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ANALYSIS OF MODERN CONSTRUCTIONS OF SOLAR WATER-HEATING COLLECTORS

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Annotation: An analysis of modern designs of solar water-air heating collectors shows that, compared to traditional single-function (water only or air only) systems, combined systems provide higher energy efficiency and environmental friendliness. Combined (hybrid) solar water-air collectors are modern high-efficiency heliotechnical devices designed to heat water and air at the same time. Unlike traditional water-only or air-only heating systems, these structures serve to make integrated use of solar energy and provide heat and hot water (DHW) to buildings. The technical and economic indicators of flat, vacuum and hybrid collectors were compared, and the latest innovations in the field were considered.

Keywords: Solar collector, absorber, vacuum tube, air heater, efficiency, selective coating, nanomaterials.

Log In

Dwindling energy resources, global warming and environmental problems are forcing humanity to switch to alternative energy sources. The use of solar energy is an alternative energy source that is environmentally friendly, renewable and cost-effective in the long run. Solar collectors, in particular, which transmit heat through a water-air mixture, are seen as an environmentally friendly system with high thermal efficiency.

The advantage of water-air collectors is that they allow for rapid heating through air, and heat through water for a long time. On the basis of this article, modern constructions of such combined solar water-air heating collectors are analyzed.

During the study, models of solar irradiation will be analyzed on the basis of modern constructs of energy production due to temperature variations.

This approach allows Uzbekistan to ensure environmental security by expanding the use of solar energy in climatic conditions.

Types and structure of modern constructions

Modern water-air collectors are mainly divided into the following constructions according to the interaction of heat-absorber panels, fluid pipes and air circulation ducts:

Bifacial solar panels (Bifacial solar panels) are modern technologies that convert sunlight into electricity not only from the front (face), but also due to rays returning to the back (albedo effect).

The structure and schemes of operation of these devices differ significantly from traditional unidirectional panels. Below we consider in detail their structure scheme, mechanism of operation and ways to increase efficiency.

Layout diagram of double sided panel

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In conventional panels, the background will be covered with a plastic (most often white or black) material. And in the case of double-sided panels, the back is also transparent so that light passes through.

The principle of operation of double-sided panels: direct and rotary beam. Source: VectorMine/Getty Images

The sequence of panel layers:

1. **Front protective glass:** Antireflective glass with high conductivity.
2. **EVA/POE encapsulant layer:** A transparent film that protects the solar cells from moisture and shocks.
3. **Bifacial Solar Cells:** Typically made in monocrystalline p-PERC, n-PERT or HJT (heteropriority) technology. On their back, too, metal contacts are thinly worked in the form of grids.
4. **Back encapsulant layer:** Transparent POE (Polyolefin) film.
5. **Protective back layer:** Transparent glass (Glass-Glass panels) or special transparent backsheet (Glass-Transparent Backsheet).

Operation and installation schemes:

The effectiveness of double-sided panels directly depends on where and how they are installed. Below is a diagram of their performance environment:

Important design requirements (installation scheme):

Height (*H*): The panel should be at least 1–1.5 meters above ground level. This allows more returned rays to fall to the back.

Reducing shadowing: metal frames (mounting profiles) located along the back of the panel are made using profiles that are made of special thin or fixed on the edge parts so as not to cast a shadow on the solar elements.

Inverter (Inverter) circuit: The current capacity (DC/AC ratio) of the inverters is chosen slightly higher due to the arrival of additional current from the back. Often, **smart inverters with** MPPT system, which control each row separately, are used.

Role of the Earth's surface (Albedo coefficient):

The scheme of the highest efficiency of these devices is manifested in the following surfaces:

Snow cover: reflects light by up to ~80% (highest efficiency, energy up to +30%).

White gravel or painted roof: reflects light by up to ~60%.

Sand/Desert: Reflects ~30-40% of the light.

Green grass/Soil: Reflects ~10-20% of light (least effective).

The most suitable solar cell technologies (PERC, TOPCon, HJT) for double-sided panels.

Vacuum tube hybrid systems (Evacuated tube hybrid systems) are basically devices that combine solar thermal energy (thermal) and other types of energy (most often electric or conventional heating systems) at the same time to achieve maximum efficiency.

These hybrid systems guarantee an uninterrupted supply of hot water and heat, even in the heat of winter and on cloudy days. Below we consider the schemes of the most popular hybrid constructions and the principles of operation.

PVT (Photoelectric + Thermal) Hybrid Vacuum Devices

In this construction, both a solar panel (PV) and a heat-sink collector are attached to the inner part of the vacuum pipe.

Heat Pipe Hybrid System Scheme. Source: Hydro Solar Innovative Energy

1. **Electricity generation: A** narrow hybrid plate installed in a vacuum tube generates electricity at the expense of sunlight.

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2. **Heat absorption:** When a solar panel heats up, its efficiency decreases. Copper Pipe (Heat Pipe) glued behind the panel itself absorbs excess heat.

3. **Hybrid effect: Electricity efficiency increases by** 15-20% as the panel stays always cool, while the absorbed heat is directed to water heating (thermal energy).

This is the most common type of hybrid. In appearance, it resembles a normal solar panel, but at the base of it is copper pipes that absorb heat.

Flat Hybrid Collector (Flat-Plate PVT) Layers. Source: alejomiranda/Getty Image

Summer mode (Flat collector advantage): In summer, flat collectors give a rapid heating of a large volume of water.

The main achievement of the hybrid system: The system can operate continuously at 100% time throughout the year and can save up to 70-85% on average on traditional energy (gas or svet) costs.

Corporous absorber air–water systems: In order to expand the heat exchange surface, the aluminum or stainless steel absorber surface is prepared as corrugated (wavy) form. It provides a turbulent movement of air, which dramatically increases the thermal efficiency.

Rammed absorber air-water hybrid systems are special solar collectors designed to heat both air and water (or liquid) at the same time. The main reason for the use of **corrugated (wavy, twisted)** absorber here is a sharp increase in heat exchange with air and water by widening the surface.

Cross-section of a corrugated absorber device (internal structure)

Compared to normal smooth plates, a corrugated surface creates turbulences (vortices) in the airflow. This allows air to touch the absorber walls more and take away a lot of heat.

The inner layers of the device are schematically structured as follows:

These systems are highly adaptable and can work **in 3 different schemes depending on season and need**. In this mode, the water supply is turned off. With the help of a ventilator, cold air in the house is sucked into the collector. Air moves over the surface of the corrugated absorber, making it the most perfect scheme to ensure the maximum use of solar energy. The diagram below illustrates the connection principle of this hybrid system.

The main advantages of modern constructions

High energy density: Saves space on the roof by getting two types of energy carriers from one collector area.

Protection against overheating (Solving the problem of stagnation): When water consumption in the collector decreases in summer, the water inside the collector can overheat (stagnation). In modern systems, excess heat is discharged through the air flow, and the system cools itself.

Environmental sustainability: Drastically reduces carbon dioxide emissions and reduces the load on traditional heating sources.

Disadvantages and technical difficulties

Complexity of the construction: It is required to ensure the hermetic (density) of the water and air ducts and the use of corrosion-resistant materials. Control system: The cost of the system becomes more expensive due to the need for automated valves, sensors, and "smart" controllers that coordinate the operation of the ventilator/pump.

Comparative analysis of constructs

The table below compares the main technical and operational parameters of different types of modern collectors:

Latest innovations and prospects in the industry

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In modern helioengineering, the following new technologies are being introduced to increase efficiency:

Nanofluides (nano oils) are coalescence compounds that can be extracted by adding solid nanoparticles with diameters between 1 and 100 nanometers (nm) in size to conventional heat-transfer oils (such as water, oil, ethylene glycol).

Ordinary fats have low thermal conductivity. Nanofluids, on the other hand, have the property of transferring heat several times faster due to the metal or metal oxide particles in it.

The composition of nanofluids

The most important challenge in the preparation of nanofins is to ensure the non-solidity (stability) of particles sinking to the bottom. The following diagram illustrates the most common two-step method of nanofluide preparation:

Heat Transfer Mechanism

In conventional yeasts, heat is transmitted mainly by convection (yeast stream). In nanofluids, on the other hand, an **extra heat-conducting (conduction) chain is formed at the microscopic level due** to the irregular heat motion (Brownian motion) of the nanoparticles.

Areas of application

Due to their high efficiency, nanofluids are widely used in modern techniques:

Cooling of Electronics Devices: Microchips and computers.

In order to rapidly remove large amounts of heat that are dissociated from modern powerful processors and laser systems, nanofluides in micronals are ejected.

Automotive Industry: Radiators and Engine Oils.

When nanofluides are poured into car radiators, it is possible to reduce the radiator volume and cool the engine more efficiently.

Renewable Energy: Solar Collectors.

Solar thermal power plants increase the efficiency of absorbing sunlight and converting it into thermal energy.

Nuclear reactors: Emergency cooling systems.

In critical situations, high heat-capacity nanowires are used to cool the reactor core in very short seconds.

The main problem: The biggest obstacle to the widespread use of nanofluides in industry is that over time the nanoparticles can stick together (**agglomeration**), become heavier and sink to the bottom of the vessel. Scientists are now solving this problem by adding various surfactants (surfactants).

Hybrid PVT (Photovoltaic Thermal) hybrid systems are combined devices that allow to simultaneously generate heat and electricity from sunlight.

Conventional solar panels (PV) convert only 15-22% of sunlight into electricity, while about 80% of the remaining is heat, which heats the panel. Every time the panel temperature is raised by 1°C, its electricity generation efficiency decreases. A PVT system, on the other hand, absorbs this excess heat, cools the panel (improves efficiency) and directs the resulting heat to heat water or air.

Structural section of the PVT panel

A hybrid panel is constructed by placing a heat exchanger (collector) under a conventional solar panel. The diagram below shows the inner layers of the hybrid panel:

Based on the heat carrier, PVT collectors are divided into two types:

1. **Liquid-based: A** mixture of water or glycol flows through the channels. Very effective for hot water and floor heating systems.

2. **Air-based: Airflow** is conducted through the panel. Used in the winter for direct ventilation of premises with warm air.

Hybrid effect: Due to the continuous cooling of the panel, the solar cells in PVT system produce **15-20% more electricity** per year than conventional solar panels.

Phase Change Materials (PCM) are intelligent materials that have the property of absorbing and dissipating a very large amount of thermal energy due to the change of its aggregate state (mainly from a solid state to a liquid state and vice versa) at a given constant temperature. When simple materials (such as bricks or concrete) absorb heat, their temperature rises (this is called *significant heat*). PCM materials, on the other hand, keep the temperature completely unchanged during phase change (melting or solidifying) and store energy in a latent state (**latent heat**). To prevent leakage of PCM into the liquid state, it is placed in special micro or macro capsules:

Conclusion

Analysis of modern designs of solar water and air heating collectors shows that today the level of energy efficiency and autonomy has increased dramatically. Vacuum Heat Pipe collectors are the optimal solution for year-round hot water supply in the climatic conditions of Uzbekistan (hot summer and cold winter). For the drying industry and agriculture, **perforated air collectors** are highly cost-effective. In the future, widespread introduction of hybrid PVT systems and nanomaterials will serve to further reduce the cost of these devices.

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