Modeling of Pressure Drop and Heat Transfer Correlation through EES and Initial Phase of Commercial Scale Manufacturing of Novel Solar Thermal Collector

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Motivation

The Earth's natural rgas esources are finite and limited. About 1.08×10^{14} KW reach the Earth's surface. Total solar irradiation absorbed by Earth is 7500 times the world's total energy annual demand [2]. Natural gas plants have shown to be very dangerous.

109,000 Metric tons of Natural Gas leaked

Same As:

- 9,156,00 metric tons of CO_2
- 1,030,268,900 gal. of gasoline burned
- $21,545,930 worth of natural gas waste

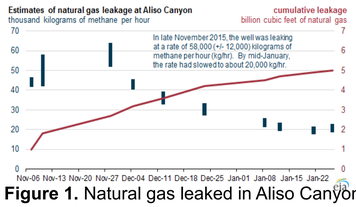

Figure 1. Natural gas leaked in Aliso Canyon

Abstract

Solar thermal collectors convert solar energy to usable thermal energy. The heated working fluid can either be directly used for domestic applications or stored in a tank to be used later in the day. The most common solar collector configurations are flat plate and heat pipe evacuated-tube, however, condenser size of flat plate systems limits the heat transfer and maintaining the evacuated-tube vacuum sealed over time can become difficult [1]. A novel aluminum mini-channel flat plate design was developed and its year-round performance was analyzed in 2012 [3,4].

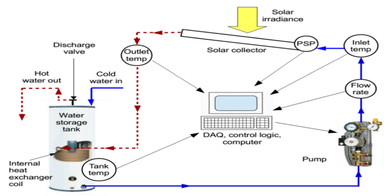

Figure 2. Schematic representation of solar collector system

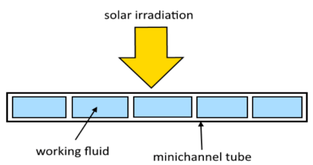

Figure 3. Mini-channel design as collector

In comparison to a conventional copper solar collector, the novel design showed an improvement of 12% in thermal efficiency [3,4].

Objective

Modify original dimensions and simulate through EES to determine difference in pressure drop and heat transfer correlation in order to meet manufacturer's capabilities . Collaborate with manufacturer to develop tailored system to meet majority of Castlebay Lane Charter School's thermal energy energy load.

Comparison of Dimensions

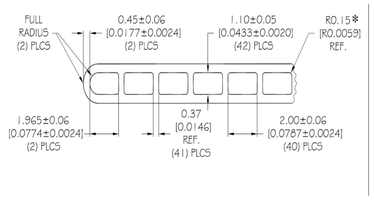

Figure 4. Dimensions of MPE design used for experimental phase

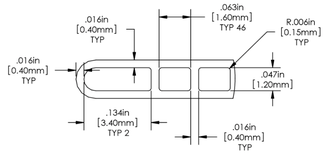

Figure 5. New dimensions simulated

Methods

Engineering Equation Solver (EES): is an equation-solving program that can numerically solve thousands of coupled non-linear algebraic and differential equations.

- high accuracy thermodynamic and transport property database that is provided for hundreds of substances in a manner that allows it to be used with the equation solving capability

```
"Tube Dimensions"
Ntubes = 11
L_tube = 1.5 {1.9304}
major = .1 {0.0159*1.5}
minor = height_port + 2*TubeWalls
TubeWalls= 0.0004
```

Results

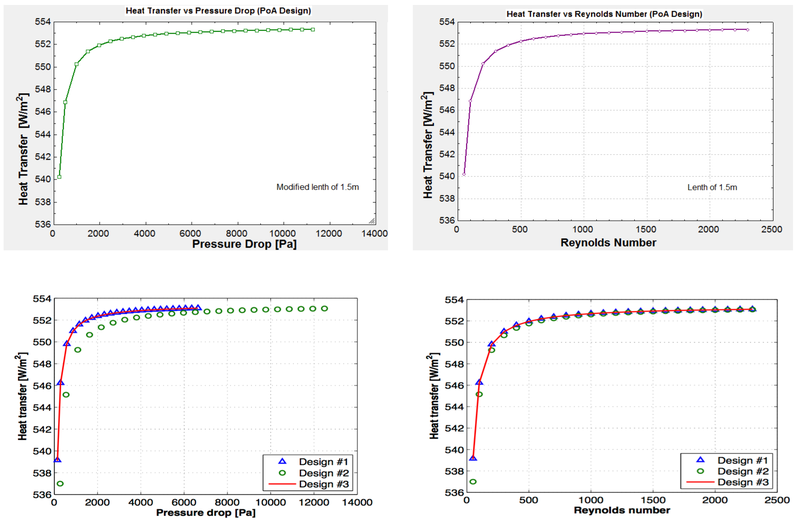

Figure 6. Heat transfer plotted with Pressure Drop and Reynolds number

1..10	ΔP [Pa]	Efficiency [dim]	flowrate [L/min]	Q_{cond} [W/m2]	$Re_{D,h}$ [dim]
Run 1	242.442	0.7786	1.1972	540.2542	50.000
Run 2	1454.653	0.7947	7.1831	551.3757	300.000
Run 3	2666.864	0.7961	13.1690	552.3973	550.000
Run 4	3879.074	0.7967	19.1549	552.7808	800.000
Run 5	5091.285	0.797	25.1408	552.9818	1050.000
Run 6	6303.496	0.7971	31.1267	553.1055	1300.000
Run 7	7515.707	0.7973	37.1126	553.1893	1550.000
Run 8	8727.918	0.7974	43.0985	553.2499	1800.000
Run 9	9940.128	0.7974	49.0844	553.2956	2050.000
Run 10	11152.339	0.7975	55.0703	553.3315	2300.000

Figure 7. Various parameters simulated for open profile mini-channel heat exchanger

Conclusion

- Pressure drop increased by less than 175 Pa
- Heat Transfer to working fluid difference was insignificant
- Potential Installation sites being analyzed
- Aluminum begins to make an appearance in solar collector field
- Open profiles available can potentially reduce cost of manufacturing

Future Direction

Remarkable performance results of the aluminum mini-channel solar water heater hint a huge potential for its marketability and commercialization. If market size and awareness increases, application of this novel design could significantly impact residential and commercial CO_2 footprint.

References

[1] Y. Tian, C. Y. Zhao, A review of solar collectors and thermal energy storage in solar thermal applications, Applied Energy 104 (2013) 538–553.

[2] M. Thirugnanasambandam, S. Iniyan, R. Goic, A review of solar thermal technologies, Renewable and Sustainable Energy Reviews 14 (1) (2010) 312

[3] N. Sharma, G. Diaz, Minichannel tube solar collector, US patent US 2011/0186043 A1 (August 2011).

[4] Duong, Van Thuc. (2015). MINICHANNEL-TUBE SOLAR THERMAL COLLECTORS FOR LOW TO MEDIUM TEMPERATURE APPLICATIONS. UC Merced: Mechanical Engineering.

[5] H. Müller-Steinhagen, K. Heck, A simple friction pressure drop correlation for two-phase flow in pipes, Chemical Engineering and Processing: Process Intensification 20 (6) (1986) 297–308.

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