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Thermoelectric power generation from waste heat of natural gas water heater

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Abstract

Waste heat is a viable source of recoverable energy in both industrial and domestic scenario. One of the methods to convert waste heat to electrical power is by using thermoelectric cells. In this paper, a power generation unit consist of 60 TECs was designed, fabricated and tested with the aim to recover the waste heat from domestic natural gas water heater. In the conceptual design, the waste heat from the flue is transferred to the hot water reservoir by using heat pipes (with fins). The cold water is entering to the power generation unit and serving as coolant for the TECs and thus at the same time, the cold water is preheated prior entering to the burner and this unit as a cogeneration system. In the experiment, the power generation unit was tested in a hot water bath at varying hot water temperature (50 °C -100 °C) and different cold water flow rates, ranging from 11 LPM to 33 LPM. With 60 TECs, the power generation unit has generated the electric power at the minimum of 3.9 W and a maximum 42.4 W under maximum flow rate, with the aforementioned range for hot water temperature and incoming cold water at 19.5 °C, which corresponds to typical scenario for hot water heating system.

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Keywords: Thermoelectric generator; Power generation; Waste heat; Heat recovery; Hot water heater; Renewable energy

1. Introduction

In recent years, sustainable resource for electricity generation has been something of which the society has undertaken to take charge on the emissions and to keep up with our rapidly growing economy. Yearly, significant

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amount of waste heat from both commercial and residential appliances is lost into the atmosphere, from which the potential never gets harnessed. With limited technology of waste heat recovery systems around, an alternative green, reliable and cost effective method is by the use of thermoelectric technology, which utilizes a solid state device, capable of converting temperature gradients into electric power. Numerous research has been carried out to investigate the potential of thermoelectric system with various kinds of heat source such as automotive exhaust heat [1,2], thermal oil heater [3], cook stoves [4,5] and waste heat from industrial process [6]. In Australia, 48% of Australian households use natural gas to power their hot water heaters, plus another 4% in remote areas use LPG systems [7]. Thus, there is more than half of the Australian household's have a perfectly viable heat source for the generation of electricity. By scavenging the hot exhaust gas exiting the flue and the use of cool water from mains, we are able to use the temperature gradient for power generation using TECs. Besides preheat the water entering the hot water service the system proposed is generating a small amount of usable electrical power.

Nomenclature

PGU	power generation unit
TEC	thermoelectric cell
T_c	cold side temperature
T_h	hot side temperature
$\dot{V}_c$	cold side volume flow rate

2. Operation of domestic natural gas heater and conceptual design of test rig

The operation (the heating cycle) of the typical domestic natural gas heater can be illustrated in the diagram given in Fig. 1.

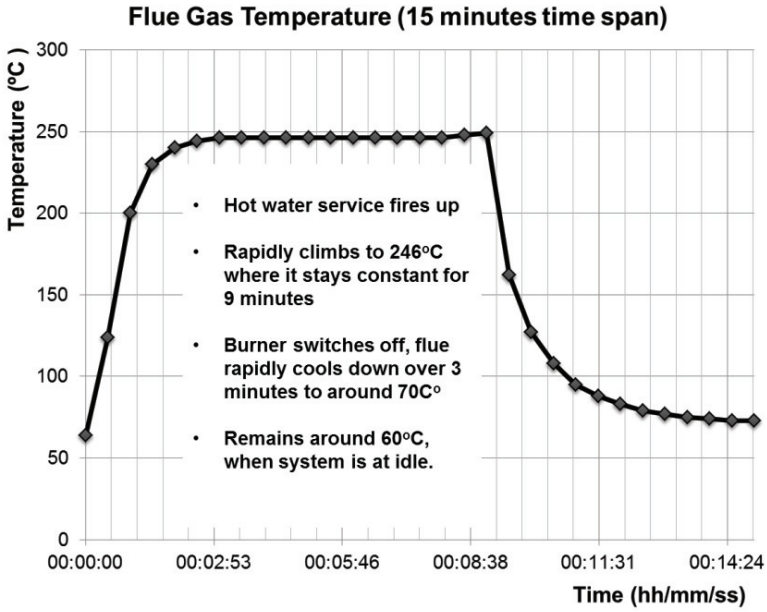

Fig. 1. Typical heating cycle of domestic natural gas heater.

Fig. 2 shows the schematic diagram of the domestic natural gas heater coupled with PGU. A loop heat pipe (1) is transferring the exhaust heat to the PGU. The natural gas or propane flame (11) heats the water inside the tank, in which then the exhaust gas also heating the heat pipe. From here, due to the thermosiphon effect the working fluid in