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The regenerative water-air heat exchanger

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Abstract

The article describes an energy-efficient scheme for using solar energy in district heat supply systems reducing capital and operation costs and to a great extent replacing conventional heat sources. The versatility of systems using this scheme provides their multi-zone applications: from cottages to heating industrial premises and greenhouse complexes.

The principle of the suggested scheme is as follows: a solar collector is attached through heated medium is to an air duct and to antifreeze circulating in the contour tank – accumulator – solar collector. The method of intensification of heat exchange due to the use of intensifiers of hole type. Such intensification efficiency is determined by calculation of daily heat absorption of two-dimensional air collector with intensification by holes and without it, as well as economic effect of the implementation of the suggested method. In accordance with calculations, the suggested scheme of heating and intensification of heat exchange on the surface of integrated collector can provide significant economic effect if implemented.

Keywords: solar collector, heat-carrying medium, design, simulation system, experiment, consumer, control, heat, energy saving, load optimization.

The strategic aim of state energy policy in the field of development of rational fuel-power balance is the optimization of production structure, domestic consumption and export of fuel-power resources with due consideration of requirements of energy security, economical and energy efficiency and improvement of Russia foreign economical

performance. It should be considered that the overriding priority of the "Energy Strategy of Russia for the Period until 2030" is the growth of importance of renewable energy source in satisfying public energy demands. Without implementation of technologies that can drive out organic fuel from the country fuel balance, It is impossible to full fill basic provisions of the Strategy envisaging maximum efficient use of natural energy resources and potential of power-generating sector for steady economic growth and the improvement of the quality of life of the RF population. For most RF regions the most promising of renewable energy sources is solar energy.

The Heat Supply Scheme

So far a wide range of various schemes of solar energy use in hot water supply and heating systems has been developed. Heating premises with hot air using heat sources of various types in many cases allows to considerably reduce capital and operational costs. Solar heating with the use of collectors of various types will make it possible to considerably increase such systems efficiency and to expand replacement of conventional heat sources. In such systems, depending on temperature mode, water or air as heat carriers in combined heating is applied – water for hot water supply and air for heating. As our final objective is heating air in premises, it is exactly the schemes that allow to obtain maximum efficiency, excluding intermediate diary processes and conversion. As energy source heat of combusted fuel, as well as heat generated by solar collectors, can be used [1].

The versatility of such systems determines their multi-zone application - from cottages to heating huge industrial premises and greenhouses complexes.

The advantages of air heating are as follows [2]:

1. Heat economy - heat is generated directly in heated premises.
2. Improved living conditions in premises, as air heating by 40-70 °C is sufficient for positive pressure ventilation.
3. Fast response as the hot air heating system makes it possible to provide full heating of premises for 1.5-2 hours.
4. The absence of intermediate heat-carrying medium, that allows to exclude the construction of water heating systems. In winters as soon as the risk of defreezing the system is excluded.
5. High degree of automation allows to generate heat as required.

Most of the advantages of this system are possible only when non-freezing solutions are used in solar collectors. Air can be heated both in an intermediate heat exchanger from liquid heated in the collector, and directly init. The Fig. 1 shows the scheme of the solar heat use allowing to combine these methods [3]

The given scheme will make it possible to use the advantages of air heating systems in the implementation of solar collectors of combined type (with combined heating of air and liquid heat-carrying medium) and to lower down the temperature of radiant heat absorbing plate, and so radiation loss as well.

The principle of the suggested scheme is as follows: a solar collector is attached through heated medium to an air duct and antifreeze circulating in the contour "tank – accumulator – solar collector". Air through solar radiation equipment and due to forced convection in flowing tube and a plate is heated, after which it is supplied to the air heating system. As to the tank through a storage tank through accumulating heat-carrying medium is connected to cold water pipe and extra new heat source powered through submerged heating surface. At Fig. 1 connection circuit and operation mode of the solar plant are presented.

Fig. 1. Solar air heating system:

1 – storage tank; 2 – pump of solar contour; 3 – solar air collector; 4 – calorifier; 5 – automated control system; 6 – intake air ventilator; 7 – triple valve of the solar contour.

The collector efficiency (Fig. 1) can be considerably increased through intensification of heat exchange on surfaces with semispherical holes due to increased heat exchange surface area.

As early as in 1990-ies R. Serebryakov, G.I. Kiknadze, Yu. K. Krasnov and others in their works [4, 5, 6] studied a new class of quasipotential gas and liquid swirl flows formed either due to merging of specifically directed jets of working continuous medium, or due to streamlining its three-dimensional “holes” (so-called vortex generators”) at heat exchange or carrying areas.

Highly-efficient practical application of such flows became possible due to large-scale thermodynamic research and design and development works. Thus, in accordance with experimental data, vortex flows for medium keeping with exact solutions of hydrodynamic equations increase gas or liquid consumption twice in comparison with flows with other structures at similar gas load in pipe lines of similar size and form. Such swirled flows are self-organized in flows of energy carriers stream lining energy exchange surfaces formed by special profiles “vortex generator” [5, 6], considerably intensify heat and mass exchange while aerodynamic drag of energy exchange channels is reduced.

Calculation of daily heat absorption

To determine intensification efficiency, daily heat absorption of flat-plate water-air collector with hole intensification and without it [7].

Climatological data: Chita: longitude - 113 hours 23 min., latitude - 52 hours 6min., October 1, 2013.

Surface orientation: incidence angle to horizon - 45 °, azimuth direction 180°.

Plate: accepted size 1000x100x1mm, material– copper, wall thickness - 2 mm.

Pipes: number – 10, diameter – 25 mm, material – copper, wall thickness – 1 mm, coverage - 50%, thermal interface – tin, layer thickness – 500 μ.

Absorber: paint –matblack (degree of absorption- 95, blackness - 5, selectivity – 0.4).

External insulation: glass – two layers, thickness 1 mm, attenuation coefficient 0.4 1/mm, air passage size 30 mm.

Air parameters: air temperature at the inlet - 00C, air consumption - 1000 m3/hour.

When calculating daily heat absorption of there generative water-air heat exchanger with high efficiency of heat exchange with the use of standard method, coefficients of heat transfer are increased in proportion to average (on the hole surface) relative coefficients of heat transfer. To consider increase of heat exchange surface, it is necessary to assess its relative increase K_F and include it in standard technique.

For suggested geometric parameters of hemispherical holes K_F assumes values from 1.09 to 1.116 independence on packing density (for preliminary calculation $K_F = 1.1$ was assumed). Calculations showed that flow pattern was turbulent: $Re=696364$. Forsuch pattern during intensification in spherical intensifier it is assumed that $\bar{\alpha} = 1.25$ (Fig. 2 [8]).

Results and their discussion

The results of the calculation of daily heat absorption of the flat-plate water-air collector are presented in Table 1.

Fig.2. Average (on the hole surface) relative coefficients of heat transfer for spherical hole

Table 1

Results of the calculation of a flat-plate collector (air inlet temperature = ambient temperature = 0°C)

№	Local time	Heat usefully absorbed by the collector (without intensification), W:	Heat usefully absorbed by the collector (intensification: $K_F = 1.1$, $\bar{\alpha} = 1.25$), W:
			3
1	9:00	0	0
2	10:00	150	152
3	11:00	362	377
4	12:00	550	590
5	13:00	625	635
6	14:00	670	675
7	15:00	655	660
8	16:00	585	595
9	17:00	455	465
10	18:00	260	267
11	19:00	50	52
12	20:00	0	0
13	Total	4362	4468

Intensification provide deficiency increase by 2.43%. Yearly efficiency of the collector efficiency will amount to 106 kW/m².

Considering the current tariff in the Chita district, heat supply system (1 925 rouble/Gcal) economic efficiency is 175.5 rouble/m².

Conclusions

The calculation of economic efficiency of the suggested scheme of solar air heating and intensification of the integrated collector by holes demonstrated considerable economic effect from the implementation of these methods.

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