Microgroove copper tube

Microgroove Copper Tube Heat Exchangers

Part 3 of 3

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Design of AC with 5 mm Tube Under Cooling and Heating Condition

The variable factors in the design of air conditioner with 5mm tube under cooling and heating condition contain three parts:

1) Tube circuitry, tube number, tube arrangement, fin type and fin pitch in indoor unit,
2) Tube circuitry, tube number, tube arrangement, fin type and fin pitch in outdoor unit, and
3) Capillary tube length and refrigeration charge.

The detailed contents are introduced as follows.

Plan A: AC with 2-Row Indoor Unit and 2-Row Outdoor Unit

The tube circuitry of the designed air conditioner with 2-row indoor unit and 2-row outdoor unit is shown in *Figure 17(a)* and *(b)*.

The system simulation result is shown in *Table 24*, and the comparison of fin and tube consumption between the designed air conditioner and the prototype air conditioner is shown in *Table 25*.

The heating capacity of the designed air conditioner decreases by 0.32% while COP reduces to 3.11 from 3.12, and the cooling capacity of the designed air conditioner increases by 0.3% while EER reduces to 2.96 from 2.97 compared with the prototype air conditioner.

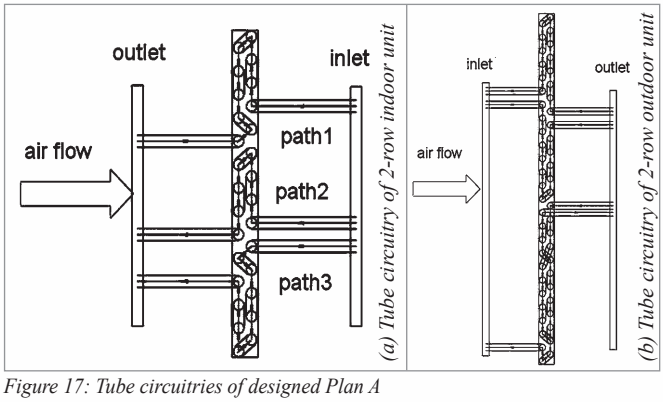

Figure 17: Tube circuitries of designed Plan A

About the Author

Shankar Sapaliga 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.

Table 24: System simulation result for designed Plan A

		Prototype air conditioner	Designed air conditioner	Relative change
Under heating condition	Heating capacity (W)	2857	2855	-0.07%
	Input power (W)	916	918	+0.22%
	Mass flow of refrigerant (g/s)	14.01	14.02	+0.07%
	Outlet pressure of outdoor (kPa)	523	523.5	+0.096%
	Outlet temperature of outdoor °C	5.1	5.0	-0.1
	Superheat °C	3.4	3.3	-0.1
	Outlet pressure of compressor (kPa)	1860	1865	+5
	Outlet temperature of indoor °C	36.4	36.6	+0.2
	Subcooling °C)	7.60	7.58	-0.02
	COP	3.12	3.11	-0.32%
Under cooling condition	Cooling capacity (W)	2549	2551	+0.08%
	Input power (W)	862	860	-0.20%
	Mass flow of refrigerant (g/s)	15.54	15.48	-0.39%
	Outlet pressure of outdoor (kPa)	634	632	-0.32%
	Outlet temperature of outdoor °C	13.3	13.1	-0.2
	Superheat °C	5.7	5.6	-0.1
	Outlet pressure of compressor (kPa)	1870	1860	-10
	Outlet temperature of compressor °C	83.5	83.2	-0.3
	Subcooling °C	9.2	9.5	+0.3
	Outlet temperature of outdoor °C	39.0	38.3	-0.7
	EER	2.96	2.97	+0.3%

Table 25: Comparison of tube and fin consumption in designed Plan A

	Prototype air conditioner	Designed air conditioner	Relative change
Fin pitch of indoor (mm)	1.50	1.30	+13.33%
Fin area of indoor (m^2)	2.716	2.424	-10.75%
U tube length of indoor (m)	14.898	16.044	+7.69%
Fin pitch of outdoor (mm)	1.50	1.20	+20%
Fin area of outdoor (m^2)	6.738	7.297	+8.30%
U tube length of outdoor (m)	36.72	39.78	+8.33%

Plan B: AC with 2-Row Indoor Unit and 3-Row Outdoor Unit

The tube circuitry of the designed air conditioner with 2-row indoor unit and 3-row outdoor unit is shown in *Figure 18 (a)* and *(b)*.

The system simulation result is shown in *Table 26*, and the comparison of fin and tube consumption between the designed air conditioner and the prototype air conditioner is shown in *Table 27*.

The heating capacity of the designed air conditioner increases by 1.9% while COP rises to 3.18 from 3.12, and the cooling capacity of the designed air conditioner increases by 3.0% while EER rises to 3.05 from 2.96 compared with the prototype air conditioner.

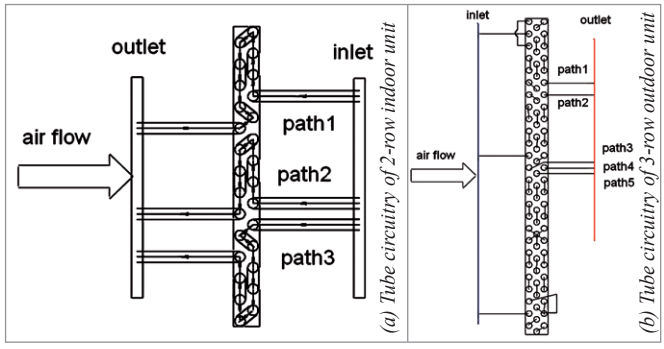

Figure 18: Tube circuitries of designed Plan B

Table 26: System simulation result for designed Plan B

		Prototype air conditioner	Designed air conditioner	Relative change
Under heating condition	Heating capacity (W)	2857	2942	+3.0%
	Input power (W)	916	926	+1.1%
	Mass flow of refrigerant (g/s)	14.01	14.81	+5.7%
	Outlet pressure of outdoor (kPa)	523	553	+5.7%
	Outlet temperature of outdoor °C	5.1	6.3	+1.2
	Superheat °C	3.4	3.5	+0.1
	Outlet pressure of compressor (kPa)	1860	1895	+35
	Outlet temperature of compressor °C	77.8	78.6	+0.8
	Outlet temperature of indoor °C	36.4	36.7	+0.2
	Subcooling °C)	7.60	7.50	-0.10
	COP	3.12	3.18	+1.9%
Under cooling condition	Cooling capacity (W)	2549	2574	+1.0%
	Input power (W)	862	842	-2.3%
	Mass flow of refrigerant (g/s)	15.54	15.48	-0.4%
	Outlet pressure of outdoor (kPa)	634	631	-0.5%
	Outlet temperature of outdoor °C	13.3	13.0	-0.3
	Superheat °C	5.7	5.5	-0.2
	Outlet pressure of compressor (kPa)	1870	1800	-70
	Outlet temperature of compressor °C	83.5	81.0	-2.5
	Subcooling °C	39.0	36.9	-2.1
	Outlet temperature of indoor °C	9.2	9.6	+0.4
	EER	2.96	3.05	+3.0%

Table 27: Comparison of tube and fin consumption in designed Plan B

	Prototype air conditioner	Designed air conditioner	Relative change
Fin pitch of indoor (mm)	1.50	1.30	+13.33%
Fin area of indoor (m^2)	2.716	2.424	-10.75%
U tube length of indoor (m)	14.898	16.044	+7.69%
Fin pitch of outdoor (mm)	1.50	1.20	+20.00%
Fin area of outdoor (m^2)	6.738	10.945	+62.43%
U tube length of outdoor (m)	36.72	59.67	+62.50%

Plan C: AC with 3-Row Indoor Unit and 3-Row Outdoor Unit

The tube circuitry of the designed air conditioner with 3-row indoor unit and 3-row outdoor unit is shown in *Figure 19 (a)* and *(b)*.

The system simulation result is shown in *Table 28*, and the comparison of fin and tube consumption between the designed air conditioner and the prototype air conditioner is shown in *Table 29*.

The heating capacity of the designed air conditioner increases by 5.1% while COP rises to 3.28 from 3.12, and the cooling capacity of the designed air conditioner increases by 6.4% while EER rises to 3.15 from 2.96 compared with that of the prototype air conditioner.

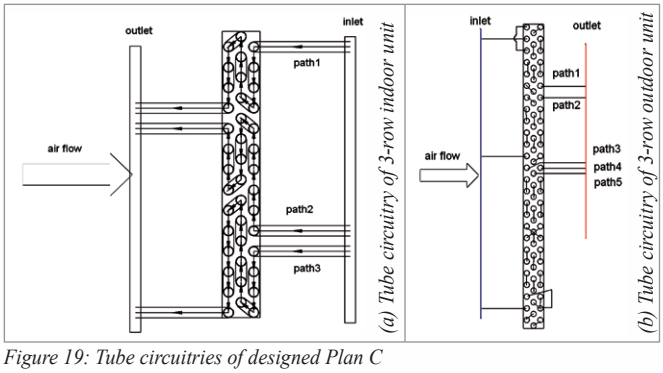

Figure 19: Tube circuitries of designed Plan C

Table 28: System simulation result for designed Plan C

		Prototype air conditioner	Designed air conditioner	Relative change
Under heating condition	Heating capacity (W)	2857	2967	+3.9%
	Input power (W)	916	904	-1.3%
	Mass flow of refrigerant (g/s)	14.01	14.81	+5.7%
	Outlet pressure of outdoor (kPa)	523	553	+5.7%
	Outlet temperature of outdoor °C	5.1	6.3	+1.2
	Superheat °C	3.4	3.5	+0.1
	Outlet pressure of compressor (kPa)	1860	1810	-50
	Outlet temperature of compressor °C	77.8	76.5	-1.3
	Outlet temperature of indoor °C	7.60	7.52	-0.08
	Subcooling °C)	36.4	35.1	-1.3
	COP	3.12	3.28	+5.1%
Under cooling condition	Cooling capacity (W)	2549	2659	+4.3%
	Input power (W)	862	842	-2.3%
	Mass flow of refrigerant (g/s)	15.54	16.05	+3.2%
	Outlet pressure of outdoor (kPa)	634	656	+3.5%
	Outlet temperature of outdoor °C	13.3	13.0	-0.3
	Superheat °C	5.7	4.2	-1.5
	Outlet pressure of compressor (kPa)	1870	1800	-70
	Outlet temperature of compressor °C	83.5	78.2	-5.3
	Subcooling °C)	9.2	9.4	+0.2
	Outlet temperature of indoor °C	39.0	36.9	-2.1
	EER	2.96	3.15	+6.4%

Table 29: Comparison of tube and fin consumption in designed Plan C

	Prototype air conditioner	Designed air conditioner	Relative change
Fin pitch of indoor (mm)	1.50	1.20	+20.00%
Fin area of indoor (m^2)	2.716	4.390	+61.63%
U tube length of indoor (m)	14.898	24.066	+61.54%
Fin pitch of outdoor (mm)	1.50	1.20	+20.00%
Fin area of outdoor (m^2)	6.738	10.945	+62.43%
U tube length of outdoor (m)	36.72	59.67	+62.50%

Plan D: AC with 3-Row Indoor Unit and 2-Row Outdoor Unit

The tube circuitry of the designed air conditioner with 3-row indoor unit and 2 row-outdoor unit is shown as *Figure 20(a)* and *(b)*.

The system simulation result is shown in *Table 30*, and the comparison of fin and tube consumption between the designed air conditioner and the prototype air conditioner is shown in *Table 31*.

The heating capacity of the designed air conditioner increases by 2.2% while COP rises to 3.19 from 3.12, and the cooling capacity of the designed air conditioner increases by 4.1% while EER rises to 3.08 from 2.96 compared with that of the prototype air conditioner.

Table 30: System simulation result for designed Plan D

		Prototype air conditioner	Designed air conditioner	Relative change
Under heating condition	Heating capacity (W)	2857	2874	+0.6%
	Input power (W)	916	902	-1.5%
	Mass flow of refrigerant (g/s)	14.01	13.98	-0.21%
	Outlet pressure of outdoor (kPa)	523	521	-0.24%
	Outlet temperature of outdoor °C	5.1	5.2	+0.1
	Superheat °C	3.4	3.5	+0.1
	Outlet pressure of compressor (kPa)	1860	1800	-60
	Outlet temperature of compressor °C	77.8	76.3	-1.5
	Outlet temperature of indoor °C	7.60	7.52	-0.08
	Subcooling °C)	36.4	35.1	-1.3
	COP	3.12	3.19	+2.2%
Under cooling condition	Cooling capacity (W)	2549	2643	+3.7%
	Input power (W)	862	859	-0.3%
	Mass flow of refrigerant (g/s)	15.54	16.15	+3.9%
	Outlet pressure of outdoor (kPa)	634	659	+3.9%
	Outlet temperature of outdoor °C	13.3	13.0	-0.3
	Superheat °C	5.7	4.1	-1.6
	Outlet pressure of compressor (kPa)	1870	1860	-10
	Outlet temperature of compressor °C	83.5	80.2	-3.3
	Subcooling °C	39.0	38.6	-0.4
	Outlet temperature of indoor °C	9.2	9.2	0
	EER	2.96	3.08	+4.1%

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Table 31: Comparison of tube and fin consumption in designed Plan D

	Prototype air conditioner	Designed air conditioner	Relative change
Fin pitch of indoor (mm)	1.50	1.20	+20.00%
Fin area of indoor (m^2)	2.716	4.390	+61.63%
U tube length of indoor (m)	14.898	24.066	+61.54%
Fin pitch of outdoor (mm)	1.50	1.20	+20%
Fin area of outdoor (m^2)	6.738	7.297	+8.30%
U tube length of outdoor (m)	36.72	39.78	+8.33%

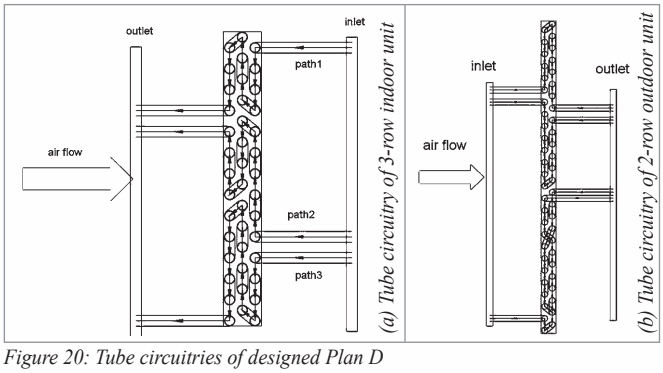

Figure 20: Tube circuitries of designed Plan D

Conclusion

The results of all the system simulation plans for designed air conditioner with 5mm copper tube are shown in *Table 32*.

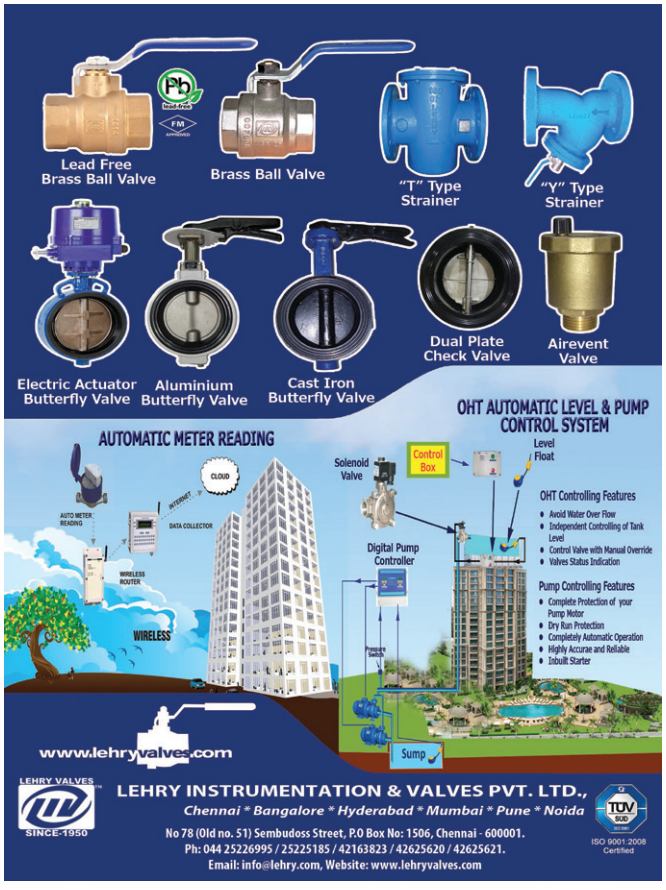

Table 32: System simulation result for designed air conditioner

		Plan A	Plan B	Plan C	Plan D	Prototype
Type of indoor unit		2 row 5 mm	2 row 5 mm	3 row 5 mm	3 row 5 mm	2 row 7 mm
Type of outdoor unit		2 row 5 mm	3 row 5 mm	3 row 5 mm	2 row 5 mm	2 row 7 mm
Fin pitch of indoor (mm)		1.30	1.30	1.20	1.20	1.50
Fin area of indoor (m^2)		2.424	2.424	4.390	4.390	2.716
U tube length of indoor (m)		16.044	16.044	24.066	24.066	14.898
Fin pitch of outdoor (mm)		1.30	1.20	1.20	1.20	1.50
Fin area of outdoor (m^2)		6.775	10.945	10.945	7.297	6.738
U tube length of outdoor (m)		39.78	59.67	59.67	39.78	36.72
Under heating condition	Heating capacity (W)	2855	2942	2967	2874	2857
	Input power (W)	918	926	904	902	916
	Mass flow of refrigerant (g/s)	14.02	14.81	14.81	13.98	14.01
	Outlet pressure of outdoor (kPa)	523.5	553	553	521	523
	Outlet temperature of outdoor °C	5.0	6.3	6.3	5.2	5.1
	Superheat °C	3.3	3.5	3.5	3.5	3.4
	Outlet pressure of compressor (kPa)	1865	1895	1810	1800	1860
	Outlet temperature of compressor °C	78.1	78.6	76.5	76.3	77.8
	Outlet temperature of indoor °C	36.6	36.7	35.1	35.1	36.4
	Subcooling °C	7.58	7.50	7.52	7.52	7.60
	COP	3.11	3.18	3.28	3.19	3.12
Under cooling condition	Cooling capacity (W)	2551	2574	2659	2643	2549
	Input power (W)	860	842	842	859	862
	Mass flow of refrigerant (g/s)	15.48	15.48	16.05	16.15	15.54
	Outlet pressure of outdoor (kPa)	632	631	656	659	634
	Outlet temperature of outdoor °C	13.1	13.0	13.0	13.0	13.3
	Superheat °C	5.6	5.5	4.2	4.1	5.7
	Outlet pressure of compressor (kPa)	1860	1800	1800	1860	1870
	Outlet temperature of compressor °C	83.2	81.0	78.2	80.2	83.5
	Outlet temperature of outdoor °C	38.3	36.9	36.9	38.6	39.0
	Subcooling °C	9.5	9.60	9.40	9.20	9.20
	EER	2.97	3.05	3.15	3.08	2.96

When using 2-row 5mm copper tube in indoor unit and 2-row 5mm copper tube in outdoor unit, the system performance is similar to that of the prototype; and when the number of copper tubes in indoor or outdoor unit are increased, system performance is higher than the prototype.