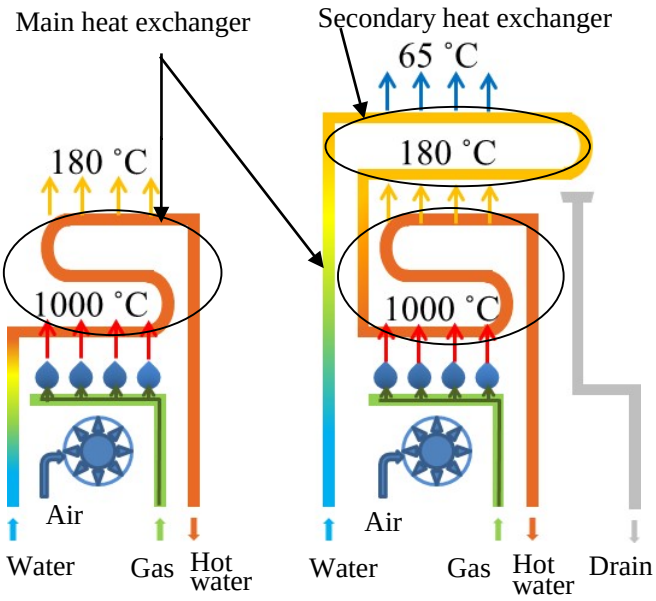
Figure Captions

Table Captions



(a) Without secondary heat exchanger (b) With secondary heat exchanger

Fig. 1. Water heater systems.

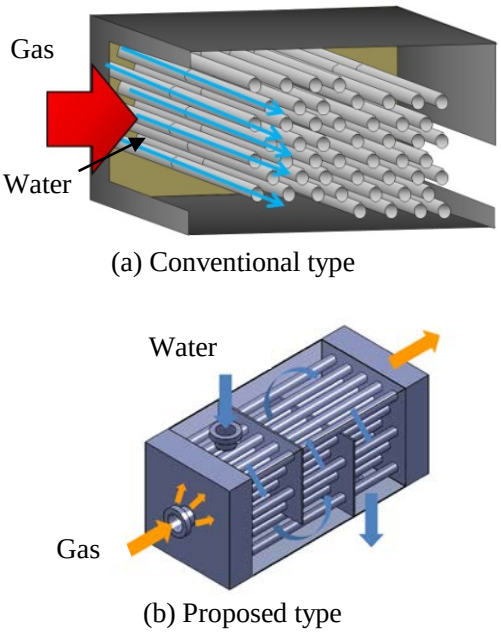
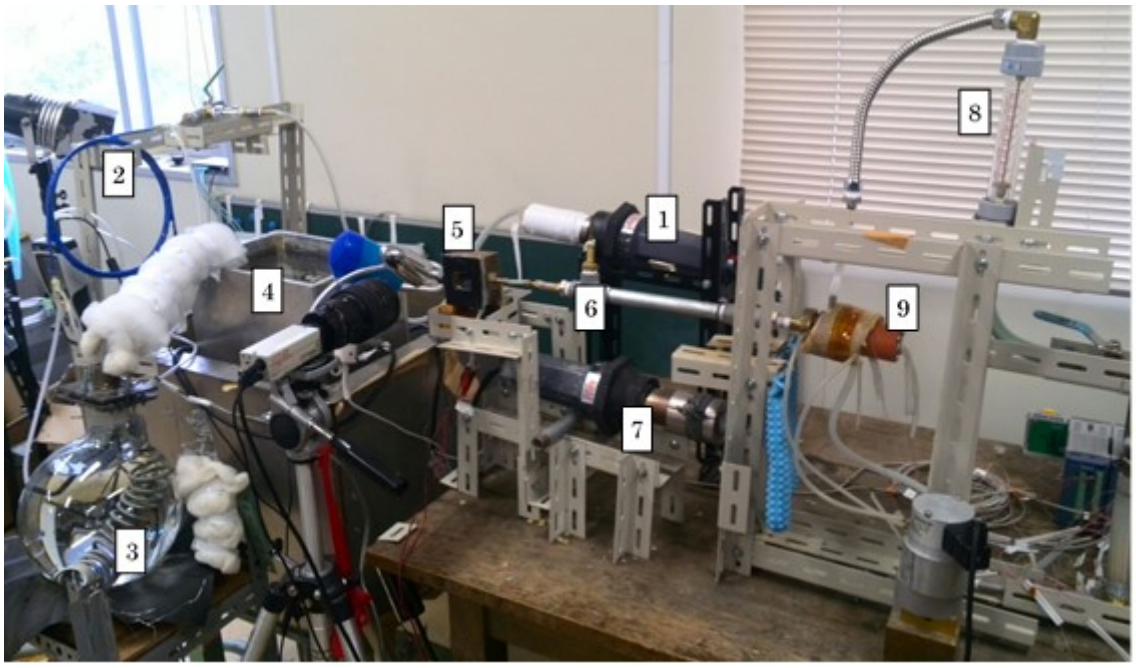
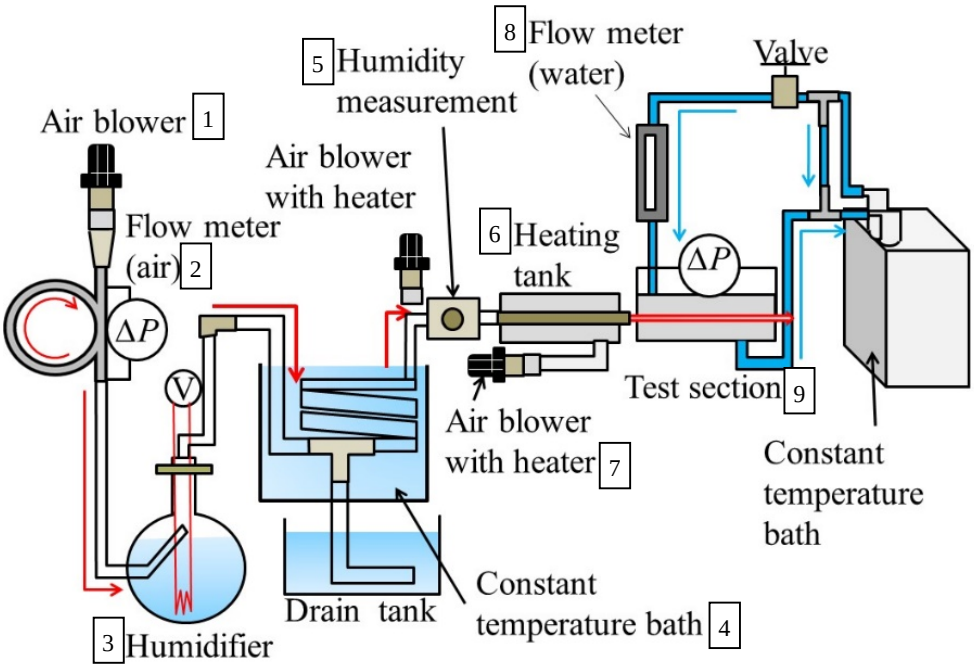


Fig. 2. Schematic illustration of a shell & tube type heat exchanger.



(a) Photograph of experimental system



(b) Schematic of experimental system

Fig. 3. Experimental system

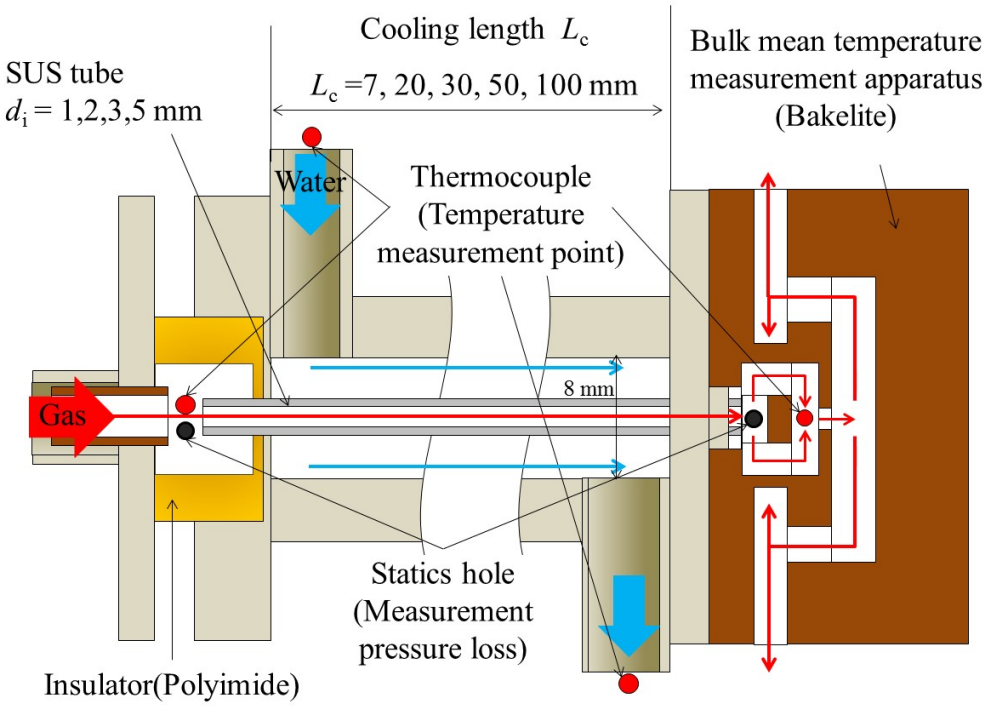
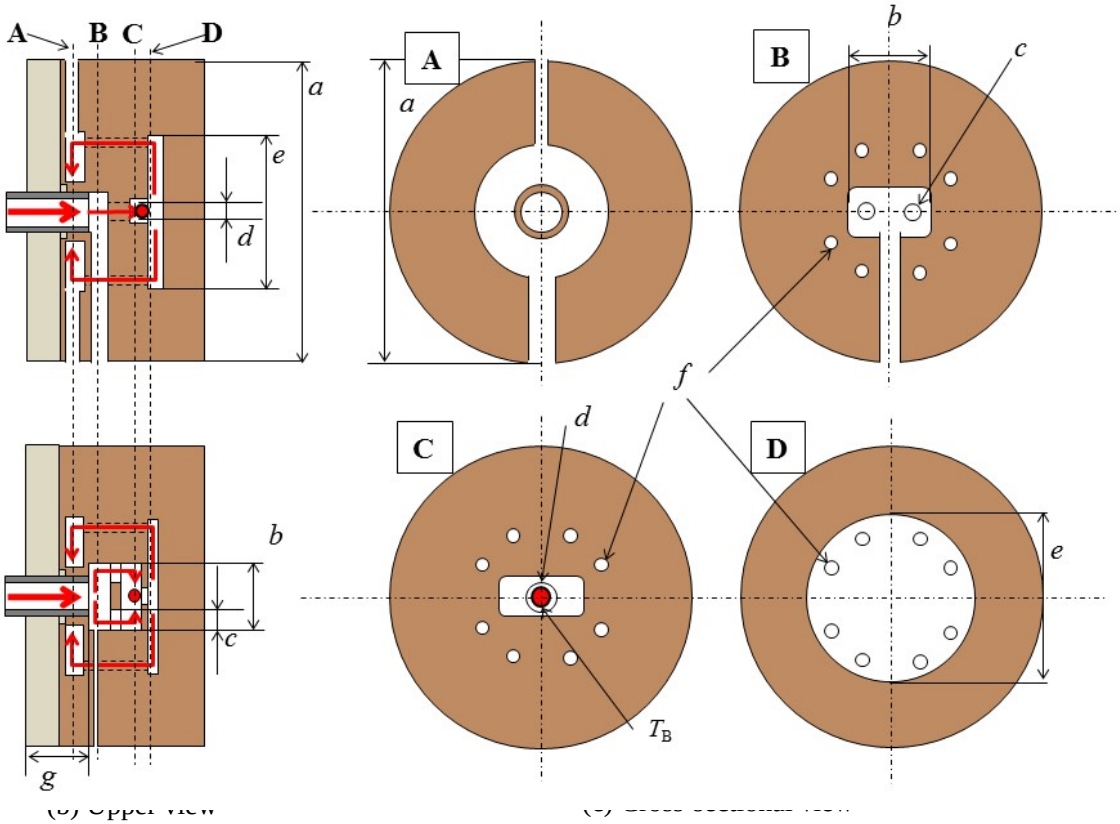


Fig. 4. Details of test section.



(d) Dimensions of apparatus

d_i (mm)	a (mm)	b (mm)	c (mm)	d (mm)	e (mm)	f (mm)	g (mm)
1.0, 2.0	45	7	1	1	20	0.8	3
3.0, 5.0		14	2.5	2.5		1.6	

Fig. 5. Details of bulk mean temperature measurement apparatus.

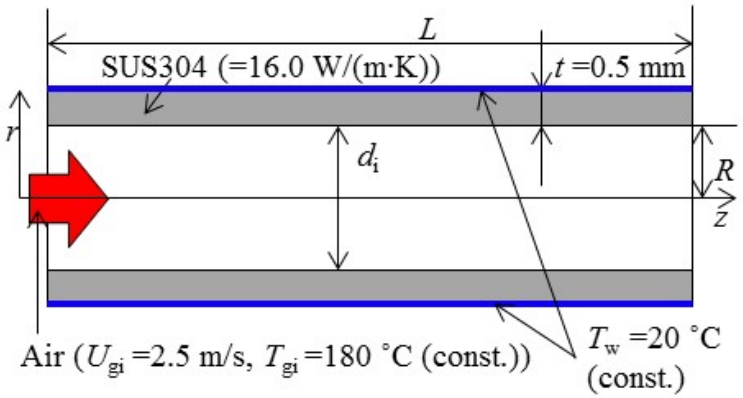


Fig. 6. Calculation model.

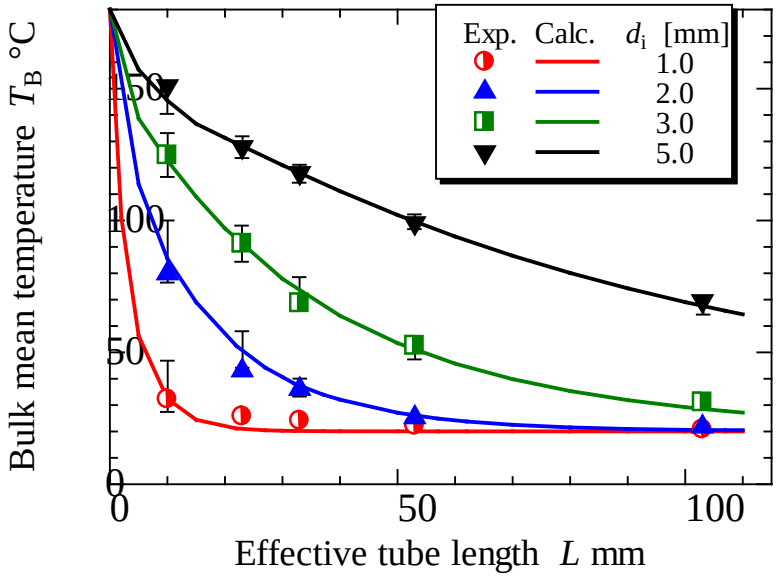


Fig. 7. Variation of bulk mean temperature against effective tube length for dry air.

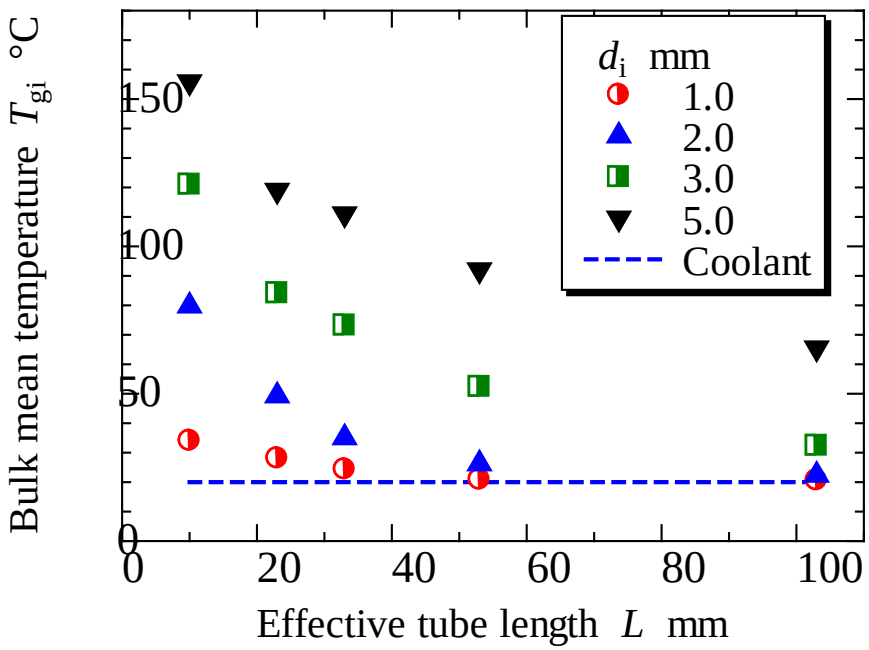


Fig. 8. Variation of bulk mean temperature against effective tube length for moist air.

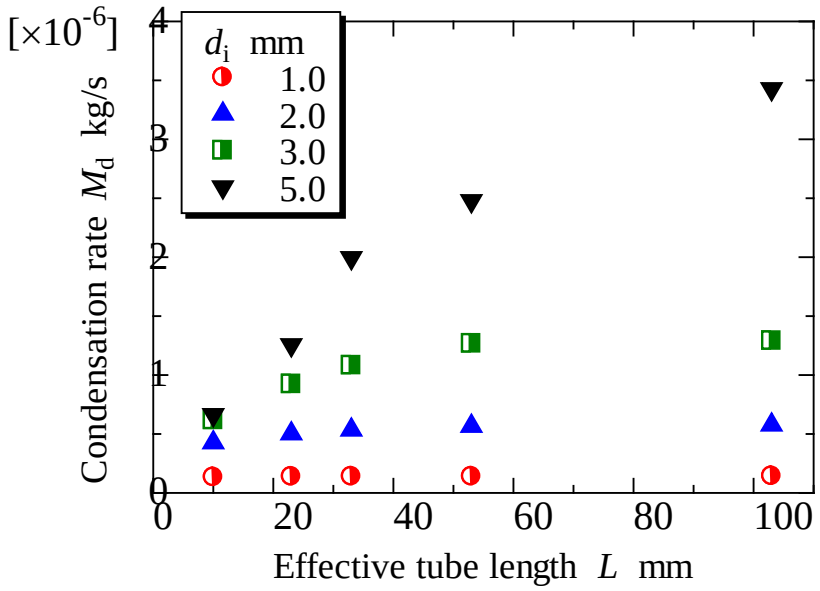


Fig. 9. Variation of condensation rate against effective tube length.

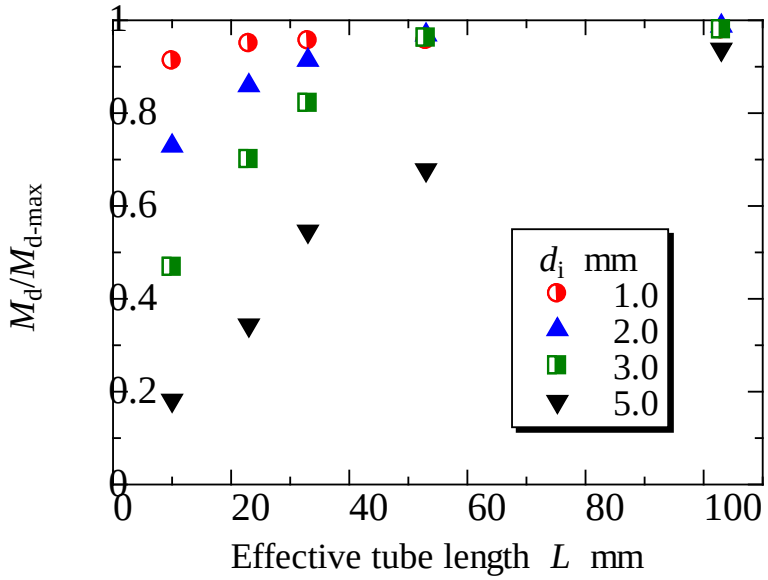


Fig. 10. Ratio of condensation rate to total humidity in gas flow.

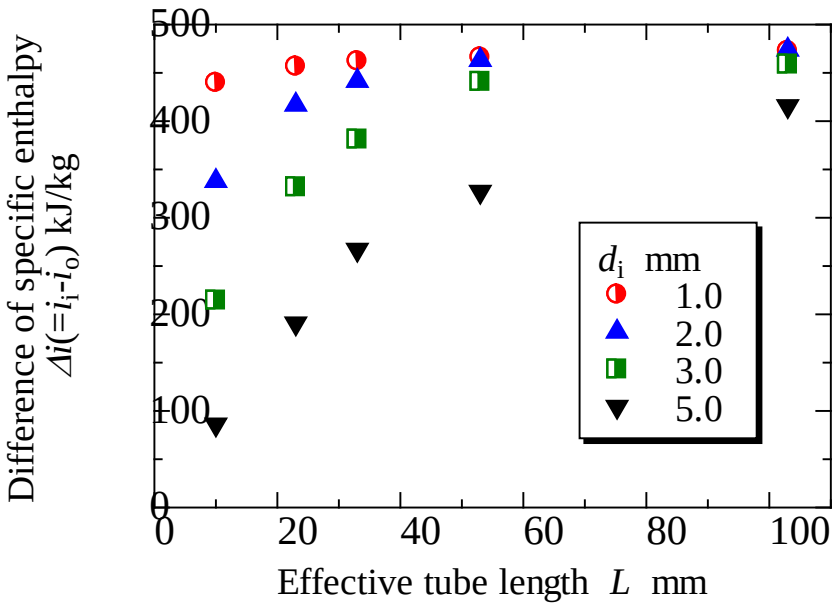
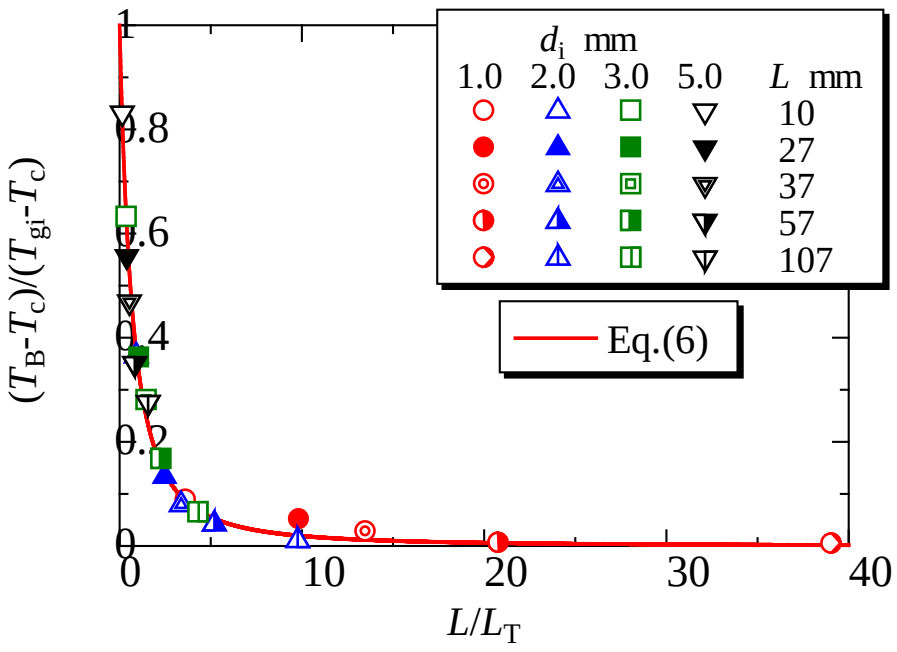
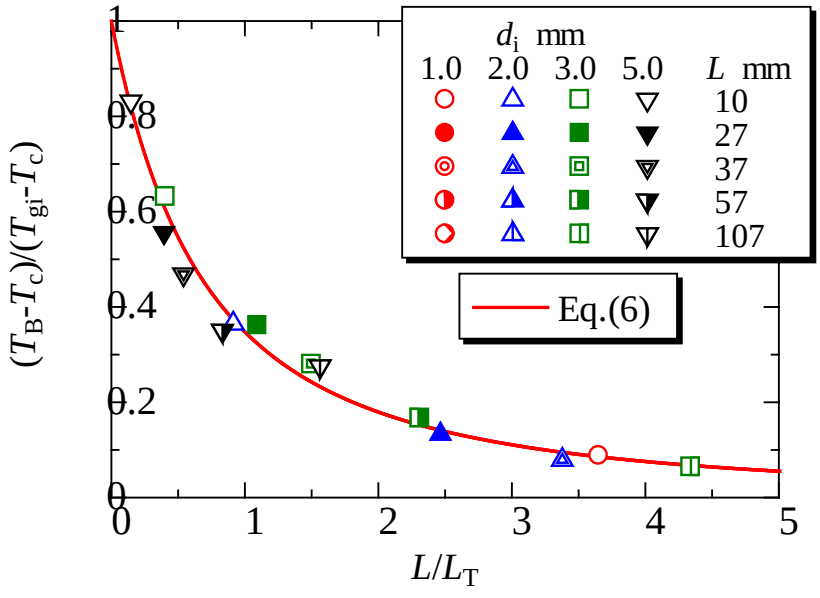


Fig. 11. Difference in specific enthalpy against effective tube length.

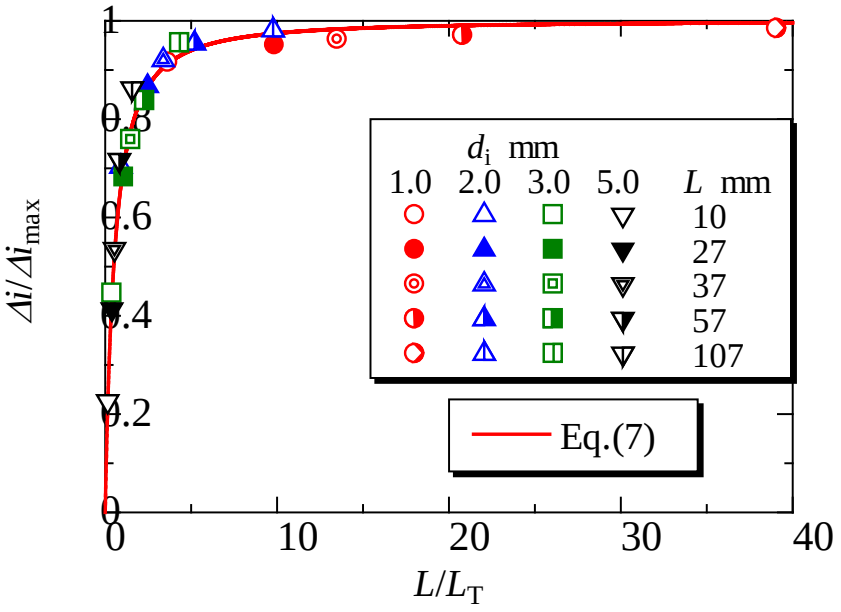


(a) $0 \le L/L_T \le 40$

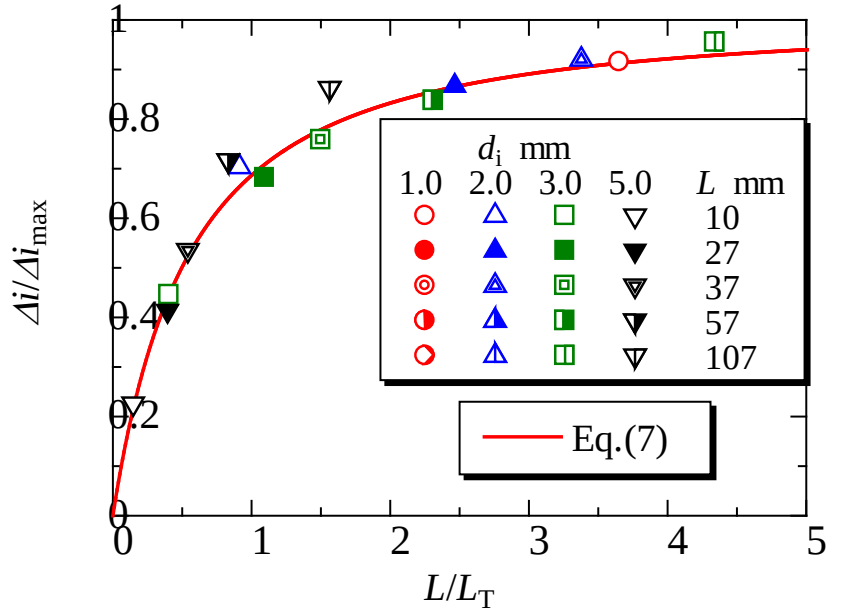


(b) $0 \le L/L_T \le 5$

Fig. 12. Relation between non-dimensional tube length and bulk mean temperature.



(a) $0 \le L/L_T \le 40$



(b) $0 \le L/L_T \le 5$

Fig. 13. Relation between non-dimensional tube length and difference in specific enthalpy.

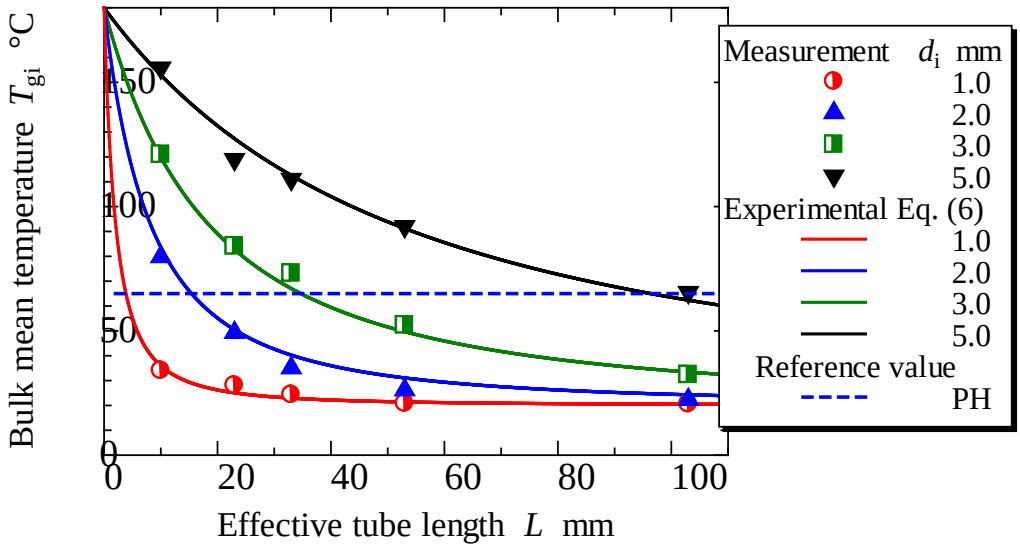


Fig. 14. Comparison of experiments and Eq. (6).

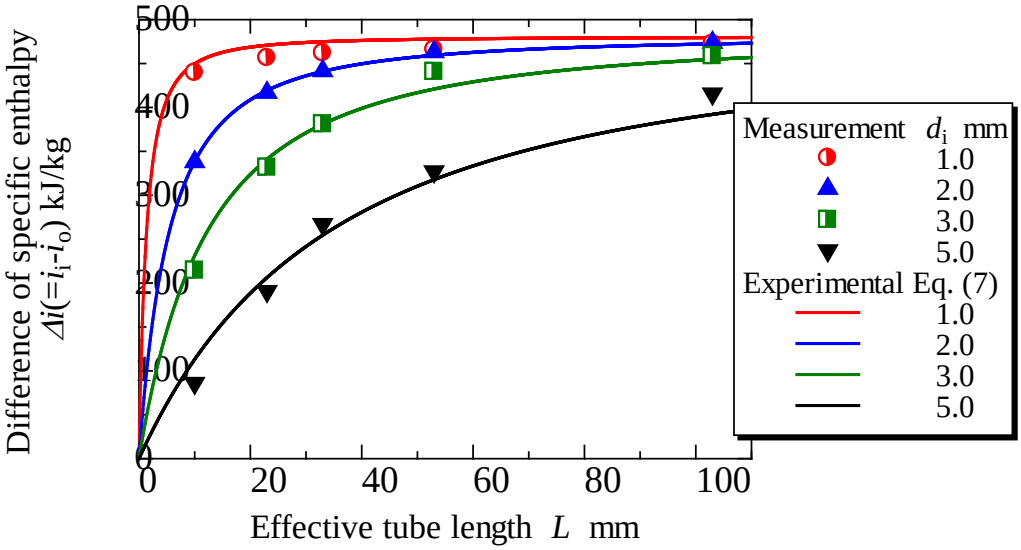


Fig. 15. Comparison of experiments and Eq. (7).

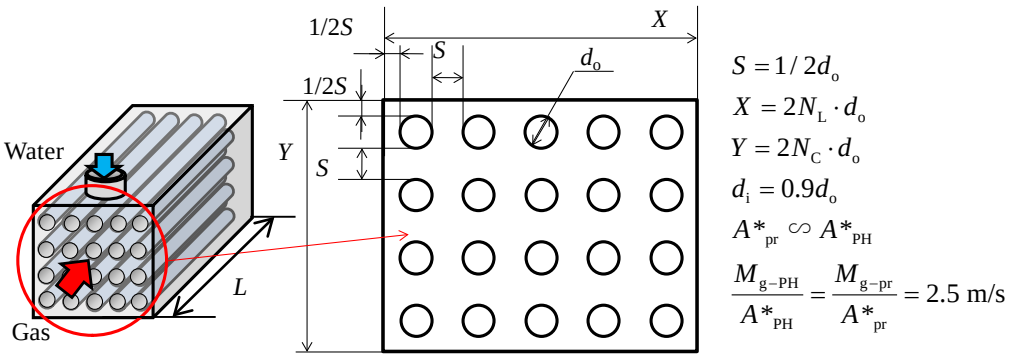


Fig. 16. Dimensional standard of configuration for proposed heat exchanger

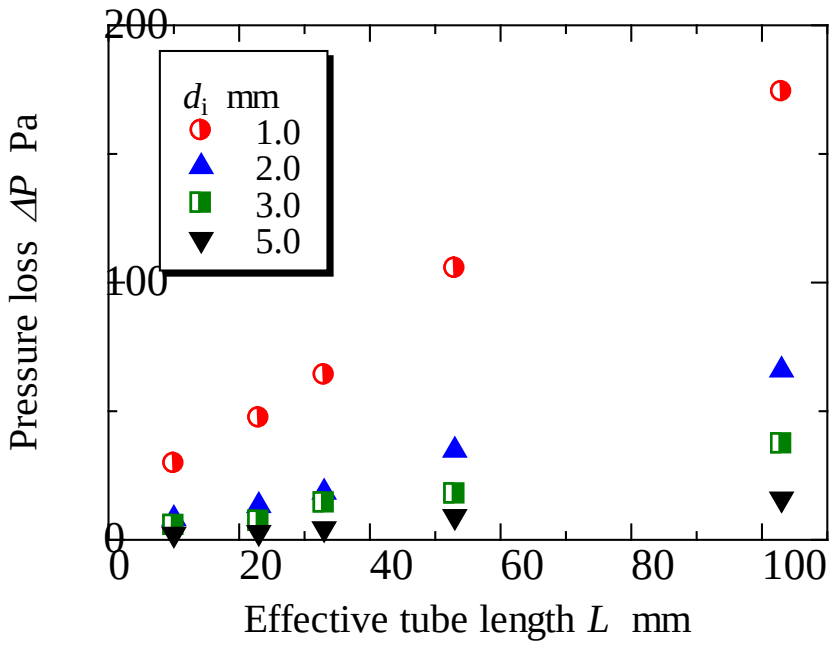


Fig. 17. Variation of pressure loss against effective tube length for moist air.

Table 1. Experimental conditions.

		Present study	PH
	Gas	Humid air	City gas
Tube	Material	SUS304	SUS316L
	Cooling length L_c [mm]	7, 20, 30,50,100	105
	Tube length [mm]	12, 25, 35, 55, 105	300
	Thickness t [mm]	0.5	0.3
	Inner diameter d_i [mm]	1.0, 2.0, 3.0, 5.0	5.4
Gas	Velocity U_g [m/s]	2.5	2.5
	Inlet temperature T_{gi} [ºC]	180	180
	Specific humidify x [kg/kg]	0.11	0.11
	Mass flow rate M_g [kg/s]	1.5, 5.9, 13.5, 37.5 ($\times 10^{-6}$)	0.028
Coolant	Velocity U_c [m/s]	1.2	1.2
	Inlet temperature T_{ci} [ºC]	20	20
	Mass flow rate M_c [kg/s]	5.8, 5.0, 4.2, 2.5 ($\times 10^{-2}$)	0.22

Table 2. Comparison of heat exchange volumes calculated by Eqs. (6) and (7).

	d_i [mm]	1.0	2.0	3.0	5.0	PH
Present method using Eqs. (6) and (7)	L [mm]	3.9	15.4	34.7	96.4	105
	Volume ratio	0.043	0.17	0.39	1.03	1