Proceedings
of
International Conference on

RENEWABLE AND SUSTAINABLE ENERGY (ICRSE 2017)

HINDUSTHAN EDUCATIONAL AND CHARITABLE TRUST
H E C T

April 12th & 13th 2017

Editors

Dr. M. Mohanraj
Dr. K. Siva
Dr. J. Manikandan

Organized by

Department of Mechanical Engineering
Hindusthan College of Engineering and Technology
(An Autonomous Institution Affiliated to Anna University, Chennai)
(Accredited with 'A' Grade by NAAC)
Coimbatore - 641032, India.
www.hindusthan.net | icrse2017@gmail.com

Proceedings of

International Conference

on

Renewable and Sustainable Energy

(ICRSE 2017)

April 12th & 13th, 2017

Organized by

Department of Mechanical Engineering

Hindusthan College of Engineering & Technology

Coimbatore, India.

www.hindusthan.net

Preface

The continuous depletion of fossil fuel resources and its adverse environmental impacts on global climate puts forward great challenges for the research and development in the field of Energy Engineering and Technology. The concept of energy efficiency and its necessity needs to be explored. To full-fill the current social requirements and to meet the future energy demand, the Department of Mechanical Engineering, Hindusthan College of Engineering and Technology, Coimbatore has organized an International Conference on Renewable and Sustainable Energy 2017 to focus the recent research developments in the field of Renewable Energy Technology and to provide a plat form to disseminate the new developments and ideas to enhance the energy efficiency. We also invite renewable energy product manufacturers for exploiting their innovative products in conference exhibition. The outcome of this conference aims to bring the researchers, engineers, industrial experts, scientists and research scholars in the sphere of technical interests. This proceeding contain two abstracts of keynote address, forty technical papers published by the research scholars in the field of solar energy applications, thermal energy storage, bio-diesel energy, wind energy and the issues related to energy and the environment. We also thank the reviewers for their valuable review support for selecting the papers for the conference. Further, the selected papers of this conference will be published in Thermal Science: Scientific Journal.

We would like to be grateful to the Management of Hindusthan College of Engineering and Technology, Coimbatore for providing an opportunity to organize this event. We also express our gratitude to our Principal, Heads of Departments and faculty members for their kind support during every stages of the conference. Besides, we would like to thank all the authors for their value contributions to ICRSE2017. Further, the work contributions provided by all the supporting staffs are recognized. We also thank all the financial sponsors, for their financial support to make the conference a grant success. Moreover, the technical experts for their keynote address are highly acknowledged. The supports provided by student voluntaries are highly appreciated.

Editors

About the institution:

Hindusthan College of Engineering and Technology (HICET) was started during the year 2000 by the industrialist and philanthropist, Thiru. T. S. R. Khannaiyann, Chairman, and Tmt. Sarasuwathy Khanniayann, Secretary. The institution is accredited by NAAC and National Board of Accreditation (NBA), New Delhi. HICET is spread over 120 acres and is located on Coimbatore-Pollachi Highways about 12 kms from Coimbatore Railway Junction. HICET has got autonomous status from the academic year 2016-17. HICET is currently offering following degree programs:

Bachelor degrees Programs (Under graduate Courses):

B.E - Aeronautical Engineering

B.E - Automobile Engineering

B.E - Computer Science and Engineering

B.E – Civil Engineering

B.E – Electronics & Communication Engineering

B.E - Electrical & Electronics Engineering

B.E – Electronics and Instrumentation Engineering

B.E - Mechanical Engineering

B.E - Mechatronics Engineering

B. Tech - Information Technology

Master degree Programs (Post Graduate Courses):

Masters in Business Administration (M.B.A)

Masters in Computer Applications (M.C.A)

M.E – Specialization in CAD/CAM

M.E – Specialization in Communication Systems

M.E - Specialization in Applied Electronics

M.E - Specialization in Computer Science and Engineering

Research Programs:

Ph. D - Computer science and Engineering

Ph. D - Electronics & Communication Engineering

Ph. D - Mechanical Engineering

Ph. D- Electrical and Electronics Engineering

About the Department: The Mechanical Engineering Department was started in the year 2000. The department has qualified faculty members and well equipped laboratories. The department has annual intake of 180 students in Bachelors degree program in Mechanical Engineering and 18 students in Masters Degree Program in Mechanical Engineering with specialization in CAD/CAM. The department has been recognized as research center by Anna University, Chennai.

International Advisory Committee:

Dr. S. Jayaraj, *University of Pittsburg, USA*

Dr. Gautam Dutt, *VP Science and Tech., MGM Innova, Argentina*

Dr. K. Sumathy, *North Dekotta State University, USA*

Dr. K. T. Ooi, *Nanyang Technological University, Singapore*

Dr. Arif Hepbasli, *Yasar University, Turkey*

Dr. A. Kaltayev, *Al Farabi Kazakh National University, Kazakhstan*

Dr. Alexander Georgiv, *Sofia University, Bulgaria*

Dr. M. Esen, *Firat University, Turkey*

Dr. R. M. Singh, *University of Surrey, United Kingdom*

Dr. J. G. Singh, *Asian Institute of Technology, Thailand*

Dr. K.B. Sopian, *Solar Energy Research Institute, Malaysia*

Dr. A.H.B. Shamsuddin, *Universiti Tenaga Nasional, Malaysia*

Dr. T. Sivasakthivel, Tokyo University of Agiculture and Tech., Japan.

Dr. J. Ji, *University of Science and Technology, Hefei. China*

Mr. R. Srinivasan, *Bitzer, Dubai.*

Mr. A. Senthil Kumar, *DAVINCI Development A/S, Oslo, Norway*

National Advisory Committee:

Dr. C. Muraleedharan, *National Institute of Technology, Calicut.*

Dr. A.S. Ramadhas, *Indian Oil Corporation, Faridabad,*

Dr. S.P.S. Rajput, *National Institute of Technology, Bhopal.*

Dr. Sanjeev Anand, *Shri Mata Vaishno Devi University,Katra.*

Dr. S.K.Tyagi, *SSS Nat. Inst. of Renewable Energy Kapurthala.*

Dr. A. Kumar *TERI University, Delhi.*

Dr. E. Nataraj, *Anna University, Chennai,*

Dr. N. Murugan, *Coimbatore Institute of Tech., Coimbatore.*

Dr. S. Suresh Kumar, *National Institute of Technology, Trichy.*

Dr. Varun, *National Institute of Technology, Hamirpur.*

Dr. Calvin S. King, *Presidency University, Bangalore,*

Dr. R.Thuntil Karupparaj, *Vellore Institute of Technology,Vellore.*

Dr. M. Ashok kumar, *General Motors, Bangalore.*

Dr. N. Lakshmanan, *ELGI equipments, Coimbatore,*

Dr. R. Manivel, *Kumaraguru College of Tech., Coimbatore.*

Dr. A.S. Krishnan, *Coimbatore Institute of Tech., Coimbatore.*

Dr. A. Selvaraj, *Pondichery Engineering College, Pondichery.*

Dr. L. Godson Ashirwatham, *Karunya University, Coimbatore .*

Dr. R. Velavan, *PSG College of Technology, Coimbatore.*

Dr. K. Kalidasa Murugavel, *National Engg. College, Tirunelveli.*

Dr. P.K. Srividhya, *Periyar Maniammai University, Thanjavor,*

Dr. S. Ayyappan, *Mahalingam College of Engg & Tech., Pollachi.*

ORGANIZING COMMITTEE

Chief Patrons:

Shri. T. S. R. Khannaiyann, Chairman

Tmt. Sarasuwathy Khannaiyann, Secretary

Mrs. Priya Satish, Joint Secretary

Patrons:

Dr. S. Annadurai, Advisor

Dr. T. Kannadasan, Principal

Convener:

Dr. K. Siva, Professor and Head

Coordinators:

Dr. M. Mohanraj, Professor

Dr. J. Manikandan, Professor

Reception Committee:

Dr. P. Jeyalakshmi, Professor

Mr. C. Nithyanandam, Associate Professor

Mr. C.A.Jagadish, Assistant Professor

Technical and Review committee:

Dr. M. Mohanraj, Professor

Dr. P. Jeyalakshmi, Professor

Mr. R. Sankar Ganesh, Assistant Professor

Mr. V. Senthil Murugan, Associate Professor

Conference Invitation/ Printing and proceedings committee

Dr. J. Manikandan, Professor

Mr. A. Nazeer Ahamed, Assistant Professor

Mr. S. Alagar, Assistant Professor

Mr. D. Amalraju, Assistant Professor

Mr. A. Sasi kumar, Assistant Professor

Finance and Accounts committee

Dr. J. Manikandan, Professor

Mr. S. Sivakumar, Asssitant Professor

Mr. S. Alagar, Assistant Professor

Mr. S. Krishnamoorthy, Assistant Professor

Hospitality and refreshment committee

Mr. R. Sankar Ganesh, Assistant Professor

Mr. K.R.Sakthivel, Assistant Professor

Mr. C.A.Jagadish, Assistant Professor

Mr. K. Sivakumar, Assistant Professor

Mr. N. Prasanna Venkatesan, Assistant Professor

Mr. S. Sivakumar, Asssitant Professor

Registration and certificate committee members

Dr. S. Kannan, Professor

Mr. S. Vidya Prakash, Assistant Professor

Mr. M. Veeramani, Assistant Professor

Mr. S. Krishnamoorthy, Assistant Professor

Public addressing and Hall arrangements committee:

Mr. A. Nazeer Ahamed, Assistant Professor

Mr. K. Rameshkumar, Assistant Professor

Mr. K.R.Sakthivel, Assistant Professor

Mr. K. Sivakumar, Assistant Professor

Mr. D. Prabhu, Assistant Professor

Transport and accommodation committee:

Mr. R. Arul Kumar, Associate Professor

Mr. J. Dineshkumar, Assistant Professor

Mr. N. Dhayananthan, Assistant Professor

Mr. L. Karthick, Assistant Professor

Exhibition and sponsor committee:

Mr. Y. Ras Mathew, Assistant Professor

Mr. V. Senthil Murugan, Associate Professor

Mr. P.N. Karthikeyan, Associate Professor

Mr. A. Sasikumar, Assistant Professor

Mr. G.P. Arun Babu, Assistant Professor

Photography, Press and Media

Mr. K. Aruchamy, Associate Professor

Mr. P. N. Karthikeyan, Associate Professor

Mr. D. Prabhu, Assistant Professor

CONTENTS

NUMERICAL SIMULATION OF A HEAT PUMP ASSISTED REGENERATIVE SOLAR STILL WITH PCM HEAT STORAGE FOR COLD CLIMATES OF KAZAKHSTAN

Ye. Shakir[1], B. Saparova[1], M. Mohanraj[2], Ye. Belyayev[1], S. Jayaraj[3], A. Kaltayev[1]

[1]Department of Mechanics, Al-Farabi Kazakh National University, Almaty, Kazakhstan
[2]Department of Mechanical Engineering, Hindusthan College of Engineering and Technology, Coimbatore, India
[3]Department of Mechanical Engineering, National Institute of Technology, Calicut, India

Email: mohanrajrac@yahoo.co.in; yerzhan.belyayev@gmail.com

A numerical model has been proposed in this work for predicting the energy performances of the heat pump assisted regenerative solar still with PCM heat storage under Kazakhstan climates. The numerical model is based on energy and mass balance. A new regenerative heat pump configuration with PCM heat storage is proposed to improve the performance. A comparison of results has been made between the conventional solar still and heat pump assisted regenerative solar still with PCM. The numerical simulation was performed for wide range of ambient temperatures between -30 ℃ and 30 ℃ with wide range of solar intensities between 100 W/m^2 and 900 W/m^2. The numerical simulation results showed that heat pump assisted regenerative solar still is more energy efficiency and produce better yield when compared to the conventional simple solar still. The influences of solar intensity, ambient temperature, different PCM materials, heat pump operating temperatures are discussed. The predicted values were found to be in good agreement with experimental results reported in literature.

Key words: *Solar stills; PCM heat storage; Heat pumps; Cold climates; Kazakhstan*

INTRODUCTION

Water is the main element, essential for all forms of life, for the existence of natural ecosystems, social and economic development of any country. Fresh water on Earth is just 3%. In addition, water resources are distributed according to the land surface is extremely uneven. By 2025, according to UN forecasts, the acute shortage of water will experience more than 2.8 billion people. Increasing water scarcity is caused by the growing world population and the development of the global economy and climate change.

To date, as a result of combination of anthropogenic and natural factors the desertification processes in varying degrees subject to more than 70% of the territory of Kazakhstan. In particular, the Aral Sea dried up almost 90%. Kazakhstan is experiencing an acute shortage of water resources for the needs of industry and agriculture and for drinking water. However, in Kazakhstan there are huge reserves of groundwater, including brackish water. Also there is the Caspian Sea and Balkhash Lake. The production of clean water using various desalination technologies is a very important task for the socioeconomic development of Kazakhstan.

In the previous work [1], numerical simulation of heat pump assisted regenerative solar still for cold climates of Kazakhstan without heat storage was carried out. For cold climate conditions using the heat pump for pre-heating of water is justified. In [1] it is also shown that the integration of a heat pump with a solar still increases the productivity of clean water by 2-3 times. In [2] experimental investigation of solar still equipped with an external latent heat storage system and evacuated tube collectors was presented. The maximum yield and daily efficiency of 6.555 kg/m^2 day and 50% were obtained for a solar still with an external condenser filled with PCM. Experiments were conducted for the climatic conditions of Tehran, Iran. In [3] experiments were conducted with sand and servotherm medium oil as sensible passive storage in a single slope single basin solar still. The experiments were conducted in South India. For sand and servotherm medium oil shows higher productivity compared to conventional still. In [4] exergy analysis of solar desalination still combined with heat storage system using PCM was presented for meteorological conditions of Morocco. It was shown that the instantaneous exergy efficiency of the solar still is less than 5% during the daytime but there are some cases where it exceeds 80% at night-time. In [5] a double passes solar air collector–coupled modified solar still, with PCM, have been experimentally investigated. The experimental results show that, the freshwater productivity approximately reached 9.36 (L/m^2 day) for the double passes solar air collector-coupled modified solar still, with PCM, while its value is recorded 4.5 (L/m^2 day) for the conventional still. The results were presented for the Egyptian climatic conditions. It can also be noted earlier researches [6-14] on the integration of a solar distiller with heat storage material to increase productivity.

All the above theoretical and experimental work was presented for warm climatic conditions where additional heating elements such as a heat pump, were not used. A brief review of the combination of a desalination system with a heat pump was presented in [1]. In present research numerical simulation of a heat pump assisted regenerative solar still with PCM heat storage for cold climates of Kazakhstan is conducted. A numerical algorithm to study performance of heat pump assisted regenerative solar still with PCM heat storage system has been developed.

SYSTEM DESCRIPTION

The schematic diagram of the heat pump assisted regenerative solar still, which will be used to conduct experiments is depicted in Figure 1. The heat pump assisted regenerative solar still consists of a hermetically sealed reciprocating compressor, a shell and coil type condenser with thermal storage, a liquid receiver, a sealed-type refrigerant drier, a thermostatic expansion device, plate type evaporator with heat storage provision, basin area 2 m^2 that accommodates brackish water. The condenser will contribute to heat basin water (evaporation), especially during low solar radiation using heat pump refrigerant (R134a). The water in the basin is heated by the incident solar radiation transmitted through the glazing surface. The water will condense under this glass cover and the evaporator. The condensate will be collected by two beakers.

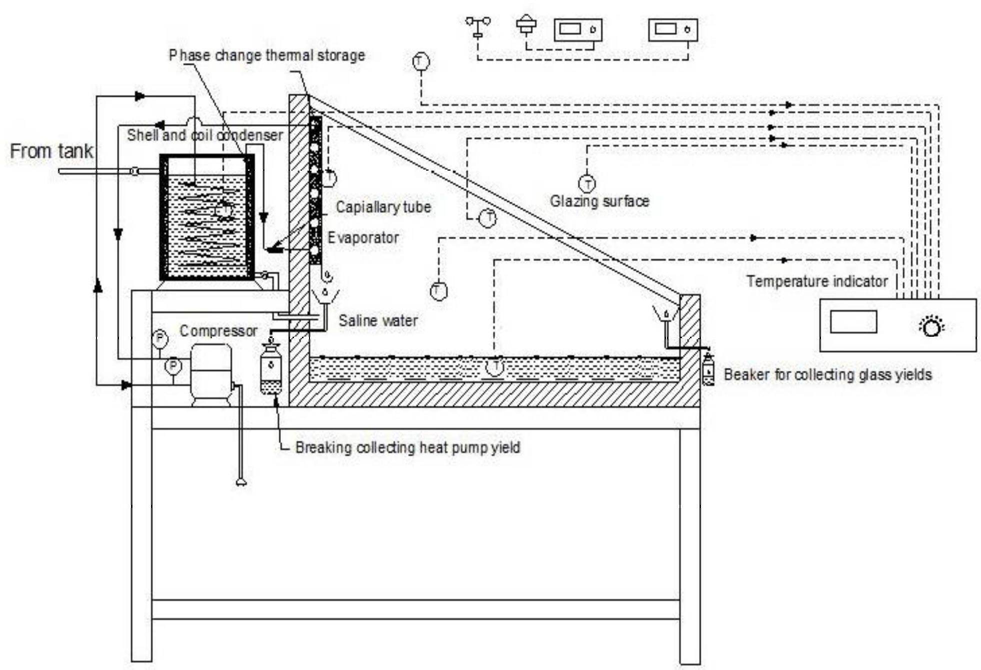


Fig. 1. Schematic view of the heat pump assisted regenerative solar still with PCM

MATHEMATICAL MODEL

To simulate the performance of heat pump assisted regenerative solar still the following mathematical model according to [1, 15] was formulated. Basic assumptions of mathematical model:

1) all the process are steady state;
2) pressure drop, potential, kinetic and chemical effects are assumed to be negligible in heat pump circuit;
3) compression of the refrigerant vapor is assumed to follow a polytrophic process;
4) expansion of refrigerant liquid is considered to be isenthalpic;
5) the water temperature gradient is negligible;
6) vapor losses through the side, as well as other losses are negligible;
7) the heat conduction within the still is negligible.

According to [15] energy balance equations for different part of heat pump assisted regenerative solar still are as follow:

Energy balance for glass cover:

$$m_g \cdot C_g \cdot \frac{dT_g}{dt} = (1-\rho_g) \cdot \alpha_g \cdot G_H + (q_{ev,w-g} + q_{r,w-g} + q_{c,w-g}) - q_{r,g-a} + q_{c,g-a} \tag{1}$$

Energy balance for the evaporator

$$m_e \cdot C_e \cdot \frac{dT_e}{dt} = q_{c,w-e} + q_{ev,w-e} - q_{ev,f} \tag{2}$$

Energy balance for the water

$$m_w \cdot C_w \cdot \frac{dT_w}{dt} = (1-\rho_g) \cdot (1-\alpha_g) \cdot \alpha_w \cdot G_H - (q_{ev,w-g} + q_{r,w-g} + q_{c,w-g}) \cdot \frac{A_g}{A_w} + q_{c,b-w} + \frac{W}{A_w} \tag{3}$$

Energy balance for the absorber

$$m_b \cdot C_b \cdot \frac{dT_b}{dt} = (1-\rho_g) \cdot (1-\alpha_g) \cdot (1-\alpha_w) \cdot \alpha_b \cdot G_H - q_{c,b-w} - q_{c,b-pcm} \tag{4}$$

Energy balance for the PCM

$$M_{eq} \cdot \frac{dT_{pcm}}{dt} = q_{c,b-pcm} - q_{loss} \tag{5}$$

where M_{eq} is the equivalent heat capacity of PCM [16], and it is indicated in different phases of the PCM during the process of state change from solid to liquid as follows:

$$M_{eq} = m_{pcm} C_{s,pcm} \quad for \quad T_{pcm} < T_m$$
$$M_{eq} = m_{pcm} L_{pcm} \quad for \quad T_m \le T_{pcm} < T_m + \delta'$$
$$M_{eq} = m_{pcm} C_{l,pcm} \quad for \quad T_{pcm} > T_m + \delta'$$

The rate of condensation is estimated:

$$\frac{dm_c}{dt} = \frac{q_{ev,w}}{H_w} = \frac{A_w \cdot q_{ev,w-g} + A_e \cdot q_{ev,w-e}}{A_w \cdot H_w} \tag{6}$$

In the right hand side of expressions (1)-(6) unknown terms mainly describe convective and radiative heat transfer between different parts of the heat pump assisted solar still according to [15-16].

METHOD OF SOLUTION

Numerical algorithm for solution of (1)-(6) based on the fourth order Runge-Kutta method [1]. Computer program for implementation of numerical algorithm developed by means of C++ programming software. As the initial conditions for temperature at the different part of the heat pump assisted solar still ambient temperature were assumed. At the first time step this temperature value was used to calculate convective and radiative heat transfer coefficients. Based on this values and physical properties temperatures at the different positions of the system were calculated. In Table 1 the basic system parameters are performed.

Table1. Basic parameters of the heat pump assisted solar still

Parameter	Symbol	Value	Unit
Mass of the glass cover	m_g	10.12	$kg \cdot m^{-2}$
Specific heat of glass	C_g	800	$J \cdot kg^{-1} \cdot °C^{-1}$
Absorptivity of glass	σ_g	0.0475	-
Reflectivity of glass	ρ_g	0.0735	-
Mass of water	m_w	20.60	$kg \cdot m^{-2}$
Specific heat of water	C_w	4178	$J \cdot kg^{-1} \cdot °C^{-1}$
Absorptivity of water	σ_w	0.05	-
Mass of plate absorber	m_b	15.60	$kg \cdot m^{-2}$
Specific heat of plate absorber	C_b	480	$J \cdot kg^{-1} \cdot °C^{-1}$
Absorptivity of plate absorber	σ_b	0.95	-
Thermal conductivity of plate absorber	k_b	16.30	$W \cdot m^{-1} \cdot K^{-1}$
Thermal conductivity of insulation	k_i	0.039	$W \cdot m^{-1} \cdot K^{-1}$
Mass of evaporator	m_e	7.35	$kg \cdot m^{-2}$
Specific heat of evaporator	C_e	385	$J \cdot kg^{-1} \cdot °C^{-1}$

RESULTS AND DISCUSSION

A numerical modeling for predicting energy performances of the heat pump assisted regenerative solar still with PCM heat storage in Fort-Shevchenko town of Kazakhstan on the eastern shore of Caspian Sea has been conducted. Kazakhstan is one of the leading countries in the Central Asian region with the average annual solar radiation potential. Annual duration of sunshine is 2200-3000 hours, and the estimated capacity of 1300-1700 kW per 1 m^2 per year, which exceeds that of Northern and Central Europe. Fig.3 shows the average daily direct and diffuse solar radiation on a horizontal surface with actual conditions of cloudiness for Fort-Shevchenko town, W/m^2.

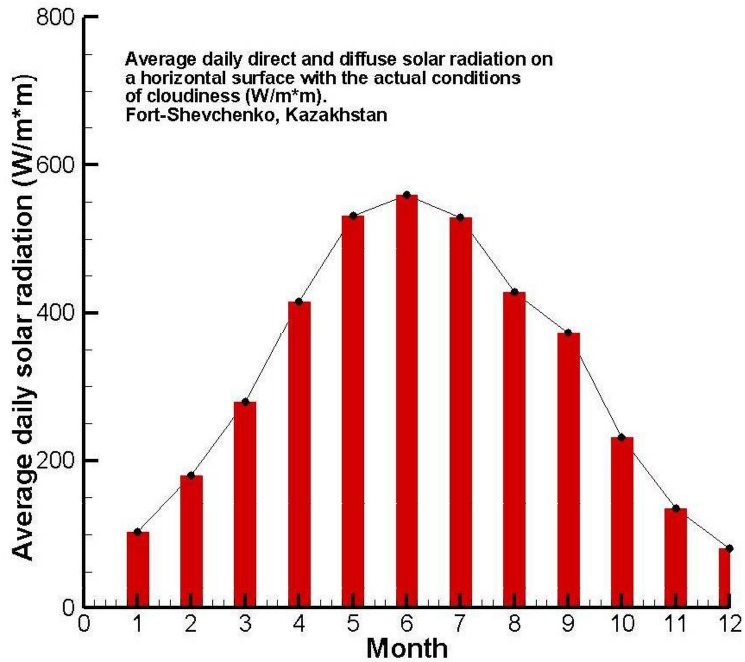
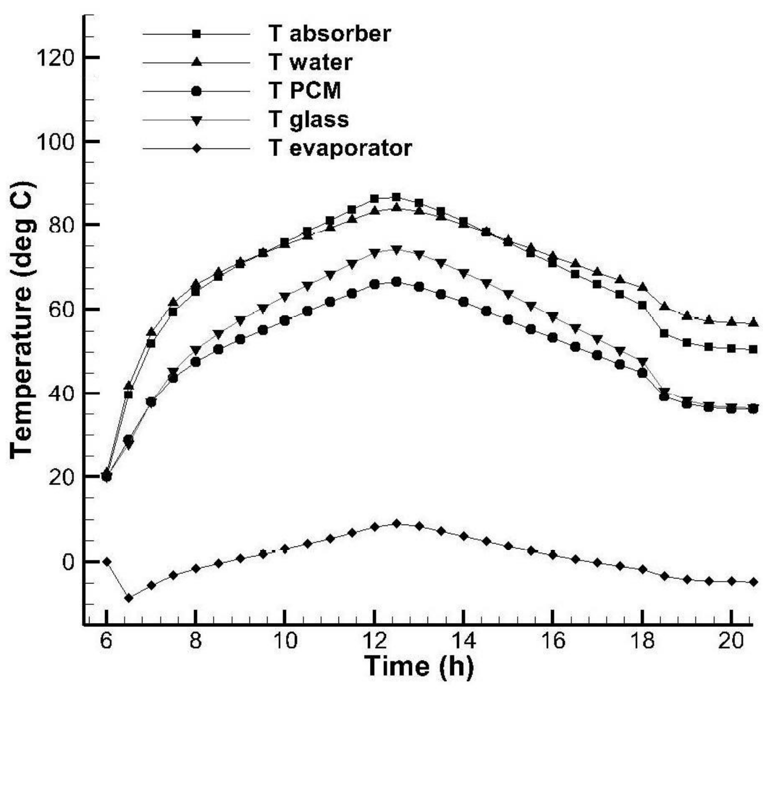


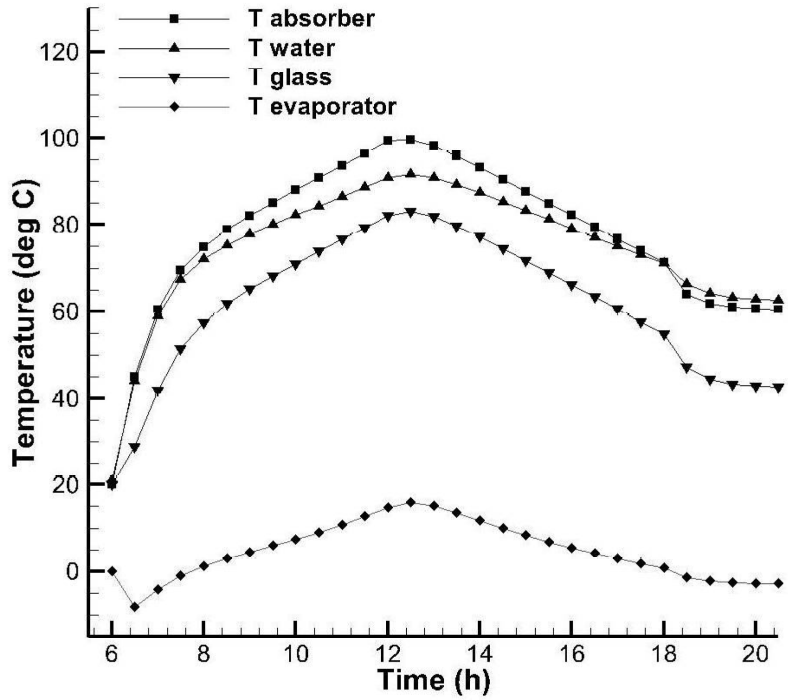
Fig. 2. The total solar radiation in Almaty city

Numerical values of temperature variation with and without PCM in Fort-Shevchenko town for July month is illustrated in Figure 3.

a)



b)



a) – with PCM, b) - without PCM

Fig.3. The temperature variation of the different solar still parts

According to the Fig.3 at the beginning of the day the curves gradually increase, reaching maximum at 12 h and 14 h, then gradually decreased. Due to the high absorption coefficient of the absorption plate with black paint its temperature reaches a maximum value of 86.6 and 99.7℃ in July with and without PCM, accordingly. The temperature of the glass is 74.2 and 83 ℃ with and without PCM. Almost 20℃ difference between absorber and glass temperatures is due to convective heat exchange with ambient air and water vapor condensation at the evaporator. Water temperature is 92℃ without PCM. In PCM including case water temperature is 84℃, while PCM temperature is 66.5℃.

Fig.4 shows the productivity of heat pump assisted regenerative solar still with and without PCM. More than 75% of condensed water is produced by evaporator comparing to glass cover. A large amount of water vapor is condensate very quickly due to the low temperature of the refrigerant. Total, glass and evaporator productivity without using PCM are above compared to using PCM. This is due to the fact that a certain amount of heat is expended for the melting of PCM.

Fig.5 shows temperature variation without heat pump. As a phase change material Paraffin 62 was taken. Melting temperature of Paraffin 62 is ranging between 52-67℃. During calculations the melting point of PCM was assumed to be equal to 57℃. The water temperature without PCM is higher than with PCM, 6℃ difference between them. The maximum temperature of paraffin reaches 53 ℃. This temperature is not sufficient for melting PCM.

Fig.6 shows water temperature variation with and without heat pump. During calculations, PCM was not taken into account. It follows from the Fig.6 that the water temperature without a heat pump is much lower than with its inclusion. Also after 6 pm the water temperature drops to the level of the environment, whereas with the heat pump the distiller operates continuously and at night with a minimum temperature of 60℃.

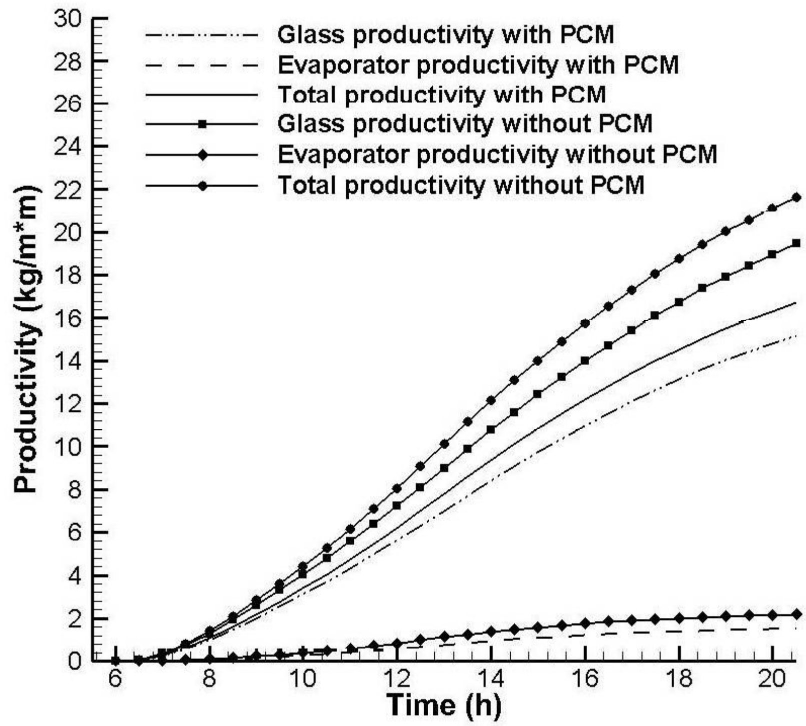


Fig.4 – Productivity of the distiller for a typical summer day (July)

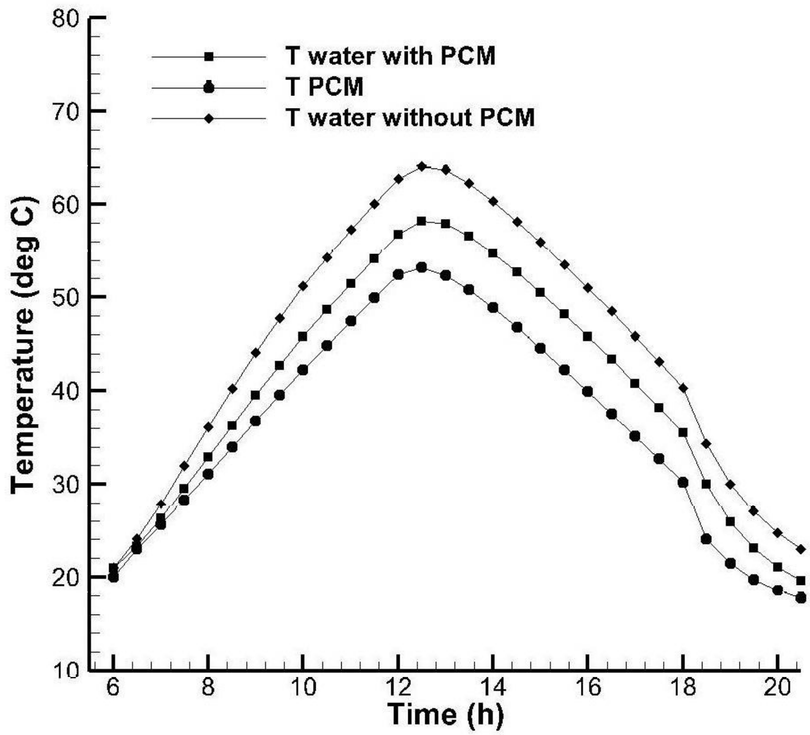


Fig.5 – The temperature variation without heat pump

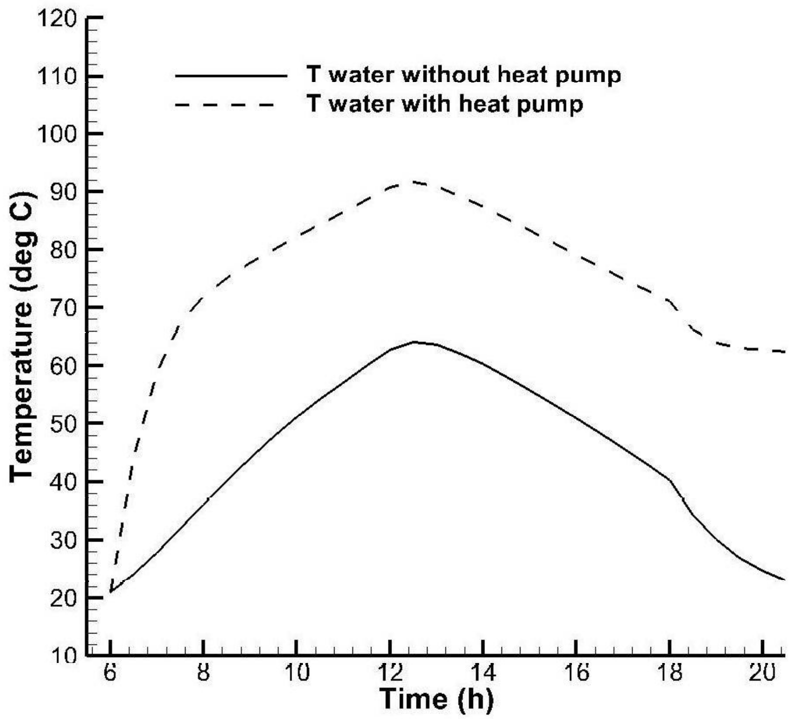


Fig.6 – The water temperature variation

CONCLUSION

Numerical simulation of a heat pump assisted regenerative solar still with PCM under meteorological conditions of Kazakhstan has been conducted. Numerical results show that integrating the heat pump gives a much greater solar still productivity compared to PCM. Mathematical model and numerical algorithm accurately characterizes the thermal performance of the solar distiller. In the future work it is planned to build an experimental setup.

REFERENCES

[1] Ye. Shakir, M. Mohanraj, Ye. Belyayev, S. Jayaraj, A. Kaltayev. Numerical simulation of a heat pump assisted regenerative solar still for cold climates of Kazakhstan, Bulgarian Chemical Communications 48 (2016) 126–132.

[2] Meysam Faegh, Mohammad Behshad Shafii. Experimental investigation of a solar still equipped with an external heat storage system using phase change materials and heat pipes, Desalination 409 (2017) 128-135.

[3] H.S. Deshmukh, S.B. Thombre. Solar distillation with single basin solar still using sensible heat storage materials, Desalination 410 (2017) 91-98.

[4] Mohamed Asbik, Omar Ansari, Abdellah Bah, Nadia Zari, Abdelaziz Mimet, Hamdy El-Ghetany. Exergy analysis of solar desalination still combined with heat storage system using phase change material (PCM), Desalination 381 (2016) 26-37.

[5] A.E. Kabeel, Mohamed Abdelgaied, M.Mahgoub. The performance of a modified solar still using hot air injection and PCM, Desalination 379 (2016) 102-107.

[6] B. A. Akash, M. S. Mohsen, O. Osta, Y. Elayan. Experimental evaluation of a single-basin solar still using different absorbing materials, Renewable Energy 14 (1998) 1–4.

[7] A. M. Radhwan. Transient performance of a stepped solar still with built-in latent heat thermal energy storage. Desalination 171(1) (2005) 61–76.

[8] F. F. Tabrizi, M. Dashtban, H. Moghaddam. Experimental investigation of a weirtype cascade solar still with built-in latent heat thermal energy storage system. Desalination 260 (2010) 248–253.
[9] M. Dashtban, F. F. Tabrizi. Thermal analysis of a weir-type cascade solar still integrated with PCM storage. Desalination 279(1–3) (2011) 415–422.
[10] A. A. F. Al-Hamadani, S. K. Shukla. Water Distillation Using Solar Energy System with Lauric Acid as Storage Medium. International Journal of Energy Engineering 1(1) (2012) 1–8.
[11] D.C. Kantesh. Design of solar still using Phase changing material as a storage medium. International Journal of Scientific & Engineering Research 3(12) (2012) 1–6.
[12] A. K. Rai, V. Sachan. Experimental study of a tubular solar still with phase change material. International Journal of Mechanical Engineering and Technology 6340 (2013) 379–385.
[13] O. Ansari, M. Asbik, A. Bah, A. Arbaoui, A. Khmou. Desalination of the brackish water using a passive solar still with a heat energy storage system. Desalination 324 (2013) 10–20.
[14] R. Sathyamurthy, P. K. Nagarajan, H. J. Kennady, T. S. Ravikumar, V. Paulson, A. Ahsan. Enhancing the Heat Transfer of Triangular Pyramid Solar Still Using Phase Change Material As Storage Material. Frontiers in Heat and Mass Transfer 5 (2014) 1–5.
[15] Hanen Ben Halima, Nader Frikha, Romdhane Ben Slama Numerical investigation of a simple solar still coupled to a compression heat pump. Desalination 337 (2014) 60-66.
[16] Faramarz Sarhaddi, Farshad Farshchi Tabrizi, Halimeh Aghaei Zoori Comparative study of two weir type cascade solar stills with and without PCM storage using energy and exergy analysis. Energy Conversion and Management 133 (2017) 97-109.