SOLAR WATER HEATING SYSTEMS: THE ANALYSIS OF SCHEMES

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The summary. In article results of the analysis of schemes of installations with the solar collectors, the buildings intended for a heat supply and constructions of different function are presented. Features of work of solar collectors with accumulators of warmth of various types and heat pumps are investigated.
Schemes of installations with low temperature sources of warmth which can replace a solar energy at a sunlight lack are offered. Optimization of schemes of solar installations is executed for cases of application of special regenerative heat exchangers, accumulators of warmth and the heat pump providing recycling of warmth of sewage and ventilating air of buildings.
Keywords: *a solar collector, the accumulator of warmth, the thermal pump, the heat exchanger, drains.*

Introduction. The heat supply in the conditions of Russia with its long and severe enough winters demands considerable expenses of fuel which surpass almost in 2 times of an expense for electro supply. The basic lacks of traditional sources of a heat supply are low power, economic and ecological efficiency. Besides, high transport tariffs for delivery of energy carriers aggravate the negative factors inherent in a traditional heat supply.
It is necessary to consider and such serious thermodynamic lack, as low efficiency of use of chemical energy of fuel for systems of a heat supply which in the centralized systems of heating usually does not exceed 60 - 70 %.
Every year in Russia expenses on operation of thermal networks and boiler installations which are, possibly, most unreliable element in systems of the centralized heat supply increase. All listed negative factors of a traditional heat supply press a heavy use of nonconventional methods of power supply.
One of such methods is useful use low temperature (5 - 30 °C) natural warmth or waste industrial heat for a heat supply by means of heat pumps (HP). The considerable economy of fuel and the electric power we can see at a combination of the heat pump and solar water heating system (SWHS). In this case there is a possibility to duplicate a changeable source of thermal energy - a sun light at the expense of reception of additional warmth from the thermal pump connected to low temperature source of warmth, and also to provide accumulation of surpluses of the warmth, generated SWHS.
Choice of type HP. Now it is created and the big number HP the installations differing under thermal schemes, a kind of a working body and on structure of the used equipment is maintained.
For the systems of a heat supply including SWHS, working on the liquid heat-carrier in the range of temperatures 60 - 150 °C, the most comprehensible are compression HP and absorpsion HP, heat supplies most often used in systems and air-conditionings.
Choice of low temperature source of warmth. Application of the heat pump in a combination with SWHS allows to solve some the important problems:
- HP transforms warmth from low temperature source, duplicating SWHS in the absence of a sunlight or small productivity of solar collectors;
- HP provides seasonal accumulation of warmth during the summer period at the lowered consumption of warmth and use of the warmth saved up in heat accumulators during the winter period;
- HP reserves surpluses of warmth from solar collectors SWHS, for daily accumulation of thermal energy. It allows to consume in regular intervals hot water with constant temperature within day;
- HP constantly recycles the warmth consumed from system of a heat supply with solar collectors, increasing efficiency SWHS to the greatest possible level.

Application HP in a combination with SWHS in this or that foreshortening is defined basically by presence low temperature a warmth source.
Geothermal sources of warmth. As geothermal sources of warmth soil thermal accumulators, underground waters, artificial underground pools and special water underground thermal accumulators are used. In most cases soil heat exchangers of a various design are applied to a heat transfer. These designs are widely applied last 10-15 years as low temperature source of heat to systems of heating and hot water supply with use HP. The basic lack of geothermal sources of warmth is considerable cost of a design of the soil heat exchanger or the specialized thermal accumulator.

Air sources of warmth. Except use of heat of a ground by the most attractive source of warmth for HP air is. As the source of heat air possesses a number of lacks, careful optimization of a design of system of regeneration of warmth depending on an installation site as air temperature can essentially change both on a season, and on time of days therefore is required. For increase of economic efficiency and reliability of system of a heat supply additional heaters (for example an electric copper), joining when the heat pump cannot cover full thermal loading of a building are established. If the heat pump is connected to SVHS demanded capacity the electric heater or a gas copper joins only in extreme climatic conditions or at an emergency.

Thermal drains and ventilating emissions. HP can use thermal emissions of a building, for example, deleted air or gas streams, and also waste water (for example, from system of consumption of hot water). Efficiency use of these thermal emissions is defined by the expense of utilized warmth and temperature potential of a drain. In some cases the expense of the warmth reserved in drains can be equal to total daily generation of thermal energy from SWHS, and sometimes and to exceed capacity SWHS. It allows to double thermal productivity of system of the heat supply equipped SWHS at application HP.

Operating experience HP in Russia has shown, that because of the big duration of the heating period in comparison, for example, with the Western Europe, and also is considerable more an acute problem of transport of fuel economic efficiency of application HP in Russia more than in other countries. Mid-annual factors of transformation HP for regions Russian Federations with duration of the heating period 5000 - 5600 hours depending on temperature a source make:

Source temperature, ° C	5	10	15	20	25	30	35	40
COP	3,6	4,1	4,6	5,3	5,9,	6,6,	7,2	7,9

At identical thermal productivity (for example equal 1,16 MBт), the economy of fuel at use HP in systems of the decentralized heat supply makes in comparison: with electro heating 0,277 - 0,335 tons; from a coal boiler-house (efficiency = 0.65) 0,113 - 0,121 tons; from a gas boiler-house (efficiency = 0,8) 0,072-0,130 tons., where the first value concerns use in the heat pump of low temperature source of heat with temperature 5 °C, the second - with temperature 40 °C. In case of combination HP with SWHU the settlement economic prize resulted above can be increased in 1,5 - 2 times.

Optimization of schemes of SWHS. In most cases industrial SWHS provide a part of manufacture of the warmth consumed by system of a heat supply of a building. For increase of thermal generation SWHS it is necessary to analyze various variants of modernization of maintained installation for the purpose of definition of necessary changes of hydraulic and electric schemes, and also the knots of automatics which are ensuring functioning SWHS.

In climatic conditions of Russia SWHS has usually three contours working on different heat-carriers. The solar power plant investigated in work concerns this type SWHS (fig. 1).

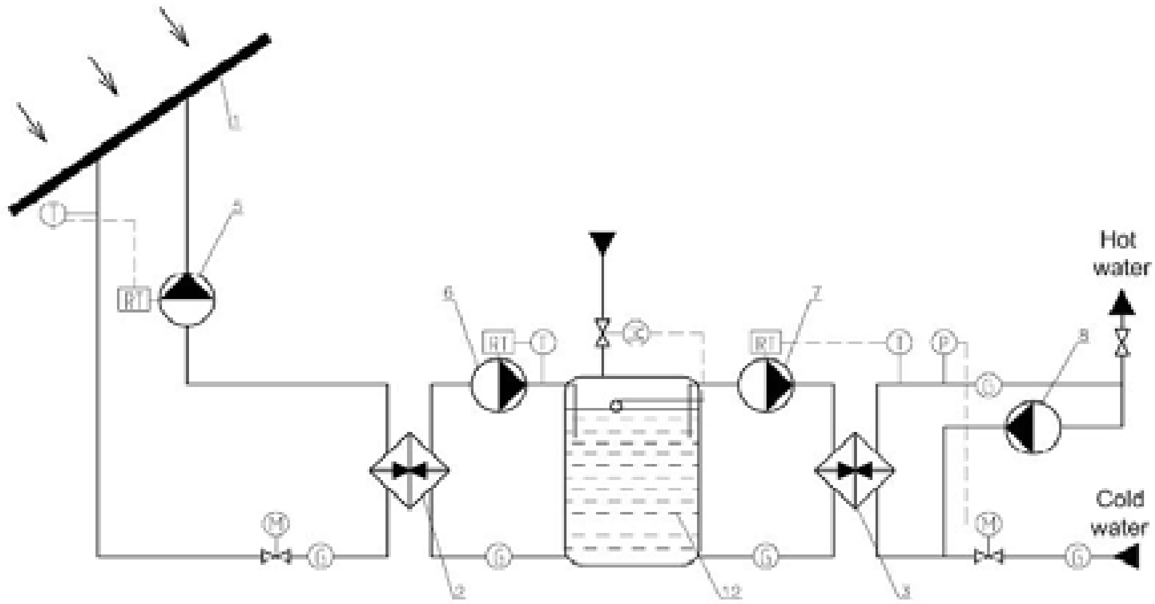

Fig. 1: Basic scheme SWHS with regulation of the expense of heat-carriers in circulation contours (designations in tab. 1)

The first contour including solar collectors 1 and heat exchanger 2 (type M6-FG), is filled by the nonfreezing heat-carrier. The maximum temperature of the heat-carrier in the first contour is 105 °C.

The second contour is intended for water heating in accumulator tanks through the heat exchanger 2 first contours. The maximum temperature of water in tanks accumulators is 85 °C. A problem of the second contour is also giving of the heat-carrier from accumulator tanks on the lamellar heat exchanger 3 types M6-MFG for heating of cold water for needs of consumers to temperature 60 °C. The third contour provides giving of hot water to consumers.
SWHS it is equipped by gauges of date in each of three considered contours - water measured counter, gauges of temperature and pressure of environment. 3 contours of heating of water and the valve of switching-off of solar collectors concern automatics means in first contour SWHS a regulator of pressure at achievement of temperature of water in a accumulator tanks is 85 °C.
Industrial SWHS it is necessary to carry the limited thermal productivity (35-40 KW) to the basic lacks, caused by insufficient quantity of solar collectors at low heat-sink ability of system because of small volume of a accumulator tanks and non-uniform distribution of loading in a contour of consumption of hot water within days. In high intensity solar lights (day time) consumption of hot water slightly and solar collector SWHS work with low efficiency. Increase of norm of consumption of hot water during the evening period leads to fast fall of temperature of water in a accumulator tanks and necessity of inclusion of an electric copper for additional heating of water.
Optimization of scheme SWHS can be executed by several methods:
- At the expense of increase in volume of an accumulator tank. That increases duration of a supply of warmth in a contour of heating of water in a maximum of consumption of warmth;
- At the expense of increase of the surface of the mounted solar collectors for increase in thermal productivity SWHS (this decision will be effective only with increase the volume of an accumulator tank);
- At the expense of using of the heat pump. HP are pumping thermal energy from a source with a having low temperature and are transporting additional warmth in the thermal accumulator. In this case we have the maximum expense of hot water for consumers.

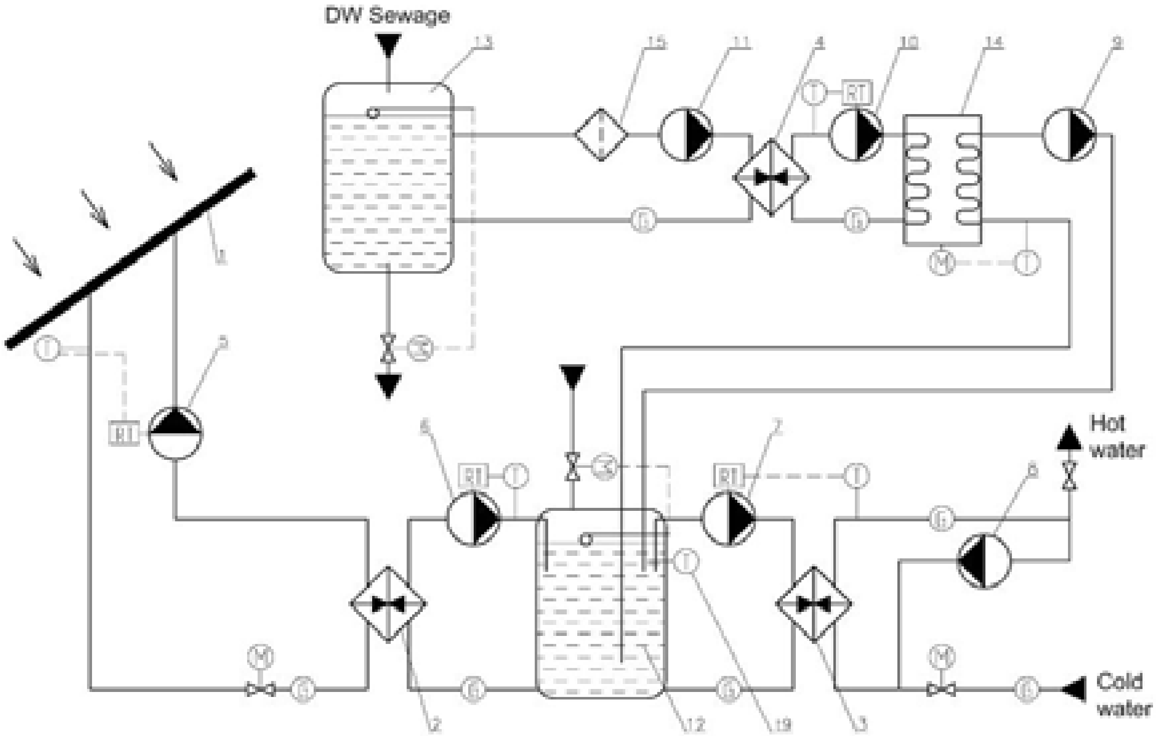

Fig. 2: Scheme SWHS with HP, connected to a tank of sewage (Designations in tab. 1)

As the most effective variant scheme SWHS with the heat pump is analyzed. Such decision not only is economically more favorable (on capital expenses) but also allows to receive an additional source of warmth as the additional source to a sunlight transformed by solar collectors SWHS in thermal energy. Sources of warmth of low temperature potential for the heat pump are sewage from system of hot water supply of a building or warmth of ventilating emissions.
As an additional variant it is offered to use the intermediate buffer thermal accumulator for alignment of the schedule of consumption of hot water.

At connection to SWHS the heat pump (fig. 2) is required complication of system with addition in two circulating contours. The first additional contour connects a tank 12 with evaporator HP 4. The second additional contour connects condenser HP 4 to the basic accumulator tanks 11. The tank 12 serves for accumulation of the sewage having temperature 25 - 30 °C.
The investigated scheme allows to recycle the warmth submitted from a accumulator tank 11 in system of a heat supply of a building by means of the heat pump. However at transition from a night operating mode on day in the maximum generation of warmth by solar collectors 1 SWHS swapping of warmth from a tank 12 in a accumulator tank 11 heat pump 4 can lead to fast rise in temperature of water in a storage container 11. After that transfer of warmth from collectors 1 to a accumulator tank 11 will be impossible. Therefore at achievement of certain temperature in the thermal accumulator 11 HP 4 should be switched off. It will lead to partial loss of the warmth which is taken away from sewage.
For redistribution of thermal loading between SWHS and HP the effective decision is application of the additional buffer accumulator of warmth (fig. 3). According to considered schemes knot HP is allocated in the separate element including two circulating contours: the tank of sewage 12 incorporates to the heat pump 4 as well as in the previous scheme (fig. 2), and the high-temperature heat-carrier from the heat pump 4 passes through the coil which has been built in an additional accumulator tank 13.

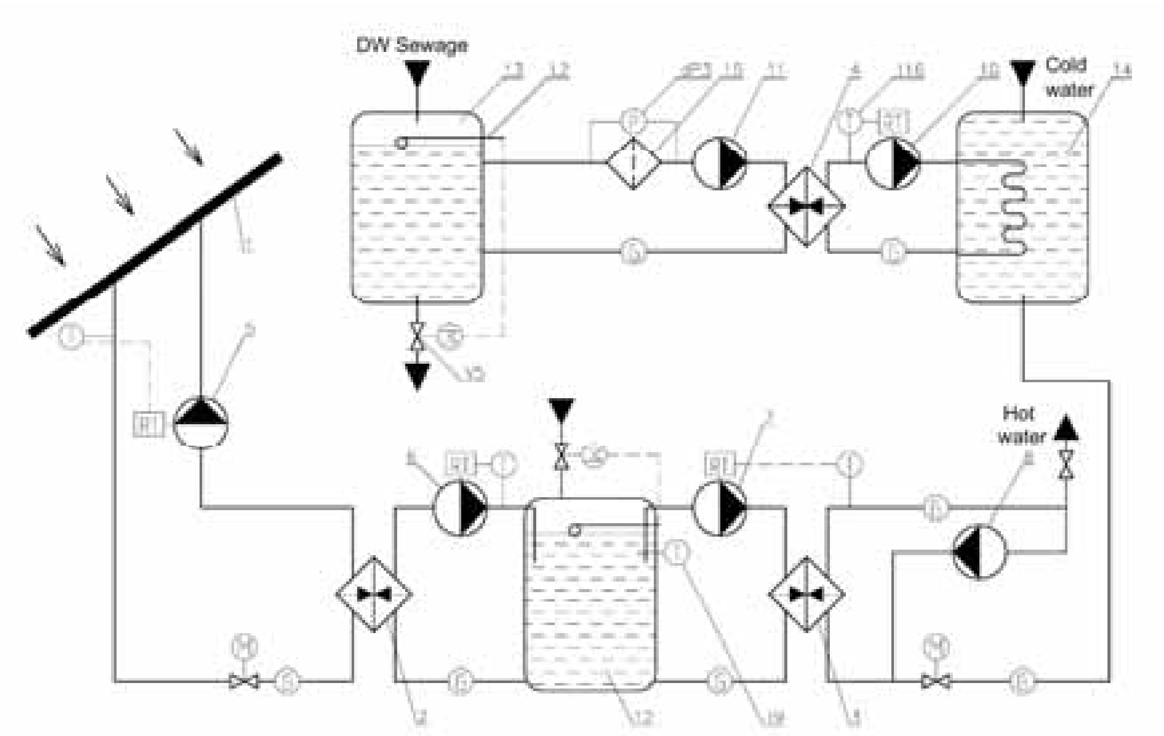

Fig. 3: Scheme SWHS with HP and the buffer accumulator of warmth (Designations in tab. 1)

In the investigated scheme rise in temperature of cold water from system of water supply of a building can lead to infringement of steady work of a accumulator tank 11 and a contour of solar collectors SWHS. Besides, at scheme realization (fig. 3) will are a problem connected with a choice of volume of a accumulator tank 13. It can be solved only by installation modeling. In the scheme on fig. 3 independent work HP is provided, however it is negatively reflected in thermal mode SWHS. Therefore in heat exchangers 2 and 3 it is required to apply the special accumulator tank 11 divided on some sections to effective heat exchange, working at various change of temperature of the heat-carrier The problem of accumulation of the additional warmth arriving from HP 4, can be solved by application of the special thermal accumulator working by a principle of change of a phase condition of substance. Such scheme is presented on fig. 4.

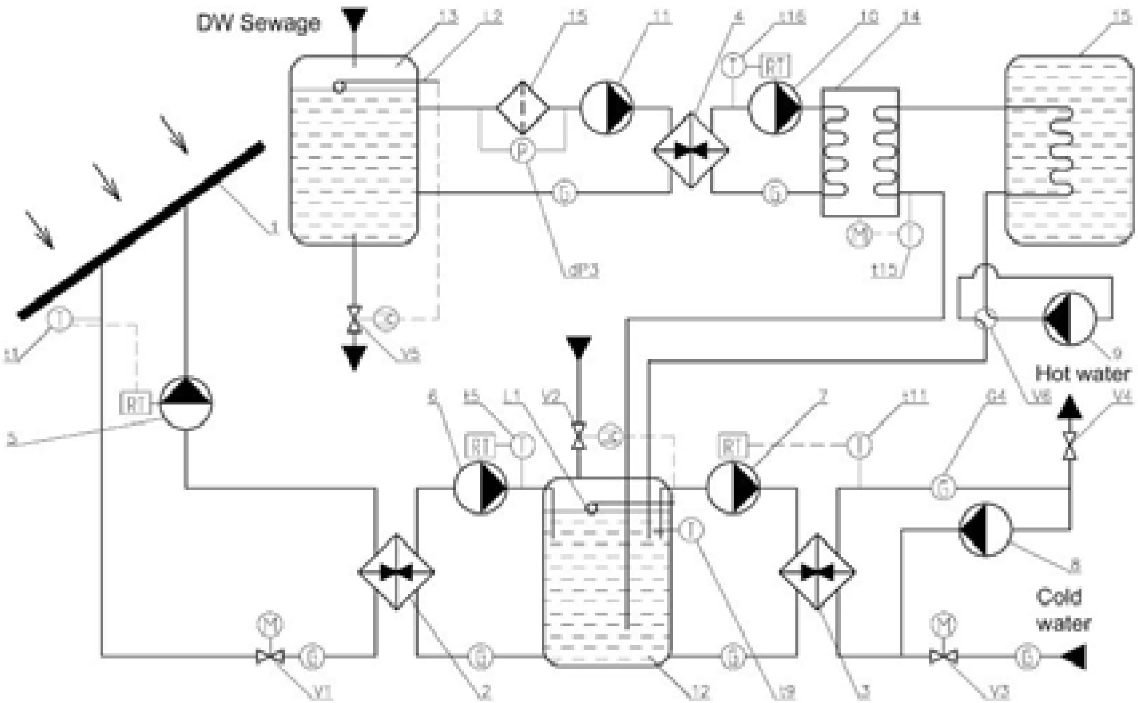

Fig. 4: Scheme SWHS with a buffer storage container and switched HP (Designations in tab. 1)

Tab. 1: The specification to fig. 1-4

№	The name	Designation	Quantity	Type	Characteristics
1	Solar collector	1	1		
2	Heat exchanger	2	1	M6-FG	70 kW
3	Heat exchanger	3	1	M6-MFG	270 kW
4	Circulating pump	5	2	WILO-30/10	300 W
5	Circulating pump	6	2	WILO-25/7	195 W
6	Circulating pump	7,9,10	4	WILO-40/10	480 W
7	Circulating pump	8	2	WILO-25/2	195 W
8	Accumulator tanks	11	3		3,5 m^3
9	Accumulator tanks	12	1		5,0 m^3
10	Accumulator tanks	13	1		5,0 m^3
11	Temperature gauge	t1-t20	20	PT1000	
12	Pressure converter	P1-P3	3	MSB 32	
13	Differential gauge of pressure	dP1-dP2	2		
14	Water measured counter	G1-G5	5	AS-001-50	
15	Crane	V1-V3, V5	4	X2777	Electric drive
15	Valve four-running	V6	1		Electric drive
16	Consumer	V4			
17	Level gauge	L1, L2	2	DUU2M	
18	Heat pump	4	1		

Proceeding from structure of the investigated scheme the accumulator tank is connected to condenser HP 4 13 with the substance having the set temperature of phase transition. In this case HP it will be connected with the basic accumulator tank 11 through the buffer accumulator tank 13, phase transition of substance working on a principle. In the scheme (fig. 4) the accumulator tank 13 starts to work effectively at achievement of the set maximum temperature of the heat-carrier in the bottom part of a accumulator tank 11. Such operating mode allows to protect system of accumulation of warmth from an overheat and to reserve surplus of warmth in the additional accumulator 13 instead of its emergency dump.

Conclusions

1. The analysis of perspective circuit decisions for modernization of system of a heat supply of the building, including a solar power plant, the compressor heat pump and accumulators of warmth of various type is made. The technical decisions, allowing to recycle thermal energy consumed in the form of hot water, by means of the heat pump are offered, and also to use for a heat supply warmth of ventilating emissions.
2. The choice of a working variant of scheme SWHS with HP for designing and realization will be executed on the basis of data of mathematical modeling of investigated installations and the estimation of operating modes of system of a heat supply equipped with modern devices of automation and monitoring of dates.

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