Simulation Modeling: Reducing System Design Time and Cost

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Agenda

- Objective
- Introduction
- Systems Analyzed
- Results
  - » 5 Ton Pool Pump
  - » 3 Ton Residential AC With Microchannel Condenser
  - » 3 Ton Split Residential Heat Pump
  - » System Optimization
- Conclusions
- Q/A Session

Objective

- Evaluate System Modeling Software for Designing Air-Conditioners and Heat Pumps
- Capabilities
  - » Simple To Use w/ Short Learning Curve
  - » Flexible & Physics Based Model
  - » Robust w/ Good Track Record
  - » Detailed System Inputs / Output
  - » Offer System Design Options
    - – HX Geometry, Compressors, Indoor/Outdoor Air Flow….
  - » No Limits to System Size
  - » Scale Components
  - » Good Accuracy

Introduction

- Industry Undergoing Major Emphasis on Energy Efficiency
  - » Lower Energy Consumption
- Redesigning Product At Both Component and System Level
- Normally Use Trial and Error Procedure for Designing Systems
  - » Costly And Lengthy Testing
- Our Investigation Shows System Model Can Enhance Engineering Productivity & Significantly Lower Design Time
  - » Example: System Design Simulator

Features: System Design Simulator (SDS)

- Hardware Based Model w/ Rapid Processing Speed and User Friendly Windows Interface
  - » Based on Oak Ridge National Lab's Steady-State Modeling Engine
    - – Air & Water Source Heat Pump Models
    - – Micro Channel HX Capability
    - – Refrigerant Selection & Charge Prediction
    - – Scaling Factors (HX & Compressor) to Improve Correlation Between Simulation & Tests
    - – Automated Means to Conduct Parametric Performance of Selected Design Variables
    - – Database of Coaxial HXR & Copeland Compressors
    - – Detailed Output: Capacity, Power, Efficiency, Pressure, Temperatures Throughout Cycle. Heat Transfer Related Information Also Available
    - – SEER and HSPF Capable
    - – Additional Tools: Thermodynamic Properties of Refrigerants, Application Engineering Bulletins

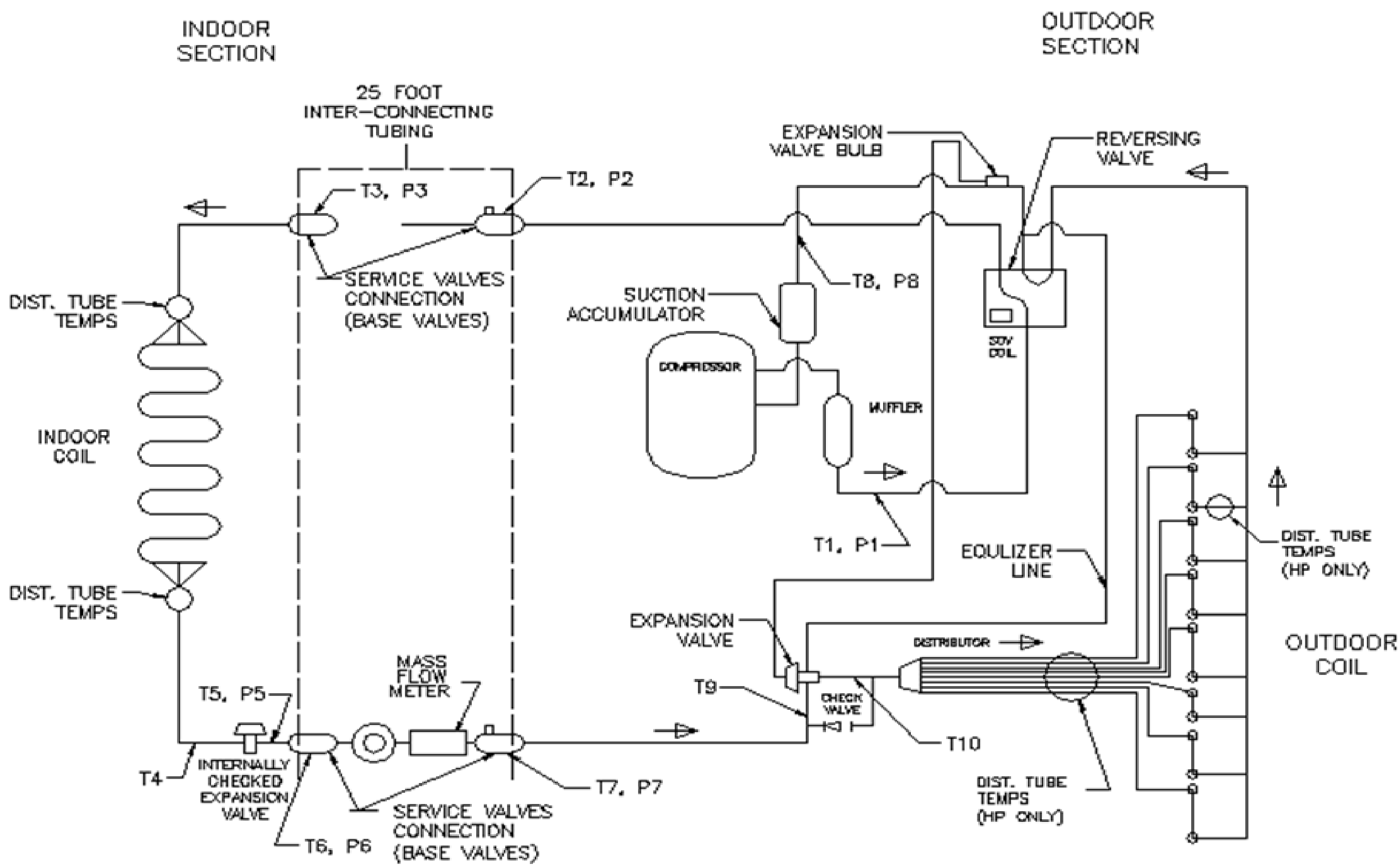
Systems Analyzed

- 3-Ton Air Source Heat Pump (ASHP)
  - » Most Common System Using Conventional Round Tube Finned HX in Indoor & Outdoor Units
- 5-Ton Heat Pump Pool Heater
  - » Coaxial HX in Outdoor Unit
  - » Round Tube Finned HX in Indoor Unit
- 3-Ton Residential Split Air-Conditioner With a Micro-Channel Condenser (MCHX)
  - » Micro Channel Condenser in Outdoor Unit
  - » Round Tube Finned HX in Indoor Unit
- All Systems: R-410A w/ Scroll Compressors

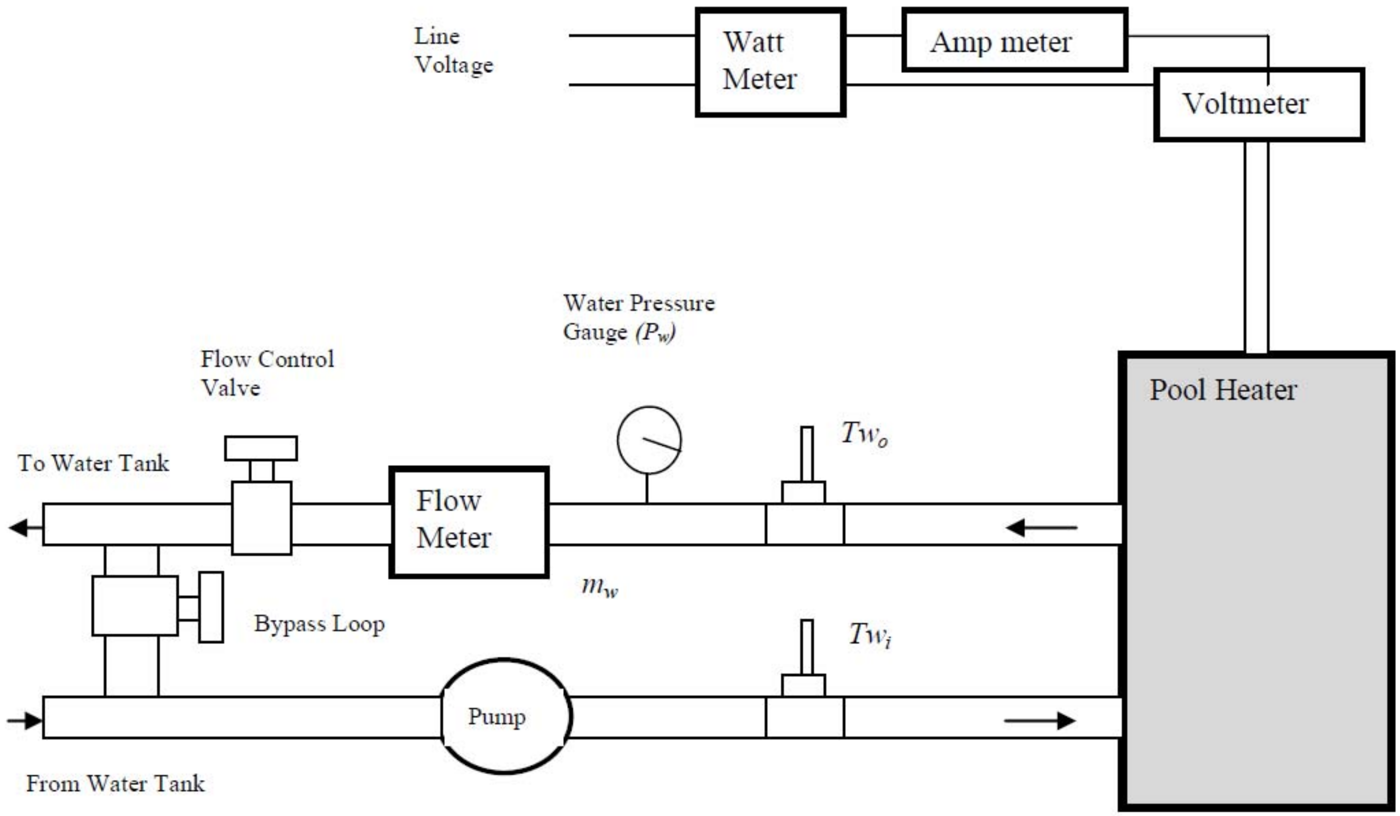
Methodology

- Results of Findings Are Grouped in Two Categories
  - » **Validation Results**: Tests Vs. Simulation For The Three Systems
  - » **System Optimization Exercise**: Selected 3-Ton ASHP To Illustrate Design Options Available
    - – Example: Optimized Refrigerant Charge by Identifying the Best Combination of Compressor Superheat and Condenser Subcooling

3 Ton Residential ASHP – Test Setup



5 Ton Pool Heater – Test Setup



5 Ton Pool Heater – Analysis Approach

System Tests

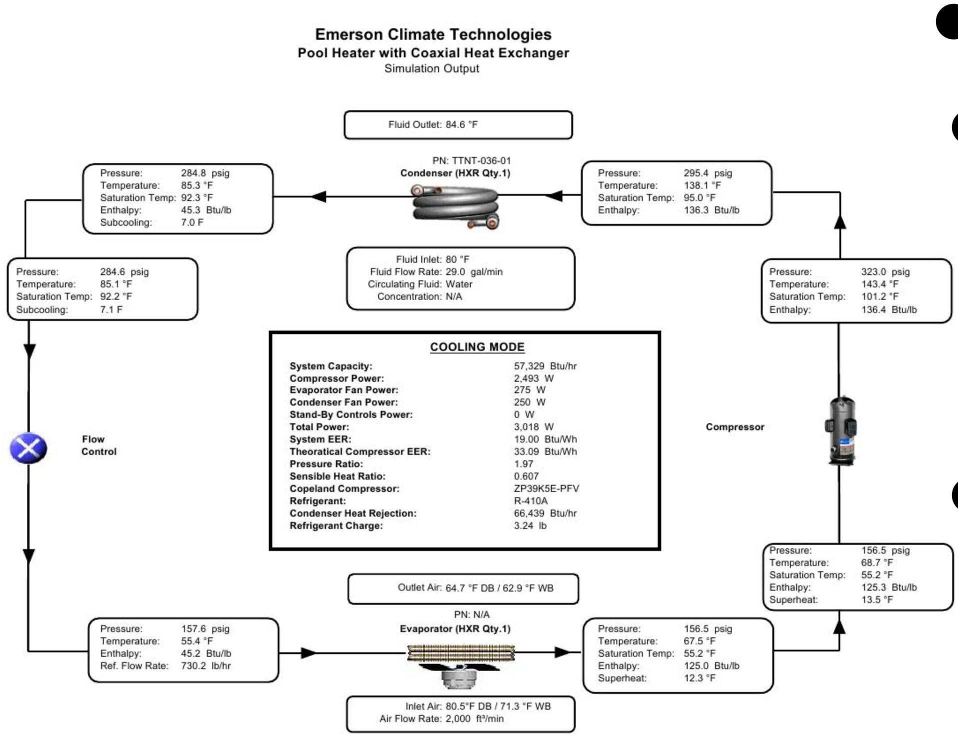
- 2 Standard Tests
  - » Followed AHRI Std. 1160
- Performance: Capacity, Power & COP

System Model Inputs

- Prepare Detailed Inputs
  - » HX Geometries, Flow Control Settings, Conn. Tubing, Air Flow/Power, Line Heat Transfer, Inlet Air Conditions, Shell Loss Factor, …
  - » 10-Term Compressor Coeffs. for Refrigerant Flow Rate & Power

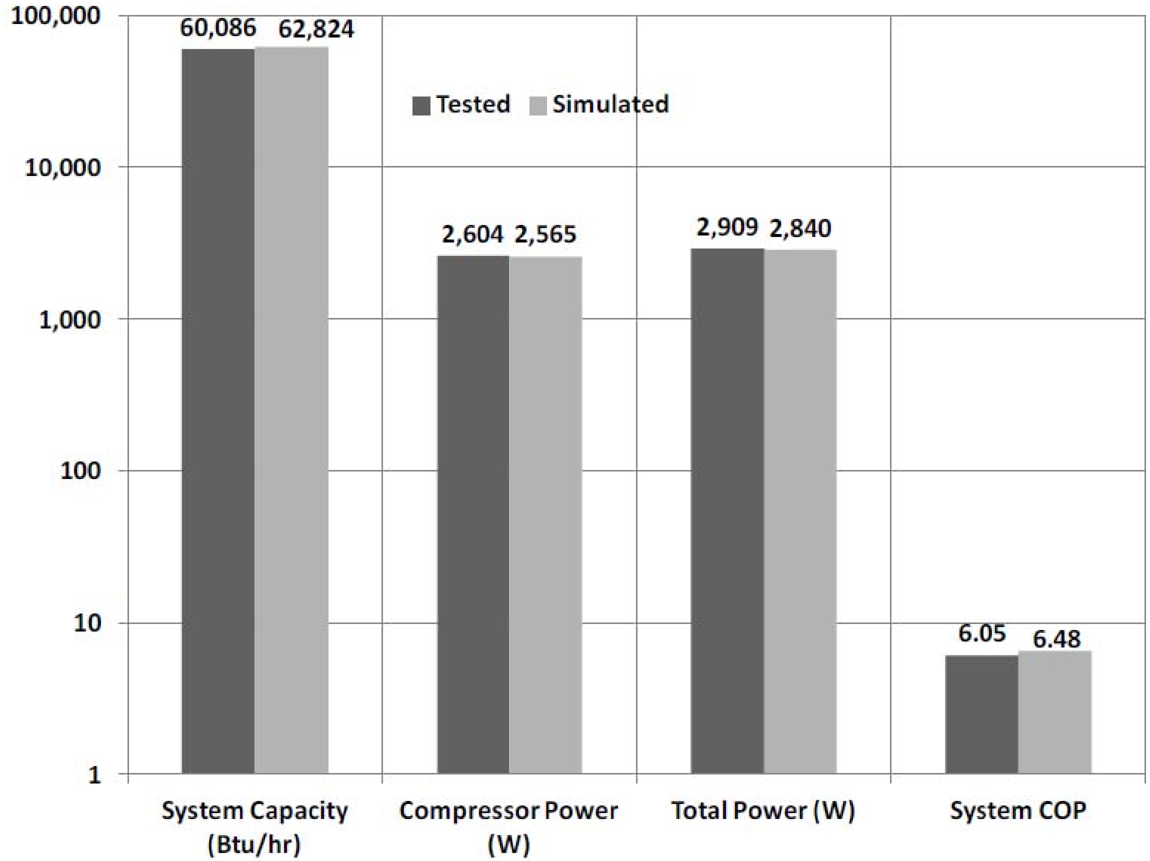
	Air Temperature Surrounding Unit		Water Temperature Entering Unit	Water Flow Rate (or Less if Specified by the Manufacturer)	
	Dry-bulb °F [°C]	Wet-bulb °F [°C]	°F [°C]	gpm	L/s
High Air Temperature - Mid Humidity (62% RH)	80.6 [27.0]	70.7 [21.5]	80.0 [26.7]	0.450 per 1000 Btu/h	0.028 per 293.1 Watts
Low Air Temperature - Mid Humidity (63% RH)	50.0 [10.0]	44.6 [7.0]	80.0 [26.7]	Same flow rate as established in High Air Temperature - Mid Humidity (62% RH)	

Example: Output of Model



- System Model Output
- Detailed Output
  - » Capacity, Power, Efficiency
  - » Pressure, Temperature, Enthalpy…
- Heat Transfer Related Parameters

Results: 5 Ton Pool Heater



	System Capacity (Btu/hr)	Compressor Power (W)	Total Power (W)	System COP
% Error	+5%	-1%	-2%	+7%

Other Systems – Analysis Approach

- Test Setup Based on ASHRAE 37 & AHRI 210/240 Std.

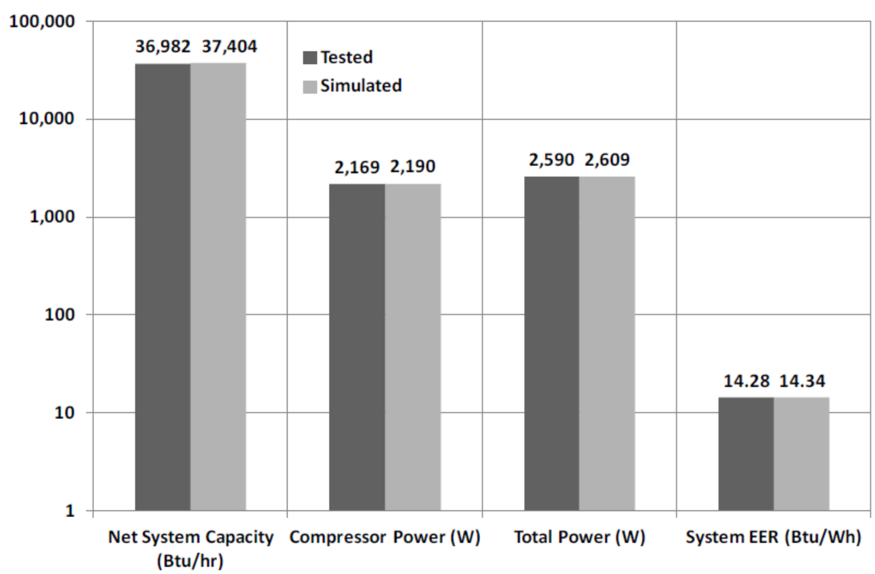
Test Description	Air Entering Indoor Unit Temperature		Air Entering Outdoor Unit Temperature		Cooling Air Volume Rate
	Dry-Bulb (°F)	Wet-Bulb (°F)	Dry-Bulb (°F)	Wet-Bulb (°F)	
A Test	80.0	67.0	95.0	75.0	Cooling Full Load
B Test	80.0	67.0	82.0	65.0	Cooling Full Load
C Test	80.0	≤ 57.0	82.0	-	Cooling Full Load
D Test	80.0	≤ 57.0	82.0	-	Airflow Nozzle(s) Static Pressure Difference Same As During C

- Results for **B** Condition Test: ASHP & Split Systems

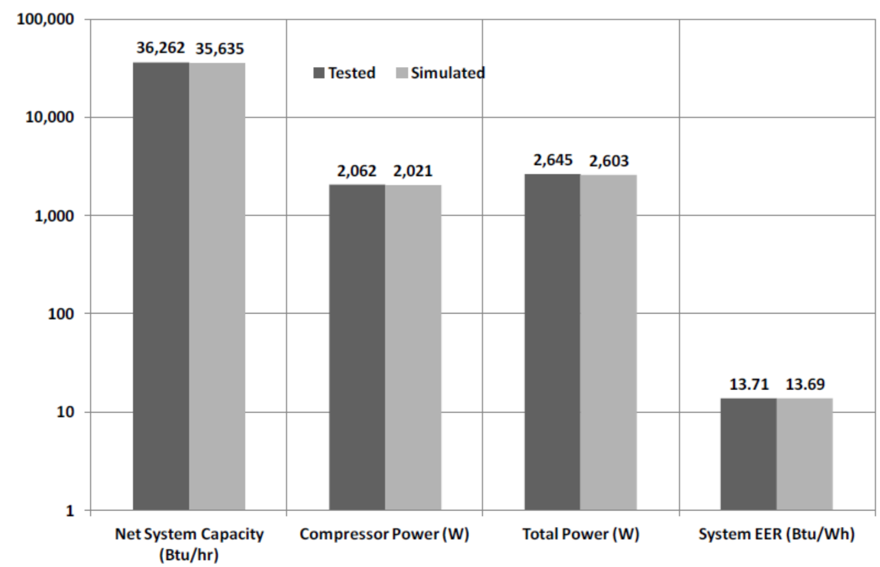
	Net System Capacity (Btu/hr)	Compressor Power (W)	Total Power (W)	System EER (Btu/Wh)
3-Ton ASHP	36,982	2,169	2,590	14.28
3-Ton Split MCHX	36,262	2,062	2,645	13.71

Results: 3 Ton Residential Systems

Validation Results - ASHP



Validation Results - MCHX



	Net System Capacity (Btu/hr)	Compressor Power (W)	Total Power (W)	System EER (Btu/Wh)
3-Ton ASHP (% Error)	1.14%	0.97%	0.73%	0.40%
3-Ton Split AC with MCHX (% Error)	-1.73%	-1.99%	-1.59%	-0.14%

Optimization Exercise: 3 Ton ASHP

- Evaluated Effect of Components & Settings Changes on System Performance
- Options Evaluated
  - » Refrigerant Circuits in Indoor & Outdoor Coils
  - » Refrigerant Charge Management Via Compressor Superheat & Condenser Subcooling
  - » Higher Efficiency Fan Motors in Both Units
  - » Air Flow Rate
  - » Smaller Displacement Compressor
  - » Two-Capacity Compressor

Optimization Exercise: Results

Record No.	Design / Setting Change	Incremental Gain (%)	Total Gain In SEER (%)	SEER (Btu/Wh)
1	Optimize Number of Refrigerant Circuits In Indoor & Outdoor Units	1.0	1.0	13.75
2	Optimize Subcooling & Superheat	0.0	0.0	13.75
3	BPM Indoor Fan Motor & Higher Efficiency Outdoor Fan Motor	3.3	4.3	14.21
4	Blower Operation: Reduce Air Flow Rate to 70%	2.5	6.8	14.54
5	Lower Displacement Compressor	3.1	9.9	14.97
6	Two-Capacity Compressor	6.3	16.2	15.83

Conclusions

- System Simulation Models Have Improved Significantly Over Years
  - » Provide Excellent Design and Analysis Capabilities
  - » Short Learning Curve
  - » Quickly Identify Several System Configurations
  - » Significant Cost Reduction in Lab Testing
  - » Good Accuracy: Test Vs. Simulation (About 5%)
    - – Optimization Effort Would Require About 12 Weeks of Testing
    - – Model Inputs Require ½ Day. Once Set Up, Evaluating Other Design Options Are Quick
- Test Only Configurations That Provide Best Energy Efficiency And Or Cost Advantage

Nomenclature and References

- ASHP – Air Source Heat Pump
- MCHX – Micro-Channel Heat Exchanger
- SEER – Seasonal Energy Efficiency Ratio
- SDS – System Design Simulation

- ARI Standard 210/240 *Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment* Air Conditioning, Heating and Refrigeration Institute, 20078; 2111 Wilson Blvd, Suite 500, Arlington, VA 22201, U.S.A.
- ANSI/AHRI Standard 1160 (I-P) (Formerly ARI Standard 1160) *Standard For Performance Rating of Heat Pump Pool Heaters* Air-Conditioning, Heating and Refrigeration Institute, 20078; 2111 Wilson Blvd, Suite 500, Arlington, VA 22201, U.S.A

Q/A Session

Questions?