INDUCED AIR FLOW THROUGH A VERTICAL PIPE HEATED BY RADIATION EFFECTS

Gerardo Carbajal
Universidad del Turabo, Caguas, PR, USA, gcarbajal1@suagm.edu

Luis R. Rivera Santiago
Universidad del Turabo, Caguas, PR, USA

Felix O. Cotto Flores
Universidad del Turabo, Caguas, PR, USA

ABSTRACT

An experimental study of radiation effects on induced air flow through a vertical pipe is presented. To simulate the radiation effects, four bulbs of 120W each one, with a total power of 480W, were used in the experiments. Special concave plates were specially designed and built to receive the maximum radiation. An appropriate expression for the shape factor was applied. All the surfaces exposed to the direct radiation heat transfer were black painted. Different radiative power were tested in order to determine the minimum conditions for induced air flow. It was found that it was possible to generate a steady air flow inside the pipe. A radiative power of 240 W applied to a 11.4 cm inside pipe diameter produced and air flow with an average velocity of 0.1667 m/s.

Keywords: radiation effect,

1. INTRODUCTION

Natural convection occurs on a warm, sunny day. The sun emitts radiant energy that is absorbed by the earth surface during sunlight, it was found that certain portions of the surface absorb more than other portions. Due to the complex geometry of the earth, the air near the surface heats unevenly. The sun's energy cause the warmest air expands, becomes less dense than the surrounding cooler air then it rises (Rousie, 2006). Santos Bernales (2010) presented a detailed information of the development and advances of solar chimney power plants (SCPP). Based on the natural air flow by bouyancy effect, Solar Tower technology has tested and proven successfully a small-scale pilot plant constructed in Manzanares Spain. The pilot project was the result of collaboration between the Spanish Government and the German designers, Schlaich Bergermann and Partner. The plant operated for seven years between 1982 and 1989, and consistently generated 50kW output of green energy.The pilot plant conclusively proved the concept works and provided data for design modifications to achieve greater commercial and economic benefits associated with an increased scale of economy (EnviroMission, 2013). Using the spanish prototype HuiLan et al. (2007) performed a simulation calculation of a SCPPS. They applied the Boussineq model and the discrite ordinate radiation model. Pretoriuos et al. (2006) evaluated the performance of a large scale chimney power plant, they developed a new heat transfer model and predicted a reduction of annual power plant by 11.7 percent. Sangi et al. (2011) performed a numerical simulation of a SCPP by using the CFD software Fluent. The transient effects on SCPP was also investigated by Zheng et al. (2010); they shown that soil and gravel can be used as a energy stirage material for the solar chimney system. The present research consist of an experimental study to determine the minimum velocity of the air using as radiant energy source one and four light bulbs of 120 W respectively. A SCPP prototype was designed and built, all the concave surfaces expose to radiation were black painted in order to the maximize the radiation. Additionally the induced air velocity through the vertical pipe was measured. A spiral device was also installed a the bottom side of the chimney to verify the effect of twister in the air flow velocity.

2. THE EXPERIMENTAL SETUP

To perform this investigation a customized deviced was designe and built. It consisted of a base of four concave plates painted black with the following dimensions of 4.5in x6.5in with 4in of inner radius, Fig (1). The base is connected to a vertical PVC pipe rigid with 3ft hight and 4.5in diameter. In addition three hole were made along the PVC pipe to measure the air velocity. A digital anemometer was used to measure the speed of the air. Four light bulbs, with an individual electrical power of 120W, were appropriatly located on top of the concave plate to simulate the sun's radiation. Figure 2 shows the complete assembly of the heating system.

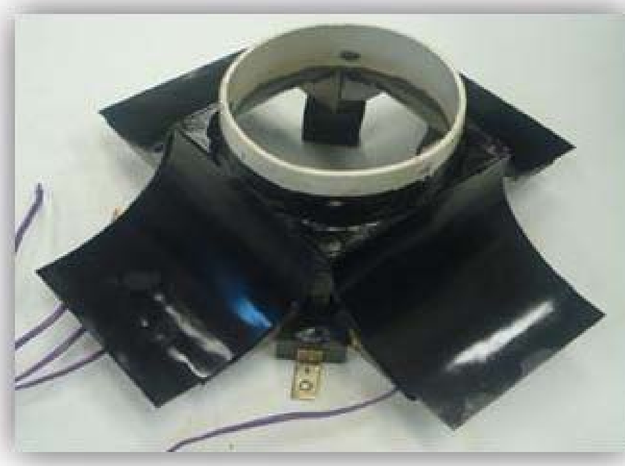


Figure 1: The black painted base concave plate

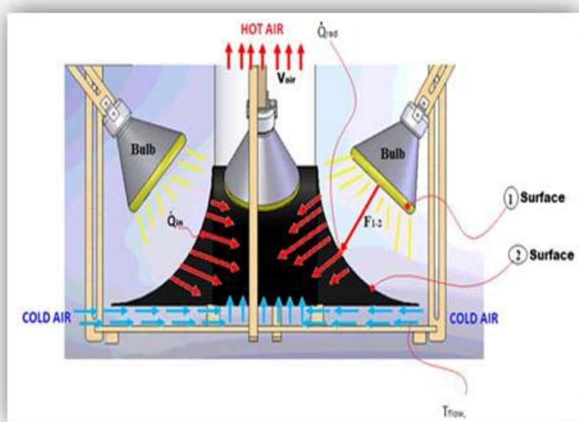
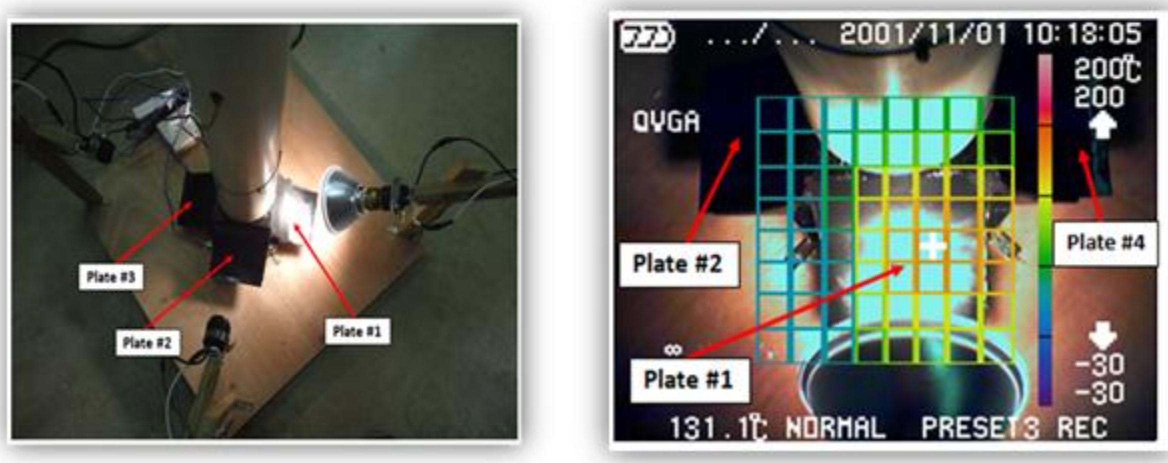


Figure 2: The vertical pipe radiation system

Several thermocuples were installed in the device to measure the temperature history of the system. The thermocuples were connected to a LawView software that recorded the temperature at every one second interval.

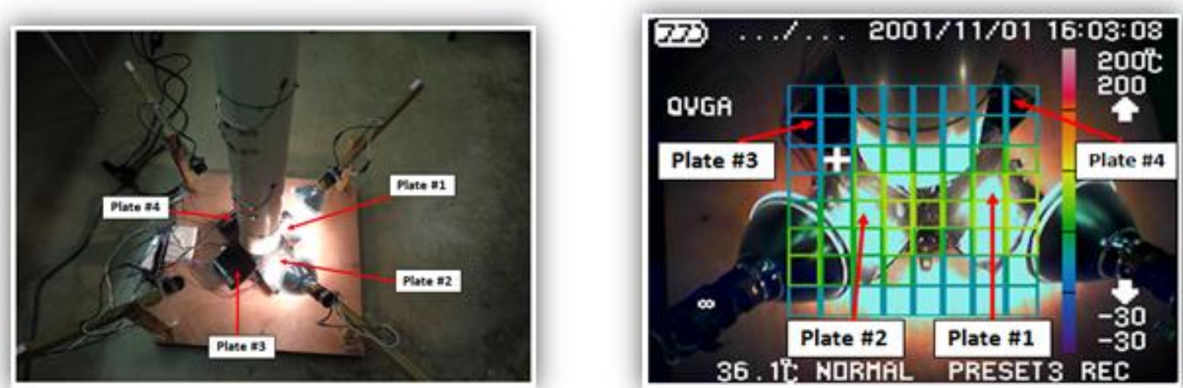
3. THE EXPERIMENTAL RESULTS AND DISCUSSION

The following experimental results correspond to four different heat input cases. In the first case one light bulb was used, for the second case two light bulbs were turned on, for the third and fourth cases three and four light bulbs were used respectively. Figure 3 represents the heating process with one bulb, the thermal infrared camera shows a surface temperature on plate # 3 of 131 ^{o}C. Similarly, Figures 4 to 6 show the cases for two, three and four light bulbs turned on. The thermal infrared camera was used to measure the temperature of the system at different locations were no thermocouples were installed. To prevent convective effects on the concave surface of the system, it was tested in a closed system with an ambient constant temperature of 26 ^{o}C.



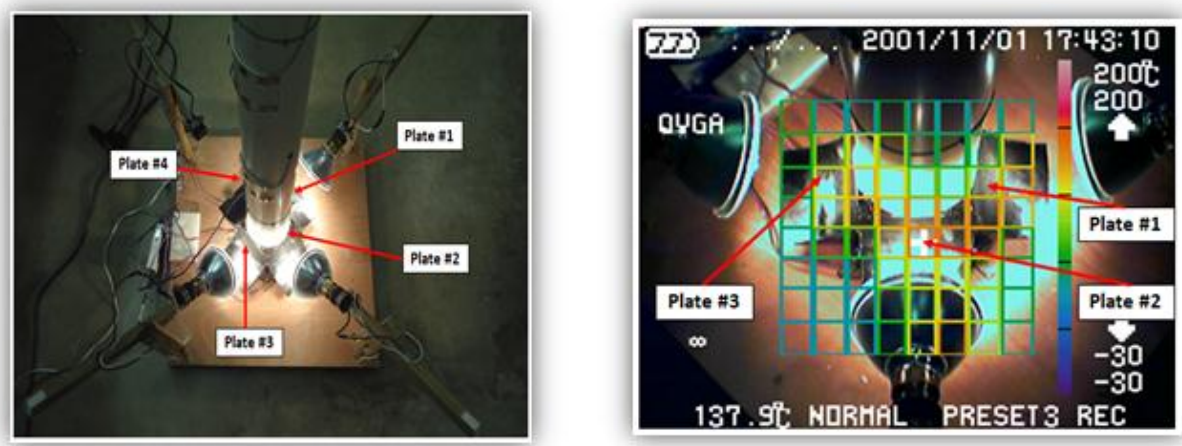
(a) **(b)**

Figure 3: The heating process: (a) one light bulb, (b) thermal infrared camera response



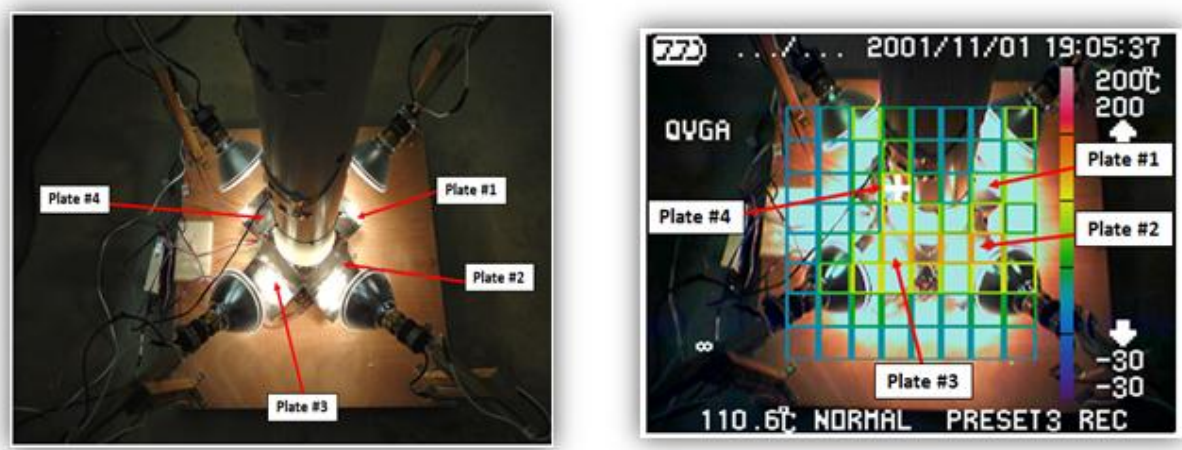
(a) **(b)**

Figure 4: The heating process: (a) two light bulbs, (b) thermal infrared camera response



(a) **(b)**

Figure 5: The heating process: (a) three light bulbs, (b) thermal infrared camera response



(a) **(b)**

Figure 6: The heating process: (a) four light bulbs, (b) thermal infrared camera response

Figure 7 represents the surface temperature of the plates versus time when the four light bulbs were on. The plates reach the steady state very quick; after 15 seconds of exposed to the radiative effects of the light bulbs the surface temperatures on the four plates were approximately of 404, 400, 396 and 388 degree Celsius. A non-linear response of the induced air velocity was observed in Fig. (8). As expected the velocity is cero at time equal to cero which corresponds to the time when the light bulbs are turned on. Contrary to the temperature response the induced air velocity did not show a steady state condition for the time the light bulbs were turned on (approximately one hour).

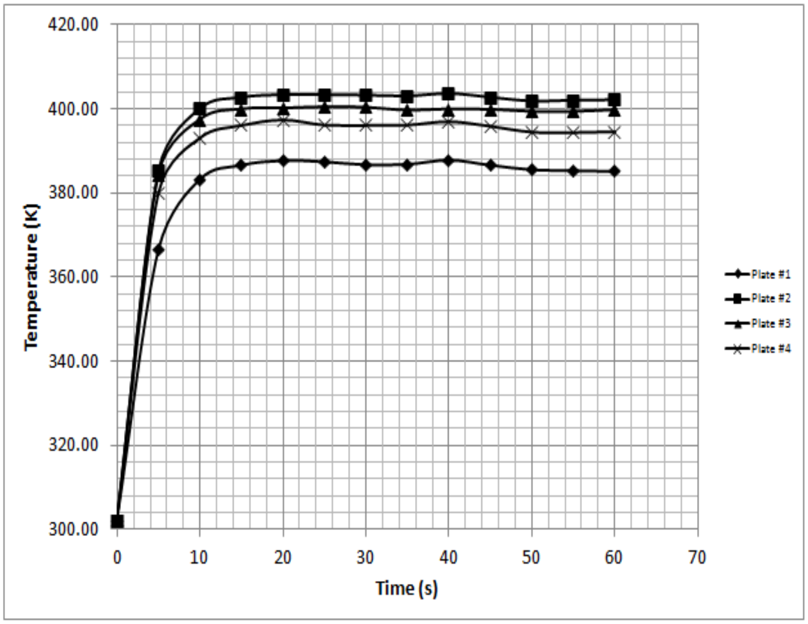


Figure 7: The temperature response of the four plates (four light bulbs).

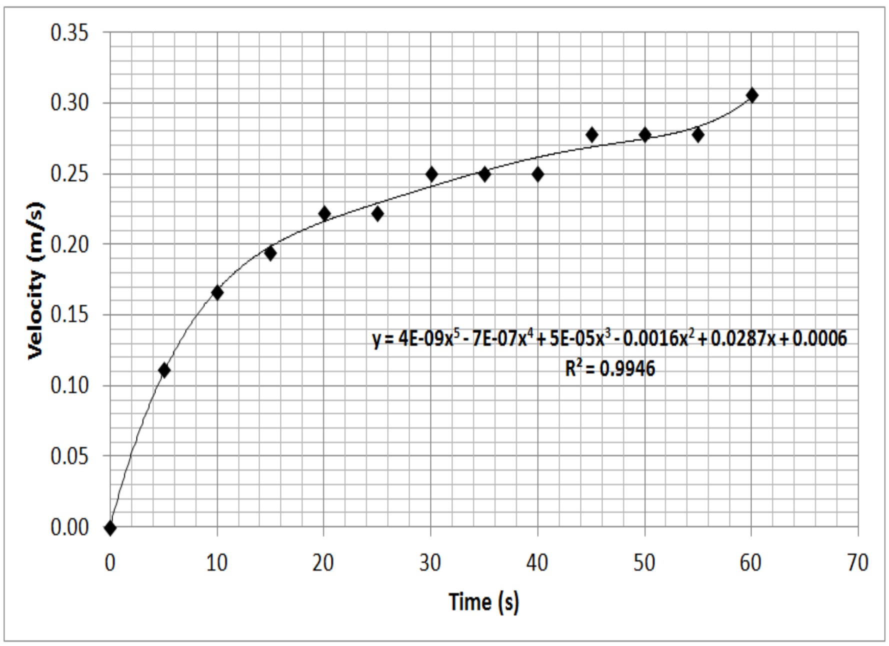


Figure 8: The induced air velocity inside the vertical pipe (four light bulbs).

4. Conclusion

The experimental results indicate that it is possible to induce a passive air flow along the vertical pipe. The induced mass flow rate was directly related with the magnitude of the heat input. In the present analysis black painted aluminum plate were used to heat the air. The aluminum plate surface temperature reach very quick the steady conditions after being exposed to the radiative effects of the light bulbs.

References

EnviroMission (2013), http://www.enviromission.com.au/evm/content/home.html, 01/01/13

HuiLan Huang, Hua Zhang, Yi Huang, Feng Lu (2007) "Simulation Calculation on Solar Chimney Power Plant System". Challenges of Power Engineering and Environment, pp 1158-1161.

Marco Aurélio dos Santos Bernardes (2010) "Solar Chimney Power Plants – Developments and Advancements". Solar Energy, Radu D Rugescu (Ed.), ISBN: 978-953-307-052-0, InTech, Available from: http://www.intechopen.com/books/solar-energy/solar-chimney-power-plants-developments-and-advancements.

Pretoriuos J.P. and Kroger D.G. (2006) "Critical evaluation of solar chimney power plant performance". Solar Energy, Vol. 80, No. 5, pp. 535-544.

Rousie K.R. (2006), University of Illinois at Urbana-Champaign, http://www.atmos.illinois.edu, 03/15/12

Sangi R., Amidpour M., Hosseinizadeh B. (2011) "Modeling and numerical simulation of solar chimney power plants". Solar Energy, Vol. 85. No. 5, pp. 829-838.

Zheng Y., Ming T. Z., Zhou Z., Yu X. F. , Wang H. Y., Pan Y. and Liu W (2010), "Unsteady numerical simulation of solar chimney power plant system with energy storage layer". Journal of Energy Institute, Vol. 83, No. 2, pp. 86-92.

Authorization and Disclaimer