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THE COMPRESSOR-PHOTOELECTRIC TECHNOLOGY TO PRODUCE POTABLE WATER FROM MOISTURE AIR

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Obtaining drinking water in areas where water resources (even contaminated or salty water) are completely lacking is an extremely important and complex problem. At the same time, there is always a certain amount of water vapor in the air present everywhere. The Earth's atmosphere contains a good amount of water vapor in addition to dry gases such as oxygen, nitrogen, carbon dioxide, etc. Water vapor constitutes 3% of the air mass by 4% in volume and the rest are dry gases.

However, known methods of obtaining fresh water from air vapors are extremely low-efficiency, difficult to implement and have not been widely used in practice in recent years.

At the same time, climatological studies indicate that the maximum amount of water vapor appears in the air at night, but the natural rate of their condensation is extremely low. Condensation efficiency can be significantly improved by artificial cooling techniques, which requires an external source of energy. There is a way to get the required energy from renewable sources (e.g. the sun) during the day and accumulate it for use during the night in refrigerated condensation systems.

The current study included experimental results for economical method to get a potable water, especially in areas without any the water source, such as the desert by using the air humidity condensing technique through vapor compression refrigeration -photovoltaic system. The results of the experimental study showed that the compression refrigeration - photovoltaic model produces about than 6.5 liters of freshwater per day, while consuming 0.7 kW*h/l of energy.

The results are ten times higher than the efficiency of natural (convective) water extraction processes and have lower energy costs than for obtaining fresh water by thermal distillation of 0.72 kWh/l from seawater.

Key words: potable water, vapor- compression refrigeration, photovoltaics, accumulate, atmosphere, sun, desert.

КОМПРЕССОРНО - ФОТОЭЛЕКТРИЧЕСКАЯ ТЕХНОЛОГИЯ ПОЛУЧЕНИЯ ПРЕСНОЙ ВОДЫ ИЗ ВЛАЖНОГО ВОЗДУХА

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Получение питьевой воды в зонах, где полностью отсутствуют водные ресурсы (даже загрязненные или соленые воды) является чрезвычайно важной и сложной проблемой. В тоже время в присутствующем повсеместно атмосферном воздухе всегда содержится некоторое количество водяного пара. Атмосфера Земли содержит значительное количество водяного пара в дополнение к сухим газам, таким как кислород, азот, углекислый газ и т.д. В среднем концентрация водяного пара составляет около 3% от массы воздуха (4% в объеме), а остальные сухие газы.

Однако известные методы получения пресной воды из содержащихся в воздухе паров имеют чрезвычайно низкую эффективность, сложны в реализации и не находят в последние годы широкого применения в практике. В тоже время климатологические исследования указывают, что максимальное количество паров воды появляется в воздухе в ночные часы, однако естественная скорость их конденсации является чрезвычайно низкой. Эффективность конденсации можно значительно повысить, используя методы искусственного охлаждения, что требует наличия внешнего источника энергии. Возможен путь получения требуемой энергии от возобновляемых источников (например - солнца) в дневной период и аккумулирования ее для использования в ночной период в рефрижираторных системах конденсации.

В данной работе представлены экспериментальные результаты получения питьевой воды, особенно в областях без какого-либо источника воды, таких как пустыня, с использованием метода конденсации влаги в воздухе с помощью компрессионной холодильной системы - фотоэлектрической системы. Результаты экспериментального исследования показали, что компрессионно- охладительная - фотоэлектрическая система производит около 6,5 литров пресной воды в день, потребляя при этом 0,7 кВт*ч / л энергии.

Полученные результаты в десятки раз превышают эффективность процессов естественного (конвективного) извлечения воды из воздуха и имеют затраты энергии более низкие, чем на получение пресной воды путем термической дистилляции из морской воды 0,72 кВт*ч / л.

Ключевые слова: питьевая вода, парокомпрессионное охлаждение, фотовольтаика, аккумулирование, атмосфера, солнце, пустыня.

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Публикации: более 450 научных трудов, в том числе 5 монографий, 80 изобретений.

Introduction

Getting drinking-water is important to health, a basic populace's right and a component of an effective policy of populaces health protection. Furthermore, potable water is important as health and the development affair at local, national and regional levels [1]. It has been shown that operation of drinking water supply in certain zones can yield a net economic feasibility benefit and the reductions in health insurance and care costs; which overbalance the costs of installing a freshwater solutions system. This is genuine and an effective part of the major strategy, infrastructure investments in water treatment to supply fresh water supply to the homes and save the life of the poor populace in the rural, urban zone or militarism segments on limits of the country (the boundary of the country) [2]. Over a million populaces lack found by the World Health Association that admission to the cleanest drinking water. Furthermore, most of these populaces are living in rustic regions where it is difficult to construct a freshwater solutions system [3]. One applied of solar energy applications is a solar water distillery to producing freshwater from brackish water. harvesting humidity (potable water) from a moist air [4–6].

The current study aims to produce potable water experimentally with less energy consumption in the region without any water sources such as deserts, through condensation of moisture air and getting a potable water by Compression Refrigeration -Photoelectric Technology to extract potable water from humid Air (CRPT).

list of symbols	
Units	
V	Volte
A	Ampere
W	Watts
$W\ /\ m^2$	Watt per square meter
$kW * h$	Kilowatt-hour
$kW * h\ /\ l$	Kilowatt-hour per liter
$A\ *\ h$	Ampere-hour
°C	
Nomenclatures	
CRPT	Compression Refrigeration - Photoelectric Technology

1. The wet air condensation technology

The condensation process happens by one of two methods, first one when air cooled to its dew point, second method when air becomes saturated with water vapor and cannot hold more. The Earth's atmosphere contains a good amount of water vapor in addition to dry gases such as oxygen, nitrogen, carbon dioxide, etc. Water vapor constitutes 3% of the air mass by 4% in volume and the rest are dry gases. Therefore, moisture can be extracted from a wet air by passing the latter on a surface with a lower temperature than the passing air (the surface temperature below the dewpoint of moisture air) in order to separate moisture from the humid air, a conventional cooling methods are usually used to separate moisture from air, where the air temperature is lower than the temperature at which water vapor condensation begins [7–11]. However, they are distinguished by either low efficiency or large energy costs for cooling water condensing systems.

To increase the productivity of such installations use several techniques:

- artificial increase in humidity by heating salty or contaminated water (in the presence of such water) due to the energy of the sun, waves, wind, etc. sources [12-14];

-use of effective sorbents to collect water from the air of natural humidity [15];

-use of intensive cooling systems to increase the condensation efficiency of natural humidity from the air using natural convection or forced cooling at the expense of solar, wave, wind, etc. energy sources [16-21].

1.1. The CRPT model description

The CRPT model provides experimental results of an effective system to produce potable water using a photovoltaic solar energy converter, as a renewable energy source for a compression refrigeration system that which is used to extract potable water from humid air, which passes through the refrigeration unit (Heat exchanger-evaporator) as in Figure. 1.

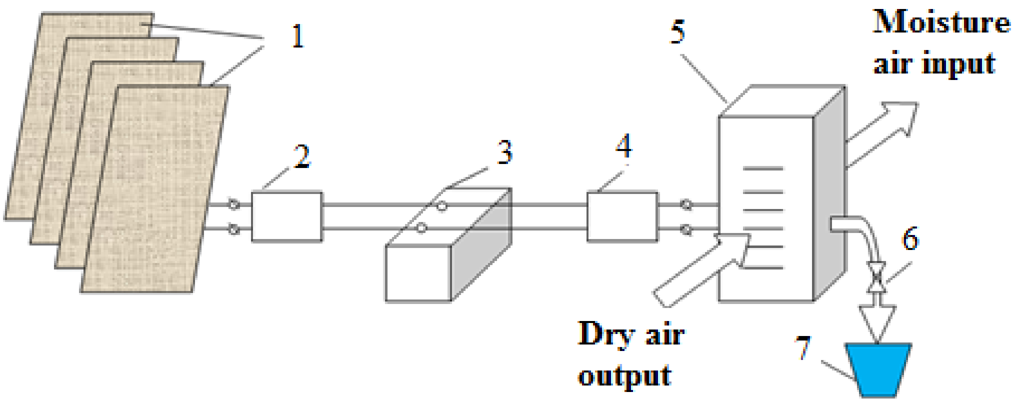

Fig. 1. Scheme diagram of the vapour compression refrigeration -photovoltaic system
1-Photoelectric converters, 2- Charge controller, 3- Rechargeable battery, 4-Inverter 24V-220V,
5- Compression refrigeration- potable water production unit, 6- valve, 7- Potable water collection tank.
Рис.1. Принципиальная схема компрессорной - фотоэлектрической установки
1- фотоэлектрические преобразователи, 2- MPPT контроллер, 3- аккумуляторная батарея, 4-инвертор 24В-220В,
5- компрессорный водогенератор, 6- вентиль, 7-водоприемная емкость.

In the experiments, compressor air dryer type DEXP DH-10NGMA has been used, as shown in Fig. 2, and its characteristics in table. 1.

Table 1

Characteristics of the refrigeration unit

Таблица 1

Технические характеристики холодильной установки

Refrigerant	R290
Power consumption	330 Watt
Supply voltage	220 - 240 V
Current rate	1.6 A

To ensure continuous operation of the Compression refrigeration- potable water production unit, a 330 W and 220 V, 50 Hz has been used. Therefore, the total electric power required for a production unit throughout the day is 7.92 kW*h. In order to supply power to the potable water generator, a photovoltaic unit has been used, which includes 6 photovoltaic panels, an MRPT charging controller, a battery 200 A * h and an inverter 24V-220V. The characteristics of the photovoltaic panel are given in table. 2.

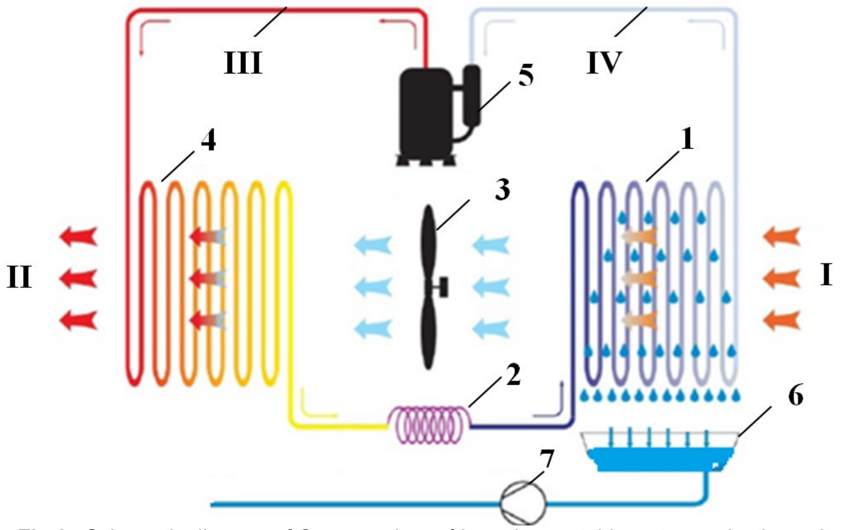

Fig.2. Schematic diagram of Compression refrigeration- potable water production unit
1-Heat exchanger-evaporator, 2- Capillary tube, 3- Air supply fan, 4- Heat exchanger-condenser,
5- Compressor, 6- Water tank, 7- Freshwater pump.
I - Wet air inlet, II - Dry air outlet, III - High pressure side (freon-liquid), IV - Low pressure side (freon-steam).
Рис.2. Принципиальная схема компрессионной водогенерирующей установки
1-теплообменник - испаритель, 2- капиллярная трубка, 3- вентилятор подачи воздуха,
4- теплообменник - конденсатор, 5- компрессор, 6- бак - водосборник, 7- насос пресной воды.
I – вход влажного воздуха из атмосферы, II – выход осушенного воздуха в атмосферу,
III – контур жидкого фреона, IV – контур парообразного фреона.

Table. 2

Photovoltaic panel specifications

Таблица 2

Технические характеристики фотоэлектрической панели.

Parameter	Value
Peak Power, W	180
Open circuit voltage, V	37.3
Efficiency%	15

Different devices have been used to measure the different parameters as shown in table 3. SD data logger 4 channel has been used with K-type 0.3 mm thermocouples, which calibrated between 0 and 100 °C, to measure the temperatures at different places of system. Anemometer device has been used to measure the ambient wind speed and solar power meter device used to measure solar radiation intensity in W/m^2. Humidity and temperature meter device have been used to measure the temperature and relative humidity for the ambient air. Daily data of solar radiation are shown in Fig. 3.

Table. 3

The experimental measuring devices with their accuracy.

Таблица. 3

Экспериментальные измерительные приборы с их точностью.

Measuring Device	*Accuracy*
SD data logger 4 channel (model 88598)	$\pm 0.3\%\ rdg + 1°C$
Digital laser infrared thermometer temperature (model TEGMART TE-TEM-LS-PRB).	$\pm 1.5\%$
Humidity and temperature meter (model GM1362)	Humidity 3% Temperature 0.5%
Solar power meter device (model TENMARS TM-207)	$\pm 10\ W/m^2$
Anemometer device (model ut363)	$\pm 5\%\ rdg + 0.5°C$

1.2. Experimental procedures

The experimental test carried out in the Ural Federal University during June 2019 according to Ekaterinburg/ Russia city climate (Latitude 56.84 °N, Longitude 60.58 °E). All tests started at morning 24:00 am to 24:00 am for the next day (24 hours) and for different days. Data has recorded hourly, which includes solar radiation intensity and hourly potable water productivity. The study was conducted over one month with variable environmental conditions, as well as the time of sunrise and sunset ranging from 05:20 am to 08:40 pm. The number of tests was 10 and chosen 30.06. 2019 as perfect days.

2. Results and discussion

Figure 4 shows typical data on the daily change in humidity and ambient air temperatures in the summer for a perfect day 30.06.2019 according to climatic of Yekaterinburg city. In figure 4 it is obvious that the intensity of solar radiation varies depending on the weather, in the Yekaterinburg city rarely the weather is clear and without clouds. The effect of solar radiation started after 6:00 am and the maximum intensity of the solar radiation is approximately at 12:00 pm, in which the intensity of radiation $790\ W\ /\ m^2$. Early in the morning times, intensity of solar radiation and ambient temperature are relatively low, at the noontime, between 12:00 pm to 14:00 pm, the rate of solar radiation increases then falls again in the afternoon. When solar radiation reaches the Earth's surface, it transmits thermal energy to the surrounding areas, so the maximum ambient temperature occurs at around 12:00-13:00 pm. Figures 3, 4 shows direct relationship between the solar radiation and ambient air temperature during a typical day. The increased solar radiation intensity led to an increase in the ambient air temperature and vice versa. While the relationship was inverse between solar radiation and ambient temperature with relative humidity. The increased solar radiation and ambient temperature led to decrease the relative humidity. The highest relative humidity values were recorded at nighttime and lowest at sunrise, while the highest ambient air temperatures were recorded in the middle of the day at highest solar radiation and the lowest values were night times.

The daily generation of electric energy of the photovoltaic unit around to $9\ kW\ *\ h$, which is enough to power the potable water generator in the daytime and create a supply of energy in the battery to ensure operation during the night. The graph of the daily productivity of obtaining freshwater from the ambient air is shown in Fig. 5.

The total daily freshwater productivity from the unit was 6.285 liters. The specific daily energy costs for producing water using this method were $0.7\ kW * h\ /\ l$, which is slightly lower than the energy costs for producing fresh water by distillation from sea water $0.72\ kW\ *\ h\ /\ l$.

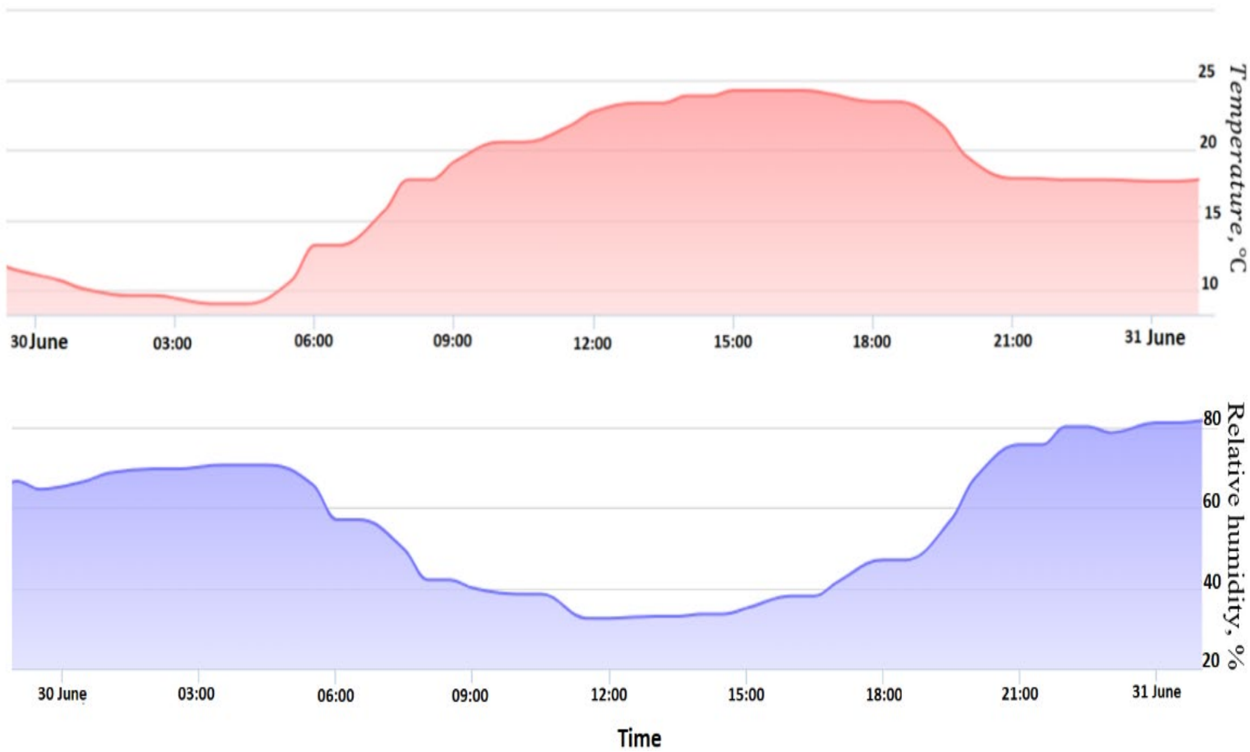

Fig .3. Change in relative humidity and ambient air temperatures 30.06.19.
Рис. 3. Изменение относительной влажности и температуры окружающего воздуха 30.06.19.

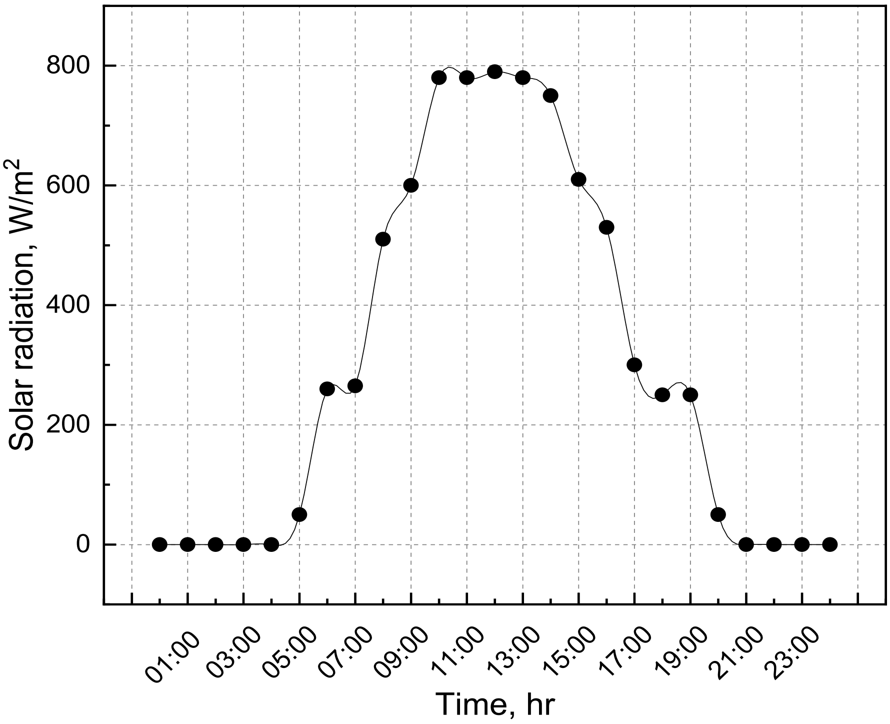

Fig. 4. Solar radiation intensity in perfect day 30.06.19.
Рис.4. Солнечная радиация в идеальный день 30.06.19.

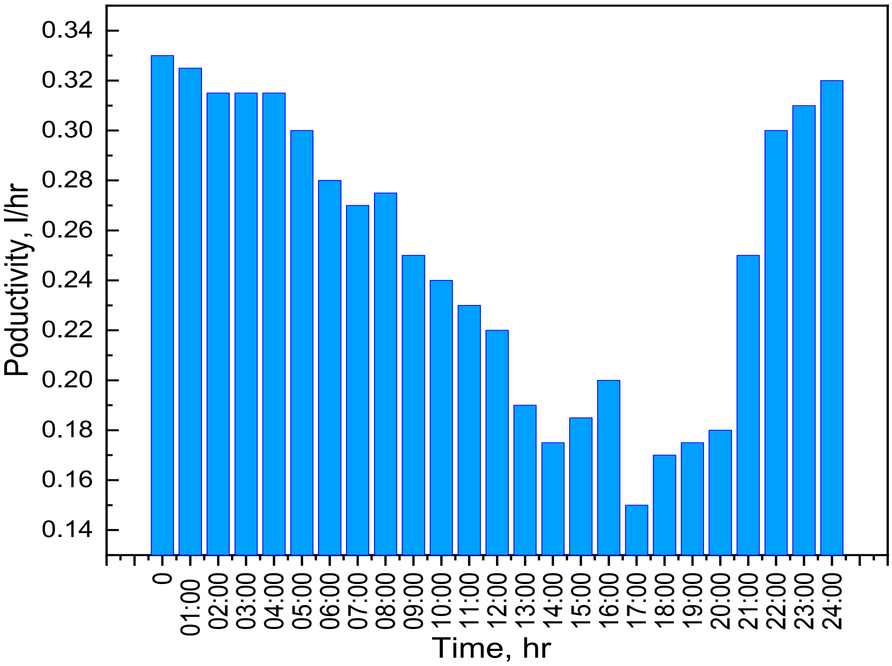

Fig. 5. Hourly freshwater productivity in perfect day 06/30/19
Рис.5. График суточной производительности получения воды в идеальный день 30.06.19.

Conclusion

1. The extraction of water from the air using compressor refrigeration units is possible.

2. The use of solar energy for energy supply of a compressor water generator is possible in regions with favorable solar availability.

3. The compression refrigeration -photovoltaic model produces about than 6.5 liters of freshwater per day, while consuming 0.7 kW*h/l of energy, which is slightly lower than the energy costs for producing fresh water by distillation from sea water 0.72 kW * h / l.

4. It is advisable to optimize the structure of the photoelectric-water-generating complex, considering the daily variation of its performance.

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