

BUILDINGENERGY BOSTON

Decarbonizing and Electrifying DHW Using Commercial-Scale CO2 Heat Pumps

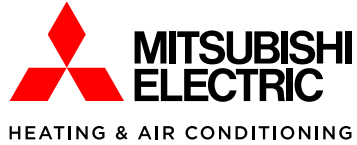
Cain White (Mitsubishi Electric Trane HVAC)

Christopher Ouellette (Mitsubishi Electric Trane HVAC)

Curated by Bart Bales and Emily Dillon

Northeast Sustainable Energy Association (NESEA)

March 29, 2023



NESEA Decarbonizing & Electrifying DHW Using Commercial-Scale CO2 Heat Pumps

Cain White – Director of Commercial Product Management

03/29/2023

QAHV Heat Pump Water Heater



- Utilizes Natural refrigerant
 - CO₂
 - Global Warming Potential of 1
- High efficiency
 - COP up to 4.52
- High Temp Hot water
 - Up to 176°F



Low Ambient Temperature Operation

- Operable at low outdoor temperatures
 - Down to -13°F (with capacity rating)
 - Down to -35°F (without capacity rating)
- 100% heating capacity at 36°F
- 50% heating capacity at -13°F

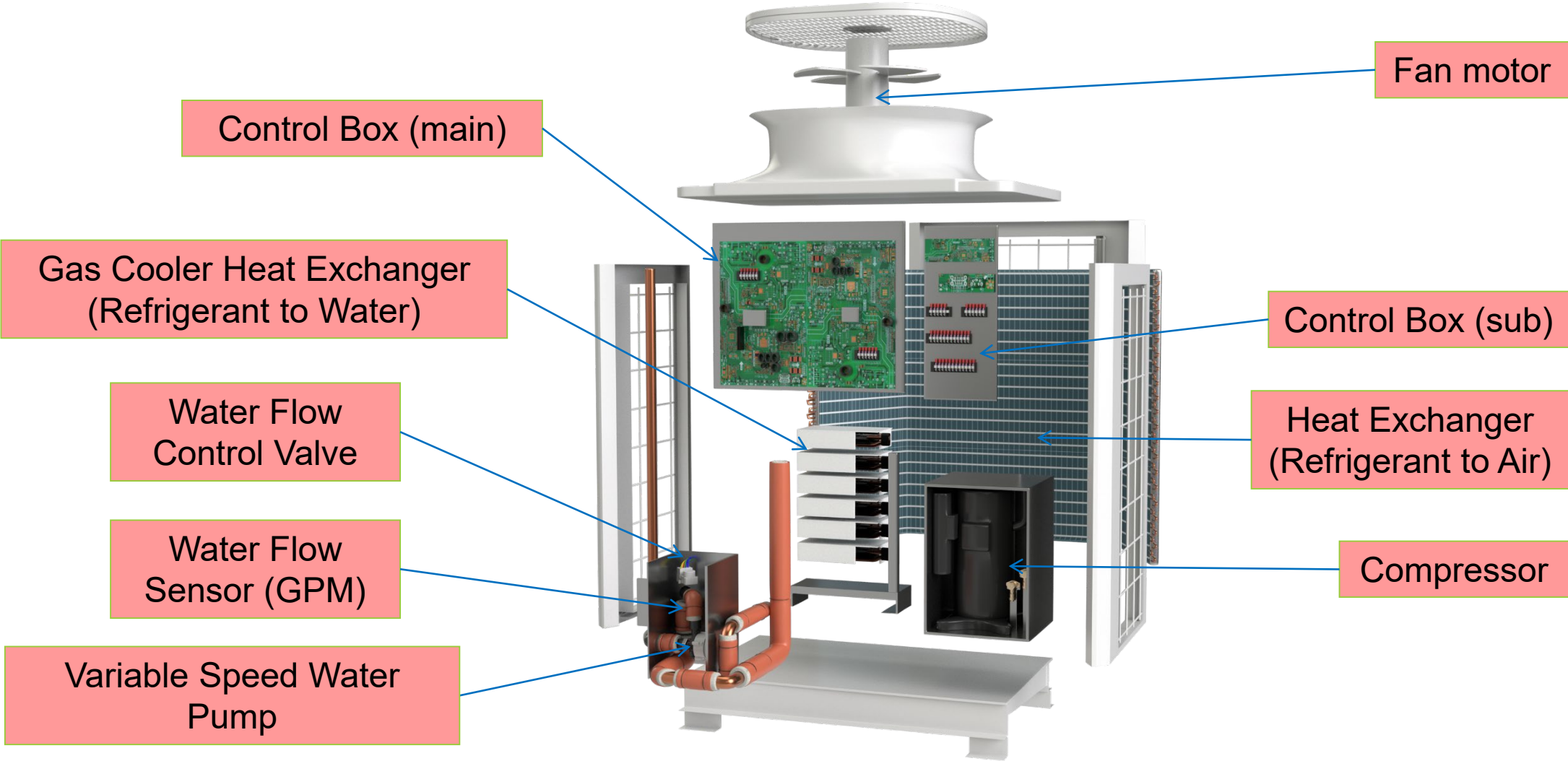


Variable Capacity

- 3 Capacity Settings
 - 136,485 BTU/hr. / 40kW
 - 170,607 BTU/hr. / 50kW
 - 204,728 BTU/hr. / 60kW
- Up to 16 units can be piped in parallel
- Maximum system size
 - 2,183,770 BTU/Hr. / 640kW



Unit Structure



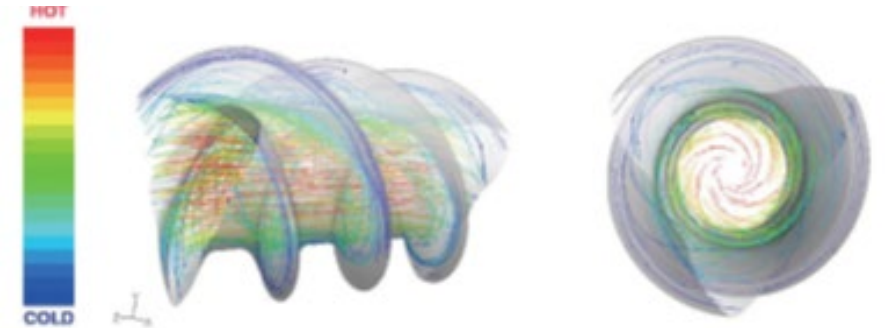
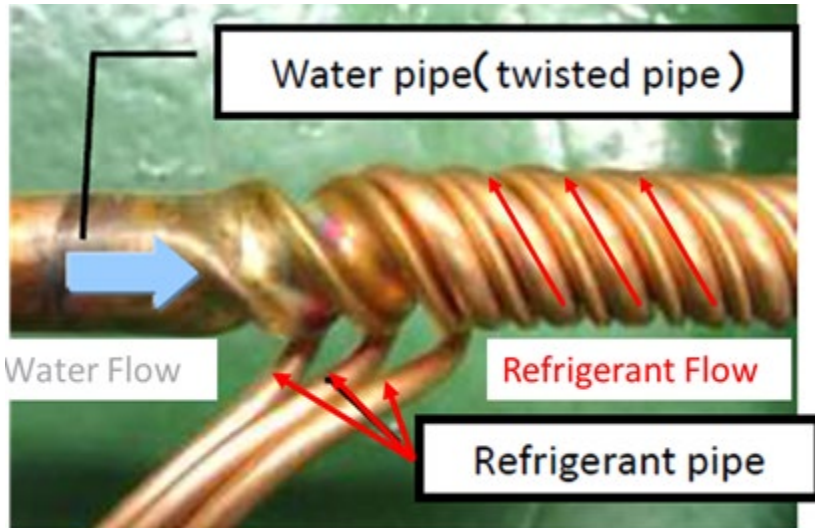
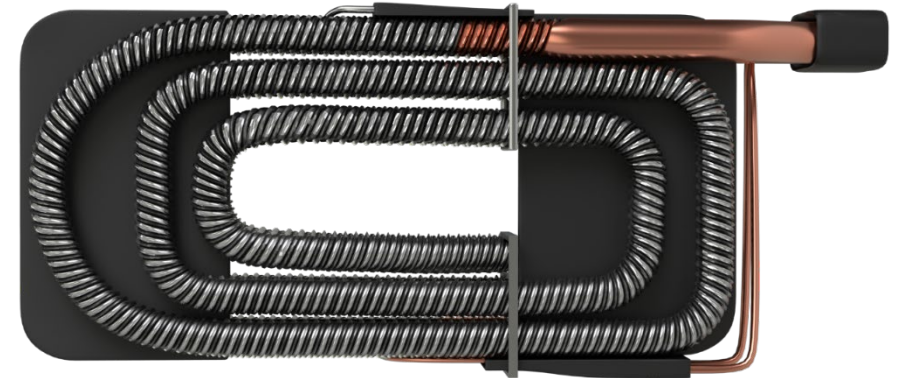
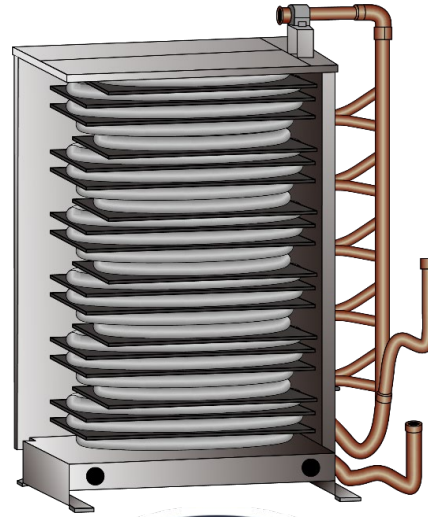
Refrigerant to Water Heat Exchanger

Twisted Spiral Gas cooler

Patented technology

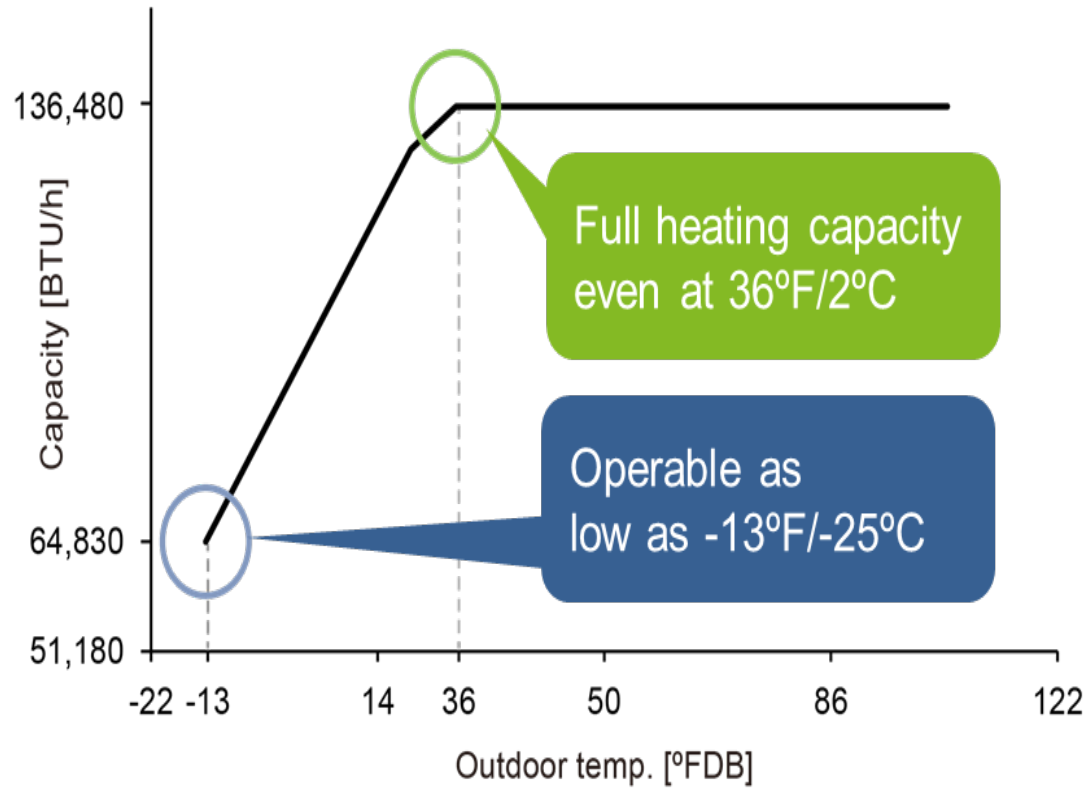
Double Wall construction

6 per QAHV



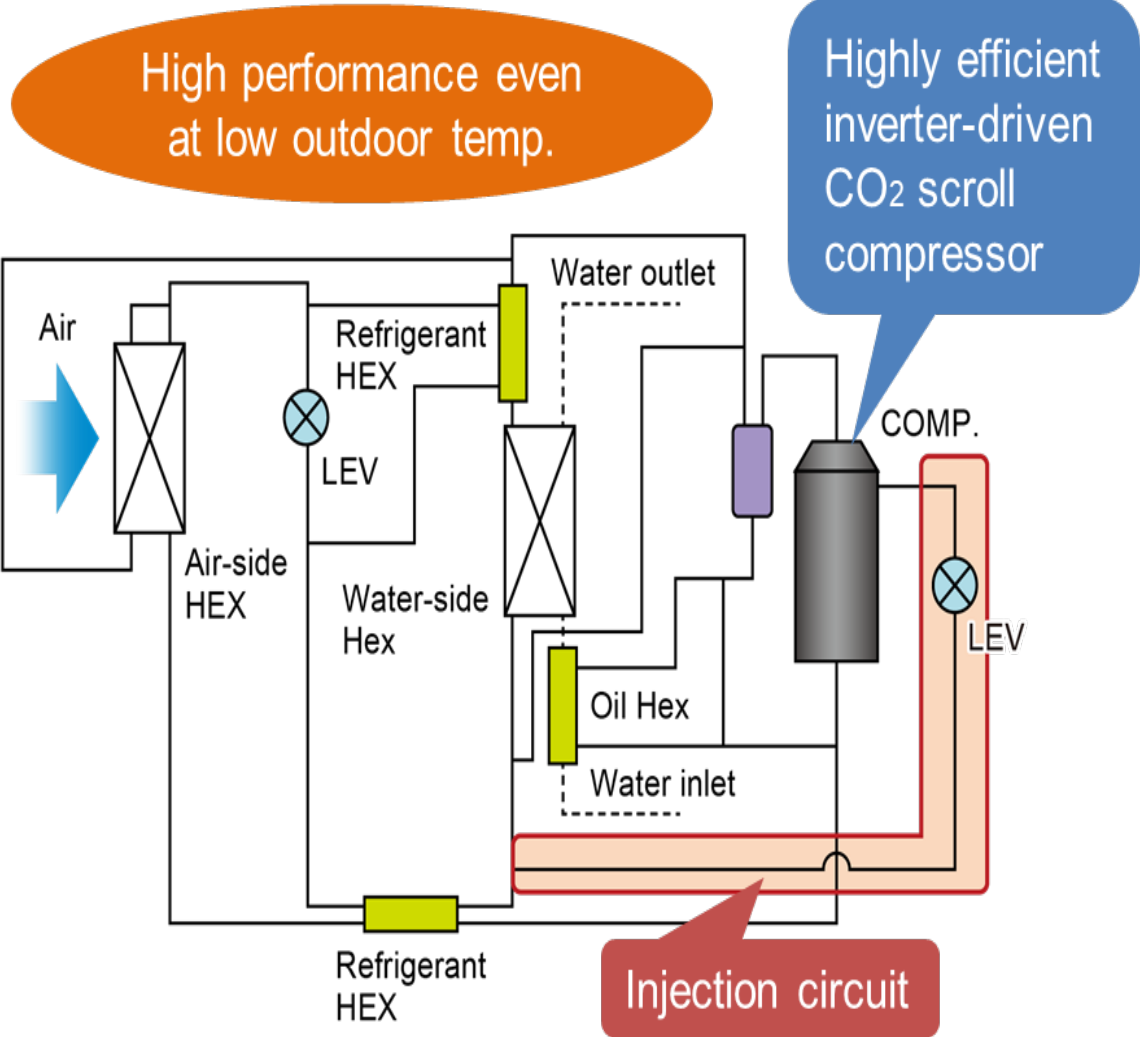
Flash Injection Technology

■ Stable Heating Capacity even at low temperature



Full heating capacity even at 36°F/2°C

Operable as low as -13°F/-25°C



Why CO₂

Environmentally friendly

Global Warming Potential of 1

Ozone depletion potential of 0

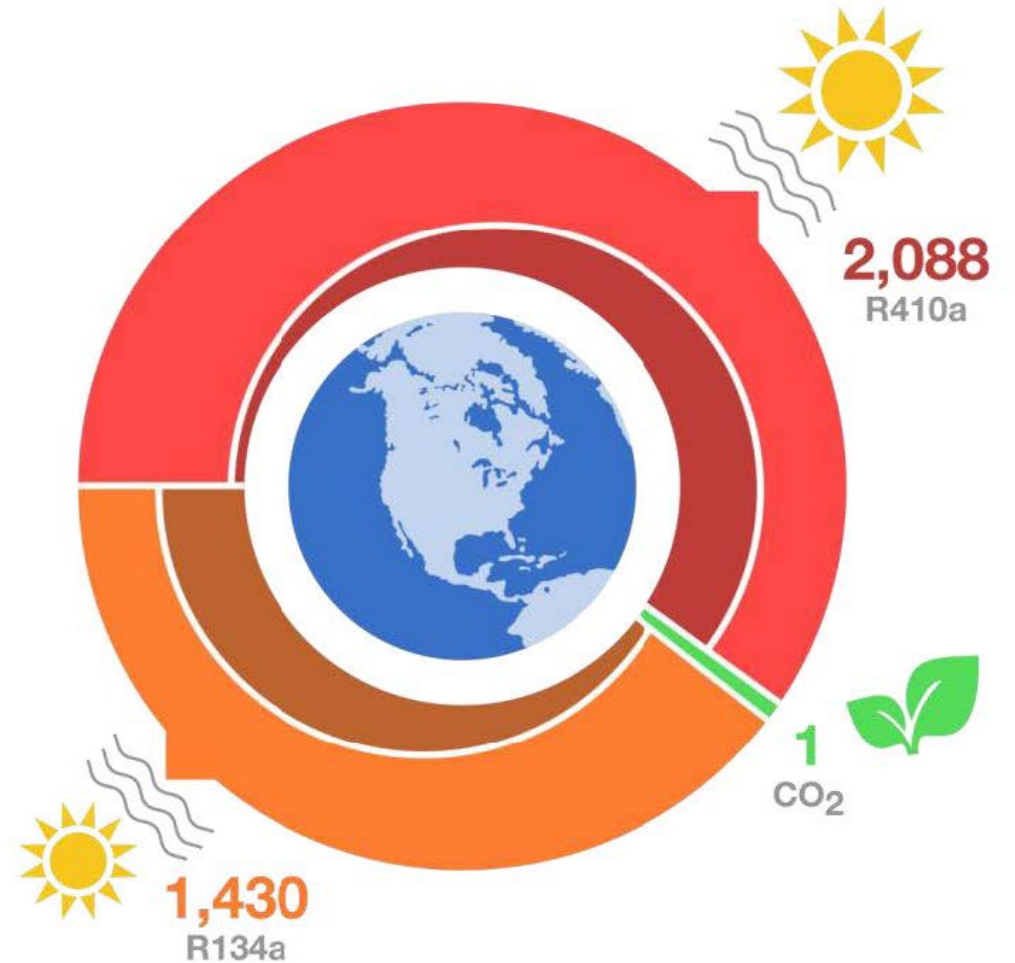
Nonflammable

Nontoxic

High pressure/temperature refrigerant

Excellent Low Ambient Performance

Highly efficient



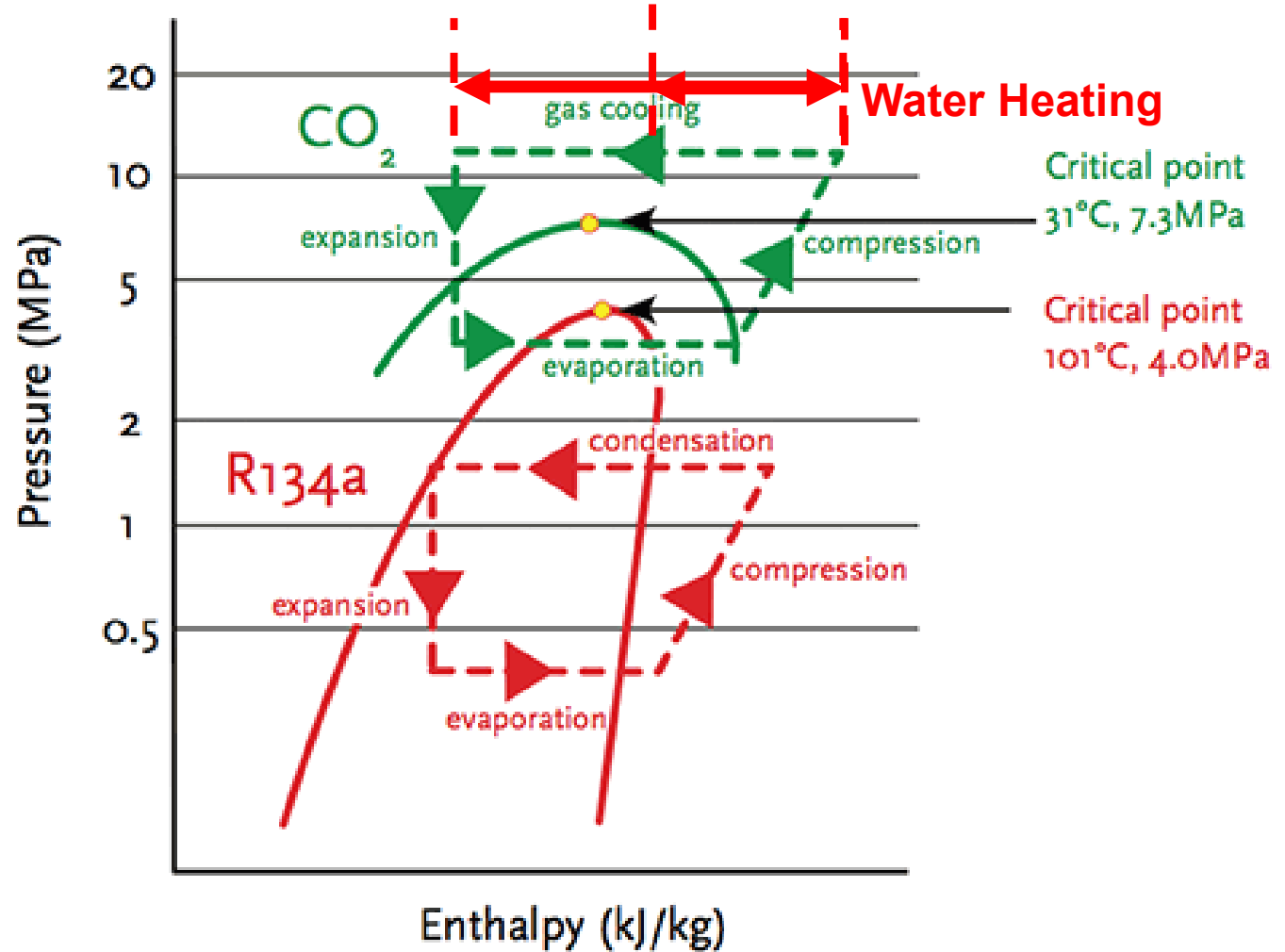
CO₂ and the Trans-critical cycle

Higher Pressure compared to R134a

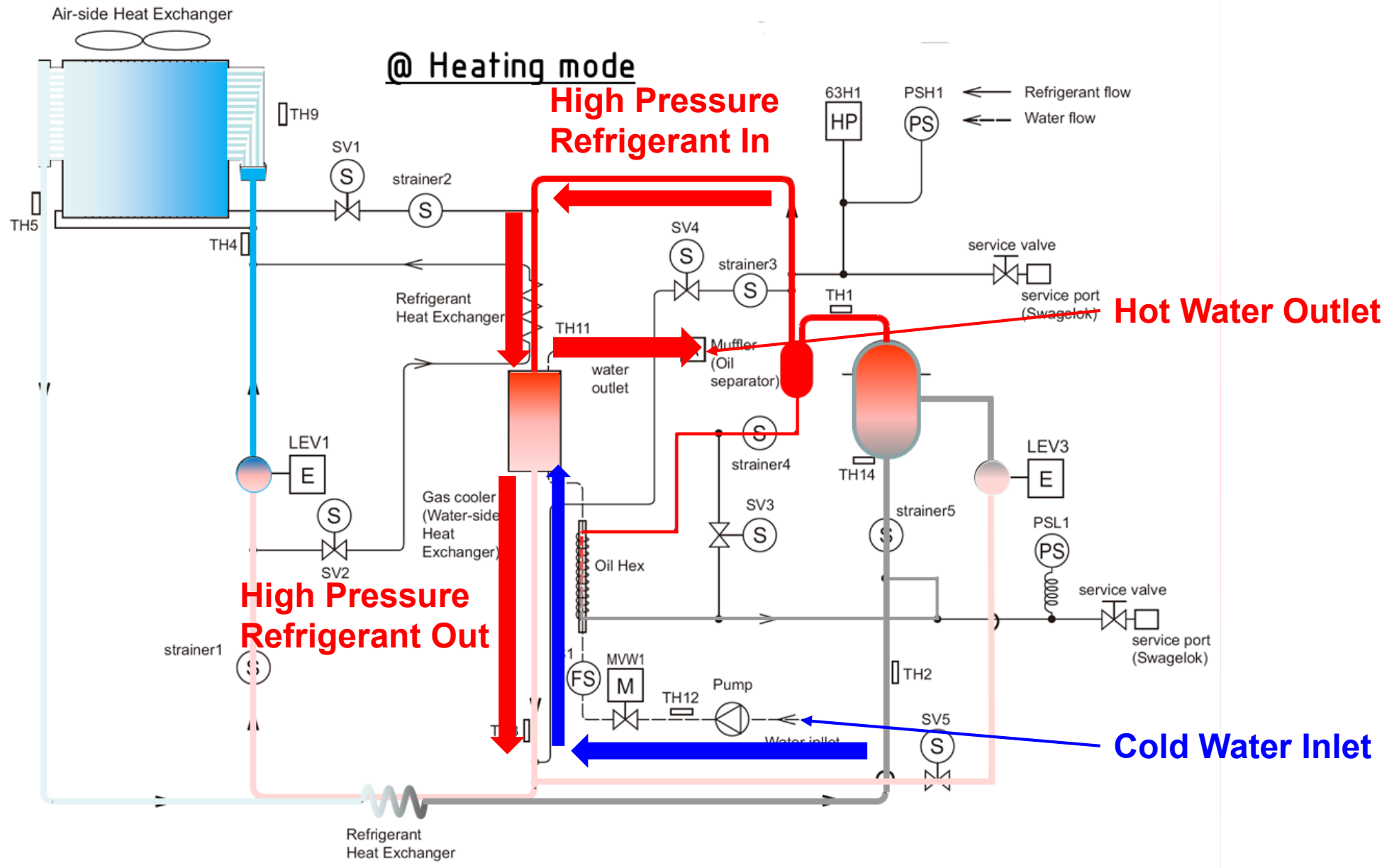
Refrigerant remains in a vapor state during the heating cycle

High heat transfer coefficients

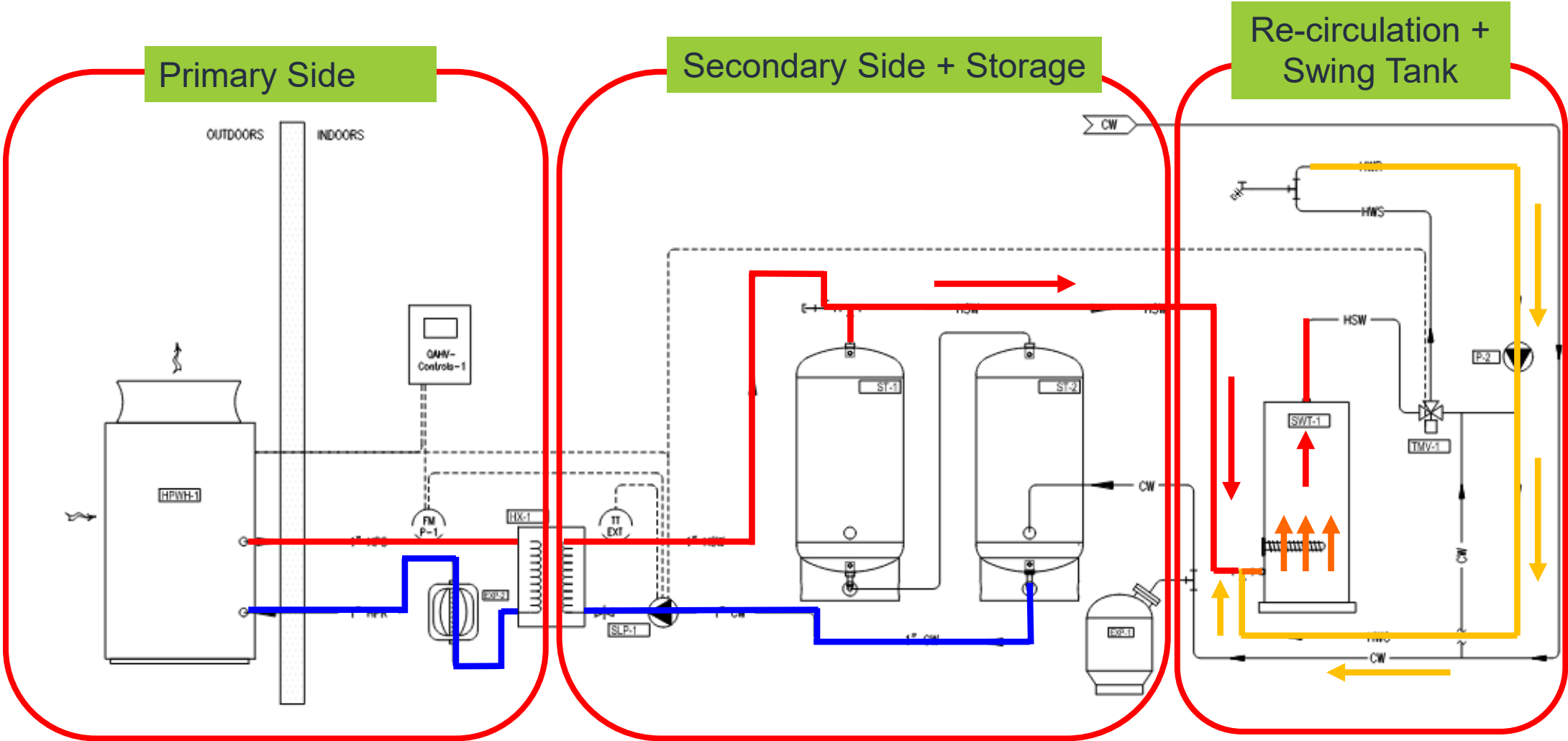
Higher volumetric capacity



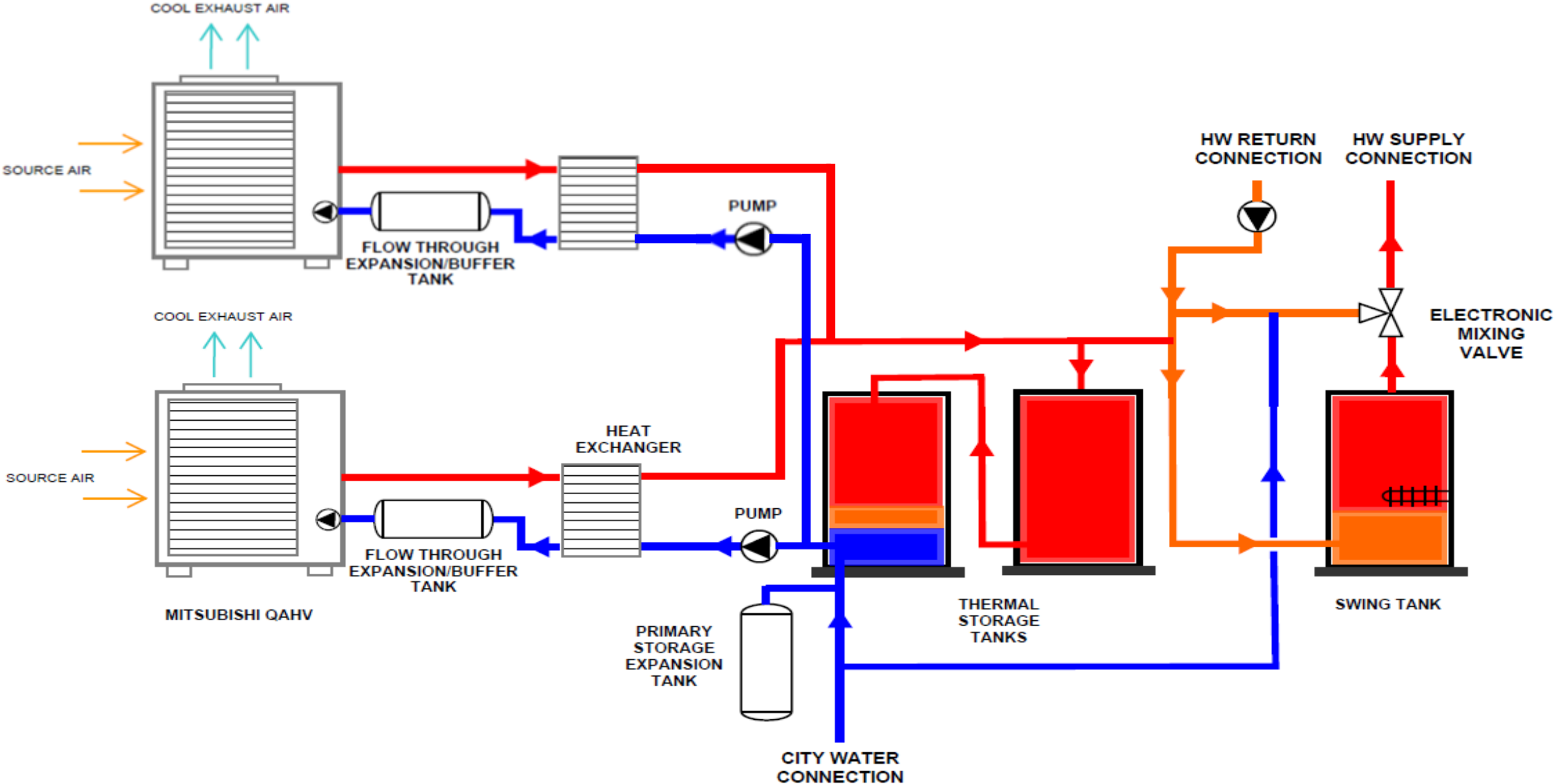
Refrigerant Circuit – Heating Mode



CO2 Heat Pump System Schematic



Basic System Schematic – Multiple Heat Pumps

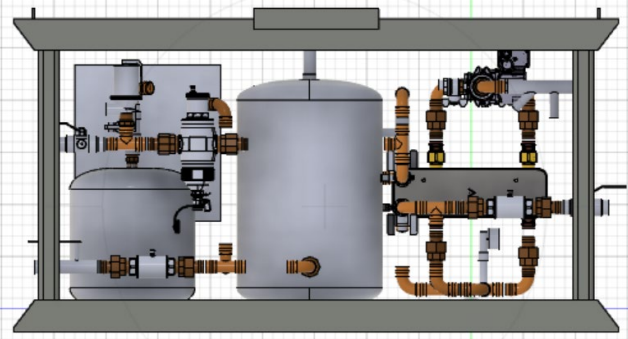


Commercial CO2 System Components



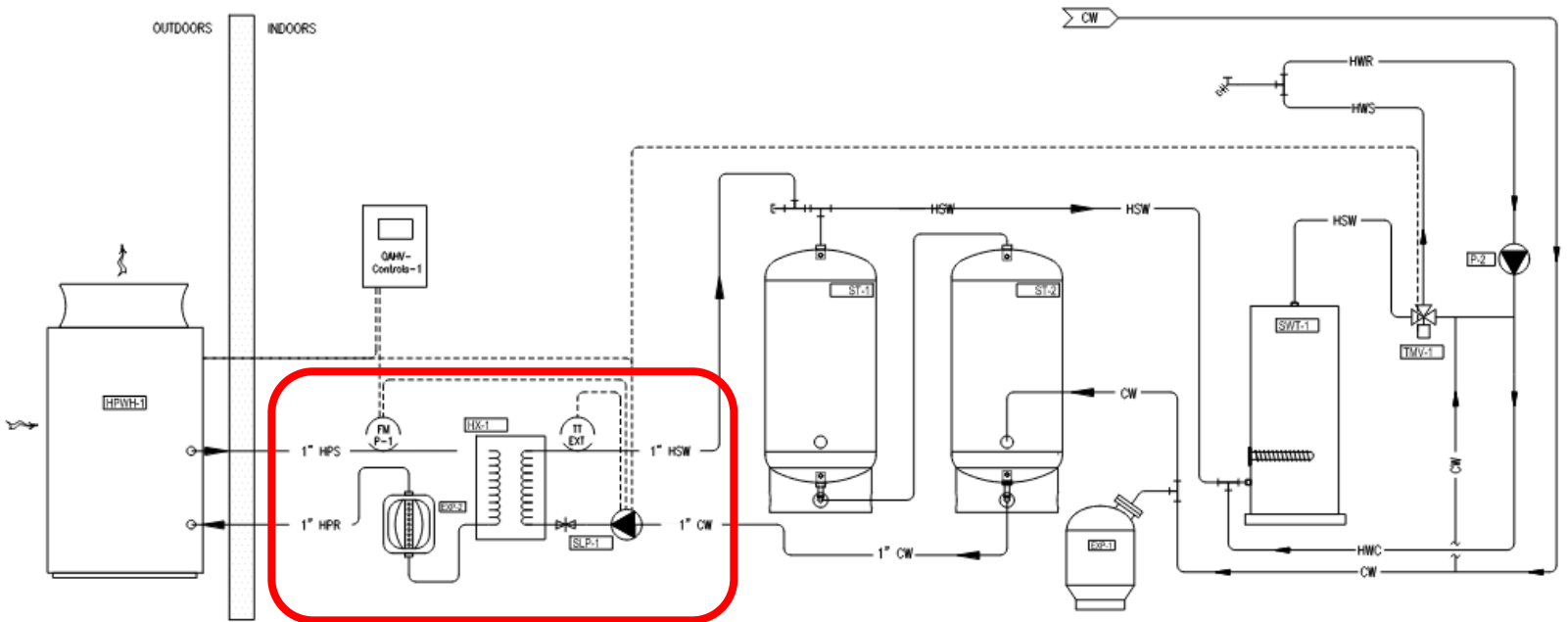
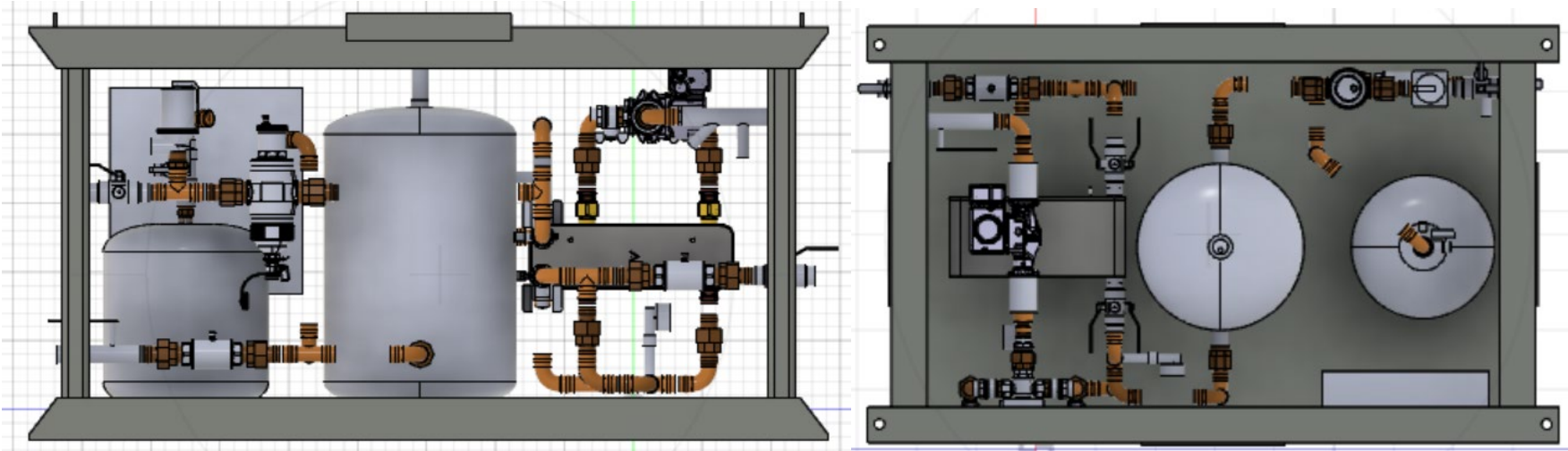
Installation Complexity
Mistakes
Labor
Cost

Skid Approach



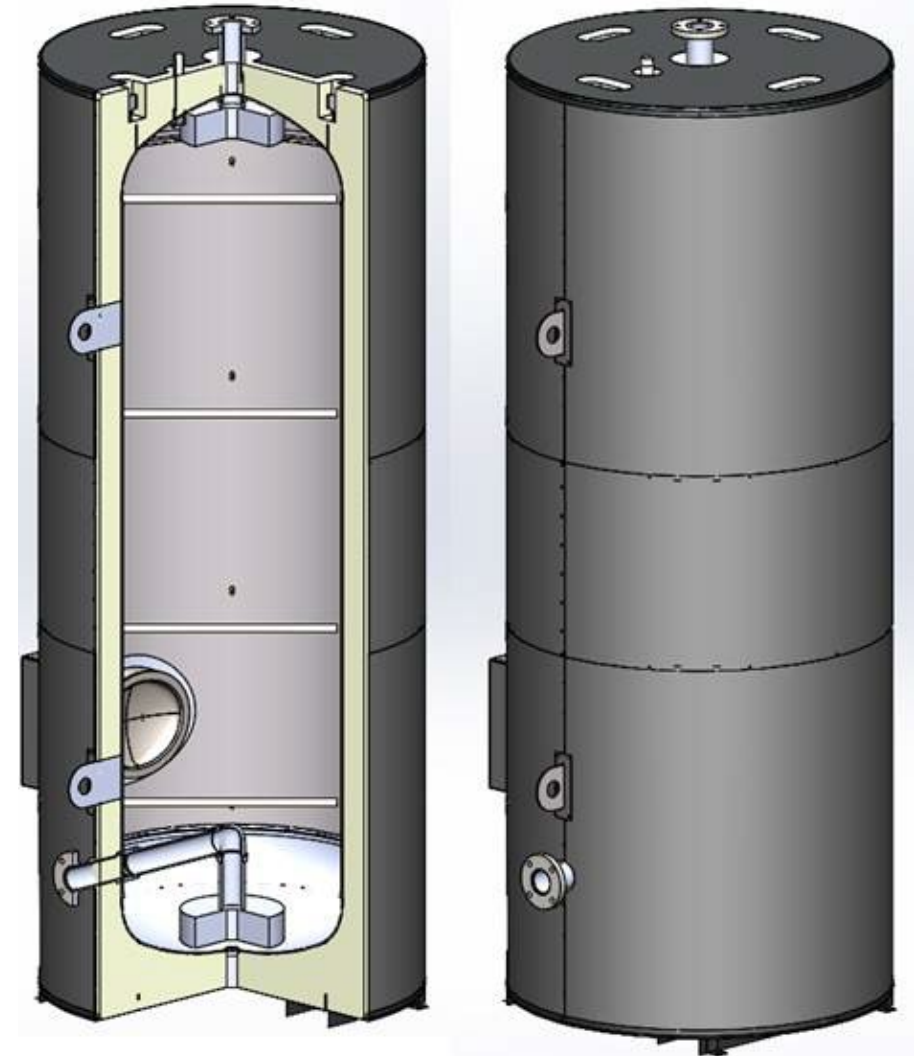
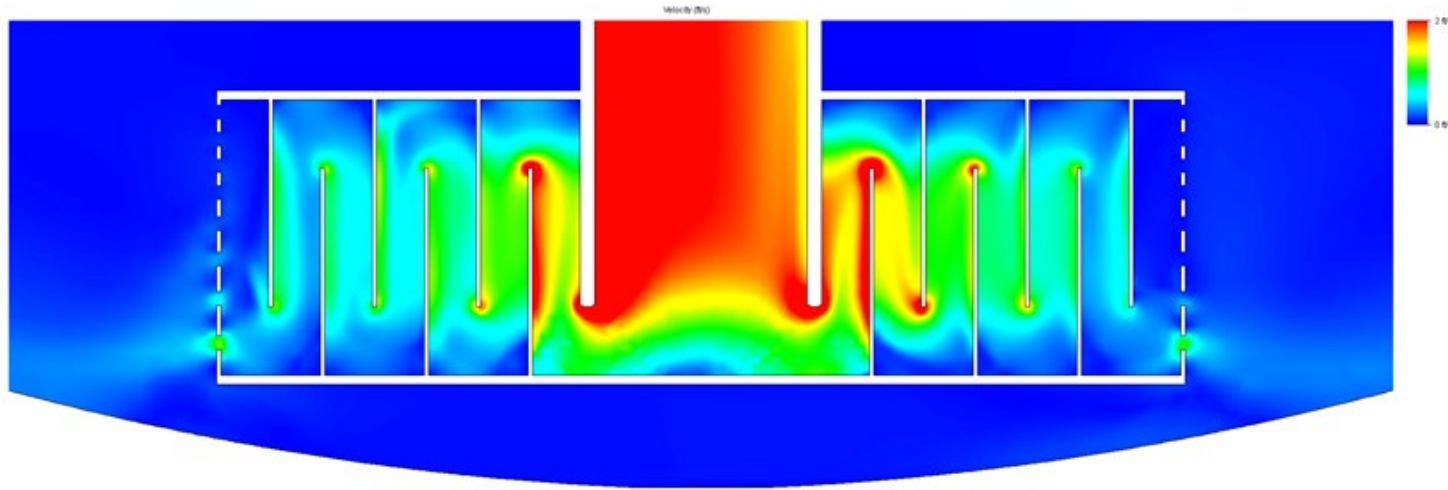
Intermediary Skid

- Factory assembled
- Secondary Pump
- Secondary HEX
- Buffer Tank
- Expansion Tank
- Key Valves
- Controls
- Fits through standard doorway
- Reduced on-site complexity
- Less labor required
- Quality - works 1st time

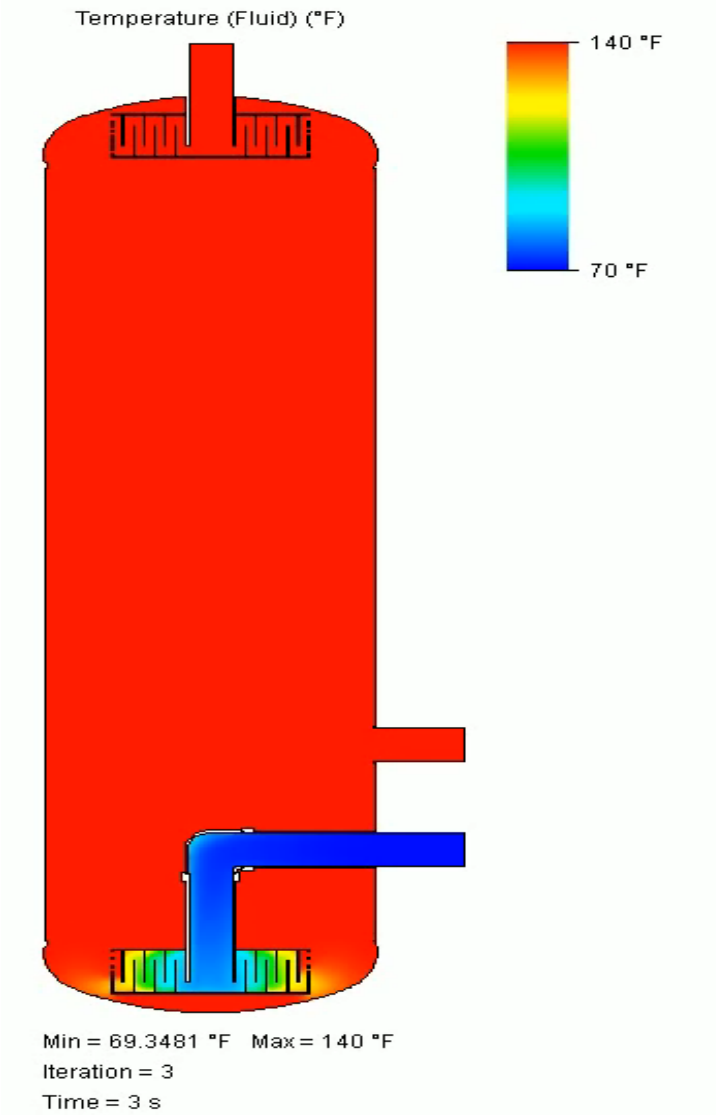
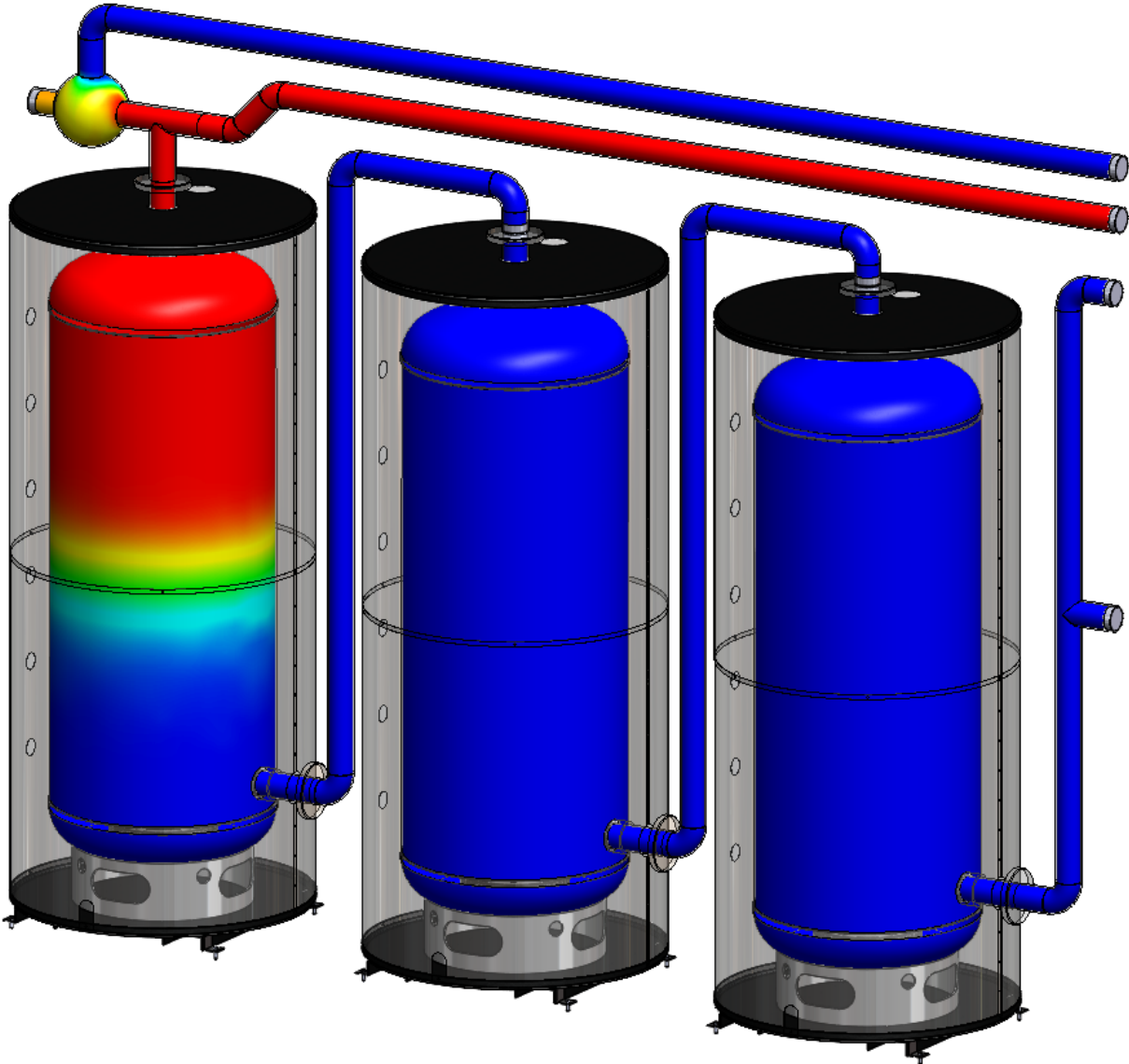


Unique Tank Designs

- Engineered storage tank solutions to **maximize the efficiency** of the **system**
- Patent Pending baffle design promotes reduced velocity in both directions



Tank Stratification – 95% Volume Utilization



Design Selection Software

The screenshot shows the 'Project Properties' dialog box in the Design Selection Software, with the 'Design Conditions' tab selected. The dialog is divided into several sections for configuring project parameters. The 'Outdoor Air Temperatures' section is highlighted with a red box, showing values for Heating Dry Bulb (12.0 °F), Heating Wet Bulb (10.8 °F), Heating Rel. Humidity (72.8 %), Cooling Dry Bulb (90.0 °F), Cooling Wet Bulb (73.0 °F), and Cooling Rel. Humidity (60 %). The 'Indoor Entering Coil Temperatures' section shows values for Cooling Dry Bulb (80.0 °F), Cooling Wet Bulb (67.0 °F), Cooling Rel. Humidity (51.8 %), and Heating Dry Bulb (70.0 °F). The 'Outdoor Unit Water' section shows Inlet Water Heating (86.0 °F) and Inlet Water Cooling (68.0 °F). The 'Indoor Unit Water' section has an 'Override' checkbox. The 'Altitude Derate Note' is set to 'Commercial Residential' and the altitude is 13.0 ft. A derate table is provided at the bottom, showing derate factors for Air and Water units. The software version is 4.3.1.16 and the database version is 4.0.0.0. The status bar shows 'File saved' and a zoom level of 100%.

Project Properties

Project Info | Unit Config | **Design Conditions** | Submittal Package | Extended Warranty | Sharing

Profile: Default (Modified) [Save] [Edit Name] [Set Default] [Delete]

Outdoor Air Temperatures

Location Manual

US/Canada Other Countries

New York | New York City

Heating Dry Bulb: 12.0 °F

Heating Wet Bulb: 10.8 °F

Heating Rel. Humidity: 72.8 %

Cooling Dry Bulb: 90.0 °F

Cooling Wet Bulb: 73.0 °F

Cooling Rel. Humidity: 60 %

Indoor Entering Coil Temperatures

Cooling Dry Bulb: 80.0 °F

Cooling Wet Bulb: 67.0 °F

Cooling Rel. Humidity: 51.8 %

Heating Dry Bulb: 70.0 °F

Outdoor Unit Water

Inlet Water Heating: 86.0 °F

Inlet Water Cooling: 68.0 °F

Indoor Unit Water

Override

Inlet Water Heating

Inlet Water Cooling

Altitude Derate Note: [Commercial Residential](#)

Altitude: 13.0 ft [Reset]

Source	Air		Water	
Unit	Outdoor	Indoor	Outdoor*	Indoor
Derate	1.00	1.00	1.00	1.00

*Water source units and PWFY indoor units are excluded from this altitude derate.
**The application of these correction factors depends on system type. Refer to the application notes for details

Quick Results

For pipe limit values

Pipe length to HX:

Correction Factors

Temperature:

Defrosting:

Conditions

QAHV Entering Water

QAHV Secondary Side

Cumulative QAHV Cap

Cumulative Tank Capa

Cumulative Swing Tan

File saved | Software Version: 4.3.1.16. Database Version: 4.0.0.0 | OK | Cancel | Apply | 100%

Selection Software System Sizing

The screenshot displays the Diamond System Builder interface with the QAHV Design Configurator dialog box open. The dialog box contains the following fields and controls:

- Instructions:** A red-bordered box contains the text: "Instructions: use Ecosizer tool to establish system requirements" and a link: <https://ecosizer.ecotope.com/sizer/size>
- Input From Ecosizer:**
 - Required Heating Capacity: Btu/h
 - QAHV Entering Water Temperature: °F
 - Secondary Side Leaving Water Temperature: °F
 - Required Tank Volume: gal
 - Number of Tanks:
 - Actual Tank Volume: gal
- Tank Selection:** Six dropdown menus for Tank 1 Size through Tank 6 Size, all currently set to "Not Used".
- Required Swing Tank Volume:**
- System Configuration:**
- Swing Tank Power Source:**
- Buttons:** "Ok" and "Cancel" buttons at the bottom.

The background software interface shows the "Diamond System Builder" title bar, a menu bar (File, Home, Tools, Units, Display, Export, Help, Account), and a ribbon with various tool icons. The status bar at the bottom indicates "Unsaved", "Ready", and "Software Version: 4.3.1.18. Database Version: 4.3.1.12.test".

Ecosizer Heat Pump and Tank Sizing Tool

User Friendly sizing tool developed by Ecotope

Simple input options for the user

Quick results with the ability to edit and customize the selection

The screenshot shows the 'APARTMENT SIZE & OCCUPANCY RATES' section of the tool. It includes input fields for 'Number of People' (250), 'Number of Apartments' (180), and a slider for 'Peak Gallons per Day per Person' set to 25. Below these are 'Design Cold' (50°F), 'Supply' (120°F), and 'Hot Storage' (150°F) fields. An 'ADVANCED OPTIONS' section contains 'Aquastat Fraction' (40%) and 'Storage Efficiency' (80%).

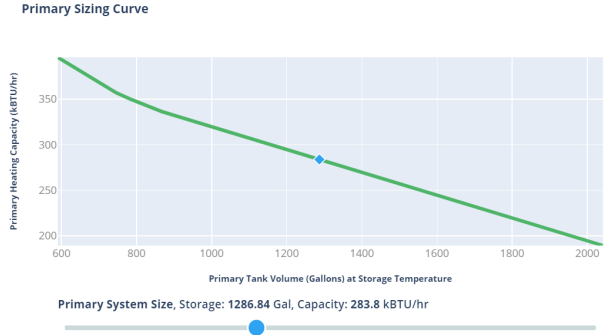
Tank Volume [?](#)
1,287.00 Gallons

Swing Tank Volume [?](#)
120 - 300 Gallons

CA Title 24 Swing Tank Volume [?](#)
480 Gallons

Heating Capacity [?](#)
283.80 kBTU/hr

Swing Resistance Element [?](#)
31.5 kW · 107.5 kBTU/hr



RECOMMENDATIONS
The recommended minimum heating capacity shown below is the **minimum** needed average output capacity of the selected equipment at the design cold air temperature in your climate zone. Note that you must also account for manufacturer specific defrost penalty.

Daily Hot Water Usage
25.0 Gallons per Day per Person

Total Hot Water
6,250.00 Gallons per Day

Recirculation Loop
Heat Loss
100.0 Watts per Apartment

SAVE RESULTS TO PDF

SEND US YOUR FEEDBACK

Selection Software Inputs

QAHV Design Configurator

Instructions: use Ecosizer tool to establish system requirements
<https://ecosizer.ecotope.com/sizer/size>

Input From Ecosizer

Required Heating Capacity: 283800 Btu/h

QAHV Entering Water Temperature: 50 °F

Secondary Side Leaving Water Temperature: 150 °F

Required Tank Volume: 1287 gal

Number of Tanks: 3 Compute Optimal Tanks

Actual Tank Volume: 1500 gal

Tank 1 Size	Tank 2 Size	Tank 3 Size	Tank 4 Size	Tank 5 Size	Tank 6 Size
500	500	500	Not Used	Not Used	Not Used

Required Swing Tank Volume: 150 Gallon

System Configuration: Swing Tank

Swing Tank Power Source: 208/230V 3-Phase Power

Ok Cancel

Quick Results

For pipe limit values

Pipe length to HX:

Correction Factors

Temperature:

Defrosting:

Conditions

QAHV Entering Water Temperature:

QAHV Secondary Side Leaving Water Temperature:

Cumulative QAHV Capacity:

Cumulative Tank Capacity:

Cumulative Swing Tank Capacity:

Cumulative Swing Tank Heating Capacity:

Unsaved Ready Software Version: 4.3.1.18. Database Version: 4.3.1.12.test 100%

Selection Software System Schematic

Diamond System Builder

File Home Tools Units Display Export Help Account

Undo 1 Redo 0 Edit Undo Limit: 10

Add Centralized System Build Add System Project Properties Units of Measurement Properties Renumbr Groups Disable Check

Partial Demand Partial Cooling/Full Heating Full Demand Diversity Factor 0 BTU/h

Design View Controls View LAN View Piping View Equipment View Ventilation View Show Configurator QAHV

Control Sy... Centralized Sy System 1

Project QAHV-N136TAU-HPB 290,983 BTU/h

CW Inlet

HWR from Building HSW to Building

0.0 ft 0.0 ft Ts Fs

EXPANSION TANK (13)

500 GAL 500S-00 TH15 TH16 TH17

500 GAL 500S-00

500 GAL 500S-00

150 GAL JEV150J45ADE

SWING TANK W/ HEATER

Units

Quick Results

For pipe limit values
 Pipe length to HX: 0.0/196.0feet

Correction Factors
 Temperature: 0.72
 Defrosting: 0.99

Conditions
 QAHV Entering Water Temperature: 50.0
 QAHV Secondary Side Leaving Water Temperature: 150.0
 Cumulative QAHV Capacity: 2909
 Cumulative Tank Capacity: 1500
 Cumulative Swing Tank Capacity: 150.0
 Cumulative Swing Tank Heating Capacity: 45.0

Unsaved Ready Software Version: 4.3.1.18. Database Version: 4.3.1.12.test 100%

Controls

- Cohesive controls package required
 - BACnet connectivity
 - Load shifting / demand response
 - **CTA2045** compatible
 - Monitoring of 3rd party devices
 - COP Monitoring of System
 - Install wizard



Bayview Tower - QAHV Retrofit Project

- 100-unit multifamily building
- Pre-retrofit monitoring
- Packaged skid delivered to site
- Demand response controls through CTA-2045
- Measurement and Verification System

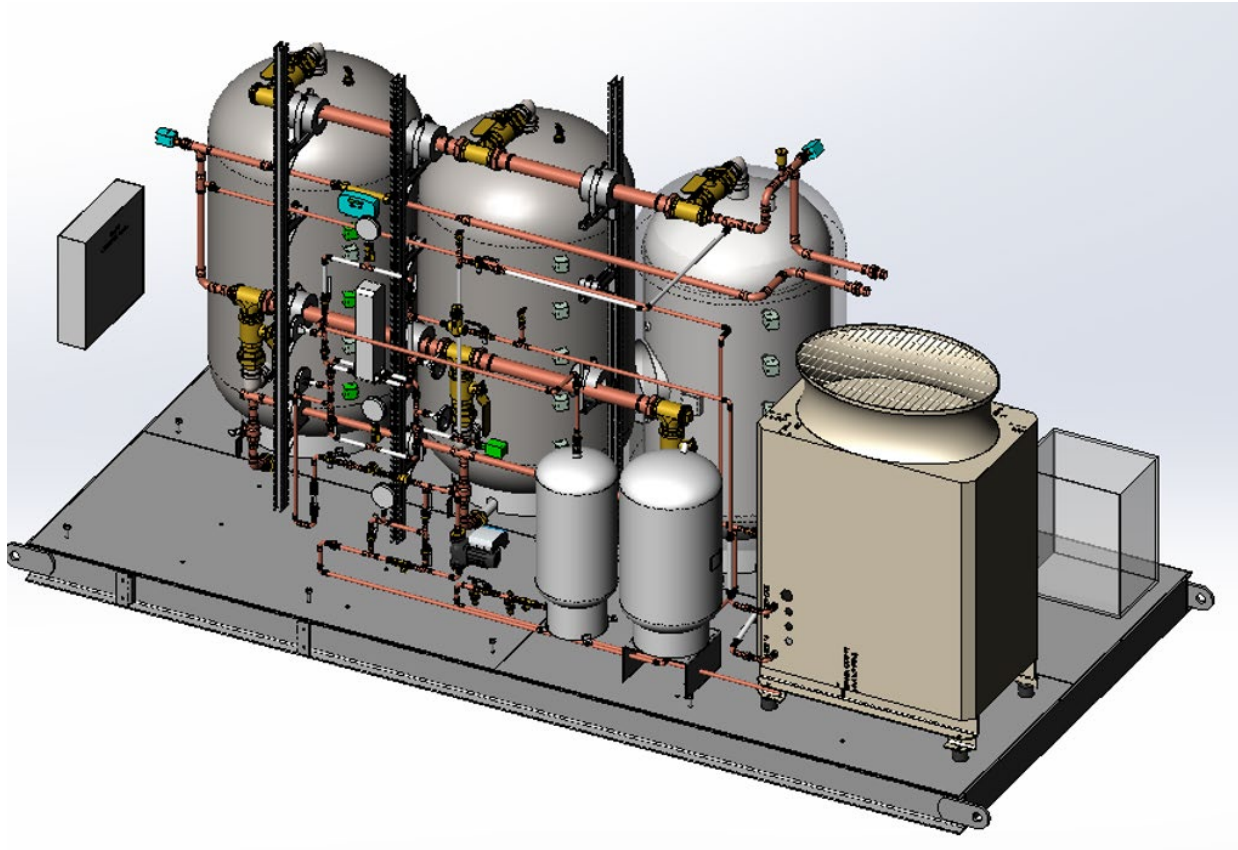
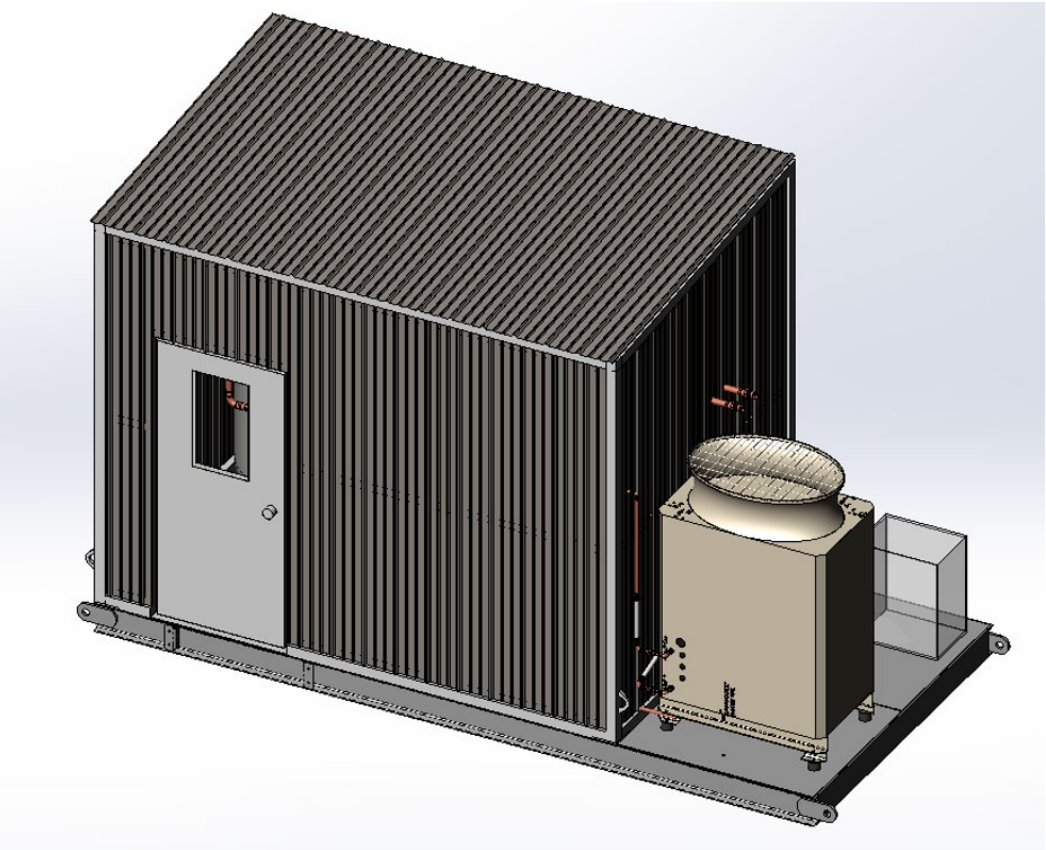


Pre-retrofit Monitoring

- 3,600 Gal/day peak load
- 3,150 Gal/day avg load
- ~20 gal/day/person
- 80 W/apt recirculation load
- Recirculation approximately 40% of total load



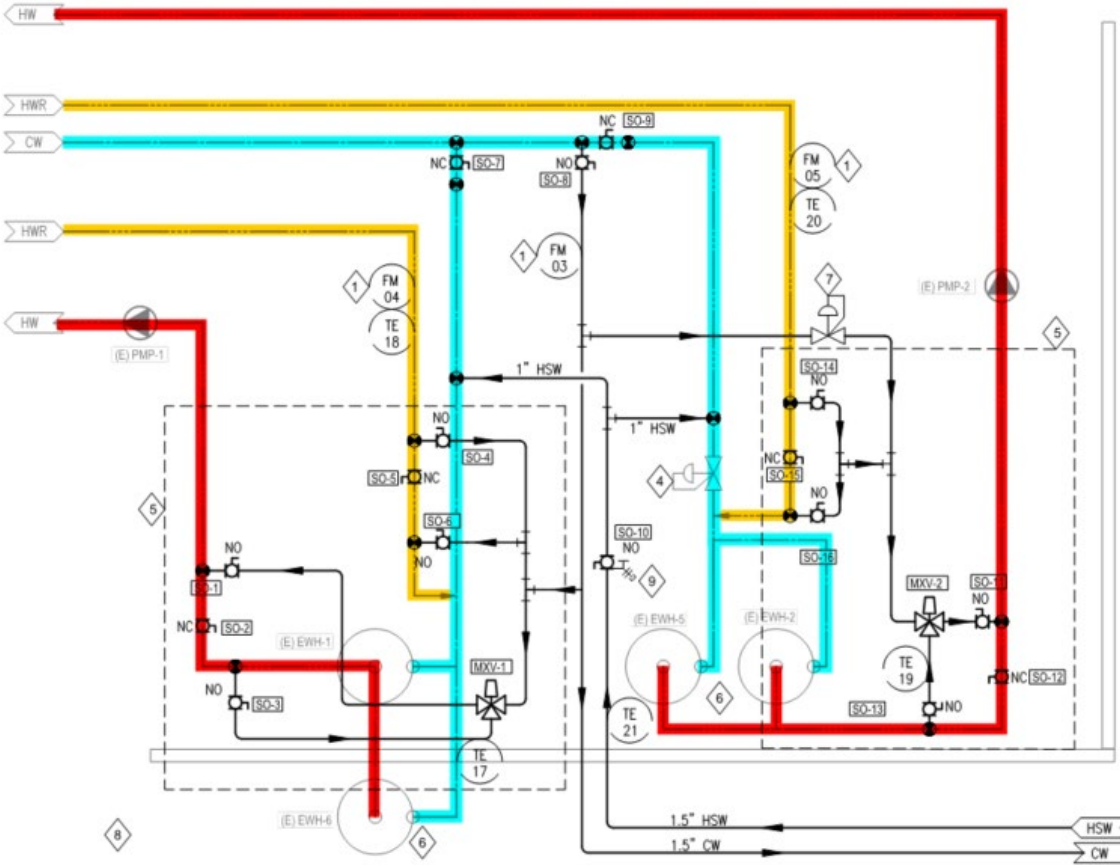
Packaged Skid



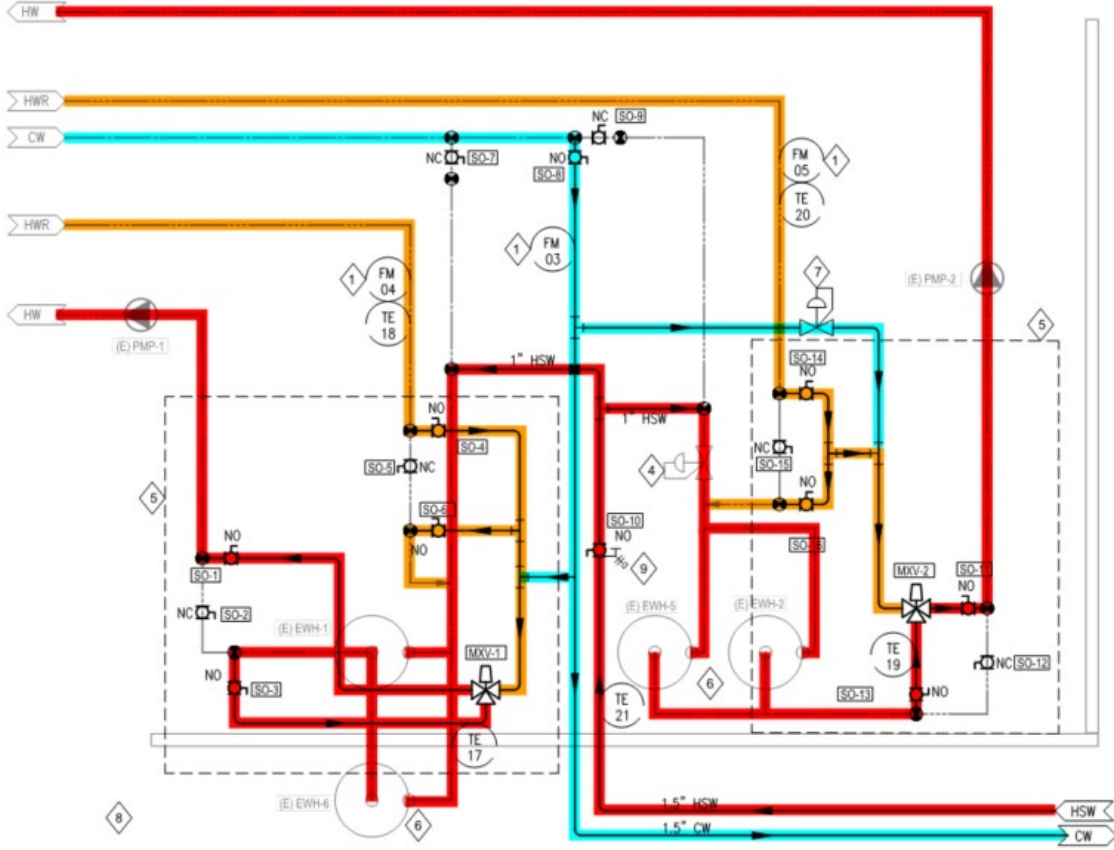
Skid installation



Piping Design



Electric Resistance Operation



Heat Pump Operation

Bayview Tower – Energy Use Comparison

- Previous System
 - 102kW Power Input (6 Rheem Commercial Water Heaters)
- Heat20 System
 - 14kW Power Input (Plus cycling of 4 water heaters during low load/overnight operation)
 - 2 Rheem water heaters removed entirely
 - Estimated energy reduction of 136,875 kWh/year or 40%
 - Estimated annual cost savings of \$15,000 based upon \$0.11 kWh electricity rate

Hotel Marcel New Haven Connecticut – Historic Pirelli Building



- 1st Net Zero Hotel in the U.S.
 - 110,000 sq. ft. retrofit project
 - 165 guest rooms
 - 60% more energy efficient than code requirements
- All electric building
 - 3 QAHV heat pump units installed
 - 12 Tesla Superchargers
 - Over 1000 photovoltaic panels
 - VRF systems for cooling/heating



Key Considerations

- Engineered solutions required - not just adding heat pump units
- System sizing is critical to operation and efficiency – consider load shifting when sizing system
- Increased storage tank volume for retrofit applications
- Where will the new storage tanks be located?
- Is the existing power supply adequate for the new heat pump loads
- Follow manufacturers recommendations for system design

Thank you!