BONNEVILLE POWER ADMINISTRATION

Emerging Technologies

QAHV System Development and Applications Testing

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QAHV System Development and Applications Testing

Prepared for

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The following report was funded by the Bonneville Power Administration (BPA) to assess emerging technology topics that have the potential to increase energy efficiency. BPA is committed to identify, assess, and develop emerging technologies with significant potential for contributing to efficient use of electric power resources in the Northwest.

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Acronyms

OAT – Outdoor Air Temperature

HPWH – Heat Pump Water Heater

EAT – Exhaust Air Temperature

IWT – Incoming Water Temperature

NSF - National Sanitation Foundation

SDWA – Safe Drinking Water Act

IECC - International Energy Conservation Code

COP – Coefficient of Performance

PLC - Programmable Logic Controller

BPHE – Brazed Plate Heat Exchanger

GPM – Gallons per minute

Executive Summary

Throughout 2020, Ecotope worked with Mitsubishi Electric Trane US (METUS) to develop a fully packaged system for product launch in the United States. A full set of components for the heat exchanger and pump assembly, thermal energy storage, and temperature maintenance were selected. Piping and controls details were developed to provide a well-operating system that can serve up to 20 stories. Applications testing was successfully performed at both METUS's lab in Atlanta and as part of commissioning for the demonstration project that is now in place in Seattle.

While the product is ready for market, there are opportunities for improvement. The heat exchanger and pump assembly, thermal energy storage system, and temperature maintenance system all have areas that could be improved with another design iteration.

This study follows both a product Feasibility Study[i] and Load Shift Feasibility Study[ii]. Measurement and verification[iii] (M&V) is the next step in the Technology Innovation Model (TIM) and will help identify other potential design improvements; optimize performance by fine-tuning controls sequences; calculate system COPs; and assess demand-response capability.

Packaged System Components

The following sections discuss development and test findings for the major components in the QAHV packaged system. See Figure 1 for a simplified schematic of the system identifying the heat exchanger and pump assembly, thermal energy storage, and

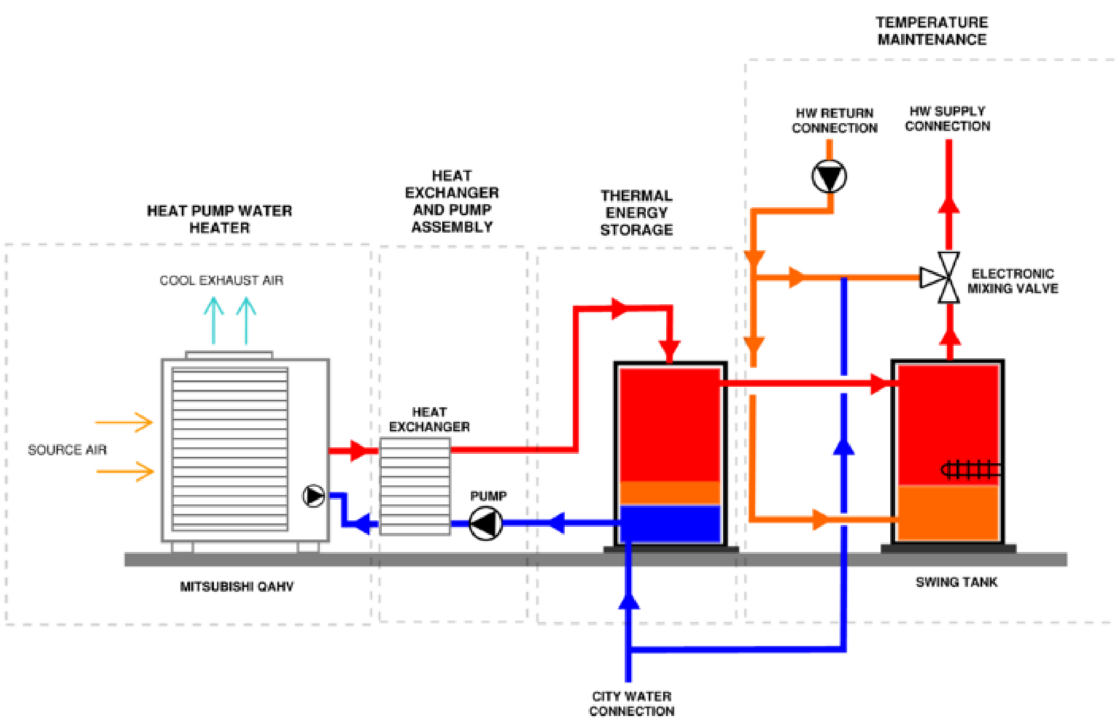


Figure 1. QAHV packaged system simplified schematic

temperature maintenance discussed subsequently.

Heat Exchanger and Pump Assembly

The QAHV requires a heat exchanger between it and the potable water to protect its internal CO_2 gas cooler from variable potable water quality. The additional heat exchanger means a separate pump on the potable water side is needed. The heat exchanger, pump, connected piping, and ancillary piping equipment – strainers, shut off valves, air separator, pressure and temperature sensors, flow meter, expansion tank, and buffer tank – are, together, considered the heat exchanger and pump assembly.

A flow-through expansion tank is used to act as both a buffer tank and expansion tank. While this design strategy simplifies the assembly, it also requires the expansion tank hold 10-gallons of water at cold fill, which requires a special commissioning procedure. To ensure commissioning is done correctly, METUS's Diamond Builder software will include a calculation that was developed to provide air and water pressure settings in the flow-through expansion tank for each installation. Ecotope recommends this procedure be added to the "start-up wizard" built into the control panel sold with the QAHV.

METUS has considered offering the heat exchanger and pump assembly as a pre-packaged skid by contracting with a local US manufacturer. This assembly would be comparable to the *Thermal Exchange Module* currently sold in France with the QAHV and shown in Figure 2. A pre-packaged skid for the assembly would simplify installations.

Figure 2. Thermal exchange module sold in France

The US packaged system uses a variable speed pump to control flow through the heat exchanger on the potable water side. The heat exchanger and pump assembly is unusual because very low flow rates are required through the heat exchanger. The CO_2 refrigerant cycle operates most efficiently with cold entering water and hot leaving water temperatures, which are ideal for domestic water systems, but require low flow rates.

The flow range required in mild climates is at the limits of what can be controlled using a standard (centrifugal) pump. In climates where winter temperature drop below 10°F a pump alone may not be able to meet a 150°F outlet water setpoint. At -10°F, the current approach may not be able to produce 120°F in a single pass through the heat exchanger.

While a control valve could be added to the assembly to meet setpoint under extremely cold conditions, it would likely be costly to develop. There are no currently available NSF-rated control valves. So, to add a control valve to the assembly, a valve would need to be NSF-certified, or a low-lead valve could be packaged with an NSF-certified pre-packaged skid – like the one discussed previously.

Additionally, a method of controlling the valve would have to be developed. A convenience of using a variable-speed pump to modulate water flow is that it can adjust its speed to meet a setpoint on the outlet of the heat exchanger using built-in controls.

Although a control valve-based option may not be made available until future market adoption of the technology allows for economic feasibility, METUS has started investigating options. Appendix A includes the test setup for Applications Testing. The detail *Heat Exchanger and Pump Assembly Test* shows a piping configuration that will allow METUS to test different control valves. Figure 3 shows a picture of the test setup in Atlanta.

Figure 3. Heat exchanger and pump assembly control valve test setup

Parallel Electric Water Heater

Another way to meet setpoint in cold climates is by using parallel electric water heater design – shown in Appendix B. The design allows the same electric water heater to provide four functions:

1. Swing tank heating
2. Backup heating in case of heat pump failure.
3. Temperature boost to meet setpoint in cold conditions.
4. Temperature boost for demand response "Load Up" conditions.

Because it reduces the total electrical service required, it is also discussed below under *Swing Tanks*.

Using a parallel electric water heater to boost temperature to meet setpoint in cold conditions will slightly increase energy usage. However, because the QAHV efficiency drops with colder outdoor air temperatures, energy increases will usually be small and the economic and functional benefits likely outweigh the small increase in energy usage.

In many cases it will not make sense to add additional QAHVs to meet demand in cold conditions. QAHV capacity also drops with outdoor air temperature, and the cost of adding additional capacity with additional QAHV is high compared to adding a small instantaneous electrical water heater. Engineers and building owners may prefer to allow electric resistance heating to supplement QAHV heating during the coldest few days of the year. Fortunately, it is only during the coldest days of the year that the QAHV will not be able to reach setpoint without a control valve. The electric water heater can both provide supplemental heat and boost temperature to meet setpoint on those days.

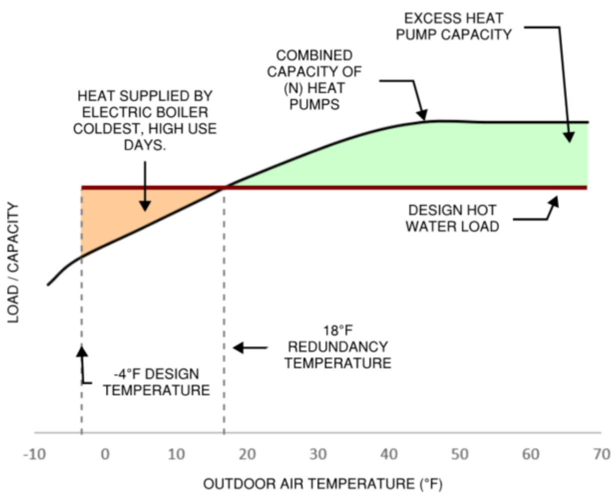


Figure 4. Cold climate sizing methodology with parallel electric water heater

Figure 4 illustrates a cold climate sizing method for a QAHV system with a parallel electric water heater. A "Redundancy Temperature" of 18°F was chosen – this means the number of QAHVs selected can meet the design load at 18°F. However, there is a design temperature of -4°F at this location. The electric water heater is selected to provide supplemental heating at low temperatures and backup heating in case a QAHV fails.

Thermal Energy Storage

Tank Design

QAHV thermal storage tanks are specifically designed to increase stratification and thermal energy storage performance.

Figures 5 and 6 show side and top views of the storage tank offering. The tanks are provided with six thermowells for more detailed monitoring and control. Specially designed sparged fittings are used on top and bottom inlet/outlets to increase stratification. The sparged fittings both lower the entering velocity and divert the flow direction from vertical to horizontal, which prevents mixing. Figure 7, illustrates how vertical inlets can create undesirable flows within a storage tank that degrade stratification.[iv]

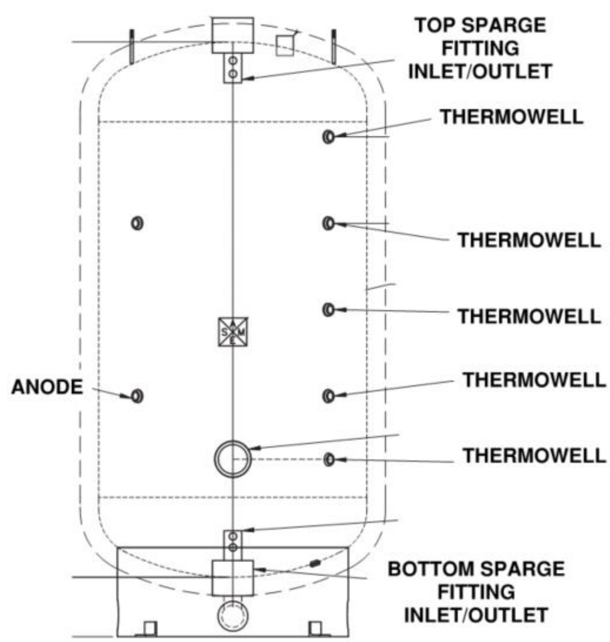


Figure 5. Stratified storage tank side view

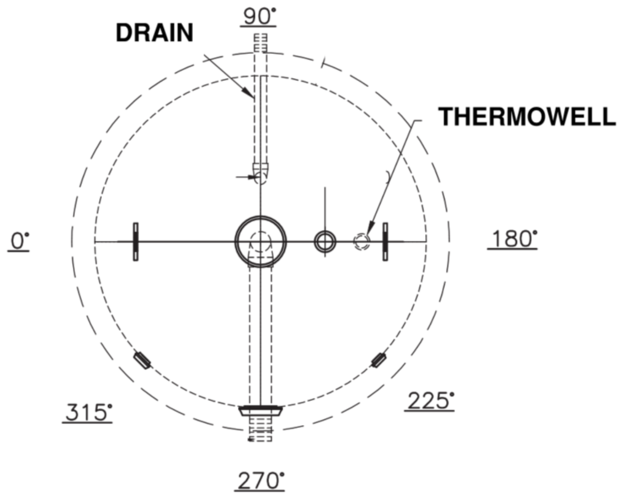


Figure 6. Stratified storage tank top view

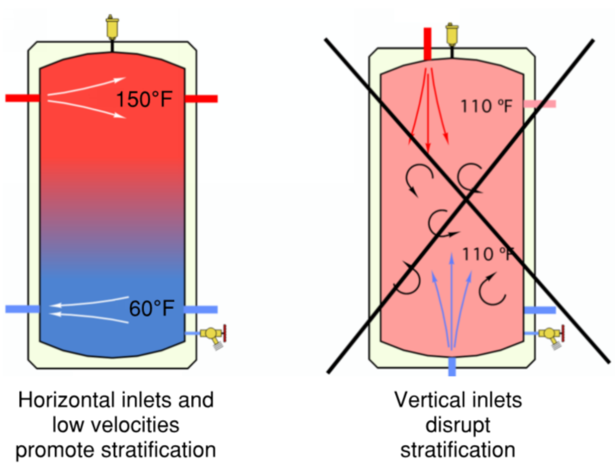


Figure 7. Piping design to promote stratification

The QAHV packaged system currently offers three tank sizes: 175-gal, 285-gal, and 500-gal. The 175-gal tank will primarily be used for retrofits and tight spaces. The 285- and 500-gal tanks are ideal for new construction or retrofits with more space and flexibility. METUS is adding 750-gal and 1,000-gal tank options for larger buildings that should be available early in 2022.

Unfortunately, during construction of the demonstration project it was discovered that the thermowell on the bottom of the tank does not have enough clearance to be used. METUS is in the process of having this thermowell moved to the side of the tank in their standard offering.

Multiple Tanks

Both series and parallel configurations, shown in Figures 8 and 9, were discussed as options when more than one tank is required. Key advantages to each option are below.

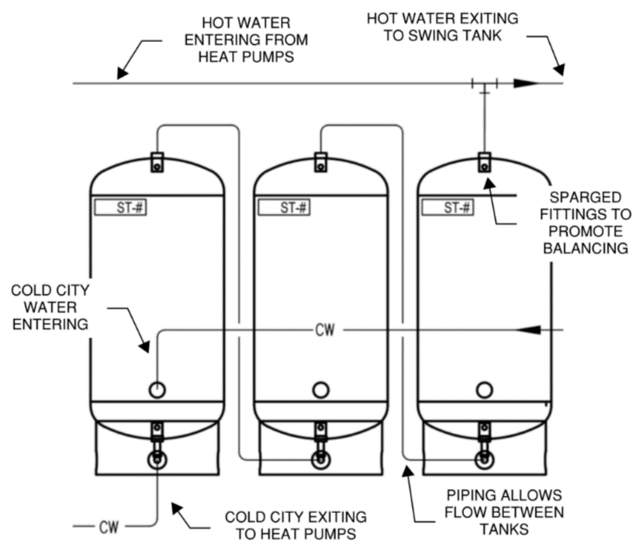


Figure 8. Series thermal storage system piping

Series Configuration:

1. Different sized tanks can be used.
2. Simple balancing with just one set of inlets/outlets for the system.
3. When multiple tanks are used, staging can be achieved using one temperature sensor per tank.

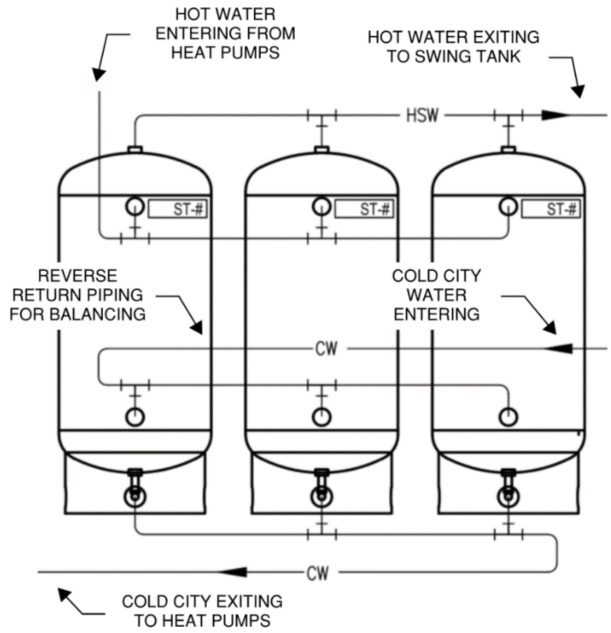


Figure 9. Parallel thermal storage system piping

Parallel Configuration:

1. Ability to isolate, drain, and perform maintenance on a tank without interrupting the system.
2. Potentially increases stratification through low inlet/outlet velocities and a single thermocline region across tanks.
3. Lower pressure-drop through storage system.
4. More consistent control setup with different numbers of tanks.

The initial tank offering will be series, due to balancing concerns, but parallel is being tested at the demonstration project in Seattle. If M&V results indicate the system can be balanced METUS will allow a parallel offering.

Swing Tanks

Initially, two electric resistance heating tanks were selected as swing tanks – a 150-gallon tank, and a 200-gallon tank. The swing tanks selected each have three electric resistance heating elements and three relays that allow them to engage a different number of electric elements and alter the setpoint. During normal operation, the swing tank will operate with the minimum electric resistance. During a demand response *Load Up* condition, additional electric resistance capacity can be used to rapidly elevate temperature. And should the QAHV fail for any reason, the swing tank can be used as a temporary electric resistance backup.

METUS is expanding its swing tank options in 2022. Swing tanks with lower electrical input will be offered, as well as additional tank volumes, and options for 460V power.

Applications testing was done using a traditional swing tank design, which will be offered in the first iteration of the QAHV packaged product. However, in order to reduce the amount of electric resistance needed in the system, Mitsubishi may test alternate configurations, and, if those configurations prove successful, alter the packaged system in the future.

System Configuration Updates to Reduce Connected Electric Load

Unfortunately, the current swing tank configuration has high power draws, which, increases electrical service requirements. High power draws can create higher demand charges, are more difficult to install in retrofits, and are more difficult for utilities to serve. METUS understands this issue and is looking for ways to reduce the overall peak-power draw without compromising functionality.

Preferably, QAHV systems would have no electric resistance heating. However, that may not be feasible, especially in cold climates. Three design changes to reduce electrical requirement are:

1. Parallel electric water heater.
2. Return to primary
3. Controlled return to primary.

The parallel electric water heater design allows a single electric water heater to heat both the primary storage and the swing tank. Although the electric resistance is not removed entirely, this configuration makes the most use of a small amount of electric resistance capacity. Additional benefits were described previously under *Heat Exchanger and Pump Assembly: Parallel Electric Water Heater*.

Return to primary is the simplest approach. The swing tank is removed, and recirculation water is returned directly to the primary storage. While all electric resistance capacity could be removed, QAHV COP and ability to provide demand response would be degraded. The QAHV would be forced to cycle on and off more and heat water already at a high temperature, which is undesirable.

Controlled return to primary adds complexity but could allow for a system with no electric resistance heating elements. Two open/closed control valves are added to the system. When the swing tank cools to a point where heating is required, the control valves are used to divert recirculation return water from the swing tank to the bottom of the primary storage tanks. This will create an artificial system draw and pull hot water from the top of the storage tanks into the swing tank, heating it.

Testing and Findings

Testing was performed in both Atlanta and Seattle. Testing in Atlanta took place one week prior to the demonstration project installation in Seattle. Because there was little time between applications testing and demonstration project installation, no changes could be made in response to applications test findings. Fortunately, the QAHV performed well in applications testing and few onsite modifications were needed. Functional tests were performed in Seattle to meet application testing criteria.

Atlanta

Testing in Atlanta allowed METUS controls engineers a preview to what the technicians would encounter in Seattle when starting the QAHV. A start-up wizard was developed to guild installers through QAHV setup.

Seattle

The HPWH skid arrived in Seattle on July 26th. It was then lifted onto the rooftop structural platform and connected to power and the existing hot water system. Start-up and testing occurred July 27th through July 29th. During this time, the startup wizard developed in Atlanta was used for the first time. It proved valuable, but some changes will be made to improve it for future installations.

After the start-up wizard was followed to set up the equipment, tests where run to make sure the controls parameters input were functioning as expected. The QAHV performed exceptionally and the only minor issue, which occurred with secondary loop pump control, was resolved by adjusting a control setting.

In addition to functional testing, the team observed satisfactory reactions to a power outage and clogged strainer. Power loss to the unit did not require a hard reset and the system started back up as expected after a power loss. Simulated clogged strainer created heat buildup in the primary loop and caused the QAHV to shut off on high refrigerant temperature. A built-in delay prevents the unit from starting back up immediately and an alarm is signaled.

Conclusions

Ecotope and METUS have work together to design a packaged HPWH system around the QAHV. Applications testing was performed in Atlanta and Seattle which proved it should operate successfully at the demonstration project. M&V is currently underway.

Changes may be made in the future to make the system easier to install, reduce electric service requirements, and function more efficiently. However, the first iteration is a success and a leap forward for the water heating market.

Works Cited

[i] Spielman S., Grist C., and Heller, J. 2020. Mitsubishi QAHV CO2 Heat Pump Water Heater Feasibility Study.
[ii] Spielman S. 2021. Mitsubishi QAHV Load Shift Feasibility Study
[iii] Banks A., Spielman S., Heller J. 2022. Mitsubishi QAHV Retrofit: Bayview Tower, Seattle WA
[iv] Siegenthaler, J., 2016, *Heating with Renewable Energy,* Cengage Learning.

Appendix A – Applications Testing Setup

HEAT PUMP WATER HEATER

MARK	SERVICE	MAKE, MODEL	HEAT CAPACITY (kW)	COP	CONNECTIONS (INCHES)	DIMENSIONS (L, W, H) (INCHES)	WEIGHT (LBS)	ELECTRICAL VOLT/PHASE /FREQ	ELECTRICAL RATED INPUT [kW]	ELECTRICAL SCCR [kA]	ELECTRICAL MCA [A]	ELECTRICAL MOP [A]	REMARKS
HPWH-1	HOT WATER	MITSUBISHI, QAHV	40, 60 (1)	3.83	0.75 (x2)	48, 30, 72.5	882	208 / 3PH / 60 Hz (1)	19	5	67	110	

NOTES:
(1) 40 kW IN NORMALLY EFFICIENCY MODE AND 60 kW IN MAXIMUM CAPACITY MODE.

PLATE AND FRAME HEAT EXCHANGERS

MARK	SERVICE	BASIS OF DESIGN (MAKE, MODEL)	TYPE	TOTAL CAPACITY (kW)	HEAT TRANS. AREA (FT²)	HOT SIDE GPM	HOT SIDE FLUID TYPE	HOT SIDE EWT °F	HOT SIDE LWT °F	HOT SIDE PD (PSI)	HOT SIDE PIPE CONN (")	HOT SIDE SCALE FACTOR/ EXCESS S.A. (%)	COLD SIDE GPM	COLD SIDE FLUID TYPE	COLD SIDE EWT (°F)	COLD SIDE LWT (°F)	COLD SIDE PD (PSI)	COLD SIDE PIPE CONN (")	COLD SIDE SCALE FACTOR/ EXCESS S.A. (%)	REMARKS
HX-1	DOMESTIC HOT WATER	SWEP, B85Hx49/2P	BRAZED PLATE AND FRAME	40, 60 (1)	30.4	4.5	WATER	160	60	3.0	3/4 (x2)	5%	5	WATER	45	150	3.0	3/4 (x2)	5%	

NOTES:
(1) SIZE FOR NORMAL OPERATION AT 40 kW AND HIGH CAPACITY OPERATION AT 60 kW.

EXPANSION TANKS

MARK EXP	SERVICE	MINIMUM TANK VOLUME (GAL)	MIN. ACCEP. VOLUME (GAL)	DIMENSIONS DIA (IN)	DIMENSIONS HEIGHT (IN)	DIMENSIONS SYSTEM CONN. (IN)	MAKEUP WATER REGULATOR PRESSURE (PSI)	AIR CHARGE PRESSURE (PSIG)	BASIS OF DESIGN MFTR	BASIS OF DESIGN MODEL	REMARKS
EXP-1	DOMESTIC HOT WATER	34	27	20	35	1	75	55	AMTROL	ST-130CL	(2)
EXP-2	HEAT PUMP LOOP	26	17.5	16	34	1	-	-	WESSELS	TTA-60-RX	(1)

(1) FLOW THROUGH MODEL ALSO SERVES AS BUFFER TANK. AIR CHARGE DETERMINED BASED ON SYSTEM HEIGHT. REDUCE AIR PRESSURE TO ALLOW FOR 10 GALLONS AT COLD FILL.
(2) DOMESTIC WATER LOOP VOLUME NOT TO EXCEED 530 GALLONS.

STORAGE TANK

MARK	SERVICE	VOLUME (GALS)	EMPTY WEIGHT (LBS)	FULL WEIGHT (LBS)	PIPE CONNECTIONS	DIMENSIONS DIAMETER (INCHES)	DIMENSIONS INSULATED DIAMETER (INCHES)	DIMENSIONS HEIGHT (INCHES)	BASIS OF DESIGN (MAKE, MODEL)	REMARKS
ST-1	DOMESTIC HOT WATER	175	340	1,793	3" CW INLET, 2" HSW INLET/OUTLET, 1.5" CW OUTLET TO HX-1	30	44.5	63	NILES, S-30-063	(1), (2)
ST-2	DOMESTIC HOT WATER	175	340	1,793	3" CW INLET, 2" HSW INLET/OUTLET, 1.5" CW OUTLET TO HX-1	30	44.5	63	NILES, S-30-063	(1), (2)

NOTES:
(1) PROVIDE UPRIGHT TANK WITH R-16 INSULATION AND WEATHER PROOF ACRYLIC TOP COAT.
(2) PROVIDE TANK WITH CUSTOM QAHV DESIGN FOR STRATIFICATION AND SPARGED FITTINGS

PUMPS

MARK EXP	SERVICE	FLOW (GPM)	HEAD (FT)	WEIGHT (LBS)	PIPE CONNECTION (INCHES)	PORT SIZE (INCHES)	ELECTRICAL VOLTAGE (VAC)	ELECTRICAL PHASE	ELECTRICAL CURRENT (AMPS)	POWER (W)	BASIS OF DESIGN MFTR	BASIS OF DESIGN MODEL	REMARKS
P-1	HEAT PUMP LOOP	5	12	12.3	1	1.26	115	1	1.01	107.7	GRUNFOS	MAGNA 32-60	(1), (3)
P-2	DOMESTIC HOT WATER	10	15	12.3	1	1.26	115	1	1.01	107.7	GRUNFOS	MAGNA 32-61	(2), (3)

(1) CONTROLLED THROUGH 0-10V SIGNAL FROM QAHV
(2) CONTROL WITH FLOW ADAPT SETTING FOR 15 GPM
(3) FLANGED CONNECTION

THERMOSTATIC MIXING VALVES

MARK	SERVICE	BASIS OF DESIGN (MAKE, MODEL)	VALVE COEFFICIENT	MINIMUM SYSTEM DRAW (GPM)	RECIRCULATION FLOW RATE (GPM)	GPM AT 5 PSI	DIMENSIONS INLETS (INCHES)	DIMENSIONS OUTLETS (INCHES)	REMARKS
TMV-1	HOT WATER	CALEFFI, MIXCAL+, 5231 SERIES	7	0	10	15.6	1	1	

NOTES:

SWING TANK

MARK	SERVICE	MAKE, MODEL	HEAT CAPACITY (kW)	CONNECTIONS (INCHES)	DIMENSIONS (D, H) (INCHES)	WEIGHT (LBS)	ELECTRICAL VOLT/PHASE /FREQ	ELECTRICAL RATED INPUT [kW]	REMARKS
SWT-1	DOMESTIC HOT WATER	NILES, JEV150-J12	12	1.5 (x2)	20, 60	650	208 / 3PH / 60 Hz (1)	12	

ECOTOPE

SCHEDULES

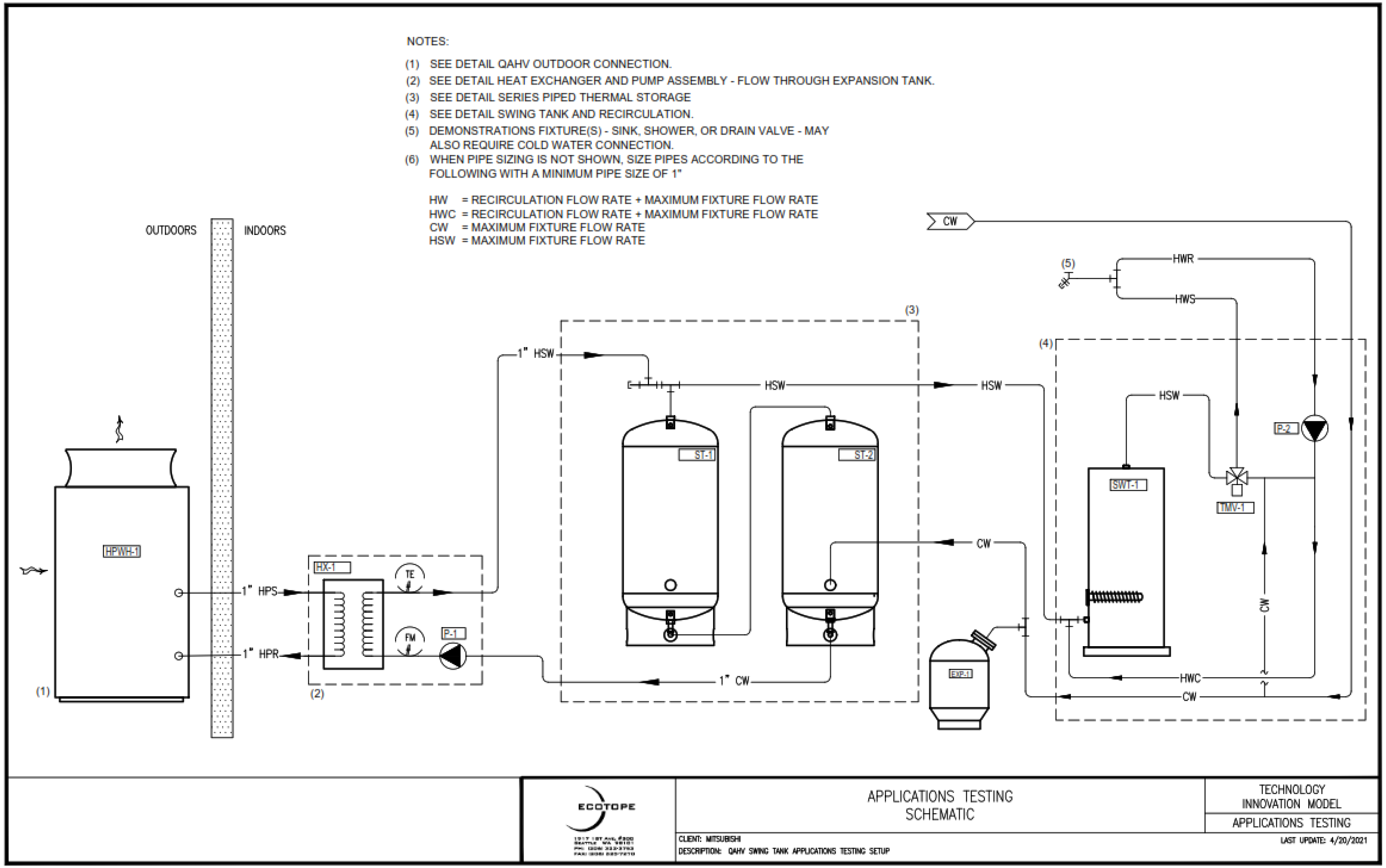
TECHNOLOGY INNOVATION MODEL

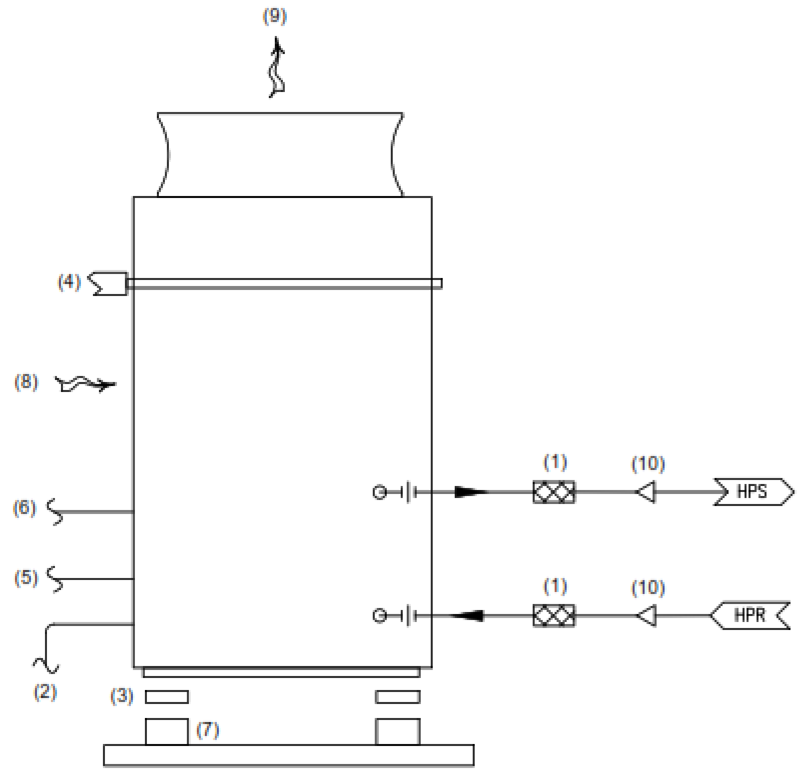
APPLICATIONS TESTING

CLIENT: MITSUBISHI

DESCRIPTION: SCHEDULES FOR APPLICATIONS TEST SETUP

LAST UPDATE: 4/20/2021

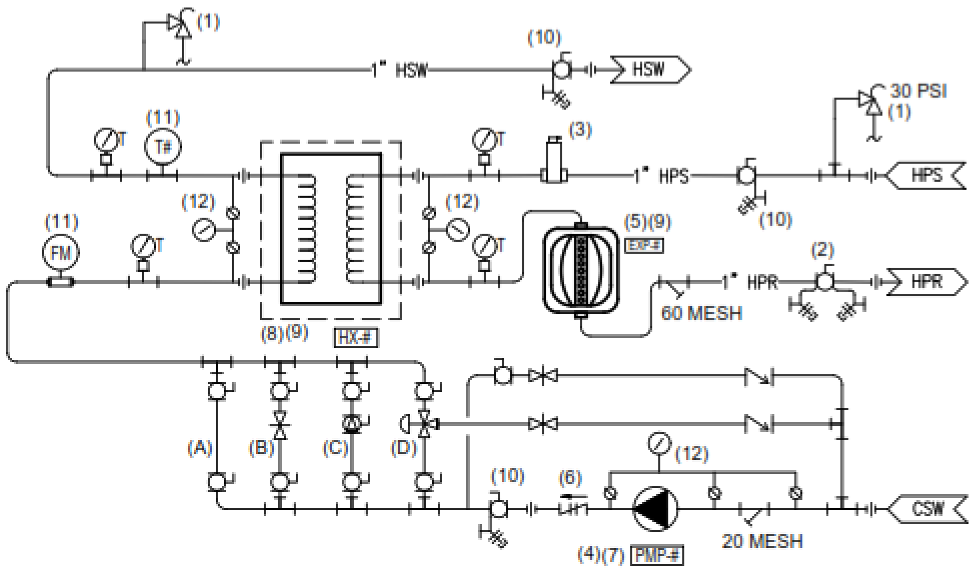

NOTES:
(1) SEE DETAIL QAHV OUTDOOR CONNECTION.
(2) SEE DETAIL HEAT EXCHANGER AND PUMP ASSEMBLY - FLOW THROUGH EXPANSION TANK.
(3) SEE DETAIL SERIES PIPED THERMAL STORAGE
(4) SEE DETAIL SWING TANK AND RECIRCULATION.
(5) DEMONSTRATIONS FIXTURE(S) - SINK, SHOWER, OR DRAIN VALVE - MAY ALSO REQUIRE COLD WATER CONNECTION.
(6) WHEN PIPE SIZING IS NOT SHOWN, SIZE PIPES ACCORDING TO THE FOLLOWING WITH A MINIMUM PIPE SIZE OF 1"
HW = RECIRCULATION FLOW RATE + MAXIMUM FIXTURE FLOW RATE
HWC = RECIRCULATION FLOW RATE + MAXIMUM FIXTURE FLOW RATE
CW = MAXIMUM FIXTURE FLOW RATE
HSW = MAXIMUM FIXTURE FLOW RATE
OUTDOORS
INDOORS
HPWH-1
(1)
1" HPS
1" HPR
HX-1
TE
FM
P-1
(2)
1" HSW
(3)
HSW
ST-1
ST-2
CW
1" CW
EXP-1
CW
(5)
HWR
HWS
(4)
HSW
HSW
P-2
SWT-1
TMV-1
CW
HWC
CW
ECOTOPE
APPLICATIONS TESTING
SCHEMATIC
TECHNOLOGY
INNOVATION MODEL
APPLICATIONS TESTING
CLIENT: MITSUBISHI
DESCRIPTION: QAHV SWING TANK APPLICATIONS TESTING SETUP
LAST UPDATE: 4/20/2021



NOTES:

(1) FLEX CONNECTIONS.
(2) ROUTE UNIT CONDENSATE OUTLET TO NEAREST DRAIN.
(3) PROVIDE VIBRATION ISOLATION.
(4) PROVIDE SEISMIC BRACING WHERE REQUIRED BY JURISDICTION
(5) ELECTRICAL POWER CONNECTION
(6) CONTROL WIRE CONNECTION
(7) MOUNT AND PROVIDE VIBRATION ISOLATION PER MANUFACTURERS INSTRUCTIONS.
(8) SOURCE AIR STREAM
(9) EXHAUST AIR STREAM
(10) PIPE SIZE REDUCTION FROM 1" TO 3/4" FOR CONNECTION TO HEAT PUMP.

ECOTOPE	QAHV OUTDOOR CONNECTION	TECHNOLOGY INNOVATION MODEL APPLICATIONS TESTING
	CLIENT: MITSUBISHI DESCRIPTION: OUTDOOR CONNECTED PIPING	LAST UPDATE: 5/8/2021



TEST SETUPS:

(A) MODULATING PUMP CONTROL.

(B) (1) MODULATING PUMP CONTROL WITH BALANCING VALVE. (2) MODULATING CONTROL VALVE.

(C) MODULATING V-PORT BALL VALVE.

(D) MODULATING THREE WAY VALVE.

NOTES:

(1) PRESSURE/TEMPERATURE RELIEF VALVE. ROUTE OUTLET TO NEAREST DRAIN.

(2) PURGE AND FILL VALVE OR VALVE ASSEMBLY WITH THREADED HOSE DRAIN CONNECTIONS.

(3) MICROBUBBLE AIR AND DIRT SEPARATOR.

(4) PROVIDE CUSH-A-THERM SUPPORTS (OR SIMILAR) WITHIN 6" OF EITHER SIDE OF PUMP.

(5) FLOW THROUGH EXPANSION TANK WITH AIR CHARGING VALVE SIZED TO PROVIDE 10-GALLONS OF BUFFERING. REDUCE AIR CHARGE IN COLD FILL TANK TO ALLOW FOR 10-GALLON BUFFERING.

(6) INLINE SPRING CHECK VALVE

(7) SECONDARY SIDE LOOP PUMP.

(8) PROVIDE INSULATION BLANKET.

(9) PROVIDE STRUCTURAL SUPPORT FOR HEAT EXCHANGER AND EXPANSION TANK. DO NOT SUPPORT WITH PIPING.

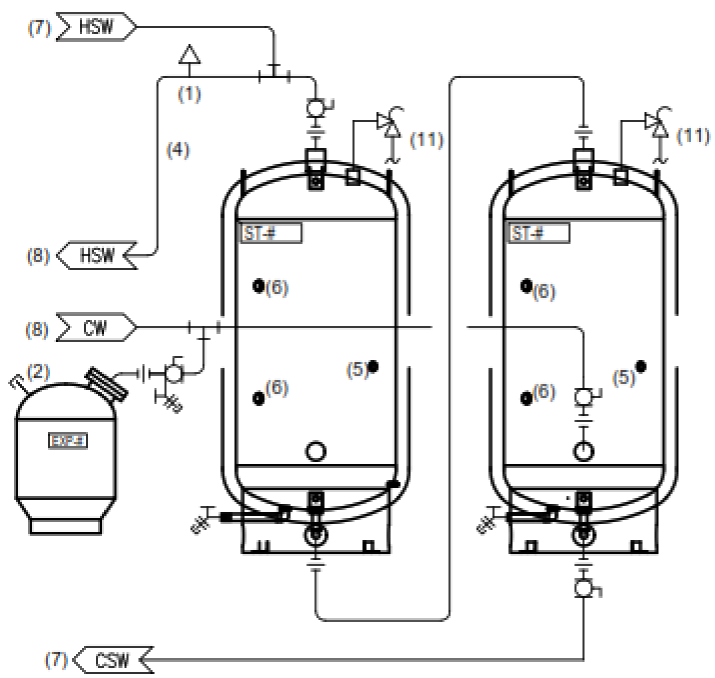
(10) ISOLATION/FLUSHING VALVES USED FOR ISOLATING, DRAINING AND CLEANING.

(11) FLOW METER AND TEMPERATURE ELEMENT PART OF SECONDARY SIDE LOOP KIT.

(12) PROVIDE A SINGLE PRESSURE GAUGE WITH NORMALLY CLOSED SHUT-OFF GAUGE VALVES TO MEASURE PRESSURE IN MULTIPLE LOCATIONS.

(13) POTABLE WATER RATED FLOW CONTROL VALVE CAPABLE OF FINE CONTROL WITH 0-10V SIGNAL FROM QAHV. USE ACTUATED V-PORT BALL OR GLOBE VALVE.

ECOTOPE	HEAT EXCHANGER AND PUMP ASSEMBLY – FLOW THROUGH EXPANSION TANK	TECHNOLOGY INNOVATION MODEL APPLICATIONS TESTING
	CLIENT: MITSUBISHI DESCRIPTION: ADDITIONAL VALVING INCLUDED FOR TESTING SECONDARY SIDE LOOP CONTROL CONFIGURATIONS	LAST UPDATE: 4/20/2021



NOTES:

(1) PROVIDE AUTOMATIC AIR VENT WITH SERVICING CHECK VALVE AT HIGH POINT.

(2) AIR CHARGING PLUG VALVE.

(3) PROVIDE HOT WATER MANIFOLD WITH MINIMUM [XX] INCHES OF 0.25 U-VALUE INSULATION. PIPE DIMENSIONS SHALL MATCH TANK CONNECTION SIZE. HEADER ENDS AT HEAT TRAP.

(4) PROVIDE HEAT TRAP PIPING. DROP PIPE MINIMUM OF 12" BELOW ELEVATION OF TANK CONNECTION.

(5) PROVIDE ONE THERMOWELL IN EACH TANK. THERMOWELLS SHALL BE COMPATIBLE FOR 157MM 15K THERMISTOR WIRED DIRECTLY TO QAHV.

(6) CONNECTION FOR SACRIFICIAL ANODE.

(7) TO AND FROM HEAT EXCHANGER AND PUMP ASSEMBLY. CONNECT AS REVERSE RETURN WITH HOT SIDE AS SHORTER RUN TO REDUCE HEAT LOSS.

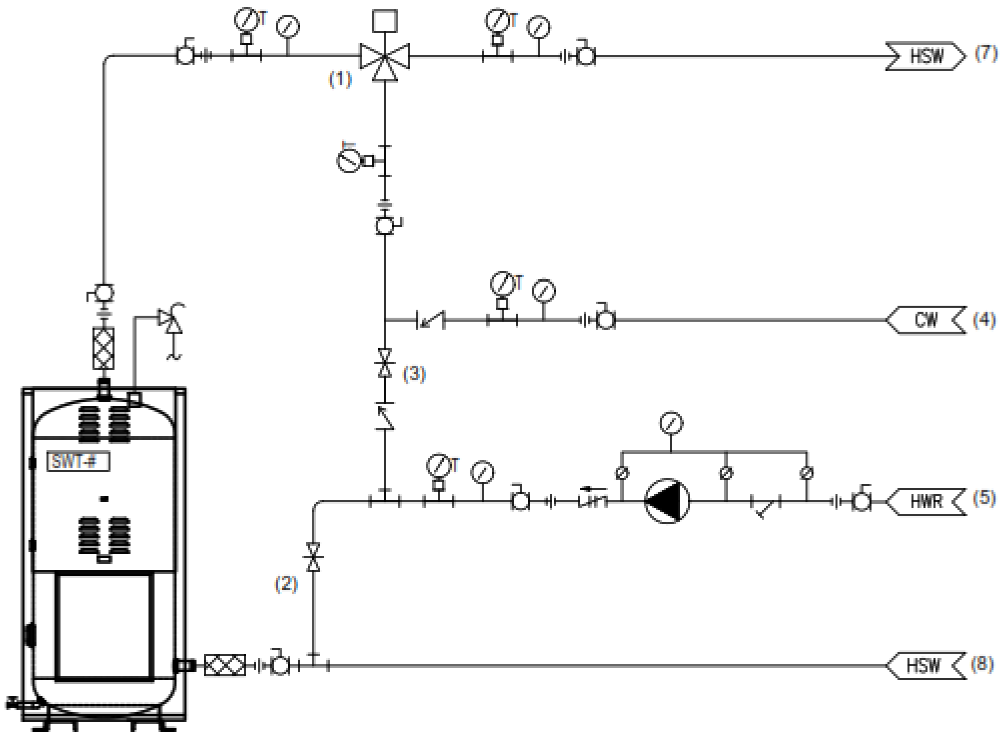
(8) TO AND FROM DOMESTIC WATER SYSTEM. DOMESTIC COLD WATER INTO BOTTOM OF STORAGE. HOT SUPPLY WATER OUT OF TOP OF STORAGE.

(9) PROVIDE UNIONS AT EACH TANK CONNECTIONS FOR TANK REMOVAL.

(10) PROVIDE TANK WITH SKIRT AND SEISMIC CLIP AS REQUIRED PER LOCAL JURISDICTION.

(11) ROUTE TEMPERATURE/PRESSURE RELIEF VALVE TO NEAREST DRAIN.

ECOTOPE	SERIES PIPED THERMAL STORAGE	TECHNOLOGY INNOVATION MODEL APPLICATIONS TESTING
	CLIENT: MITSUBISHI DESCRIPTION: SERIES PIPED THERMAL STORAGE WITH SPARGED DIFFUSERS TO ENCOURAGE STRATIFIACTION	LAST UPDATE: 4/20/2021

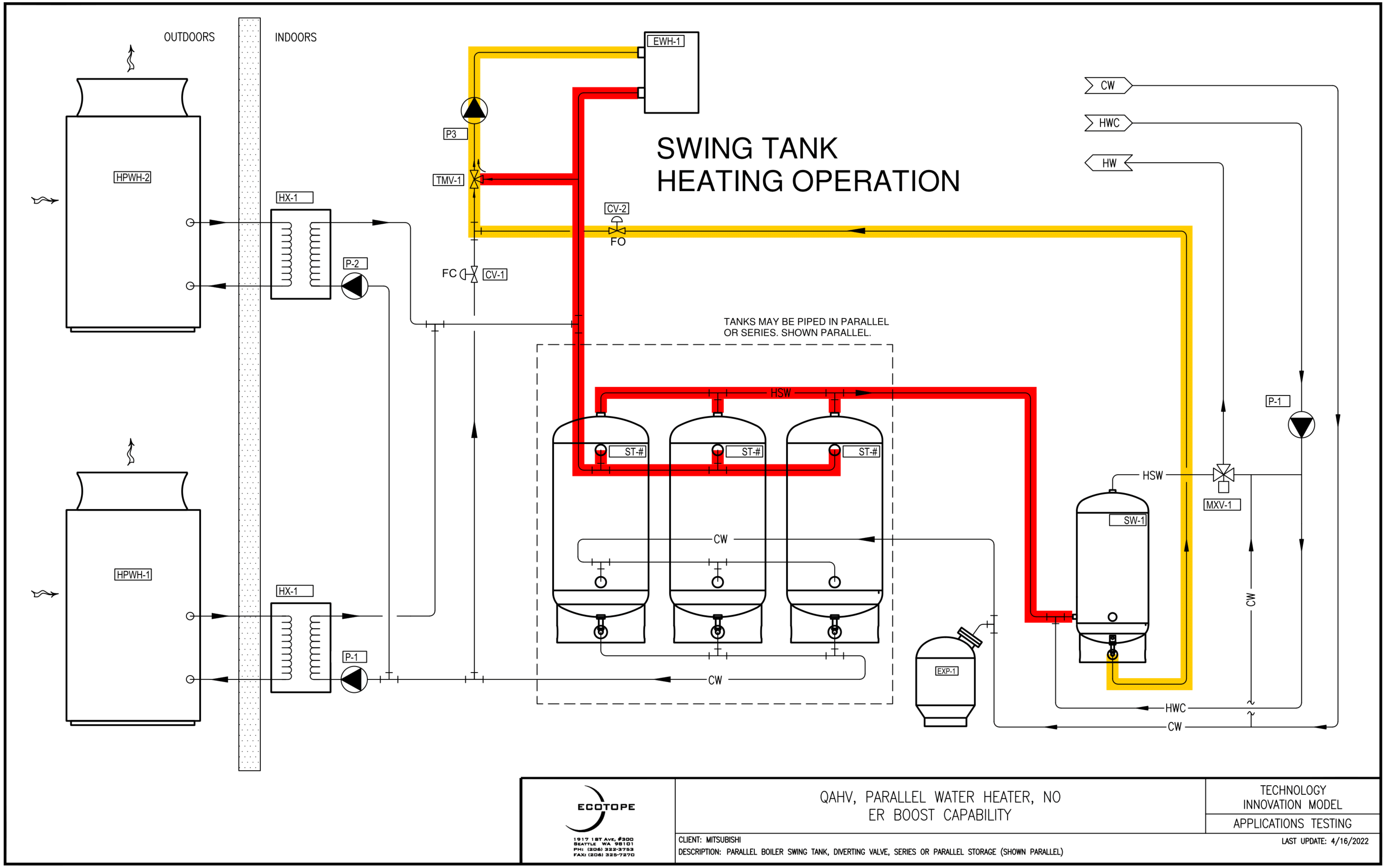


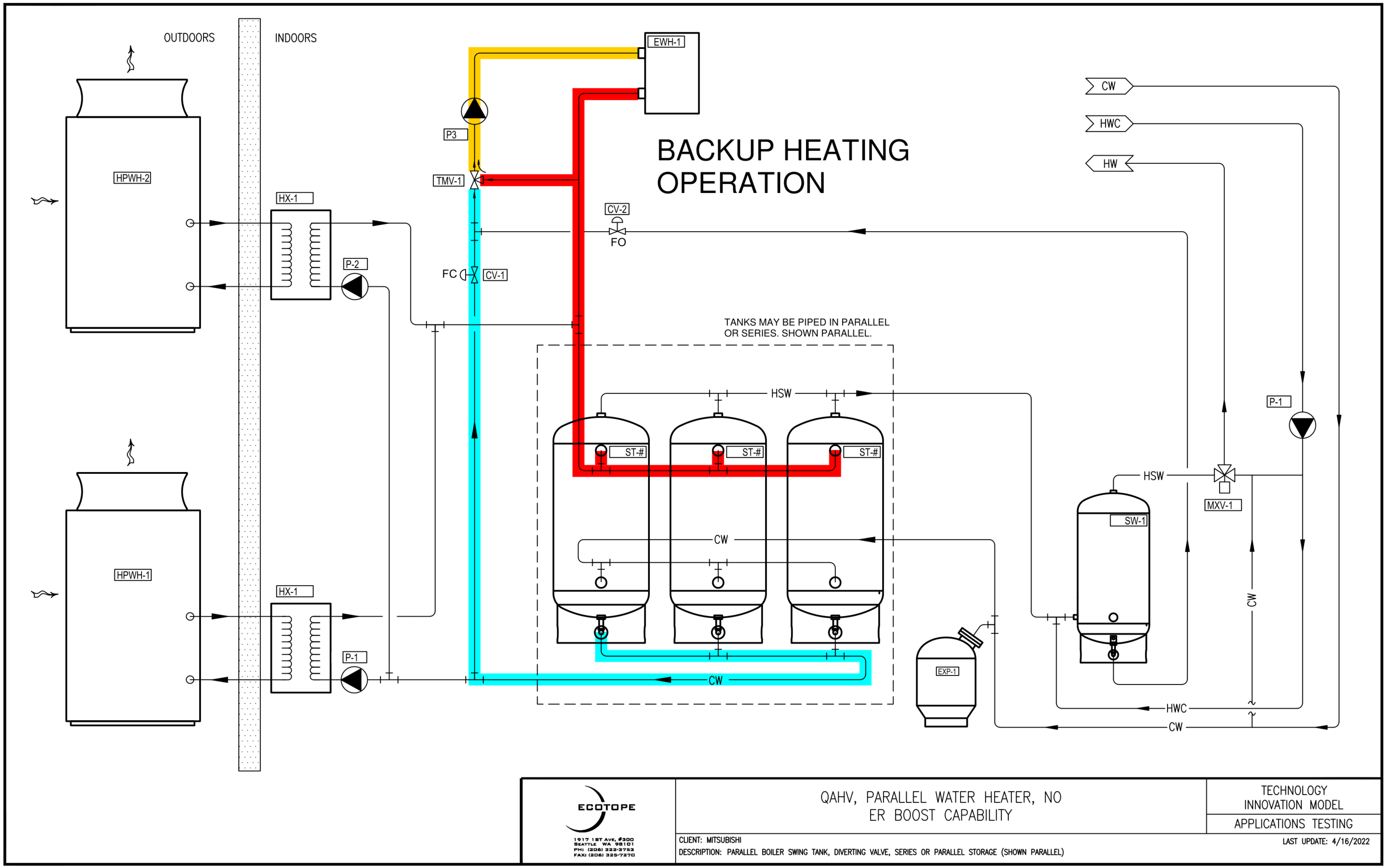
NOTES:

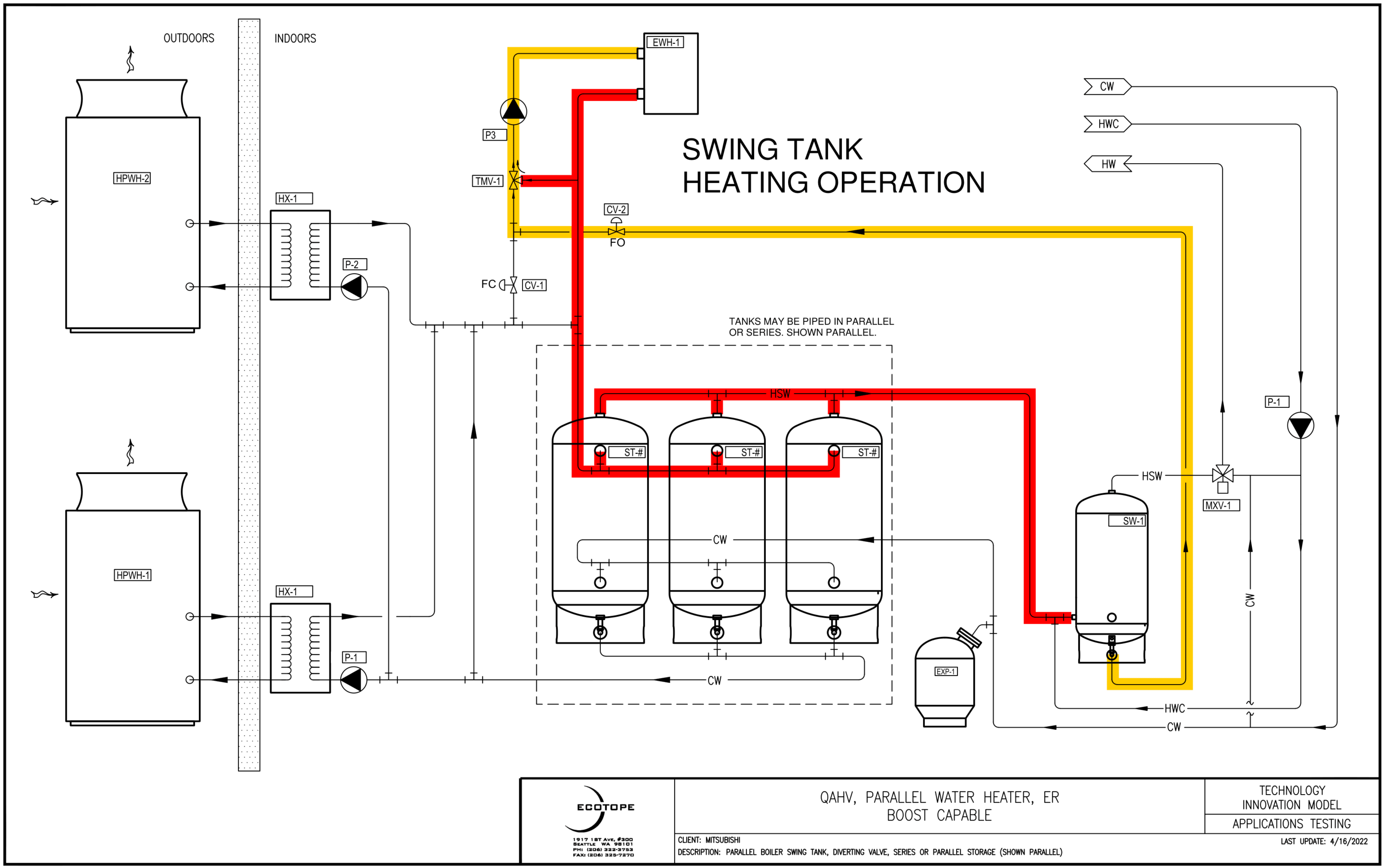
(1) THERMOSTATIC OR ELECTRONIC MIXING VALVE. SEE EQUIPMENT SCHEDULE.
(2) SET BALANCING VALVE TO 25% FLOW.
(3) SET BALANCING VALVE TO 75% FLOW.
(4) DOMESTIC COLD WATER CONNECTION.
(5) HOT WATER RECIRCULATION RETURN.
(6) HOT WATER RECIRCULATION TO SWING TANK.
(7) HOT WATER SUPPLY TO BUILDING.
(8) HOT STORAGE WATER FROM PRIMARY STORAGE.

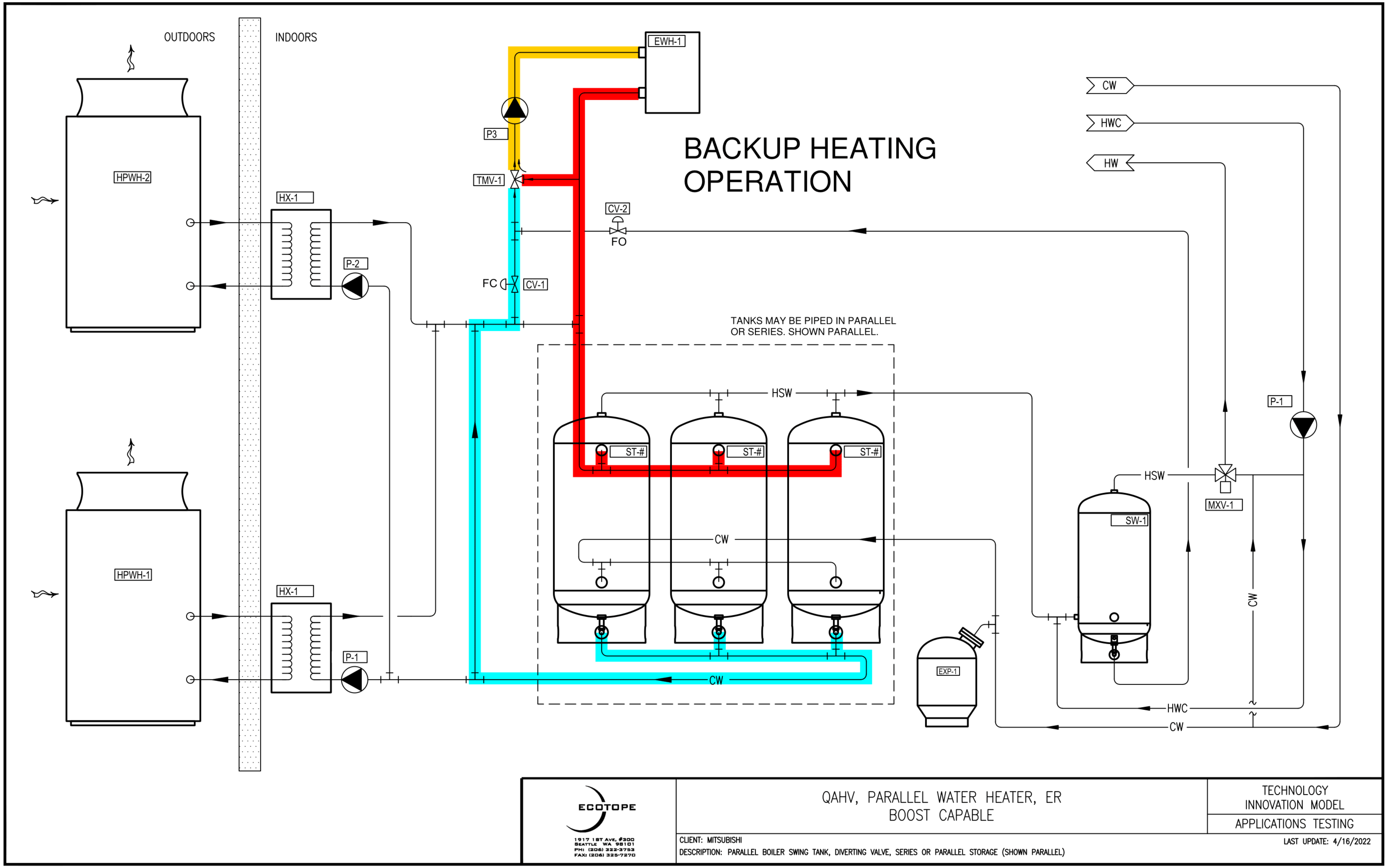
ECOTOPE	SWING TANK AND RECIRCULATION	TECHNOLOGY INNOVATION MODEL APPLICATIONS TESTING
	CLIENT: MITSUBISHI DESCRIPTION: STANDARD ELECTRIC RESISTANCE SWING TANK	LAST UPDATE: 4/20/2021

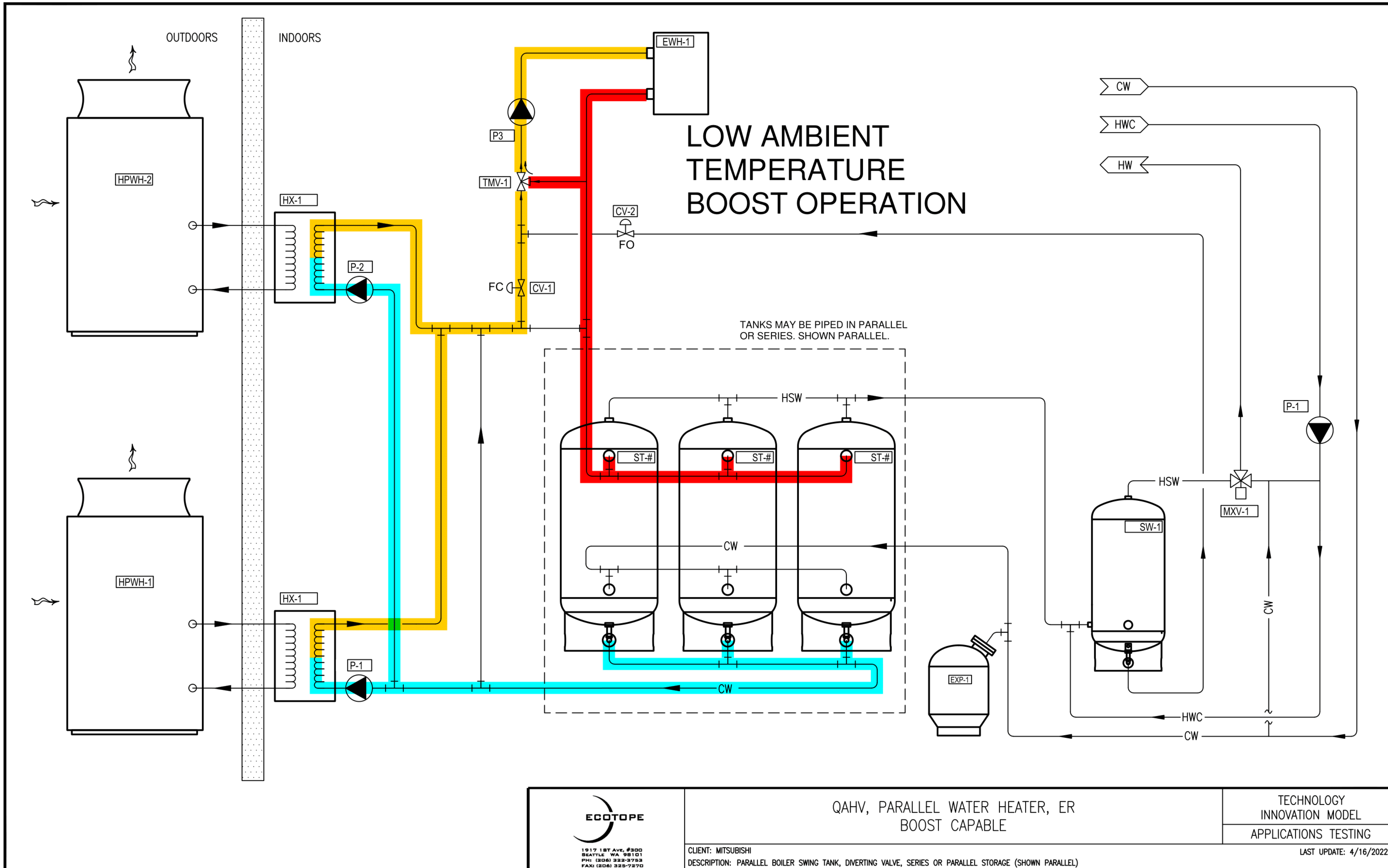
Appendix B – Parallel Electric Water Heater




OUTDOORS
INDOORS
HPWH-2
HPWH-1
HX-1
HX-1
P-2
P-1
P3
TMV-1
EWH-1
FC
CV-1
CV-2
FO
BACKUP HEATING OPERATION
TANKS MAY BE PIPED IN PARALLEL OR SERIES. SHOWN PARALLEL.
HSW
ST-#
ST-#
ST-#
CW
CW
EXP-1
SW-1
HSW
MXV-1
P-1
CW
HWC
HW
CW
HWC
CW
ECOTOPE
1917 1ST Ave, #300
SEATTLE WA 98101
PH: (206) 322-3753
FAX: (206) 325-7270
QAHV, PARALLEL WATER HEATER, NO ER BOOST CAPABILITY
TECHNOLOGY INNOVATION MODEL
APPLICATIONS TESTING
CLIENT: MITSUBISHI
LAST UPDATE: 4/16/2022
DESCRIPTION: PARALLEL BOILER SWING TANK, DIVERTING VALVE, SERIES OR PARALLEL STORAGE (SHOWN PARALLEL)


OUTDOORS
INDOORS
HPWH-2
HPWH-1
HX-1
HX-1
P-2
P-1
EWH-1
P3
TMV-1
CV-2
FO
FC
CV-1
SWING TANK
HEATING OPERATION
CW
HWC
HW
TANKS MAY BE PIPED IN PARALLEL
OR SERIES. SHOWN PARALLEL.
HSW
ST-#
ST-#
ST-#
CW
CW
P-1
HSW
MXV-1
SW-1
EXP-1
HWC
CW
CW
ECOTOPE
1917 1ST AVE, #300
SEATTLE WA 98101
PH: (206) 322-3753
FAX: (206) 325-7270
QAHV, PARALLEL WATER HEATER, ER
BOOST CAPABLE
TECHNOLOGY
INNOVATION MODEL
APPLICATIONS TESTING
CLIENT: MITSUBISHI
LAST UPDATE: 4/16/2022
DESCRIPTION: PARALLEL BOILER SWING TANK, DIVERTING VALVE, SERIES OR PARALLEL STORAGE (SHOWN PARALLEL)


OUTDOORS
INDOORS
BACKUP HEATING OPERATION
HPWH-2
HPWH-1
HX-1
HX-1
P-2
P-1
P3
TMV-1
EWH-1
CV-2
FO
FC
CV-1
TANKS MAY BE PIPED IN PARALLEL OR SERIES. SHOWN PARALLEL.
HSW
ST-#
ST-#
ST-#
CW
CW
EXP-1
SW-1
HSW
MXV-1
P-1
CW
HWC
HW
CW
HWC
CW
ECOTOPE
QAHV, PARALLEL WATER HEATER, ER BOOST CAPABLE
TECHNOLOGY INNOVATION MODEL
APPLICATIONS TESTING
CLIENT: MITSUBISHI
DESCRIPTION: PARALLEL BOILER SWING TANK, DIVERTING VALVE, SERIES OR PARALLEL STORAGE (SHOWN PARALLEL)
LAST UPDATE: 4/16/2022


LOW AMBIENT TEMPERATURE BOOST OPERATION
OUTDOORS
INDOORS
HPWH-2
HPWH-1
HX-1
HX-1
P-2
P-1
P3
TMV-1
FC
CV-1
CV-2
FO
EWH-1
TANKS MAY BE PIPED IN PARALLEL OR SERIES. SHOWN PARALLEL.
HSW
ST-#
ST-#
ST-#
CW
CW
EXP-1
SW-1
HSW
MXV-1
P-1
CW
HWC
HW
CW
HWC
CW
ECOTOPE
QAHV, PARALLEL WATER HEATER, ER BOOST CAPABLE
TECHNOLOGY INNOVATION MODEL
APPLICATIONS TESTING
CLIENT: MITSUBISHI
DESCRIPTION: PARALLEL BOILER SWING TANK, DIVERTING VALVE, SERIES OR PARALLEL STORAGE (SHOWN PARALLEL)
LAST UPDATE: 4/16/2022