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THE POLYVALENT HEAT SUPPLY SYSTEM FOR PASSIVE-TYPE EXPERIMENTAL BUILDING (area of 300 m^2) BASED ON RENEWABLE AND ALTERNATIVE ENERGY SOURCES

The results of development and implementation of heat supply system for experimental building of passive type have been presented; the optimal operating conditions have been studied; and guidelines for the creation of heat supply systems for passive type buildings have been elaborated.

Key words: passive-type building, energy saving, low heat, and heat pump.

Constantly rising energy prices make the governments, the business leaders, and the homeowners care about saving primary fuel. In addition, the pessimistic experts predict that oil deposits will be completely exhausted in 30—40 years, while the optimists give 80—100 years. However, all the experts agree that there will be no cheap oil (and gas) anymore. To minimize the consumption of fossil energy is an urgent necessity. The researchers and engineers have been studying alternative and renewable energy and new ways of combusting the fuel, as well as improving the existing design of boilers and designing the new ones. Increasing the thermal resistance of walling to the level of present-day requirements will make it possible to reduce the heat consumption several times. In Ukraine, the average heat energy consumption per a complete cycle of building operation exceeds 300 kW · h/m^2 yearly [1, 2]. According to the State Statistics Service of Ukraine, in the final structure of fuel and energy consumption, the share of household sector makes up 34%. Together with the industrial sector having a share of 35% they make the largest contribution to the total energy consumption in Ukraine. The main energy savings have been reported for the public utilities sector and the housing construction. Naturally, there is a desire to reduce energy consumption in the municipal and household sector through implementing efficient energy-saving technologies and using renewable energy sources in housing construction. One of the ways to address the problem of energy saving is the construction of energy efficient and passive buildings.

The main requirements for the passive house in Europe are as follows [3]:

- Specific heat energy consumption as specified in PHPP should not exceed 15 kW · h/m^2 yearly;
- Total primary energy consumption for all needs (heating, hot water, and electricity) should not exceed 120 kW · h/m^2 yearly.

To reach the required value of specific energy consumption for heating the passive houses in the climate of Central Europe the following mandatory requirements are established:

- Heat transfer coefficients U for the external walls, roof, and floor of the ground level should be less than 0.15 W/(m · K); heat transfer coefficient of glass walling U_{zst} < 0.7 W/(m · K); and heat transfer coefficient of window profile U_{prof} < 0.8 W/(m · K);
- Combined heat transfer coefficient of the window (mounted in the wall) U_{window} < 0.85 W/(m · K);
- Maximum reduction of the negative effect of thermal bridges;
- Efficiency of recuperative heat exchanger of ventilation system should be greater than 75%;
- The outer shell of the building should be airproof.

In addition, the passive house should have an ecological design, be comfortable for its inhabitants and friendly for the environment. The house is draught-free and has a comfort temperature, clean and fresh air, and optimal humidity.

ENERGY EFFICIENT PASSIVE HOUSE (MODEL OF THE INSTITUTE OF ENGINEERING THERMOPHYSICS OF NASU)

As part of R&D project on the creation of pilot energy-efficient building of passive type, under a contract with the State Agency for Science, Innovations and IT Development of Ukraine (№ DZ/501-2011), the Institute of Engineering Thermophysics of NASU developed a concept for creating a pilot energy-efficient building of passive type, which has been built on the Institute's site.

Parameters of pilot passive house

Total area, m²	306
Number of stories	4 + 0.5
Heat transfer resistance of the primary building, m² · K/W	3.3
Maximum heat transfer resistance of the heat-insulated building, m² · K/W	11.4
Thickness of heat insulation, mm	320—345
Specific heat consumption of the building, kW · h/(m² · yearly):	
At an external temperature of –1.1 °C	15
At an external temperature of –10.0 °C	21.8

The basic principles of creating the pilot house:

- Compactness of building;
- Reinforced heat insulation;
- Orientation towards the south and no shade;
- Tightness of the building structure;
- Prevention of *cold bridge* formation;
- Energy efficient double windows and high quality window profiles;
- Glass pane structured according to the formula 4i-8-4i-8-4 (4i is glass with energy efficient selective coating);
- Controlled system of recuperative ventilation;
- The ground floor deepened into the soil;
- Thermal protection of external walls via underground heat exchangers;
- The internal walls made of material with large thermal capacity; the external walls made of materials with low thermal conductivity;
- Multilayer (triple) walls of supporting structure;
- Thickness of insulation is 34 cm.

In fact, this house (Fig. 1) is a full-scale experimental stand for studying the energy efficiency of buildings, including:

- Dissipative heat loss through the construction materials and some structures made of them;
- Heat loss of the building as a whole; and
- Effectiveness of innovative engineering energy-saving and resource-supplying systems of the building.

PURPOSE OF THE PROJECT AND MEANS OF ITS IMPLEMENTATION

The main purpose of R&D project implemented as part of innovative contract no. 29 of 01.03.2013 with the Presidium of the National Academy of Sciences of Ukraine is to develop and to implement a polyvalent system for heat supply of pilot passive house (area 300 m²) based on renewable and alternative energy sources (solar energy, soil and water heat). In the course of the project, the optimal system operating conditions have been studied and recommendations for the creation of such heating systems for passive-type houses have been elaborated.

The primary sources of energy for heating the building consist of renewable energy of solar radiation (both the direct and the scattered light) and alternative sources of energy. The alternative energy sources are as follows:

1) Heat energy accumulated in the soil mass in the summertime;

2) Heat energy of natural soil;

3) Heat energy of the air;

4) Heat energy of water supply wells; and

5) Heat energy of flue gases generated by the cogeneration mini-plant.

The components of polyvalent system can be conventionally divided into the basic, the additional, and the ancillary options.

The basic options:

- The use of domestic heat pump of *water-water* type (required output is 6 kW), ground heat exchangers and ground heat accumulators (seasonal air, water, and air-water accumulators; two daily accumulators, one seasonal daily accumulator, one seasonal accumulator consisting of 7 wells, one four-season accumulator in the water well (Fig. 2));
- The use of solar panels.

The additional options:

- The use of the cogeneration mini-plant heat exchanger;
- The use of exhaust ventilation system with heat recovery;
- The use of heat of finned smoke pipe.

The ancillary options:

- Warm curtain of the house walls and roof in the wintertime and their cooling in the summertime;
- Heating of the air in the wintertime and cooling in the summertime using a gravitational and free convective ventilation system and underground heat exchangers;
- Recuperative ventilation system with additional heating of air.

In terms of heating appliances, the polyvalent system implies the following elements:

- Warm water floor;
- Warm capillary water floor;
- Warm water wall;
- Warm capillary water wall;
- Warm electrically heated floor;
- Warm electrically heated wall;
- Multi-coil water heat exchanger mounted into the separation wall between the two rooms;
- Air heating fan coils of *water-air* type;
- Radiators with increased surface of heat dissipation at medium temperature.

The pilot house is ventilated with the use of the following trivalent system:

1) Tidal and gravitational passive system;

2) Forced ventilation via ground heat exchangers; and

Fig. 1. Appearance of pilot passive house under construction

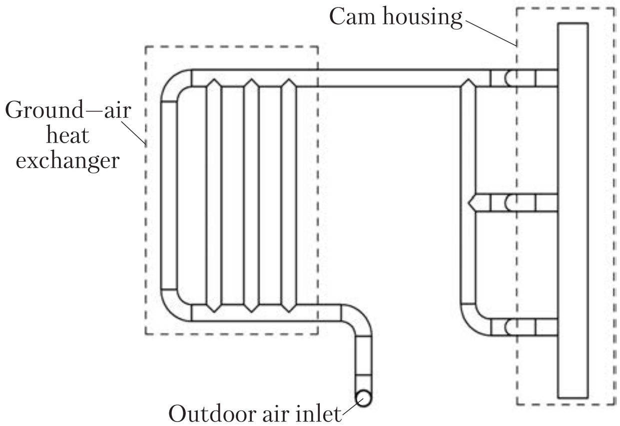

Fig. 2. Ground heat exchanger and cam housing (top view)

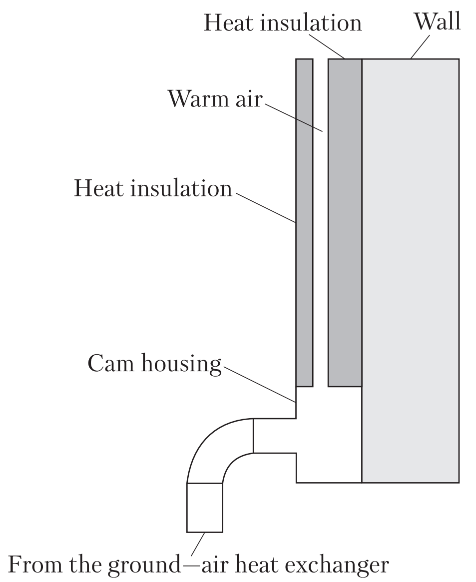

Fig. 3. Transverse cross-sectional view of the wall

3) Exhaust recuperative system (with or without air heating).

The heating system of the house (in terms of engineering solutions) is a combined polyvalent complex system of independent automatic heating (in the future, with remote control and monitoring) including heating (heating, hot water supply); air conditioning; ventilation; and warm curtain of walls.

The system uses a *VDE TH-6* heat pump.

The pilot passive house (Fig. 3) is equipped with automation sensors and relevant gauges and digital devices that are designed to monitor thermos-physical parameters of the power supply system with computerized collection, processing, and visualization of data in real time. The researchers are carrying out numerous computerized continuous (year-round) measurements of temperature fields, heat flows, humidity, pressure, airflows, air, heat, and power consumption, light intensity, and external climatic parameters. The sensors and measuring devices are located in building structures, inside the house, in the surrounding soil and in the air (Figs. 4 and 5). Fig. 6 shows some examples of installing the sensors in the building walling. The researchers will periodically inspect the thermal insulation of the building to localize heat losses and to minimize them.

CONCEPT AND FLOW CHART OF THE PASSIVE HOUSE POLYVALENT HEAT SUPPLY SYSTEM

The Institute of Engineering Thermophysics of NASU has developed a polyvalent heat-supply system for the pilot passive house using a heat pump and solar collectors regulated depending on the temperature of outdoor and indoor air. There are three modes: the summer (outdoor temperature is above 21 °C), the transition (outside temperature ranges from 8 to 21 °C), and the winter (outdoor temperature is below 8 °C for five consecutive days) ones. To maintain comfort temperature in the rooms during the year, as well as to comply with sanitary microclimate standards the adequate engineering solutions have been developed for each mode.

THE SUMMER PERIOD

The main task in the summertime is air conditioning of the rooms. The heating system has two independent air conditioning options.

The first air conditioning option is based on the use of *ground-air* heat exchangers (Fig. 7) located in the soil mass. The heat exchangers are made of pipes with an outer diameter of 110 mm; material is uPVC. The outdoor air pumped by an axial fan through the pipes is cooled in the soil mass (to a temperature of about 8 °C) and supplied to the heat exchanger of ventilation system.

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This is the way, the centralized air conditioning of the house operates.

If necessary, one can use the second option of more intensive conditioning (Fig. 8) using the water well heat exchanger (with water as coolant). While passing through the heat exchanger of ventilation system the indoor air heats the water that cools it. Then, the water of heat exchanger circuit is cooled in the water well heat exchanger by running water from the well (having a temperature of about 12 °C).

In addition, there is an option of local air conditioning using fan coils. The fan coils and the heat exchanger of ventilation system are connected using a pump with a frequency-controlled drive for pumping the cooling water.

The second task of the heating and cooling system in the summertime is heating water and heat recovery power ground (Fig. 9).

The main source of heat for hot water supply is solar collectors installed on the roof. Cold water from the well enters the pressure boost facility and is pumped into the tanks for storage of hot and cold water. The cold-water storage tank is an indirect heating boiler with integrated heat exchangers and electric heater. The cold water from the pressure boost facility comes in the inner section. PPG solution heated in solar collectors is fed to the heat exchanger. This is the way of heating water for hot water supply. As soon as both tanks are filled, the pressure boost facility shuts off automatically for power saving.

The tanks with hot and cold water are set on the top floor of the building and can be used for water supply in the case of power failure. If there is no solar energy and hot water cools down, the electric heater in the storage tank is activated automatically.

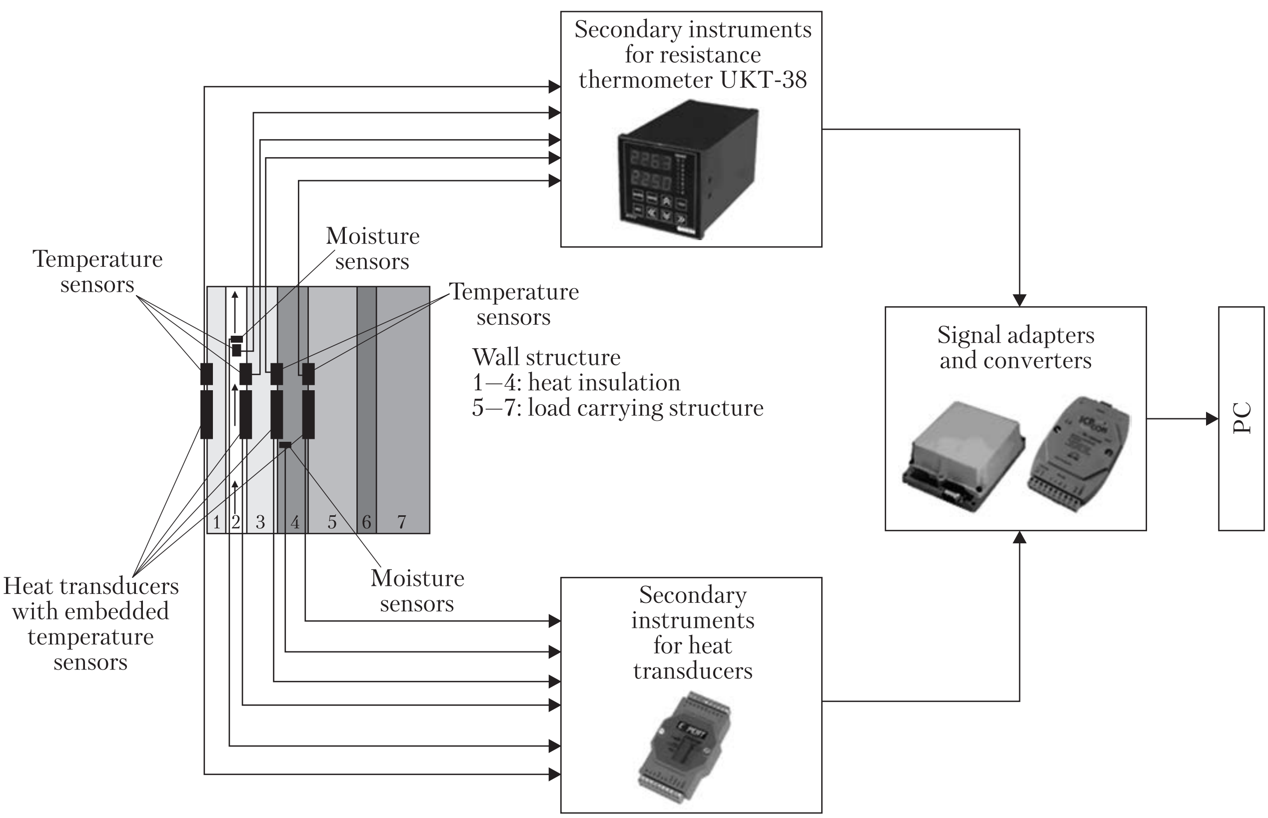

Fig. 4. Layout of measuring sensors location in the wall structure of pilot passive-type house and the flow chart of collection and transmission of their signals

In the case of excessive heat energy obtained from solar collectors, heated ethylene glycol solution is pumped through a plate heat exchanger and heating the water restores the thermal state of the ground heat accumulator (the soil mass). Later, the ground heat accumulator is used as low heat source for heat pump in the winter and transition periods. This way, excessive heat obtained in solar collectors is realized.

THE TRANSITION PERIOD

The transition period is a period when the average daily outdoor temperature ranges from 8 to 21 °C. Under these conditions, the main task is to

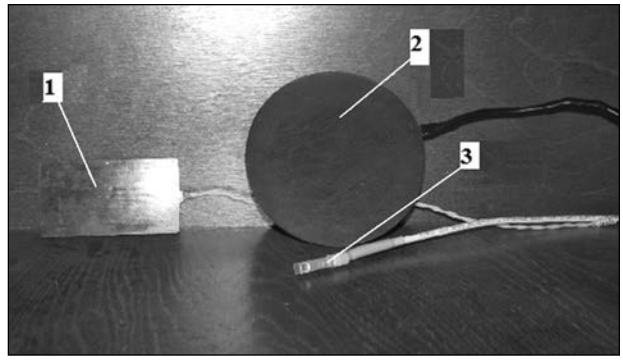

Fig. 5. Heat loss gauges mounted in the walling: *1* – rectangular heat flow transducer; *2* – round heat flow transducer with imbedded platinum resistance thermometers; *3* – copper resistance thermometer

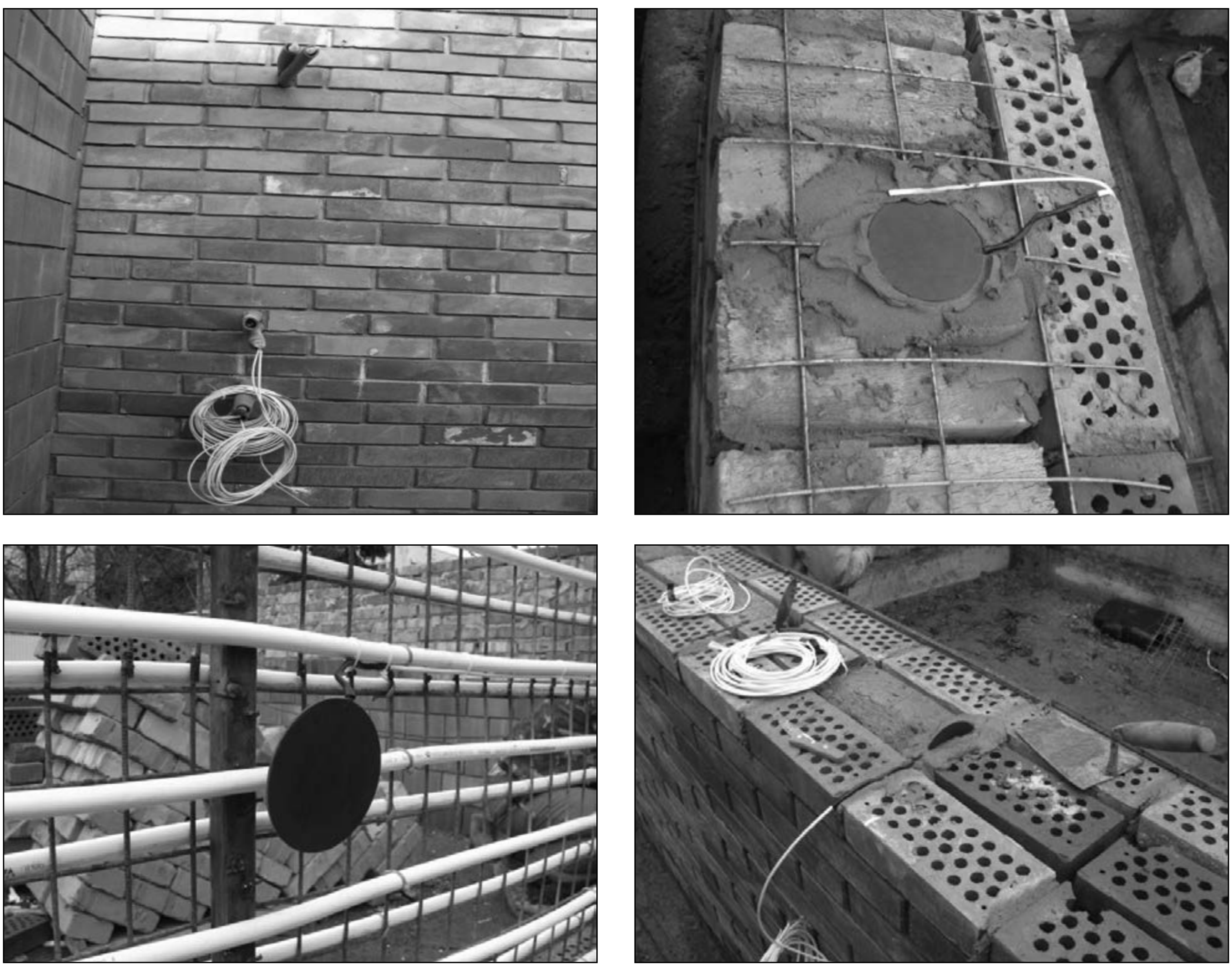

Fig. 6. Examples of sensors mounted in the walling of pilot passive-type house

ensure hot water supply and to cover heat losses of energy efficient building due to the operation of ventilation system. The operation of heating system in this period is showed in Fig. 10.

Hot water is heated in the same manner as in the summertime.

When the temperature of indoor air falls below 20 °C in two or more rooms, a portion of PPG solution heated in the solar collectors enters the plate heat exchanger and heats water that, in its turn, enters the heat exchanger of ventilation system. Decrease in temperature in two or more rooms is taken to minimize the impact of human factor (such as open windows) on the automatic equipment of heating system.

If the indoor air temperature continues to show a downward trend, after a given period, the plate heat exchanger shuts off and the heat pump is activated. This mechanism operates at night or when the intensity of solar radiation decreases because of clouds.

A set of heat exchangers is used as a source of low heat for the heat pump. Each of them has its priority. The sources are switchable both automatically and manually.

During the transition period, when the heat pump is activated, the first source of low energy for it is the water well heat exchanger.

During the transition period, the heat losses of the building are compensated by the operation of ventilation system. The fan coils are used to heat the indoor air in individual rooms. When the thermal capacity of water well drops to a level that cannot ensure the stable operation the heat pump, the pump starts to use the ground heat accumulator as low heat source instead of the water well heat exchanger.

Within the transition period, the accumulating tank of heating system is charged. It is supposed to be used in the wintertime to prepare a coolant for low-temperature heaters, especially for the warm capillary floor and for the wall capillary heat exchanger.

THE WINTER PERIOD

The heating system switches to the winter mode provided the average daily outdoor temperature falls below 8 °C for three consecutive days. The main objective of this period is to keep the indoor air temperature at 20 °C regardless of the outdoor temperature. The operation of heating system in the wintertime is showed in Fig. 11.

In this case, the main energy source for heating appliances is the heat pump. Solid fuel boiler and cogeneration mini-system can be used as well. Hot water is heated in accordance with the scheme mentioned above. The rooms are heated by both

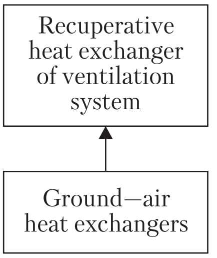

Fig. 7. Conditioning with the use of *ground—air* heat exchangers

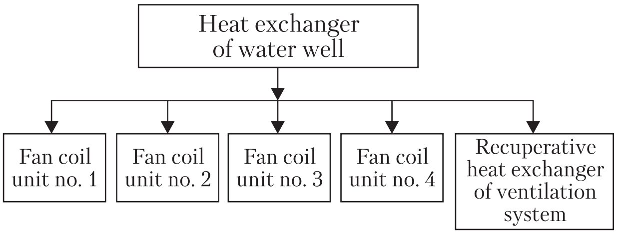

Fig. 8. Conditioning with the use of water well heat exchangers

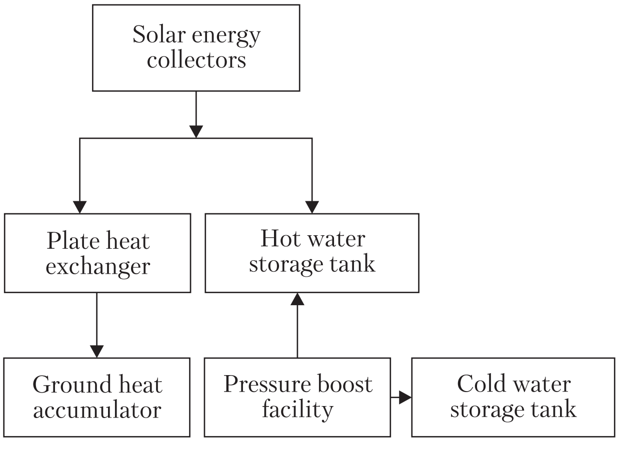

Fig. 9. Heating of water for hot water supply and regeneration of ground heat accumulator

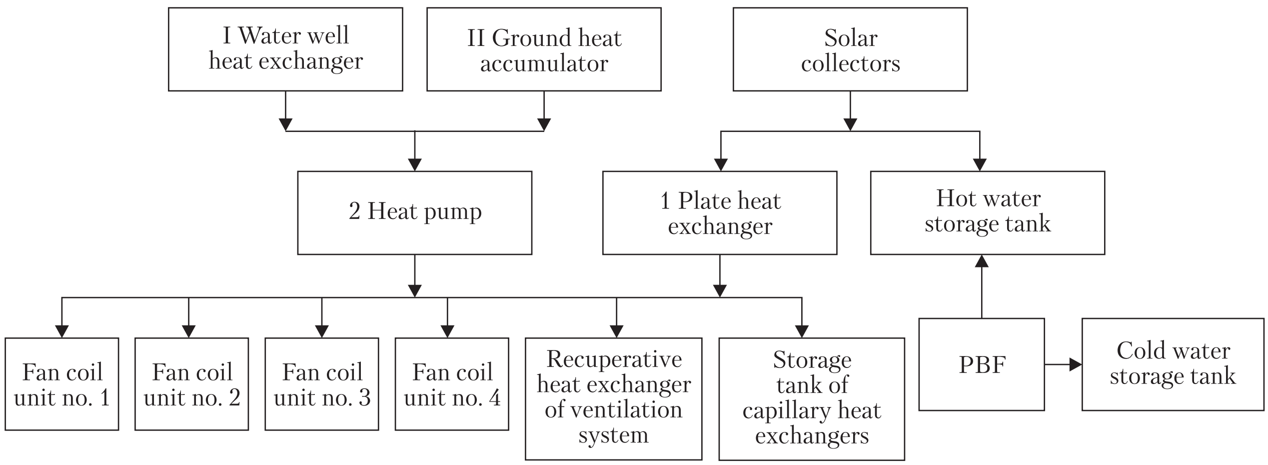

Fig. 10. Operation of heat supply system in the transition period

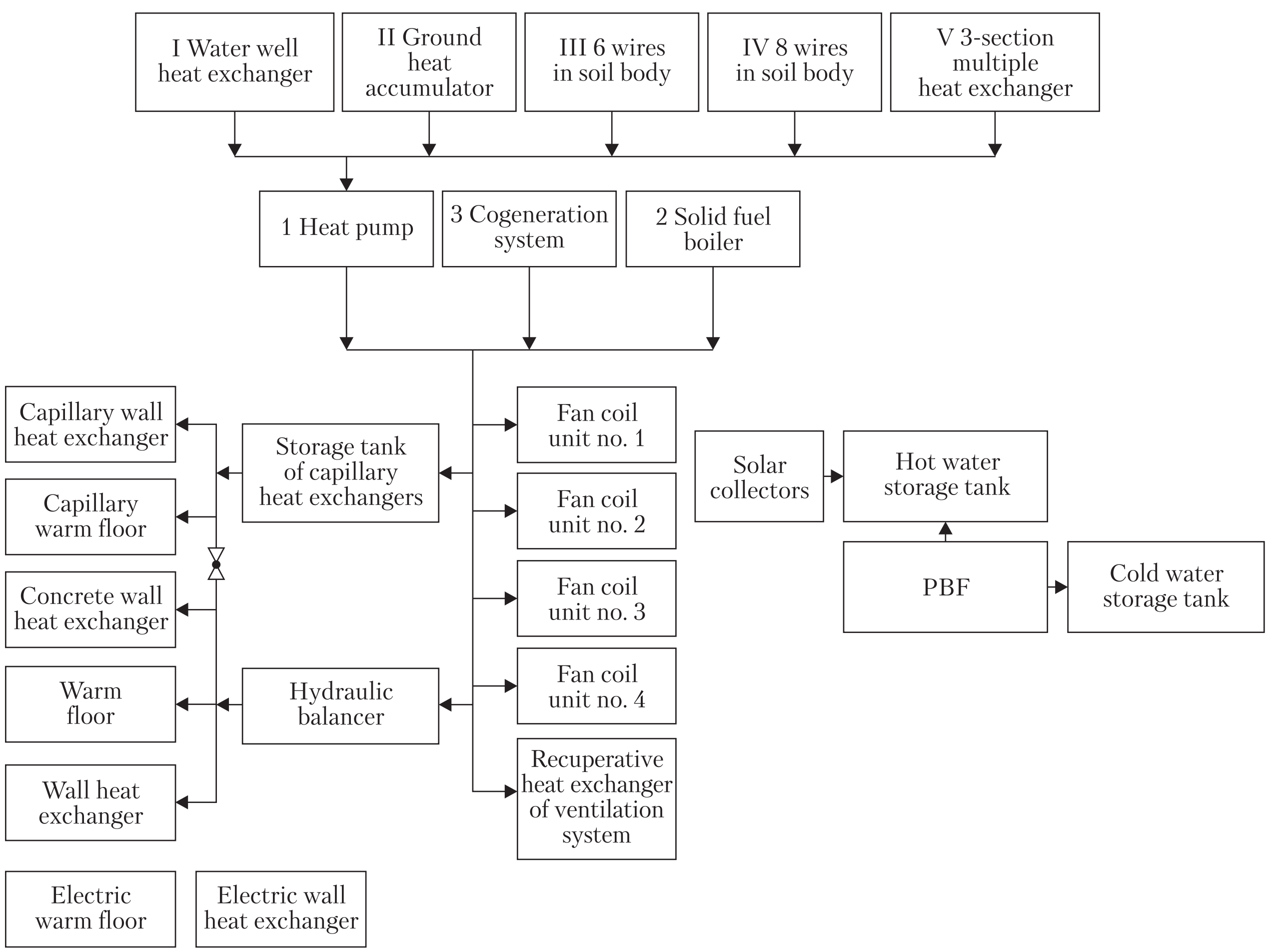

Fig. 11. Operation of heat supply system in the wintertime

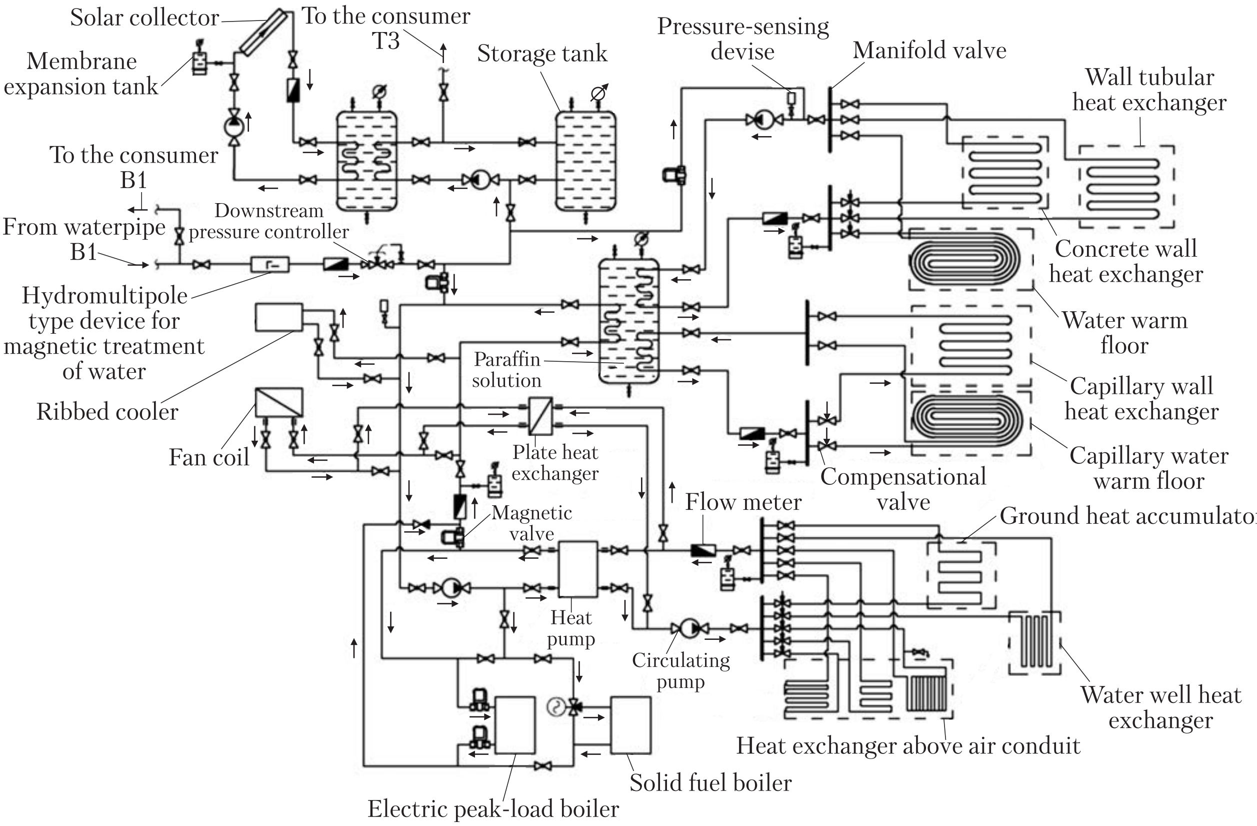

Fig. 12. A detailed schematic diagram of passive house polyvalent heating system

the ventilation system and fan coils and the low temperature heating facilities. The basic heaters are *warm floor*, capillary *warm floor*, tubular and capillary wall heat exchangers, and heat exchanger imbedded in the concrete wall. Electric *warm floor* placed in front of the entrance door and wall electric heat exchanger are used as backup heaters. The low-temperature heating devices are connected to the heat pump through the storage tank.

Particular attention should be given to a set of heat exchangers that are sources of low heat for the heat pump. In addition to the water well heat exchanger and the ground heat accumulator, there is a set of heat exchangers located in the soil mass, on thesiteoftheInstituteofEngineeringThermophysics of NASU. This set includes one-pass heat exchangers in the form of 6 wires having an outer diameter of 32 mm, which form 3 loops, each being 15 m long and 8 wires with an outer diameter of 32 mm, which form 4 loops, each having a length of 20 m. In addition, there is a three-section brazed multi-pass heat exchanger made of PE100 tube with an outer diameter of 40 mm. These heat exchangers are located on the flow chart of the heating system (see Figs. 3, 5) of passive-type building in the order of increase in their heat transfer surface. The priority of sources of low heat for the heat pump corresponds to the indices I—V.

Fig. 12 shows a detailed schematic diagram of passive house polyvalent heating system. The schematic diagram can be divided into the following components [4, 5]:

- Block of heat sources for the heat pump, block of energy transformation and heat storage;
- Block for the preparation of coolant for heating systems;
- Block for the heating of water for hot water supply;

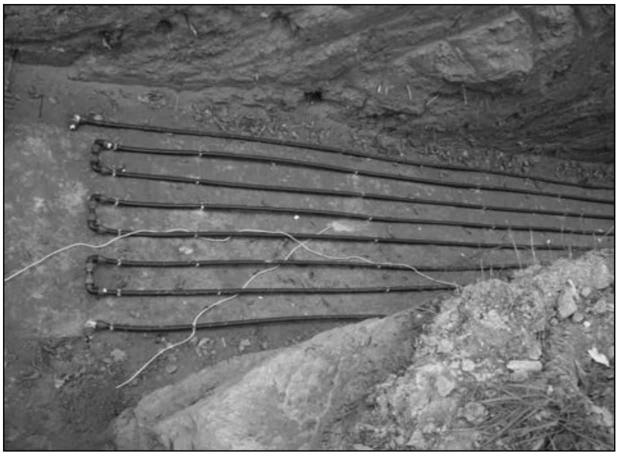

Fig. 13. *Ground—water* 8-wire heat exchanger

Fig. 14. *Ground—air* heat exchanger

Fig. 15. Three-section multi-pass *ground—water* heat exchanger

- Block of heat exchangers of the heating system; and
- Feeding block.

Let us consider the above blocks in detail.

BLOCK OF HEAT SOURCES FOR THE HEAT PUMP

This block consists of heat exchangers supplying heat for the heat pump. Some of them are located in the soil mass (3 exchangers of different designs with different nominal inside diameters). In addition, they include the water well heat exchanger and the ground heat accumulator. PPG solution is used as coolant. The coolant flow rate through each device is controlled by the balancing valve of discharge manifold located in the basement of the building.

The balancing valves make it possible to operate each heat exchanger in accordance with design parameters of pressure and flow rate, and (if necessary) to adjust the settings for effective operation of devices. The heat exchangers can operate all at once or separately due to the use of a frequency-controlled circulating pump. In the warm season, there is an opportunity of using fan coil units for air conditioning. In this case, the coolant circulates through the brazed plate heat exchanger (instead of the heat pump) and cools water in the fan coil circuit. Flowmeter and temperature sensors (not conventionally showed in the scheme) allow the researchers to receive data on the heat energy obtained and to evaluate performance of each heat exchanger.

BLOCK OF ENERGY TRANSFORMATION AND HEAT STORAGE

The main energy source for heating the passive-type building is heat pump. As the temperature of environment goes below the design value, a peak-load electric boiler for additional heating of the coolant (water) is activated automatically via the opening (or closing) of solenoid valves. On the output of peak-load electric boiler circuit, there is back-flow valve to prevent the coolant flow in the opposite direction. In the case of failure of heat pump or electric boiler, the backup boiler is activated. It operates on solid biomass fuel.

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To keep the coolant temperature at the inlet of solid fuel boiler at a given level (to prevent condensation of water vapor from the flue gases on the surface of mounted heat exchanger), a three-way electric-driven valve is used. The valve operates from a temperature sensor installed at the boiler inlet (not conventionally showed in the scheme).

THE BLOCK FOR PREPARATION OF COOLANT FOR THE HEATING SYSTEM AND THE HEAT EXCHANGER BLOCK

The main element of this block is storage tank. In this tank, the coolant is prepared for heating devices (excluding radiators and fan coil units) to ensure the operation of the following elements of heating system:
+ Electric warm floor;
+ Capillary warm water floor;
+ Warm water floor;
+ Heat exchanger of concrete partition wall;
+ Wall water heat exchanger;
+ Wall capillary heat exchanger;
+ Plate radiator convectors;
+ Fan coil units.

It should be noted that for the capillary heating devices it is not necessary to install circulation pumps. It is enough to decouple hydraulically the loops of capillary heat exchangers, warm floor, and wall heat exchangers by imbedding coiled heat exchangers into the body of storage tank. The tank's working environment is a paraffin solution for getting more heat during paraffin phase transitions. Balancing valves are installed at the inlets to each heat exchanger (except for radiators and fan coil units) similarly with the block of the energy sources for the heat pump.

Fig. 16. Heat exchanger (floor water circuit heating system)

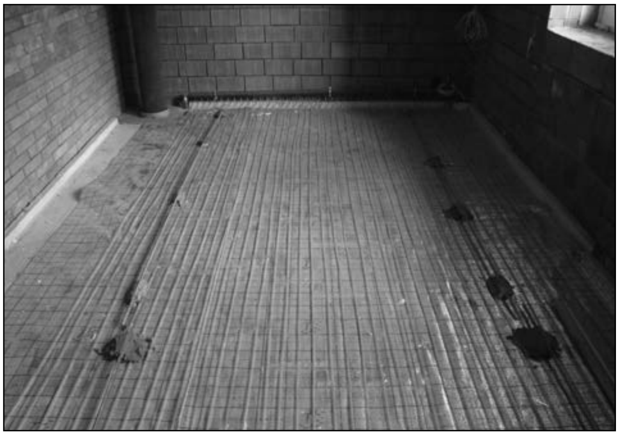

Fig. 17. Heat exchanger (capillary warm water floor type)

THE BLOCK FOR HEATING WATER FOR HOT WATER SUPPLY AND THE FEEDING BLOCK

The source of heat for hot water supply system is the solar collectors. The PPG solution heated by solar radiation in the collector circulates through the heat exchanger in the storage tank. On the other side, cold water from the aqueduct through a *hydromultipol* magnetic treatment device and a downstream pressure controller enters the circulation loop. Further, this water via pump enters the heat exchanger in the storage tank, is heated to the desired temperature and fed to consumers. During the periods when no hot water is taken, the seasonal storage tank is filled. The downstream pressure controller prevents any influence of pressure fluctuations in the water pipeline on the system operation.

The feeding system operates as follows: as the pressure in the loop decreases (with respect to the working pressure), the pressure sensor switch opens the respective solenoid valve. As the pressure levels, the solenoid valve is closed. For ensur-

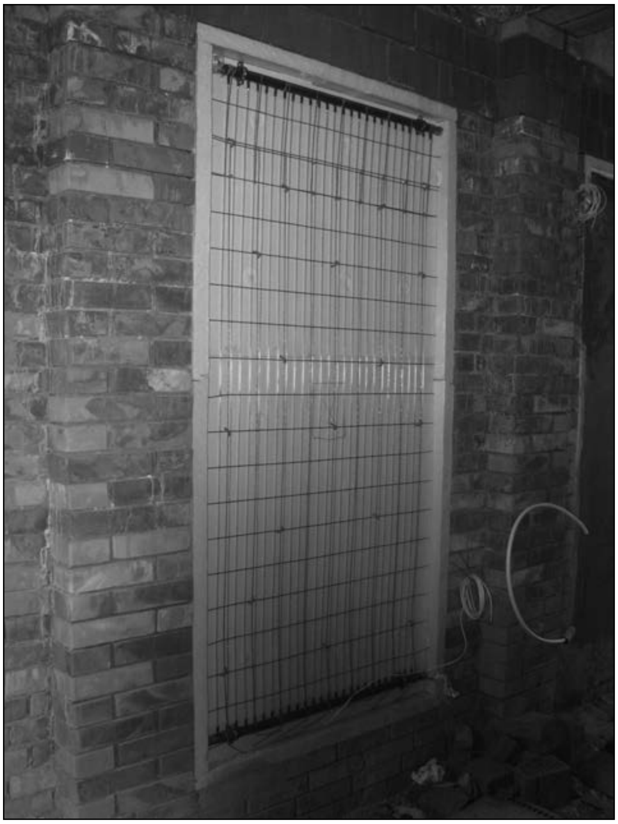

Fig. 18. Wall capillary heat exchanger

Fig. 19. Heat exchanger imbedded into the concrete partition wall

ing the correct operation of the sensors, the pressure sensor switch should be fixed before the circulating pump and as far as possible from the place where the feeding system pipeline is tied in.

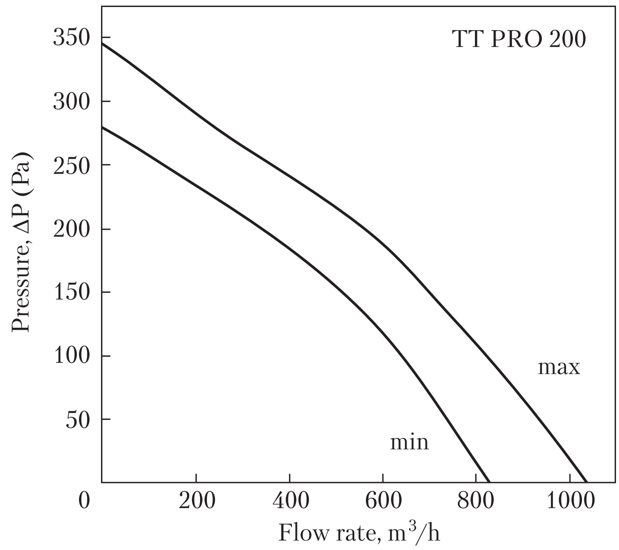

Fig. 20. Heat and rate parameters of VENTS TT Pro 200 air circulating device

The loops operating on PPG solution, as well as the capillary heat exchanger loop are fed manually, through special fittings.

To compensate the coolant thermal expansion, the membrane expansion tanks are installed in each loop. The systems for air venting, emergency coolant draining and filtering are not conventionally showed in the scheme. The specific heat load on the heating facilities of passive-type house (maximum heat flux density) is as follows: the electric warm floor 12% (30 W/m^2); the warm water floor 25% (up to 50 W/m^2); the warm water wall 18% (up to 40 W/m^2); the warm capillary wall 15% (up to 25 W/m^2); and the fan coils 30%.

USE OF HEAT EXCHANGERS IN THE PASSIVE-TYPE HOUSE HEATING SYSTEM

In the soil mass (at a depth of 2.5 m), there are the *ground-water* heat exchangers that supply heat energy for the heat pump and the *ground-air* heat exchangers of the ventilation system (Figs. 13–15).

Totally, there are 3 *ground-water* heat exchanger (6 wires, 8 wires and 3-section multi-pass

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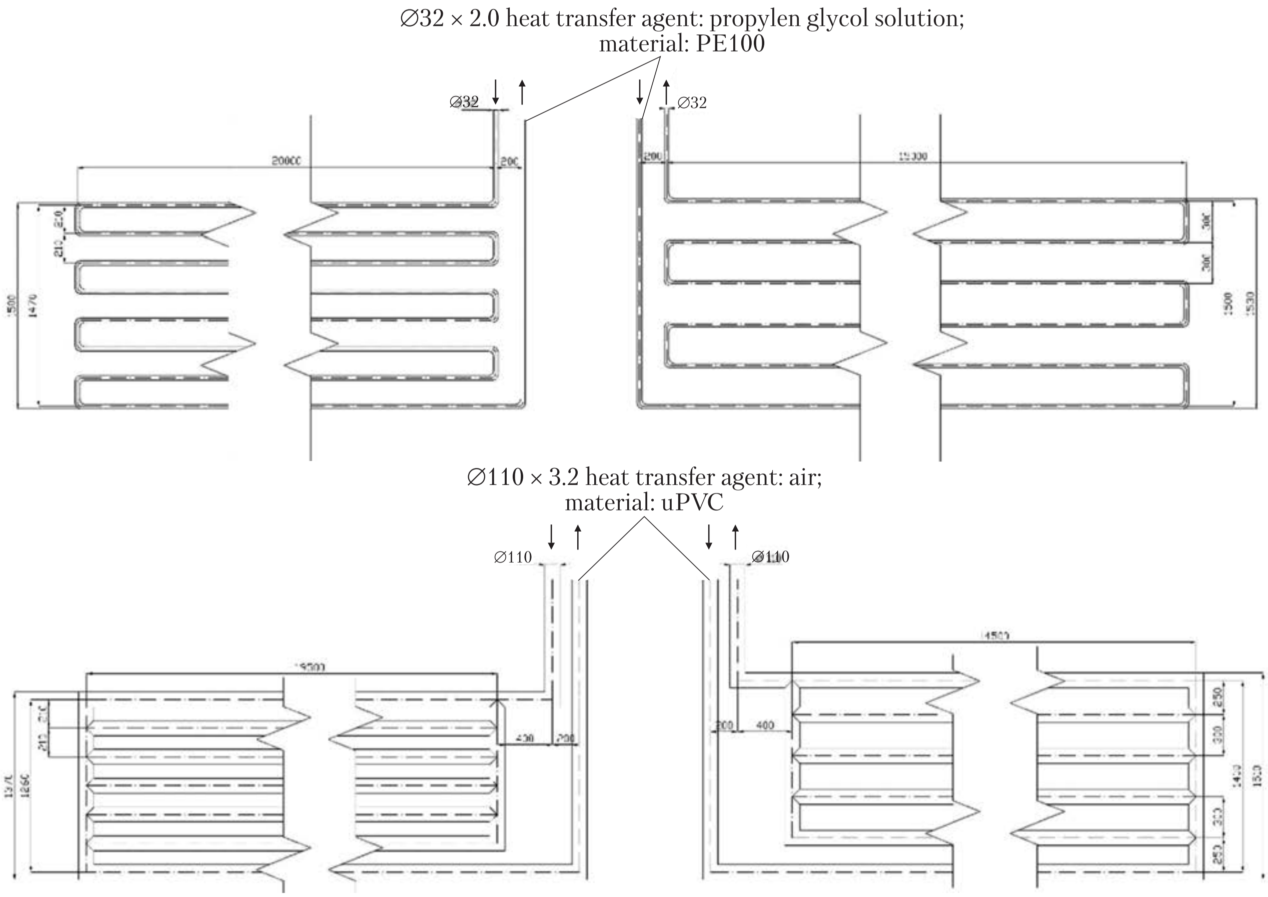

Fig. 21. Schemes of *ground—water* and multi-pass *ground—air* (north and south) heat exchangers

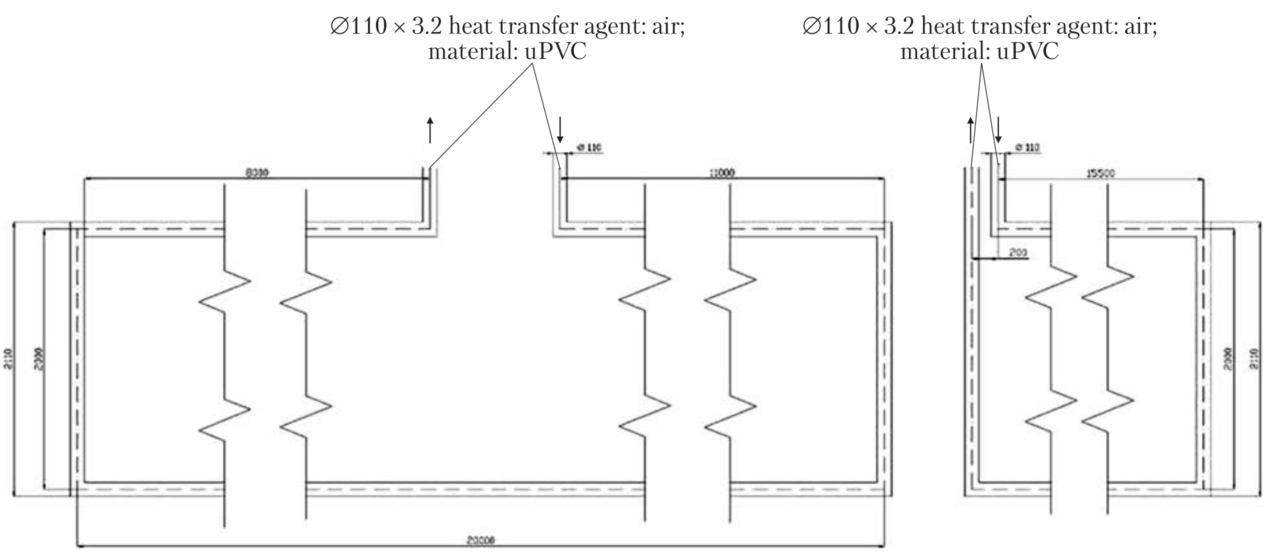

Fig. 22. Schemes of *ground—air* heat exchangers (north and south)

heat exchanger) and 4 *ground-air* heat exchangers (2 one-pass heat exchangers with discharge headers and 2 one-pass heat exchangers placed around the trench perimeter). It should be noted that the *ground-air* heat exchangers have different purposes. The one-pass heat exchangers with discharge headers heat the outdoor air that further enters the heat exchanger of ventilation system. The one-pass heat exchangers placed around the trench perimeter heat air for warm air curtain of the building.

The heat exchangers of passive-type house heating system include the warm water floor loop, the capillary warm water floor system, the wall tubular and capillary heat exchangers, as well as the multi-loop heat exchanger mounted in the concrete pier between rooms (Figs. 16–19).

EXPERIMENTAL STUDY OF HEAT ENGINEERING PARAMETERS OF UNDERGROUND HEAT EXCHANGERS OF VARIOUS DESIGNS

Figs. 20–23 show heat exchangers of various designs discussed above. Accordingly, the heat and rate parameters of air heat exchangers in various operating modes have been experimentally studied in the cold and in the warm seasons. A *VENTS TT Pro 200* centrifugal fan was used for pumping the outdoor air through the heat exchangers. Its heat and rate characteristics are given in Fig. 20. It is characterized by almost linear dependence of pressure on airflow within the entire range of device performance. For the discrete control (*min-max*) of fan performance, the device has an option switch.

For studying the heat transfer during the passage of atmospheric air through the multi-pass heat exchangers, an *RNO-250-5* autotransformer was used to change the voltage of alternating current supplied to the fan (performance within the relevant voltage range). At the same time, air speed and temperature were measured at the inlet and the outlet of air heat e xchangers (in the section outside the hydrodynamic and thermal stabilization of airflow) by *Testo 405-V1* thermometer (absolute error of temperature measurement is ± 0.5 °C, that of speed measurement is ± 0.3 m).

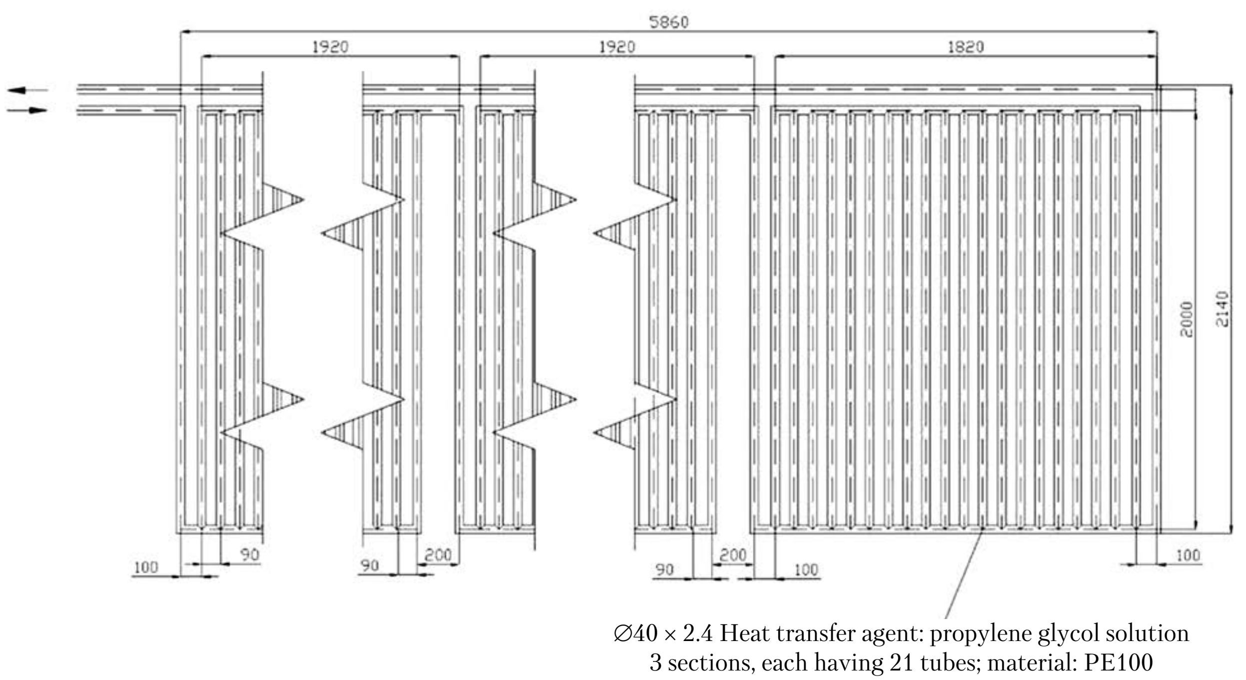

Fig. 23. Scheme of 3-section multi-pass *ground—water* heat exchanger

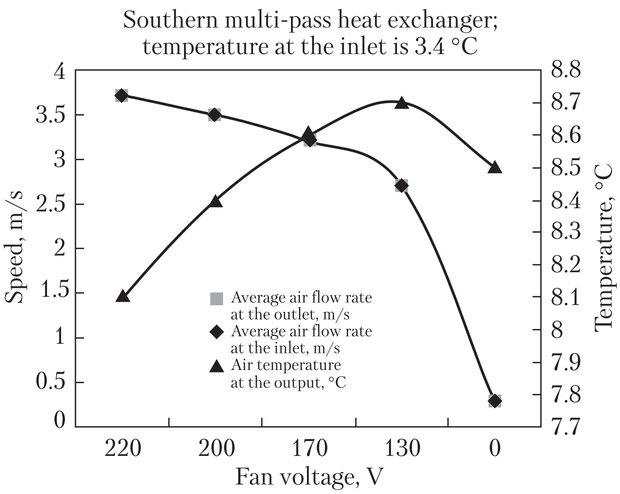

Fig. 24. Operational parameters of southern multi-pass heat exchanger (in the wintertime)

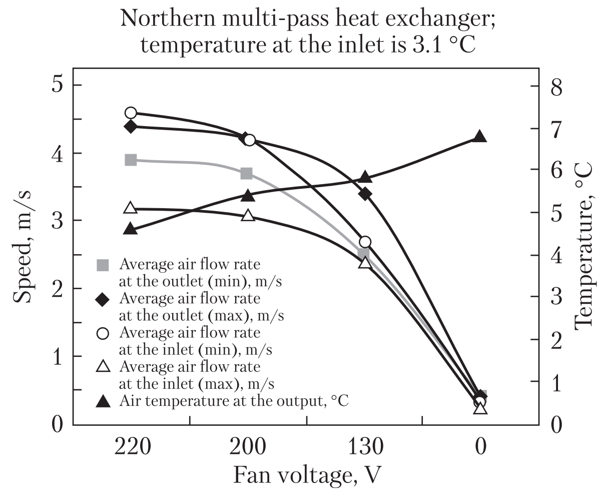

Fig. 25. Operational parameters of northern multi-pass heat exchanger (in the wintertime)

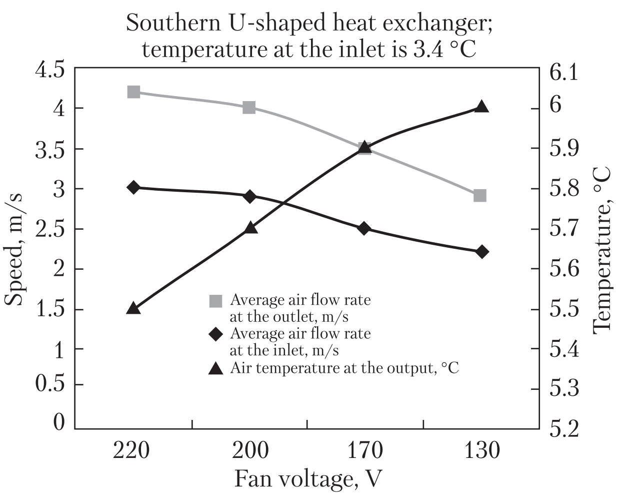

Fig. 26. Operational parameters of southern U-shaped heat exchanger (in the wintertime)

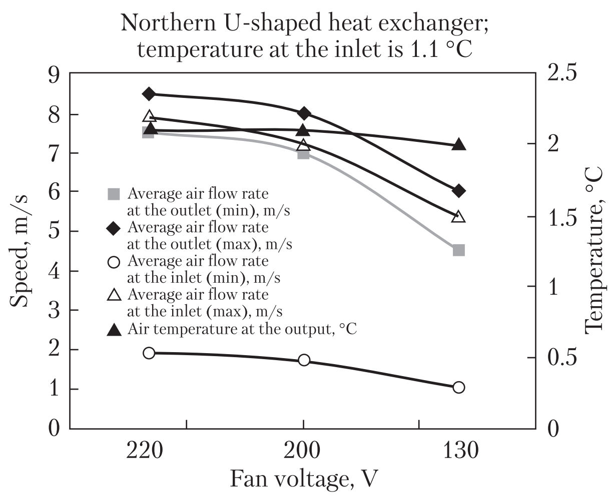

Fig. 27. Operational parameters of northern U-shaped heat exchanger (in the wintertime)

The selected results of experiments on measuring the thermal characteristics of *ground-air* heat exchangers in cold and warm seasons are showed in Figs. 24–27.

The experiments have showed that in the warm season, the outdoor air is cooled by 11.2 °C with respect to the reference value of 29.8 °C. The airspeed at the inlet and the outlet of the multi-pass southern heat exchanger is identical and equal to 3.6 m/s. The temperature of the soil mass is 8.8 °C.

Thus, in the warm season the underground heat exchanger cools the incoming air. The outdoor air enters through air intake vent the ground heat exchanger where it is cooled through the soil. Then the cooled air is supplied through air ducts to the exhaust plant that, in the summertime, has a seasonal insert element instead of heat exchanger. Thanks to this solution, air temperature in the rooms decreases improving the microclimate in the house as a whole and reducing power consumption by the air conditioning system.

In the cold season, the outdoor air enters the *ground-air* heat exchanger, where it is heated and then enters the exhaust plant for further heating in the recuperative heat exchanger. The air preheating prevents the icing of recuperative heat exchanger and exhaust plant, thereby increasing the efficient time of recuperation, and minimizes heat consumption for additional air heating in water or electric heaters.

CONCLUSIONS

1. For the passive-type buildings, it is economically expedient to create an integrated heating complex comprising the heating, the air conditioning, the ventilation and the hot water supply systems.

2. Insofar as the passive-type buildings have low heat losses through the walling, it is advisable to use low-temperature heaters (*warm floor* heat exchangers, wall heat exchangers, etc.).

3. The heat pumps utilizing the alternative resources (heat of soil and air, heat of waste systems, and solar energy) should be used as sources of thermal energy. In this respect, seasonal ground heat accumulation is an especially effective technology.

4. The heating system should operate in several modes (in the summertime, within the transition period, and in the wintertime) for ensuring comfort microclimate in the passive-type building.

5. Within the periods when the average outdoor temperature is +8 °C, it is reasonable to heat the passive-type buildings only by recuperative ventilation system, without heating appliances involved. The pre-heating of outdoor air in the *ground-air* heat exchangers is recommended.

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ПОЛІВАЛЕНТНА СИСТЕМА ТЕПЛОЗАБЕЗПЕЧЕННЯ ЕКСПЕРИМЕНТАЛЬНОГО БУДИНКУ ПАСИВНОГО ТИПУ (площею 300 м^2) НА ОСНОВІ ВИКОРИСТАННЯ ВІДНОВЛЮВАНИХ ТА АЛЬТЕРНАТИВНИХ ДЖЕРЕЛ ЕНЕРГІЇ

Надано результати розробки та реалізації системи теплозабезпечення експериментального будинку пасивного типу, досліджено оптимальні робочі режими, наведено рекомендації для створення систем теплозабезпечення будинків пасивного типу.

Ключові слова: будинок пасивного типу, енергозбереження, низькопотенційна теплота, тепловий насос.

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ПОЛИВАЛЕНТНАЯ СИСТЕМА ТЕПЛОСНАБЖЕНИЯ ЭКСПЕРИМЕНТАЛЬНОГО ДОМА ПАССИВНОГО ТИПА (площадью 300 м^2) НА ОСНОВЕ ИСПОЛЬЗОВАНИЯ ВОЗОБНОВЛЯЕМЫХ И АЛЬТЕРНАТИВНЫХ ИСТОЧНИКОВ ЭНЕРГИИ

Представлены результаты разработки и реализации системы теплоснабжения экспериментального дома пассивного типа, исследованы оптимальные рабочие ре жимы, приведены рекомендации для создания систем теплоснабжения домов пассивного типа.

Ключевые слова: дом пассивного типа, энергосбережение, низкопотенциальная теплота, тепловой насос.

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