CIB W062 Symposium
Haarlem, 2017

The prediction method of supply water temperature for energy simulation of hot water supply system

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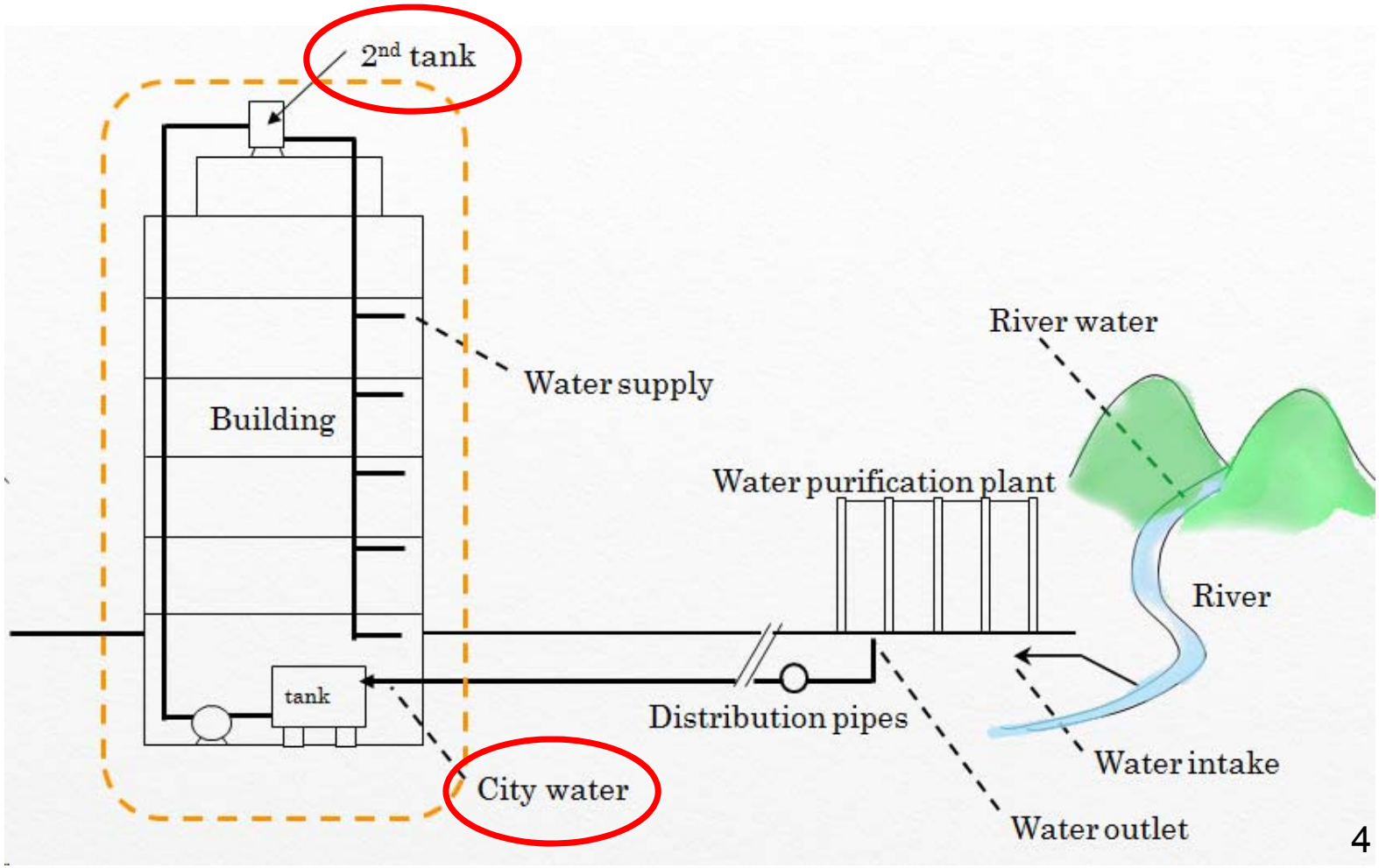
Background

- Energy consumption for hot water supply systems is high in buildings such as dwellings, hotels and hospitals.
- It sometimes accounts for up to 30 percent of a building's total energy consumption.
- Energy consumption for a hot water supply system is very important in terms of energy saving in buildings.

Target of this study

- Energy load in hot water supply system is the product of specific heat, flow rate and temperature difference between hot water in use and supply water.
- So, supply water temperature is one of the important input conditions in order to evaluate and predict the energy consumption for hot water supply
- Therefore, this study focuses on supply water temperature in a building[1)].

An overview of water flow



This paper will proceed as follows:

(1) A calculation method of city water temperature from river water temperature as the water source, from Iwamoto et al.[2)]

(2) A calculation method of the break tank water temperature from Iwamoto et al.[3)]

(3) A calculation method of supply water temperature combining (1) and (2).

(4) Results of a case study for a business hotel on energy consumption for hot a water supply system through a simulation[4)], using the supply water temperature from (3).

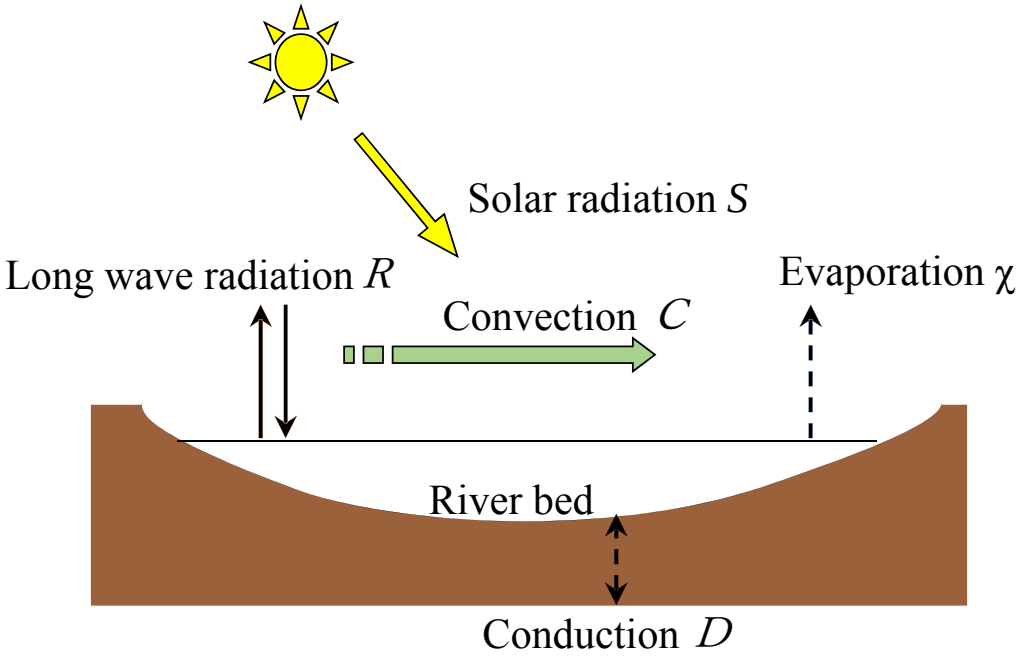
Calculation method for city water temperature

(1) The equilibrium water temperature of the river shown as formula (2).

(2) The river water temperature T_{WM} at intake in the purification plant shownvas formula (3),

(3) The city water temperature is set to T_{OUT} shown as formula (5).

Heat Balance of river water



$$S = (1 - ref_W) S^{\downarrow}$$

$$C = c_p \rho C_H U_M (T_M - T_{MW})$$

$$R = \varepsilon L^{\downarrow} - \varepsilon\sigma (T_{MW} + 273)^4$$

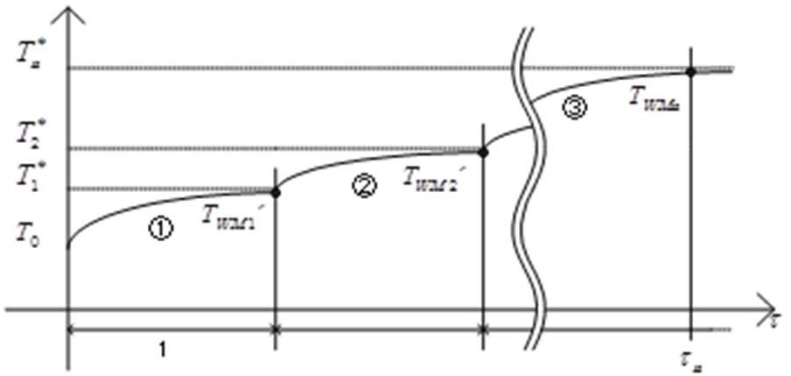
$$\chi = i \rho C_H U_M (q_{SAT}(T_{MW}) - q)$$

$$T^* = T_M + \frac{S + \varepsilon L^{\downarrow} - \varepsilon\sigma(T_M + 273)^4 - \chi}{\mu} \quad (2)$$

Calculation method for river water and city water temperature

$$T_{WM} = T_0 + \left(T^* - T_0\right)\left[1 - \exp\left(-\frac{\tau}{\tau_0}\right)\right] \quad (3)$$

$$\tau_0 = \frac{c_W \rho_W d_W}{\mu \times 3600}$$



$$\text{①}\ T_{WM1} = T_0 + \left(T_1^* - T_0\right)\left[1 - \exp\left(-\frac{\tau}{\tau_{01}}\right)\right]$$

$$\text{②}\ T_{WM2} = T_{WM1}' + \left(T_2^* - T_{WM1}'\right)\left[1 - \exp\left(-\frac{\tau - 86400}{\tau_{02}}\right)\right] \quad (4)$$

$$\text{③}\ T_{WMn} = T_{WM(n-1)}' + \left(T_n^* - T_{WM(n-1)}'\right)\left[1 - \exp\left\{-\frac{\tau_n - 86400(n-1)}{\tau_{0n}}\right\}\right]$$

$$T_{OUT} = T_{IN} + d_0\left(\nu \times 10^6\right) \quad (5)$$

Calculation method for tank water temperature

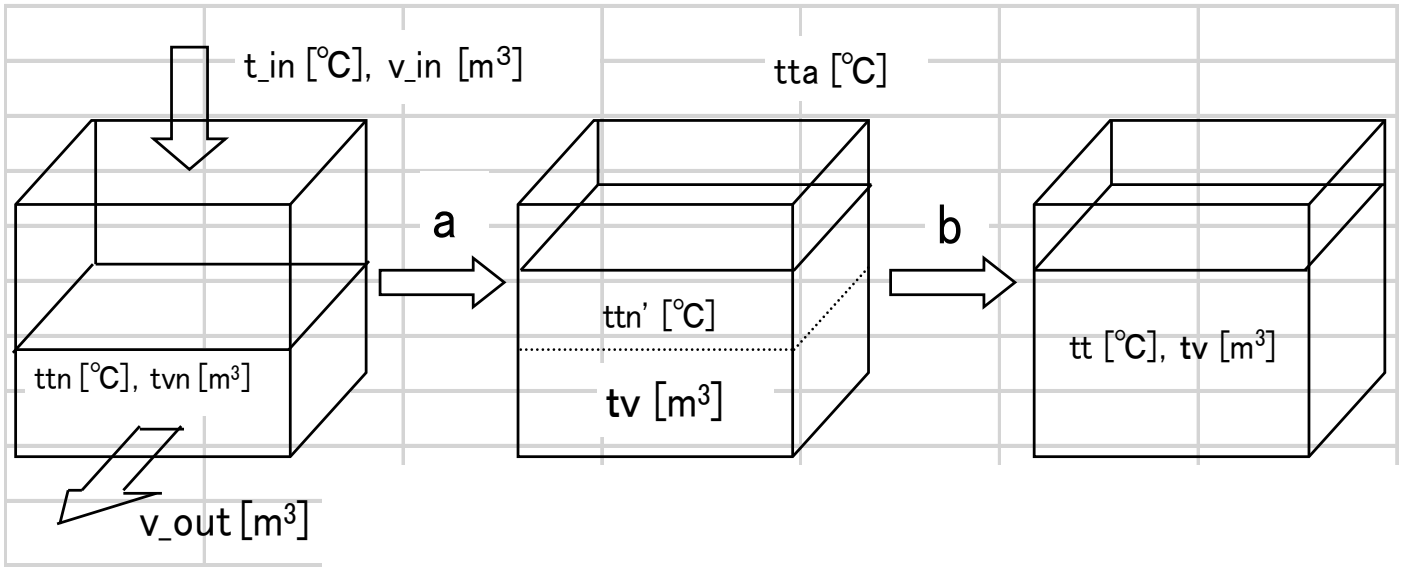


Fig.4 A summary of the calculation method of tank temperature

- Step 1 calculates the water volumes for supply and use every hour
- Step 2 calculates the initial temperature of the tank water (Arrow "a" in Fig.4)
- Step 3 calculates the temperature of tank water with overall heat transfer from/to the ambient environment (Arrow "b" in Fig.4)

Water temperature in buildings

According to Iwamoto et al.[3)], the difference between measurement and calculation results averaged for seven days is about 0.20 ° C in the break tank and 0.13 ° C in the 2nd tank,

This result shows the required conditions to calculate the temperature of tank water.

(1) Water volume of use and supply

(2) Water temperature of supply

(3) Ambient air temperature around water tank

(4) Control condition of tank water volume

Case study : a business hotel

Table 1 A summary of the hotel setting

The business hotel has	seven stories and a basement with 96 rooms Central hot water supply system booster pump water supply system.
The number of guests	150
Daily usage of water	57,500 L/day
Daily usage of hot water	29,775 L/day
The capacity of the gas boiler	116 kW X 2
The efficiency of the gas boiler	0.78
Circulation pump	0.25 kW
Circulation pump for boilers	0.75 kW2
Storage tank volume	4.5 m^3
Storage tank insulation	Rock wool 75 mm
Break tank volume	28 m^3

Water usage

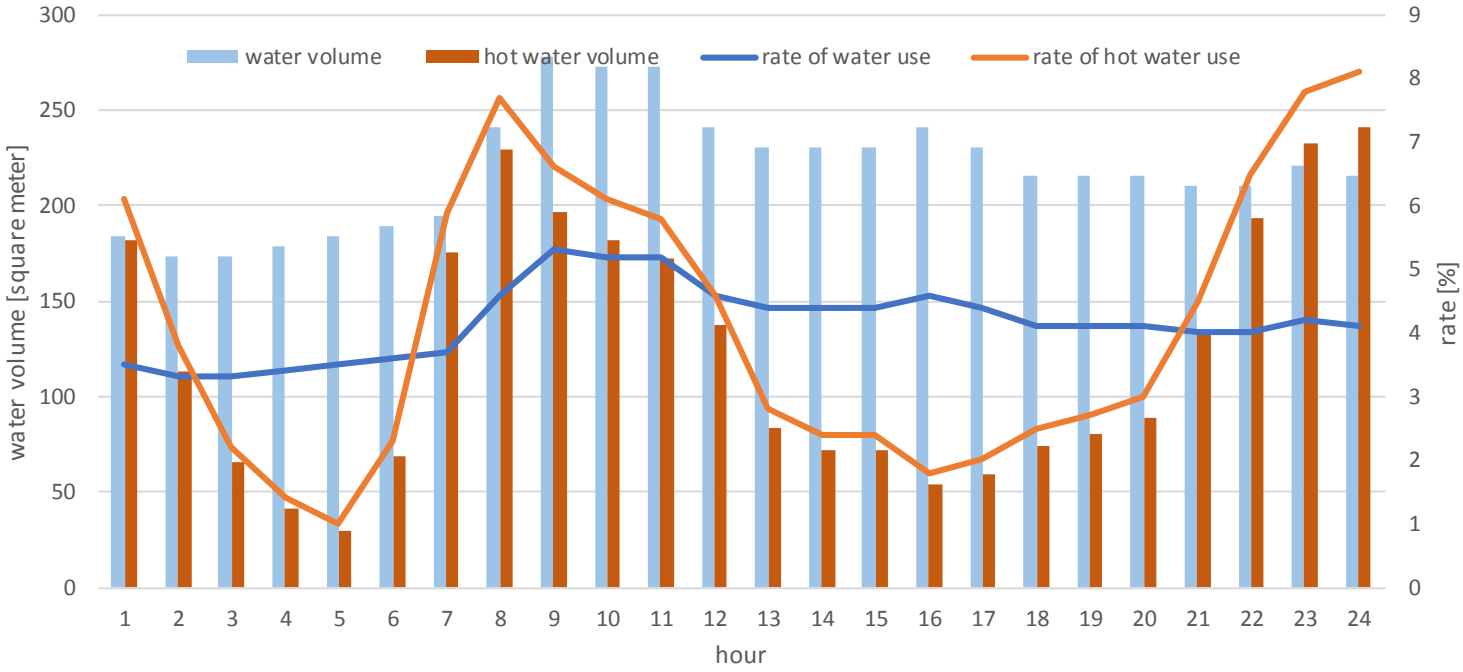


Fig.5 Water schedule and hot water usage

The calculation result of water temperatures (1)

The annual average of temperature difference between the measurement and calculation is **0.760** ° C.

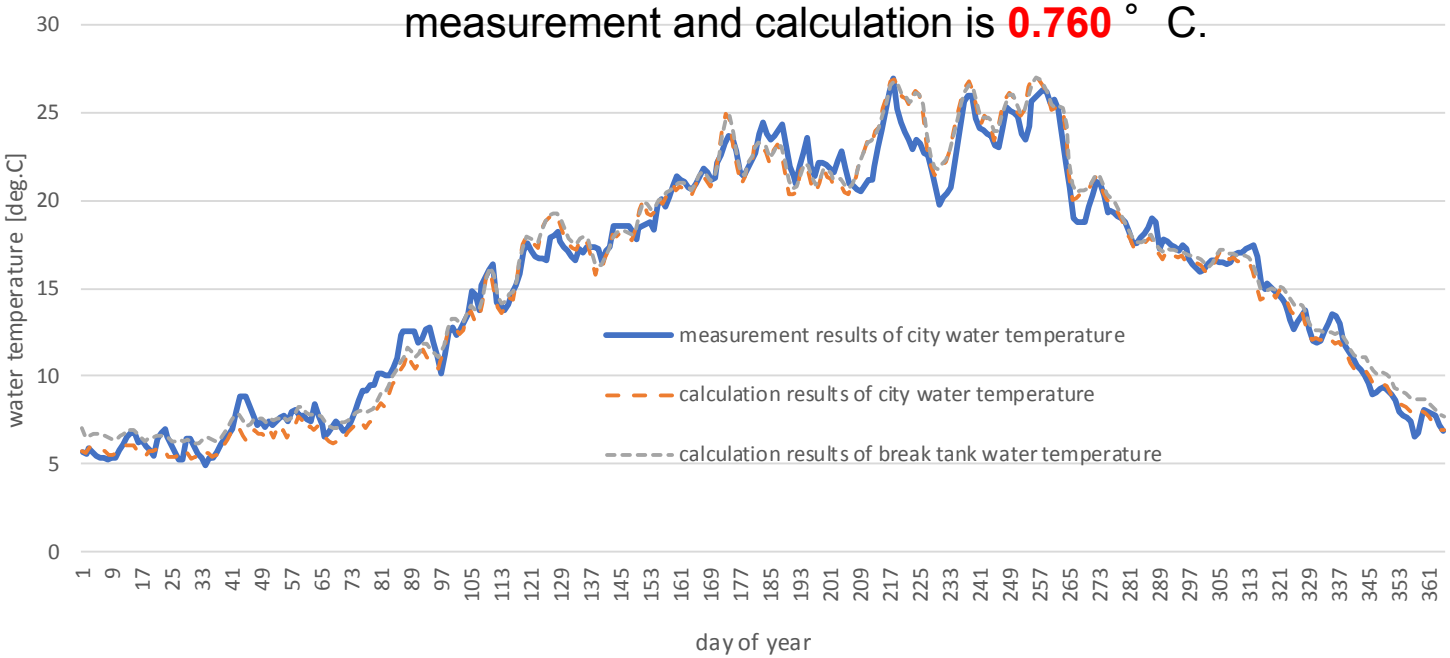


Fig.6 The results for water temperatures

The calculation result of water temperatures (2)

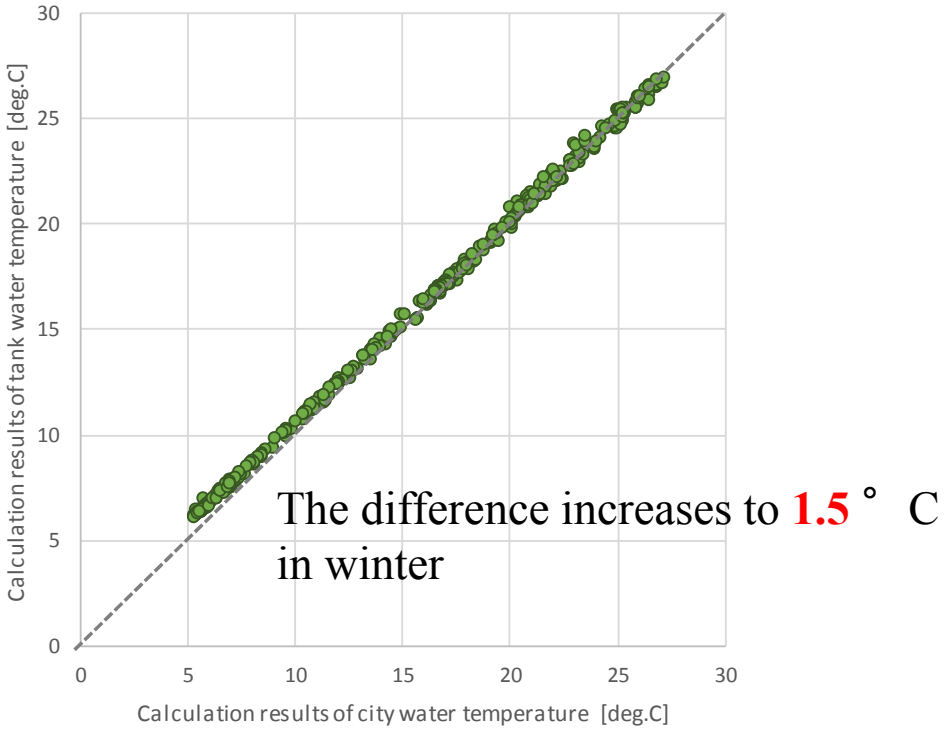


Fig.7 Temperature results for city water and break tank water

Calculation results of primary energy consumption

Table 2 The calculation results of annual primary energy consumption by CEC/HW [4)]

Item	CEC/HW[*)]	City water (%)	Tank water (%)
Hot water supply load	1,242	1,260 (101.4)	1,241 (99.9)
Heat loss due to dead end piping	021.2	021.4 (100.9)	021.2 (100)
Heat loss from circulation pipes	156.2	←	←
Heat loss from heat source side pipes	029.7	←	←
Heat loss from the hot water storage tank	010.2	←	←
Consumption energy of circulation pumps	042.5	042.8 (100.7)	042.4 (99.8)
Total primary energy consumption	**1,913**	**1,936 (101.2)**	**1,912 (99.9)**

Conclusion

This paper shows:

(1) a calculation method for temperature of city water and break tank water from references[2),3)].

(2) the calculation results of a case study for a business hotel. Water temperature differences between city water and tank water are small, such as in the example of a hotel where water is often used all day but the temperature difference is up to 1.5 ° C in winter

We plan to measure the tank water temperature over more than a year and try to show the validity of the calculation method by comparing measurement and calculation results.