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Reducing CO_2 emissions in the individual hot water circulation piping system

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ABSTRACT

Central hot water piping systems are used in large lodging buildings (e.g. hotels, dormitories, etc.) for comfort and convenience. However, the big problem to this type of system is that once the hot water leaves the storage tank and travels through the system piping, the water temperature drops due to the travel distance and ambient air temperature. Because of this drop in temperature, users need to wait for the undesirable cool water to flow out of the system before the desired hot water starts flowing out of the system. The ideal solution to this problem is to reheat the undesirable (cooled) water in the system by the use of an individual hot water circulating system. This study focuses on water saving and energy consumption in the individual hot water circulating system. The results show energy consumption is 50% less than the non-circulating central hot water system. Three parameters in wasted water demand, electric consumption, and heating source consumption were considered to transfer them with CO_2 transfer coefficient to estimate the reducing CO_2 emission. The hot water circulation system presents the benefits of water and energy saving, and reduction of CO_2 emission, but the piping connection should be improved for easy installation in the existed buildings in the future.

1. Introduction

Central hot water piping systems are used in large lodging buildings (e.g. hotels, dormitories, etc.) for comfort and convenience, as shown in Fig. 1. However, the big problem to this type of system is that once the hot water leaves the storage tank and travels through the system piping, the water temperature drops due to the travel distance and ambient air temperature. Large amounts of energy are required for continuous heating and circulation. To evaluate energy consumption and hot water temperature drop in piping, Lee et al. [1–3] utilized simplified empirical equations and figured out the hot water temperature drop in various lengths of stainless steel piping (13A) as shown in Fig. 2. The previous studies only discussed the individual hot water non-circulating system temperature drop and energy consumption. Cheng and Lee [4] figured out that energy consumption used during heating almost equaled the heat lost during transmission. Research of the energy consumption in a central hot water circulation system indicates that the amount of energy required for circulation and usage is approximately the same as the amount required for generating hot water.

Numerous studies proposed various conservation methods such as the Building Energy Conservation Regulations in Japan (Association of Building Environment Energy Conservation [5]), which focused on energy consumption of the hot water supply system and included heat loss due to circulation. Kamata et al. [6] and Sakaue et al. [7] proposed a standard hot water temperature for a supply system based on energy conservation in Japan. Balaras et al. [8] determined that the variation in pipe heat loss was caused by variations in energy consumption. Jaĉimovic et al. [9] proposed that the heat loss from heated objects is a linear function of the outdoor temperature. And Morida [10] presented heat loss calculation equations for distribution pipes. Toyosada [11] figured out the economic benefit of carbon tax via water saving [12], Cheng focused on the inter-relationship between water use and energy conservation and proposed an evaluation model of CO_2 emission for a water saving strategy [13].

Most residential buildings utilize a central hot water supply system because of the varying usage time periods, and to save energy. However, the problem with this type of system is once usage (circulation) stops, the hot water remaining in the pipes cools due to the ambient air around the piping. Therefore, before use, users need to wait for the undesirable cool water to flow out of the system before the desired hot water starts flowing out of the system. This process may waste a lot of water, depending on the length of the piping system. The ideal solution to this problem is to reheat the undesirable

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Nomenclature

A	cross section of pipe (m^2)
B	numbers of household in residential building (household)
C_W	CO_2 emission of water demand (kg)
C_E	CO_2 emission of electic consumption (kg)
C_S	CO_2 emission of heating source consumption (kg)
E_H	energy consumption of heater (kWh)
E_R	energy consumption of circulator (kWh)
L	pipe length (m)
N	using times (time)
P	persons in one household (persons/household)
Q_1	water volume in heater outlet (m^3)
Q_2	water volume in faucet inlet (m^3)
S	heating source (kg in LPG, or in different heating source)
t	period time (s)
v	water velocity (l/s)

Greek letters

ξ_W	CO_2 emissions coefficient = 0.1002 kg/m^3 in water
ξ_E	CO_2 emissions coefficient = 0.62 kg/kWh in electric
ξ_S	CO_2 emissions coefficient = 2.09 kg/m^3 in natural gas; 1.75 kg/kg in LPG; 2.92 kg/kg in coal; 2.73 kg/l in diesel oil; electric is same as ξ_E. $^*CO_2$ emissions coefficients are referred by Taiwan Environmental Protection Administration (EPA), greenhouse Gas Registry system, 2013. These coefficients relate to the heat capacity in different material producing process in different countries, please check them in the right data while using.

Subscripts

c	circulation system
i	pipe character (cross section area and length)
n	non-circulation system
p	pipe

cool water inside the piping system by the use of an individual hot water circulation piping system. This study discusses water saving and energy consumption in the individual hot water circulation system.

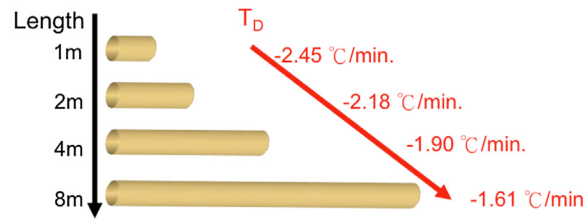

Fig. 2. Hot water temperature dropping time in different length stainless pipe (13A).

2. Individual hot water circulator

An individual hot water circulator with water reheat piping can save energy by reducing temperature drops while providing hot water at suitable temperatures. The circulation system consists of a check valve (C_1) installed before ball valves (faucets) to connect with transmission pipes for recycling and reheating the cooled water in the independent hot water circulation system, as shown in Fig. 3.

Two inlet pipes connect with a circulator, one pipe is for recycling the cooled water, and the other pipe is for cool water from urban water. A controller measures the recycled water temperature and sends an electronic signal to mechanically switch the water inlet between the recycled water and urban water. A check valve (C_2) is installed to prevent urban water from flowing into the circulation pipe. The water flows out from the circulator into the heater (e.g. gas, electrical, solar, etc.) or hot water tank to heat the recycled water or urban water. The individual hot water circulator recycles the cooled water, provides hot water, and saves a considerable amount of energy compared with the central circulated hot water system.

There are two additional parts needed in the individual hot water circulation system; the circulator, and the piping that connects from the supply pipe to the circulator and heater. Based on investigation of hot water pipe lengths in Taiwan [4], the average length is around 6.5 m (the shortest is 0.5 m, the longest is 20 m) in the residential buildings (apartments and houses). The controller for the circulator can be set by timer and remote panel to reduce the amount of electrical wiring. The added system installation costs is under US$500 with 10 m (13A) circulation pipes combined with the original hot water supply system via self-installation by the user in the newly constructed building or existing building.

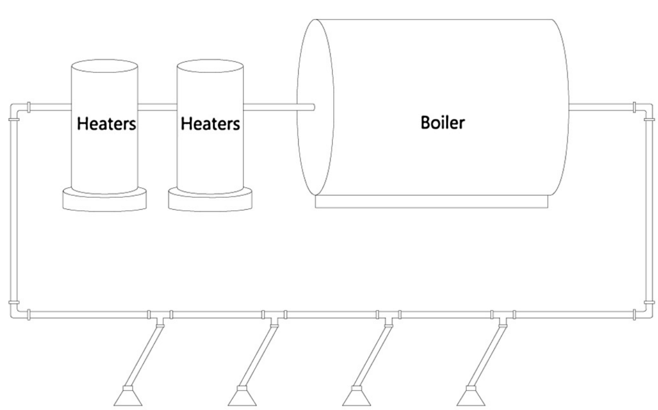

Fig. 1. Typical central circulated hot water system.