# Analysis of Air Conditioning Schemes based on Evaporative Cooling of Air using Solar Energy

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***Abstract—*** *The article presents the calculation method based on the heat and humidity parameters of the units direct and indirect-evaporative cooling in air conditioning systems in buildings are analyzed various technical diagrams. On the basis of experimental and theoretical studies established the benefits of schemes based on indirect-evaporative cooling. The processes of heat and humidity of air treatment, demonstrate the benefits of solar installations with devices indirect evaporative-type compared to conventional solutions.*

***Keywords— Climate, Air, Compressor, Rotating Heat Exchanger, Irrigation Chamber, Solar Energy, Solar Installation.***

## I. INTRODUCTION

To create a comfortable climate for a person in a microclimate in a room, it is necessary to provide air exchange and normalized air parameters. This also applies to most industrial shops in industrial production. Large air exchange in such premises entails and the corresponding heat costs for heating the supply air during the cold period of the year. In the summer, this is also associated with significant energy costs for cooling the air [1,2].

## II. LITERATURE SURVEY

When air blows through a wet medium—a tee shirt, aspen fibers (excelsior), or treated cellulose, fiberglass, or plastic—some of the water is transferred to the air and its dry bulb temperature is lowered. The cooling effect depends on the temperature difference between dry and wet bulb temperatures, the pathway and velocity of the air, and the quality and condition of the medium.

There's a world of difference between old-style swamp coolers and modern evaporative cooling systems. The latter can provide years of trouble-free service and cool, clean, comfortable, fresh air at a lower energy cost than conventional air conditioners—and initial costs are competitive as well. In addition, the latest evaporative cooler designs are a lot easier on the grid than compressor-based cooling systems. Instead of peak demands of three to five kilowatts (kW) or more, typical demands for mid-size evaporative coolers are on the order of one kW. In addition to improved performance, modern evaporative coolers include options for thermostatic control and automated flushing of reservoir water to reduce buildup of impurities.

Accordingly, wide-spread use of evaporative coolers can help delay adding expensive new power plants to the electric grid and the controversial transmission lines that often accompany them. That's the reason a number of utility companies in areas with hot, dry summers and substantial population growth have programs to promote efficient evaporative coolers.

"Direct" evaporative coolers use a fan to pull outside air through media (pads) that are kept thoroughly wet by water that is sprayed or dripped on them (Fig.1). This both filters the air and cools it. The water is typically delivered via tubes from a small pump which draws from a reservoir below. The reservoir is replenished with tap water whose level is controlled by a float valve [3, 4].

The resulting fresh, cool, humidified air is blown into buildings where the pattern of flow (and cool air delivered) is determined by the location and extent of openings in the conditioned envelope such as windows or special dedicated ducts.

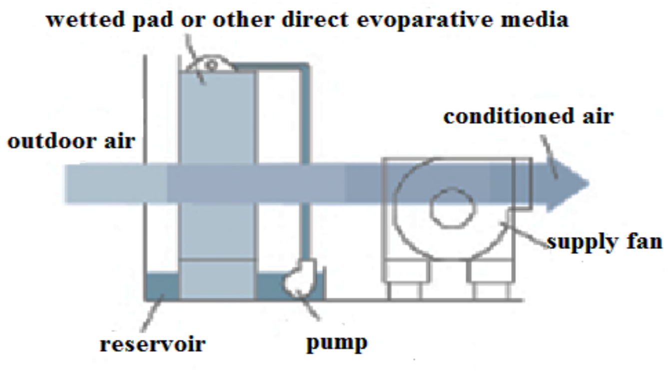


**FIGURE 1.Direct evaporative cooler. Air is pulled across a thoroughly wetted medium as evenly as possible. Lower speeds give more exposure time to the wetted media, thereby achieving more cooling.**

## III. SIGNIFICANCE OF THE SYSTEM

Currently, one of the ways to reduce the consumption of expensive traditional energy resources in industrial production and in the energy sector is to use renewable energy sources.

With the constant increase in fossil energy prices, as well as the depletion of oil and gas reserves, an increasing number of countries are using alternative(renewable) energy sources [5,6,7,8].

One of the promising ways to reduce the energy intensity of traditional air-conditioning units using compressor refrigerating machines is the use of thermodynamic non-equilibrium air as a renewable energy resource. Systems that use this energy for cold production include direct and indirect evaporative air cooling units [1, 2], which can be successfully used in solar air-conditioning plants. The principle of operation of solar conditioning plants is based on preliminary treatment of air in the adsorption dryer and subsequent cooling of the air flow in a rotating heat exchanger and an irrigation chamber (Fig.2).

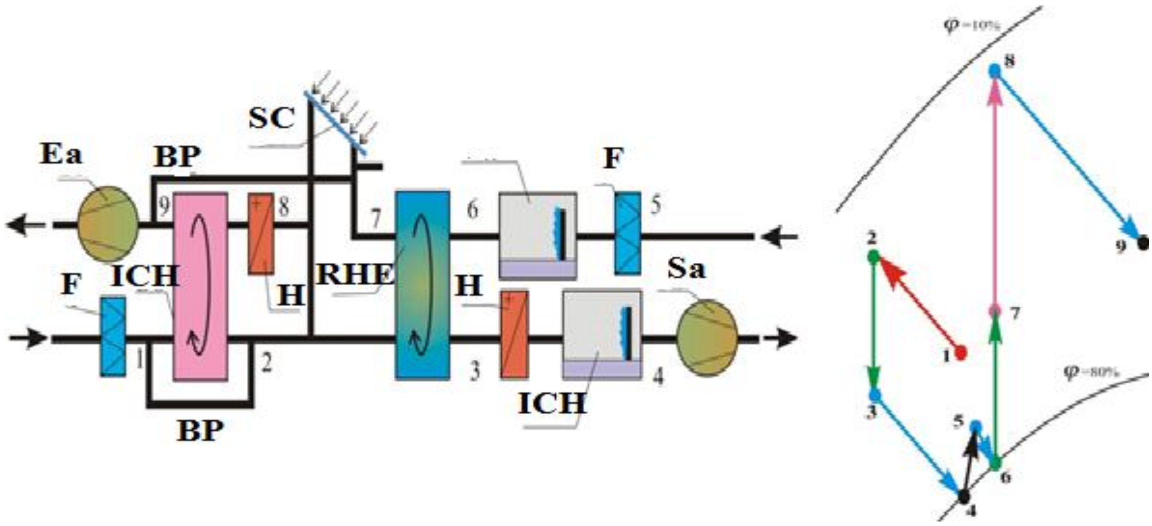


**FIGURE 2: Solar air conditioning installation a) - installation diagram; b) - air processing processes on the i-d diagram: (1-2) - dehumidification of air in the sorbing nozzle; (2-3) - cooling in a rotary heat exchanger; (3-4) - cooling and humidifying in the irrigation chamber; (4-5) - assimilation of heat and moisture in an air-conditioned room; (5-6) - cooling and humidifying the exhaust air flow in the irrigation chamber; (6-7) - preheating the exhaust air in the rotary heat exchanger; (7-8) - heating of the regeneration air in the solar collector and the air heater; (8-9) - humidification and cooling of air in the regeneration sector of the desiccant nozzle.**

## IV. SYSTEM DESIGN

In Fig. 2 shows the principle of the traditional solar air conditioning system. Pre-cleaned in the filter (P), the outside air with parameters (1) is dried and heated in the sorption nozzle of the rotor (NR) to state (2). After "dry" cooling at constant moisture content (2-3) in the rotary heat exchanger (RHE), the air is adiabatically humidified in the irrigation chamber (ICH) to state (4) and with these parameters air is supplied to the air-conditioned room, in which it assimilates heat and moisture (4-5). The exhaust air is adiabatically humidified in the irrigation chamber (5-6), after which it is heated (6-7) in a rotating heat exchanger (RHE). The final heating of the air (7-8), going to regeneration of the desiccant nozzle, is carried out in the solar collector (SC) and (with insufficient heating in the solar collector) in the air heater (H). The change in the parameters of the regeneration air in the desiccant nozzle corresponds to the i-d-line diagram (8-9). Part of the exhaust air, not intended for regeneration of the nozzle, is removed through the bypass (BP) into the atmosphere.

## V. DATASET DESCRIPTION

In winter, the air dehumidifier (ICH) is not used, and the external supply air is directed through the bypass directly to the input to the rotating heat exchanger (RHE), which in this case acts as a heat exchanger for the exhaust air [3]. In addition, it is possible to organize the recirculation of exhaust air at the outlet from the solar collector, or, when the situation permits, to partially use outside air for regeneration purposes, which leads to a reduction in energy consumption for air treatment.

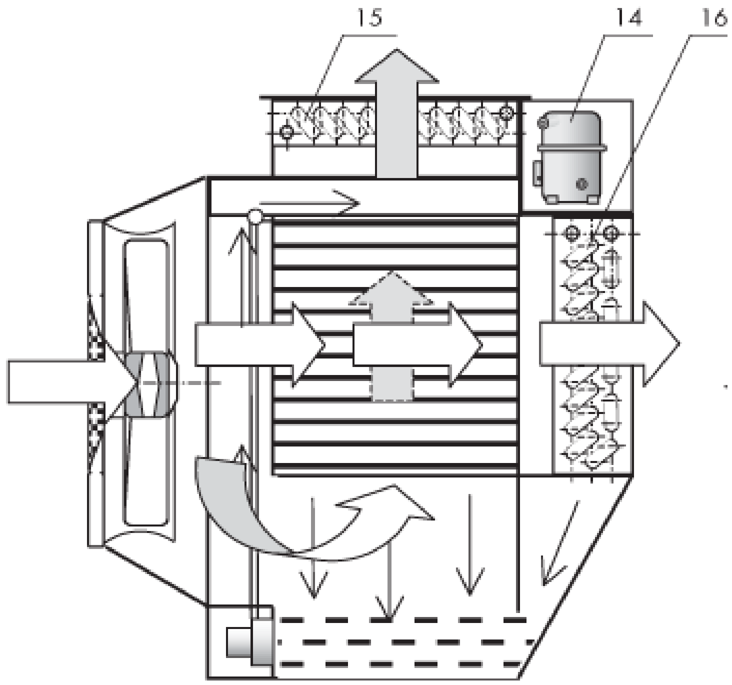


**FIGURE 3: Combined evaporative cooler with XM.**
***14 - compressor XM, 15 - condenser XM, 16 - evaporator XM.***

It should be noted that solar conditioning systems, characterized by a sufficiently high efficiency [2], have certain drawbacks. The main drawback is associated with an increase in the relative humidity of the air at the outlet from the irrigation chamber (up to 80-90%), which significantly reduces the assimilative power of the supply air in rooms with a predominance of moisture occurrences. As a result, the conditions of thermal comfort in an air-conditioned room during the summer period may be violated.

In the proposed a number of solutions aimed at eliminating the negative phenomena associated with the humidification of fresh air in the summer, and increasing the efficiency of air cooling by replacing the irrigation chamber with indirect-evaporative devices [3, 4].

Indirect evaporative cooling of air is a process in which air does not have direct contact with water, and its cooling occurs through a heat exchange surface (Fig. 3). Water that absorbs heat evaporates in another stream of air, while its temperature decreases. The flow of air, cooled by water in the absence of direct contact with it, is called the main one, and the airflow in which the evaporation of water taking up this heat from the main stream is auxiliary. In the combined apparatus, the process of cooling the main air flow is carried out in the dry channels of the nozzle with decreasing enthalpy and constant moisture content due to the evaporation of water in adjacent moist channels along which the auxiliary air flow moves [3].

The initial data for calculations based on the developed calculation procedure [4] are given in Table 1.

**TABLE 1**
**COMPARATIVE INDICATORS OF TWO SYSTEMS**

| Indicators | System Type | |
|---|---|---|
| | two-stage evaporative cooling | two independent air conditioners KC-25 |
| Performance by air, supplied to the serviced premises, in $m^3/h$ | 20000 | 10000 |
| The available pressure for the supply duct network in $kg/m^2$ | 30 | 15 |
| Cooling capacity for assimilation of heat in serviced premises in kkal/h | 40320 | 40000 |
| Total cooling of supply air in kkal/h | 126095 | 50000 |
| Installed power of electric motors for main air conditioners (drive of fans, refrigeration compressors) in kW | 12,9 | 22 |
| The amount of circulating water in the heat exchangers of the first stage or for cooling condensers of refrigerating machines in kg / h | 25964 | 9200 |
| Installed capacity to cool the circulating water in the first stage of the evaporative air-conditioning unit or in the cooling tower for autonomous air conditioners in kW | 18,6 | 8 |
| Total power consumption in the presence of a cooling tower in the scheme of independent air conditioners in kW-h | 3150 | 3000 |
| Capacity per 1000 kcal / h:<br>-by common cooling of supply air<br>-the cooling capacity for assimilation of heat in the premises | <br>0,25<br>0,785 | <br>0,6<br>0,75 |

## VI. CONCLUSION AND FUTURE WORK

Thus, the realization of IEC (in contrast to direct evaporative cooling) makes it possible to use the natural thermodynamic non-equilibrium of atmospheric air to produce cold.

The prospects of using these devices in solar air-conditioning plants are due to the possibility:

- Reducing the temperature level of the resulting cold;
- Improving the efficiency of latent heat assimilation in air-conditioned rooms;
- Reducing energy consumption by means of a purposeful combination of different flow patterns of exchanging flows;
- Rational use of heat of phase transformations and renewable energy resources of thermodynamic non-equilibrium of atmospheric air.

Fig.2. presents examples of schemes for processing fresh air in solar air-conditioning plants using the IEC cross-precision apparatus. A qualitative analysis of the proposed schemes was carried out under the following assumptions:

- Air parameters at the outlet from the sorption dryer are assumed to be the same for all options;
- The temperature of the exhaust air is equal to the temperature of the air in the room;
- Depending on the temperature of the air at the outlet of the CRO, the air exchange changes in such a way as to maintain the assimilation capacity of the fresh air, which is constant for all options;
- The efficiency of the regeneration process of the desiccant nozzle is assumed to be the same for all variants.

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