

Microgroove copper tube

Microgroove Copper Tube Heat Exchangers

Part 2 of 3

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Design of 5mm Microgroove Copper Tube Indoor Unit

Indoor Unit Design Under Cooling Condition

In order to get the precise simulation of indoor unit under cooling condition, the simulation software needs to be checked first. The way is to use the prototype indoor unit as a contrast model, and compare the simulation result with experimental data of the contrast model. The tube circuitry of prototype indoor unit is shown in Figure 9 and a comparison of the experimental data and simulation result can be seen in Table 12.

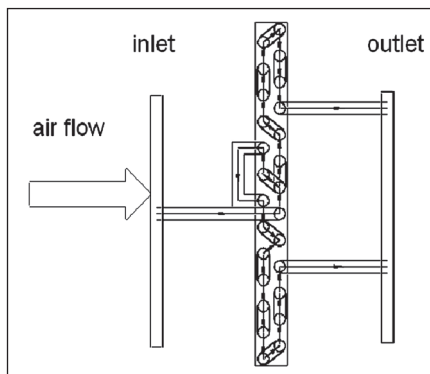


Figure 9: Tube circuitry of the prototype indoor unit

Table 12: Comparison of experimental data and simulation result for the prototype indoor unit

	Experimental data	Simulation result
Heat exchange (W)	2555	2549
Inlet temperature of wall (°C)	11.9	11.6
Middle temperature of wall (°C)	12.6	12.3
Outlet temperature of wall (°C)	14.3	14.0
Superheat (°C)	5.6	5.3
Outlet pressure of refrigerant (kPa)	637	637
Air volume (m ³ /h)	507	507

About the Author

Shankar Sopaliga is a Senior Consultant with International Copper Association India (ICAI). He is a mechanical engineer with 44 years of experience in the field of HVAC. He worked with Voltas Limited for 31 years in various capacities in India and abroad, like project planning, procurement, project execution, commissioning and testing of large central plants. He was also responsible for developing new business and energy management of large central plants. He was ISHRAE Mumbai Chapter President 2013-14 and is currently Research Promotion Chair, ASHRAE Mumbai Chapter.

observed from Table 12 that the difference of heat exchange between simulation result and experimental data is 0.23%. Therefore, the simulation software can accurately forecast the heat exchange capacity of indoor unit under cooling condition.

When the tube used in the indoor unit is changed from 7 mm to 5 mm, the pressure drop of refrigeration and thermal resistance of indoor unit will sharply increase. Both of them will lead to a decrease of heat exchange of indoor unit.

Considering the two factors above, the effective method of improving heat exchange is to adjust the tube path, fin pitch and tube number. After optimization design, the designed proposals for indoor unit with 5 mm tube are shown in Figure 10 (a) and (b). The simulation results are shown in Table 13 and 14.

Indoor Unit Optimum Design Considerations

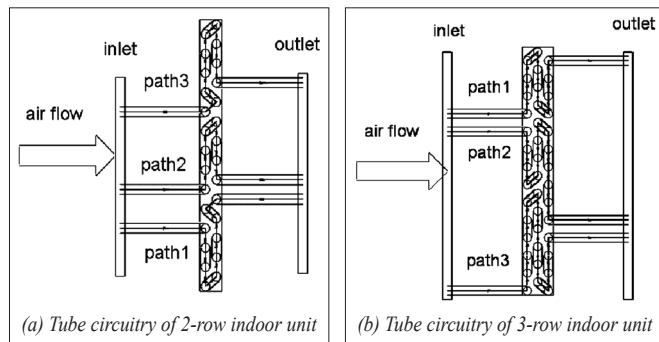


Figure 10: Tube circuitry of designed proposals for indoor unit under cooling condition

Table 13: Simulation result of 2-row indoor unit under cooling condition

	Prototype indoor unit	Designed 2-row indoor unit				
Fin pitch (mm)	1.5	1.5	1.4	1.3	1.2	
Air volume area (m ³ /h)	507	507	507	507	507	
Inlet pressure of refrigerant (kPa)	705	711	710	708	707	
Outlet pressure of refrigerant (kPa)	637	637	637	637	637	
Pressure drop of refrigerant (kPa)	68	74	73	71	70	
Inlet temperature of refrigerant (°C)	10.1	10.4	10.4	10.3	10.2	
Outlet temperature of refrigerant (°C)	13.1	11.4	12.4	13.2	13.3	
Superheat (°C)	5.3	3.6	4.6	5.4	5.5	
Middle temperature of refrigerant (°C)	12.3	12.1	12.2	12.4	12.4	
Dry temperature of outlet air (°C)	13.51	13.59	13.57	13.54	13.52	
Wet temperature of outlet air (°C)	13.46	13.53	13.49	13.46	13.47	
Heat exchange (W)	2549	2517	2537	2546	2548	

Table 14: Simulation result of 3-row indoor unit under cooling condition

	Prototype indoor unit	Designed 3-row indoor unit				
Fin pitch (mm)	1.5	1.5	1.4	1.3	1.2	
Air volume area (m ³ /h)	507	507	507	507	507	
Inlet pressure of refrigerant (kPa)	705	742	745	748	752	
Outlet pressure of refrigerant (kPa)	637	655	658	660	664	
Pressure drop of refrigerant (kPa)	68	87	87	88	88	
Inlet temperature of refrigerant (°C)	10.1	12.3	12.4	12.5	12.6	
Outlet temperature of refrigerant (°C)	13.1	12.2	12.3	12.4	12.5	
Superheat (°C)	5.3	3.6	3.6	3.6	3.6	
Middle temperature of refrigerant (kPa)	12.3	12.8	12.9	13.0	13.1	
Dry temperature of outlet air (°C)	13.51	13.31	13.25	13.14	12.98	
Wet temperature of outlet air (°C)	13.46	13.23	13.12	13.01	12.84	
Heat exchange (W)	2549	2608	2617	2628	2639	

Indoor Unit Design Under Cooling and Heating Condition

Tube circuitry of the prototype indoor unit is shown in Figure 11 and a comparison of the experimental data and simulation result can be seen in Table 15.

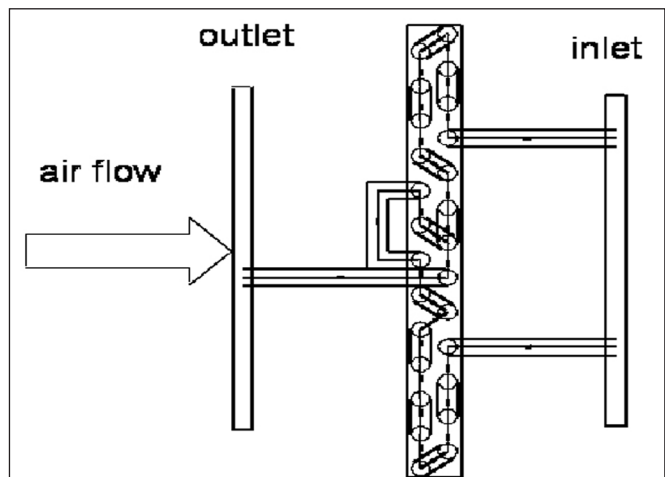


Figure 11: Tube circuitry of the prototype indoor unit

Table 15: Comparison of experiment data and simulation result for the prototype indoor unit

	Experimental data	Simulation result
Heat exchange (W)	2860	2857
Inlet temperature of wall (°C)	68.4	68.1
Middle temperature of wall (°C)	44.8	43.9
Outlet temperature of wall (°C)	30.9	31.4
Superheat (°C)	7.9	7.6
Outlet pressure of refrigerant (kPa)	1860	1860
Air volume (m ³ /h)	521	521

It can be observed from *Table 15* that the difference in heat exchange between simulation result and experiment data is 0.1%. Therefore, the simulation software can accurately forecast the heat exchange capacity of indoor unit under cooling and heating condition.

When the tube used in indoor unit is changed from 7 mm to 5 mm, the pressure drop of refrigeration and thermal resistance of indoor unit will sharply increase. Both of them will lead to a decrease in heat exchange of indoor unit.

Considering the two factors above, the effective method of improving heat exchange is to adjust the tube path, fin pitch and tube number. After optimization design, the designed proposals for indoor unit with 5 mm tube are shown as *Figure 12 (a)* and *(b)*. The simulation results are shown in *Table 16* and *17*.

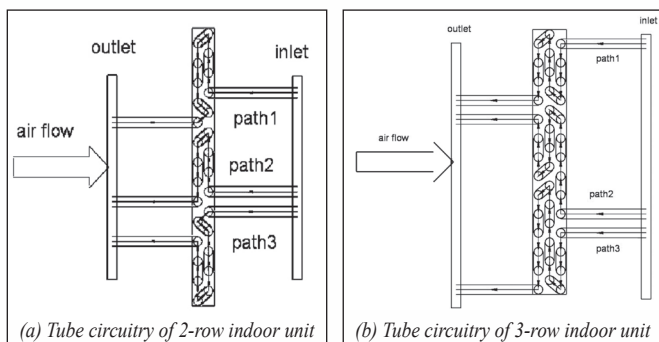


Figure 12: Tube circuitry of designed proposals for indoor unit under cooling and heating condition

Table 16: Simulation result of 2-row indoor unit under cooling and heating condition

	Prototype indoor unit	Designed 2-row indoor unit
Fin pitch (mm)	1.5	1.3
Air volume area (m ³ /h)	521	521
Inlet temperature of indoor unit (°C)	68.1	68.0
Middle temperature of indoor unit (°C)	43.9	44.1
Outlet temperature Of indoor unit (°C)	31.4	31.8
Superheat (°C)	7.6	7.8
Inlet pressure of refrigerant (kPa)	1860	1860
Heat exchange (W)	2857	2851

Table 17: Simulation result of 3-row indoor unit under cooling and heating condition

	Prototype indoor unit	Designed 3-row indoor unit
Fin pitch (mm)	1.5	1.3
Air volume area (m ³ /h)	521	521
Inlet temperature of indoor unit (°C)	68.1	68.0
Middle temperature of indoor unit (°C)	43.9	43.5
Outlet temperature Of indoor unit (°C)	31.4	31.3
Superheat (°C)	7.6	7.4
Inlet pressure of refrigerant (kPa)	1860	1800
Heat exchange (W)	2857	2863

Design of 5mm Microgroove Copper Tube Outdoor Unit

Outdoor Unit Design Under Cooling Condition

The tube circuitry of prototype outdoor unit is shown in *Figure 13* and a comparison of the experimental data and simulation result can be seen in *Table 17*.

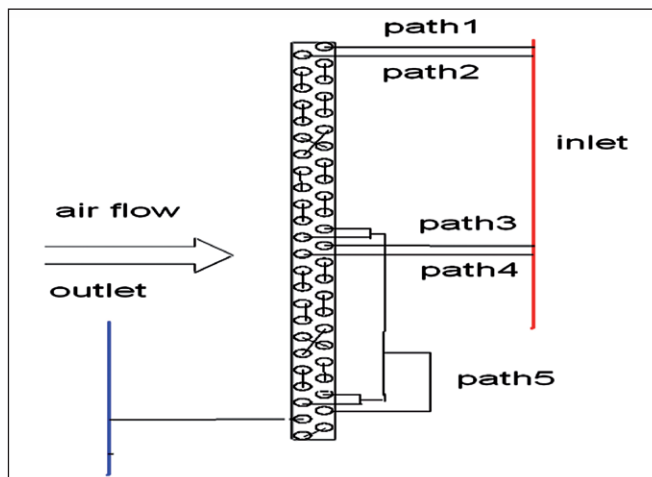


Figure 13: Tube circuitry of the prototype outdoor unit

Table 18: Comparison of experiment data and simulation result for the prototype outdoor unit

	Experimental data	Simulation result
Heat exchange (W)	3155	3151
Inlet temperature of wall (°C)	84.0	83.5
Middle temperature of wall (°C)	42.1	42.5
Outlet temperature of wall (°C)	36.1	36.3
Outlet pressure of refrigerant (kPa)	1870	1870
Air volume (m ³ /h)	1965	1965

It can be observed from *Table 18* that the difference in heat exchange between simulation result and experiment data is 0.16%. Therefore, the simulation software can accurately forecast the heat exchange capacity of outdoor unit under cooling condition.

When the tube used in outdoor unit is changed from 7 mm to 5 mm, the pressure drop of refrigeration and thermal resistance of outdoor unit will sharply increase. Both of them will lead to a decrease in heat exchange of outdoor unit.

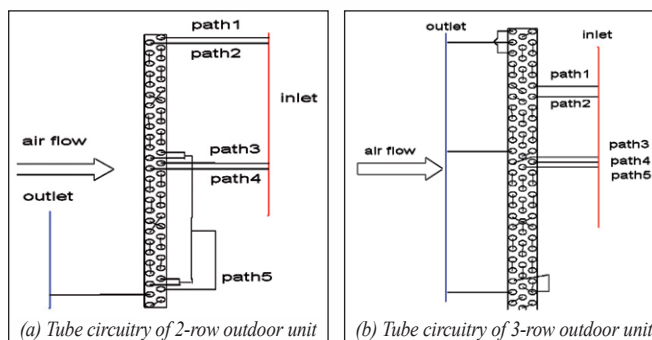


Figure 14: Tube circuitry of designed proposals for outdoor unit under cooling condition

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Considering the two factors above, the effective method of improving heat exchange is to adjust the tube path, fin pitch and tube number. After optimization design, the designed proposals for outdoor unit with 5 mm tube are shown as Figure 14 (a) and (b). The simulation results are shown in Table 19 and 20.

Table 19: Simulation result of 2-row outdoor unit under cooling condition

	Prototype outdoor unit		Designed 2-row outdoor unit	
Fin pitch (mm)	1.5	1.5	1.4	1.3
Air volume area (m ³ /h)	1965	1965	1965	1965
Inlet pressure of refrigerant (kPa)	1870	1870	1870	1870
Outlet pressure of refrigerant (kPa)	1865	1851	1852	1852
Pressure drop of refrigerant (kPa)	5	19	18	18
Inlet temperature of refrigerant (°C)	83.5	83.5	83.5	83.5
Outlet temperature of refrigerant (°C)	39.0	37.4	37.3	37.1
Subcooling (°C)	9.2	7.6	8.5	9.7
Dry temperature of outlet air (°C)	40.12	40.15	40.18	40.21
Wet temperature of outlet air (°C)	25.32	25.34	25.36	25.38
Heat exchange (W)	3151	3165	3175	3190

Table 20: Simulation result of 3-row outdoor unit under cooling condition

	Prototype outdoor unit		Designed 3-row outdoor unit		
Fin pitch (mm)	1.5	1.5	1.4	1.3	1.2
Air volume area (m ³ /h)	1965	1965	1965	1965	1965
Inlet pressure of refrigerant (kPa)	1870	1815	1810	1805	1800
Outlet pressure of refrigerant (kPa)	1865	1802	1797	1793	1788
Pressure drop of refrigerant (kPa)	5	13	13	12	12
Inlet temperature of refrigerant (°C)	83.5	82.5	82.4	82.3	82.5
Outlet temperature of refrigerant (°C)	39.0	36.1	36.1	36.0	36.8
Subcooling (°C)	9.2	8.5	8.9	9.2	9.6
Dry temperature of outlet air (°C)	40.12	40.16	40.17	40.18	40.19
Wet temperature of outlet air (°C)	25.32	25.33	25.33	25.34	25.35
Heat exchange (W)	3151	3154	3165	3176	3197

The following results can be observed:

- (1) When the fin pitch is 1.3 mm, heat exchange of 2-row outdoor unit is the highest, and it is 1.23% higher than that of the prototype outdoor unit.
- (2) When the fin pitch is 1.2 mm, the heat exchange of 3-row outdoor unit is the highest, and it is 1.46% higher than that of the prototype outdoor unit.

Outdoor Unit Design Under Cooling and Heating Condition

The tube circuitry of prototype outdoor unit is shown in Figure 15 and a comparison of the experimental data and simulation result can be seen in Table 21.

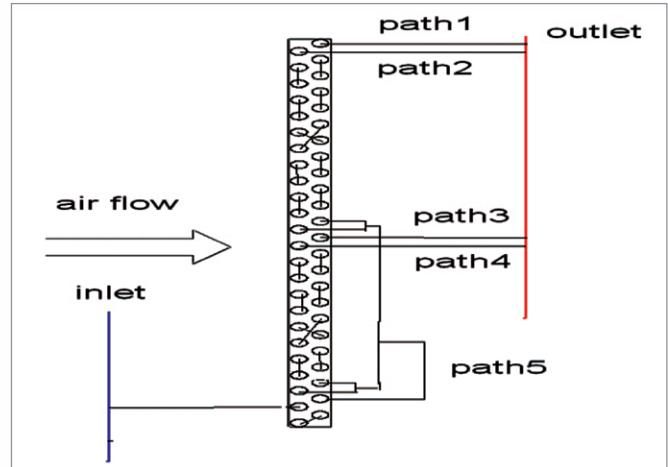


Figure 15: Tube circuitry of the prototype outdoor unit

Table 21: Comparison of experiment data and simulation result for the prototype outdoor unit

	Experiment data	Simulation result
Heat exchange (W)	2320	2325
Inlet temperature of wall (°C)	4.3	4.7
Middle temperature of wall (°C)	2.9	2.8
Outlet temperature of wall (°C)	7.0	5.7
Superheat (°C)	3.1	3.4
Outlet pressure of refrigerant (kPa)	523	523
Air volume (m ³ /h)	1965	1965

It can be observed from Table 21 that the difference in heat exchange between simulation result and experiment data is 0.22%. Therefore, the simulation software can accurately forecast the heat exchange capacity of outdoor unit under cooling and heating condition.

When the tube used in outdoor unit is changed from 7 mm to 5 mm, the pressure drop of refrigeration and thermal resistance of outdoor unit will sharply increase. Both of them will lead to a decrease in heat exchange of outdoor unit.

Considering the two factors above, the effective method of improving heat exchange is to adjust the tube path, fin pitch and tube number. After optimization design, the designed proposals for outdoor unit with 5 mm tube are shown in Figure 16 (a) and (b). The simulation results are shown in Table 22 and 23.

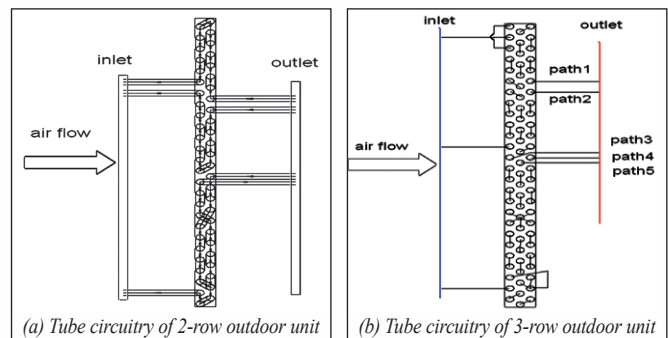


Figure 16: Tube circuitry of designed proposals for outdoor unit under cooling and heating condition

Microgroove Copper Tube Heat Exchangers

Table 22: Simulation result of 2-row outdoor unit under cooling and heating condition

	Prototype outdoor unit	Designed 2 row outdoor unit			
		1.5	1.4	1.3	1.2
Fin pitch (mm)	1.5	1.5	1.4	1.3	1.2
Air volume area (m ³ /h)	1965	1965	1965	1965	1965
Inlet pressure of refrigerant (kPa)	569.5	586.0	586.5	587.0	587.5
Outlet pressure of refrigerant (kPa)	523.0	523.0	523.0	523.0	523.0
Pressure drop of refrigerant (kPa)	46.5	63.0	63.5	64.0	64.5
Inlet temperature of refrigerant (°C)	4.2	5.3	5.3	5.3	5.3
Outlet temperature of refrigerant (°C)	4.9	2.8	3.4	4.1	5.0
Subcooling (°C)	3.4	1.3	1.9	2.6	3.5
Dry temperature of outlet air (°C)	4.40	4.57	4.51	4.43	4.41
Wet temperature of outlet air (°C)	4.28	4.35	4.32	4.30	4.31
Heat exchange (W)	2325	2267	2288	2311	2329

Table 23: Simulation result of 3-row outdoor unit under cooling and heating condition

	Prototype outdoor unit	Designed 3 row outdoor unit			
		1.5	1.4	1.3	1.2
Fin pitch (mm)	1.5	1.5	1.4	1.3	1.2
Air volume area (m ³ /h)	1965	1965	1965	1965	1965
Inlet pressure of refrigerant (kPa)	569.5	626	629	634	637
Outlet pressure of refrigerant (kPa)	523.0	543	546	550	553
Pressure drop of refrigerant (kPa)	46.5	83	83	84	84
Inlet temperature of refrigerant (°C)	4.2	6.3	6.4	6.5	6.6
Outlet temperature of refrigerant (°C)	4.9	4.3	4.3	4.4	4.4
Subcooling (°C)	3.4	3.5	3.5	3.5	3.5
Dry temperature of outlet air (°C)	4.40	4.37	4.35	4.33	4.31
Wet temperature of outlet air (°C)	4.28	4.26	4.25	4.23	4.20
Heat exchange (W)	2325	2378	2389	2401	2417

The following results can be observed:

(1) When the fin pitch is 1.2 mm, the heat exchange of 2 row outdoor unit is the highest, and it is 5.05% higher than that of the prototype outdoor unit.

(2) When the fin pitch is 1.2 mm, the heat exchange of 3 row outdoor unit is the highest, and it is 2.1% higher than that of the prototype outdoor unit. ❄

In Part 3 of this article, which will be published in the September-October 2015 issue of the Journal, we shall discuss the design of air conditioner with 5 mm tube under cooling and heating condition.