THE RETROFIT OF THE HVAC SYSTEM USING GEOTHERMAL HEAT PUMPS

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Rezumat. Din respect pentru planeta Pamant, omenirea cauta optiuni ecologice si pentru sistemele de aer conditionat. Solutia recomandata in lucrare se refera la utilizarii unei pompe de caldura geotermale. Noul sistem are ca avantaje: o economie de energie de cel putin 50% precum si faptul ca reprezinta o solutie ecologica.
Keywords: pompă de căldură geotermică, energie regenerabilă, reechipare, sistem HVAC.

Abstract. Out of respect for Earth and taking into account the decrease of fossil fuels, whose price is continually rising, a heating system based on carbon-intensive technology, long distance heat transport and high energy efficiency no longer serves any purpose so the choice of an air conditioning system based on renewable resources, appears to be the best option. The desire to retrofit will be materialized by exploiting, at local level, the renewable resources potential, by designing and implementing efficient and durable technologies, which will lead to a profitable exploitation: the geothermal closed loop with heat pumps and fan coils. The success of the new system will be given from better insulation of the building by using an efficient division of the laboratory with plasterboard panels (vertical and horizontal) both mobile and/or fixed. The new system has advantages: cleans the energy consumption with at least 50% (reduced safety), is not pollutant and has no risk of explosion.
Keywords: geothermal heat pump, renewable energy, retrofit HVAC system.

INTRODUCTION

In a time when the whole world focuses on environmental technologies and solutions, the development of a classic system is no longer suited to a laboratory of a faculty that has proposed to apply ecological systems which led us to propose a new system based on renewable resources, on this case by using heat from the earth.

The heating system of the laboratory is old, dating back the late 1970's so it has a considerable age and low energy performance. Heated water comes from the central heating system through low insulated buried pipes. In addition, there is thermal loss because the building's glazed surface isn't well insulated having only one sheet.

An extremely large space, at this moment, is difficult to be well conditioned. The idea that we want to achieve a very good insulation on exterior with expanded polystyrene of at least 10 cm thick and glass fiber mesh as it can be seen in the Fig. 2

In addition, we think that in the future it will be necessary to do a subdivision of the interior space both vertically and horizontally with fixed or mobile panels to make smaller partitions depending on the needs, which are much easier for conditioning.

Fig. 1. Side view of the building.

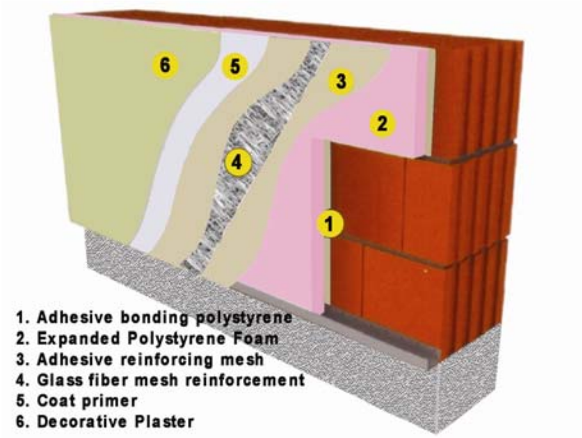

Fig. 2

To obtain a high efficiency system as it was necessary to escalate as much energy exchange with the environment and in this connection along the outer insulation of the old building, has proposed changing the existing window joinery with a wood with a triple layer or with a PVC one. Also classic windows will be replaced with some low E type with argon and in 3 sheets (0.5 m^2K/k). Because glazing surface is extremely high and is oriented both S and W, that change is imperative.

Both insulation and waterproofing of the roof must be rebuilt to ensure a lower exchange with the environment.

At this moment the building is practically a big room with the following dimensions: height = 8m, length = 31.10m, width= 13.3m. In the retrofit solution we decided first considering a two floor space on vertically as first step and then split the horizontal space too, mainly in six offices located upstairs on each side and free space in the middle.

For effective cooling, following calculations, we concluded that a system type with Geoexchange wells with closed loop and heat pumps is the best alternative.

The geological structure and the constituent rocks have good heat conductivity and as a plus the presence of the river Colentina in the close proximity, ensures a rock's humidity that is beneficial for the heat transfer between the rocks and the Ground Heat Exchanger.

The general principle that ensures the function of the Geoechange System is the capacity of the Earth's subsurface to accumulate the heat (the geothermic gradient). The block diagram from fig. 3 and fig 4 shows some of the Earth's heat sources.

The adjacent zones to effusive and intrusive rock structures have a higher temperature compared to other zones, which makes the geothermal gradient higher than the average, obviously the temperature being determined by the cooling degree of magma for respective geological formations. [3]

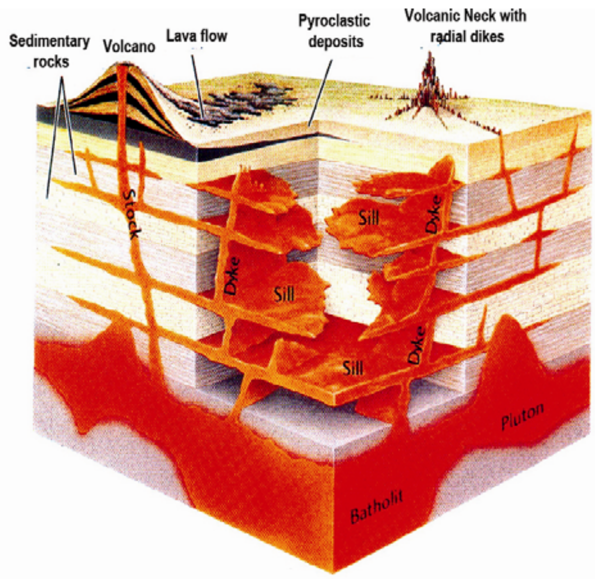

Fig. 3. Block diagram representation of Plutonic intrusive bodies geothermal power generation (effusive and intrusive eruptive rocks)

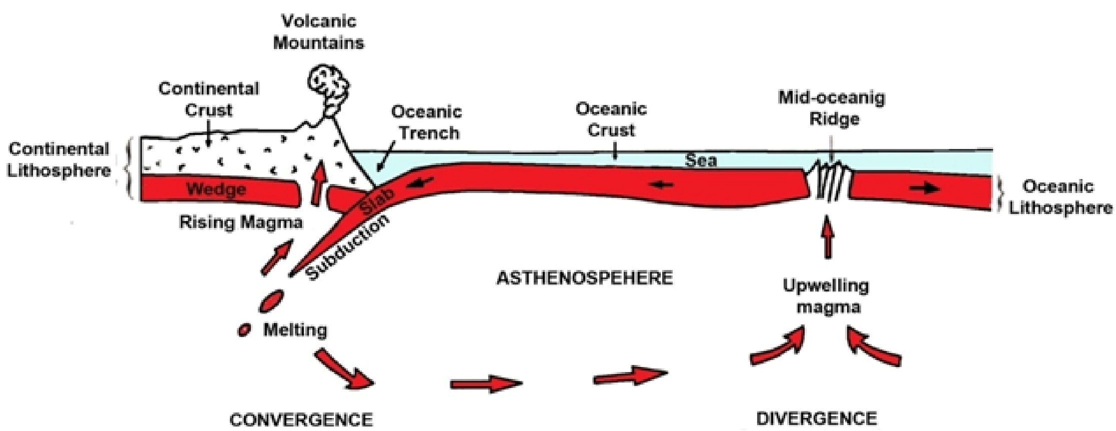

Fig. 4. The tectonic stress is another source of internal heat of the Earth; the subduction, the rising magma etc are zones where is generated heat.

Inside the Earth to the surface, the lithosphere is crossed by a stream of heat conduction, called terrestrial flow heat (HF) that justify the internal heat that can be used in the geoexchange technology. This energy is not influenced by the sun energy from the Earth surface and is a constant one.

It is also obvious that, even at a depth of 75 m, the temperature can be 12 – 15 ^{o}C which we can use in our benefit, more precisely by introducing a pipe through which water (in our case) or glycol, is circulated. Consequently would be able to warm this circulating fluid and then, by means of one or more heat pumps, we could use it in a heating system within a house, a commercial or industrial building [1]. The big advantage of this system is that it can work both ways: to heat the building during winter and to cool it during the summer. Apart from being neutral to the environment, the convincing characteristics of these thermal agents includes, above all, their excellent thermodynamic properties and a high level of economic efficiency [2]. Obviously both of them, the water and the mixture of water and glycol, are viable and safe products, as thermal agents, for more than a hundred years. Considering the increasing importance attributed to energy efficiency and resources protection, the heat pump sector will need to use more the potential offered by natural thermal agents. In this respect, the geoexchange system, uses a source of energy offered by Earth freely and also an eco-friendly thermal agent.

MATERIALS / METHODS

The well-chosen combination between a heat pump and a ground–coupled heat exchanger showed remarkable results.

In order to reduce the surface used for the ground heat exchanger a parallel vertical system with closed boreholes was chosen. The system will use a high density polyethylene HDPE, SDR 11 pipe for the heat exchange with Earth system.

The optimum diameter for borehole U-tube of 1” ensures the best combination between fluid pressure loss and thermal performance.

To estimate the length of heat exchanger, the following parameters will be taken into account:

– the necessary heat pump water flow rate;

– the type of fluid flow;

– the necessary minimum turn fluid temperature;

– the heating and cooling necessary;

– the average minimum temperature and the average maximum temperature etc.

We will use a reversible pump, that means it will ensure heating during winter and cooling during summer, coupled to a Geothermal heat exchanger.

Theoretical basis of heat transfer between the ground and HVAC system

It is important to know that considering the geothermal gradient and assuming the rocks to have a limited ability to transfer heat, the bedrock will transfer the heat from inside towards outside.

Fourier’s law

$$Q = \lambda A \frac{\partial \theta}{\partial z} \tag{1.1}$$

where: Q is the heat flux [W]; λ – thermal conductivity [Wm^{-1}K^{-1}]; A – area [m^{2}]; θ – temperature [K].

Thompson combines Fourier’s law with an equation of conductive transfer of heat.

$$\frac{\partial^2 \theta}{\partial^2 z} = \frac{\partial \theta}{S_{vc}} \tag{1.2}$$

where: z is the depth from the Earth surface [m]; λ – thermal conductivity [Wm^{-1}K^{-1}]; θ – temperature [K]; $\frac{\partial \theta}{\partial z}$ – geothermal gradient; Scv – volumetric specific heat capacity [Jm^{-3}K^{-1}]

$$\lambda = \frac{\Delta Q}{\Delta \tau} \tag{1.3}$$

Newton’s thermal transfer ratio equation:

$$q^* = h\,(\theta\text{material}- \theta\text{fluid}) \tag{1.4}$$

where: q^* is the heat transfer from rock to fluid [W/m^{2}]; h – local thermal transfer coefficient [W/m^{2}K], depends on fluid nature, flow rate, surface properties of material, etc.; θ_{fluid} – fluid temperature [K]; $\theta_{material}$ – material temperature [K].

In Fig. 5 is the schedule of the 20 boreholes that ensure the laboratory’s demand. The depth of each borehole is 80 m and the loop is about 74-76 m. The assembly of boreholes and collectors is a vertical parallel system of closed loops. It is important that all the U-tube introduced in the boreholes to be approximately the same length.

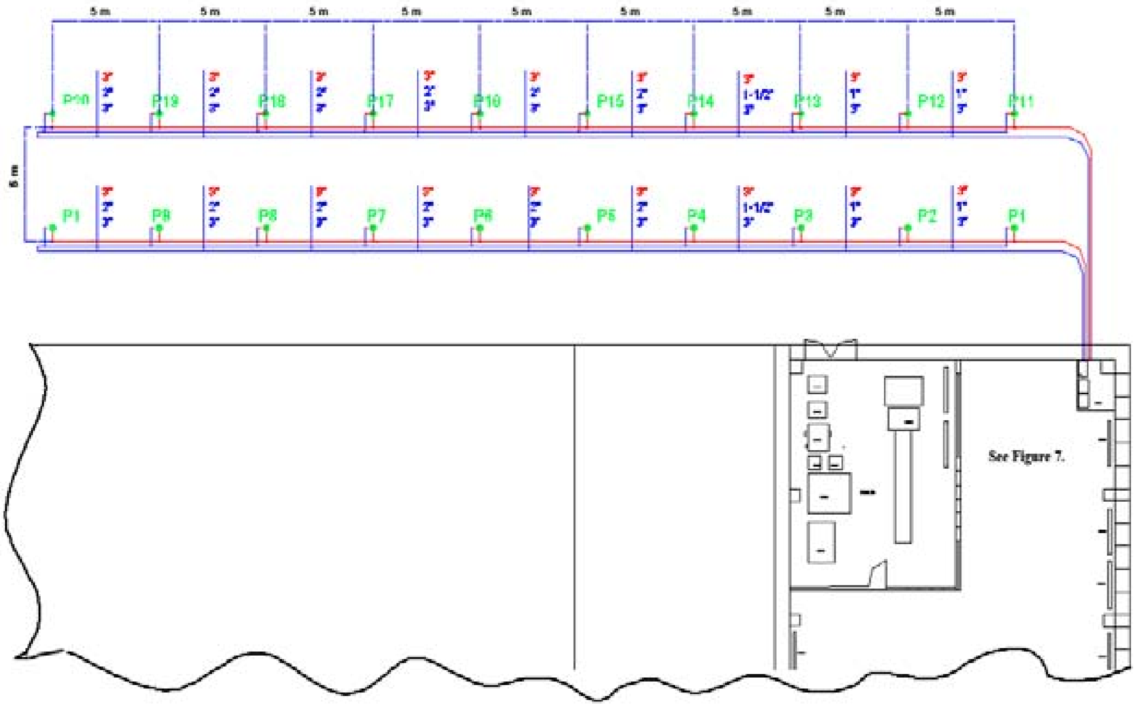

Fig. 5. The design of closed loops with collectors

Ground Heat Exchanger (GHE **) – design details**

The heart of the system (geoexchange) chosen for the laboratory, is the GHE, more precisely, the pipe system which absorbs the heat, or the cold from the ground and brings it to the surface.

A liquid, working as a thermal agent (water or a mixture between water and glycol), is circulated through the system by a circulating pump.

In order to install the pipes vertically, it is necessary for the ground to be uniform and compact, to prevent any damage to the pipes. The ground in which the pipes are to be placed should have a high humidity, so that the system can benefit from conductivity advantage of a wet ground.

For the best length determination are necessary a lot of factors to take into consideration.

In a drilling made close to the laboratory, the lithostratigraphical succession shown in the Fig. 6 has been identified. This structure and the fact that the groundwater level was identified at a depth of 7 m will ensure a good heat transfer.

However, the first sample borehole will be tested from point of view of conductivity in order to estimate more accurate the length of the heat exchanger; thermal conductivity being one of the parameters that are inserted into a complex soft-ware to determine the length of the GHE.

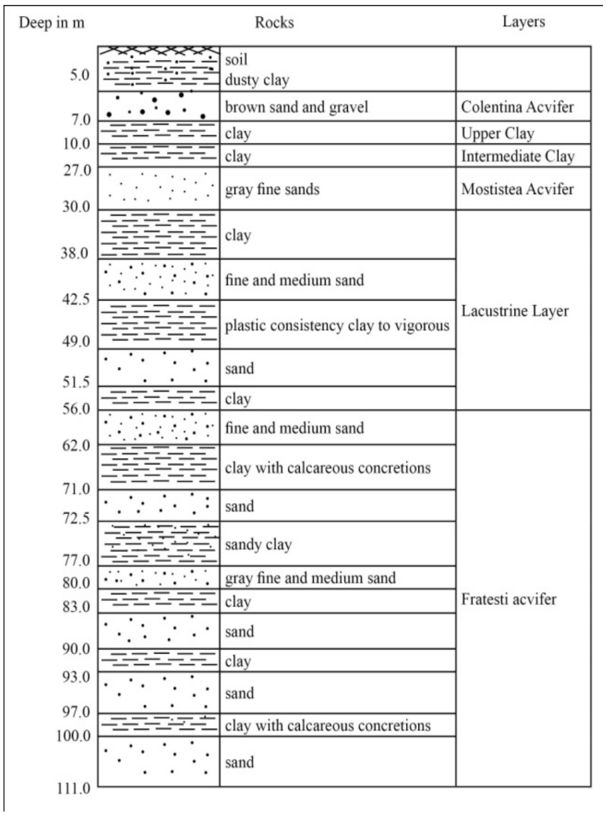

Fig. 6. The lithostratigrafical column in a borehole drilled in very near proximity.

Fig. 7. U tube for the loops.

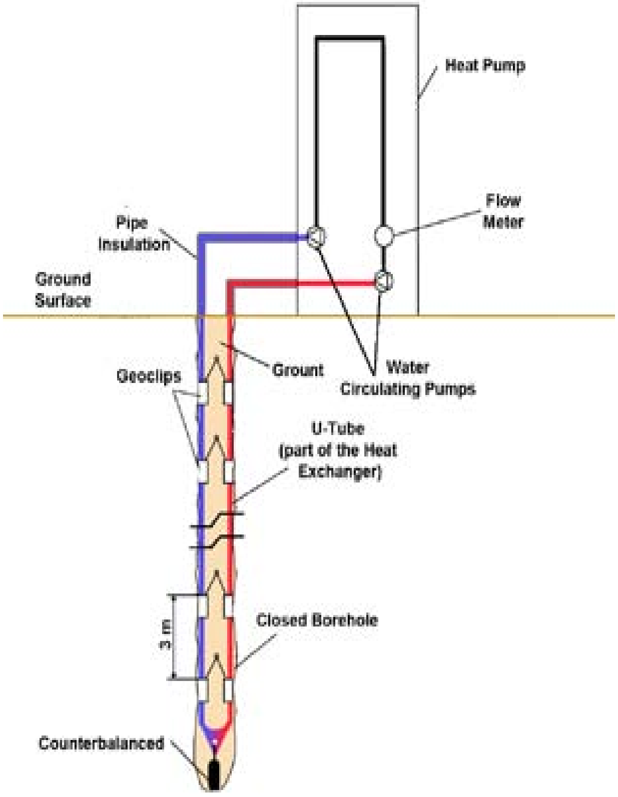

Fig. 8. Details of a borehole fully equipped and linked at a heat pumps.

The right choice translates into maximum performance at a minimum possible price. Obviously, there is no award for “the best heat exchanger”, in practice the challenge is to select the heat exchanger which best suits to the location and conditions in which it is going to work. In other words, we must accept there isn’t a perfect heat exchanger; for each particular application, to select the most efficient heat exchanger, the following considerations must meet:

1 Selecting the configuration; parallel vertical closed borehole [3];

2 Selecting the type of pipes; in our case the HDPE [3];

3 Estimating the length of heat exchanger [1]; we calculate a necessary of 20 boreholes.

For each group of 10 loops a system of collecting pipes is provided with a turn and return as it can be seen in the fig 9. All the external pipe system is connected with a circulating pump, to ensure the water circulation from the geothermal heat pumps to GHE and vice versa [4], [5].

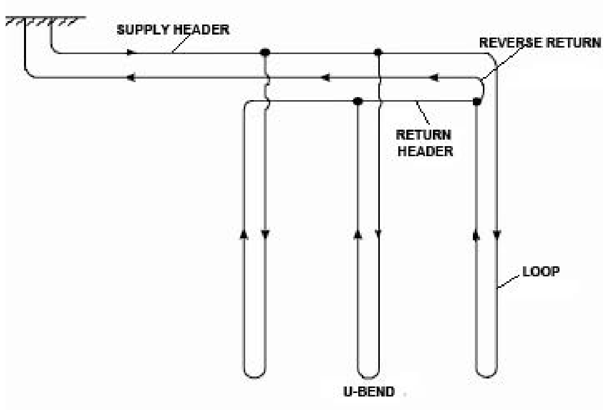

Fig. 9. Scheme of a parallel vertical system.

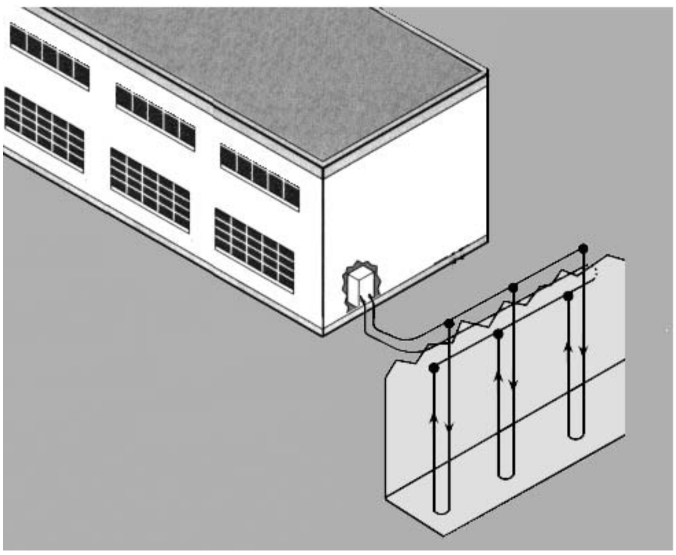

Fig. 10. Schematic GHE details.

Fig. 11. View of a heat pump.

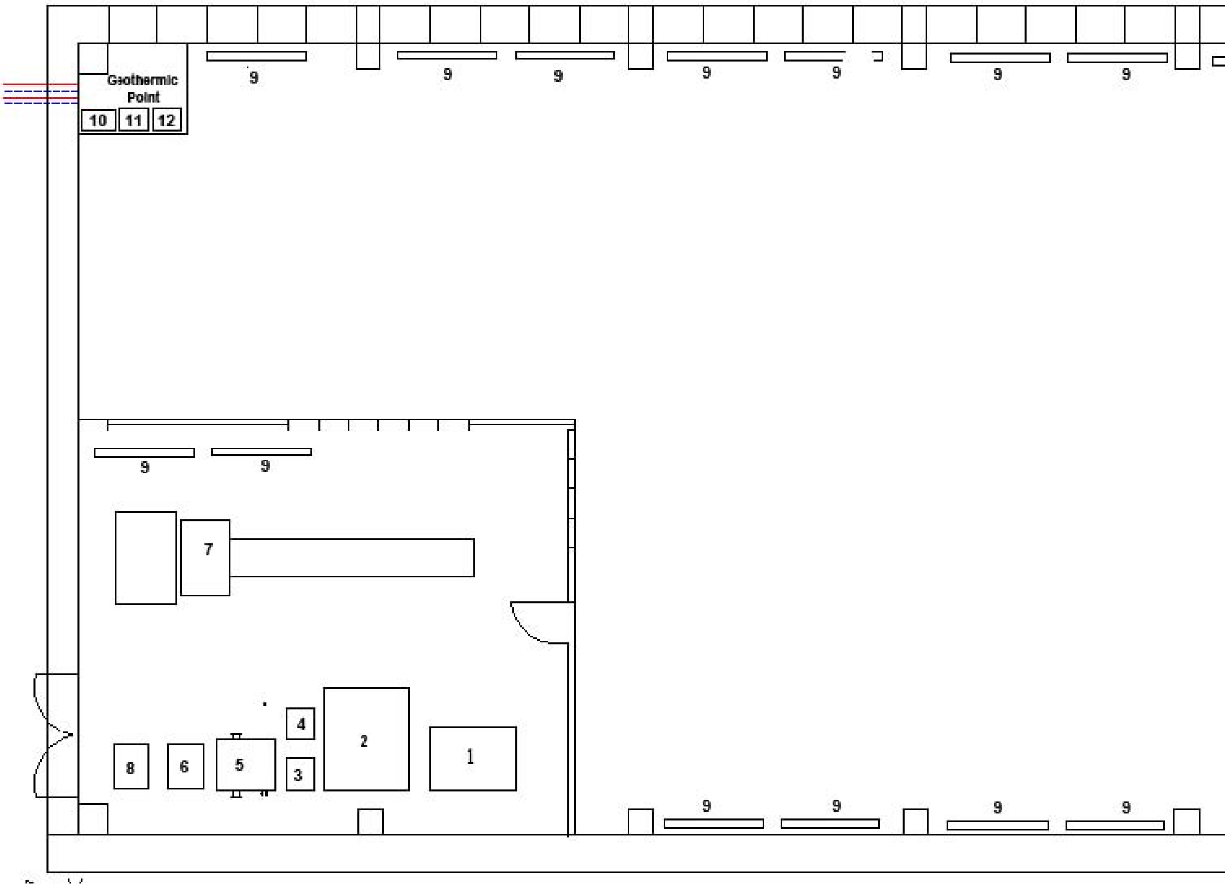

Fig. 12. Details of the arrangement and retrofit of the laboratory floor –1 –module testing room for heat and mass transfer, diffusion, jets (1900x1500x2400mm); 2 – experimental stand for heat and mass transfer, stand (2200x2100x2600mm); 3 – experimental stand freezer with absorption (600x800x560mm); 4 –experimental stand cooler with natural ecological refrigerant DME (600x800x560mm); 5 –experimental stand heat pump water–water (900x650x450mm); 6 – experimental heat pump water–water stand with incorporated boiler; the refrigerant being R134a (1730x600x700mm); 7 – experimental aerodynamic tunnel stand. Pollutants diffusion (9200x500x5500mm); 8 – geothermal heat pumps (water-water, water-soil, water-water) (1000x1000x500mm); 9 – fan coils; 10, 11, 12 – heat pumps (water-air).

Using EU and Romanian standards we find that the required heating load is 49.32 kW and the cooling load is 42.37 kW (without taking into consideration spliting the space in several rooms) so in order to supply this necessary we chose 3 Water-Air Heat pumps; with the following characteristics: - Water-Air Heat pump 1- COP=3.7; Water-Air Heat pump 2 COP=3.6; Water-Air Heat pump 3 - COP=3.4; - Circulators Pumps, Fixed speed (2 speeds), and also 1” diameter HDPE U-Tubes are used; - Vertical Fan coils Cabinet (Wall; model PV; a battery with 3 rows of tubes; Minimum speed of 187 treated air flow m^3/h).

RESULTS

The reason for which the classic system retrofit was chosen with the new one was to improve the energy performance, the quality of the control working environment and last but not least to preserve the environment.

Using a Direct Digital Control (DDC) is easy to remote control the use of the proper function of the entire system both for heating and cooling. In addition this system will allow us to do a statistical study on various data such as the number of hours used for heating or cooling, the required outside temperature to start warming up the laboratory. Also the climate control system is extremely versatile, allowing us to adapt the system as necessary; since this is obviously a laboratory study that the number of persons per square meter may vary widely at different times of the day.

Because the heat pumps are reversible, the system ensures the heating and the cooling demand, and the equipment is practically the same for both situations.

Electrical consumption which is very low is needed mainly to run the pump’s compressor, not to provide any heating or cooling (load).

The fact that the system is non-pollutant is an environmental friendly aspect.

Even the design of the pump and the fan-coil units will improve the space comfort, and also ensure a refined look.

CONCLUSIONS

The new air-conditioning system is very efficient with maintenance costs reduced with 50%. It is based on the use of Earth's heat and has no noxious release in the atmosphere responsible for increased greenhouse effect.

The new system is very versatile and allows adaptation to internal temperature of the working conditions inside the compartments, depending on the number of people who are at that time inside. The equipment used is extremely quiet and is not bulky. Since it is a new environment ensured by a friendly system, students may become interested in learning more about its functionality.

The main advantages of a geoexchange system with closed borehole are: Energy efficiency; Simplicity; Low maintenance; Water heating; No auxiliary heat needed; No outdoor equipment; Compact equipment with low noise level; Environmentally "green"; Lowers peak demand; Low life-cycle cost; Allows more architectural freedoms; Better zone comfort control (by using a Direct Digital Control of the Heat Pumps)

Unfortunately the disadvantage of geoexchange system is the high price of initial investment but it has to take into consideration that the pay back period ranges from 3-5 years, because the maintenance costs are 50% lower than the classic systems.

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