CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF CIVIL ENGINEERING

DEPARTMENT OF MICROENVIRONMENTAL AND BUILDING SERVICES ENGINEERING

TECHNICAL REPORT

ATTACHMENT 1

Heating and ventilation system design for villa house

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Contents

Building Basic information

Building type	residential, private villa house
Construction type	new
Investor	private investor, information not disclosed
Project realization by	ModernDream Design s.r.o.
Building location	Novy Vestec, Czech Republic
Living area	235.94 m2
Total area including parking and terraces	387.34 m2
Number of floors	2
Capacity	6 people

Building description

The building is located in the Central Bohemian Region of the Czech Republic, in a small town Novy Vestec. It is single-owner residential building, which is a private property of the investor. The villa house has two floors above the ground. The interior of the first floor includes entrance hall with the closet room, living space and a kitchen with pantry, the laundry room, which is also a technical room, a small gym and two bathrooms. The exterior design includes parking spot with a storage cell, covered by a roof, and two open terraces. The second floor is typically designed as a "quiet area" with 4 bedrooms, 3 bathrooms and an office room. Two bedrooms allow access to two different terraces. The villa is permanently inhabited with 6 people.

Documentation

The initial documentation for this project was provided by the project designer company ModernDream Design s.r.o. That included the exterior model view from all cardinal points, two floor plans (for each floor), two sections, the description of construction compositions, situation plan.

Technical drawings

1. Ventilation system 1NP
2. Ventilation system 2NP
3. Heating system 1NP
4. Heating system 2NP
5. Heating system – Section
6. Plan and section of technical room

Basic Technical Information

Location and outdoor temperatues

Novy Vestec is officially located in the Central Bohemian Region, however it is only 14km away from the Prague city boarder. Therefore, complying with the CSN EN 12831, as for location Prague, the calculations were done with the values Θ_e= -12 °C for the external outdoor temperature and Θ_e= -3 °C for the temperature under the foundation. Novy Vestec is 173 m above the sea level.

Indoor temperatures

Indoor design temperatures were also set up in accordance with CSN EN 12831:

- Θ_i= 20 °C for mainly occupied rooms (kitchen with pantry, living room, hall with closet room, bedrooms);
- Θ_i= 24 °C for bathrooms and WC
- Θ_i= 15 °C for gym and technical/laundry room

Heat losses of the structure

The total transmission heat losses of the building $\Phi_T = 7.091\ kW$

The total ventilation heat losses under conditions of air exchange rate 0.5 h^{-1} for living spaces and 1.5 h^{-1} for sanitary facilities, kitchen and gym $\Phi_V = 6.304\ kW$

The total ventilation heat losses under conditions of centralized ventilation system with heat recovery 80% $\Phi_V = 1.261\ kW$

Ventilation

The building will be equipped with centralized forced ventilation system with recuperation. The design fresh air supply values were purposely increased in order to reach fresh and airy indoor environment, resulting in maximum total air flow volume calculated 575 m^3/h. The recuperation will be provided by the unit DUPLEX 570 EC5.RD5.CF with the capacity 570 m^3/h, which is more than sufficient for complying with the standards (ČSN EN 15251). The ventilation unit has size 370x930x1290, it will be installed on the wall in the technical room on the ground floor. The main branch of the ductwork will have diameter Ø250 mm, it be connected to the unit through the connecting junction with same diameter Ø250 mm. On further sections of the duct network will be used diameters DN 80, DN100, DN150, DN180, DN250. The ventilation ductwork will be placed under suspended ceiling structure, made of gypsum boards. The unit will be connected to the sewage pipe through the small siphon with sufficient height (min. 150 mm), in order to allow the discharge of condensate.

DUPLEX 570 EC5.RD5.CF		
Energy class	A+	-
Maximal air flow rate	570	m^3/h
Acoustic output	42	dB
Maximal recuperation efficiency	94	%
Height	370	mm
Width	930	mm
Length	1290	mm
Diameter of connecting junction	250	mm
Weight	72	kg

** for more details refer to the Attachment 5 – Technical Lists of equipment*

Heat Source

The building will be equipped with the gas condensation boiler CerapurModul (ZBS30/150S-3MA). The unit model was chosen based on the energy demand for heating, hot water preparation and heat up of the supply air after recuperation. The unit is specified with maximum output capacity 30.5 kW. The unit has dimensions 1860x600x600 and weight 166 kg. It will be installed in the technical room on the ground floor. The concentric outlet for the exhaust fumes with diameter ø80/125 will be installed according to the technical list of provider through the opening in the floor structure of 2NP and roof. The air supply concentric pipe will be leading directly to the gas boiler. The high efficiency circulation pump is a part of the boiler.

Output 40/30 °C	*7.1 – 30.6*	*kW*
Output 80/60 °C	*6.4 – 29.4*	*kW*
Input	*6.5 - 30*	*kW*
Max flow rate of HW (40 °C)	*16.4*	*l/min*
Adjustable temp. range	*40 – 60*	*°C*
Volume of HW storage tank	*150*	*l*
Max operation overpressure	*3*	*bar*
Volume of expansion vessel	*12*	*l*
Size (height/width/depth)	*1770/600/600*	*mm*
Total weight	*128*	*kg*

** for more details refer to the Attachment 5 – Technical Lists of equipment*

Hot water storage tank

Following the standard CSN 06 0320 with the daily hot water demand for the residential building 82 l per person, and assuming 6 occupants of the villa house, the total hot water daily demand was set as V_{2P} = 492 l/day. Based on these parameters, the minimum required volume of hot water storage tank was evaluated as V_z = 138 l. Hot water storage tank was designed with volume 150l, which is a part of the heat source – condensation gas boiler CerapurModul (ZBS30/150S-3MA). The option of a built-in HW storage tank allows keeping system compact within the technical room.

Expansion Vessel

Following the standard EN 12 828 for the expansion vessel design, the minimum volume was evaluated V_e = 9.4 l. The expansion vessel was designed with the volume 12 l, which is embedded into the heat source – condensation gas boiler CerapurModul (ZBS30/150S-3MA). The volume of a built-in expansion vessel is sufficient and there is no need for additional unit.

Heat emitters

Two-pipe water-based heating system with forced circulation and temperature gradient 70 °C/60 °C was designed for the villa house. The convectors will be installed in the living room, kitchen and gym on the ground floor and in four bedrooms and office room on the second floor. All five sanitary facilities in the whole building will have a towel rails type of radiators installed on the wall, which is typical for WCs and bathrooms. The rest of the space will be heated with the flat plate radiators with the wall-pipe connection, each will be equipped with the thermostatic regulator and air-release valve.

The designed boiler allows maximum operational overpressure of the system 3 bar. The heating system design showed higher remaining overpressure on some sections, which will be assessed in the manner of increasing the pressure loss on particular sections of the system by adjusting the regulation fittings on heat emitters.

List of heat emitters in the villa house	
KORALUX LINEAR COMFORT 1220/450 (White RAL 9016)	1 pcs
KORALUX RONDO COMFORT - M 900/595	1 pcs
KORALUX RONDO COMFORT - M 1220/595	1 pcs
KORALUX RONDO COMFORT - M 1220/745	1 pcs
KORALUX RONDO COMFORT - M 1820/745	1 pcs
KORATHERM HORIZONTAL K10H 514/800	1 pcs
KORATHERM HORIZONTAL K10H 588/600	1 pcs
KORATHERM HORIZONTAL K11HM 144/800	1 pcs
KORATHERM HORIZONTAL K11HM 218/900	1 pcs
KORATHERM HORIZONTAL K11HM 218/1000	1 pcs
KORATHERM HORIZONTAL K11HM 218/1600	1 pcs
KORATHERM HORIZONTAL K11HM 514/800	1 pcs
KORAFLEX FKX 90/1600	1 pcs
KORAFLEX FKX 90/1800	1 pcs
KORAFLEX FKX 90/2400	1 pcs
KORAFLEX FKX 110/3000	2 pcs
KORAFLEX FVX 90/1600	1 pcs
KORAFLEX FVX 90/2000	1 pcs
KORAFLEX FVX 90/2400	1 pcs

List of pipes and piping connectors in the villa house		
Seamless steel thread pipe DN 20	19.69	m
Seamless steel thread pipe DN 25	18.51	m
Seamless steel thread pipe DN 32	1.61	m
Seamless steel thread pipe DN 15	159.69	m
Seamless steel thread pipe DN 32	0.11	m
Connection for seamless steel thread pipes DN 20 and DN 32	1	pcs
Connection for seamless steel pipes DN 20 and DN 32	1	Pcs
Connection for seamless steel thread pipe DN 32 and seamless steel pipe DN 32	1	Pcs
Connection for seamless steel thread pipes DN 25 and DN 32	1	pcs

Putting system into operation

After the installation, the heating system will be thoroughly flushed and filled with water. Afterwards, the following tests will be performed in accordance with ČSN 06 0310:

- leakage test (overpressure the system to 0.3 MPa for 6 h, the test is successful, when there was no pressure drop)
- expansion test (the heat transfer medium will be heated to the highest possible temperature and then will be allowed to cool down to the ambient temperature)
- heating test (functionality of all fittings will be checked, presettings will be adjusted)

After successful tests according to ČSN 06 0310, the system will be put in operation.

Legislation

ČSN 73 0540-2:2011	Heat protection of the buildings
ČSN EN 13 790	Calculation of energy consumption
ČSN EN 12831	Heat losses calculation
ČSN 06 0320	Hot water storage tank calculation
EN 12 828	Expansion vessel design
ČSN EN 15665/Z1	Ventilation intensity
ČSN EN 15251	Air quality

Conclusion

The whole project has been executed and will be tested in accordance with the Czech Technical Specifications (ČSN) and other related regulations. The testing of the appliances will be executed in accordance with ČSN 06 0310 by the specialized authorised company prior to pouring concrete layer on the heating system. The testing results and the procedure will be recorded in the written or electronic predefined form into the testing protocol which will be attached to the site diary.

Calculations

Annual Energy Demand Calculation

Annual energy demand for heating (day-degree method)

$$Q_{H,a} = \frac{24 * Q_c * \varepsilon * D}{t_{is} - t_e}$$

Q_c = 8.334 kW … total heat losses

$\varepsilon = \frac{e_i * e_t * e_d}{\eta_o * \eta_r} = \frac{0.9*0.9*1.0}{0.97*1.0} = 0.835$ *… reduction coefficient*

e_i = 0.9

e_t = 0.9

e_d = 1.0

η_o = 0.97

η_r = 1.0

*D = (t_{is} - t_{es}) * d … degree day*

t_{is} = 20.7 °C … average indoor temperature

t_{es} = 4°C … average outdoor temperature during the heating season

d = 216 … amount of days of hating season

*D = (20.7 - 4) * 216 = 3607.2 K.day*

$\boldsymbol{Q_{H,a}} = \frac{\mathbf{24*8334*0.835*3607.2}}{\mathbf{20.7-(-12)}} = 18\,423\ kWh$

$Q_{H,d} = \frac{18423565}{216} = 85.294 kWh$

$Q_{H,h} = \frac{85294}{24} = 3.553\ kWh$

Daily energy demand for hot water preparation

V_{2P} = 82 l/person.day … hot water demand for residential building (CSN 06 0320)

Assuming 6 people live in the house:

V_{2P} = 492 l/day

E_{2P} = E_{2T} + E_{2Z} … total energy demand from the heater for one day period

*E_{2T} = V_{2P} * c * (t_2 - t_1) … theoretic heat for heating the hot water demand V_{2P}*

c = 1.163

t_1 = 55 °C

t_2 = 10 °C

*E_{2T} = 0.492 * 1.163 * (55 - 10) = 25.7488 kWh/day*

*E_{2Z} = E_{2T} * z*

z = 0.5

*E_{2Z} = 25.7488 * 0.5 = 12.8744 kWh/day*

⇨ *E_{2P} = 25.7488 + 12.8744 = 38.6 kWh/day*

Annual energy demand for hot water preparation

$$Q_{HW,a} = Q_{HW,d} * d + 0.8 * Q_{HW,d} * \frac{55 - t_s}{55 - t_w} * (N - d)$$

d = 216 … amount of days of hating season

t_s = 15 °C … cold water temperature in summer

t_w = 5 °C … cold water temperature in winter

N = 350 … number of working days of heater operation

$Q_{HW,a} = 38623.2 * 216 + 0.8 * 38623.2 * \frac{55-15}{55-5} * (350 - 216) = 11\,655$ *kWh/year*

Annual energy demand for ventilation with recuperation

$$Q_{V,a} = V * \rho * c * z * D_V$$

V =570 m^3/h … air volume, running through the recuperation unit

P =1.19 kg/m^3 … air density

c = 0.28 Wh/(kgK) … specific heat capacity of air

z = 20 h/day … number of operation hours of recuperation unit

*D_V = 3500 K*day … day-degree for ventilation during the heating season*
(value for Prague region)

$Q_{V,a} = 570 * 1.19 * 0.28 * 20 * 3500 = 13\,295\ kWh/year$

** calculation performed with the recuperation efficiency 80%*

Total annual energy demand

$$Q_A = Q_{H,a} + Q_{HW,a} + Q_{V,a} = 18\,423 + 11\,655 + 13\,295 = 43\,372\ kWh/year$$

Storage tank design

… based on previously calculated "Daily energy demand for hot water preparation"

E_{2T} = 25.7 kWh/day … Theoretic heat for heating the HW demand

E_{2Z} = 12.9 kWh/day … Heat Losses

E_{2P} = 38.6 kWh/day … Total energy demand from the heater

Hot water usage according to ČSN EN 15 316-3

- *from 0 to 6 h = 0 %*
- *from 6 to 9 h = 35 %*
- *from 9 to 19 h = 15 %*
- *from 19 to 22 h = 40 %*
- *from 22 to 24 h = 10 %*

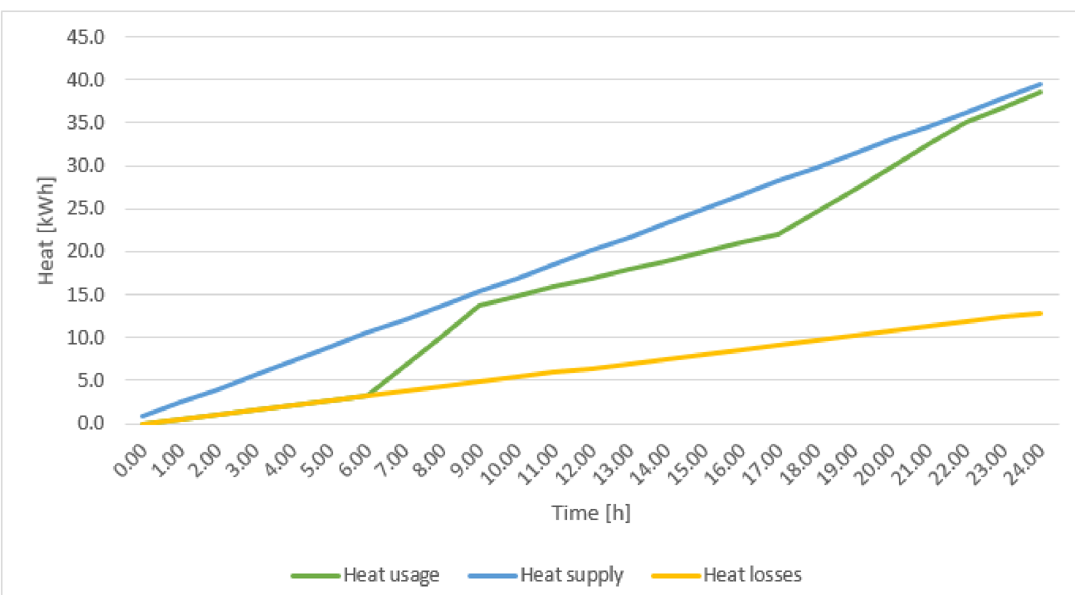

Figure 1 – Graf of heat supply and heat usage

⇨ $_{\triangle}E_{max} = 7.2$ kWh

$V_z = {}_{\triangle}E_{max} / c * (t2 - t1)$ … minimum volume of HW Storage Tank

$V_z = 7.2 / (1.163 * (55-10)) = 0.13758$ [m3] => 138 l

Design: $V_z = 150$l

Thermal output of heater calculation

$\Phi_{HL} = \Phi_T + \Phi_V = 13.395$ kW … total heat losses *

$\Phi_T = 7.091$ kW … transmission heat losses *

$\Phi_V = 6.304$ kW … ventilation heat losses *

*values taken from RAUCAD/TechCON heat loss calculation

After the preliminary design of the heating system, including heat emitters and piping layout, the necessary output of the heat source for the heating only is:

$Q_H = 8.334$ kW … energy output necessary for heating

$Q_V = 0.456$ kW … energy output necessary for heat up of recuperated air (with recuperation unit efficiency 80%)

$Q_{HW} = 12.875$ kW … energy output necessary for hot water preparation

$$Q_{P,1} = 0.7 * Q_H + 0.7 * Q_V + Q_{HW} = 0.7 * 8.334 + 0.7 * 0.456 + 12.875 = 19.028 \text{ kW}$$

$$Q_{P,2} = Q_H + Q_V = 8.334 + 0.456 = 8.79 \text{ kW}$$

$$Q_P = max(Q_{P,1} ; Q_{P,2})$$

$Q_P = 19.03$ kW … required thermal output of the heater

Heat source design

Design: CerapurModul (ZBS30/150S-3MA)

The condensation boiler was designed with a higher output, as from the practical point of view the decision making factor was the parameter of maximum flow rate of hot water, which is 16.4 l/min for the chosen boiler. This model has a built-in 12l expansion vessel and 150l hot water storage tank.

Output 40/30 °C	*7.1 – 30.6*	*kW*
Output 80/60 °C	*6.4 – 29.4*	*kW*
Input	*6.5 - 30*	*kW*
Max flow rate of HW (40 °C)	*16.4*	*l/min*
Adjustable temp. range	*40 – 60*	*°C*
Volume of HW storage tank	*150*	*l*
Max operation overpressure	*3*	*bar*
Volume of expansion vessel	*12*	*l*
Size (height/width/depth)	*1770/600/600*	*mm*
Total weight	*128*	*kg*

** for more details refer to the Attachment 5 – Technical Lists of equipment*

Expansion vessel design (EN 12 828)

$V_{system} = V_b + V_p + V_{he} + V_r$ = 130.9 l … total volume of heating system

V_b = 4 l … boiler volume according to technical list from provider

$V_p + V_{he}$ = 126.9 l … piping and heat emitters volume

(value taken from RAUCAD/TechCON)

$V_e = 1.3 * V_{system} * n * \frac{1}{\eta} = 1.3 * 130.9 * 0.0222 * \frac{1}{0.4} =$ *9.4 l … expansion vessel volume*

n = 0.0222 … volume expansion coefficient

η = 0.4 … application level of expansion vessel

$\eta = \frac{P_{h,dov} - P_d}{P_{h,dov}} = \frac{2.5 - 1.5}{2.5} = 0.4$ *[-]*

$P_{h,dov}$ = 2.5 bar … max operational overpressure (opening absolute pressure of safety valve)

P_d = 1.5 bar … hydrostatic absolute pressure (min operational overpressure)

$P_d = \rho * g * h * 10^{-3} + p_B = 1000 * 9.81 * 5.1 * 10^{-3} + 100 = 150.031$ *kPa*

ρ = 1000 kg/m^3 … water density

g = 9.81 m/s^2 … gravity acceleration

p_B = 100 kPa … barometric pressure

The condensation boiler has a built-in expansion vessel with volume 12l, which is sufficient. No need for additional expansion vessel.