



Business Case for Natural Refrigerants

19-21/11/2018 – Lago di Garda

**Sub-Zero, MTL Cool and LU-VE optimize MicroGroove
copper-tube coils for use with natural refrigerants**

1. **MTL Cool:**

- a. **R290** display cabinets
- b. Actual performance data

2. **Sub-Zero:**

- a. **R600a** domestic refrigerator application
- b. HX optimization - MOGA

3. **Lu-Ve:**

- a. **R744** CO₂ Heat Pump and Gas Coolers

4. Microgroove and Natural refrigerants **Conclusions**

Manufacturing Production Line Opened in 2017
Increased 4x - Pepsi and Kroger recent orders
Product Available for Export to Europe in Summer 2019
Invitation to visit plant at ICR 2019 Montreal



Punch



Paint



Insulate

MTL Cool Sample Products



LPC series,
R290



Alpine Series,
R290



Aspen Series,
R600

Prototype Heat Exchangers

Typical heat exchanger coils using small diameter copper tube

Evaporator



Condenser

MTL Cool

Recent Performance Data



VISTA DOUBLE-DOOR DISPLAY CABINET 115V

CAPACITY: 750 L (26.5 CU FT)

- Type 1 Refrigerator. Ambient conditions 75°F/55% RH
- AMPERAGE:
 - R134a – 10.50A
 - R290 – 6.09A.....**42% Power Reduction**
 - ✓ 5mm MicroGroove evaporator tubing
 - ✓ 5mm MicroGroove condenser tubing
 - ✓ ECM fan motors on both evaporator and condenser
 - ✓ LED lighting
- Refrigerant charge reduction.....**38%**
- Product Pulldown from 75°F to 38°F, improved by..... **9%**

MTL Cool

Recent Performance Data



LP-300 SINGLE DOOR DISPLAY CABINET 115V

CAPACITY: 300 L (10.6 CU FT)

- Type 1 Refrigerator. Ambient conditions 75°F/55% RH
- AMPERAGE:
 - R134a – 3.60A
 - R290 – 1.90A.....**47% Power Reduction**
 - ✓ 5mm MicroGroove evaporator tubing
 - ✓ 5mm MicroGroove condenser tubing
 - ✓ ECM fan motors on both evaporator and condenser
 - ✓ LED lighting
- Refrigerant charge reduction.....**43%**
- Product Pulldown from 75°F to 38°F, improved by..... **8%**

Sub-Zero: Refrigerator application

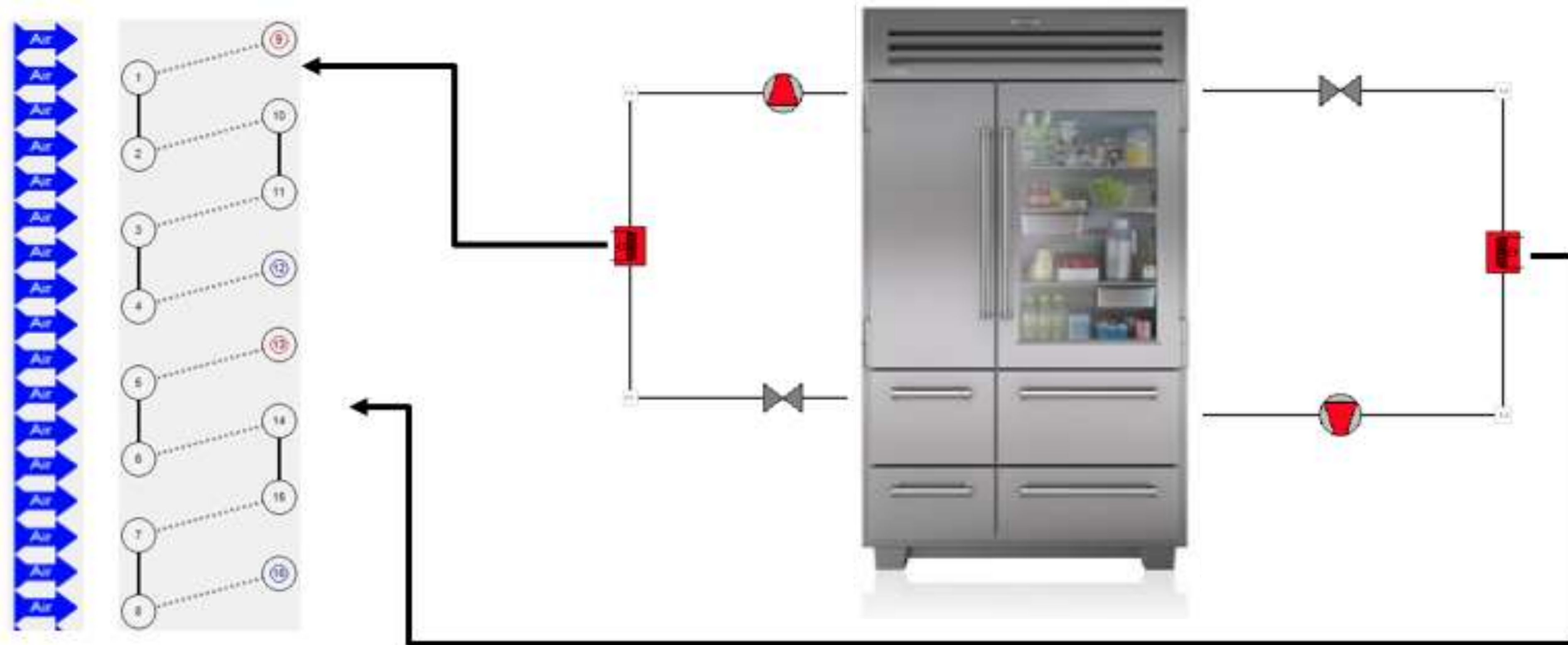
Sub-Zero is a global leader of high-end appliances with presence across Europe

- Main Motivation:
Use Natural Refrigerant R600a *and maximize performance*

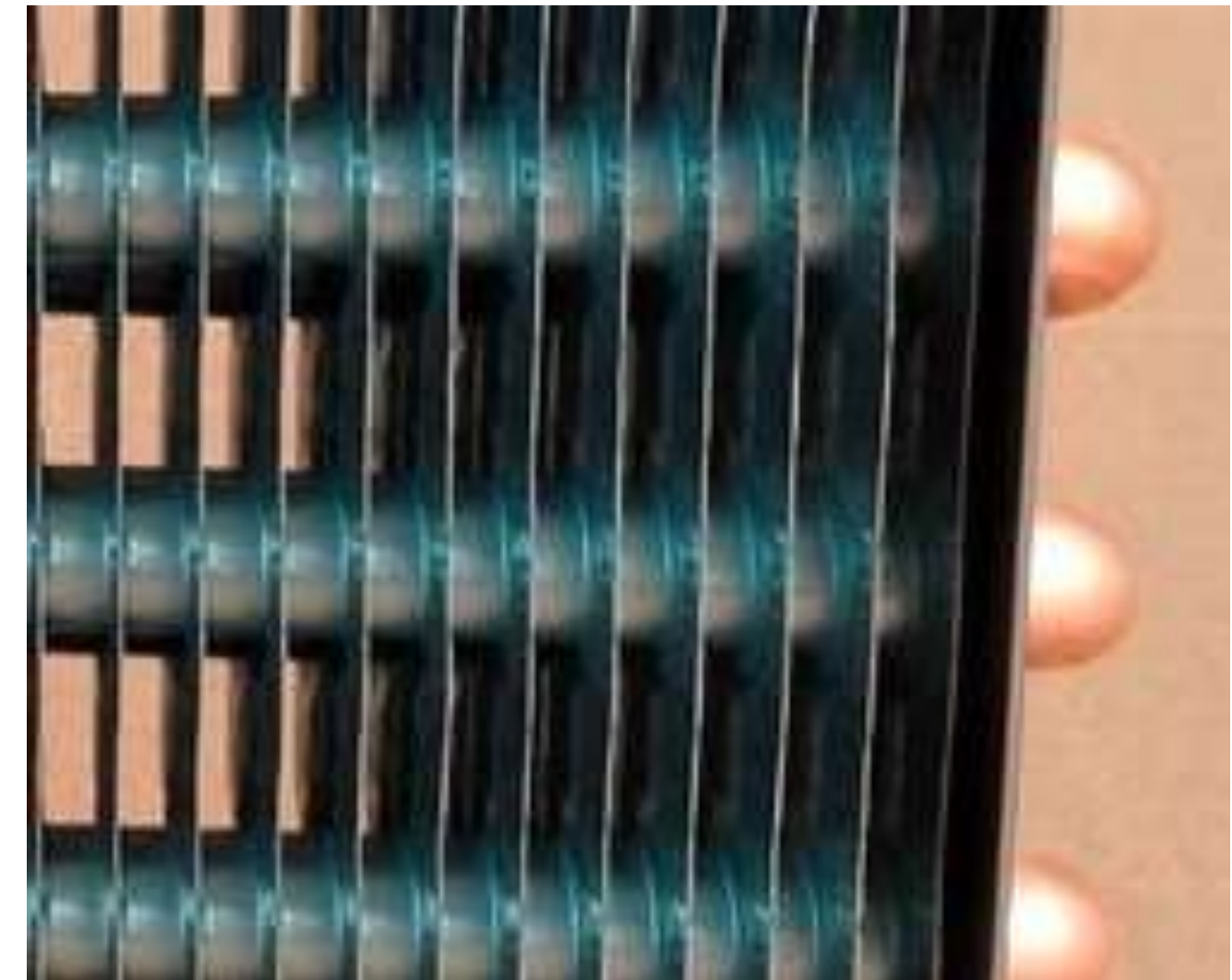


Sub-Zero Refrigerator

- The baseline refrigerator (Pro-48) uses two vapor compression cycles (VCCs) which share a condenser to maintain the freezer and refrigerator temperatures
- The condenser coil has two circuits, each circuit serves one of the VCCs

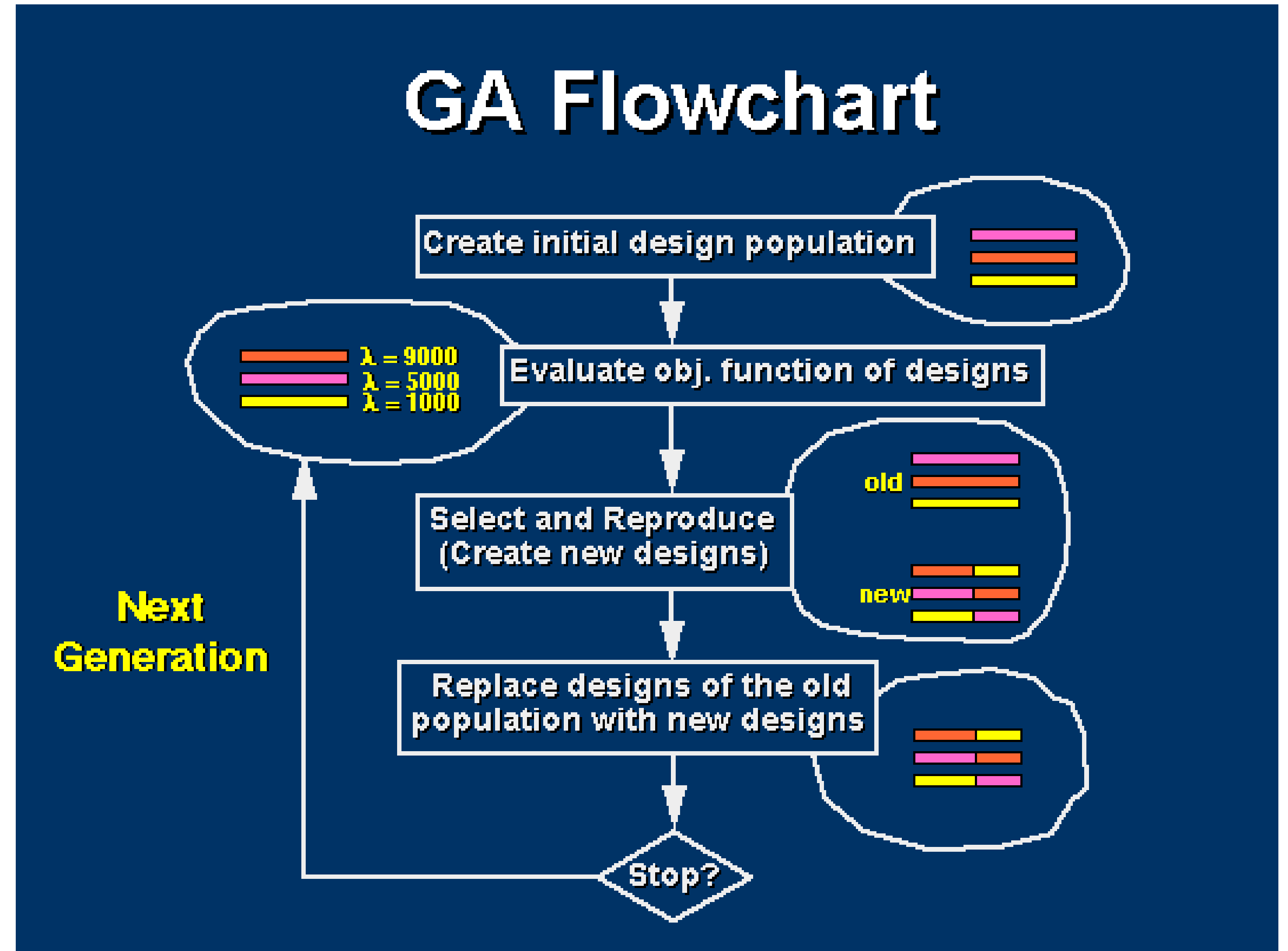


- To achieve **highest** HX efficiency, simulation work included Multi-Objective Genetic Algorithm (MOGA)
- HX design **variables** using 5mm OD tube in HX:
 - Heat exchanger length
 - Fin density
 - Horizontal tube spacing
 - Vertical tube spacing
 - Fin geometry



Genetic Algorithm is a type of evolutionary algorithm

A *population* of possible solutions is evaluated in each iteration



Multi-objective algorithm:

Multiple objective functions are evaluated simultaneously

Single objective
(for example, weighted sum)

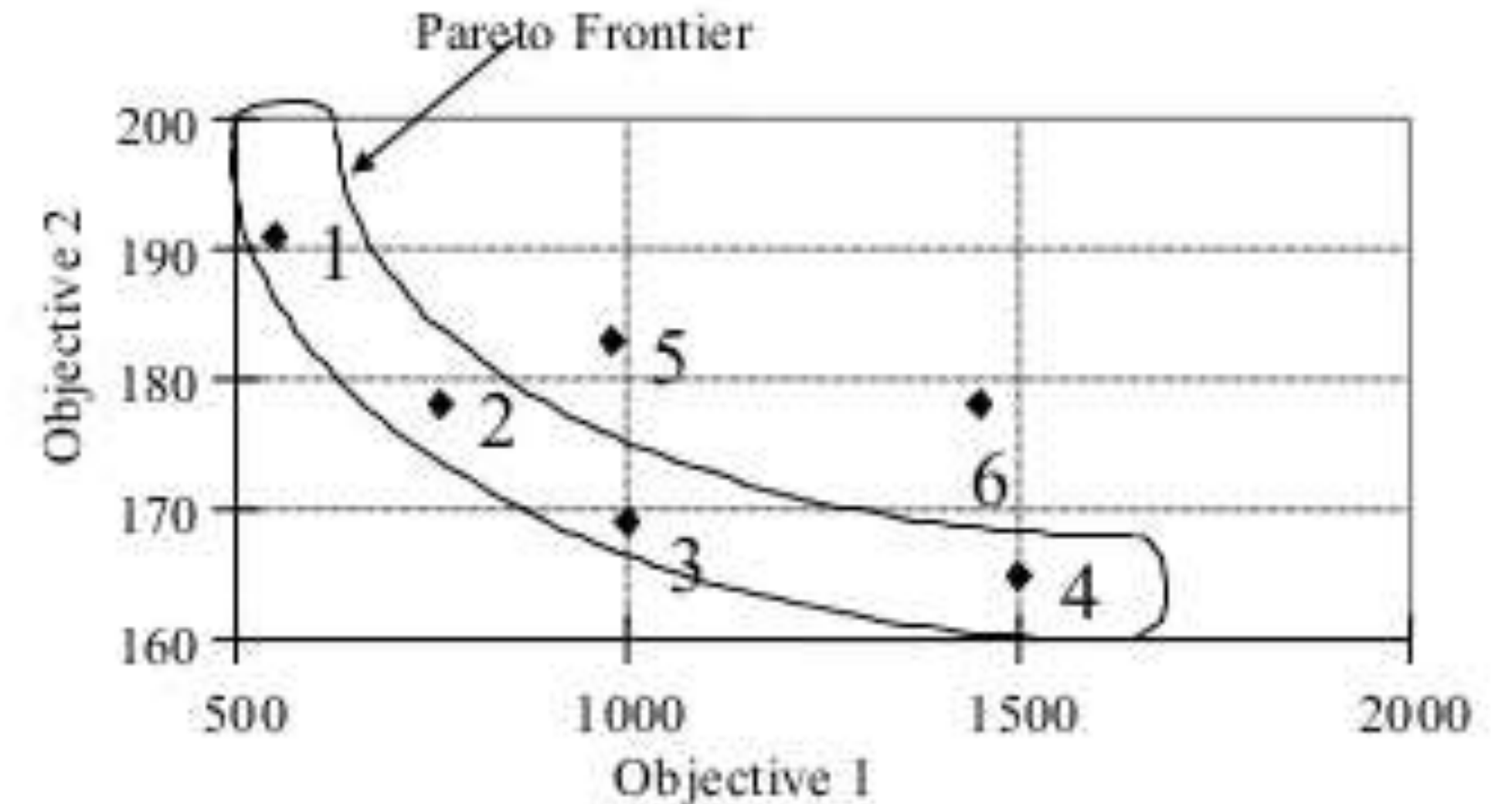
Decision made before the search

$$FO_i = \sum_{j=1}^q w_j F_j$$

$$\begin{cases} 0 \leq w_j \leq 1 \\ \sum w_j = 1 \\ 0 \leq F_j \leq 1 \\ 0 \leq FO_i \leq 1 \end{cases}$$

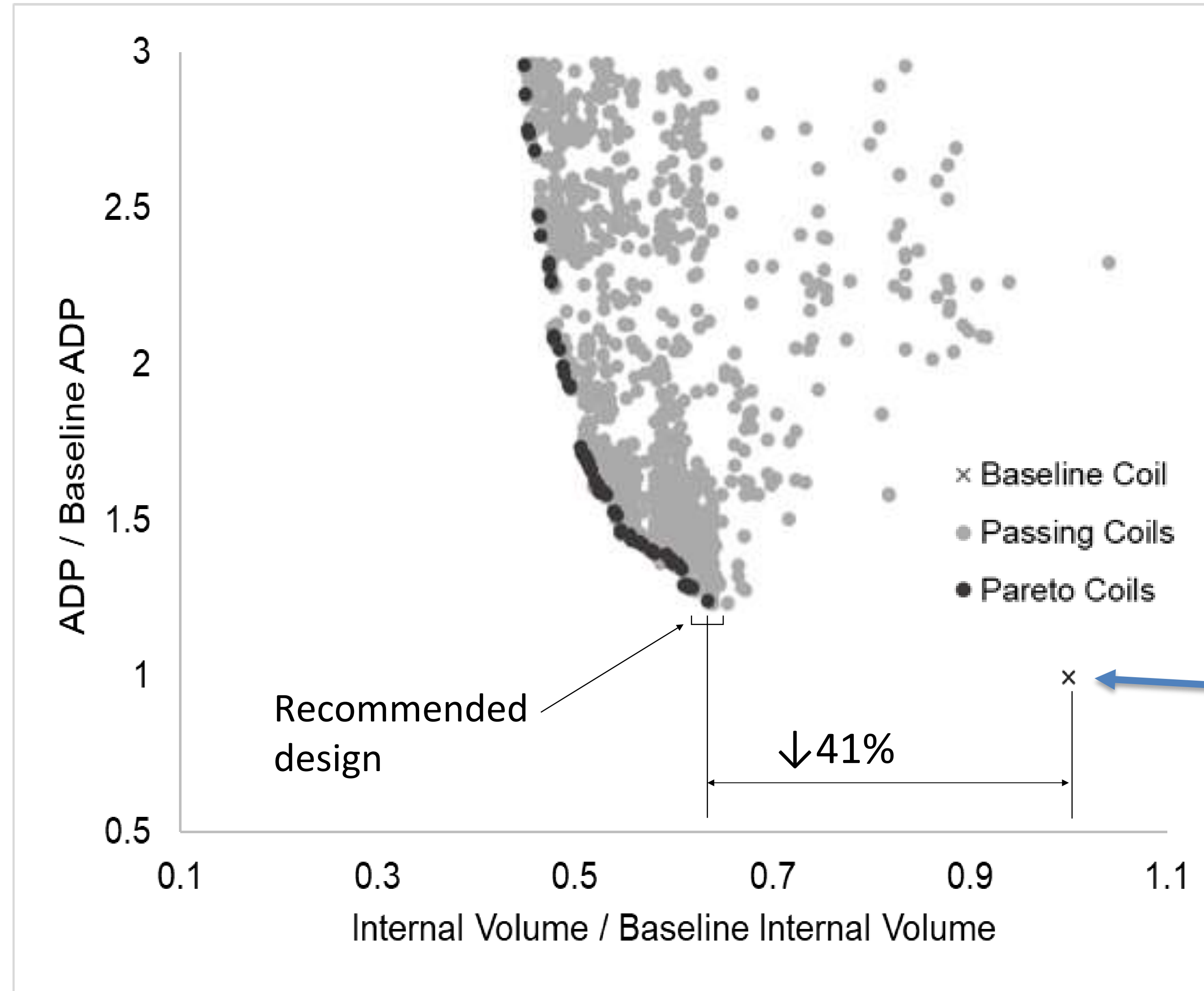
Multiobjective optimization

Decision made after the search



MOGA results, using 5mm tubes instead of the baseline 6.35mm tubes

- × Baseline coil
- MicroGroove coils



LU-VE CO₂ Gas Cooler

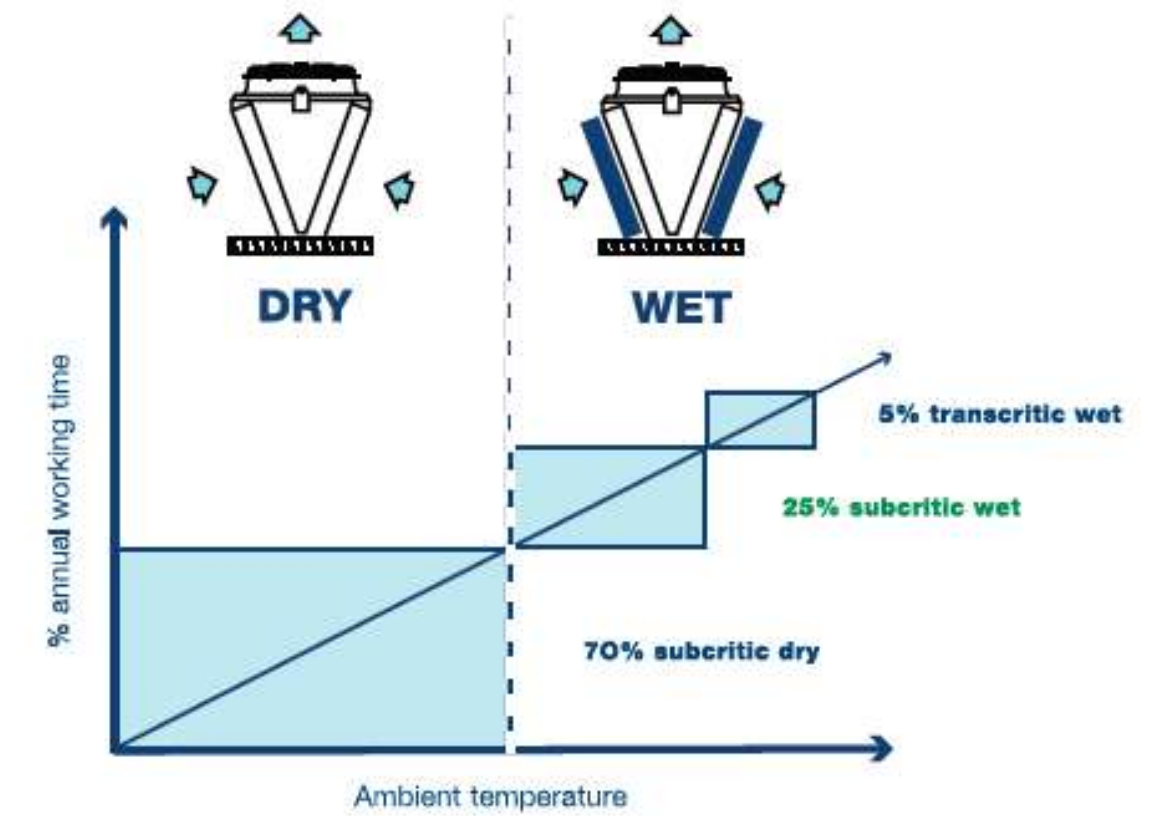


ø5 mm adiabatic CO₂ gas cooler

Adiabatic CO₂ gas cooler, new generation for transcritical applications:

- > extends subcritical operations
- > CO₂ equator redrawing

NEW



Minichannel

HIGH-EFFICIENCY Ø5 mm HEAT EXCHANGERS

120 bar max working pressure

Extremely compact solution

Adiabatic System

PRE-COOLING SYSTEM

Increases the overall efficiency of transcritical systems

Advanced controller

Propeller

HIGH-EFFICIENCY ELECTRONIC RADIAL MOTOR FAN

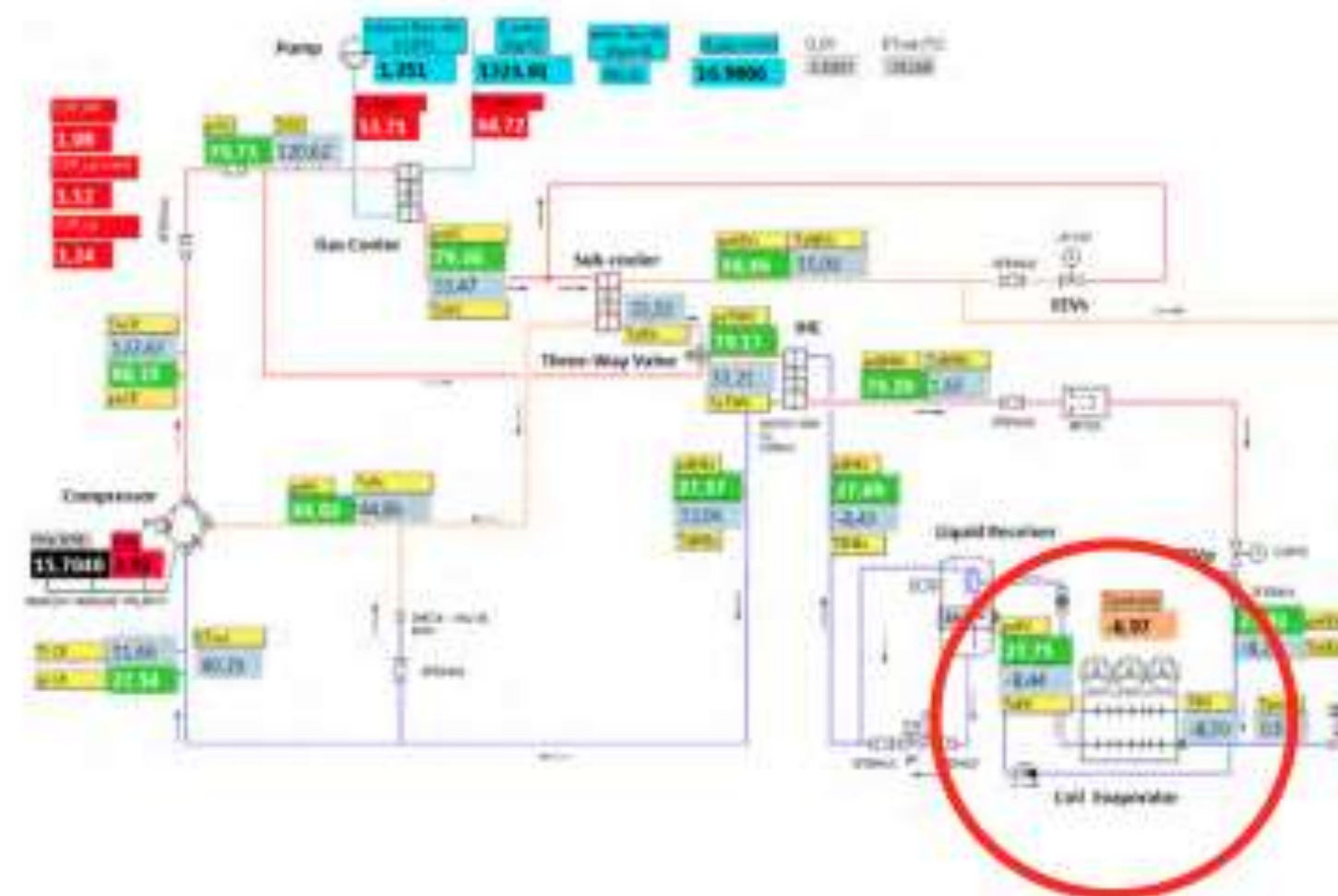
High static pressure to canalize outlet air

Heat recovery



COIL TYPE:

- Refrigerant: CO₂
- Fin pack dimensions: 2000x1200x69
- Tube diameter: 5,0 mm
- Numbers of tubes: 60
- Numbers of rows: 4
- Numbers of circuits: 40
- Fin spacing: 3,0 mm



LU-VE CO2 Heat Pump

	Geometry 25x21,65 tube Ø9,52	Geometry 20x17,32 tube Ø5
Capacity [kW]	33,40	33,17
Tube diameter [mm]	10,12	5,00
Header volume [dm3]	0,74	0,74
Header diameter [mm]	28	28
Tubes volume [dm3]	25,08	7,13
Total coil internal volume [dm3]	25,82	7,87
Internal volume difference		-69,5%
Coil weight [kg]	78,06	45,71
Coil weight difference		-41,4%
Air pressure loss [Pa]	66,53	62,70
Air pressure loss difference		-5,8%

Microgroove and Natural Refrigerants

- **Summary:**
 - New HX design using 5mm copper tubes and **natural refrigerants** have:
 - Lower internal volume
 - Weight reduction
 - Performance improvement
 - Also:
 - Methodology used (MOGA) successful in finding optimized designs
 - Small-diameter copper tube HX are suitable for R290 and R600a natural refrigerants, and others.

Prior ATMO Presentations

R290 heat exchanger designs at prior ATMOSphere Conferences:

Chicago, 2016 <http://www.atmo.org/media.presentation.php?id=920>

New copper-tube technologies for heat exchangers: R290 coil and R744 gas cooler

By Yoram Shabtay, Jian Yu & Nigel Cotton

San Diego, 2017 <http://www.atmo.org/media.presentation.php?id=1051>

Select case studies of copper heat exchanger coils for natural refrigerants

By Yoram Shabtay & Nigel Cotton

For more information: www.microgroove.net

Thank you!



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