Development of the schematic thermal circuit of the heat power complex for highly effective use of secondary and renewable energy resources

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Abstract. Development process of a schematic thermal circuit of a heat power complex for highly effective use of secondary and renewable energy resources is considered in this article. Earlier authors developed basic elements of the developed scheme they are warmth transformation block (cascade thermal pump) and warmth accumulation block (accumulators of warmth and cold). The schematic thermal circuit of a heat power complex also contains additional units. It is the module of additional low-potential sources of warmth and cold connection, solar collector, the soil probe (heat exchanger), consumers of heat energy for a heat power complex. Authors defined receivers they are heating, hot water supply, conditioning, freezing and sources of energy are low-potential energy soil/air, solar energy, recuperation of ventilating air, utilization of warmth when conditioning rooms, using a sewer source.

1. Introduction
The majority of available renewable sources of energy and secondary energy resources are characterized by very uneven diagram of receipt. But diagrams of consumption have other form and are more accurately defined [1-3]. For providing diagrams of warmth consumption and cold within implementation of a research «Using a difference of the average seasonal temperatures for autonomous heat supply, power supply and conditioning» the technologies of highly effective heat storage and cold allowing to increase volumes of the accumulated energy up to 4,5 times in comparison with the known solutions were developed. It allows to provide the modes of heating and conditioning completely at the expense of renewable energy resources.

2. The existing situation in the field of power complexes on renewable and secondary power sources
There is a set of systems for maintenance of a microclimate in the rooms operating on various types of fuel [4-6] in the world. Usually these systems are aimed at one of solvable tasks: heating, hot water supply or conditioning. Holistic solution of an objective, as a rule, is solved by application of several systems at once [7, 8]. This approach limits a possibility of secondary power sources using, is collateral received during the work any of systems. The deficit of organic fuel is increasing in the world and dictates need for increase in power efficiency of installations by use of renewable energy resources and
secondary energy resources. It is possible to provide this efficiency only in case of the combined heat generation and cold on the uniform power platform.

With the maximum power efficiency, we suggest to develop multifunction thermal point for ensuring heating, conditioning and hot water supply of the consumer, in which the heatpumping cycle is assumed as a basis. This choice is based on that thermal pump, being the warmth transformer, transfers it from a source, cooling it, to the receiver, heating it. It is lately difficult to call heatpumping technologies nonconventional as they are applied everywhere [9, 10]. But in the existing systems their energy potential is realized not completely as modern thermal pumps carry out a narrow task or heating, conditioning, hot water supply. At the same time possibilities of the combined development and increase in efficiency of installation are not considered.

For increase in cost efficiency of a heat power complex it is necessary to improve, on the one hand, its power efficiency, and on the other hand, to reduce the cost of single installation.

3. Development of the thermal scheme

3.1. Bases for development of a schematic thermal circuit of a heat power complex

The schematic thermal circuit is under construction on the power scheme (figure 1) and allows to distribute power overflows. For their implementation two blocks of the basic work items are required: accumulators of heat/cold and transformers of warmth. Proceeding from the power scheme, work of all functions of a heat power complex requires 6 transformers of warmth (thermal pumps). Each of them will work in the optimum thermal mode, according to the selected type of the compressor and coolant. However, such complex from 6 cascades will be economically inexpedient because of high cost. For this reason we accept the power scheme as the greatest possible operation mode of a complex and we develop the thermal scheme of a complex proceeding from the maximum simplification of construction. At the same time it is necessary to save the maximum number of functions and power efficiency and also a possibility of block building of the connected sources and receivers of heat energy.

For development of the thermal scheme of a heat power complex it is necessary to define accurately what secondary and renewable energy resources we will use.

Renewable energy resources:
- low-potential energy soil/air;
- solar energy with use of 3 modes: low, average and high solar activity.

Secondary power sources:
- recuperation of ventilating air;
- return of warmth when conditioning rooms;
• we put use of a sewer source in the general structure of a complex, but we do not include the accompanying additional equipment, for the reason from big dimensions and specificity of use (we provide a possibility of this module connection).

Energy receivers:
• heating;
• hot water supply;
• conditioning;
• freezing.

3.2. Thermal scheme development of the warmth transformation block

For implementation of all modes of warmth transformation the using one vapor-compression thermal pump in the different thermal modes is possible. It is not so energetically effective as six cascades, but it sharply simplifies and reduces the price of the scheme. At the same time the overall performance of the compressor, on the selected coolant will be optimum for a number of the modes, and for a row, with a little underestimated efficiency (no more than 5% of best value). In the figure №2 the circuit solution which provides transformation of warmth in all modes is presented, using one vapor-compression transformer of warmth. In the figure №2 the following positions are shown: 1 – evaporator, 2 – compressor, 3 – condenser, 4 – throttle valve, 5 – circulation pump of a secondary circuit, 6 – magnet valve, 7 – circulation pump of primary circuit, 8 – collector of sources, 9 – collector of receivers, 10 – modules for connection of additional sources (air, sewer etc., and also sources for accumulator charging of cold from environment cold).

Figure 2.
Schematic circuit of the warmth transformation block of a heat power complex.

Switching of the warmth transformer between sources and receivers is carried out by use of the collector of sources 8 and the collector of receivers 9, to which all sources and all receivers are respectively connected. The choice of a specific source and the receiver is carried out by opening of solenoid valve 6, the relevant source and the receiver. Thus, this transformer of warmth allows to pump over warmth from any source in any receiver. Circulation of the heat carrier in a circuit of a source is carried out by circulation pump 7, in a receiver circuit – circulating pump 5.

The warmth transformer at the same time makes warmth and cold. In the existing schemes of power supply only one of products (either warmth / or cold) is used, twice reducing efficiency of energy use of regarding available potential. Energy received in passing is not used due to the lack of an opportunity to accumulate it. In the current mode heat and cold using at the same time is practically not applied. Just for these purposes we develop the multilevel accumulator of warmth and cold that there was an opportunity to reserve in passing received energy and to use it as necessary.
3.3. Development of the thermal scheme of the multilevel heat and cold accumulator

Optimization of diagrams of heat energy of renewable sources and secondary resources with diagrams of heat and cold consumption will be provided at the expense of the multilevel heat accumulator and cold with a different potential. For its development we will take highly effective accumulators of warmth and cold accumulator developed by our collective.

As a result of a research execution it was defined that for ensuring system operation of heating and hot water supply most effective using of the two-level highly effective accumulator of warmth on phase transition. As heat-retaining materials the most optimum defined the following. Glauber salt (phase transition at 32 C), for the lower section, the providing need of heating and preliminary heating for hot water supply. Paraffin (phase transition at 55-60 C), for upper section, intended for reheating of the heat carrier up to 55 C for use for hot water supply. The schematic circuit of the accumulator of warmth is presented in the figure №3. In the figure №3 the following positions are shown: 1 – casing, 2 – thermal insulation, 3 – heat exchange surface of the upper section, 4 – heat exchange surface of the lower section, 5 – hot water supply, 6 – three-way valve, 7 – gate-type cranes, 8 – heating devices.

As a result of a research execution it was defined that for ensuring system operation of conditioning and freezing, effective use of the two-level highly effective cold accumulator on phase transition. As the most optimum heat-retaining materials defined the following. Water (phase transition at 0 C), for the lower section, providing conditioning and preliminary cooling of the heat carrier for freezing of products. Ammonium chloride crystalline hydrate (phase transition at minus 15 C), for upper section, for cooling of the heat carrier to minus 12 C for freezing of products. Also, this accumulator is intended for collaboration with the soil probe (heat exchanger) in the mode of passive conditioning. Schematic power circuit of a conditioning system is presented in the figure №4. In the figure №4 the following positions are shown: 1 - highly effective cold accumulator; 2 - residential building (private house, cottage); 3 - a residential zone conditioning devices; 4 - a freezing zone conditioning devices; 5 - a food products zone conditioning devices; 6 - the heat exchanger for a cold accumulator charge (air/water heat exchanger); 7 - the geothermal probe in the well; 8 - locking and adjusting armature (three-way valves etc.); 9 - residential zone; 10 - storage area of products; 11 – a freezing products zone; 12 - upper part of the cold accumulator; 13 - lower part of the cold accumulator; 14 – circulation pump.
In the provided scheme charging of the zones of the cold accumulator is carried out at the expense of environment cold. It is reasonable to save this function in the developed heat power complex, having left the module for the sources of cold connection.

For development of a schematic circuit of the multilevel heat and cold accumulator (figure №5) the existing practices described above are used. Extremely valuable solution is to use solar activity in three modes:

1. accumulate low solar activity at a material temperature of 20-30 °C, section 3. For further transformation to the level of heating 32-35 °C, or to the level of hot water supply 55-60 °C;

2. direct average solar activity 30-55 °C either to heating or accumulate in section 4 (Glauber salt, for example);

3. direct high solar activity (more than 55 °C) to hot water supply, or accumulate in section 5 (paraffin, for example).

In the figure №5 the following positions are shown: 1 – freezing section (ammonium chloride crystalline hydrate, for example), 2 – conditioning section (water, for example), 3 – section of low solar activity (polyethylene glycol, for example), 4 – heating section (Glauber salt, for example), 5 – section of hot water supply (paraffin, for example), 6 – cranes for the warmth transformation module connection, 7 – cranes for the solar collector connection, 8 – solenoid valves the choice of the solar activity mode, 9 – cranes of connection to a heating system, conditioning and hot water supply of the consumer.
By combining the multilevel heat and cold accumulator scheme with the block of transformation of warmth scheme, we receive the scheme of a heat power complex for highly effective use of secondary and renewable energy resources (figure № 6). At the same time there will be no binding to consumers of warmth and cold.

In figure the № 6 the following positions are shown: 1 – warmth transformation block, 2 – multilevel heat accumulator, 3 – module of connection of additional low-potential sources of warmth and cold, 4 – solar collector, 5 – soil probe (heat exchanger).
As it was already noted above, the consumers of warmth and cold provided for the developed heat power complex are the following:

- heating;
- hot-water supply;
- conditioning;
- freezing.

The schematic thermal circuit of the consumption devices of heat energy is given below (Figure №7). In the figure №7 the following positions are shown: 1 – cranes of connection to a heat power complex, 2 – circulation pumps, 3 – boiler for hot water supply, 4 – heating devices system, 5 – air conditioning devices system, 6 – heat exchanger for the ventilation exhaust utilization, 7 – freezing chamber.

Figure 6. The heat power complex for highly effective use of secondary and renewable energy resources.
3.4. Resulting schematic thermal circuit of the heat power complex

Resulting thermal circuit is working the following way. The boiler of hot water supply of 3 indirect heatings takes heat energy from the fifth section of the multilevel accumulator of warmth (paraffin, for example, phase transition at 55-60 °C). The system of heating devices can be presented by such devices as heat-insulated floors fancoils. Also, it can be the ejector batteries working in low-temperature condition. The system is getting energy from the fourth section of multi-level heat accumulator (glauber’s salt, for example, phase transition at 32 °C). A conditioning devices system can be presented as fancoils or colt flows. It getting energy from either soli probe (passive conditioning system) or second section of multi-level heat accumulator (water, for example, phase transition at 0 °C). The heat exchanger the utilization of warmth ventilating exhausts 6 is connected to the same section. It transmits warmth of the leaving ventilating air to section 2, melts material which is frozen afterwards at withdrawal of this warmth from the second in the fourth or fifth sections by the warmth transformation block. This solution allows to work to the warmth transformer discretely in the mode, optimum for it. The section of the accumulator allows to buffer irregularity of ventilating air intake diagrams, operation of the warmth transformer and other sections of the heat accumulator. The freezing camera 7 takes cold energy from the first section of the multilevel heat accumulator (water, for example, phase transition at 0 °C and ammonium chloride crystalline hydrate, for example, phase transition at minus 15 °C).

The final thermal scheme (figure №8) is received by combination of thermal schemes of a heat power complex and consumers of warmth. In the figure №8 the following positions are shown: 1 – warmth transformation block, 2 – multilevel heat accumulator, 3 – connection module for the additional low-potential sources of warmth and cold, 4 – solar collector, 5 – soil probe, 6 – consumers of heat energy for the heat power complex.

Figure 7. The schematic thermal circuit of the consumption devices of heat.
4. Conclusion
During the researches the main emphasis was put on accumulation of mean seasonal renewable energy. At the same time use of secondary energy resources and overflows of heat fluxes within the consumer was not considered though it has the essential potential for energy saving.

In this research the problem of complex use of renewable and secondary power sources taking into account internal overflows of heat energy in the consumer when heating and conditioning was solved. It will allow to minimize uses of fuel in power balance of the building. Within a solution of the above-stated tasks the thermal scheme of a heat power complex was also developed.

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