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Cascade Use of Low Enthalpy Geothermal Water at the University of Oradea

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ABSTRACT

The geothermal well located in the campus of the University of Oradea has the following characteristics: well head temperature about 85°C, artesian flow rate about 30 l/s; pumped flow rate 55 l/s. Considering a reference temperature of 20°C, the available heating power is about 8 MWth. The university campus extended during the last years by the construction of new buildings (library, student hostels, gymnasium), and by the transfer to the university of some buildings previously used by the army. Given the need to supply, in the near future, also the thermal energy demand of the new buildings of the University of Oradea, the possibilities of cascading the use of the energy from geothermal water from this well has been analyzed. For a complete and efficient use of the energy available from geothermal water produced from the existing well, it is necessary to use a complex system that would allow exploitation of the thermal energy down to the lowest possible temperature of the geothermal water. The proposed system will provide space heating for some buildings using existing cast iron radiators requiring higher inlet temperature (3.685 kWth), the outflow being used for other buildings which will have floor heating (1.300 kWth), the outflow from which will further used for heat pumps to supply other buildings with floor heating (1.400 kWt). Sanitary hot water (750 kWth) will also be supplied. The last use, before disposal in the nearby stream, will be snow melting (700 kWt). Implementing this cascade system will increase use of the thermal energy available from the borehole and will decrease the cost, as the university is invoiced for the geothermal used water, not energy.

1. INTRODUCTION

University of Oradea is the only university in Romania and in the world is one of the few universities heated fully with thermal energy from geothermal resources. The general plan of the campus with thermal energy from geothermal resources is given in figure 1, that contains buildings with an approximate construction area of 70.000 m^2 (built- up volume $V_{cl.tot}$ = 155.000 m^3); in this campus operates the Faculty of Power Engineering, the Faculty of Management and Technological Engineering, Faculty of Letters, Faculty of Science, Faculty of Physical Education and Sport, Faculty of Orthodox Theology, Faculty of Economical Science, Library, Faculty of Music, Gymnasium, New Library, Faculty of History, Geography and International Relations, Faculty of Social Humanistic Science, Euro regional Research Centre, Experimental Chirurgical Centre, Geothermal Research Centre.

Also, in developing plan of the university, it is taken into account to realize construction with a volume of 62.000 m^3, from which 32.000 m^3 for the new library and 30.000 m^3 for new student hostels.

Figure 1. General plan of the University of Oradea

In Figure 1: A – Faculty of Power Engineering; B – Faculty Management and Technological Engineering; C – Faculty of Letters, Faculty of Science, Faculty of Physical Education and Sport, DGTAT, CSAT; D – Rectorship, Faculty of Theology; E – DPPPD; F – Aula, Faculty of Economical Scince; G – Police Station; H – Compartment of Arts; I – Building of Administration, Departament of International Relations; J – Library; K – Laboratories; L – Geothermal Research Centre; M – Faculty of Music, Surgery; N – Carpentry workshop; O – Hall of Athletics; P – Gymnasium; R – Sară; S – New Library; T – New Hall; U – Dining hall; V – Faculty of History, Geography and Internaitonal Relations, Faculty of Social Humanistic Science; X – Department of Labour protection and PSI; Y – Euro regional Research Centre; Z – Experimental Chirurgical Centre; C1 – Student hostel for boys; C2 – Student hostel for girls

In the Campus of the University of Oradea, is located the geothermal drilling of exploitation no. 4796, with the following features:

- Temperature of geothermal water 85°C;
- Artesian flow 30 l/s (108 m^3/h);
- Approximate pumped flow 45 l/s (160 m^3 / h – in the well is placed a pump at a depth of 90 m);
- Available thermal power 6.800.000 kcal / h = 7.900 kW (as reference temperature is considered 20^{o}C);
- The production characteristic of the probe is given in figure 2

▪ For a complete and efficient use of the geothermal water's thermal energy from the well no.4796 in Romanian, to assure the necessary heat and domestic hot water for the buildings in the campus, the results of the made analyzes conduced to use the heat in cascade in the thermal energy centre, using battery of heating pump. In figure 3 is given the block diagram of utilization in cascade of geothermal energy in University of Oradea, using batteries of heat pumps.

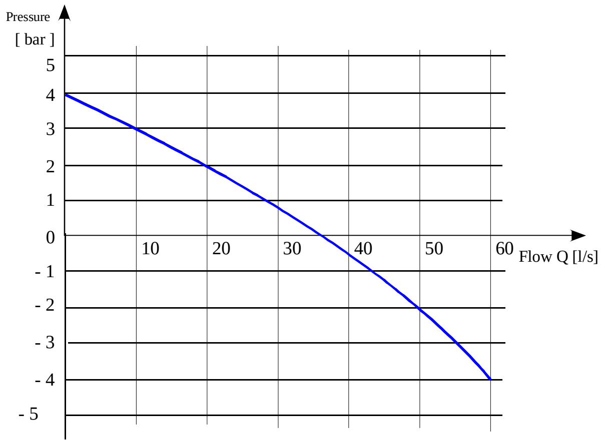

Figure 2. The production characteristic of the 4796 probe in Romania

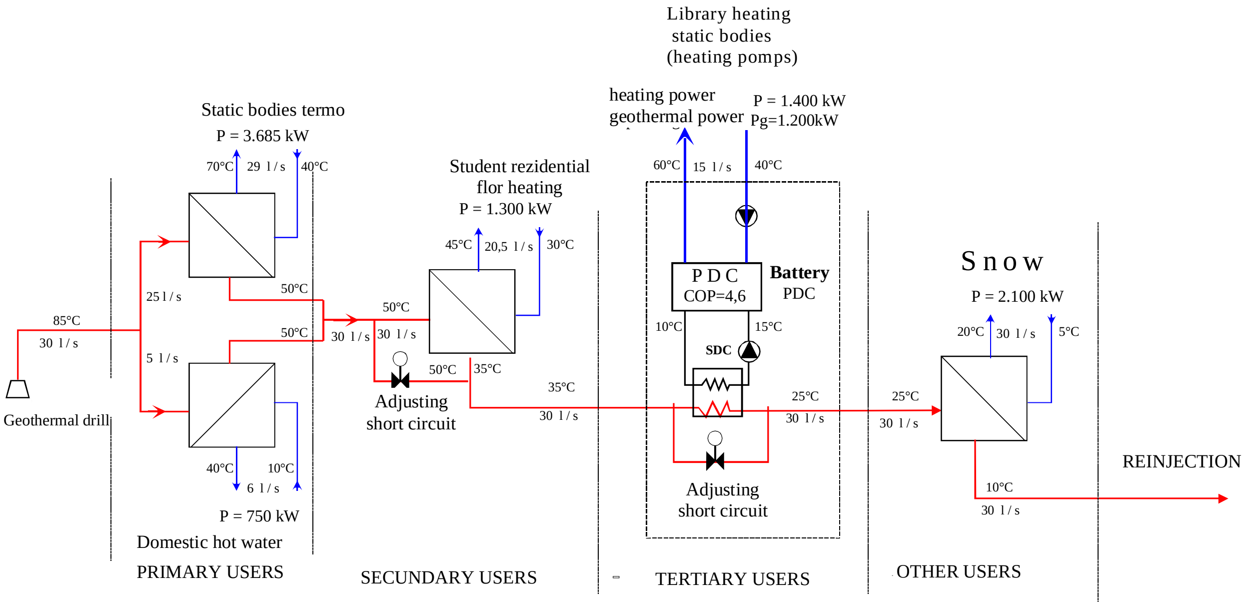

Figure 3. Block diagram of thermal centre pilot plant, using heat pumps

2. CONSTRUCTIVE – OPERATION ELEMENTS

2.1 The Station of the Well

The station of the well no.4796 in Romania, placed in the campus of University of Oradea, is composed from the geothermal drill with an artesian flow of 30 l / s, with a depth pump, of „axe" type at deepness of 90 m, trained by an electric motor of 65 kW (General Motors, USA). The engine is located on the upper part of the pump – axe group, allowing a flow in pumping mode of 45 l / s; the supplying system with geothermal water (figure 4) also includes: a buffer tank of 300 m^3, placed near the well's station with role of degasification and system uniformizing; the pumping station, near the well's station is equipped with two Grundfos pumps and with the necessary auxiliaries. The role of the pumping station is to supply with geothermal water the equipment in downstream at necessary flow and pressure.

2.2. Geothermal Heat Consumers

The urban energy needs for heating and preparing the domestic hot water, with a view to realize an efficient estimation, are divided into the following categories: for heating, ventilation and domestic hot water.

The heat consume for heating - Q^h_{inc} - depends on the external temperature of the air, thus on climatic factors. Noted with:

- $V[m^3]$ - constructed volume for heating
- $q_u\,[kcal/m^3h\,grd]$ - unit of thermal characteristic $q_u = (0{,}5 \div 2)\ kcal/m^3h\,grd$
- $t_i[^oC]$ the room's air temperature
- $t_e[^oC]$ outside temperature

The heat consume for heating is:

$$Q^h_{inc} = q_u \cdot V \cdot (t_i - t_e)\ [kW;\ kcal/h] \qquad (1)$$

The maximal heat quantity is determined for the standard outside temperature, defined basing on statistical data for each locality in the country.

For ventilation, the heat consume - Q^h_{vent} - is different in function with the room's destination. Without special ventilation installations in the residential buildings it has the value of (5÷20)% Q^h_{inc} and may be enclosed in the first approximation. For social, commercial and industrial buildings, the heat consume for ventilation attains (20 ÷30) % of Q^h_{inc} and it is separately considered.

The thermodynamic equations that characterize the processes from thermal centre are:

$$\dot{m}_{p1} \cdot c \cdot (t_{p1in} - t_{p1ies}) = \dot{m}_{s1} \cdot c \cdot (t_{s1ies} - t_{s1in}) = = K_1 \cdot S_1 \cdot \frac{(t_{p1in} - t_{s1ies}) + (t_{p1ies} - t_{s1in})}{2} \qquad (2)$$

$$\dot{m}_{p2} \cdot c \cdot (t_{p2in} - t_{p2ies}) = \dot{m}_{s2} \cdot c \cdot (t_{s2ies} - t_{s2in}) = = K_2 \cdot S_2 \cdot \frac{(t_{p2in} - t_{s2ies}) + (t_{p2ies} - t_{s2in})}{2} \qquad (3)$$

To choose the heat exchangers, which equips the thermal centre it is taken into account the given technical data by the producing company. The equation that influences the choosing of the heat exchanger and that characterizes the exchange of the heat is:

$$Q = K \cdot S \cdot \Delta t_{med} \qquad (4)$$

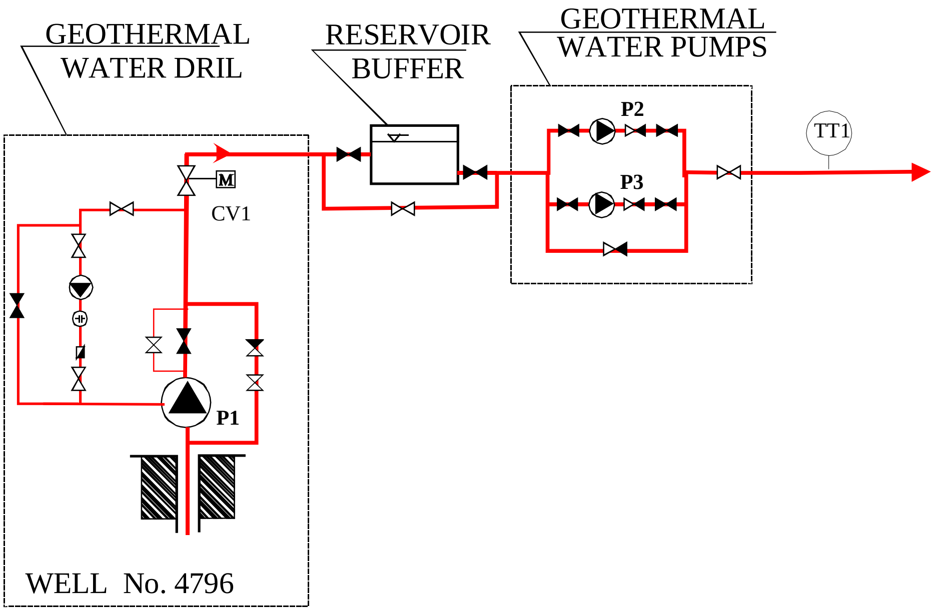

Figure 4.Station of the well no. 4796 in Romania –constructive-operational block

where:

$$\Delta t_{med} = \frac{(t_{pin} - t_{sies}) + (t_{pies} - t_{sin})}{\ln\left(\frac{t_{pin} - t_{sies}}{t_{pies} - t_{sin}}\right)} \qquad (5)$$

$$\Delta t_{med} \approx \frac{(t_{pin} - t_{sies}) + (t_{pies} - t_{sin})}{2}$$

Q - the flow of the changed heat with the water from the two circuits (primary / secundary)

S – surface of the heat change

K – global coefficient of heat exchanger (for heat exchangers with plate K = 1÷7 kW / m^2K)

2.2.1. Calculation of the Primary Users – Heating with Static Bodies

Basing on the outside temperature curve for Oradea – Romania -, it will be obtained the annual curve of the heat consume for the consumers from campus, given in figure 5.

The necessary heat for the existent campus [the area is approximate as be 70.000 m^2 (constructed volume $V_{cl.tot}$ = 155.000 m^3)] will be assured by a heating system with statically bodies with following parameters (see figure 6):

- primary agent: geothermal water
- flow: 90 m^3/h (25 l/s)
- temperature (turn / return): 85°/50°C
- pressures (turn / return): 2,5/0,8 bar
- secondary agent: warm water
- flow: 104,5 m^3/h (29 l/s)
- temperature (turn / return): 70°/40°C
- pressures (turn / return): 3,5/1,5 bar
- requested power: 3.685kW (3.168.530kcal/h)

2.2.2. The Calculation of Primary Users – Preparing Domestic Hot Water

For an average consume of domestic hot water at the university, in correlation with figure 7, results:

- average necessity of domestic hot water: 21,5 m^3/h (6 l/s)
- requested temperature for domestic hot water: 40°C
- temperature of the water from the network: 10°C.

2.2.3. Calculation of the Secondary Users – New Student Hostels, Floor Heating DH2

For heat consume the annual curve for consumers given in the development plan is presented in figure 8. For zone of Oradea, the curve was drawn in concordance with the curve of the outside temperature.

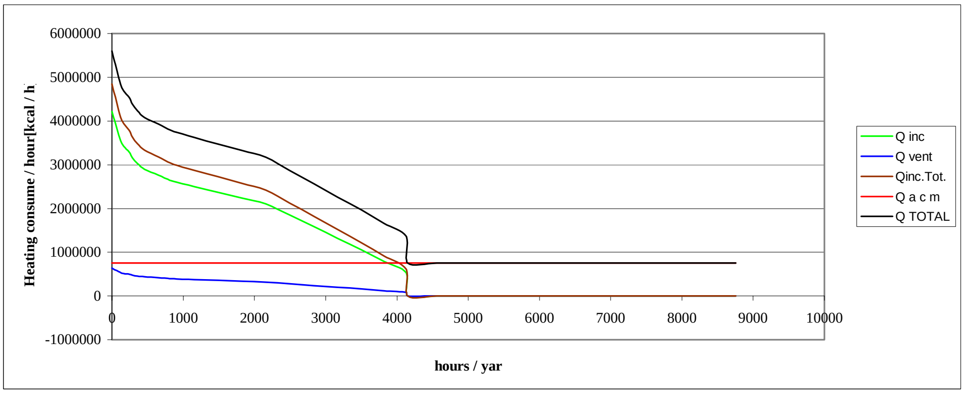

Figure 5 - Annual curve of heat consumer for University of Oradea – actual constructions

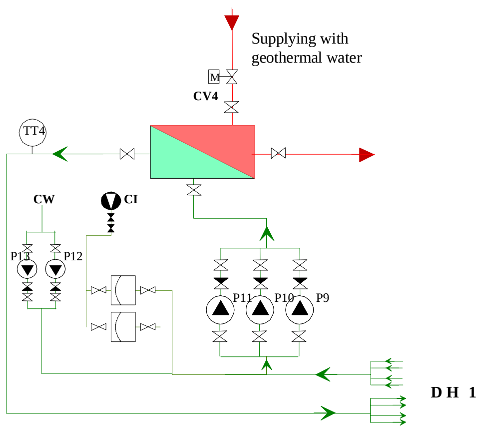

Figure 6. Constructive – operational block: Primary users – heating with statical bodies

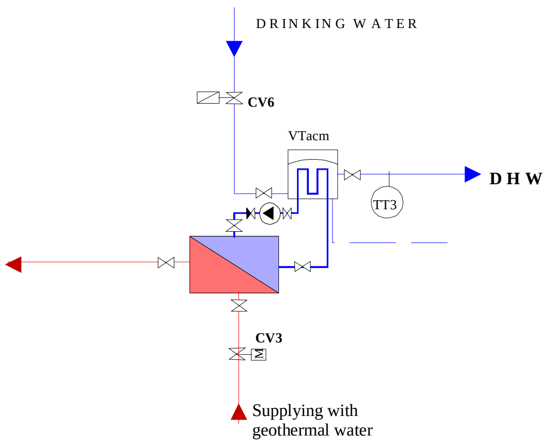

Figure 7. Constructive – operational block: Primary users – preparing domestic hot water

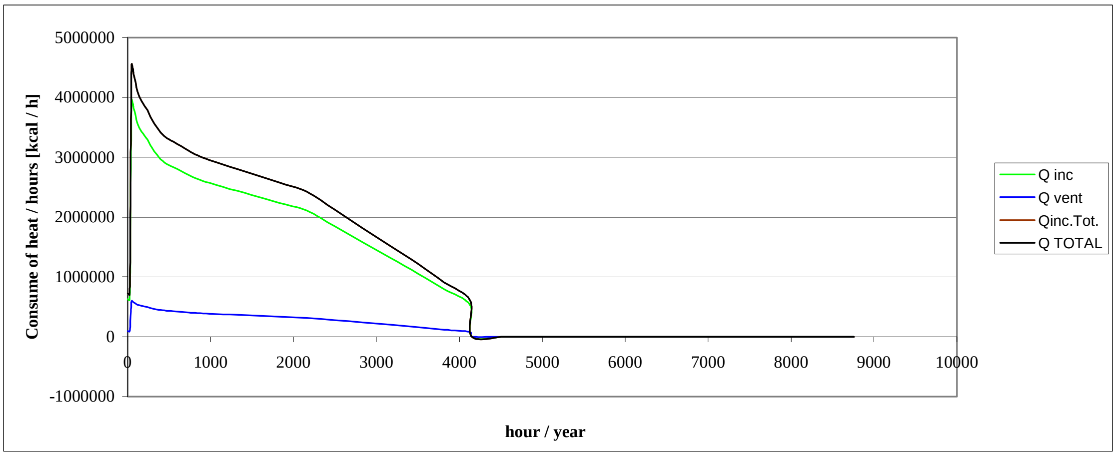

Figure 8. Classified annual consume of heat for consumers of the development plan of the University of Oradea

The student hostel is foreseen to be heated by "floor heating system", see figure 9 and will have the following characteristics, in accordance with technical designs:

- total volume: $V_{cl.cam} = 30.000\ m^3$
- walls from efficient bricks with cavity (thickness of 37,5 cm)
- coupled double windows from wood
- unitary thermal characteristic:
  - $q_u = 0{,}95\ kcal / m^3\ h\ grd$ (6)
- air temperature of chambers: $t_i = 20°C$
- outside temperature of computing: $t_e = -12°C$
- period of heating: 172 days in a year (15/10÷15/4)
- necessary power for heating $P_{nes.c}$= 1.300 kW (1.100.000 kcal/h)

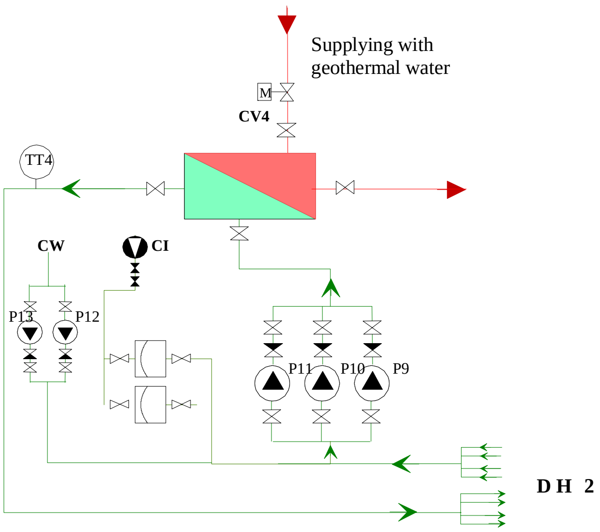

Figure 9. Constructive – operation scheme: Secondary users – floor heating

2.2.4. Tertiary Users Compute – New Library, Heating System With Static Bodies – Using DH3 Heating Pumps

The building of the new library is foreseen to be heated with "static heating bodies" and will have the following characteristics:

- total volume: $V_{cl.cam}$=32.000 m^3
- walls from efficient bricks with cavity (thickness of 37,5 cm)
- coupled double windows from wood
- unitary thermal characteristic:
  - $q_u = 0{,}95\ kcal / m^3\ h\ grd$
- air temperature of chambers: $t_{ch} = 20°C$
- outside temperature of computing: $t_o = -12°C$
- period of heating: 172 days per year (15/10 ÷ 15/4)
- necessary power for heating $P_{nes.c}$ = 1.400 kW (1.200.000 kcal/h)

Will be used 16 units of PDC soil - water WPF 66 STIEBEL-ELTRON, connected in parallel, or three units in modular series of 400 kW, connected in parallel, see figure 10.

The constructive parameters of PDV of soil – water type WPF 66 STIEBEL-ELTRON after Catalogue STIEBEL-ELTRON manufactured 2007 – 2008 are:

- H x L x l [mm] 1160x1250x870;
- weight [kg] 600;
- cold source temperature (the fluid in the well) from -5 la +20 [grade Celsius];
- maximal temperature on turn +60 [grade Celsius];
- requested flow of the cold source (the fluid of the well) 16,3 [mc/h] la 230 [hP];
- requested flow of the heating circuit (thermal agent) 12,5 [mc/h] la 280[hPa];
- coupling connection to the heating circuit and to the cold source in outside circuit G 2 ½ ;
- refrigerant R410A;
- at 0 grade [grade C] of the fluid temperature in the well and at de + 35 [grade C] temperature of the thermal agent on turn (W0/W35):
- total thermal power 66 [kWth];
- absorbed electric power 14,3 [kWel];
- COP = 4,6;

2.2.5. Calculation for Another Users – Snow Melting and Drying the Parking and Alleys in University

The parking in the campus has an approximation area of 10 000 m^2 as the alleys total length is 1000 lm, with an average width of 1 lm. To compute the necessary heat for snow melting on alleys is made taking account the following technical parameters:

- total surface of snow melting is S_{ts}=11 000 m^2
- annual total average period with precipitation as snow P_{year} = 120 days
- annual average quantity of precipitation as snow m_s=0,8 kg/m^2
- average temperature of the snow t_{ms}= -5 °C
- necessary of thermal energy to heat, melt and vaporizes the snow mass Q_{us}=2 844,95 kJ/kg
- the melted snow total annual average mass m_{ts}=1056*10^3 kg
- necessary total heat quantity to heat, melt and vaporizes the total snow mass is Q_{Ts} = 3004,3*10^{6}kJ
- necessary power for heat, melt and vaporize the mass of the snow is P_{Ts} = 289,7 kw(249 000kcal/h)

To satisfy the thermal energy necessity for snow melting, will be used a heat exchanger with a 2100 kW capacity, that allows to cover the power losses in environment, respectively, it can take the peaks of the load defined by the eventually abundant snowing, that exceeds significant the annual averages used in calculation of heat energy necessity.

3. ASPECTS REGARDING THE AUTOMATION OF THE PROCESSES

3.1. Aspects Regarding the Driving of Primary Users– DH1 Heating

For DH1 system, is used the below presented strategy: After determining the requested temperature of thermal agent for heating - the measurements about the weather (made with temperature transducer TTe1 and with the wind speed transducer WTe1) the temperatures are between 40 and 70°C;

if: $t_{ext\ med} \le -12°C \quad t_{s1\ out} = 70°C$;

if: $t_{ext\ med} \in (-12, 10)°C$

$$t_{s1\ out} = (53{,}5 - 1{,}35 \cdot t_{ext\ med})°C;$$

if: $t_{ext\ med} \ge 10°C \quad t_{s1\ out} = 40°C$

This algorithm is valid for operation period of the heating system, generally for period of 15 October – 15 April.

To assure the temperature for secondary agent at its leaving of the heat exchanger, temperature measured with TT1 transducer, by verifying the flow of geothermal water which circulates in the exchanger. This fact is realized by regulator RG1 that controls the opening of CV1 valve.

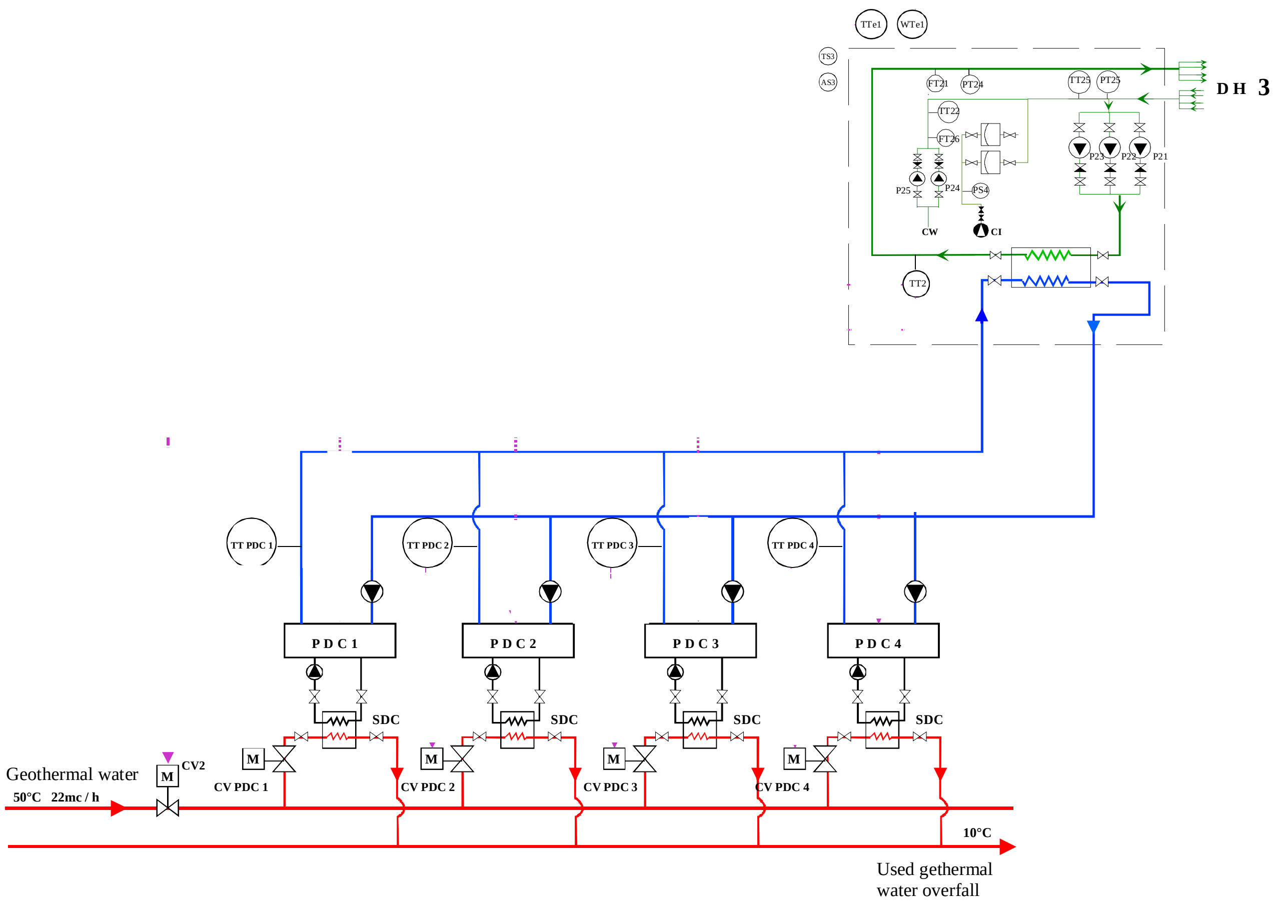

Figure 10. Batteries for PDC heating system with static bodies using heating pumps

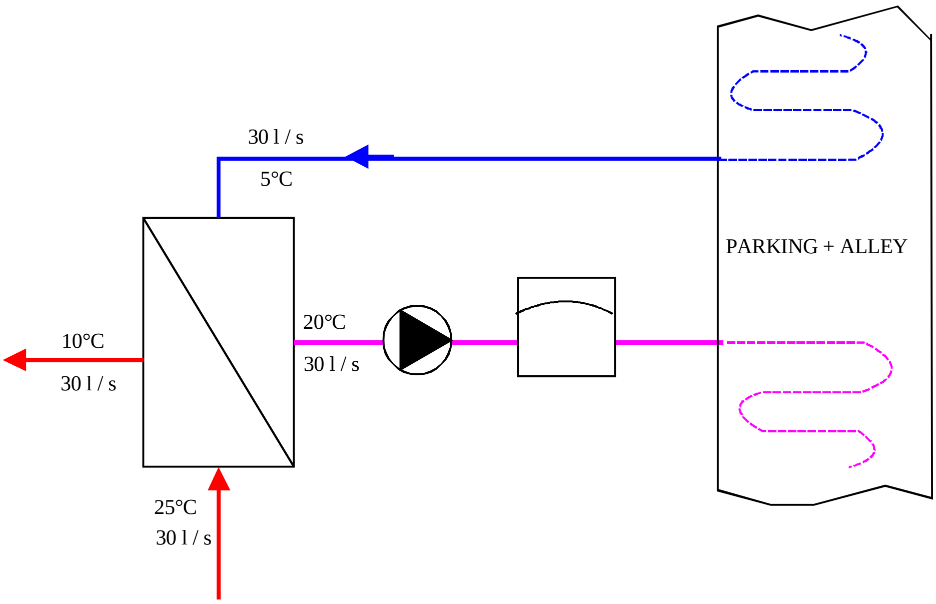

Figure 11

Assuring the pressure of geothermal water in the system (for good operation of the heating pumps), pressure measured by TPx pressure transducer, by the control of the flow in the system. This is realized by RGx regulator that commands the CVx valve opening;

The alternative operation of the circulation pumps P5, P6, P7 (simultaneously two) to avoid the overstress of the driving electric motor;

Assuring the static pressure in the control system, of the completing pumps P8, P9 and of compressor CI, is made by the operator from SCADA.

In figure 12, is given the thermal system's block with the control loops, which assure the requested heating energy to heat the static bodies (system DH1).

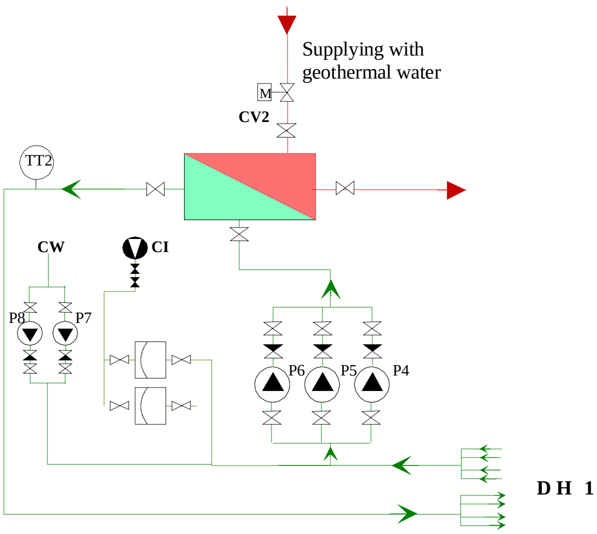

Figure 12. Control block of the heating system DH1

Adjusting the output temperature of heat exchanger's secondary agent, appropriate to DH1 circuit, is realized as:

t_1 temperature measured at TT2 temperature transducer is equal (at output of secondary agent from heating exchanger) to requested temperature for a good operation of DH1 system, as $t_{s1\,necesar}$, resulted from the made measurements by TTe1 and WTe1 processed and registered in RG1 regulator. $t_{s1\,necesar} = 70°C$ is appropriate to an outdoor temperature of $t_{ext} \leq -15°C$.

if $t_1 > t_{s1\,necesar}$ and CV2>0 →RG1 controls the closing of CV2

if $t_1 < t_{s1\,necesar}$ and CV2<1 →RG1 controls the opening of CV2

if $t_1 > t_{s1\,necesar}$ and CV2=0 →SCADA alarm signals by CV2

if $t_1 < t_{s1\,necesar}$ and CV2=1 → SCADA alarm signals by CV2

3.2. Aspects Regarding the Driving of Primary Users – DHW Driving System of Domestic Hot Water Preparation

Domestic hot water is obtained by heating the cold water obtained from the source of drinking water of the university and stocked in reservoir for domestic hot water, with the capacity of 10 m^3 (see figure 13).

The delivery temperature of domestic hot water is continuously measured by temperature transducer TT3. RG3 regulator compares the measured value with the prescribed value of the temperature (60°C) and controls the valve CV3. Through CV3 valve is controlled the geothermal water's flow that crosses the heat exchanger. The system also has a one directional valve CV6, that protects it from unexpected pressure variations.

The reservoir buffer – for domestic hot water, VT_{acm}, by the stocked volume of water, attenuates the temperature variation of delivered domestic hot water together with the variation of the consume; so CV3 valve is protected from repeated controls

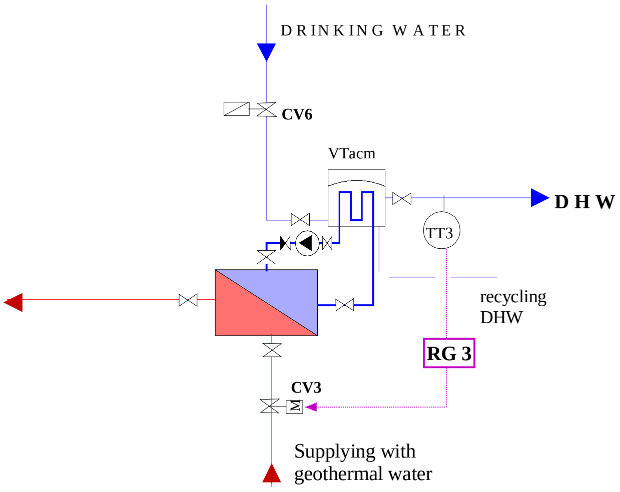

Figure 13. Preparing block system of domestic hot water with control loops

3.3. Aspects Regarding Secondary Users Drive – New Student Residential, Floor Heating DH2

The reason to calculate t2 temperature measured by tT4 transducer, has the same logic as the calculation of t1 temperature measured by TT1 for DH1 system, with t2 temperature difference between 30÷45°C. The automation loop for DH2 system is given in figure 14.

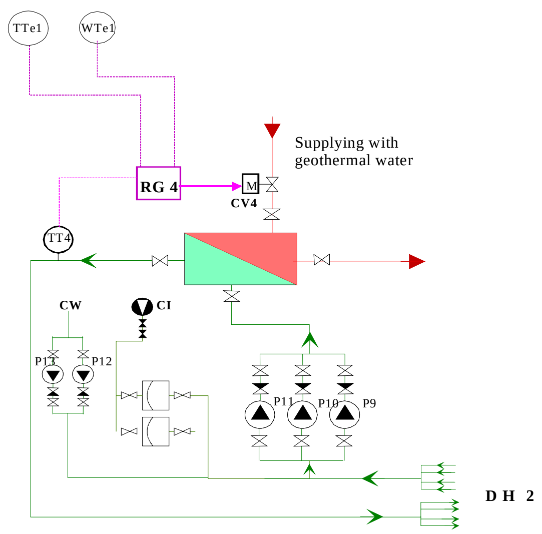

Figure 14. Driving block of DH2 heating system

Adjusting the output temperature of the heat exchanger's secondary agent, according to DH2 circuit, is realized as follows: t_2 temperature, measured by TT5 transducer (at the output of secondary agent from the heat exchanger) is equal with the requested temperature for good operation of DH2 system, $t_{s2\ necessary}$, resulted from the measures made by TTe1 and WTe1, processed and memorized in RG4 regulatory, $t_{s2\ necessary} = 45°C$, properly for outdoor temperature of $t_{ext} \leq -15°C$.

- If $t_2 > t_{s2\ necessary}$ and CV4>0 →RG4 controls to closing of CV4
- If $t_2 < t_{s2\ necessary}$ and CV4<1 →RG4 controls to open of CV4
- If $t_2 > t_{s2\ necesary}$ and CV4=0 →SCADA alarm signals at CV4
- If $t_2 < t_{s2\ necesary}$ and CV4=1 → SCADA alarm signals at CV4

3.4. Aspects Regarding Secondary Agents Drive – New Library, Heating System With Static Bodies – Using DH3 Heat Pumps

The reason to calculate t_3 temperature measured with TT5 transducer has the same logic as the computing of t_1 measured with TT1, for DH1 system, with difference that t_3 temperature is between 40÷60°C. In figure 15 is shown the thermal system with its driving loops that assure the necessary of thermal energy for heating using heating pumps (DH3 system).

3.5. Aspects Regarding Tertiary Users Driving –Snow Melting and Drying of Parking and Alleys in the University

To snow melting in the parking and alleys is made with the stored thermal energy in geothermal fluid of the last step in the heat centre, the flow parameter is 30 l / s and input temperature of 25°C. The automation of the system is made by a comparative analyze of the alleys temperature with a before established temperature (0°C), respectively, with a humidity analyser for the whole period of the cold season with snow precipitation. In function with the two parameters it is established the flow of the geothermal fluid by a flow regulator which controls the adjusting valve, so that it can be delivered the whole thermal energy necessity to snow melting and drying of the surfaces, equipped with snow melting system (parking, alleys). The power reserve for the snow melting process is 2100 kW, reserve, that allows satisfying the load peaks (abundant precipitations of snow) as well as the heat losses by thermal convection in environment, respectively, by thermal conduction in the soil.

CONCLUSIONS

The pilot installation characteristics in the proposed thermal centre are:

- Installed power of 8.000.000 kcal/h (9.235 kW_t);
- Constructed total volume to be heated: 217.000 m^3;
- Installed power for primary heating with static bodies of 3.170.000 kcal/h (3.685 kW_t);
- Installed power for secondary heating (floor) of 1.120.000 kcal/h (1.300 kW_t);
- Installed power for secondary heating (heating pumps) of 1.200.000 kcal/h (1.400 kW_t);
- Installed power for melting of snow (other users) of 1.800.000 kcal/h (2.100 kW_t)
- Installed power for heating of domestic hot water of 645.000 kcal/h (750 kW_t);
- Flow of domestic hot water 21,5 m^3/h (6 l/s);
- Input / output temperature of geothermal water: 85/10°C;
- Battery from heat pumps of WPF 66 STIEBEL-ELTRON type (fig.7)

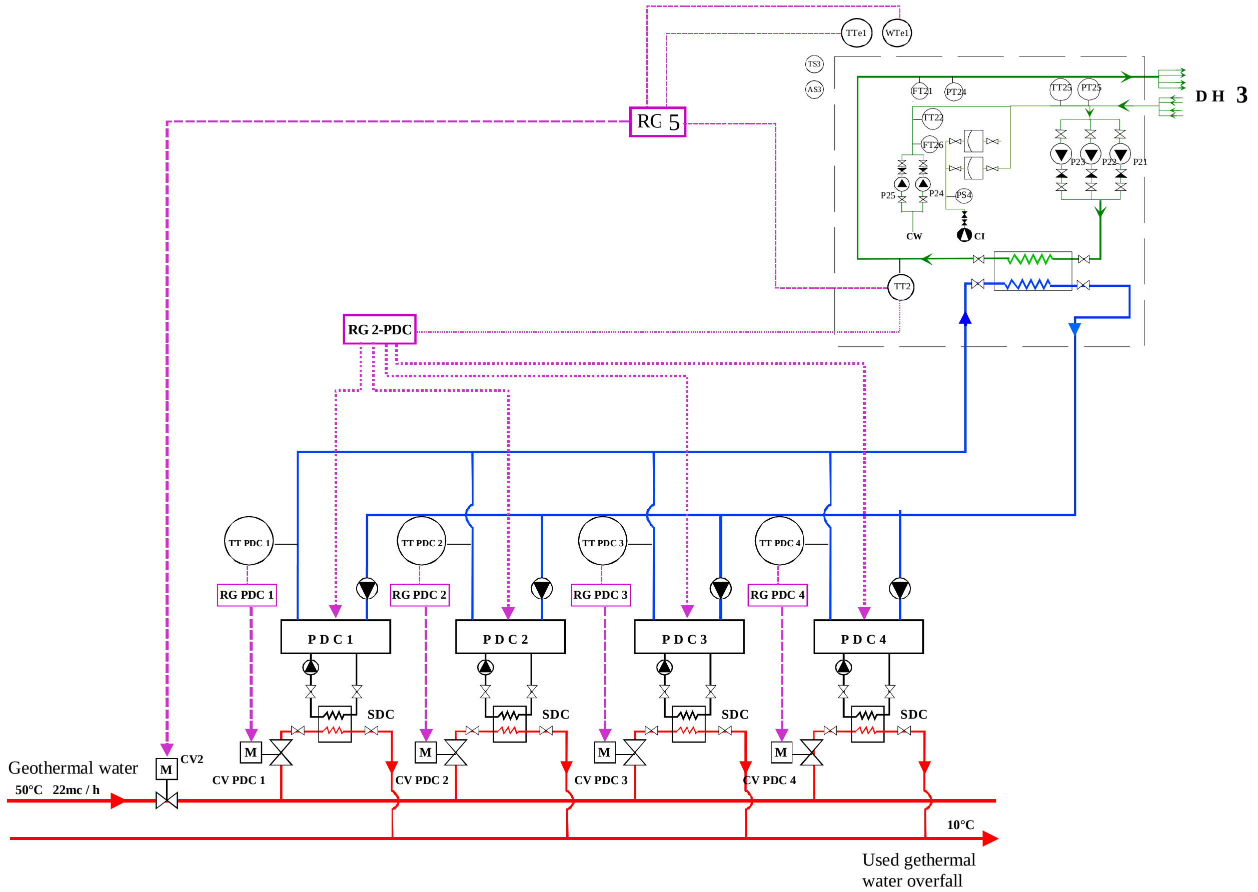

Figure 15.Driving block of DH3 heating system

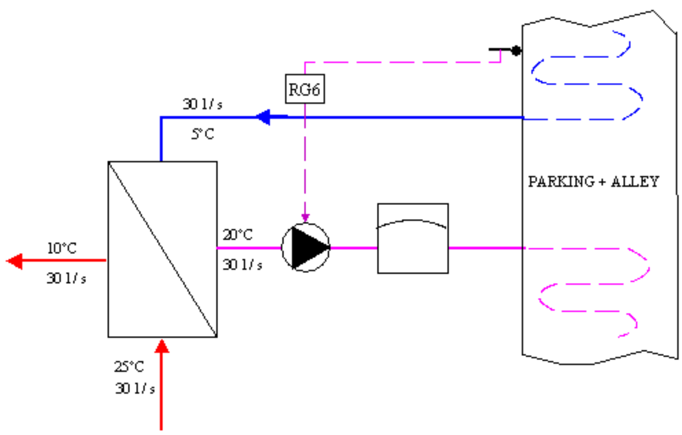

Figure 16.

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