CEEE CENTER for ENVIRONMENTAL ENERGY ENGINEERING

Airside Performance Correlations and Optimal Air-Conditioning Heat Exchanger Designs Based on 0.5mm-2mm Finless Round Tube Bundles

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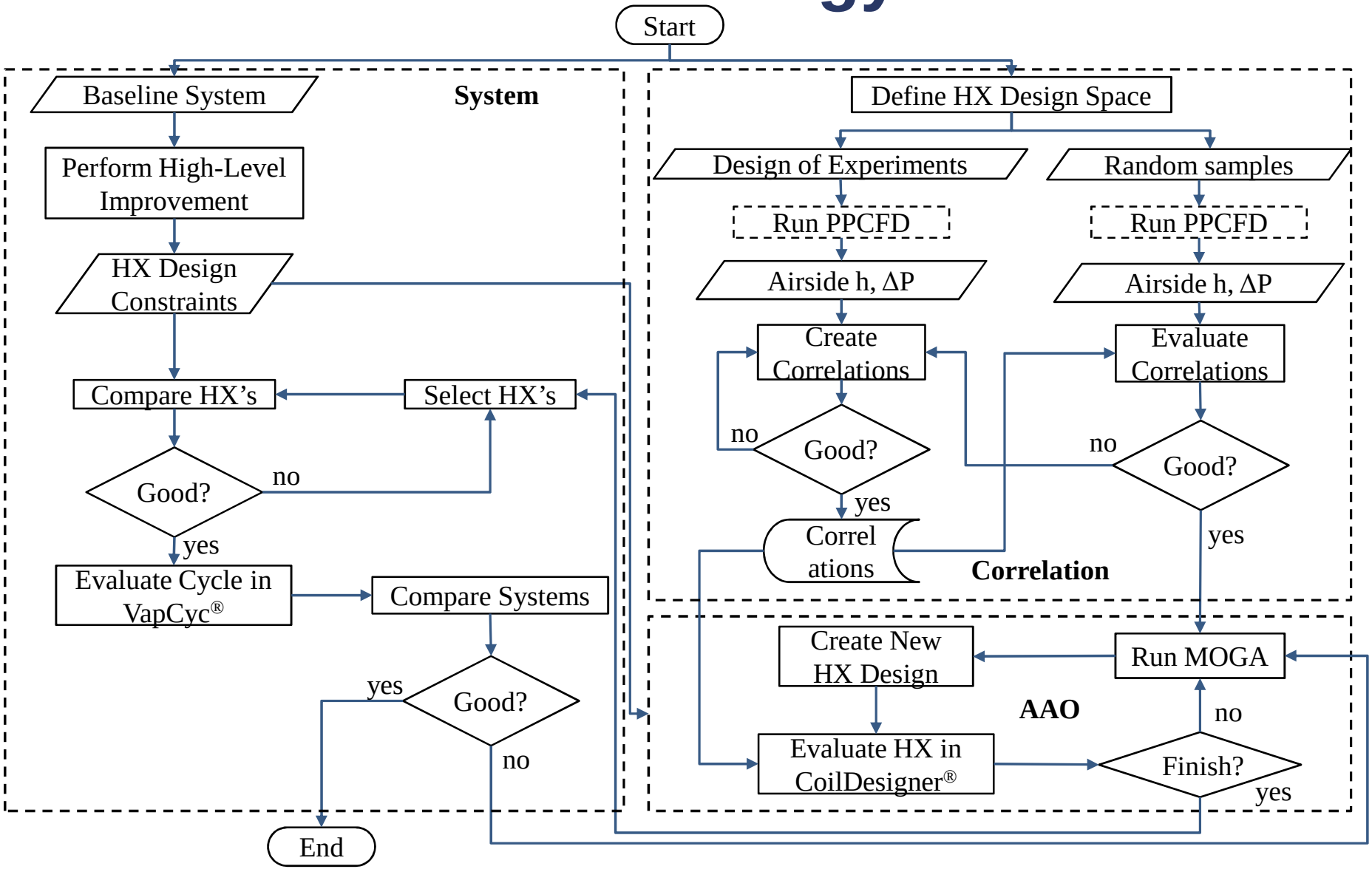
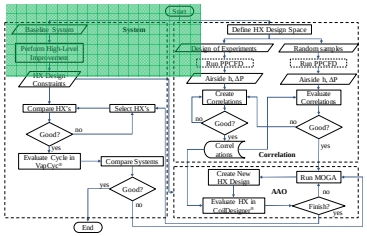
Objectives

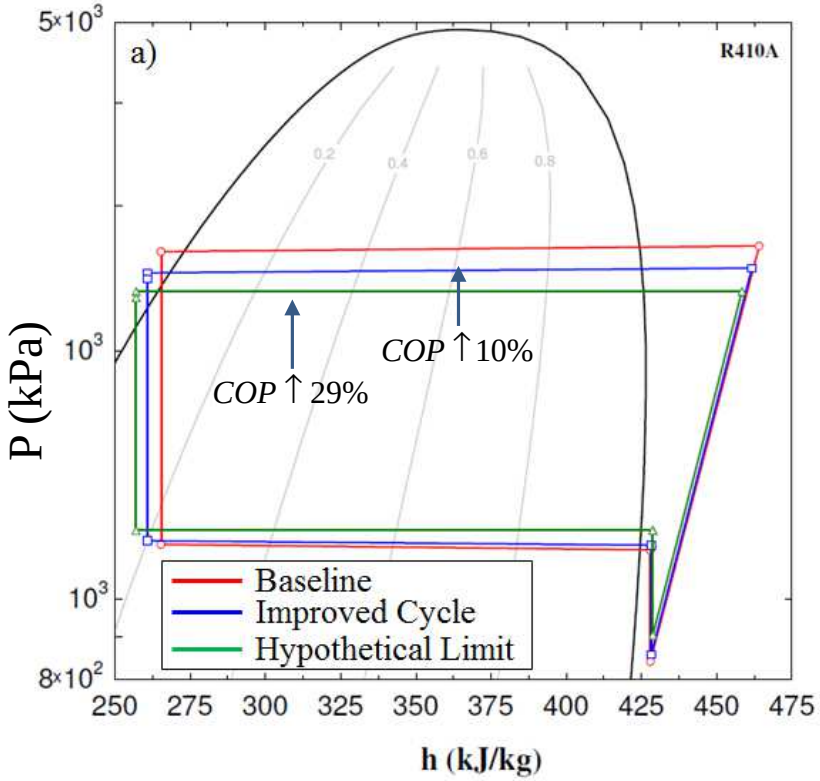
- Present a new set of equations for thermal hydraulic performance for in-line bare tube bundle with tube diameters of 0.5mm-2.0mm
- Design and optimize condensers and evaporators using small diameter bare tube bundle (both staggered and in-line) for the 3Ton A/C system (R410A)
- Demonstrate the system improvements by utilizing small diameter tube HX’s

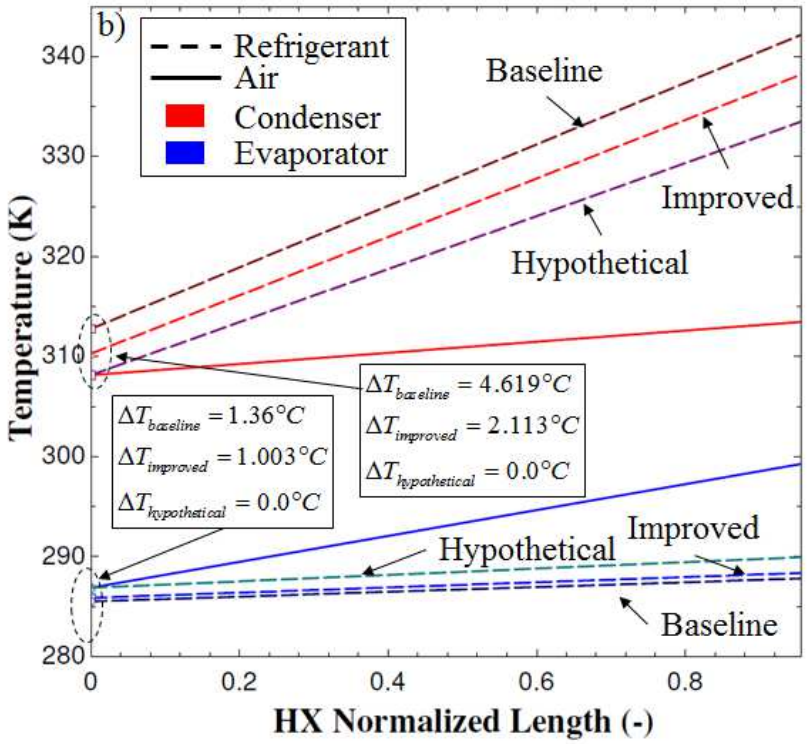
Methodology



3 Ton System Analysis



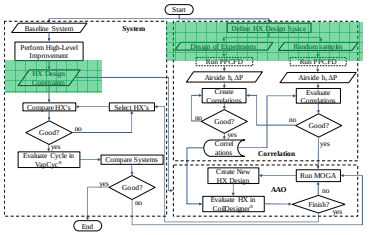




Cycle	Charge	COP*	COP	Q	Super heating	Sub-cooling	Ref. ṁ	Evap. AFR	Cond. AFR
	kg	-	-	kW	K	K	kg/s	m³/s	m³/s
Baseline (rated)	5.557	4.507	3.900	10.029	5.447	3.890	0.06224	0.505	1.84
Baseline (simulated)	4.907	4.506	3.858	10.025	5.445	3.901	0.06168	0.505	1.84
Improved system	-	**4.992**	**4.210****	**10.030**	**5.447**	**3.911**	**0.05994**	**0.505**	**1.84**

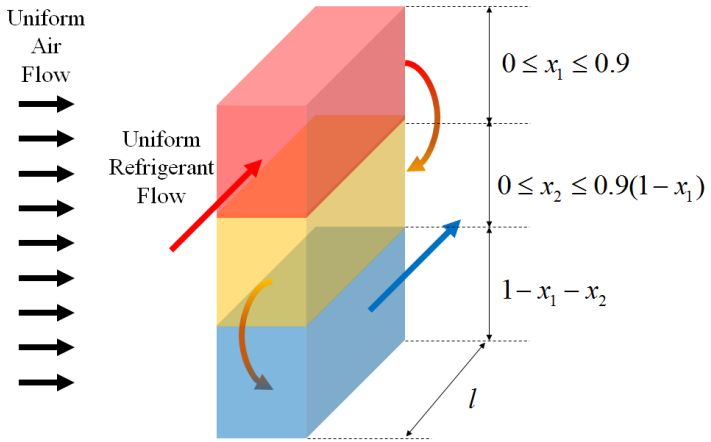
**w/o fan power **using rated fan power*

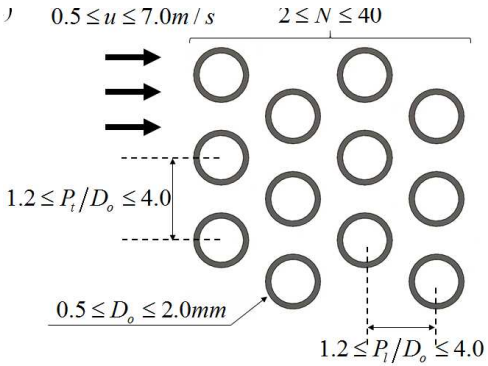
3Ton Heat Exchangers

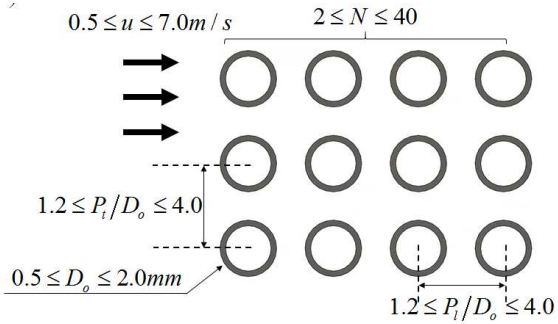


HX	Evaporator						Condenser					
Metric	Q	P_{sat}	ΔP_{ref}	UA_{Norm}	ΔT_{ml}	ΔP_{air}	Q	P_{sat}	ΔP_{ref}	UA_{Norm}	ΔT_{ml}	ΔP_{air}
	kW	kPa	kPa	-	K	Pa	kW	kPa	kPa	-	K	Pa
Baseline	10.025	1166	18	1.00	4.86	57.2*	12.251	2682	41	1.00	13.43	N/A
Improved	10.030	1178	13	1.14	4.26	N/A	12.040	2521	33	1.39	9.49	N/A

**Rated value*



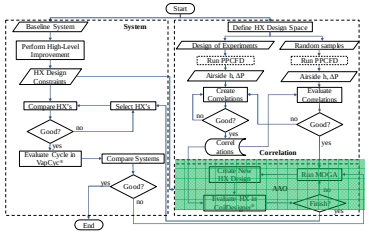




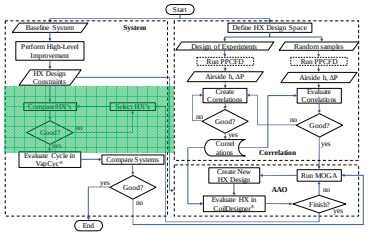
HX Multi-Objective Optimization

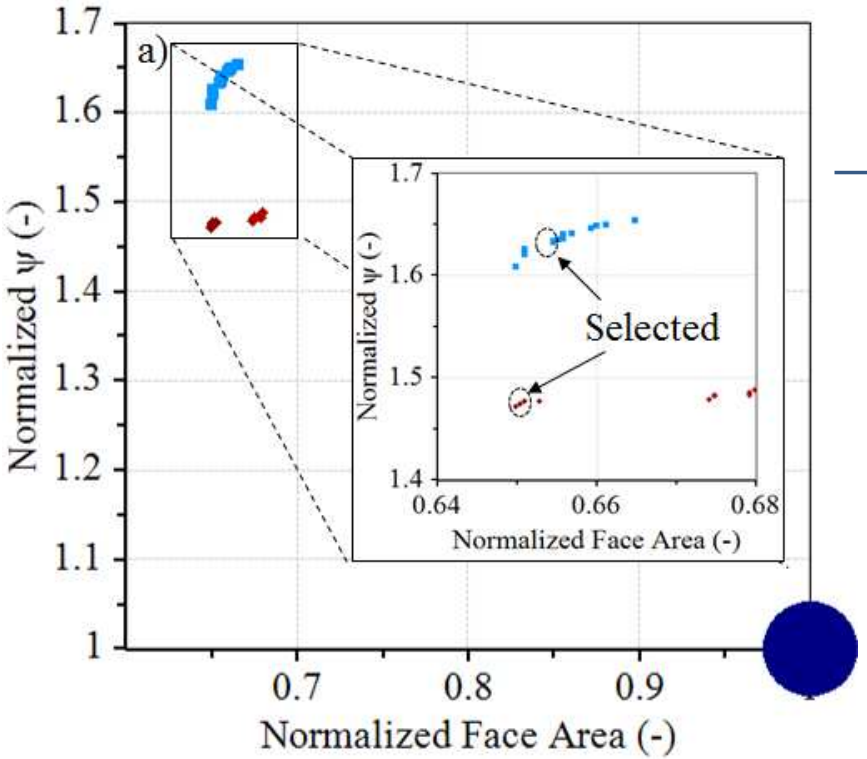
$$\psi = \frac{N_{tu}}{N_s}$$

Evaporator	Condenser
$\max \psi$	$\max \psi$
$\min A_f$	$\min A_f$
$s.t.$	$s.t.$
$10.02 \le \dot{Q}_{evap} \le 10.04 kW$	$12.00 \le \dot{Q}_{evap} \le 12.05 kW$
$V_{HX} \le 14,612\ cm^3$	$V_{HX} \le 41,884\ cm^3$
$\Delta P_{air} \le 50\ Pa$	$\Delta P_{air} \le 15\ Pa$
$\Delta P_{ref} \le 13.78 kPa$	$\Delta P_{ref} \le 15.0 kPa$

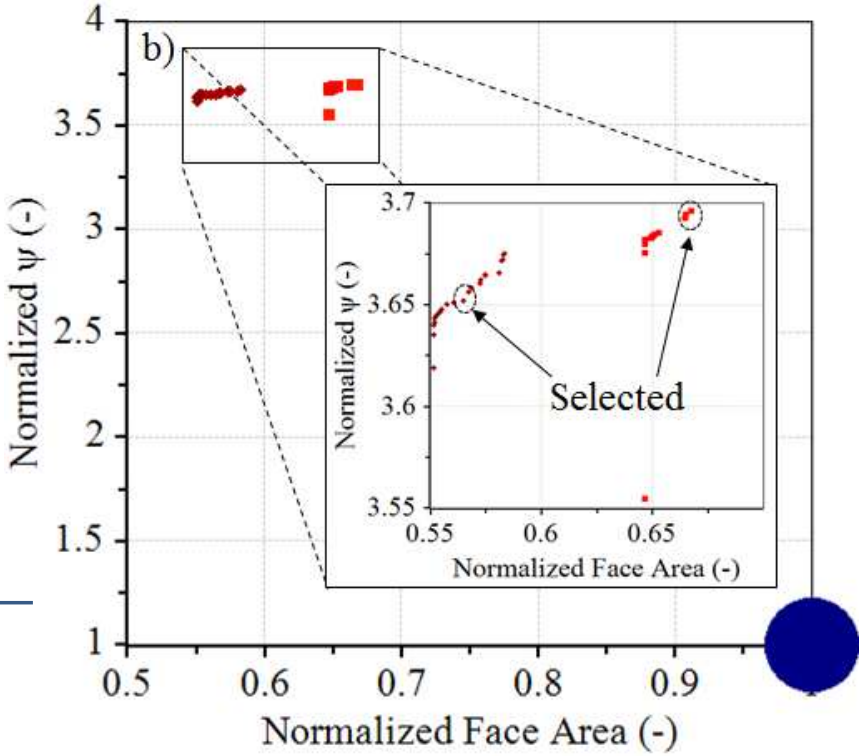


Results

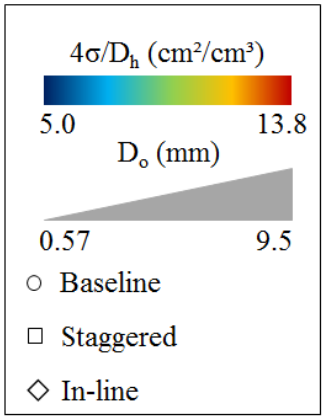




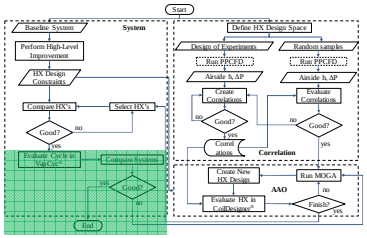
Evaporator

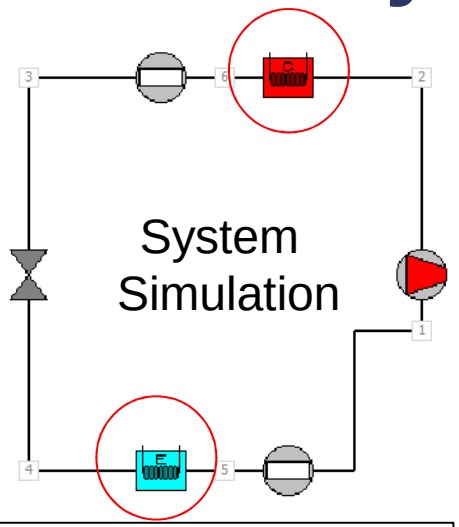


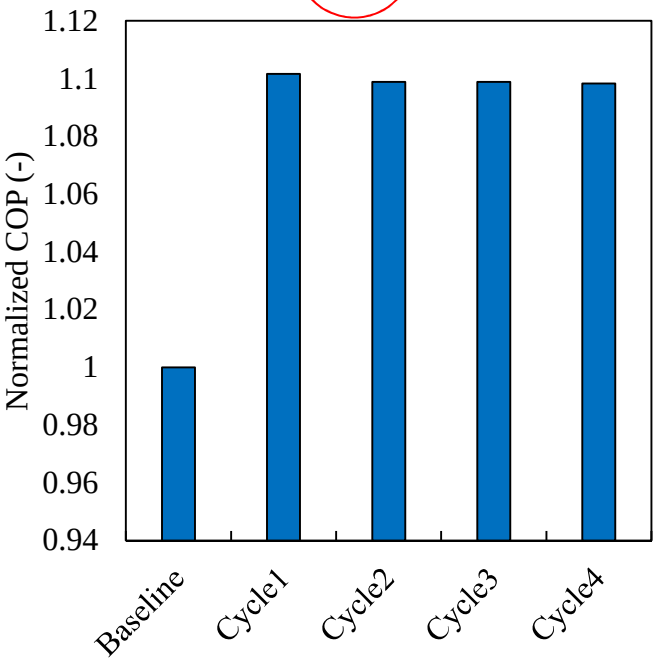
Condenser

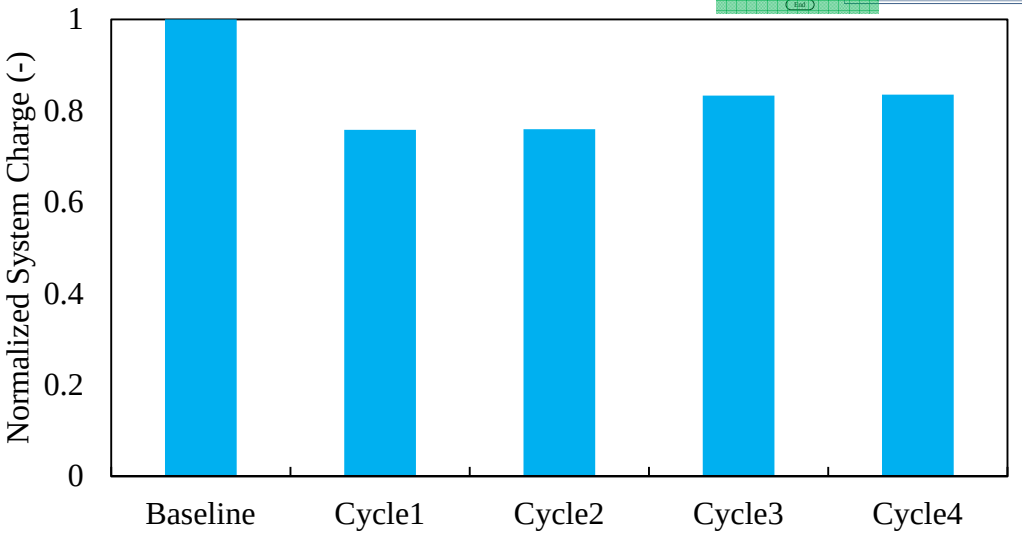


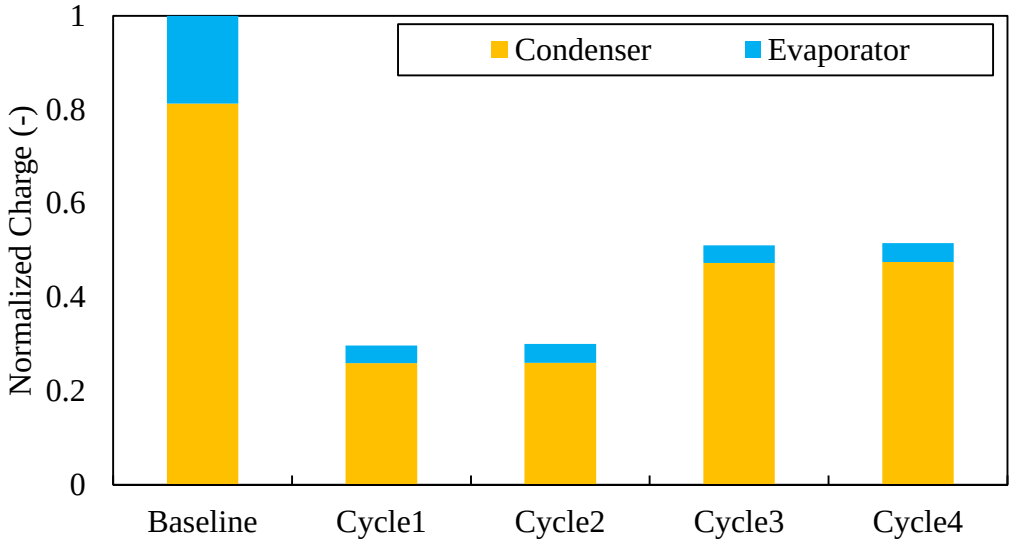
System Analysis











Conclusions

- Design framework for evaporators and condensers → R410A; 3 Ton system
- Theoretical maximum COP improvement of 29%; approach temperatures of at least 1C result in 10% better COP (w/o fan)
- Optimum HX's: D_o < 0.9mm, Af 67% of baseline, 2x more compact, 80% reduced material
- System: 10% COP improvement; 50% less charge within HX's and 20% less charge within the system

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THANK YOU!