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Heat Transfer Technologies

New copper-tube technologies for CO_2 heat exchangers:

CO2 Gas Cooler and DX Coil

by Y. Shabtay, Dr. Jian Yu, N. Cotton

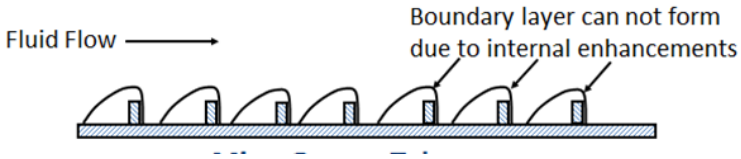
Introduction

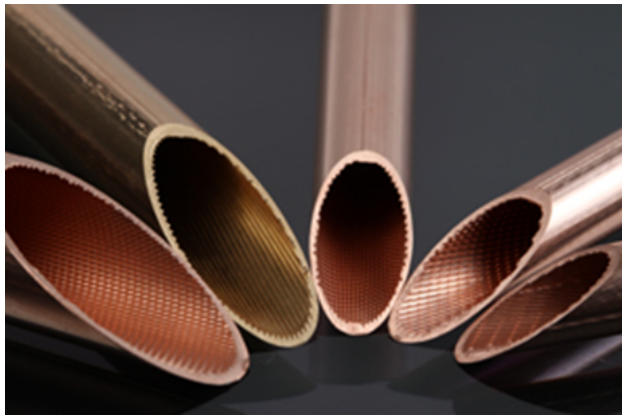
- This paper presents reasoning for the selection of small diameter copper tubes in air conditioning and refrigeration equipment using new alternative refrigerants.
- Two examples are provided:
  - CO_2 gas cooler
  - R290 DX coil
- It will be shown that Heat exchangers based on 5mm inner-grooved copper tubes provide effective and lower cost solutions
- Copper fins advantages

CO_2 gas cooler

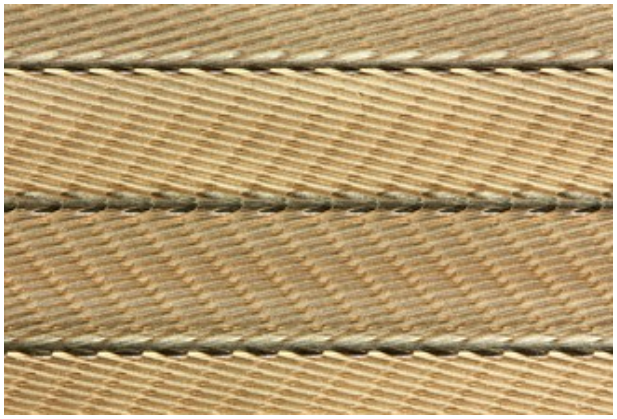
Efficiency Analysis - tubes

- Copper tube + aluminum fin modified for greatly enhanced heat transfer:
  - Smaller diameter tube (7 to 4mm)
  - Inner grooving patterns
  - Thinner walls
  - Smaller refrigerant charge
  - Better refrigerant mixing
  - More flexible circuiting to eliminate refrigerant mal-distribution





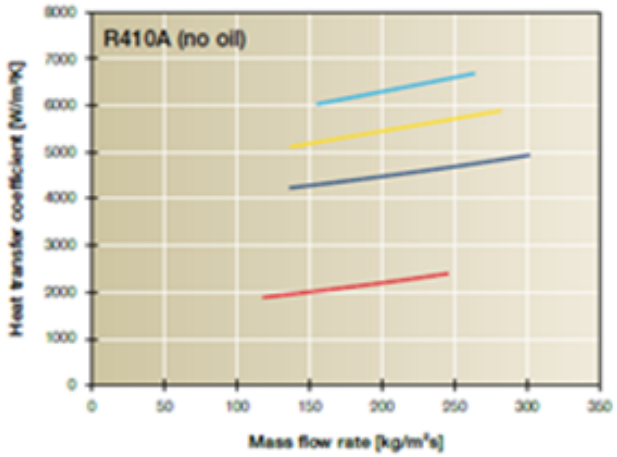
Tubes of 7mm to 4mm diameter

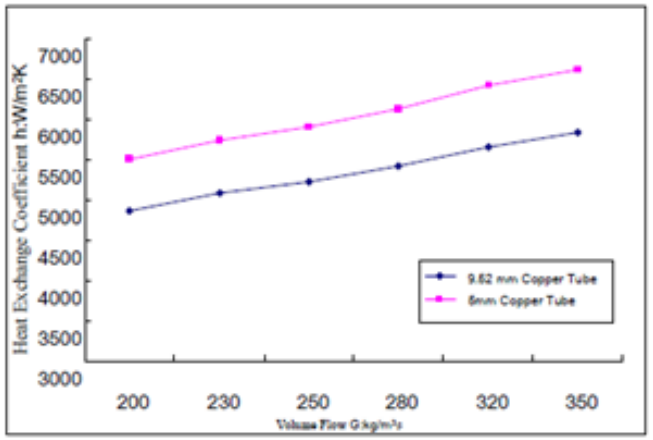


Herringbone pattern grooving

Efficiency analysis - grooving

+50% HTC with 2nd generation tube; +100% vs smooth tube using R410A





+20% HTC with 5mm Cu vs 9.53mm tube using HFC refrig.

Test conditions

Condensation – 9.52 mm tubes
t_c = 35 °C
subcooling ~2 K, inlet superheat ~5 K
tube length 2 m

- 2nd generation condensation tube
- Optimized condensation tube
- Standard inner-grooved tube
- Smooth tube

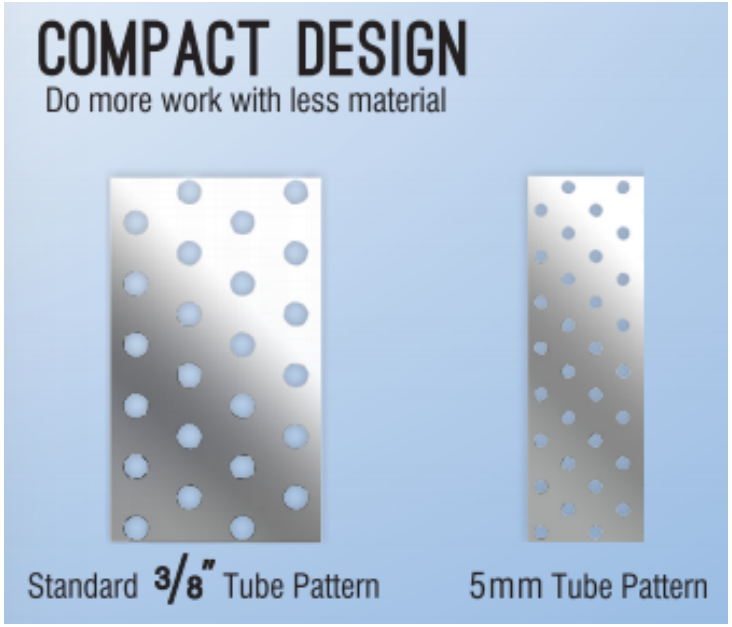
5mm vs 9.53mm tube heat exchanger:

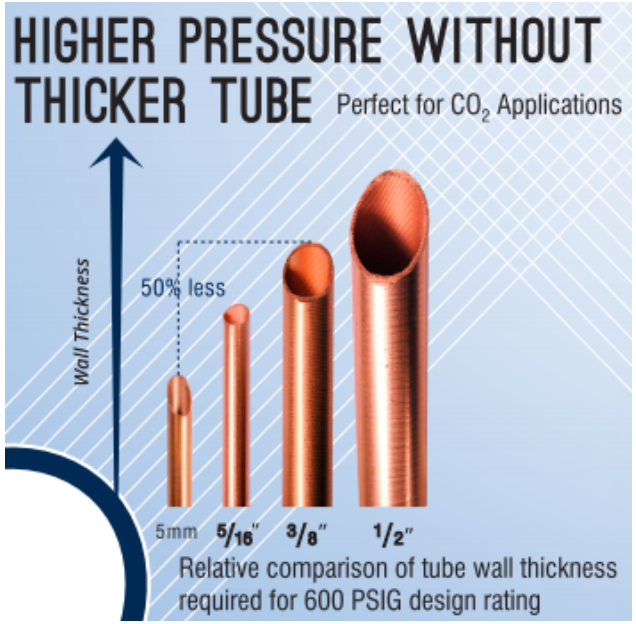
- Up to 50% tube and fin weight reduction
- 50+% reduction in internal volume
- 50% wall thickness reduction
- 50+% HTC enhancement
- 40% reduction in heat exchanger cost

Efficiency Analysis - size

For R290 and R744 – Smaller diameter copper tube an advantage:

- Higher pressure capable, Lower refrigerant charge, Compact design
- High-strength copper alloy (CuFe2P) available for higher pressure





Super Radiator Coils

Barriers and their solutions:

- Fin dies more elaborate
- Pressure expansion - a solution for long tubes

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Case 1 comparison

Super Radiator Coils

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CO2 Gas Cooler	Unit	5mm tube	5/16” tube	Ratio
Capacity	BTUH	43,000	43,000	
Design Pressure	PSIA	1,005	1,005	
Coil Size	in	18 x 37	18 x 37	
Row		4	4	
Fin Density	FPI	16	12.5	
Tube Pattern	In	0.75 x 0.449	1.0 x 0.625	
Tube Material		Cu	Cu	
Tube OD	in	0.197	0.3125	
Tube Wall	in	0.040	0.049	
Tube Weight	Lbs.	24.5	37.7	**65%**
Fin Material		AL	AL	
Fin Thickness	in	0.0039	0.0045	
Fin Weight	Lbs.	7.5	9.5	**79%**
Total Internal Volume	Liter	1.2	2.2	**54.5%**

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Case 2 comparison

Super Radiator Coils

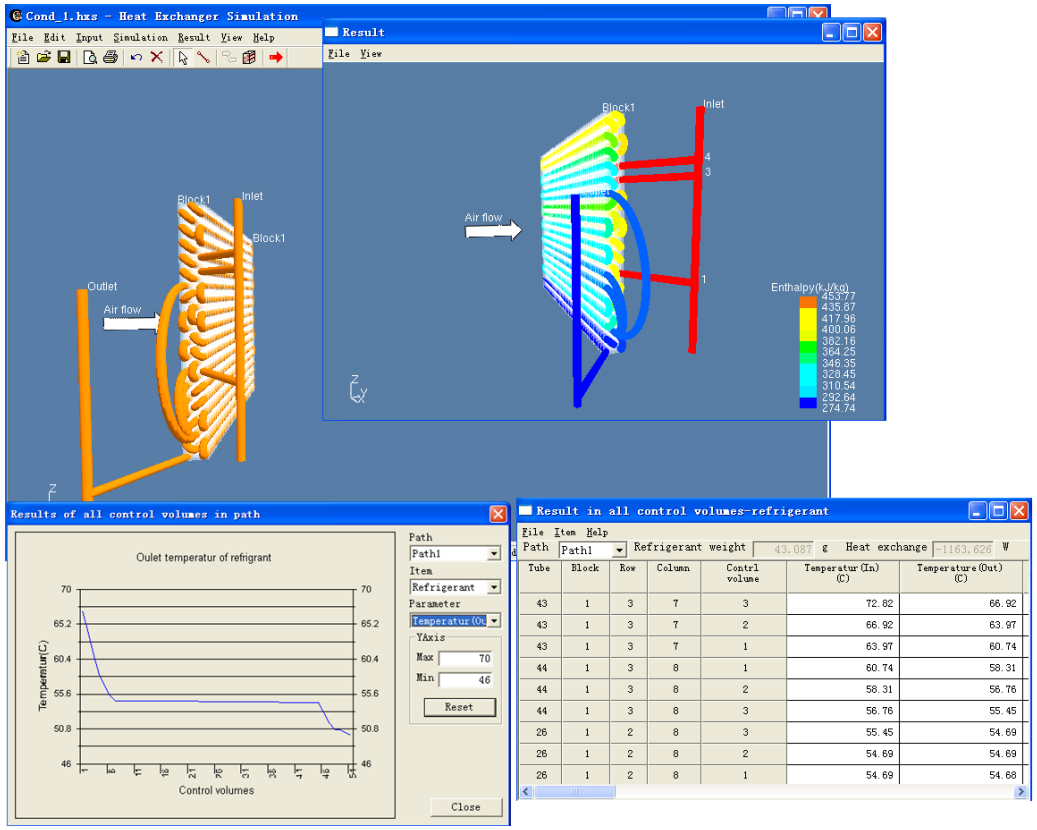
Heat Transfer Technologies

R290 DX Coil	Unit	5 mm Tube	3/8” Tube	Ratio
Capacity	BTUH	2800	2800	
Design Pressure	PSIA	60	60	
Coil Size	in	7.5 X 24	8 x 24	
Row		6	4	
Fin Density	FPI	4	4	
Tube Pattern	in	0.75 x 0.449	1.0 x 0.866	
Tube Material		Cu	Cu	
Tube OD	in	0.197	0.375	
Tube Wall	in	0.010	0.015	
Tube Weight	Lbs.	3.4	5.3	**70%**
Fin Material		AL	AL	
Fin Thickness	in	0.0039	0.0055	
Fin Weight	Lbs.	0.8	1.5	**53%**
Total Internal Volume	Liter	0.8	1.6	**50%**

Design software available

Heat Transfer Technologies

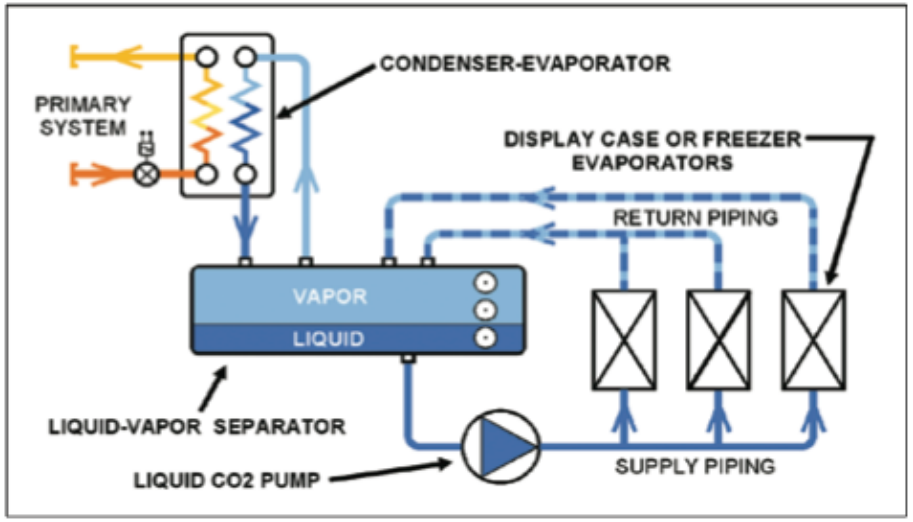
- Heat exchanger and system design software is available for small diameter copper tube HX in Refrigeration systems
- Gives user the option to choose a tube diameter, inner groove tube geometry, fin design and refrigerant type
- Optimizes entire system of compressor, evaporator, and condenser with a cost analysis
- Simulates all key technical parameters needed to optimize the performance and cost of small diameter copper tube heat exchangers and total system



Simulation results in 2D and 3D views with parameter charting

Additional applications

Liquid CO_2 Secondary loop:
Pumps circulate liquid CO_2 through a smaller refrigeration device (like a display case) at the required case temperature



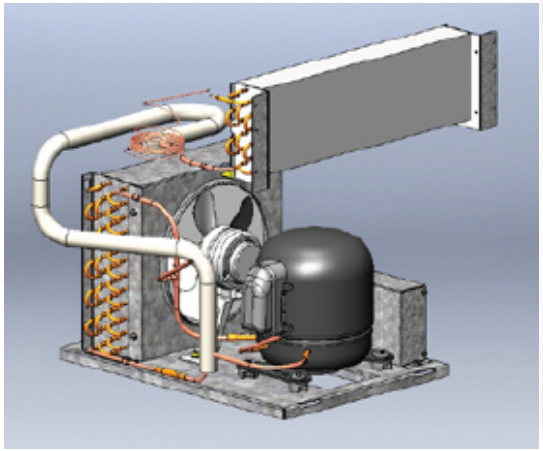
Low Temp secondary loop system can benefit from CuFe2P copper piping for liquid CO_2

Source: Hill Phoenix

Vending refrigeration machines using CO_2 refrigerant:

10 MPa operating pressure

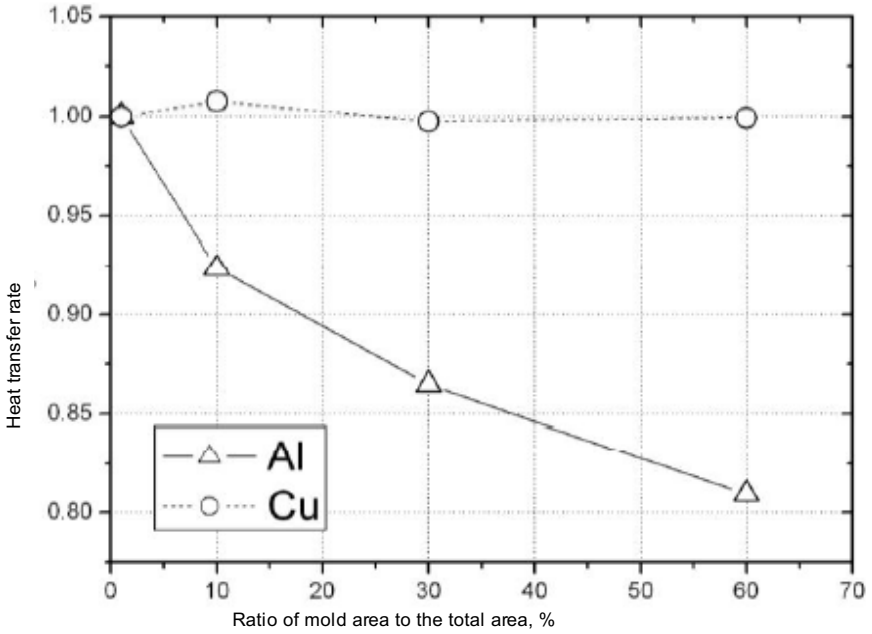
Evaporator and condenser both use 5mm inner-grooved copper tube



(Sanden Vendo America)

Copper fin improves efficiency

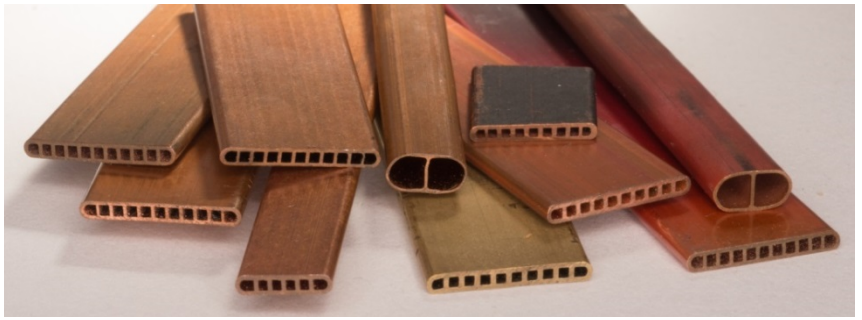
- Mold buildup cuts efficiency
- No change in efficiency with all-copper vs 19% decline with aluminum fin as mold growth reaches 60% of total heat exchanger area
- Important to maintain efficiency throughout system operational lifetime

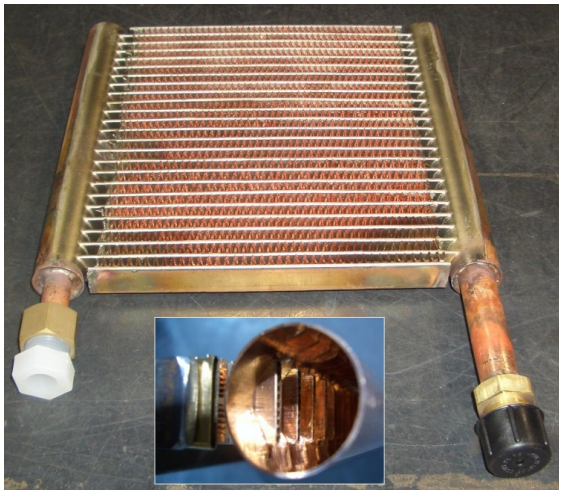


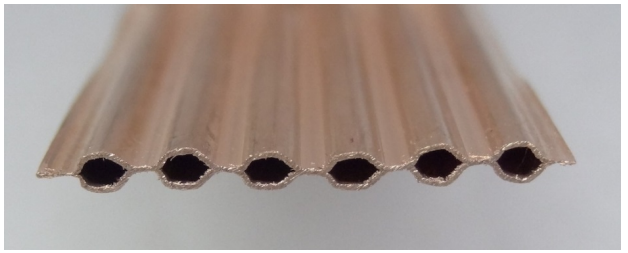
Source: Ding, G.(2007). Comparative Study of the Long-term Performance of Copper and Aluminum Fin-and-Tube Heat Exchangers. Report V to ICA

Additional tube options in dev.

- Tubes Produced by hot extrusion or roll-bonding
- Precision, thin-wall, 0.2mm
- Multichannel copper profile, 1.0mm channel width
- Up to 62 MPa burst pressure with 0.4mm wall and 1mm channels
- Especially attractive for high pressure (17 MPa) and temperatures (180C) of CO_2
- Burst pressures predicted for tubes of 1mm channel width and 0.3mm wall:
- **UNS C12200 copper: 47.6 MPa**
  AA 3102 aluminum: 18.6 MPa
  AA 3003 aluminum: 26.9 Mpa
- 2x27mm Roll formed tube burst at 12MPa







Conclusions

- CO_2 gas cooler manufactured using 5mm copper tubing reduced tube weight by 65%, fin weight by 79% and has 54% lower internal volume compared with 5/16” tube (7.93mm)
- R290 DX coil manufactured using 5mm tubing reduced tube weight by 70%, fin weight by 53% and lowered internal volume by 50% compared to 3/8” tube (9.5mm)
- Significant degradation in efficiency from mold buildup and corrosion can be addressed by the use of all-copper heat exchangers
- Using 5mm copper tubes brings substantial cost savings and reduction of internal volume making it an attractive solution for many products requiring Natural Refrigerants.

Thank You