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Drain water heat recovery horizontal for energy conservation and reduction of CO_2 emissions

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Abstract. One of methods to reduce energy consumption for hot water heating is install of Drain Water Heat Recovery (DWHR) units. The purpose of using this device is to take the thermal energy of the warm drainage water and transfer it to incoming cold water. Many DWHR systems work optimally in a vertical position. Due to the waste water flow in drain pipes. But these requirements are prohibitive to be applied on a large scale of this technology, as many buildings do not have enough space to accommodate the vertical DWHR in their sewage drainage system. This paper presents testing and analysis of the horizontal DWHR system. The result of the test showed the level of effectiveness of the horizontal DWHR unit created by 25.54 percent. Implementation of this technology in regional area, is one of the potential opportunities for energy saving, and reduce CO2 gas emissions.

1. Introduction

Energy efficiency has now become one of the indicators of economic development, and the rationalization of its use is the subject of many scientific studies. Around the world, the goal is to demonstrate the negative impact of energy on the environment, especially in the industries that contribute the most to its degradation. Data from the International Energy Agency showed that in 2010 carbon dioxide emissions from the world's fuel combustion amounted to 30,326 Mt. It was an increase of almost 94% compared to the previous 37 year, i.e. in 1973, when Emissions equivalent to 15,637 Mt. [1]. The increase in the amount of greenhouse gases entering the atmosphere is the consequence of growing demand for energy resulting from the growing population of the world, as well as the ongoing development of civilization. Environmental pollution is caused by excessive CO2 emissions resulting from the burning of fossil fuels, increasing the need to find solutions that will contribute to energy savings, and thus also protecting the atmosphere.

In the Paris agreement after the Conference, conference attendees in 2015, Conference of the Parties (COP) 21, representatives from all countries in the world approved the target to withstand the rise of global average temperatures up to below 2 °C above pre-industrial by reducing global greenhouse gas emissions. An important field of action was the demand for building energy, as it contributed a third of global greenhouse gas emissions in 2002 [2]. Therefore, the European directive on the energy performance of buildings states that all new buildings built after December 31, 2020 should be "buildings with almost zero energy". All member states are required to apply this directive in national legislation and set a comparable standard for this term [3].

It has made researchers develop new renewable energy research and research to improve energy efficiency in all areas. As well as conducted research activities to reduce the contribution of energy activities that resulted in global warming and climate change.

Globally, energy consumption in Indonesia during the years 2007 to 2017 experienced an average increase of 38% [4]. But the rapid growth of energy consumption was not followed by the efforts to increase energy efficiency in various sectors. Energy saving opportunities in both industrial and commercial sectors in Indonesia are large enough, which is an average of 10-30%. [5].

Most of the energy used in household water heaters is wasted for drainage systems by applications such as bathing, bathing, dishwashers etc. This heat recovery of waste from domestic wastewater has proven to be a viable method to improve the energy efficiency of the building. The existing system only operates vertically due to the nature of the waste water flow in the disposal pipe according to where the research was conducted. This research will make the system operate horizontally according to the condition of the building or villa in Bali. The existing models is shown in Figure 1.

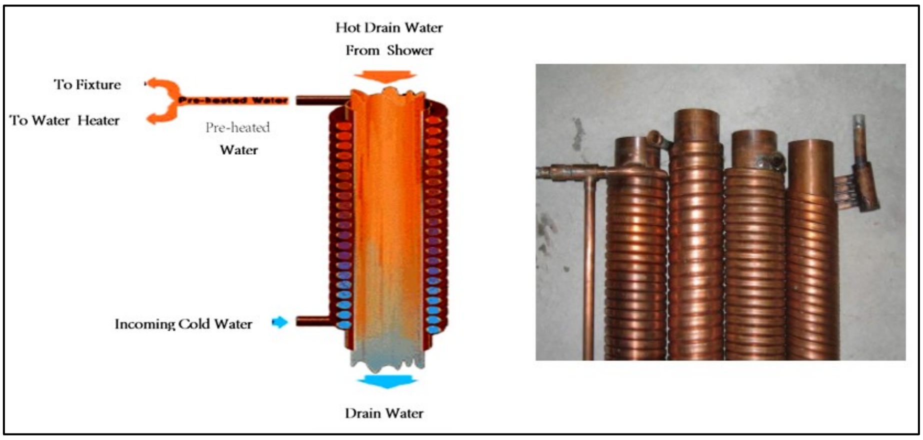

Figure 1. Models of Heat Recoveri Drain Shower vertikal (HRDS) [6].

Research has been conducted, waste water from the shower dumped into the drain, the average still contains 80-90% [7] of the heat energy it contains (relative to cold supply water) when leaving the water heater. A study of three manufacturers of DWHR units showed an energy saving of 16% on energy loads of water heaters.

Model that we will propose according to the condition that is in Bali, which will be put horizontally, where the pipe is the magnitude of the pipe drain is made of PVC material 3 inch size, pipe supplies cold water made of copper pipe 1/2 inches are inserted into PVC pipe.

2. Methodology

2.1. Drain Water Heat Recovery (DWHR)

The DWHR system operates on the principle of heat exchange between the incoming cold water supply and the flow water drain shower/waste that is still hot water from a building.

There are 2 types of DWHR that exist according to building type. Vertical and Horizontal type. Vertical type is applied to buildings or buildings that have a basement, while vertical for buildings that are not terraced or who do not have a basement. Fluid flow in drainage pipes is illustrated as in Figure 2.

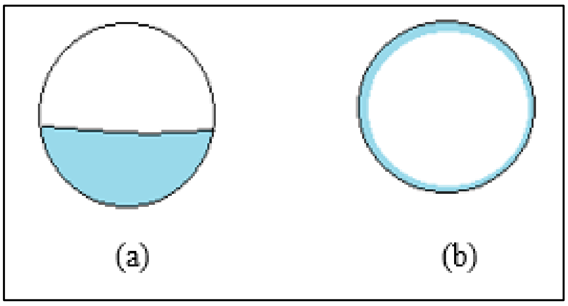

Figure 2. Cross sectional view of waste water flow in (a) Horizontal pipe drain and (b)Vertical pipe drain.

In the horizontal pipe drain, water flows under the pipe, while in the vertical, waste water will flow around the pipe wall lining the entire wall of the pipeline as the film stream. It is clear that the flow for heat exchange with high efficiency occurs throughout the drainage pipe walls. However that in the horizontal, heat exchanges only occur along the fractional wall of the pipeline, resulting in lower DWHR device efficiencies in previous research. Therefore modification of the design to overcome the efficiency of horizontal pipe drain.

2.2. Proposed new design

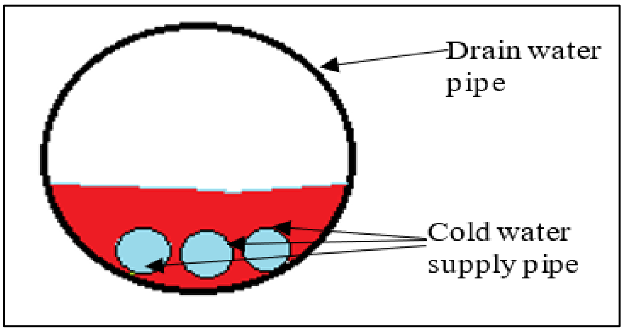

Figure 3. Section of the new design proposal DHWR.

Figure 3 the new section of the DWHR proposal, which aims to increase the heat transfer efficiency in the horizontal type. The proposed design consists of 3-inch PVC pipe drain. There are 3 pipes for cold water supply with 1/2-inch copper material inserted into pipe drain to maximize contact between hot water drainage with cold water coming in. Figure 4 shows the DWHR design applied to the residential house. Installed in the ground outside the building.

Figure 4. New Horizontal DHWR.

2.3. Effectiveness

The method for calculating the coefficient of overall heat transfer and the rate of heat transfer is that the effectiveness method of its effectiveness is the ratio of actual heat transfer rates to the maximum heat transfer rate possible in heat exchanger. The empirical heat transfer rate (q) is calculated using the actual effectiveness (ε) that takes into account the cold fluid output temperature. The method for calculating the coefficient of overall heat transfer and the rate of heat transfer is that the effectiveness method of its effectiveness is the ratio of actual heat transfer rates to the maximum heat transfer rate possible in heat exchanger. The empirical heat transfer rate (q) is calculated using the actual effectiveness (ε) that takes into account the cold fluid output temperature.

$$\varepsilon = \frac{(T_{c,o} - T_{c,i})}{(T_{h,i} - T_{c,i})} \tag{1}$$

$$C = \varepsilon\,(T_{h,i} - T_{c,i}) \qquad \text{kW} \tag{2}$$

$T_{c.o}$ = Cold water supply out (ºC)
$T_{c.i}$ = Cold water supply in (ºC)
$T_{h.i}$ = water inlet (ºC)

$$C = \dot{m}.Cp \ \text{(J/s ºC)} \tag{3}$$

$\dot{m}$ = mass flow rate cool water (kg/sec)
C_p = fluid heat capacity cool water (kJ/kg ºC)

2.4. Experimental set up and design

Based on conceptual design, test rig Protite is made as in Figure 4. Test rigs consist of 3-inch PVC drainage pipes. 3 pieces of copper pipe 1/2 inch as cold water supplies inserted as in Figure 3. Pipe supplies cold water is positioned unmerged along a part of waste pipe to optimize heat exchange and drainage pipe of PVC Material act as insulator to retain heat from drainage water. The work scheme of the expression done is shown in Figure 5.

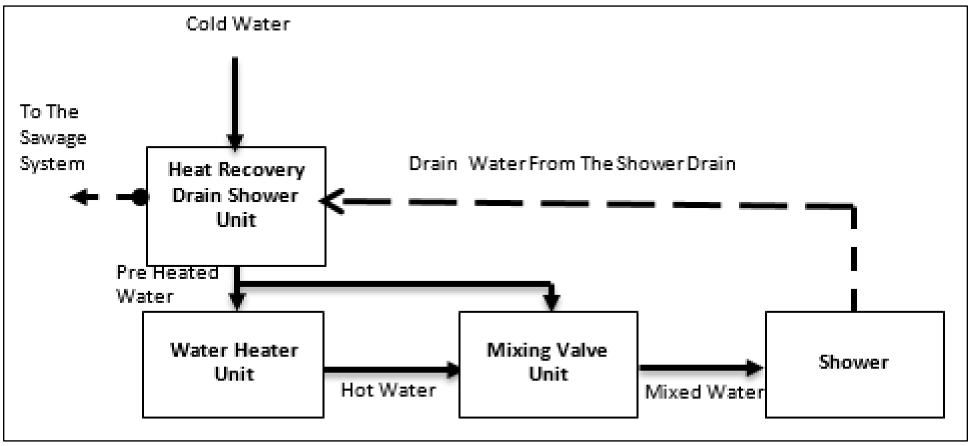

Figure 5. Working scheme test Rig heat recovery drain shower.

Testing procedures are conducted following The Natural Resources Canada [6] standard, with the following provisions:

- Flow conditions should be the same, namely the supplies cold water and the supplies water drainage must be the same.

- Condition supplies cold water should be 28 °C ± 1.5 °C
- Flow rate should be 9.5 l/min. ± 0.5 l/min.
- Ambient temperature should be equal to the average temperature of the unit DWHR ± 5 °C.
- Temperature measurement should be taken from the water flow and not outside the pipeline.

In addition to the above provisions, measurements in this study used a K-type Thermocouple. This is recorded and logged using data logger (Data scan 7320 MSL) and laptop.

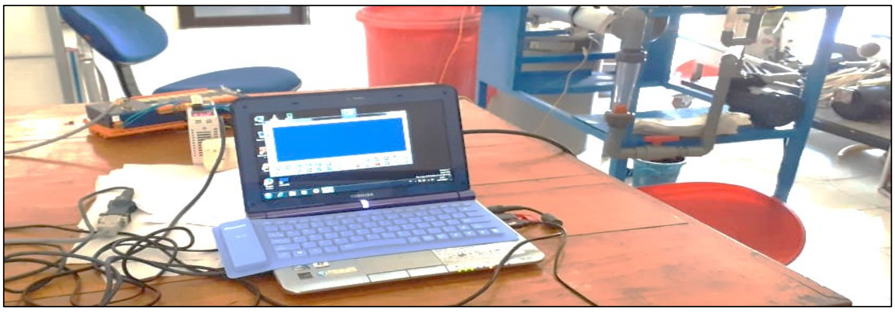

Figure 6. Data retrieval process.

3. Results

3.1. Experimental performance

The test is conducted in 3 conditions; (1) The first condition with standard conditions, (2) The second condition of Flow is changed and the temperature of incoming drainage water increases (54°C) (3) The third condition of the Flow is equal to the second condition and the temperature of the inlet drainage is equal Standard (39°C). Performance of the DWHR is tested as shown in Table 1.

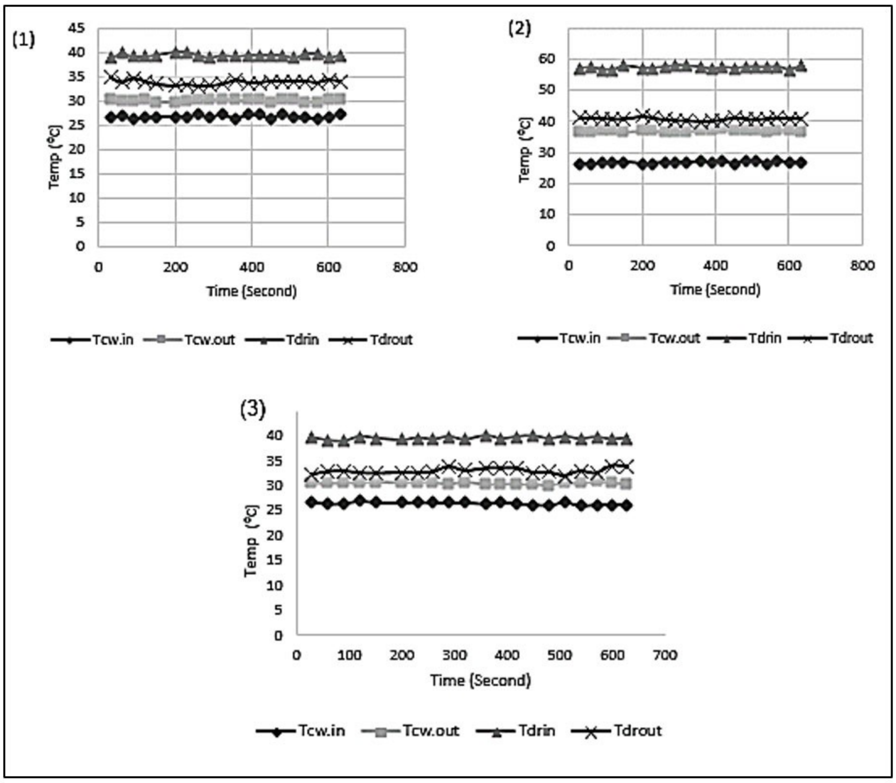

Figure 7. Test result with 3 condition.

Tabel 1. Experiment result.

Experimen condition	Experiment Result	Effectiveness
Condition 1	$T_{CW\ in}$ = 26.78 ºC $T_{CW\ out}$ = 30.00 ºC T_{drin} = 39.39 ºC T_{drout} = 33.85 ºC Q = 9.5 l/min	25.54%
Condition 2	$T_{CW\ in}$ = 26.73 ºC $T_{CW\ out}$ = 36.97 ºC T_{drin} = 57.37ºC T_{drout} = 40.82 ºC Q = 6.5 l/min	33.44%
Condition 3	$T_{CW\ in}$ = 26.55 ºC $T_{CW\ out}$ = 30.43 ºC T_{drin} = 39.60 ºC T_{drout} = 31.91 ºC Q = 6.5 l/min	29.74%

Performance DWHR on standard trial conditions showed 25.54% slightly higher than the results of research conducted by Aonghus McNabola and Killian Shields for 23.0% [8]. Effect of due to changes in discharge drain water temperature lower water drain and high drain temperature shows the performance of 33.44% DWHR, whereas if issuer lowered to produce performance 29.74%.

3.2. Energy savings and economic benefits

Electrical energy that can be saved from testing with some conditions is like in Table 2. Data from BPS 2019 the number of foreign tourist arrivals entered through Bali for 6,025,760 people [9], it is assumed that every guest arriving in Bali will only stay for a day, if everyone takes a shower two times a day and turns on the shower for three minutes.

Table 2. Energy saving from experiment.

Effectiveness	Energy saving (kW)
25.54%	31.072

Using these assumptions, the potential savings can be obtained by 18,723,228 kW/year. Potential financial savings that can be obtained with electricity price IDR 1,467.28/kWH [10] is IDR 27,472,218,225.19 or about IDR 27.5 M.

Based on the Bank's Word data 2019, CO2 intensity (kg per kg of oil equivalent energy use) C02 emission (kg/kWh) for Indonesia at 2.1 [11], the potential of CO2 emissions reduction if DWHR was applied was 3.9 tons of CO2/year.

4. Conclusions

Horizontal DWHR application is very possible in Bali, because of the condition building is not highrise building. The results of this test show that this method can be an alternative to savings with a satisfactory outcome rate. Potential financial savings that can be about IDR 27.5 M and the potential of CO2 emissions reduction is 3.9 tons of CO2/year.

5. References

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