Exploratory Lab Testing of a Residential-Scale Combined Space and Water Heating CO_2 Heat Pump

ACEEE Hot Water Forum 2017

Session 1B

February 27

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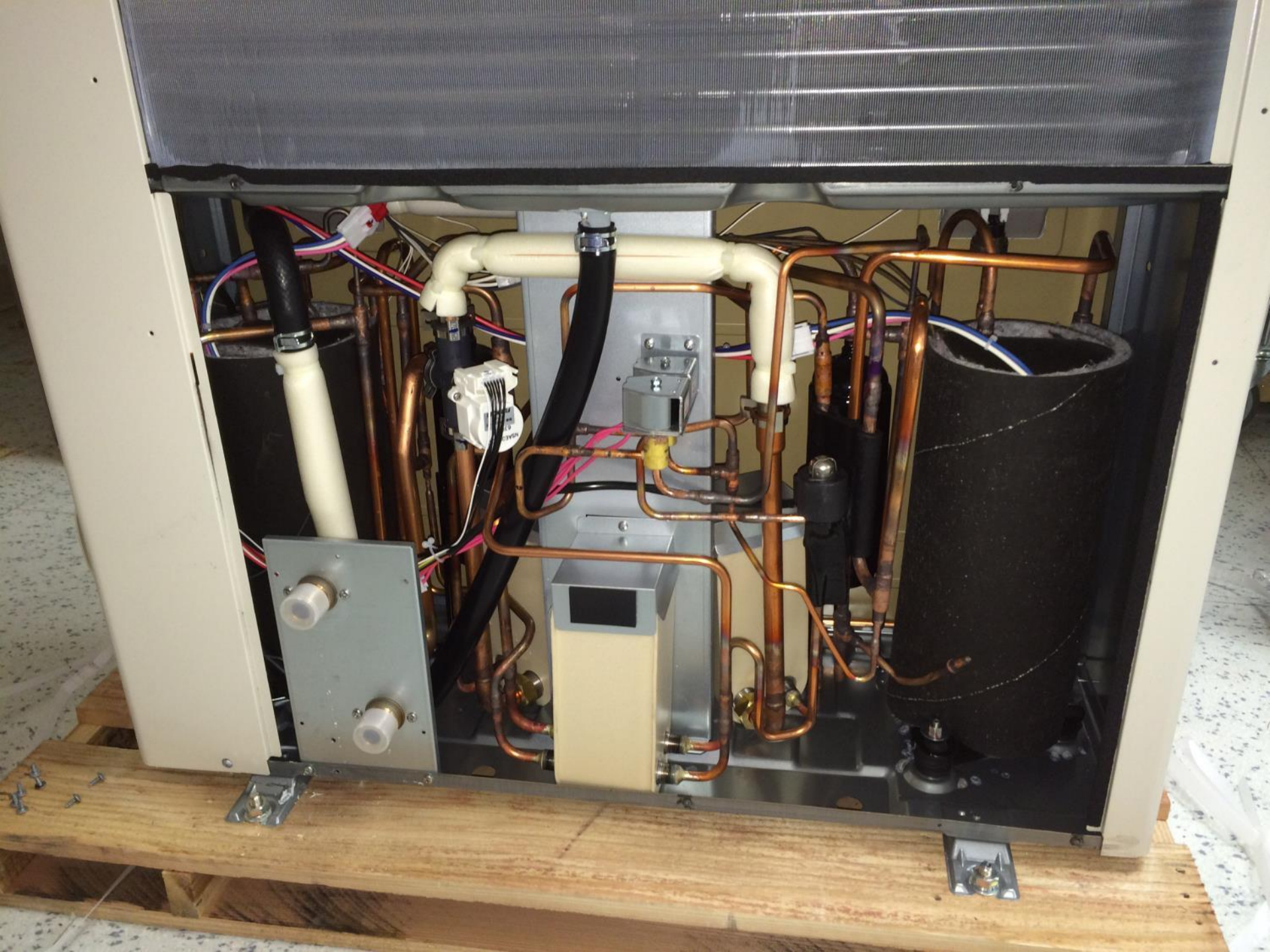
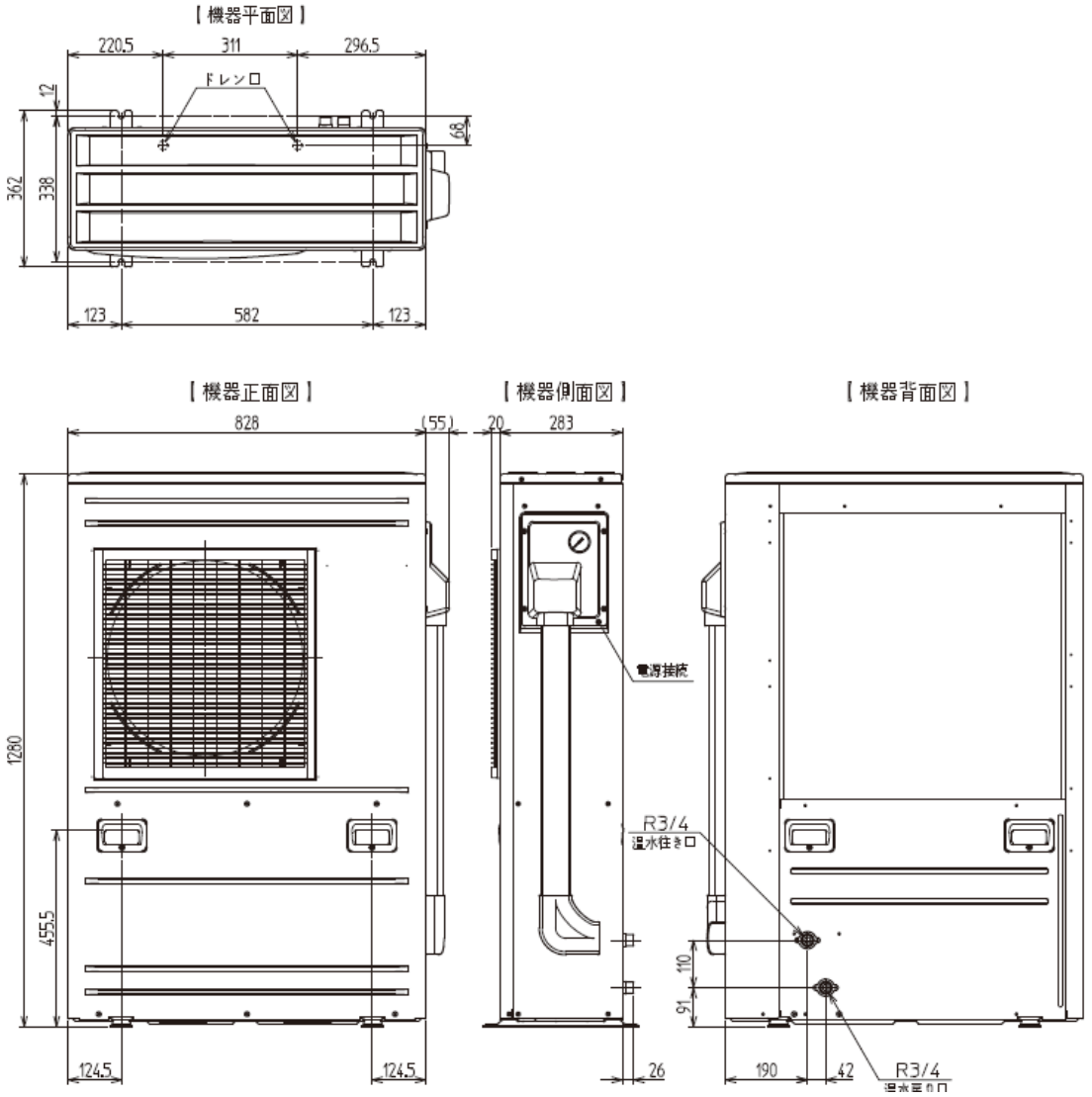
Problem Statement(s)

- HFC refrigerants will (may?) be phased out one day
- What does water heating look like with alternate refrigerants?
- Can the same box be used to provide both space and water heat?
- How do you measure performance of a combined space+water heat pump CO_2 system in a lab?

The Equipment



Dimensions


【機器平面図】
220.5
311
296.5
ドレン口
12
68
362
338
123
582
123
【機器正面図】
【機器側面図】
【機器背面図】
828
(55)
20
283
1280
455.5
124.5
124.5
電源接続
R3/4
温水往き口
110
91
26
190
42
R3/4

Specifications

CO_2ヒートポンプ温水暖房機 仕様

形　　式	EDS-C110A
電　　源	単相200V 50/60Hz
最大電流	25A
定格加熱能力※1	3.5kW
定格消費電力※1	0.80kW
エネルギー消費効率※1	4.3
加熱能力※2	11.0kW
最大消費電力※2	4.0kW
ドレン凍結防止ヒーター	0.1kW
運　転　音	47dB
外形寸法(H×W×D)	1280×828×283mm(突起部除く)
製品質量	98kg
使用冷媒	R744(CO_2)
温水温度設定	45℃～70℃の3段階
温水配管接続口	R3/4

※1.外気温7℃/6℃(DB/WB)入水温度23℃
※2.外気温7℃/6℃(DB/WB)入水温度30℃

Output at some condition
Input Power at some condition
COP at some condition
Output at another condition
Input Power at another condition

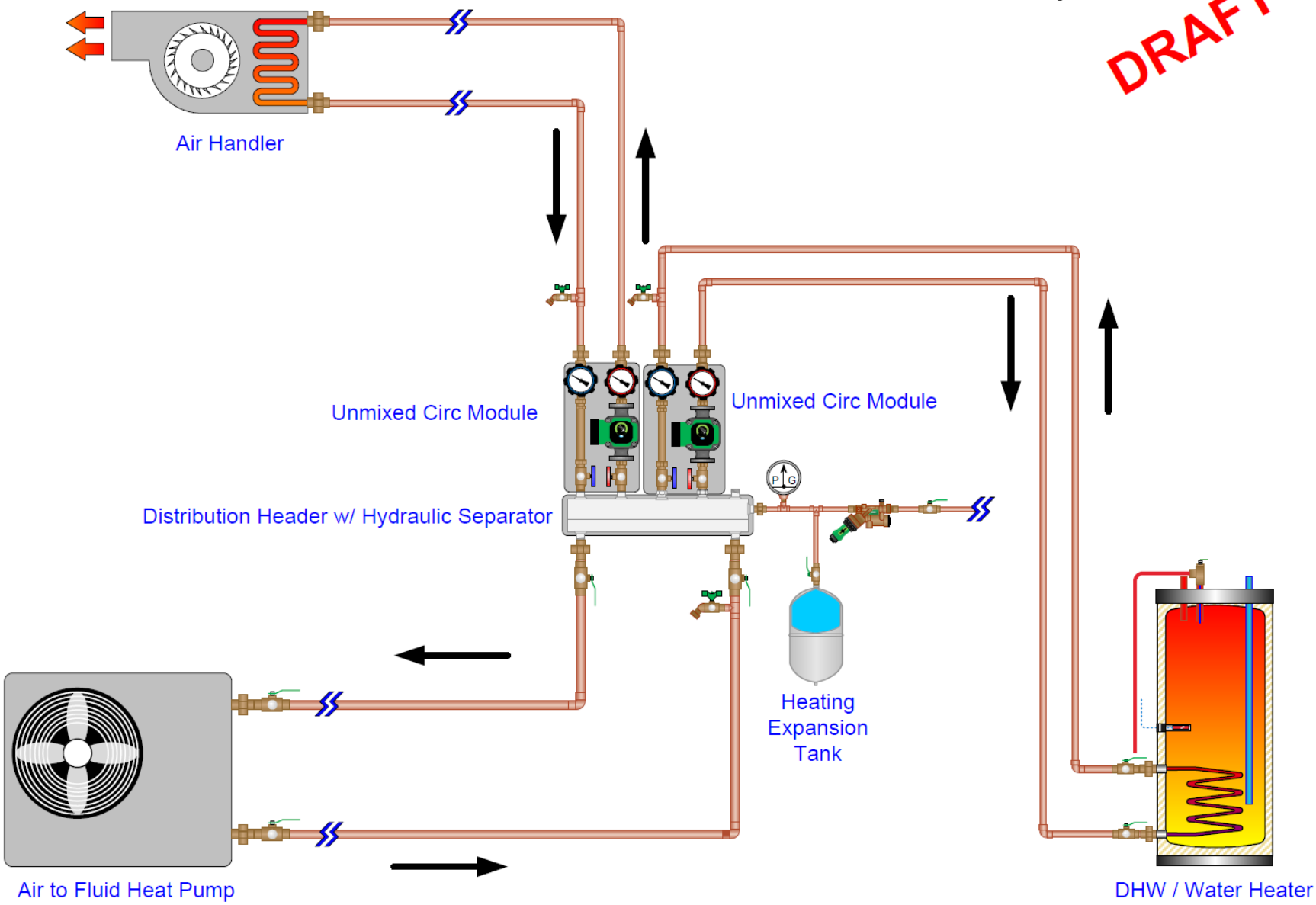
Sound Level
Dimensions
Weight

Outlet Water Temperature Range

Combined Space and Water

- EcoRuno designed specifically for space heating applications
  - Two compressors, separate refrigeration cycles, multiple internal heat exchangers
- Large Output Capacity
  - Sanden GAU was 4.5kW, EcoRuno is 11-12kW
- Outlet Water Temperature 70 °C/158 °F allows for many space heating strategies
  - We tested a fan coil
- Output capacity should heat a water tank *really* fast
  - Traditional electric tanks have 4.5kW output

Draft schematic courtesy Taco.



Pumps, Pumps, and More Pumps

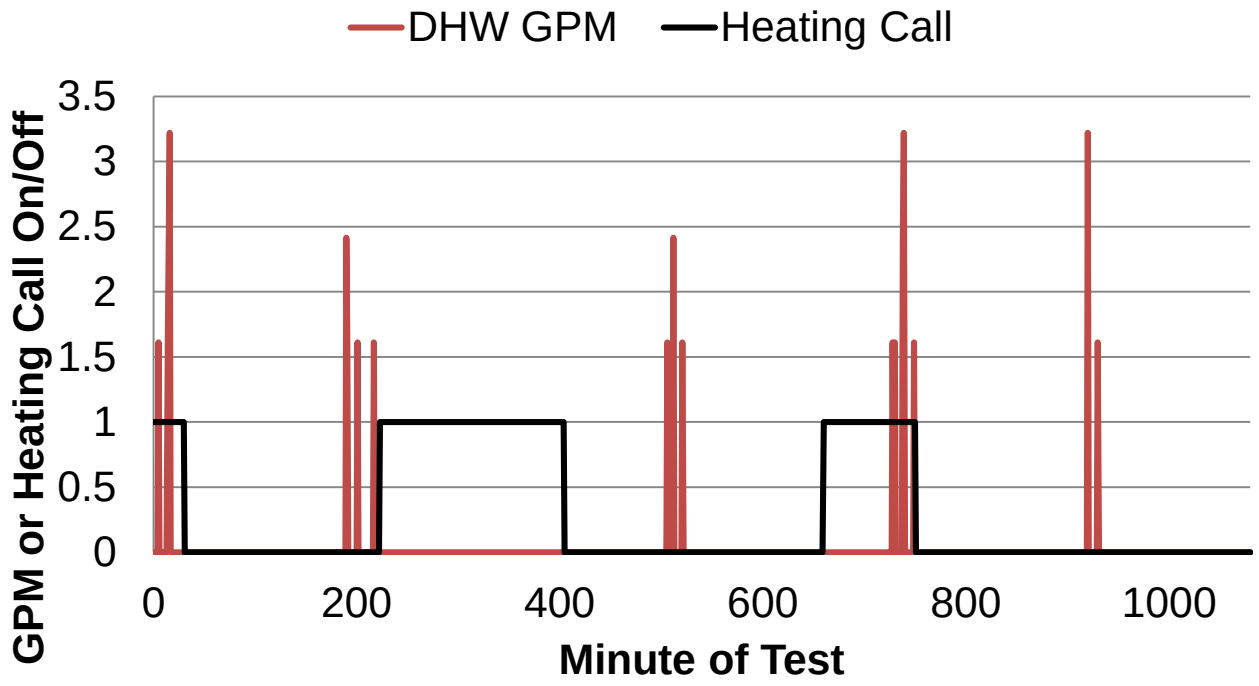
- Primary Loop
  - Pump on-board the EcoRuno (not externally controllable)
- Secondary Loop
  - Pump for water heater
  - Pump for space heating
- Adjusting pump flow rate is primary method for adjusting energy flows, water temperatures, and, efficiency

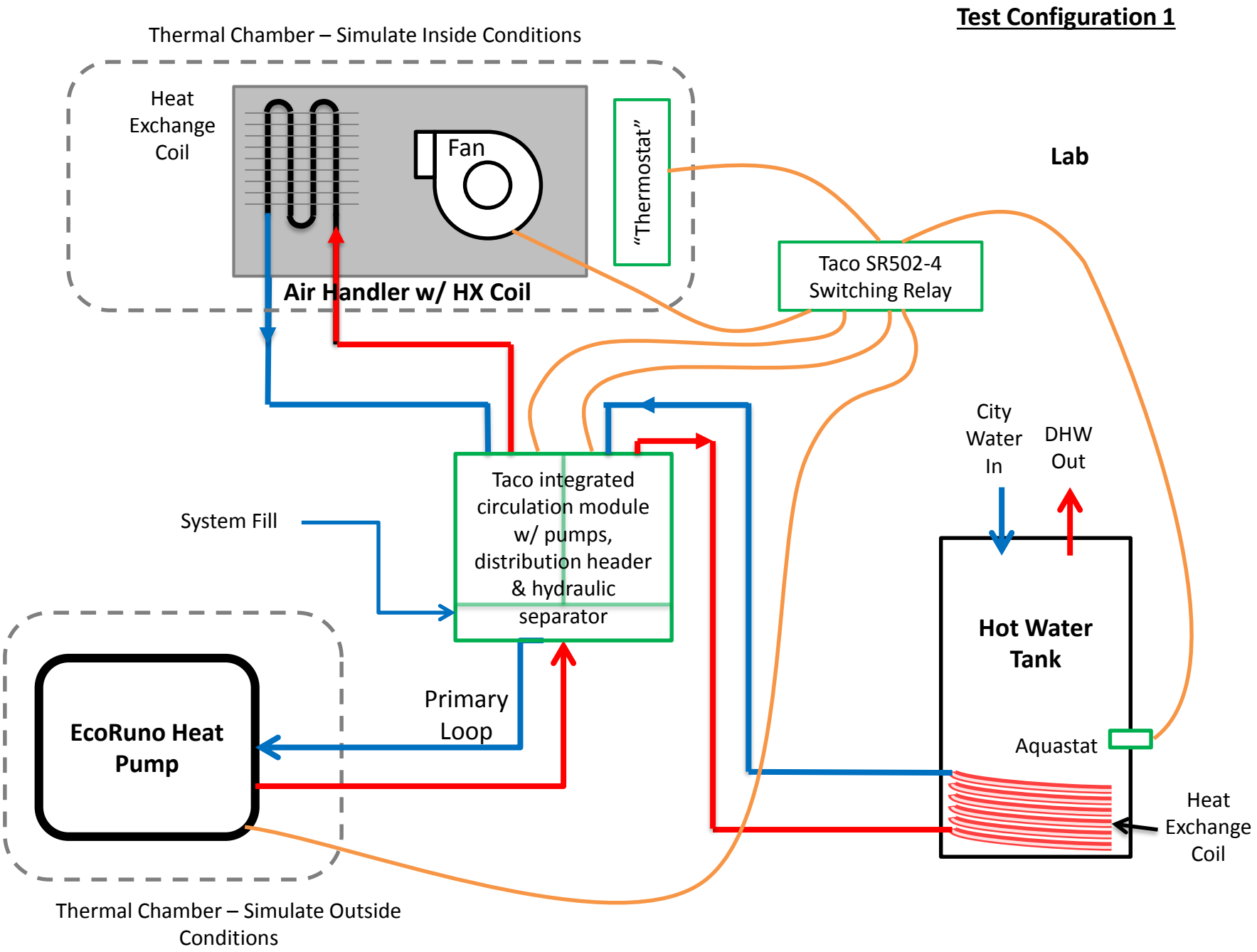
Test Conditions

- Space Heat Only
  - Ambient Air: 5F, 17F, 35F, 47F
- Water Heat Only
  - Ambient Air: 35F, 67.5F, 95F
    - Both Indirect Tank and Side-Arm
- Combination Tests
  - Ambient Air: 5F, 17F, 35F, 47F
    - Indirect Tank Only

Test Profile – 18hrs

- Water Heating Only
  - 46 GPD profile
- Space Heating Only
  - 2-3 ton load: 0.5hrs, 3 hrs, 1.5 hrs
- Combined Space and Water Heating

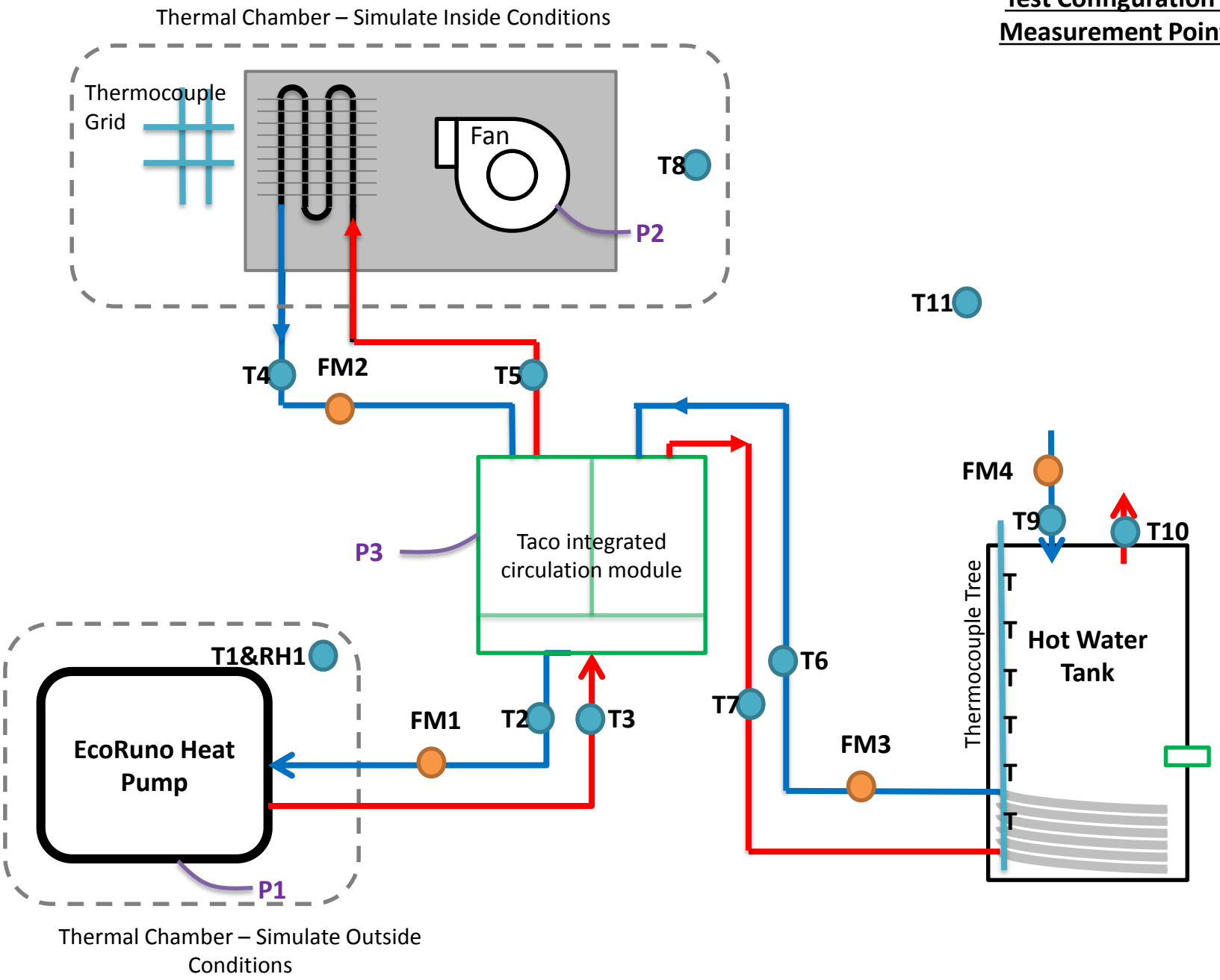



Test Configuration 1
Thermal Chamber – Simulate Inside Conditions
Heat Exchange Coil
Fan
"Thermostat"
Air Handler w/ HX Coil
Lab
Taco SR502-4 Switching Relay
City Water In
DHW Out
Taco integrated circulation module w/ pumps, distribution header & hydraulic separator
System Fill
Hot Water Tank
Aquastat
Primary Loop
EcoRuno Heat Pump
Heat Exchange Coil
Thermal Chamber – Simulate Outside Conditions

Measurement Setup

- Collect enough data points to calculate energy flows throw the system wherever possible
  - Flow rates and temperature differences
- Measure output capacities and inputs
- The list
  - 4 water flow meters & 8 wet temperature sensors
  - 6 Thermocouple tree in tank
  - 9 Thermocouple grid at air handler output
  - 3 Air temperature sensors
  - 3 Power measures
  - One-time air flow

Test Configuration 1
Measurement Points

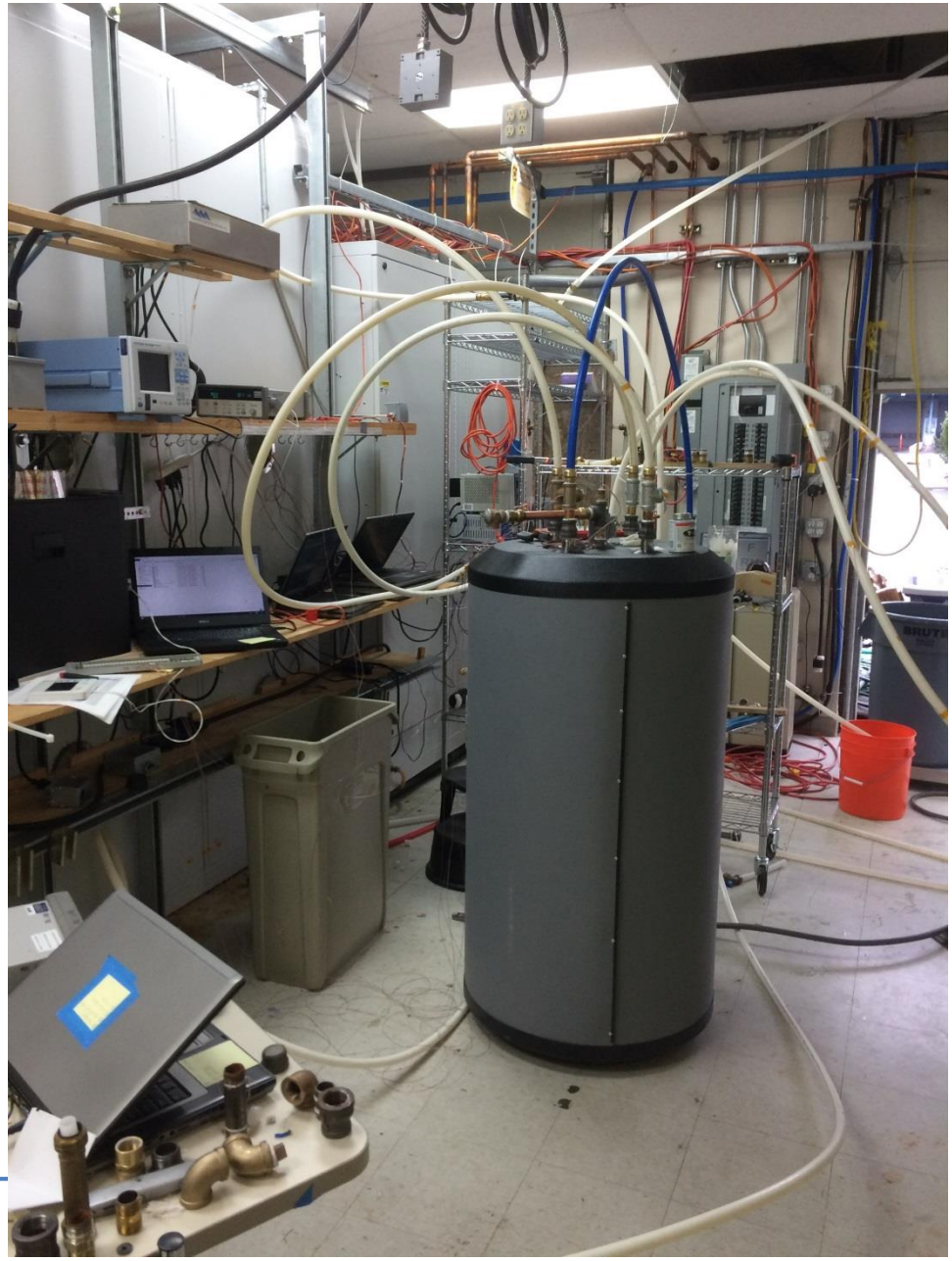


Air Handler

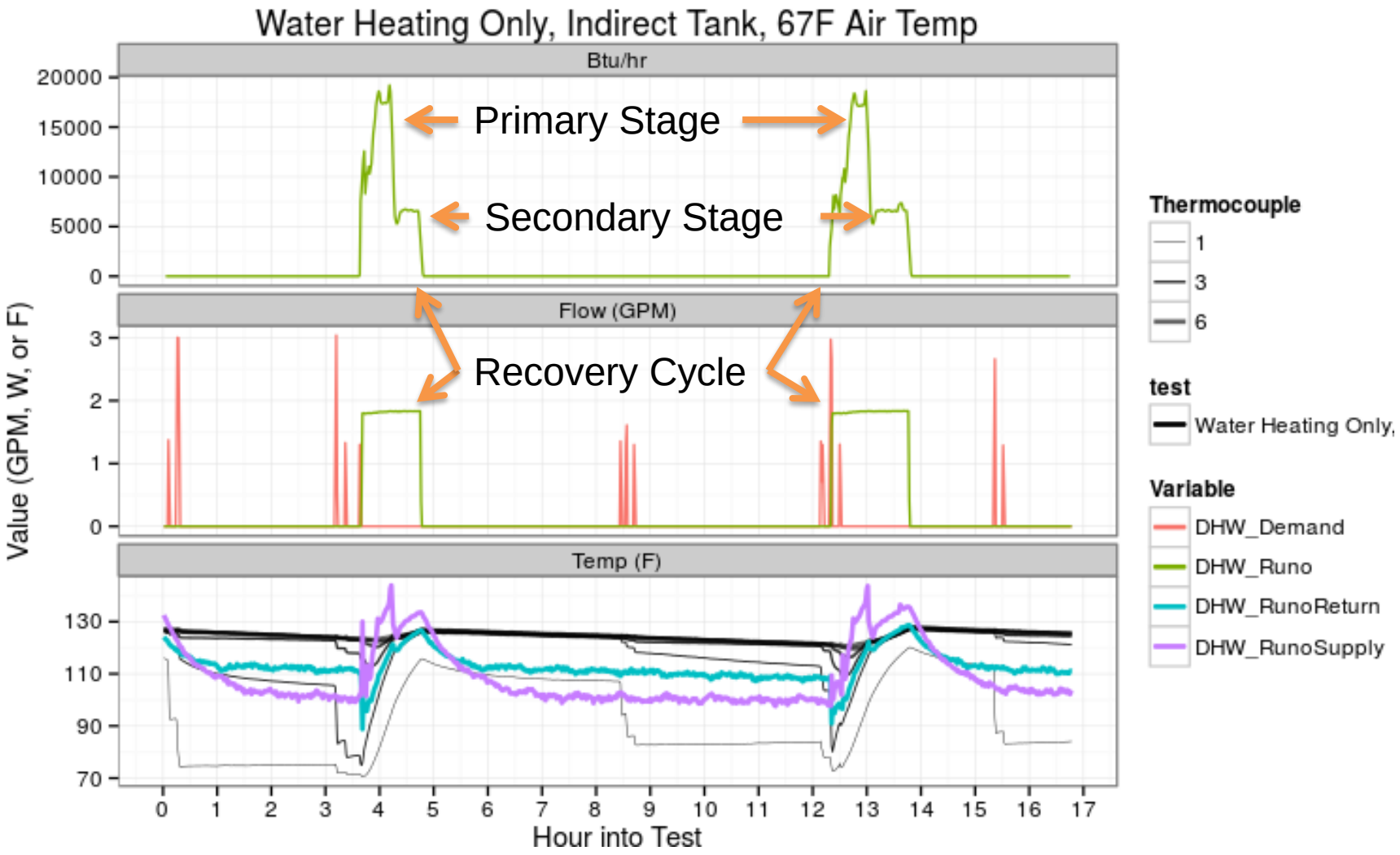
- Water-to-air heat exchanger
- Variable speed fan

Water Tank

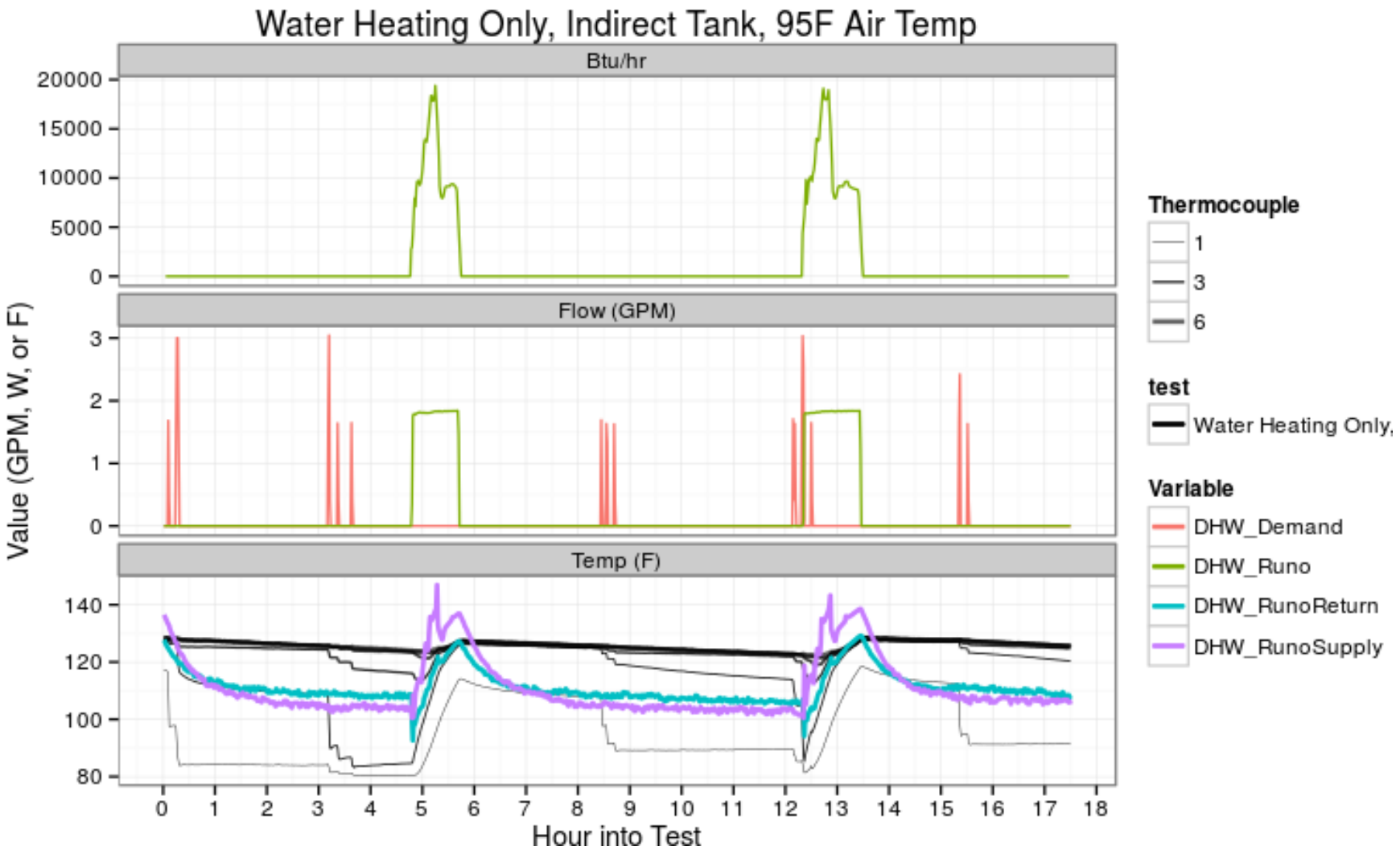
- Indirect, water-to-water heat exchange coil
- Aquastat at bottom third of tank



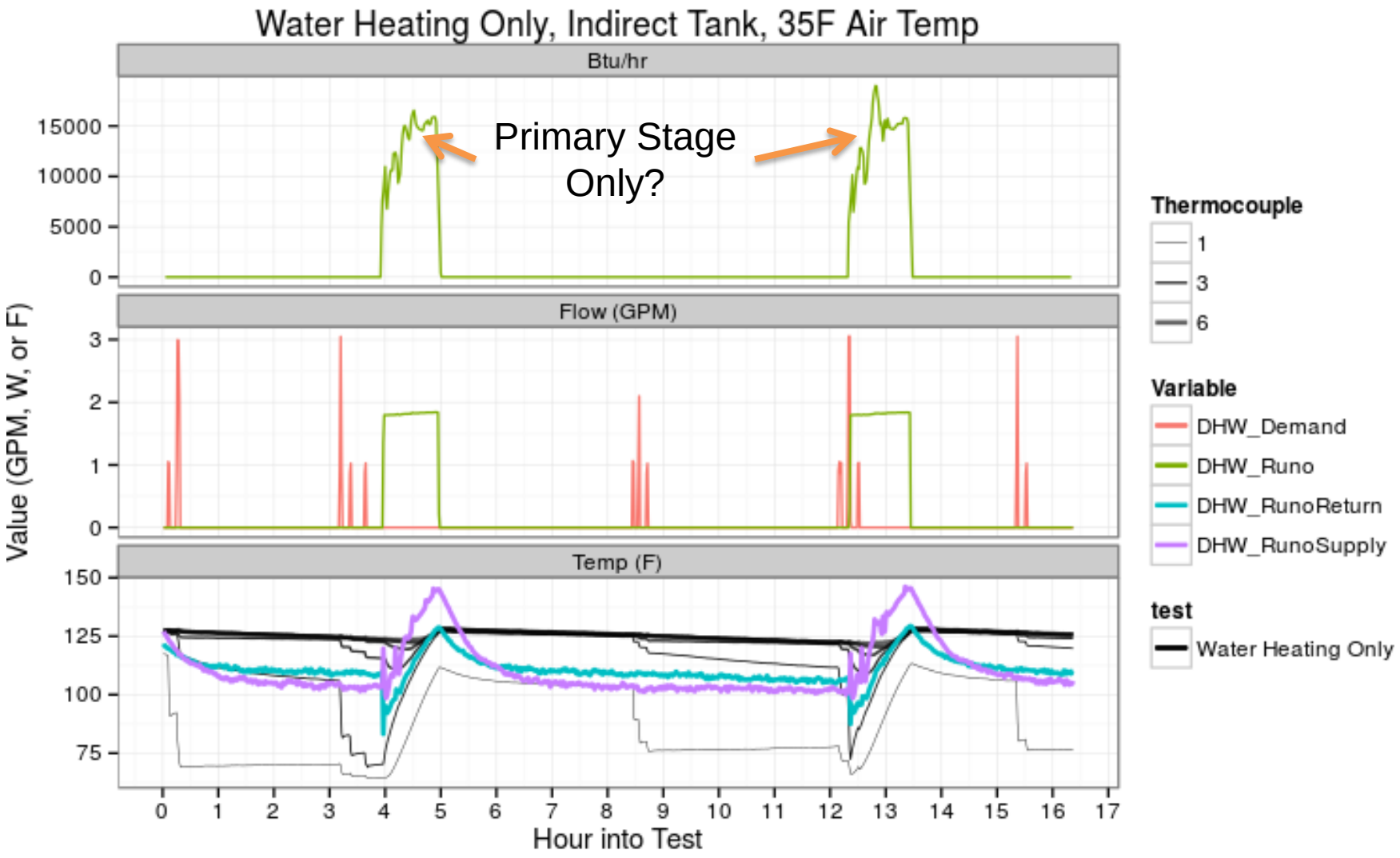
Water Heat Only – 67.5F Air Temperature



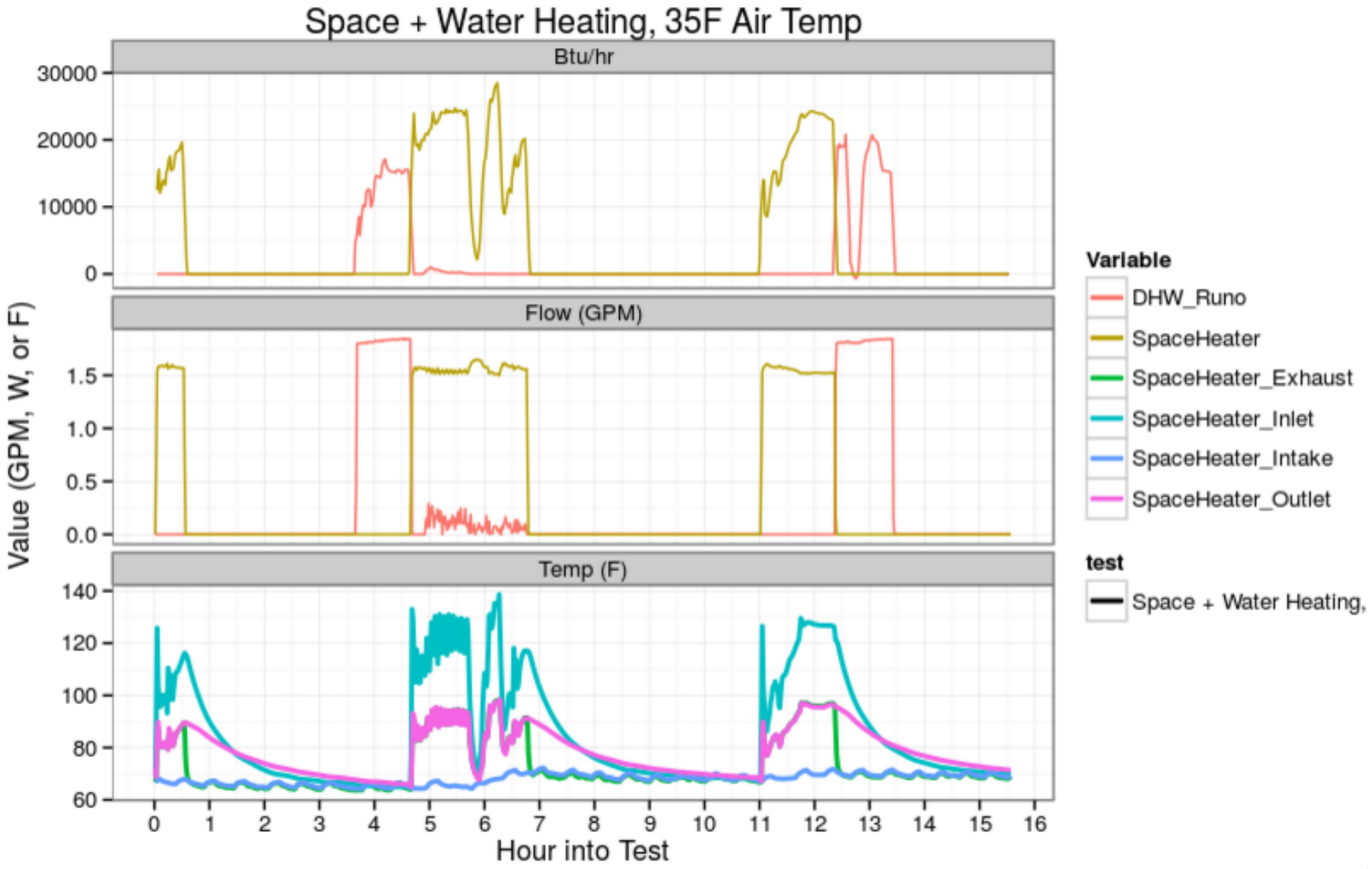
Water Heat Only – 95F Air Temperature



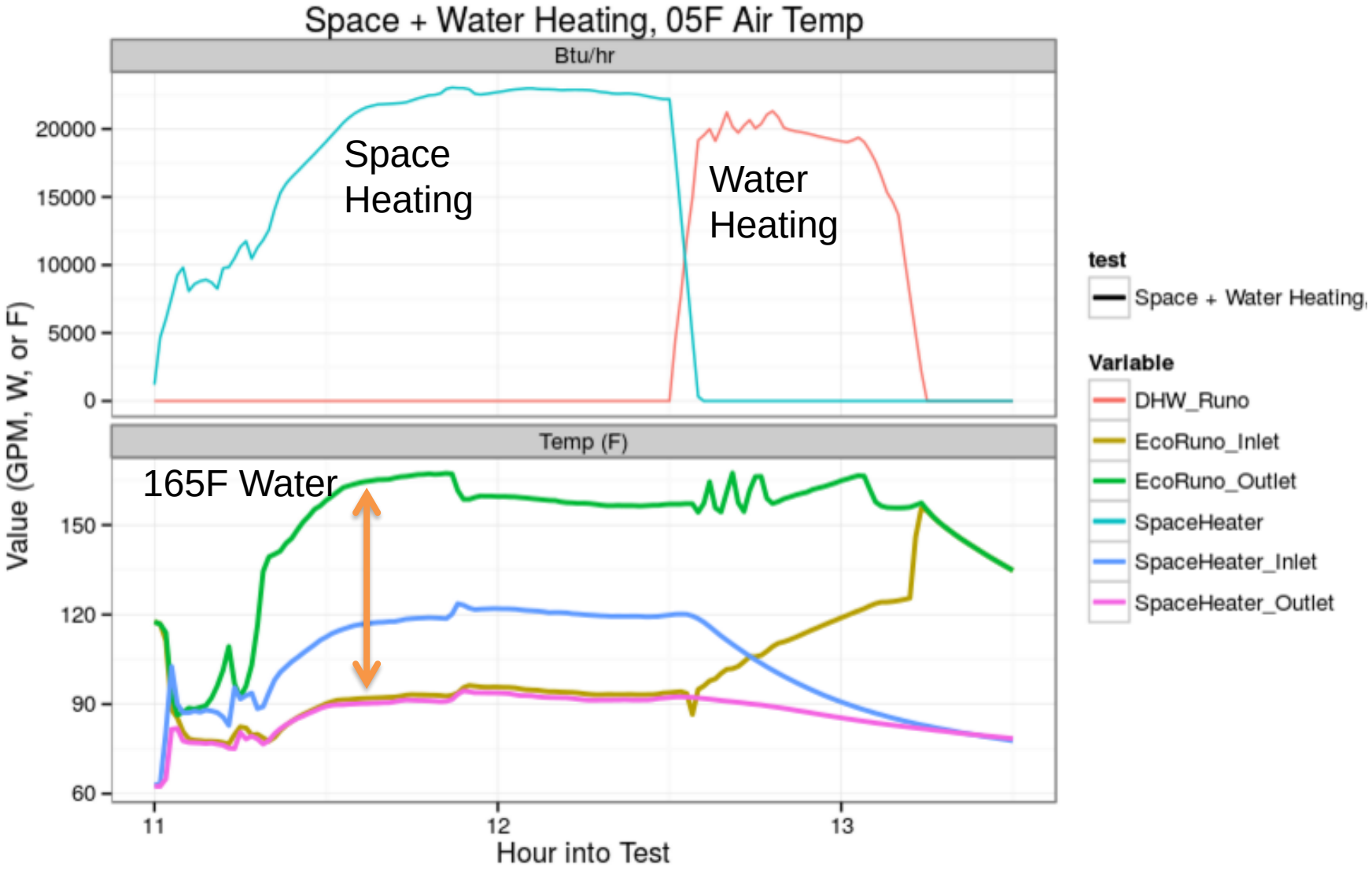
Water Heat Only – 35F Air Temperature



Space Heat Only – 35F Air Temperature


Space + Water Heating, 35F Air Temp
Btu/hr
30000
20000
10000
0
Flow (GPM)
1.5
1.0
0.5
0.0
Temp (F)
140
120
100
80
60
Value (GPM, W, or F)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Hour into Test
Variable
DHW_Runo
SpaceHeater
SpaceHeater_Exhaust
SpaceHeater_Inlet
SpaceHeater_Intake
SpaceHeater_Outlet
test
Space + Water Heating,

Space + Water Heat 5F



Outcomes

- CO_2 systems can make really hot water when it's really cold out
- Testing and measurement can be done
  - Install enough instrumentation to help troubleshoot and optimize system configuration
- Return water temperatures to heat pump matter
  - Balancing the needs of both space and water heating with a single heat pump is challenging for maximizing output and minimizing energy use

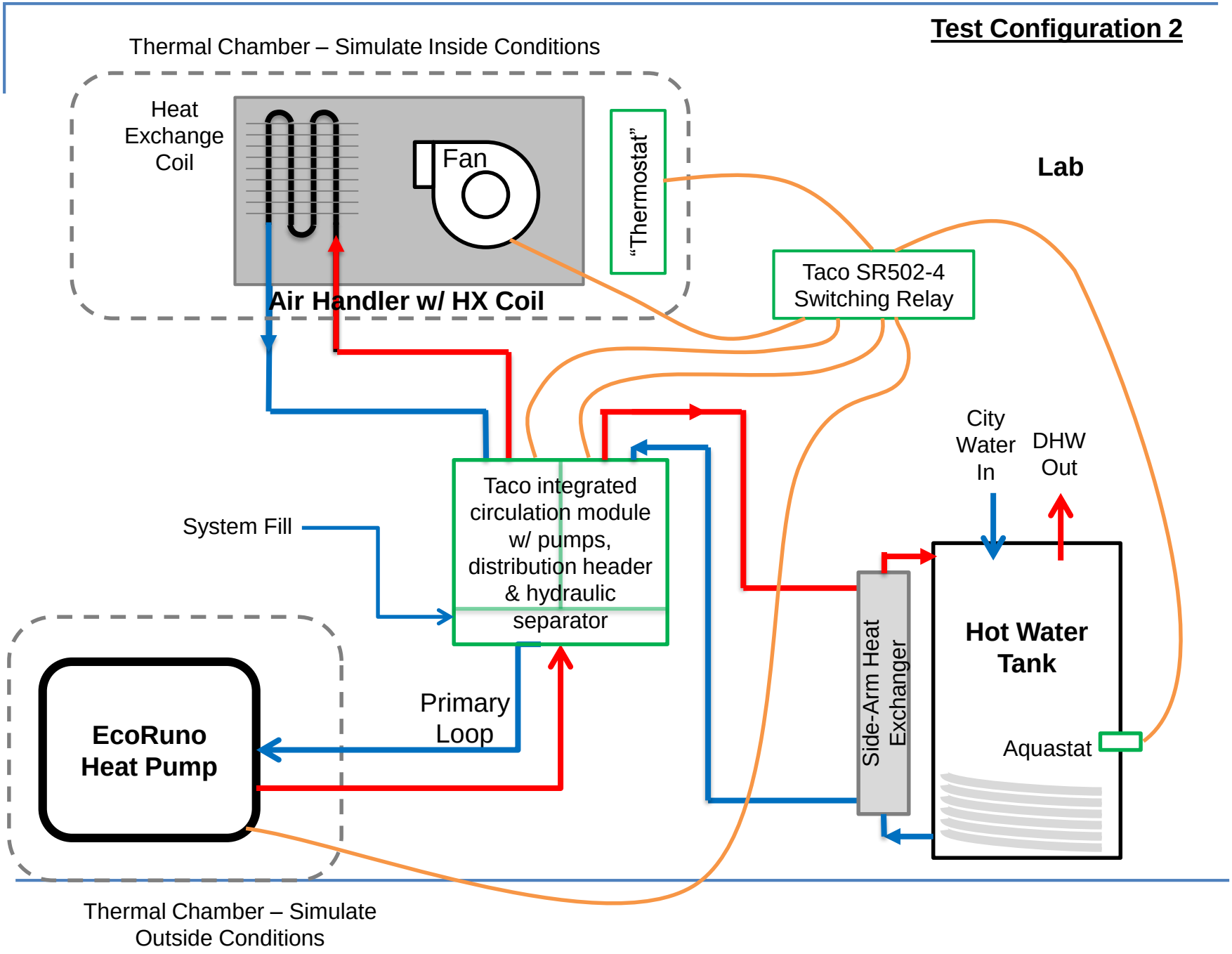
Q & A

- Thanks!

Extras

Guide

- **Orange** lines are electrical control wires
- **Blue** lines are the cold or return side of various water loops
- **Red** lines are the hot or supply side of various water loops
- **Green** boxes are system control components
- Measurement Points
  - Power in **Purple**
  - Flow Meters in **Orange**
  - Temperature in **Teal**
- Water tank, side-arm, circulation module, and switching relay are all to be placed in the lab, outside of thermal chambers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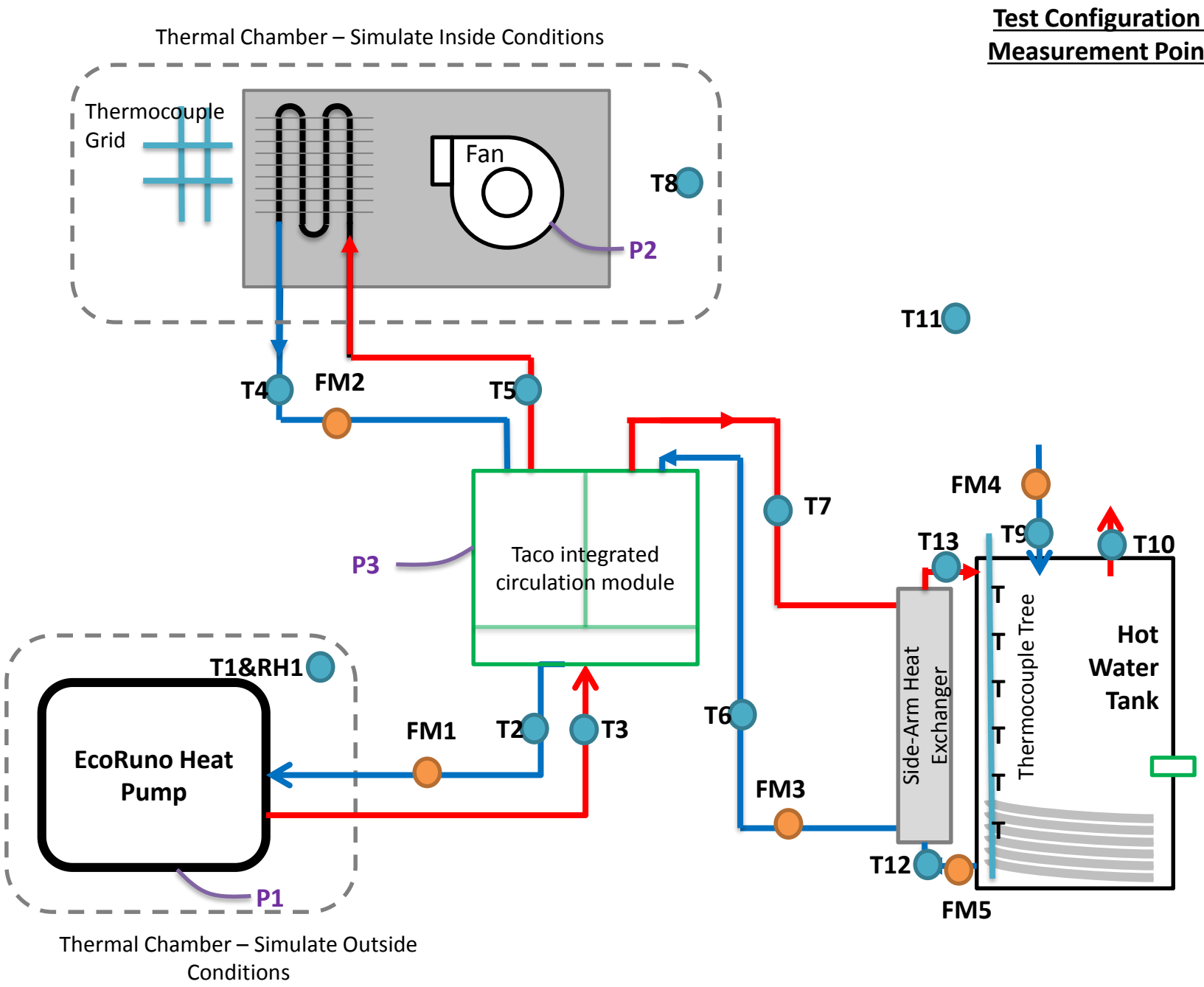
System Fill
Side-Arm Heat Exchanger
Hot Water Tank
Aquastat
EcoRuno Heat Pump
Primary Loop
Thermal Chamber – Simulate Outside Conditions


Test Configuration 2
Measurement Points
Thermal Chamber – Simulate Inside Conditions
Thermocouple Grid
Fan
T8
P2
T11
T4
FM2
T5
T7
FM4
T9
T13
T10
P3
Taco integrated circulation module
T
T
T
T
T
T
Thermocouple Tree
Hot Water Tank
T1&RH1
FM1
T2
T3
T6
Side-Arm Heat Exchanger
FM3
T12
FM5
EcoRuno Heat Pump
P1
Thermal Chamber – Simulate Outside Conditions

Space + Water Heat 35F