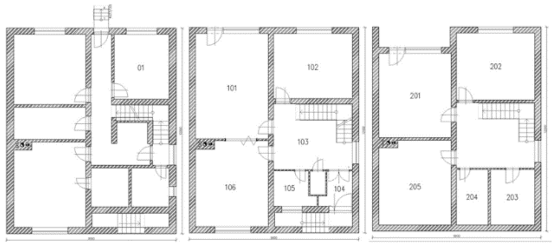


Figure. 2 Simplified construction drawing indicating the rooms to be heated; 1st floor, 1st floor and 2nd floor

Tab. 1.1 Designation of heated rooms

Room designation	number m.
Study	1
Living room	101
Room	102
Hall	103
Hall-2	103.2
Hall	104
Bathroom	105
Kitchen	106
Bedroom	201
Bedroom	202
Cloakroom	203
Bathroom	204
Room	205
Total	12

2.0 THERMAL LOSSES

Before designing the heating system, it is necessary to know the thermal technical properties of individual structures and to determine the heat losses. The calculation of heat losses is carried out according to the standard ISI 12831 Heating systems in buildings - Calculation of heat output [1]. Unless otherwise stated, all relationships used in this paper are taken from that standard.

2. 1 Climate data

The basic data for determining the heat loss of an object are its geographical location, location in the landscape, or whether the surrounding buildings are adjacent to sit or stand alone. The calculation values for a given area are determinant and unalterable quantities. Climatic data for the calculation area Tripoli are given in Tab. 2.1.

Tab 2.1 . Climate data

	Altitude	Outdoor calculation temperature	Length of heating period	average daily temperature in heating
marking	hnm	tem	d	period
unit	[m]	[° C]	[day]	t_m, e
Tripoli	81	-3	120	[° C]

The length of the heating period and the average temperature in the heating period depend on how we define this period. For the beginning of the heating period, respectively. Continued heat supply can be considered a day before the average daily temperature falls below the defined value for two consecutive days and due to the meteorological forecast it is not expected to increase the average daily temperature above this value the following day. End of heating period, resp. the interruption in heat supply occurs when the average daily temperature for two consecutive days exceeds a defined value and if the average daily temperature cannot be expected to fall below this value due to the weather forecast. This defined value is usually +13 ° C, optionally 12 ° C, or 15 ° C. "For new and well-insulated houses, there is a tendency to reduce this limit - even up to 10 ° C, due to low energy needs." [2].

2.2 Room information

The heat loss of the room is directly proportional to the internal calculation temperature of the room. The design values of the internal calculation temperature for heated spaces are taken from the ISI 73 0540 Thermal Protection of Buildings - Part 3: Design values. [3]

2.3 Components

To determine the heat losses, it is necessary to describe the composition of individual building structures, both in terms of dimensional and thermal properties. These are characterized by the coefficient of thermal conductivity λk [W / m.K], which gives a measure of the ability of the material to conduct heat. The values of the thermal conductivity coefficient for individual materials are taken from the standard ISI 07 0540 Thermal protection of buildings - part 3: Design values. [3]

2.3.1 Heat transmission through hole fillings

The heat transfer coefficient of the window Uw or the door Ud is proportional to the glazing area and the frame area [4]. Heat transfer coefficients of windows and doors are given in Tab. 2.2

Tab. 2.2 Thermal properties of whole fillings

Building part	Description	**Uw**	**ΔUtb**	**Aw**
		W/m2.K	W/m2.K	m2
18	Entrance door	1,06	0,56	2,80
19	Outside courtyard door	3,47	0,56	1,60
20	Outside side doors	1,08	0,28	1,60
21	French window bottom	0,88	0,74	5,21
22	French window upper	0,88	0,74	5,21
23	Kitchen window	0,87	0,43	3,05
24	Window bathroom	1,06	0,19	0,84
25	Window laundry	2,43	0,46	1,26

26	Roof windows	1,15	0,32	0,92
27	Bedroom window	0,87	0,43	3,05
28	Window room	0,87	0,43	3,05
29	Office window	0,92	0,34	2,03
30	Workshop window	2,47	0,68	2,03
31	The pantry window	2,38	0,16	0,36
32	Window hallway - small	1,03	0,13	0,63
33	Window hallway - large	0,83	0,29	2,60

where Uw is the heat transfer coefficient of the window [W / m2.K]

Aw total window area [m^2]

Linear heat transfer coefficient - ie the effect of a thermal bridge

2.4 Heat loss of heated rooms

The total heat loss of the heated space Φi is given by the sum of the heat losses through the passage and ventilation

$$\Phi_i = \Phi_{T,i} + \Phi_{V,i} \qquad ..(1)$$

where ΦT, i is the heat loss through transmission [W]

ΦV, i the heat loss through ventilation [W]

Celkovái total heat loss [W].

2.5 Heat loss through heat transfer

Heat loss through heat is determined by the following factors:

$$\Phi_{T,i} = \left(H_{T,ie} + H_{T,iue} + H_{T,ig} + H_{T,ij}\right) \cdot (t_i - t_e) \qquad ..(2)$$

where

HT_{ie}, ie is the heat loss coefficient of transmission from the internal heated space directly to the external environment

HT_{iue}, is heat loss coefficient by passing through unheated space

HT_{ig}, is coefficient of heat loss to soil

HT_{ij}, is the heat loss coefficient by penetrating into a room heated to a different temperature

3.0 RADIATORS

Insufficient nominal output of existing radiators at the newly designed temperature gradient (Figure 3) and the age of the entire heating system led to the decision of a complete renovation.

The investor's requirements to minimize construction interventions, especially in floor constructions, have led to certain limitations. The largest of these was the elimination of the installation of floor or wall heating. Low-temperature systems are advantageous in terms of operating costs when operating the heat pump.

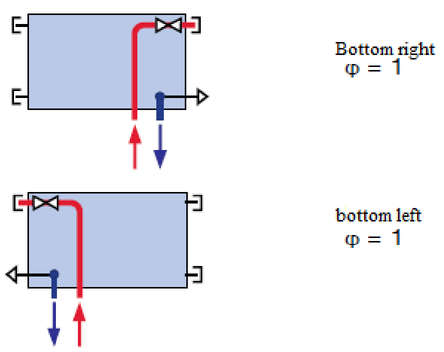


Figure. 3 Connection of radiators to the heating system [6]

Therefore, the panel radiators Radik RC VKU with left or right bottom connection from the company Korado were chosen. The connection of the bodies is shown in FIGURE. 3. These bodies are specific by controlled leakage, where by switching the valve the flow through the back plate can be fully shut off. Thus, while maintaining the same inlet temperature, the surface temperature of the rear panel of the body can be reduced, which reduces heat loss, and the surface temperature of the front panel can be increased. This leads to an increase in radiation temperature and thus an increase in thermal comfort. A secondary phenomenon is the possibility to heat the air in the room to a slightly lower temperature while maintaining thermal comfort. The operation modes are shown in FIGURE. 4.

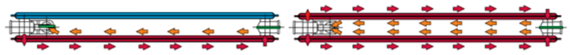


Figure 4. Illustration of the operating modes of the body with controlled flow [6]

A heat pump is more advantageous when working with a lower temperature of the heat transfer medium and with the lowest possible temperature drop (about 5 K). This is mainly due to the fact that as the heat transfer medium temperature increases, the heat pump input increases, ie the coefficient of performance (COP) decreases.

Heat output of the radiator **Q_T** je [2]:

$$Q_T = \dot{m} \cdot c \cdot (t_{w1} - t_{w2})$$ Eq 3.1

Where

$\dot{m}$ is mass flow through the body [kg / s]

c specific heat capacity of water [J / kgK]

t_{w1} temperature of water entering the body [° C]

t_{w2} temperature of water leaving the body [° C]

Q_T radiator output [W].

It follows from relation (3.1) that the output of the radiator is directly proportional to the product of the temperature difference of the heating water at the inlet and outlet of the radiator and the flow rate of the heat transfer medium. However, it also depends on the air temperature to which we want to heat the room. If a higher air temperature is required, the temperature difference between the medium medium temperature and the air temperature and thus the body performance is reduced. The nominal heat output of a radiator is usually given for several temperature gradients and a room air temperature of 20 ° C. For other design conditions it is necessary to recalculate the power according to [2]:

$$Q_T = Q_n \cdot \left(\frac{\Delta t}{\Delta t_n}\right)^n$$ Eq 3.2

where Qn is the nominal heat output of the body [W]

Δt temperature difference [° C]

The temperature difference is given by the difference between the mean temperature of the heat carrier and the air temperature:

$$\Delta t = \frac{t_{w1} + t_{w2}}{2} - t_i$$ Eq 3.3

Substituting equation (3.3) into equation (3.2), we obtain the radiator output:

$$Q_T = Q_n \cdot \left(\frac{\frac{t_{w1} + t_{w2}}{2} - t_i}{\frac{90 + 70}{2} - 20}\right)^n$$ Eq ..3.4

Heat transfer from the radiator takes place according to general heat transfer relations. Heat is transferred to the internal environment by convection and radiation:

$QT = Qk + Qs$ Eq (3.5)

where

Qk is the heat transmitted by convection [W]

Qs heat transmitted by radiation [W].

$$Q_k = \alpha \cdot S_L \cdot (t_p - t_i)$$ Eq 3.6

where

S_L is the heat transfer coefficient

external radiator transfer area [W / m^2.K] [m^2]

t_p body surface temperature [° C].

$$Q_s = S_L \cdot \varphi_{Oj} \cdot c_{Oj} \cdot \left[\left(\frac{T_p}{100}\right)^4 - \left(\frac{T_{pOj}}{100}\right)^4\right]$$ Eq 3.7

where ϕ_{Oj} is the ratio of irradiation from the selected glowing area SL to the irradiated area SOj

c_{Oj} the coefficient of mutual radiation between the S_L and S_{Oj} surfaces

T_p surface temperature of radiator [K]

Tp_{Oj} surface temperature of irradiated area S_{Oj} [K].

It is apparent from the above relationships that the performance of the body increases with the transition surface and the surface temperature of

International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com
Vol.7., Issue.4, 2019
July-Aug

the surface. A temperature gradient of 55/45 ° C was chosen. The heating system is completed with an accumulation tank.

The length of the radiators is chosen according to the width of the windows to reduce the influence of falling cold currents. The calculation of the radiators is given in Tab. 3.1.

Tab. 3.1 Radiators performance

NO. (m)	Room designation	**indoor temperature**	**heat loss**	**body performance**	**coverage of losses**	**type and dimensions**	**product line**
		ti	**Φi**	**QOT**			
		°C	W	W	%	mm	-
01	Study	20	1474	1358	98,9	22x600x1600	RC VKU
101	Living room	20	1493	1469	101,7	22x500x2000	RC VKU
102	room	20	1376	1360	98,8	22x600x1600	RC VKU
103	Room	18	1691	1665	98,5	22x600x1800	VKU
104	Hall	15	521	527	101,0	20x500x1000	RC VKU
105	Hall	24	827	857	103,5	22x900x900	VKU
106	Bathroom	20	1880	1952	105,8	22x600x2300	RC VKU
201	Kitchen	20	1451	1469	101,2	22x500x2000	RC VKU
202	Bedroom	20	1315	1305	99,2	21x600x2000	RC VKU
203	Bedroom	20	663	680	102,6	21x500x1200	RC VKU
204	Cloakroom	24		422		21x500x900	RC VKU
204	Bathroom	24	601	202	103,8	KS1220.600	KORALUX ST
205	Bathroom	20	1070	1134	105,9	21x500x2000	RC VKU

4 PIPE ROUTES

The piping network is used to transport the heat transfer medium, in our case water, to the sampling points, ie radiators. The basic division of network typologies in terms of the direction of distribution is horizontal and vertical. The investor's requirements made it impossible to use horizontal distribution systems, therefore vertical distribution systems were chosen, which to some extent preserve the existing solutions.

The heating system is designed as a two-pipe, counterflow, closed, with a horizontal horizontal distribution, vertical with forced circulation. The pipe material is copper.

The design of piping dimensions is based on hydraulic calculations, ie determination of pressure losses. The total pressure loss of the section Δp is given by [2]:

$$\Delta p = \Delta p\lambda + \Delta p\zeta \qquad (4.1)$$

where Δp is the total pressure drop of the section [Pa]

Δpλ friction pressure loss [Pa]

Δpζ pressure drop by local (connected) resistors [Pa].

Pressure losses due to friction are characterized by:

$$\Delta p_\lambda = \lambda \cdot \frac{l}{d} \cdot \frac{w^2}{2} \cdot \rho \qquad (4.2)$$

Pressure losses with in-line resistors are determined by:.

$$\Delta p_\zeta = \sum \zeta \cdot \frac{w^2}{2} \cdot \rho \qquad (4.3)$$

where ζ is the local resistance coefficient [-].

For example, the friction coefficient λ can be determined using the "Solver" function in Excel from the formula:

$$\frac{1}{\sqrt{\lambda}} = -2 \cdot \log\left(\frac{2{,}51}{Re \cdot \sqrt{\lambda}} + \frac{k}{3{,}72 \cdot d}\right) \quad (4.4)$$

where Re is Reynolds number [-]

k pipe roughness [mm].

Reynolds number is then given by dependence

$$Re = \frac{w \cdot d}{\nu} \quad (4.5)$$

where v is the kinematic viscosity [m2 / s].

Kinematic viscosity, density and specific heat capacity vary with temperature:

$\nu = 19.8 \cdot 10^{-6} \cdot t^{-0.915}$ [m²/s] (4.6)

$\rho = 1006 - 0.26 \cdot t - 0.0022 \cdot t^2$[kg/m³] (4.7)

$c = 4210 - 1.363 \cdot t + 0{,}014 \cdot t^2$ [J/kg.K] (4.8)

To determine the flow velocity, we proceed from the required flow through the bodies:

$\dot{m} = S \cdot w\, \rho$ [kg / s] (4.9)

where ṁ is the mass flow rate [kg / s].

$$w = \frac{\dot{m}}{S \cdot \rho} = \frac{4 \cdot \dot{m}}{\pi \cdot d^2 \cdot \rho} \quad (4.10)$$

$$\dot{m} = \frac{Q}{c \cdot (t_{w1} - t_{w2})} \quad (4.11)$$

The flow velocity depends on the amount of heat delivered to the radiators. We choose the pipe diameter so that the flow velocity is in the recommended economic values 0.2 to 1.5 m / s. [2] At higher speeds, the piping would wear more, noise conditions would increase, and the power of the circulation pump would also increase. In addition, there may be insufficient heat transfer on the radiator side.

The dimensioning of the individual piping sections is carried out in such a way that the pressure conditions for the radiator connection are as similar as possible while maintaining lower pressure losses. The pressure differences are then compensated by throttling the control valve on individual bodies according to the manufacturer's pressure diagram. An example of the calculation of the pressure losses of the circuit through the radiator 01 is given in Tab. 4.1. The degree of valve presetting is given in Tab. 4.2.

Tab. 4.1 Pressure losses - circuit via radiator no. 01

Section	**Q**	**m**	**l**	**d**	**w**	**R**	**R*l**	**Σζ**	**Z**	**R*l+Z**
	[W]	[kg/h]	[m]	[mm]	[m/s]	[Pa/m]	[Pa]	-	[Pa]	[Pa]
23	14 401	1 241	4,50	32	0,44	71	321	13,8	1282	1603
19	8 627	743	1,33	32	0,26	29	38	3,8	127	166
17	6 962	600	4,97	32	0,21	20	98	0,6	12	110
15	1 358	117	4,04	13	0,25	84	337	17,3	526	863
z15	1 358	117	4,04	13	0,25	84	337	25,2	767	1105
z17	6 962	600	4,97	32	0,21	20	98	3,2	70	168
z19	8 627	743	1,33	32	0,26	29	38	1,5	50	88
z23	14 401	1 241	5,20	32	0,44	71	371	7,2	671	1042
Total pressure drop										**5145**

The pressure losses of the individual sections are given in the annex "Piping sections."

The greatest pressure loss is in the radiator circuit No. 201, Δp = 5223 Pa. This value is increased by the pressure drop of the fully opened thermoregulation

International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com

Vol.7., Issue.4, 2019
July-Aug

valve according to the radiator manufacturer's diagram (the radiators are already fitted) at a known flow rate through the radiator. The mass flow rate through the body No. 201 is 127 kg / h and this flow rate corresponds to a pressure loss TRV of 2200 Pa, so the total pressure loss of the circuit through the body No. 201 is 7423 Pa. From this value we subtract pressure losses of individual circuits and this difference gives us the degree of presetting TRV when flowing through the given body. This regulation ensures the projected flow of radiators. An example of pressure drop reading and TRV setting is shown in Figure. 5.

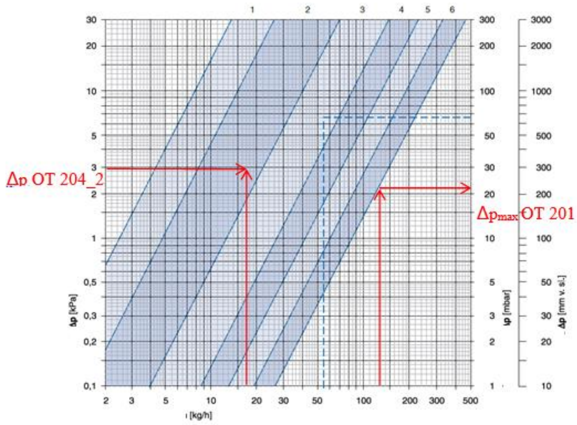


FIGURE. 5 Presetting of thermoregulation valve in pressure diagram [6]

Tab. 4.2 The degree of pre-setting of the thermoregulation valve on the individual housings

body number	**circuit pressure drop**	**differential pressure**	**mass flow**	**degree of valve presetting**
	R·l+Z	**Δp**	ṁ	**-**
	[Pa]	**[Pa]**	**[kg/h]**	**[-]**
01	5 145	2 278	117	6
101	4 542	2 880	127	6
102	4 612	2 811	117	6
103	4 523	2 900	144	6
104	3 821	3 601	45	3
105	3 774	3 649	74	4
106	5 011	2 412	168	6
201	5 223	2 200	127	6
202	4 670	2 753	112	6
203	4 090	3 333	59	4
204-1	3 831	3 592	36	3
204-2	2 890	4 532	17	2
205	4 170	3 253	98	5

The distribution piping located under the ceiling in the basement will be insulated along the entire length with 20 mm thick Mirelon thermal insulation.

5.0 HEAT SOURCE

The power output or the sum of the outputs of multiple heat sources must cover the heat losses of the object whose heating is to be or should be provided. Heat losses are determined on the basis of outdoor calculation temperature for a given area, which is determined from long-term meteorological measurements, eg over decades. For the area of Tripoli, where the object is located, this temperature is -3 ° C.

This paper deals with the design of a heating system with an air-water heat pump. The power of this type of power supply is directly proportional to the outdoor temperature, as the temperature

International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com

Vol.7., Issue.4, 2019
July-Aug

decreases, the power decreases. Ensuring coverage of 100% heat loss by a heat pump would be considerably inefficient as any increase in power is costly to invest. Moreover, it is not expedient to design its output to the outdoor design temperature, because such low temperatures occur only a few days a year. A bivalent source, which is less expensive to invest, serves to cover the lack of power at these temperatures.

In order to make the heat pump operation more advantageous with respect to initial investments, it is necessary to have a two-tariff electricity tariff. The different rate is intended for heat pumps, which is divided into 22 hours of low tariff and 2 hours of high tariff. For the duration of the high tariff, the operation of the heat pump must be blocked by the HDO signal (collective remote control). A prerequisite for obtaining the different rate is to cover at least 60% of the heat loss (at the external calculation temperature) by the heat pump. [7]

The recommended range of heat loss coverage by the heat pump is between 50 and 75% in [2]. Dimensioning the heat pump's performance to provide greater heat loss coverage would not offset operating savings from a higher initial investment. The Regulus CTC EcoAir 420 heat pump was selected according to these criteria.

5.1. An illustration of the heat pump used is shown in FIGURE. 6.

Figure 6 Regulus CTC EcoAir 420 Air to Water Heat Pump [8]

Determination of bivalence point

To determine the operating parameters, it is necessary to perform a static characteristic of the heating system. This shows the equilibrium between the heated object, the heating system and the power output. This equilibrium state is called the bivalence point and indicates the lowest outdoor temperature at which heat loss is still covered by the heat pump itself. [2] The design allows to choose between two modes in terms of operating a bivalent source at temperatures below the bivalence temperature. The sources can be operated in series, where the heat pump is shut down below the bivalence temperature and only the bivalent source is running. The second option is parallel operation, the heat pump is running simultaneously with the bivalent source. This proposal involves a second approach, ie parallel running.

In order to perform a static analysis, the following characteristics must be known:

- Dependence of heat losses on outdoor temperature QT = f (te)
- Dependence of heating system output on supply water temperature QOS = f (tw1)
- Dependence of source output on the outlet water temperature and outdoor temperature QTČ = f (tw1, te)

5.1.1 Dependence of heat losses on outdoor temperature

Heat losses were calculated in previous section. At an outdoor design temperature of -3 ° C it is 14.180 kW. This dependence is linear, the specific heat loss is 433 W / K. The specific heat loss per unit volume is 30.26 W / m^3. The specific heat loss per unit area of the heated space is 73.68 W / m^2.

From the previous relationships it is possible to construct an equithermal curve, or the dependence of the supply water temperature on the outside temperature, so that the power of the system covers the heat losses. A graph of equithermal dependence is shown in FIGURE. 7

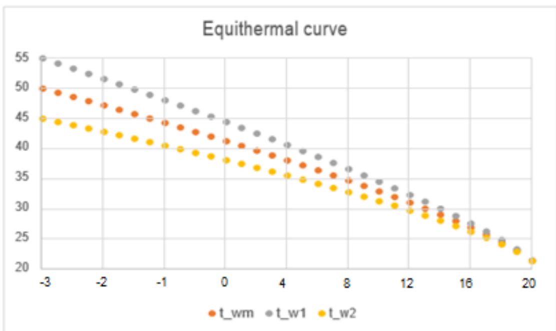


FIGURE. 7. Equithermal curve

International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com
Vol.7., Issue.4, 2019
July-Aug

Horizontal axis - outside temperature te [° C]; vertical axis - heating water temperature: t_wm - mean heating water temperature; t_w1 - supply water temperature; t_w2 - return water temperature.

5.1.2 Dependence of the power output on the outlet water temperature and outdoor temperature

From the foregoing, it is apparent that the performance of the air-to-water heat pump is dependent on both the outside air temperature and the desired leaving water temperature. These requirements diverge as the available power decreases as the outdoor temperature decreases, while higher outlet water temperatures are required, leading to a further reduction in performance. The characteristics of the heat pump are given by the manufacturer; is determined experimentally. It indicates the power dependence on the outlet water temperature at different outdoor temperatures. The characteristics of the heat pump are shown in Tab. 5.1.

Tab. 5.1 Air-to-water heat pump parameters Regulus CTC EcoAir 420

t_e	**Q**	**Q**	**Q**	**COP**	**COP**	**COP**
°C	W	W	W	-	-	-
t_w1 °C	35	45	55	35	45	55
-15	9520	9070	8720	2,52	2,09	1,76
-7	11510	11540	11430	2,92	2,52	2,19
2	14550	14020	13670	3,52	2,92	2,52
7	17520	18020	17320	4,15	3,60	3,06

5.1.3 Bivalence point

To find the point of bivalence, it is necessary to determine the equilibrium state of the previous characteristics. This is possible both graphically and numerically. Since the selection of the heat pump characteristic curve will affect the determination of equilibrium, the bivalence point will be calculated numerically.

In the previous discussion, the dependence of heat losses on the outside temperature is given.

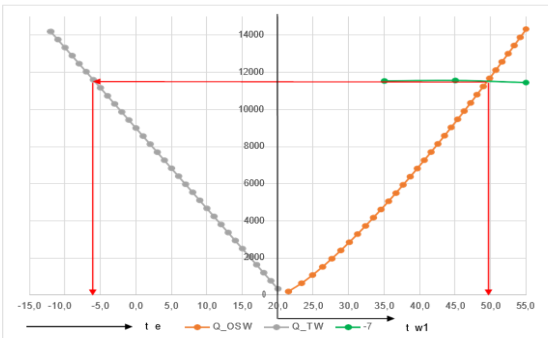
It remains to be determined at the lowest outdoor temperature the heat pump is able to supply water at the required temperature so that its performance will cover the heat loss of the object at this outdoor temperature, ie the bivalence temperature.

First, by linear interpolation, we calculate the available heat pump capacity depending on the outside temperature at three levels of the specified outlet temperature: 35, 45 and 55 ° C.

From the characteristic of the heating system we know the required flow temperature depending on the outdoor temperature. Again, we use linear interpolation, where we determine the output of the heat pump at a given outdoor temperature for the required flow temperature.

Similarly, we determine the temperature factor - COP, this data will later be used to determine the approximate seasonal heating factor SCOP.

Then we know the ratio between heat pump output, heating system output and heat losses during outdoor temperatures. We are looking for the ratio of heat pump power to heat loss closest to 1. The corresponding outdoor temperature is the desired bivalence point. In this way, the bivalence temperature tbb was determined to be -6 ° C. We will perform a graphical check for this temperature. The graphical solution is shown in FIGURE. 8.



Dr. MOHAMED MUSTAFA ABDULGALIL, Dr. IMHAMED M. SALEH ALI
KY Publications

International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com
Vol.7., Issue.4, 2019
July-Aug

FIGURE. 8 Graphic determination of bivalence point [2]

Vertical power / loss axis in Watts; t_e - outdoor temperature; t_w1 - water outlet temperature from a heat pump; Q_OS - heating system output; Q_T - heat loss of the object; heat pump output at -7 ° C outdoor temperature. The graphic solution also determines the bivalence temperature to -6 ° C. The outlet water temperature is 50 ° C.

5.2 Bivalent source

At a calculated outdoor temperature of -3° C, the heat pump has a power of 9.736 kW at an outlet water temperature of 55 ° C. The losses of the building are 14.180 kW. The minimum power of a bivalent power supply is given by their difference, ie 4,444 kW. Two electric heaters installed in the storage tank were selected as the secondary source, one of 2 kW and the other of 3 kW. In FIGURE. 9 is a photograph of a bivalent source.

FIGURE. 9 Electric heater placed in a storage tank [10]

The reason for choosing two bodies instead of one is their low cost and theoretically a higher proportional representation of the heat pump in bivalent operation and therefore less power consumption. The representation of sources in bivalent operation as a function of outdoor temperature is shown in Figure. 10.

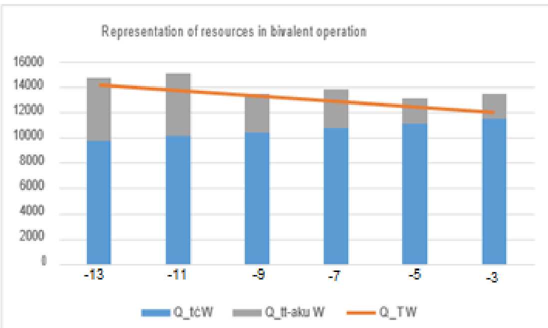


FIGURE. 10 Proportion of resources in bivalent operation

On the horizontal axis the outside temperature te, on the vertical axis the power / loss in Watts; Q_T - heat loss at a given outdoor temperature; Q_tč - heat pump performance at a given outdoor temperature; Q_tt - power of bivalent source, at te -7 to -8 ° C in operation 2 kW body, -9 to -10 ° C 3 kW body, below -11 ° C both bodies

6 ACCUMULATION TANK

The system is equipped with an accumulation tank to compensate for sudden increased heat demand. To avoid frequent cycling, ie switching the heat pump, it is necessary to observe the condition of minimum charge of the heat transfer medium. If the volume of the heating system is lower than this setpoint, the system must be supplemented with an accumulation tank. The minimum volume of heat transfer medium is also important in terms of reversing the heat pump. In this mode, the heat pump uses the heat from the heating system to defrost the frost. If the system did not contain enough water, the reversing would have a negative effect on the thermal comfort of the heated space. [2]

$V_{aku} = cca\ 15 \cdot Q_{zdroj}$ = 15 · 14.55 = 218 [l] (6.1)

where the vacuum is the minimum charge of heat carrier [l]

Q_{zdroj} Source Power Source [kW].

Here, the output at A2 / W35 conditions, ie at an outdoor temperature of 2 ° C and a flow temperature of 35 ° C for the heat pump, is considered as the source output in the case of an air-water heat pump.

As the project's requirement is to ensure the supply of hot water, a storage tank has been selected with the Regulus DUO 750/200 P built-in hot water tank. Ezocoil insulation with a thickness of 100 mm is included. The volume of the hot water tank is 192 liters, the volume of the storage tank is 565 liters. The selection of a larger tray was excluded due to the width of the door 80 cm to the utility room. The parameters of the storage tank are given in Tab. 6.1, the tank diagram is shown in FIGURE. 11.

Tab. 6.1 Storage tank parameters

Parameter	value	unit
Total volume of liquids in the storage tank	757	l
Volume of liquid in the DHW tank	192	l
Volume of liquid in the storage tank	565	l
Maximum operating temperature in the tank	95	°C
Maximum operating temperature in DHW cylinder	95	°C
Maximum working pressure in the tank	4	bar
Maximum operating pressure in DHW tank	6	bar
Weight of empty tank	118	kg
Tilting height with insulation removed	1990	mm

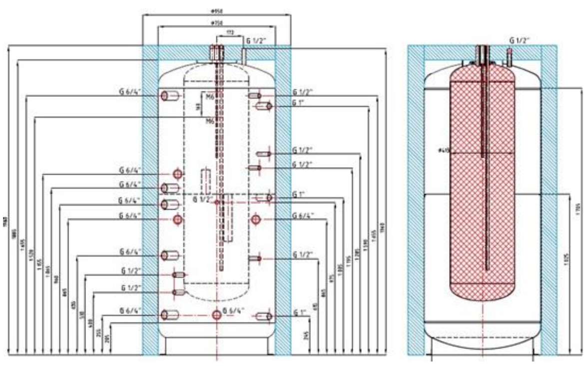


FIGURE. 11 Diagram of a storage tank with built-in storage tank [11]

7.0 HOT WATER HEATING

The assignment of the project is to ensure hot water heating. There are two approaches to hot water heating solutions. Either by selecting the storage tank size based on the available heating capacity, or conversely, at a known hot water storage volume, calculate to determine the power required to provide the heat supply. In this case, the second option was chosen because the selected storage tank contains a 192 liter hot water tank. The heat output required is determined on the basis of heat supply and demand curves.

7.1 Heat supply and consumption curves

The heat demand curve is the dependence of the heat demand on the time τ during the period.

The curve used corresponds to the standard consumption curve of residential buildings. It is constructed based on the values in Tab. 7.1. The heat supply and demand curves are shown in FIGURE. 12.

Tab. 7.1. Hot water abstraction per period [2]

subscription [%]	**From [h]**	**To [h]**
35	5	17
50	17	20
15	20	24

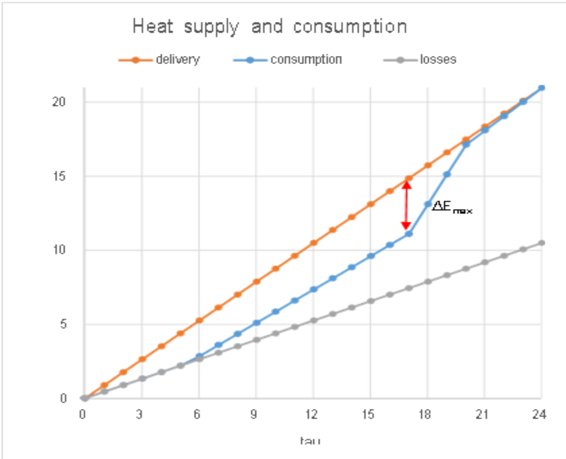


FIGURE. 12 Heat supply and demand curves [2]

8.0 CIRCULATION PUMPS

The pump must ensure the transport of the heat transfer fluid through the piping in the required quantity. The required flow rate is given in the design of the radiators, resp. heating system output. It is based on the equation (3.1), which is adjusted to the form:

$$\dot{V} = \frac{Q_{ot}}{c \cdot \Delta t \cdot \rho} \quad [m^3/s] \ (8.1)$$

where Q_{ot} is the power of the heating system [W]

$\dot{V}$ volume flow [m^3/s].

The selection of a suitable circulation pump is determined by the correct determination of the operating point. The characteristic of the pump is the dependence of the head on the flow. The increase in kinetic energy in a closed circulatory system is negligible in the case of small objects with the correct design. The third term of the equation (8.1) is already included in the manufacturer's data for the pump head. In the case of high-rise buildings where the natural pressure is given by the height difference, the pressure component would also include the effective buoyancy given by the different density. In this project, the pressure difference is only considered as losses in the pipeline network. The heat pump does not contain a circulation pump, the manufacturer gives the recommended flow rate of the heat pump of 2300 l / h. At this flow, the pressure drop of the heat pump is 5 kPa.

The valves installed in the pipeline section between the heat pump and the storage tank and the calculation of pressure losses are given in Tab. 8.1.

Tab. 8.1 Pipe section fittings between the heat pump and the storage tank

Armature	$\dot{V}$	kv	Δpv
	[m³/h]	**[m³/h]**	**[Pa]**
check valve x^2	2.3	13.8	5575
3-way valve x^2	2.3	6.9	22300
Heat pump	2.3	-	5000
pipe loss	2.3	-	20817
Total	**2.3**		**53691**

The pressure loss of 53 691 Pa is converted according to (8.4) to a head of head H = 5.56 m. The characteristics of the primary circuit circulating pump are shown in Fig. 13.

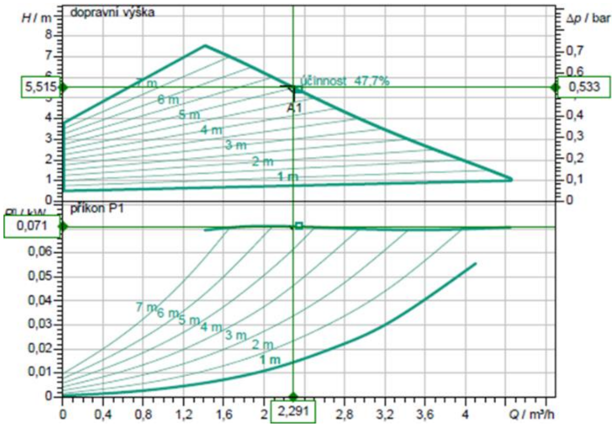


FIGURE. 13 Characteristics of the primary circuit circulation pump [12]

9 CALCULATING HEAT CONSUMPTION IN THE SIMULATION SOFTWARE

For the calculation of heat consumption, a computational model was created in the TRNSYS environment. It is a software tool for simulating the behavior of power systems. The simulation in TRNSYS was created to compare with the day-to-day method in heat consumption for heating, to calculate the expected use of a bivalent source and to verify considerations in determining the seasonal seasonal heating factor (SHF).

Weather data for Tripoli are available only from commercial sources. Therefore, meteorological data from Internet are used, which offers freely available data with a frequency of 1 h. The Tripoli area have a calculated outdoor temperature of -3 ° C. The results of the simulation will be used for comparison with the results of the day-level method for the Tripoli area with the solved object.[14]

Simplification of the calculation model: The simulation does not include domestic hot water system heating and is simplified by the absence of an accumulation tank. Similarly, solar gains are not defined as a simplified single-zone heat exchanger model was used. Internal gains were chosen 150 W, the value is taken from the TZB-info website [18]. In FIGURE. 18 shows the calculation model used.

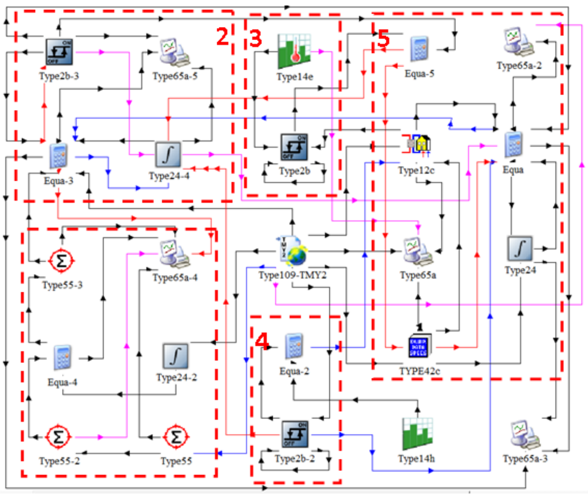


FIGURE. 18 Simulation diagram in TRNSYS

1 heating period definition, 2 out-of-heating blocking, 3 temperature program control, 4 bivalent source control, 5 heat demand and consumption calculation

9.1 Used components

Equa - calculator to define your own equations; when dividing time variables it was necessary to treat the division error by zero using the function max or min

Type2b - thermostat

Type12c - single zone heated model

Type14e - defining temperature programs

Type14h - time-dependent function definition

Type24 - integration by time

Type42c - input set of independent and dependent variables from an external text file, here the source data for the heat pump

Type55 - integration by time in cyclic intervals

Type65a - Plot the graph and save the data to an external text file for later processing

Type190-TMY2 - component reading meteorological data control function - output or input function of some components, returns 0 or 1 based on defined rules

10. CONCLUSION

The aim of this work was to design a heating system with an air-water heat pump for heating a family house. It has two floors above ground and an unheated basement. The construction of the building began in 1987 and due to the age of the heating system it was decided to reconstruct it overall. The original heat source is the Destila DP 25Z gas boiler, whose nominal output is 25 kW. In 2012, the opening fillings were replaced and the soil ceiling structure was insulated with polystyrene thickness. 220 mm. The heat loss of the building was set at 14.2 kW, while the basement is heated up to one room. The specific heat loss is 30 W / m^3 of heated space, this figure corresponds to the norm values of specific heat loss of family houses with a period of construction around 2016. Ventilation losses account for about 25% of the total heat loss.

The requirements of the investor during the reconstruction brought restrictions in the form of minimizing construction interventions. This eliminated the use of underfloor heating. Korado a.s. controlled radiators have been chosen, which are characterized by reduced energy requirements for most of the heating season with the same thermal comfort. The temperature gradient was chosen to be 55/45 ° C to maintain acceptable radiator sizes. Soldered copper pipes are used for the distribution. The pressure loss of the piping network from the accumulation tank to the radiators is 7.4 kPa, which guarantees economical operation of the used low-energy circulation pump. The pressure loss of the section between the storage tank and the heat pump is higher, where a circulation pump from a higher capacity series had to be used.

Regulus CTC EcoAir 420 with 14.5 kW output at A2 / W35 was chosen as the heat source. A bivalent source is a pair of electric heaters in a storage tank with a total output of 5 kW. The bivalence point was determined numerically and graphically at -6 ° C. At an outdoor design temperature of -3 ° C, the heat pump covers 68% of the building's heat loss, which meets the different two-tariff rate. The system is equipped with an accumulation tank to cover suddenly increased heat demand. The tank contains a nested DHW cylinder that is sufficient to cover the daily hot water demand.

The safety devices, ie the expansion vessel and the safety valve, were calculated. Another safety element is an emergency thermostat connected to electric heating elements. A controller from the heat source manufacturer has been selected for the heat pump and storage tank circuit.

An essential part of the project is the determination of heat consumption. For heating, it was calculated using the day-to-day method and compared with the simulation in TRNSYS software. The difference in results is 0.63%. We have determined a seasonal heating factor of 3.46 and an annual heating consumption of 10.2 MWh. The seasonal heating factor for TV is 3.07. This value is above the critical heating factor limit. The consumption for DHW heating is 2.5 MWh per year.

References

[1]. Heating systems in buildings: Calculation of heat output. 2005. ISI

[2]. BAŠTA, J. et al. 2001. Heating Handbook: Volume 1. 120 years of heating industry in Bohemia and Moravia. Praha: GAS, 2432 pp. ISBN 80-861-7682-7.

[3]. Thermal Protection of Buildings: Part 3: Design Values. 2005. ISI

[4]. Thermal Protection of Buildings: Part 4: Calculation Methods. 2005. ISI

[5]. Use of EN standards to calculate heat demand and primary energy use [online]. 2005.. Available from: www.mpo-efekt.cz/dokument/5138.pdf

[6]. KORADO A.S .. 2015. Energy-saving radiator: Radik RC [online]. Available from: http://rc.korado.cz/soubory/14-150204_radikrc_katalog_cz_web.pdf

[7]. D55d and D56d: Heat pump rate. 2010. In: Energy prices [online]. Available from: http://www.cenyenergie.cz/d55d-a-d56d-feed-for-the heat pump /

[8]. EcoAir 420. 2015 In: Regulus. Available from: http://www.regulus.com/en/tepelne-cerpadlo-ecoair-420

[9]. Equithermal curves. 2015 In: Tzbinfo [online]. Available from: http://vytapeni.tzb-info.cz/tabulky-a-vypocty/50-ekvitermni-krivky

[10]. REGULUS. 2015. Electric heating elements [online] Available from: http://www.regulus.cz/?download=prospekty/cz/Elektricka-telesa-A3-CZ.pdf

[11]. REGULUS. 2015. Storage tanks with nested DHW tank [online]. Available from: http://www.regulus.cz/?download=navody/cz/akumulacni-nadrze-duo-600-200-p- 750-200-p-1000-200-p-a4-en.pdf

[12]. Wilo. 2016 Wilo. In: Select pump with custom parameters [online]. Available from: https://www.wilo-select.com/ApplRange.aspx

[13]. Elektrobock. 2016. PocketHome. In: Elektrobock [online]..Available from: http://www.elektrobock.cz/en/pockethome-174-/category.html?cid=12

[14]. Heat demand for heating and hot water. 2003. In: TZB-info [onlineAvailable from: http://vytapeni.tzb-info.cz/tabulky-a-vypocty/47- need for heat-for-heating-and-heating-hot-water ENERGY INSTITUTE Department of Thermomechanics and Environmental Engineering

[15]. Regulus. 2010. Regulus [online]. Available from: http://www.regulus.cz/

[16]. Heating cheaply [online]. 2009. Available from: http://www.topenilevne.cz/

[17]. Heureka [online]. 20009 Available from: http://www.heureka.cz/