Select Case Studies of Copper Heat Exchanger Coils for Natural Refrigerants

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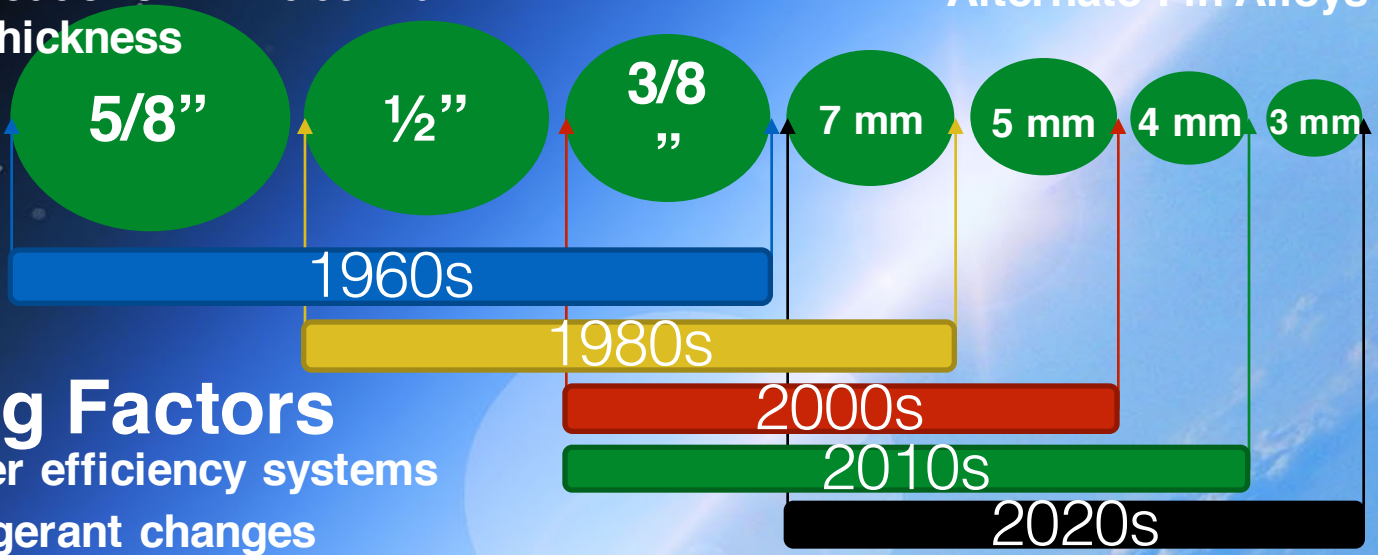
Content

- Overview / Historical trends
- Case studies: small diameter copper tube HX can
  - Increase the system energy efficiency (COP)
  - Reduce the refrigerant charge
  - Lower HX cost and reduce HX size
- Applications
- Simulation and Design
- Construction and manufacturing
- Where to get more information

Overview

Areas of Change

- **Pattern & Tube Geometry**
  - Smaller Tube Diameter → Denser Tube Patterns
  - Reduction in Tube Wall Thickness
- **Fin Design & Material**
  - Reduction in Fin Thickness
  - Alternate Fin Alloys



Driving Factors

- Higher efficiency systems
- Refrigerant changes
- Material & Labor Costs

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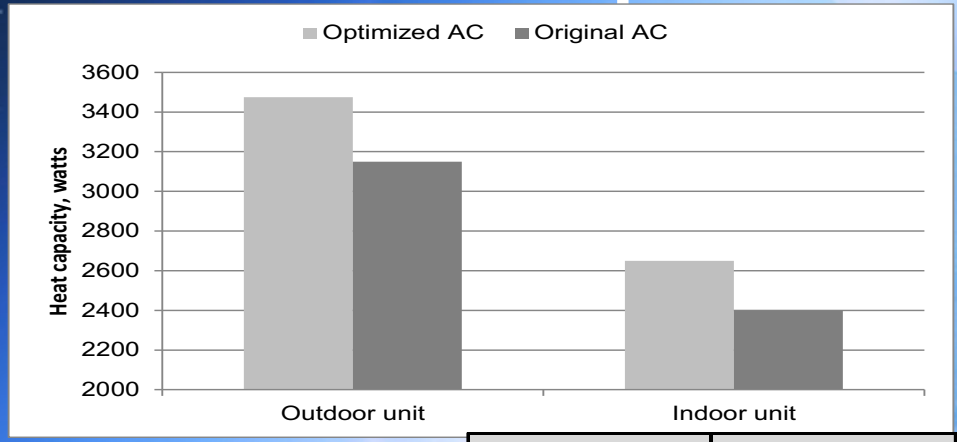
Example: R290 for mini-splits

- Compact HX design using 5mm tube in a 2,600W mini-split
- Refrigerant charge reduced 50% in indoor unit, 45% in outdoor unit, 36% overall
- Increased heat transfer coefficient leads to improved EER with the optimized small diameter copper tube HX design



	Original Design	Optimized Design
Refrigerant charge, gm	390	250
Cooling capacity, watts	2,600	2,537
EER, w/w	3.05	3.20
Heating capacity	2,757	2,786
COP, w/w	3.42	3.44
Indoor Unit Heat Capacity, watts	2,403	2,625
Outdoor Unit Heat Capacity, watts	3,183	3,430
Condensing temperature, °C	46.5	44.1
Evaporating temperature, °C	7.9	9.8

Source: W. Zheng, R. Weed, J. Hipchen, "Developing Low-Charge R290 Room Air Conditioners by Using Small Diameter Copper Tubes", pre-publication manuscript, Copper Development Association

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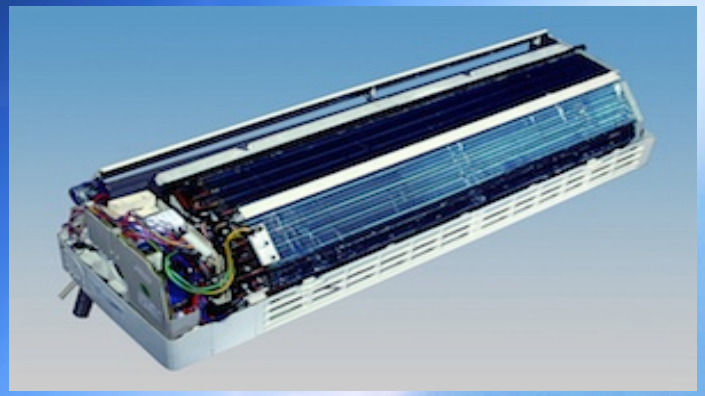
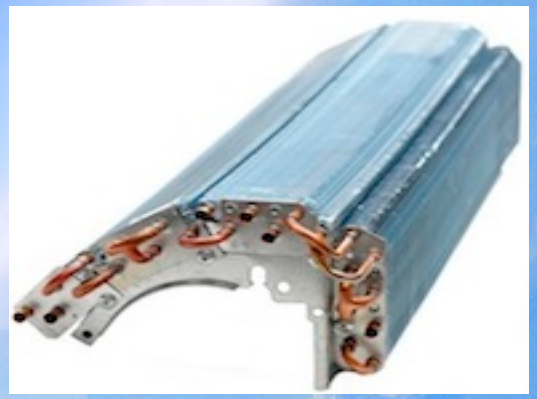
Example mini-split





5mm copper tube evaporators. Courtesy Kelon/Chigo.

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Example: Window AC condenser

- Improve system performance
- Reduce cost
- Reduce refrigerant charge
  - Slit and louver fin designs considered, working with a manufacturing partner

FRIEDRICH

Design	Tube material [kg]	Fin material [kg]	Material Reduction [%]	Simulated Charge Reduction [%]	Simulated (Measured) COP	COP Improvement [%]
Baseline 5/16" tube	1.8	2.5	-	-	2.60 (2.86)	-
Louver fin 17 FPI 4 row	1.5	1.7	**26%**	**21%**	2.77 (2.97)	**6.5% (3.8%)**

Experiment: Louver fin coil achieves 10% *system* charge reduction and 4% COP increase while reducing cost by approximately 26%

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Air Source Heat Pump Water Heater

Tube Diameter (mm)	# of turns	Tube weight (kg)	Heating time (minutes)
9.52	39	9.06	155
7	39	3.33	167
5	39	1.89	179
5	60	2.6	165
5	80	3.28	152

For tube spacing of 10mm, 5mm and 80 turns provides similar heating time to 9.52mm with only 36% weight and 52% refrigerant!

Performance analysis and optimization of wrap-around condenser in an air source heat pump water heater system: Numerical and experimental investigation
Haijian Zhou[a], Hengyi Zhao[b], Yifeng Gao[b], Fen Zhong[a], Naiping Gao[a].
12th IEA conference, Rotterdam

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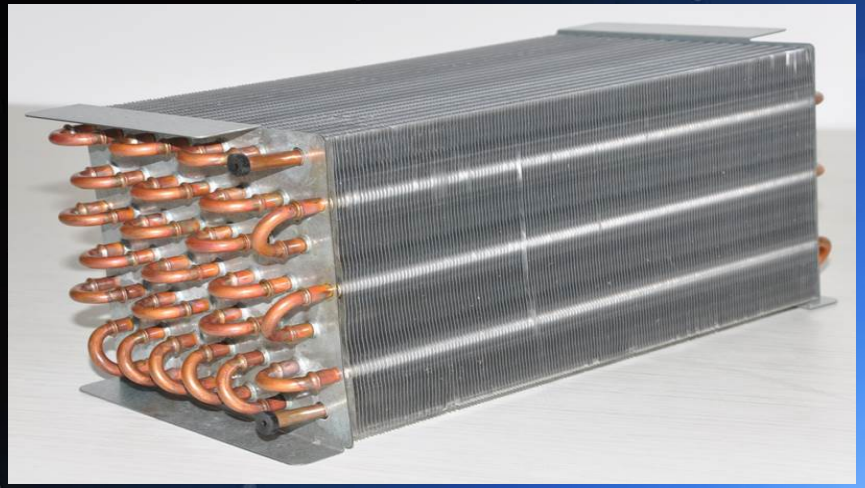
RTPF-HX Application



5-mm copper tubes for clothes-drying heat pumps. Courtesy Spirotech

Condenser with 5-mm copper tubes for split AC . Courtesy Spirotech.

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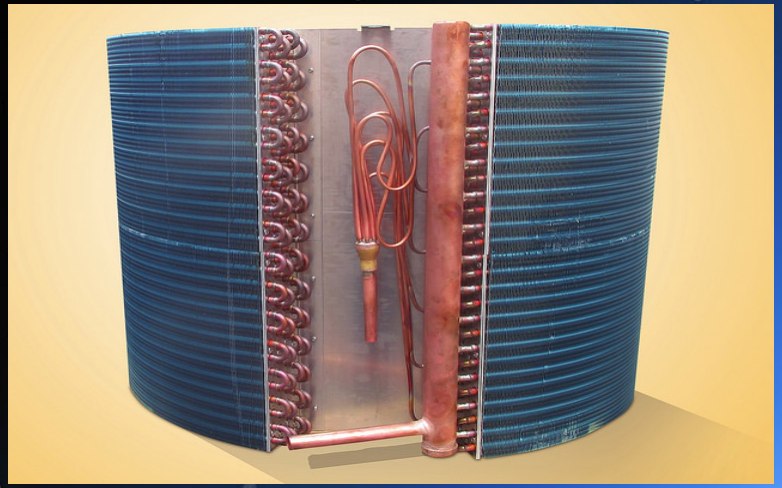
RTPF-HX Application

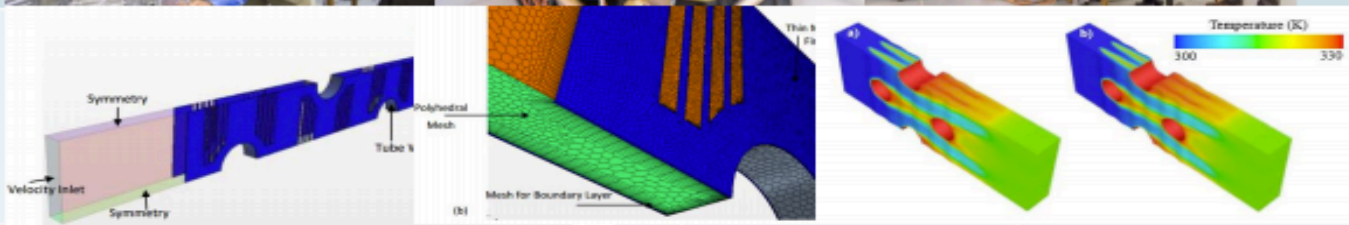


Outdoor evaporator coil for heat pump with 7 mm copper tubes.
Courtesy Lordan

Coil made from 5 mm copper tubes as designed for use in a R744 condenser.
Courtesy Spirotech.

Computer Simulation

Three methods to design heat exchangers:

Experimental	
Numerical (e.g. CFD)	
Approximation (correlations)	$j = c_1 \mathrm{Re}_{D_o}^{P_1} N_t^{P_2} \left(\frac{F_p}{D_o + 2\delta_f}\right)^{P_3} \left(\frac{P_t}{D_o}\right)^{P_4} \left(\frac{P_l}{D_o}\right)^{c_2}$ $f = c_1 \mathrm{Re}_{D_o}^{P_1} N_t^{P_2} \left(\frac{F_p}{D_o + 2\delta_f}\right)^{P_3} \left(\frac{F_p}{D_o}\right)^{P_4} \left(\frac{F_p}{P_t}\right)^{c_2}$

Optimized Thermal SYSTEMS

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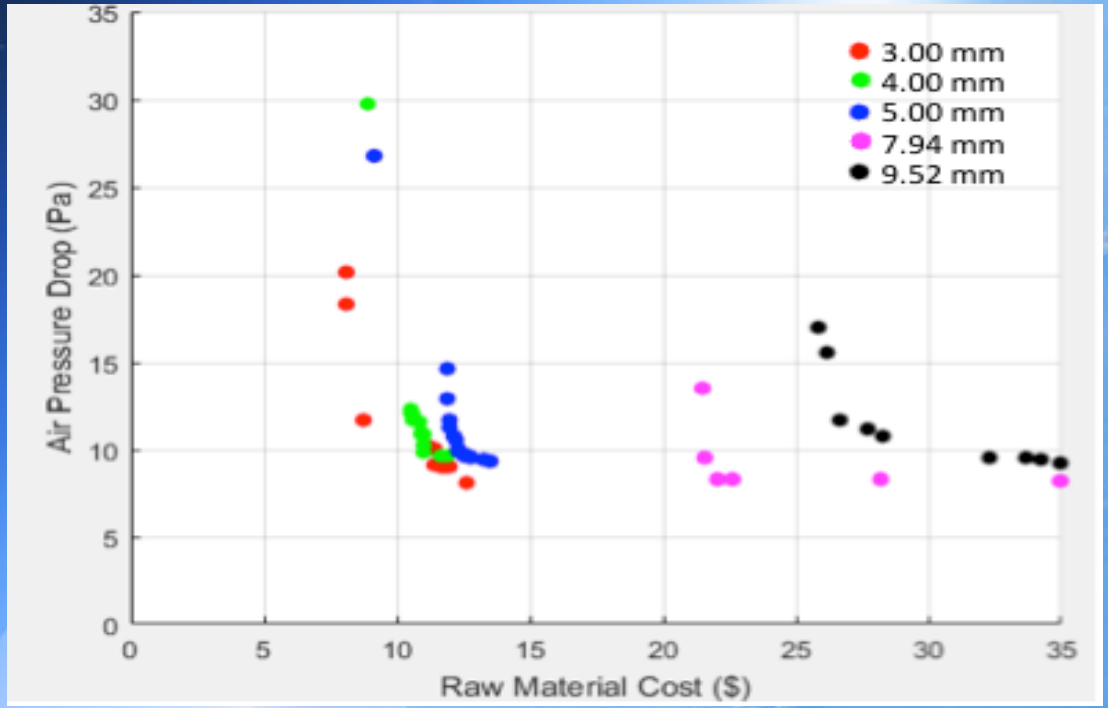
Computer Simulation

- Simulation software 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



Optimized Thermal SYSTEMS

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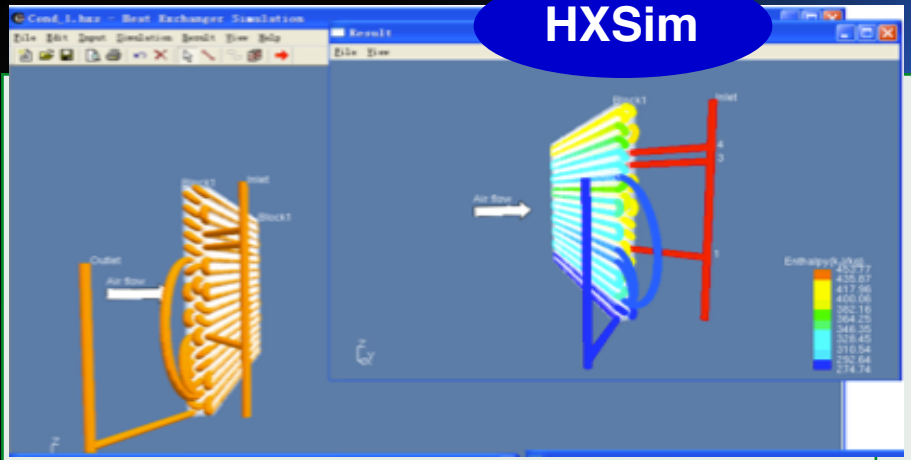
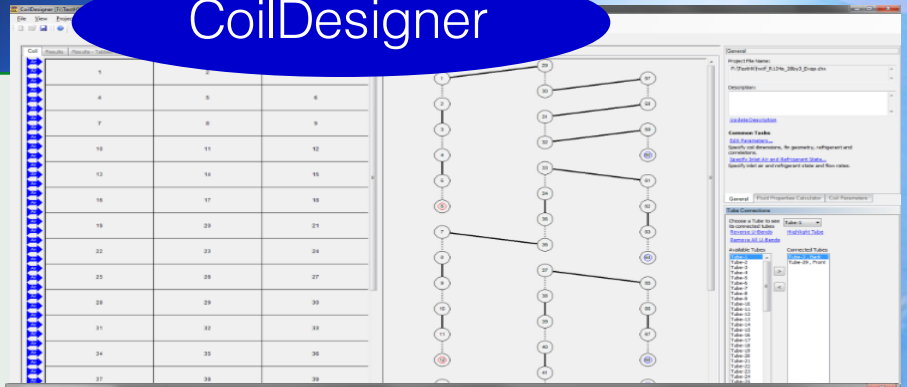
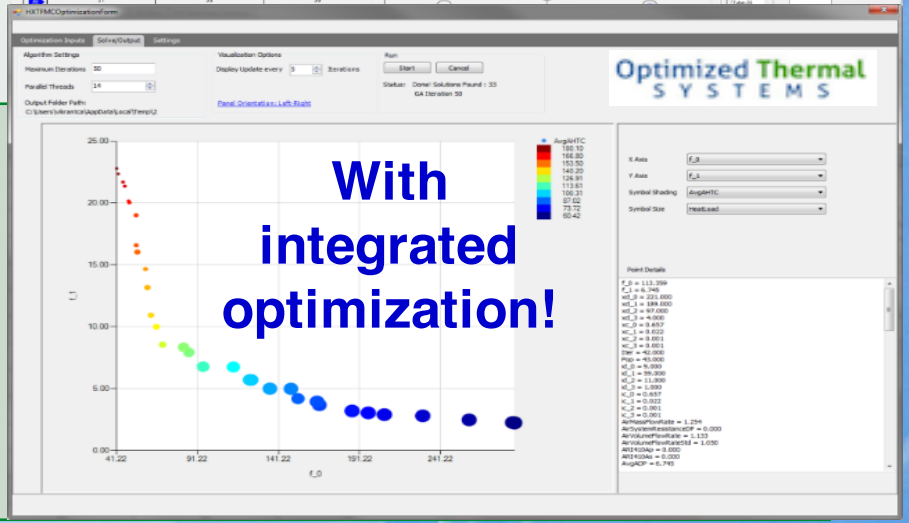
Computer Simulation

HXSim

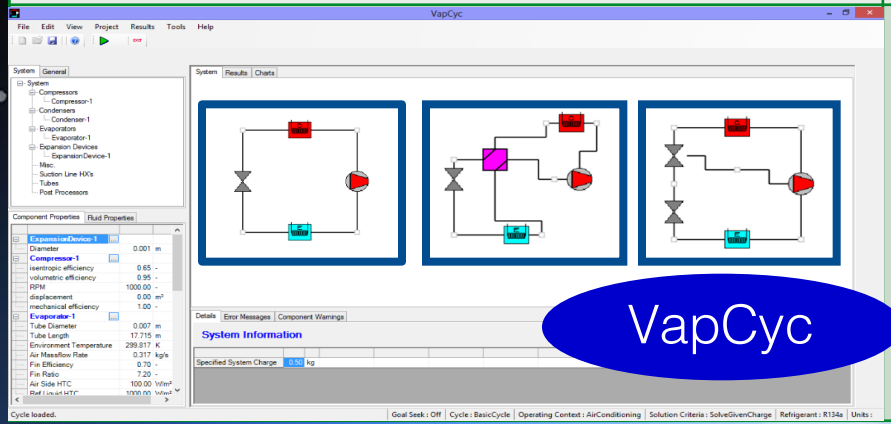


CoilDesigner





VapCyc

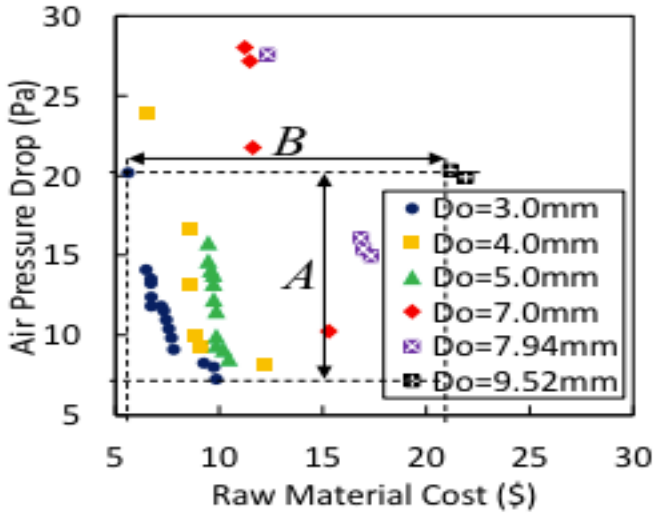


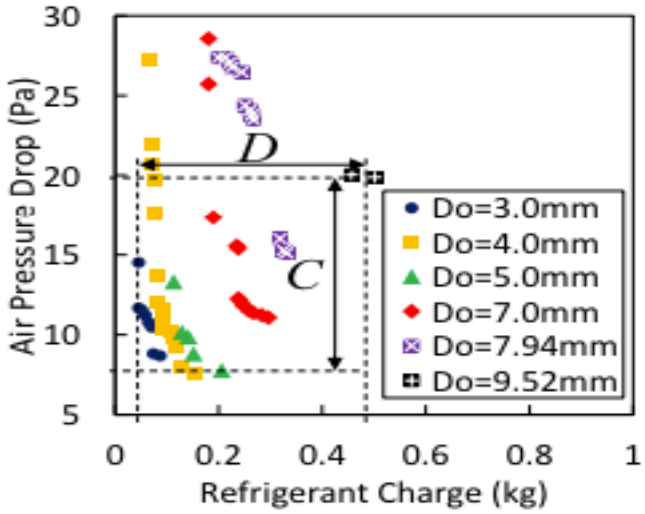
Computer Simulation Example

Identify optimal drop-in replacement condenser for 1-Ton split AC:

Constraints: Equivalent performance to baseline

Objectives: Minimize airside pressure drop,
lower material consumption
lower refrigerant charge





$A = 64\% \downarrow$

$B = 74\% \downarrow$

$C = 62\% \downarrow$

$D = 91\% \downarrow$

ASHRAE 20012 "Comparative Study of Optimized Small Diameter Tube-Fin Heat Exchangers Vs. Traditional, Larger Diameter Tube-Fin Heat Exchanger Designs" Dennis Nasuta, Shekhar Sarpotdar, PhD. Cara Martin

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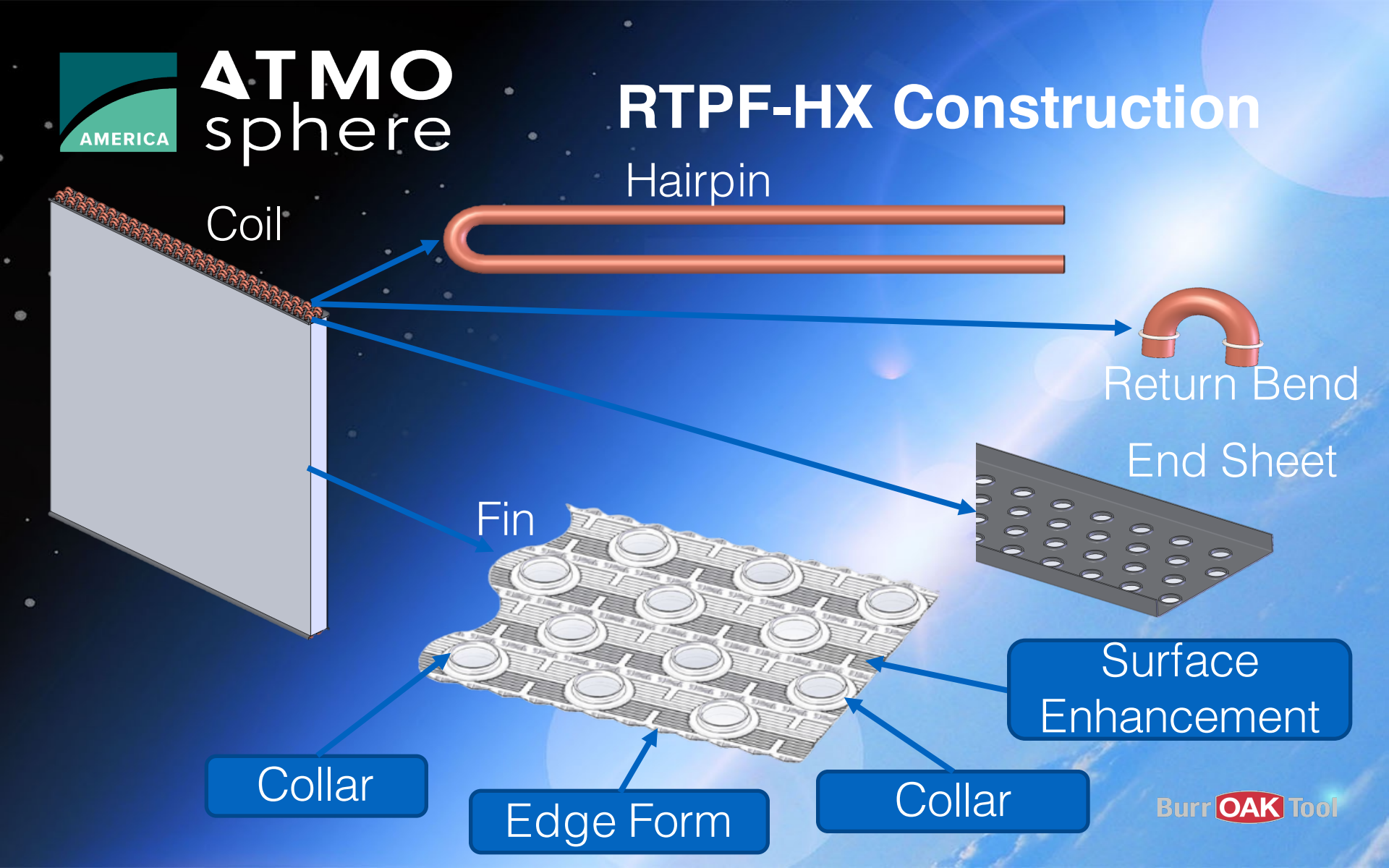
RTPF-HX Construction



Burr OAK Tool

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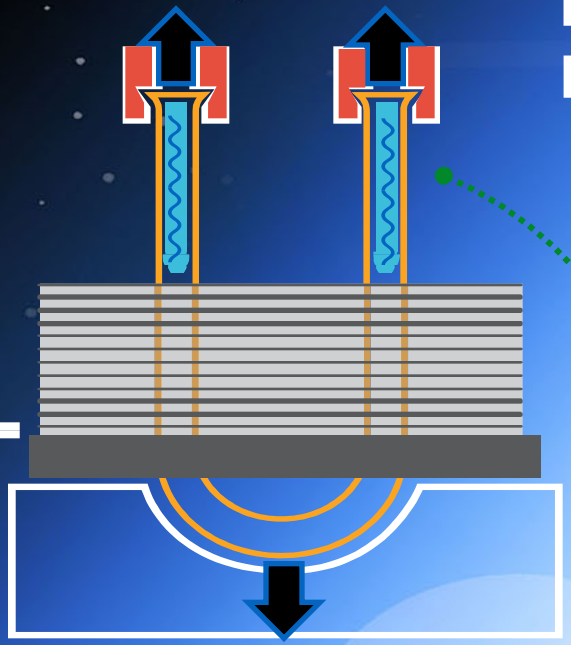
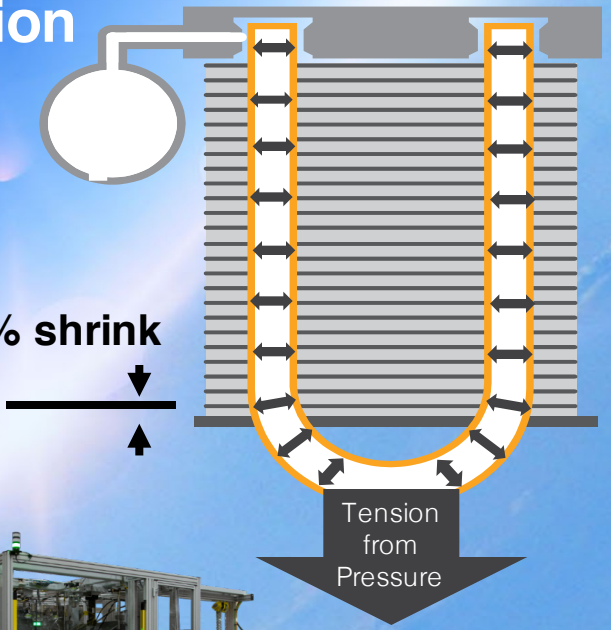
RTPF-HX manufacturing

Limited Shrink Tension Expansion

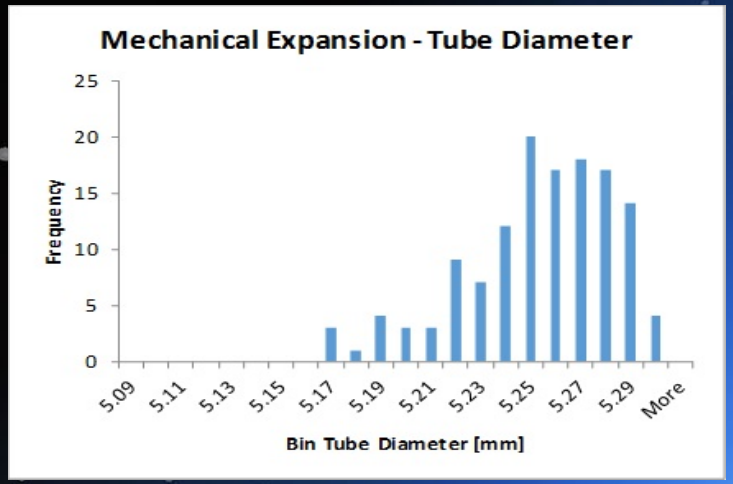


Pressure Expansion

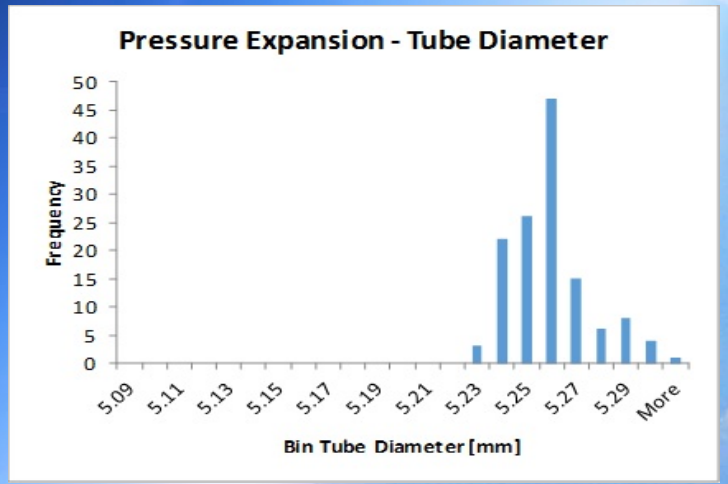


Burr OAK Tool

RTPF-HX manufacturing



S.D. = 0.029 mm



S.D. = 0.016 mm

The pressure expansion resulted in:

- No damage to internal enhancements
- Improved contact between tube and fin

A new white paper is now available from Burr Oak addressing the issue of safety [3]

Educational

- OTS-ICA Educational Outreach Program:

-Three Webinars
(Archived on MicroGrooveTech YouTube Channel)
-Coil Samples for participants
-Trial version of CoilDesigner for participants

www.microgroove.net/ots-ica-educational-outreach

Thank you!