CO_2 Heat Pump Water Heaters for Commercial & Industrial Applications

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ACEEE Hot Water Forum

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Presentation Overview

- Natural Refrigerant Summary
- EPRI Laboratory Evaluation Overview
- EPRI Laboratory Results
- Mayekawa Water Source CO2 Heat Pump Introduction
- Water Source CO_2 Heat Pump Commercial Applications
- Water Source CO_2 Heat Pump Industrial Applications

Why Use Natural Refrigerants?

Natural Refrigerants including Carbon Dioxide, Ammonia, Hydrocarbons, Air and Water have excellent thermodynamic properties in their respective temperature limits, which allow for maximum system COP when used in properly designed equipment.

- Environmental impact of each refrigerant -

Type of refrigerant	CFC (Abolished refrigerant)			HCFC (Regulated refrigerant	HFC (Substitute refrigerant)				Natural Refrigerants		
Name of refrigerant	R11	R12	R502	R22	R134a	R404A	R407C	R410A	R717 NH_3	R744 CO_2	R600a Isobu-tane
Ozone depletion potential (ODP)	1.0	1.0	0.334	0.055	0	0	0	0	0	0	0
Global warming potential (GWP)	4750	10900	4590	1810	1430	3922	1650	2088	>1	1	4
Features	・Chlorine depletes ozone layer. ・Refrigerator, car air-conditioner ・Already abolished completely in 1995.			・Target to be regulated due to Montreal Protocol ・To be abolished completely in 2020.	・Composition is very unstable. ・No depletion of ozone layer ・Specified as greenhouse gas in Kyoto Protocol				・Existing in nature Ammonia, carbon hydride, water, air, carbon dioxide		

- **ASHRAE Position Document affirmed in 2011 highly supports the wider use of Ammonia, CO2 and Hydrocarbon refrigerants for HVACR applications.**
- **Natural Refrigerant use promoted through the LEED certification program.**

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CO_2 Heat Pump Water Heaters

- CO_2 Transcritical Heat Pumps:
  - Single-pass heating
  - High hot water outlet temperature
  - Efficiency a function of temperature lift

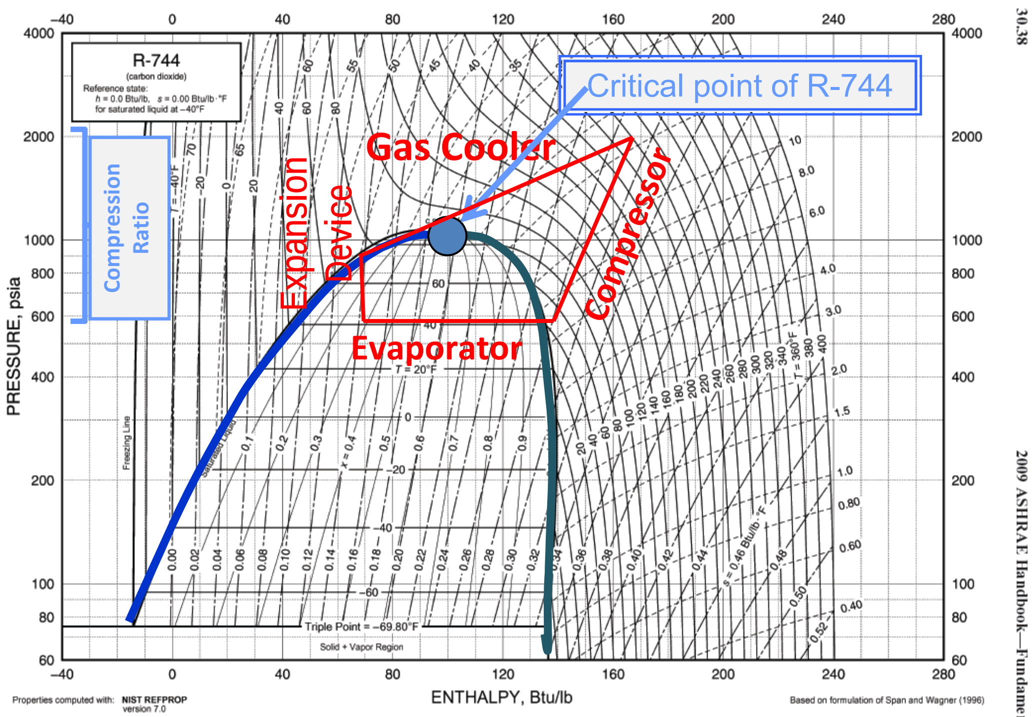

Fig. 18 Pressure-Enthalpy Diagram for Refrigerant 744 (Carbon Dioxide)

Approx. Temperature conditions shown in RED

Unit Testing at EPRI Lab

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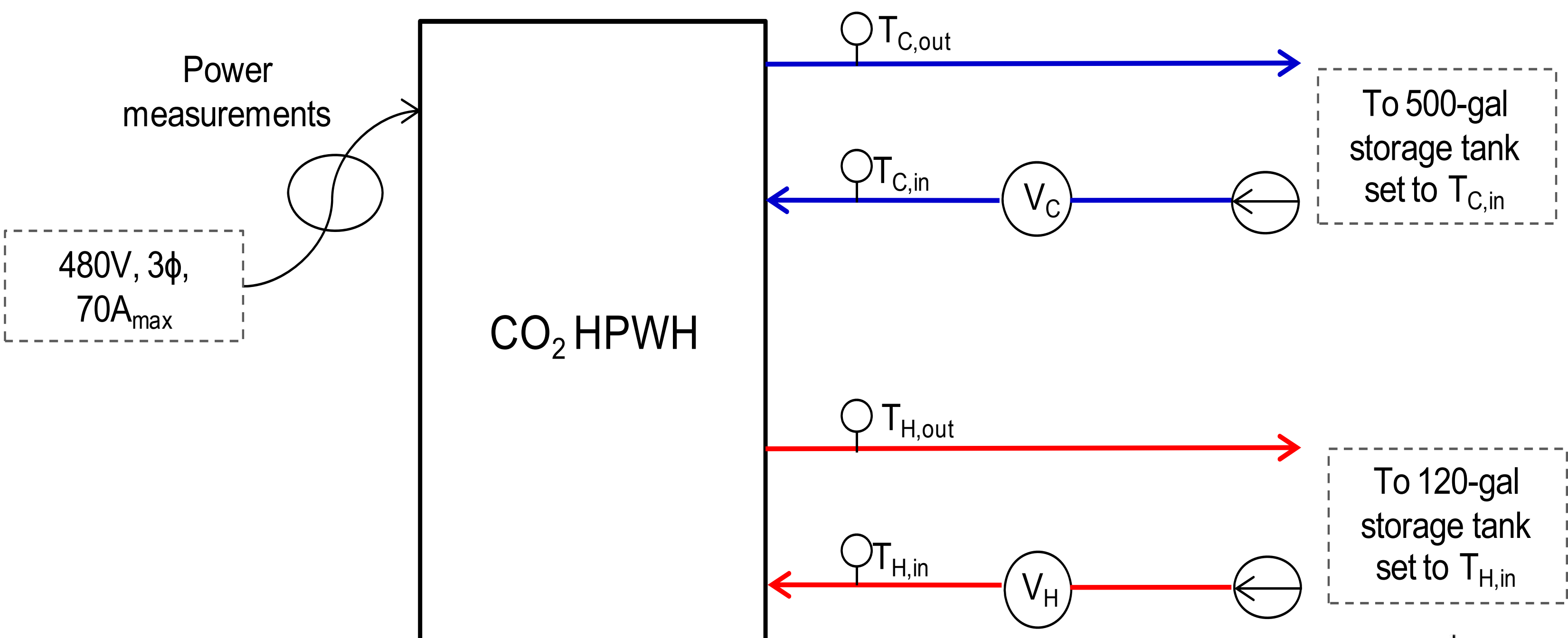
EPRI Lab Testing

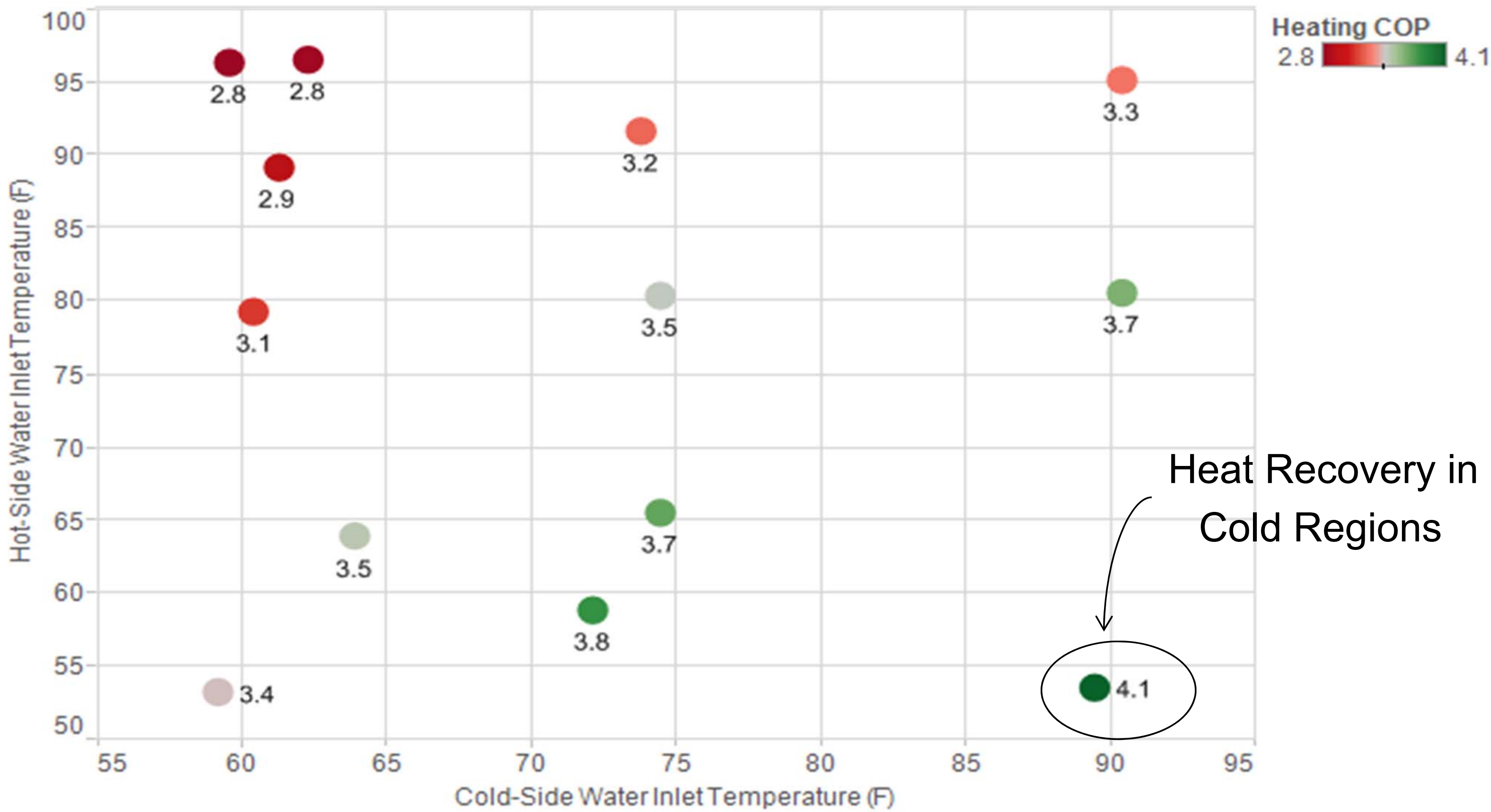
- Mayekawa HWW-2HTC water-to-water HPWH
  - Heating capacity up to 340,000 BTU/h; Cooling capacity up to 280,000 BTU/h
  - Hot water delivery at 149°F or 194°F
  - UL 1995 standard -Approved, Available in US
- Testing: "performance mapping" for various application types



EPRI Lab Testing – Results Overview

$$COP = \frac{Qh\left[\frac{Btu}{h}\right]}{3.412\left[\frac{Btu}{h-W}\right] * P[W]}$$

- Heating COP, 194°F Supply Water



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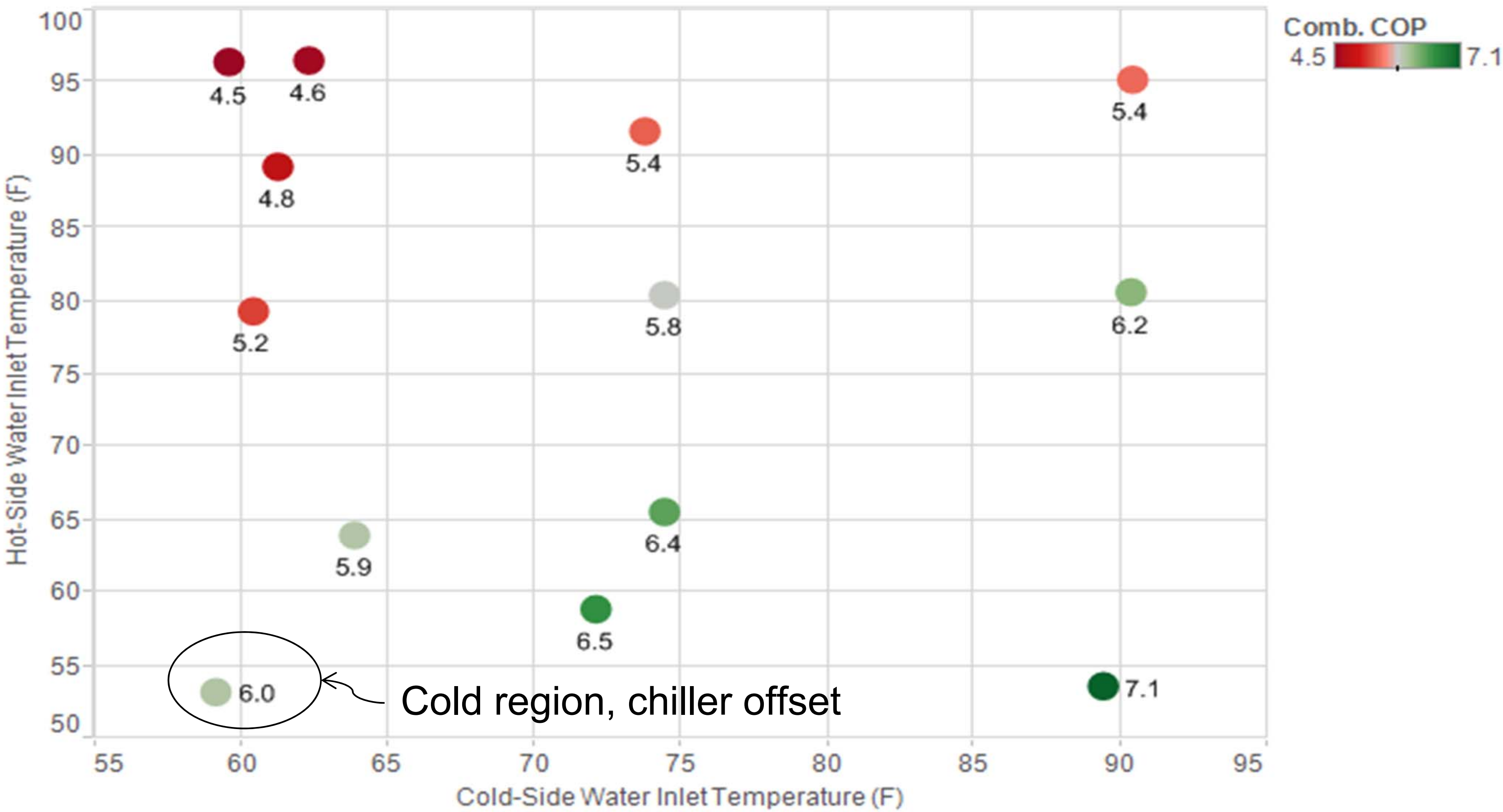
EPRI Lab Testing – Results Overview

$$COP = \frac{(Qh + Qc)\left[\frac{Btu}{h}\right]}{3.412\left[\frac{Btu}{h-W}\right] * P[W]}$$

- Combined COP, 194°F Supply Water



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Utility Value

- CO_2 HPWHs Could Fill Program Needs
  - Expands the applicability of HPWH
    - >190°F supply temperatures for applications needing high temp
  - Efficiency benefits
    - Combined COP >5.5 @ 194°F
- Applications
  - Many uses in south (cooling often needed)
  - Best-case financials in colder climates if cooling is useful or heat recovery source available

Mayekawa UNIMO ww Water Source CO_2 Heat Pump

MFG. RATED PERFORMANCE

- 100 kW @ 194 F Water
- 340,000 btu/hr @ 194ºF)

- 25 kW Motor
- (30 HP Motor)

- Heating COP is as high as 4
- Combined COP is as high as 8

Mayekawa UNIMO ww - Mfg. Rated Performance

Natural refrigerant (CO_2) heat pump to supply cold and hot water simultaneously

Capacity	Brine type	Cold water type	Heat recovery type
Heating capacity [kW]	49.9	82.1	101.8 (COP=4.4)
Cooling capacity [kW]	35.0	61.7	82.3 (COP=3.6)
Power consumption [kW]	18.4	21.8	23.1
COPt (total)	4.6	6.6	8.0
Condition	Supplied water (62→149 F) Brine (23→-16 F)	Supplied water (62→149 F) Chilled water (54→44 F)	Supplied water (62→149 F) Heat source water (72→62 F

Operation range	Water heater (Heater)	Heat Source Condition		
		Brine diversion type	Cold water diversion type	Heat recovery type
Inlet temp. (F)	40~104 (40~149*)	23 ~ 98.6	50 ~ 98.6	50 ~ 98.6
Outlet temp. (F)	**149, 194**	15 ~ 89.6	41 ~ 89.6	41 ~ 89.6
Difference between inlet and outlet temp. (F)	45~95	7～12		
Flow rate (GPM)	2.2 ~ 9.2	≧26		

* At 194 F set point

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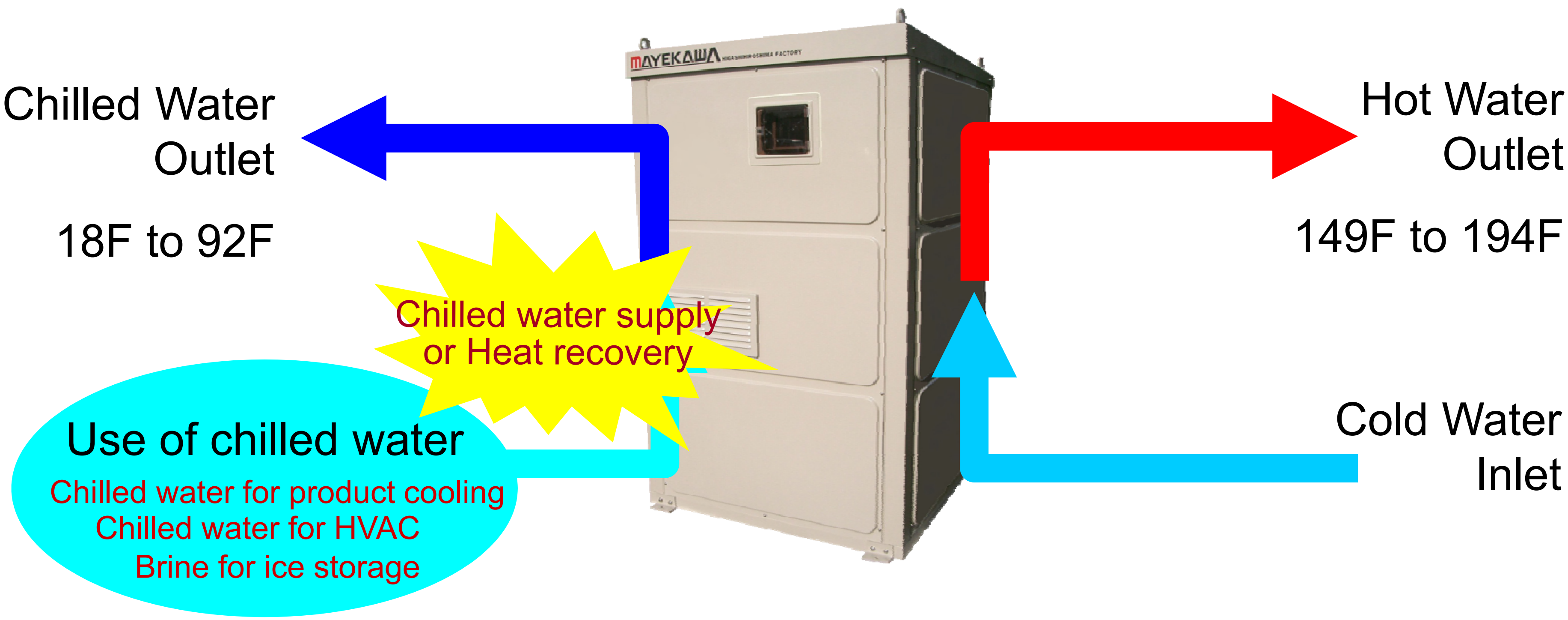
Water Source CO_2 Heat Pump Commercial Applications

“Possible to supply chilled water or heat recovery and hot water simultaneously



Are there cooling loads or heat recovery sources?
Energy conservation is possible by combining chilled water or heat recovery and hot water functions in one heat pump.

Water Source CO_2 Heat Pump Hotel Application

- Existing gas water heaters were in efficient and required constant maintenance. Only LPG.
- Hotel Owner wanted an efficient electric option
- High constant cooling load required for Hotel

SOLUTION:

CO_2 Water Source Hot Water Heat Pump

- Combine heating and cooling functions in a single compact unit.

- Low carbon emission solution.

- Increased hot water system efficiency

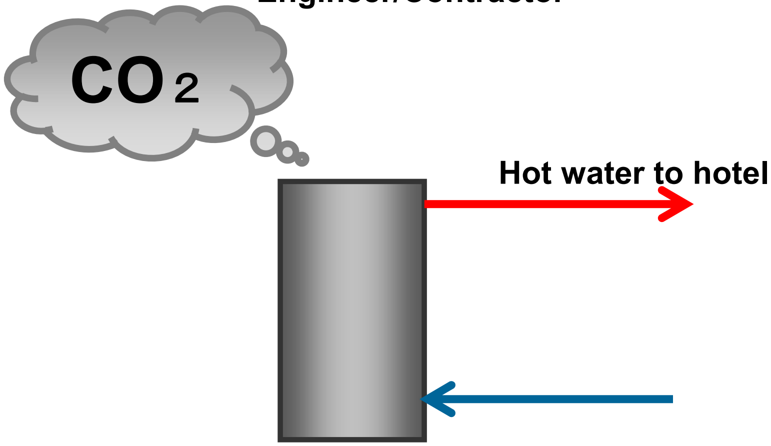
Water Source CO_2 Heat Pump Hotel Application
Existing Mechanical Equipment for Domestic Hot Water Heating and Chilled Water Air Conditioning Cooling

Simultaneous Heating and Cooling Load Requirement
- Hotel application typically uses separate equipment -
- Potential for Integrated Water Source Heat Pump -

Heating Process

Scope of work typically provided by

Plumbing Engineer/Contractor

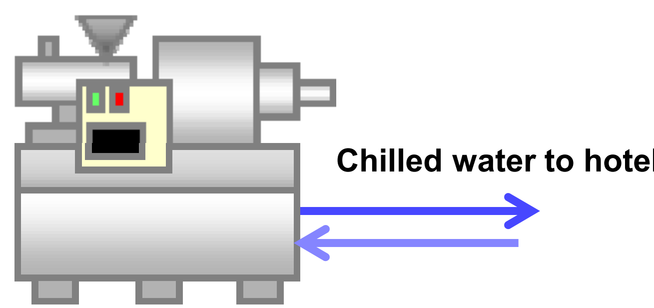


LPG Hot Water Heater

Heat Removal Process

Scope of work typically provided by

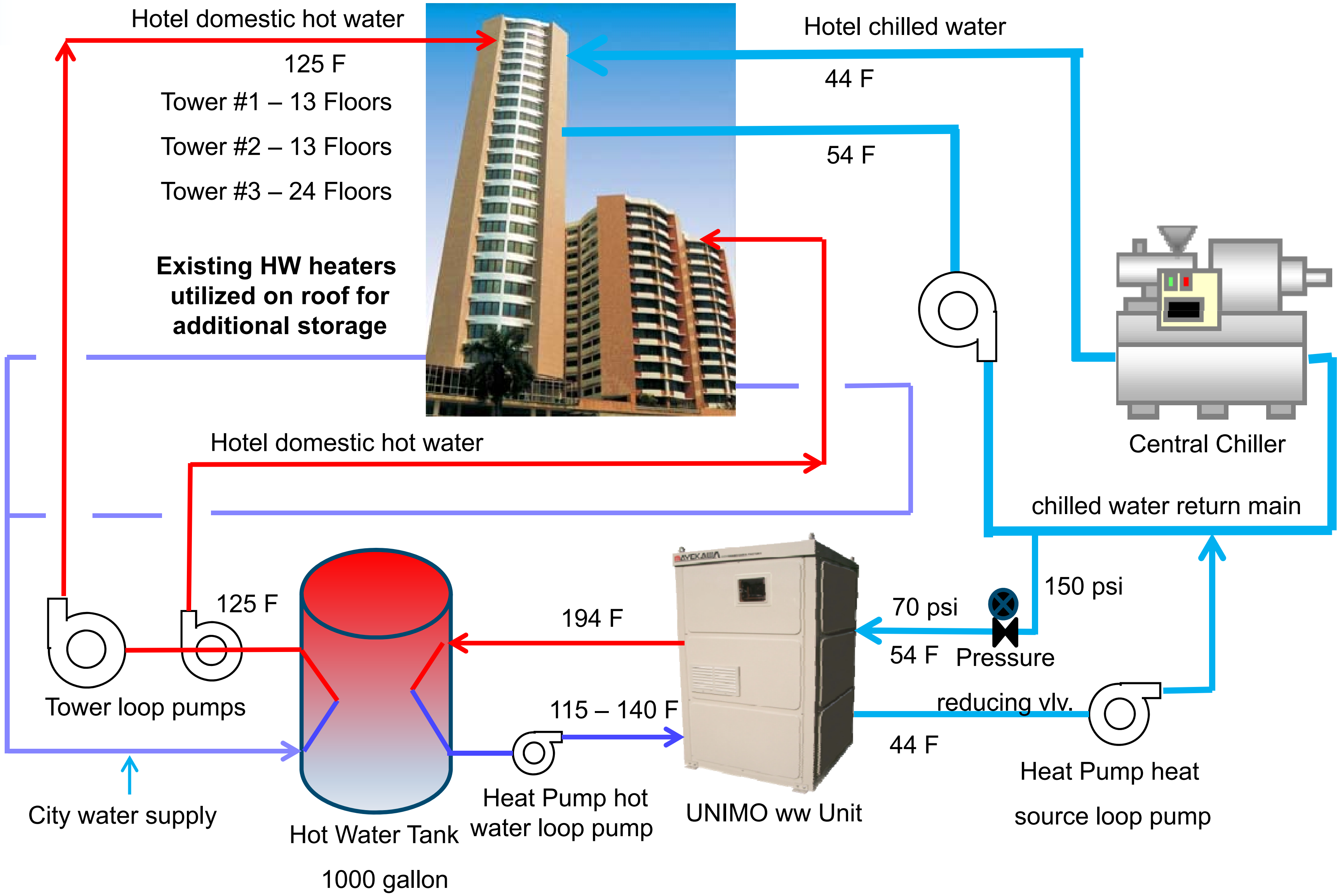
HVAC Engineer/Contractor



Central Electric Chiller

Water Source CO_2 Heat Pump Hotel Application

New Mechanical Equipment Layout with Water Source CO_2 Heat Pump



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Water Source CO_2 Heat Pump Hotel Retrofit Installation

New Mechanical Equipment Layout with Water Source CO_2 Heat Pump

UNIMO ww Unit

Hot Water Storage Tank

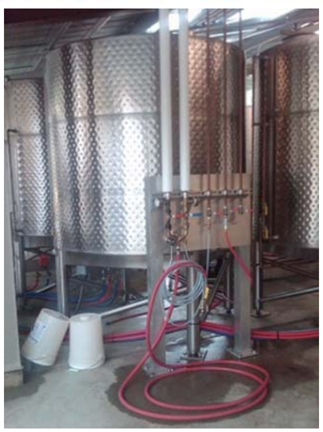
Heat Pump installed in chiller mechanical room

Hot Water Piping

Heat Source Piping

Water Source CO_2 Heat Pump Winery Application

SOMERSTON
Vineyards



Energy Efficient Estate Winery Facility located in Napa Valley, California

- ❑ Goal to become off grid for power source
- ❑ Required high hot water temperature
- ❑ Only expensive propane available

Solution: CO_2 Water Source Hot Water Heat Pump

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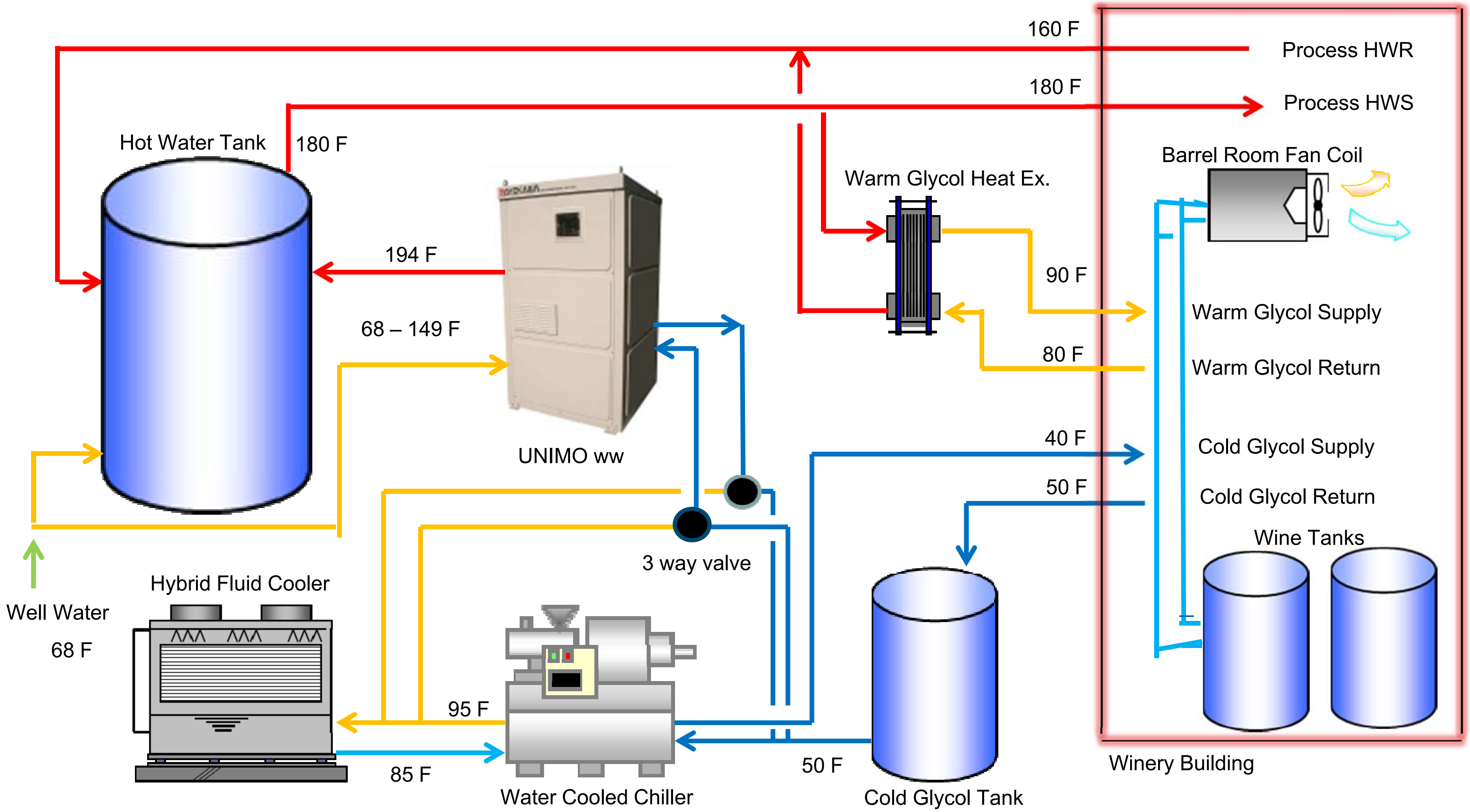
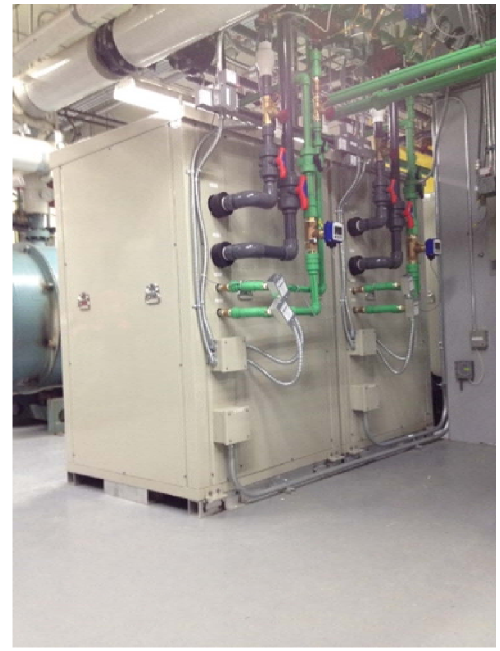
Water Source CO_2 Heat Pump Winery Piping Layout

Hybrid Glycol Cooling, Glycol Warming and Hot Water Heating



Water Source CO_2 Heat Pump Heat Recovery Building Heating Application

- (4) UNIMO ww units installed in Basement Mechanical Room.
- Seawater Heat Source 39 F to 56 F (4 C to 13 C)
- Hot Water Secondary Loop 194 F (90 C). Outlet feeds into 135 F to 160 F Building Heating Loop
- Heat Pumps used as primary Building Heating with Oil Boiler and Electric Boiler as Backup/Emergency units.



Heat Source and Hot Water Unit Piping

Seawater Heat Exchanger

MAYEKAWA

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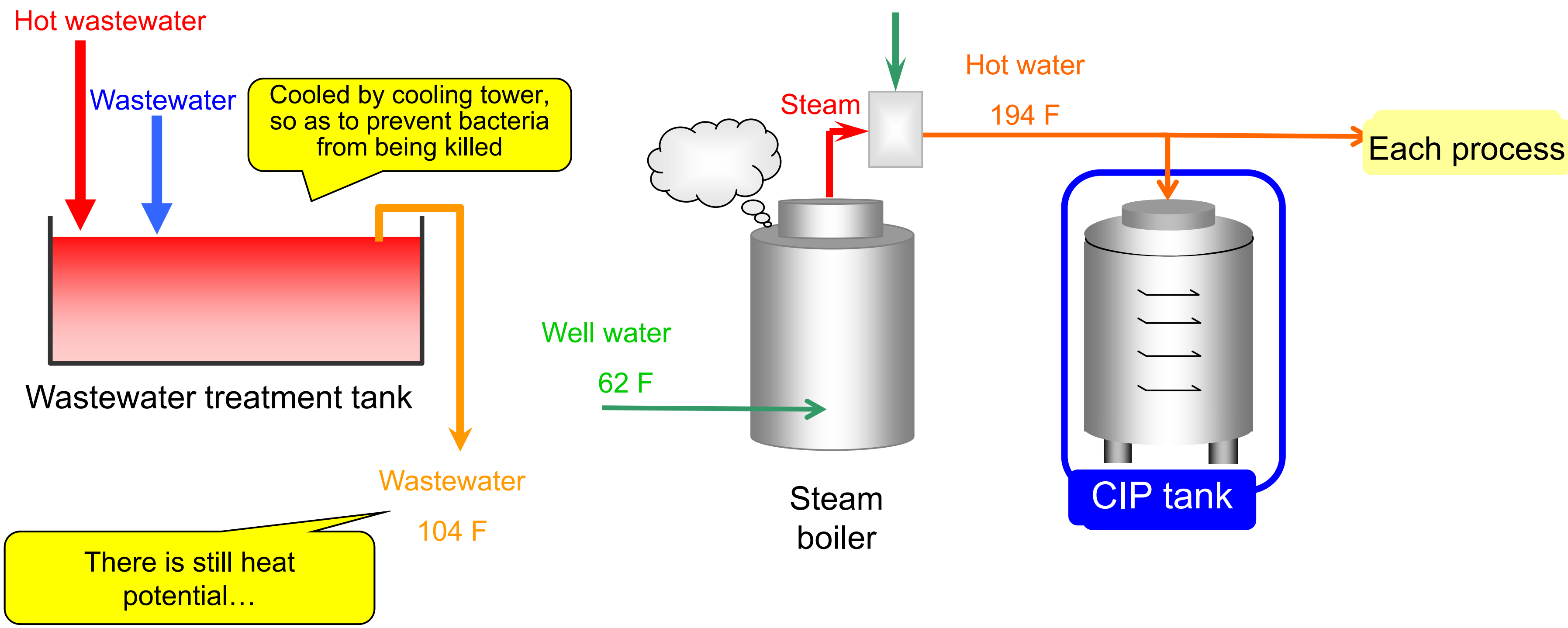
Water Source CO_2 Heat Pump
Heat Recovery Industrial Process Application

Original situation

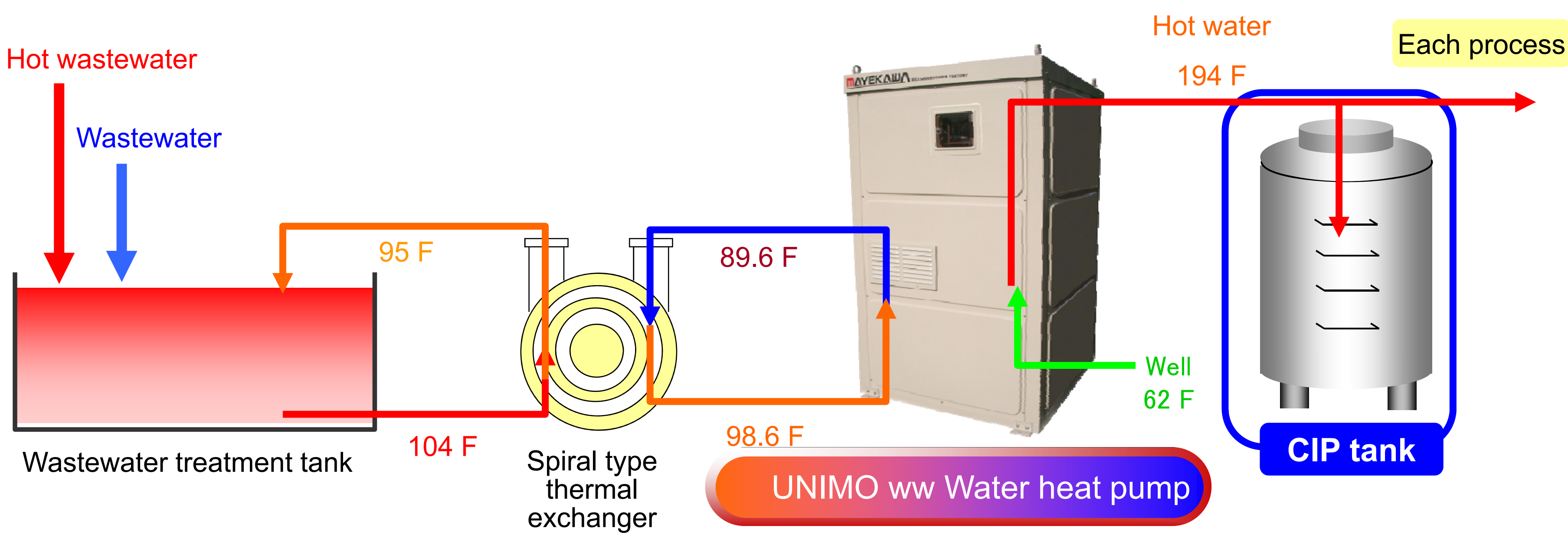
- Hot water for cleaning in each process is produced by using "steam + well water".
  - Warm wastewater exceeding 104 F and flowing to the wastewater treatment tank is thrown away.



Water Source CO_2 Heat Pump
Heat Recovery Industrial Process Layout

Installation of Water Source CO_2 Heat Pump

- High-efficiency operation of Heat Pump with warm wastewater from treatment tank as heat source
- Problem of water quality has been solved through special spiral heat exchanger



Thank you!

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