SMUD SANDEN HPWH (GADDI GROVE) ELECTRIFICATION PROJECT – M&V REPORT - FINAL

SUBMITTED BY:

TRC / MAYRA VEGA

10680 White Rock Rd, Ste 1000, Rancho Cordova, CA 95670

mvega@trccompanies.com / 916.366.0632

SUBMITTED TO:

SMUD / DAVE BISBEE

6100 Folsom Blvd, Mail Stop MA-1, Sacramento, CA 95817

dave.bisbee@smud.org / 916.732.6409

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Prepared for
Sacramento Municipal Utility District
Energy Research and Development
6201 S Street
Sacramento, CA 95817 – 1899
916-732-5594

Prepared by
TRC Advanced Energy
10680 White Rock Rd, Ste 1000
Rancho Cordova, CA 95670

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Contents

1 Introduction

1.1 Purpose of Document

This document provides measurement and verification (M&V) evaluation analysis of the project to convert gas-fired water heaters to heat pump water heater (HPWH) systems for two quadplexes in the Gaddi Grove community.

- Chapter 1 summarizes this report and describes the project site and retrofit.
- Chapter 2 summarizes the methodology for measuring the energy usage for the existing gas-fired water heaters, monitoring and gathering data for the new heat pump water heater, and analyzing the pre and post heat pump water heater energy use.
- Chapter 3 presents the results of the energy usage monitoring and the energy use analysis.
- Chapter 4 summarizes the initial analysis of the HPWH system performance and compares it to the manufacturer's (Sanden) performance claims.
- Chapter 5 describes the single heat pump water heater analysis

1.2 Site Description

The two quadplexes included in the study are located in the Gaddi Grove Townhomes community in Sacramento, CA. Each quadplex consists of four dwelling units, each with two bedrooms and one bathroom. The Gaddi Grove complex was built in 1968.

There are total of five electric meters (SMUD) and five gas meters (PG&E) serving each quadplex. Each dwelling unit has its own gas and electric meter, which measure unit heating, cooking, and baseload energy. The common electric meter serves the laundry room (washing machine motor, dryer motor, and dryer heat in Quadplex B) and common area lighting. The common gas meter serves the domestic water heater (dwellings and laundry room washing machine) and the dryer heat in Quadplex A. The existing hot and cold-water piping is a mix of copper and cross-linked polyethylene (PEX).

1.3 Water Heater Retrofit Overview

The retrofits at each building involve the replacement of the existing storage-type gas-fired water heater with an electric heat pump water heater system (HPWH). Sanden's SANCO$_2$ heat pump water heater was selected for the project. Each retrofit consists of a 119-gallon storage tank with two (2) heat pump units with carbon dioxide refrigerant. The Sanden heat pump model is No. GS3-45HPA-US. The Sanden tank is model SAN-119GLBK.

Per manufacturer recommendations, the property manager installed a mixing valve downstream of the storage tank to prevent the distribution temperature from exceeding a safe high limit of 120°F. Actual tank temperatures exceed 120°F.

During the retrofit, the property manager replaced the above ground copper piping with cross-link polyethylene (PEX) piping and installed hot water flow meters for individual dwelling units.

Retrofits at Quadplex A were completed in early January 2020, and monitoring began on January 10th. Retrofits at Quadplex B were completed in late January 2020, and monitoring began on February 5th.

2 Measurement and Verification Methodology

This section provides an overview of the M&V approach TRC implemented for the Gaddi Grove project. Please refer to Appendix A for the detailed data collection and Appendix B for additional reference materials.

2.1 Purpose of Measurement and Verification

The Gaddi Grove water heater retrofit project M&V focuses on key questions including:

- Can the installed heat pump system produce adequate temperature and quantity of hot water for the demand associated with each quadplex?
- What is the site energy impact of switching from a gas-fired water heater to a heat pump water heater?
- What are the performance efficiencies of the existing domestic hot water (DHW) systems and the replacement systems?

2.2 Data Collection Overview

To complete the M&V review, TRC collected pre-retrofit utility gas consumption of the existing gas-fired water heater, and baseline hot water spot measurements (temperature and flow) for each dwelling. Post-retrofit monitoring included HPWH electric use, domestic hot water storage tank incoming (cold) and outgoing (hot) water temperatures, post-mixing valve water temperature, and individual hot water flow to the tenant units and laundry. A schematic showing the instrumentation locations used for data collection is shown in Figure 4 at the end of this section. TRC used the data to evaluate the existing hot water load, the new HPWH performance, and to ensure the new system adequately provided hot water when needed. TRC used the data to calculate energy savings in kBtu and cost savings associated with the retrofit. TRC converted kWh and therms to kBtu for to calculate energy savings using consistent unit.

2.2.1 Pre-Retrofit Data Collection

TRC collected pre-retrofit natural gas energy data for the common gas meter, for a minimum of 365 days prior to retrofit installation. TRC also conducted surveys asking tenants about their water use habits, occupancy and measured flow rates and temperatures on all faucets.

The pre-retrofit gas-fired water heater energy use was calculated from use profiles measured during the post-retrofit period, which were seen to be sufficiently consistent and assumed to be indicative of typical use both before and after the retrofit. The pre-retrofit gas-fired water heater energy use was disaggregated from the existing common area gas meter. The existing common area gas meter serves the gas dryers in the laundry and the gas-fired water heater. Therefore, in order to estimate the gas use for the existing water heater, TRC determined a laundry use baseline during the post-retrofit period and subtracted it from historical pre-retrofit gas data. Similarly, TRC determined laundry hot water use based on hot water flow measurements collected during the post install period.

Pre-retrofit and post-retrofit dwelling hot water demand was based upon the pre-retrofit end-use temperature and flow measurements shown in Section 3.1. Prior to the retrofit, hot water delivery temperatures in the residential units of Quadplex A often exceeded 130°F in all but one location and 150°F in 5 of 12 locations. High delivered hot water temperature poses a safety and liability risk for occupants and owners. By using a thermostatic mixing valve in the retrofit system installation, occupants and owners are protected from these risks.

2.2.2 Post-Retrofit Data Collection

TRC monitored and collected post-retrofit energy and hot water use data on a weekly basis for 261 days at Quadplex A and 235 days at Quadplex B.

After the retrofit, Quadplex A's common area natural gas meter served only the dryer in the central laundry room. The property manager discontinued common area gas service to Quadplex B. TRC assumed the laundry use would remain consistent between pre- and post-retrofit, which facilitated disaggregating pre-retrofit gas use. The new HPWH was electrically sub metered. The newly installed hot water meters collect hot water flows to the tenant units and temporary sensors measured the temperatures in and out of the storage tank; allowing TRC to directly measure performance.

2.2.2.1 *Data Collection Equipment*

During the M&V period, TRC collected data in one-minute intervals through a Senseware communication platform, which sends data from the meters and sensors to a secure cloud server via a cellular modem. To facilitate interfacing with the Senseware platform, all meters have a standard output (4-20mA, 0-5V, pulse, Modbus, BACnet, etc.)

2.2.2.2 *HPWH Energy Use*

True power meters from eGauge measured the HPWH electric power. The meters offer onboard data storage for the life of the meter, ethernet connectivity, and communicate via Modbus with the Senseware platform to provide detailed power readings. Figure 1 shows an example of the real-time HPWH electricity use data presented on the online Senseware dashboard.

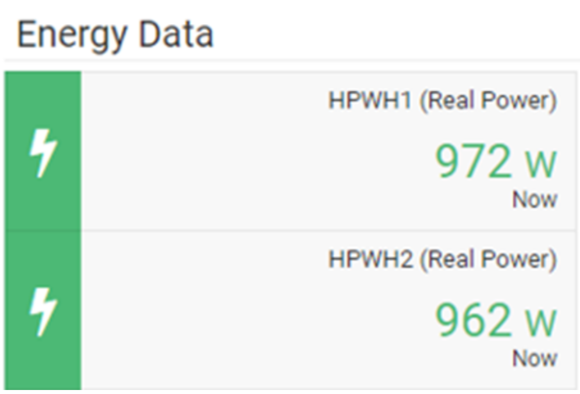


Figure 1: Real-time HPWH Electricity Consumption

2.2.2.3 *Hot Water Use*

There are several hot water meters (with pulse outputs) that interface seamlessly with Senseware. Of the available meters, the site engineer selected and installed DAE AS200U-75RP hot water meters downstream between the HPWH storage tank and the residential unit (See Figure 4 for installation diagram). The hot water meters have analog displays that show total gallons consumed. The total number of gallons consumed in a given interval is determined by subtracting the total gallons recorded at the start from the total gallons at the end.

The Senseware system records the gallons used by monitoring the pulse output from the hot water meters. A Senseware pulse bridge collects pulses on a regular interval and transmits the flow data to a secure cloud server. The hot water meters provide one pulse every one gallon. The Senseware system provides use and average flow (gpm) derived from one-minute sampling intervals. Figure 2 shows an example of the cumulative to-date (since the start of monitoring noted in Section 1.3) total hot water use data presented on the online Senseware dashboard. TRC monitored the change in total hot water use weekly and validated unexpected values through on-site verification as appropriate and possible.

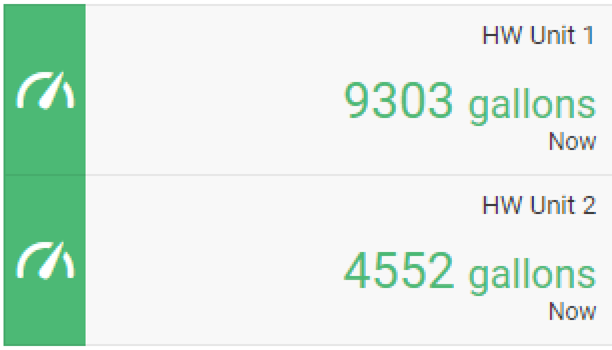


Figure 2: Example To-date Total Hot Water Use by Dwelling Unit (Quadplex B)

Prior to retrofit installation, TRC also asked residents to participate in a pre-retrofit survey about basic water use, occupancy, and water use habits. Residents completed the pre-installation survey in the presence of TRC staff and property management. Many Spanish speaking residents required assistance completing the pre-install survey. Post-retrofit surveys were provided in both English and Spanish with residents having the opportunity to complete it alone at their convenience.

TRC also collected in-unit temperature and flow measurements primarily to assure that the end uses were satisfied both before and after the retrofit. In efforts to minimize COVID-19 exposure our post-retrofit data collection was limited to the three units with the highest gallon per day average.

2.2.2.4 *Temperature*

Thermistor surface temperature sensors were used to measure the cold water in, the hot water out of the HPWH tank, and the distribution temperature after the mixing valve. The temperature sensors were in direct contact with metal pipe and placed under pipe insulation. Additionally, a thermistor was placed outside to measure outside air temperature. The sensors were connected to a Senseware thermistors bridge that transmitted temperature data to a secure cloud server. Data from a local weather station was used to check outside air temperature measurements.

Outside air temperature (OAT) was monitored through a local outdoor thermistor on Quadplex A and local weather station data. OAT impacts the HPWH performance, and lower OAT can result in lower efficiency and hot water production.

2.2.2.5 *Data Communication*

TRC collected HPWH temperature and flow data using the Senseware communication package. This equipment transmitted the data from the meters and sensors to a secure server for storage, real time access, and continual data validation. All data on the Senseware wireless mesh network was secured, using the AES 128 standard, before being transmitted wirelessly to a gateway. The gateway isolated the Senseware mesh network from the internet.

TRC validated data through real-time Senseware dashboard checks, and site verifications, when appropriate. Figure 3 shows an image of the Senseware dashboard for Quadplex B. For more details on the data communication setup, please see Appendix B: Data Communication – Additional Details.

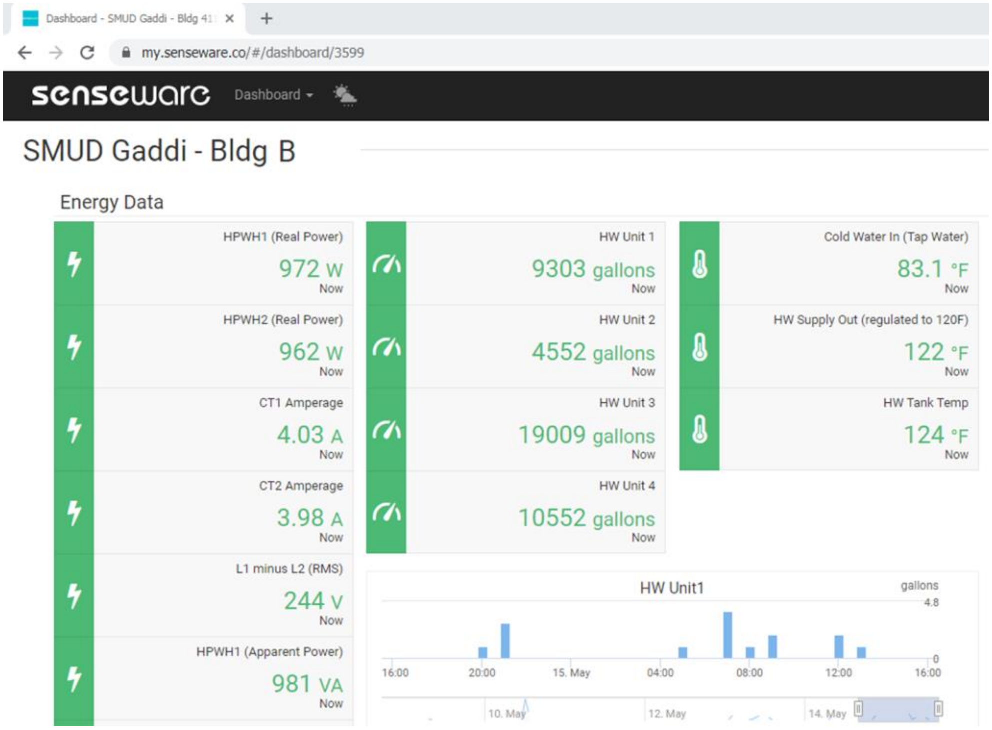


Figure 3: Senseware Monitoring Dashboard for Quadplex B

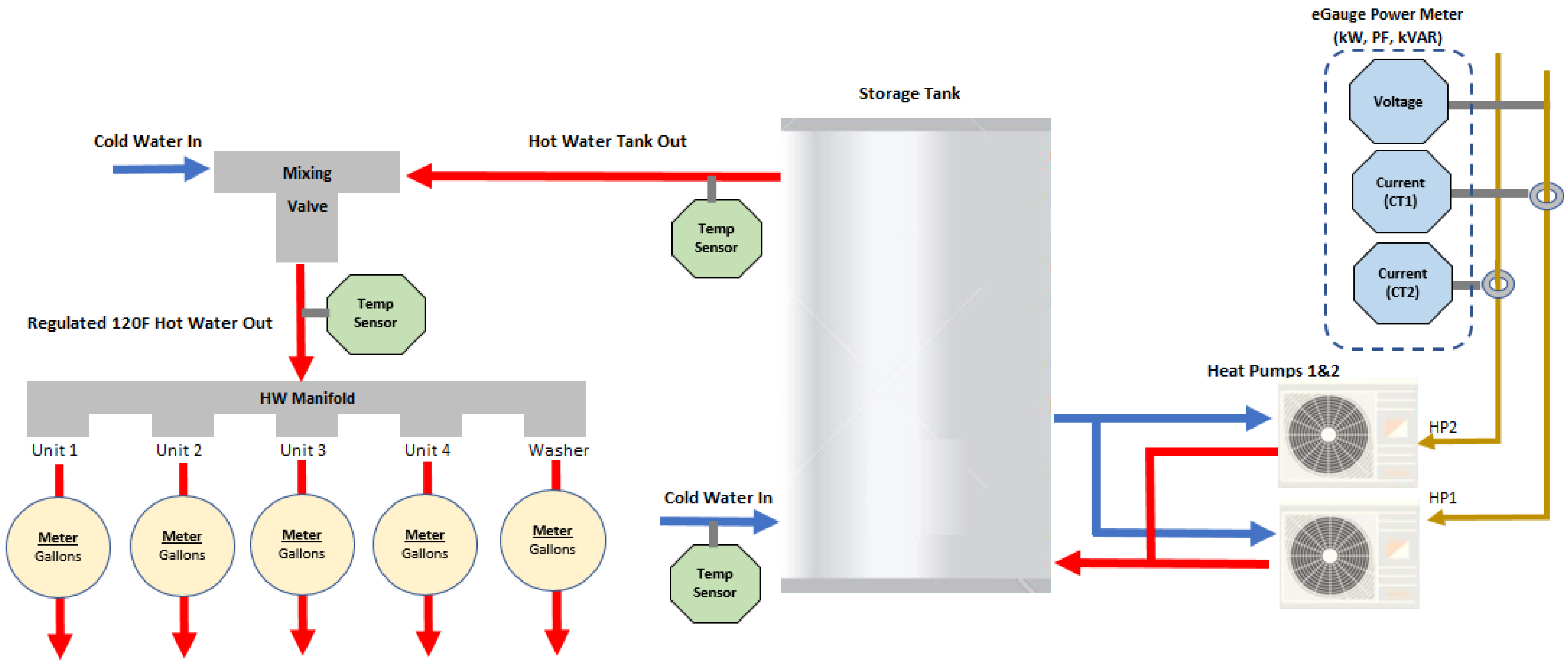


Figure 4: HPWH Monitoring Installation Schematic

3 Measurement and Verification Results

3.1 Data Collection Summary

3.1.1 Pre/Post-retrofit Natural Gas Consumption

TRC gathered pre-retrofit natural gas consumption for twelve months prior to the installation of the HPWH September 2018 – August 2019. Quadplex A's pre-retrofit natural gas consumption ranged from 7,200 to 11,600 kBtu/month over the twelve month period with peak gas usage in December 2018 and February 2019 (See Figure 5 below).

By removing the gas-fired water heater and replacing it with a HPWH, TRC anticipated a significant reduction in overall gas consumption. Post-retrofit gas consumption at Quadplex A during the eight months following the retrofit February 2020 through September 2020 billing periods show marked reductions to less than 500 kBtu/month. (See Figure 6 below). The remaining gas consumption is attributable to laundry dryer use in Quadplex A.

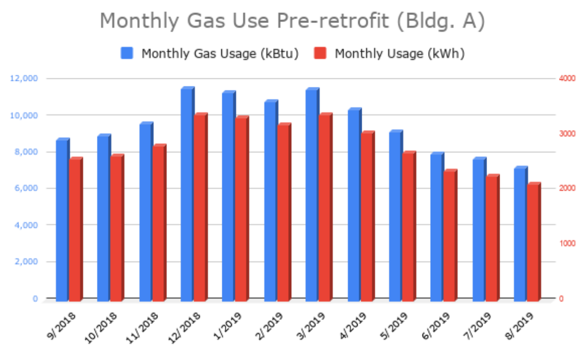


Figure 5: Quadplex A Pre-retrofit Gas Consumption

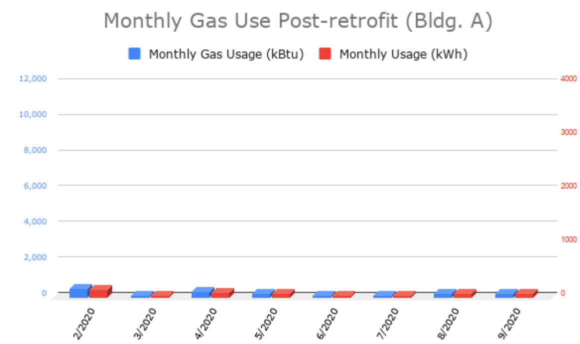


Figure 6: Quadplex A Post-retrofit Gas Consumption

TRC gathered pre-retrofit natural gas consumption for twelve months prior to the installation of the HPWH September 2018 – August 2019. Quadplex B's pre-retrofit natural gas consumption ranged from 8,600 kBtu to 12,800 kBtu over a twelve month period September 2018 – August 2019, with peak gas consumption occurring in February 2019 (See Figure 7 below). Quadplex B has no gas consumption after the retrofit as all gas-using appliances were removed and service was discontinued in Mid-February 2020. The dryer heat continues to be supplied by electricity.

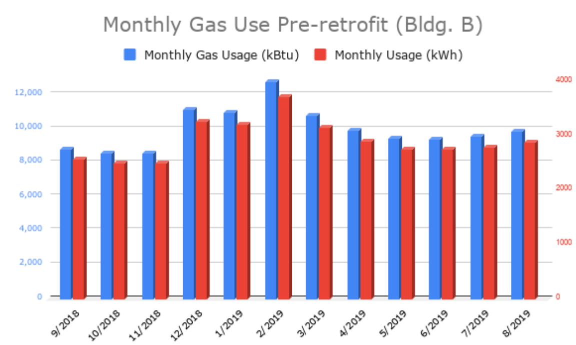


Figure 7: Quadplex B Pre-retrofit Gas Consumption

3.1.2 Pre/Post-retrofit Electricity Consumption

TRC gathered pre-retrofit electricity consumption for twelve months prior to installation of the HPWH September 2018 – August 2019. Quadplex A's pre-retrofit electricity consumption ranged from 341 to 485 kBtu/month with peak usage months of December 2018 and 2019 (See Figure 8 below). Post-retrofit electricity consumption at Quadplex A increased to a range of 1464 kBtu to 2225 kBtu during the February 2020 – October 2020 monitoring period (See Figure 9 below). This energy increase is due to the retrofit from the natural gas boiler to the HPWH.

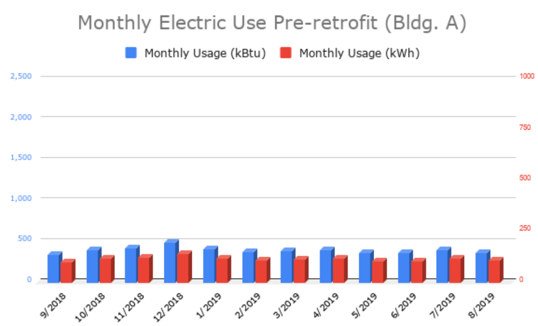


Figure 8: Quadplex A Pre-retrofit Electricity Consumption

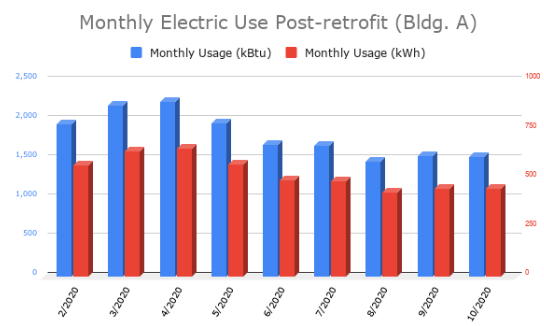


Figure 9: Quadplex A Post-retrofit Electricity Consumption

Quadplex B's pre-retrofit electricity consumption ranged from 706 to 1266 kBtu with peak usage months of February 2019 and November 2019 (See Figure 10 below). Post-retrofit electricity consumption at Building B increased to a range of 2126 to 3323 kBtu during the monitoring period February 2020 – October 2020, with peak usage months of February 2020 and March 2020 (See Figure 11 below).

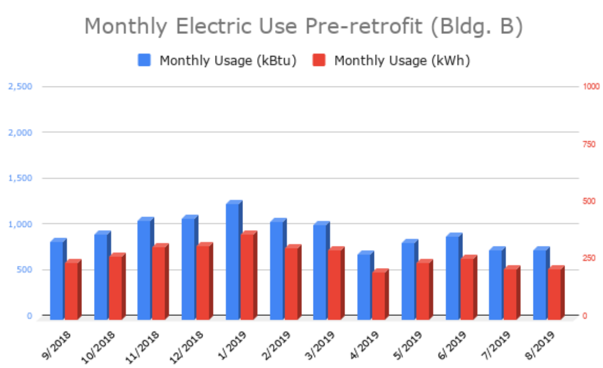


Figure 10: Quadplex B Pre-retrofit Electricity Consumption

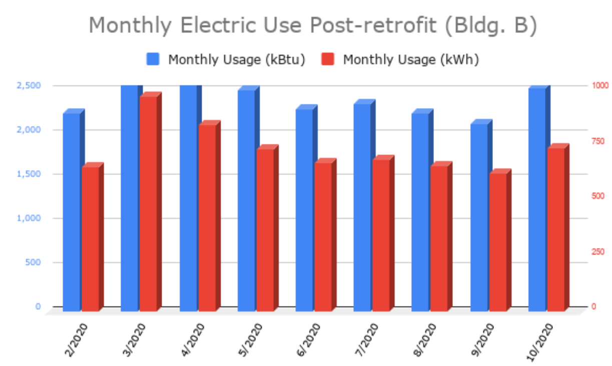


Figure 11: Quadplex B Post-retrofit Electricity Consumption

3.1.3 Hot Water Load

Table 1 and Table 2 below summarize key occupancy and laundry use details from the pre-retrofit and post-retrofit surveys respectively. Quadplex A unit 4 and Quadplex B unit 1 chose not to participate in the pre-retrofit survey. Quadplex A unit 4 and Quadplex B units 1 and 2 chose to not participate in the post-retrofit survey. For a complete list of pre-retrofit and post-retrofit survey questions and responses please See Appendix A: Data Collection.

Table 1: Pre-retrofit Resident Survey Summary

Building	Unit ID	How many people live in the unit?	How many total showers, on average, are taken each day in your home?	How many total baths, on average, are taken each day in your home?	How long is a typical shower?	How many loads of laundry does your family wash per week?
A	1	5	1	1	6-12 min	5
A	2	3	3-4	1	6-12 min	1-2
A	3	4	1	1	6-12 min	2
B	2	3	3	3	6-12, >12	3
B	3	6	1	1	6-12 min	0
B	4	1	1	3	N/A	N/A

Table 2: Post-retrofit Resident Survey Summary

Building	Unit ID	Has the number of people living in your apartment changed in 2020?	How many total showers, on average, are taken each day in your home?	How many total baths, on average, are taken each day in your home?	How long is a typical shower?	How many loads of laundry does your family wash per week?
A	1	No	1	1	5 min	0
A	2	No	1	1	>12 min	7
A	3	No	4-5	4	6-12 min	1-2
B	3	No	2-3	1	6-12 min	1-2
B	4	No	4-5	3	6-12 min	3-4

The post-retrofit survey results indicated everyone reported no change in occupancy. However, there were clear changes in the number of people living in the units compared to the pre-retrofit survey. Possible sources of error in self-reporting coupled with possible errors in verbal translation of the pre-retrofit survey rendered the results of the survey, inconclusive. As a result, TRC could not draw conclusions on whether there were changes in hot water usage pre-and post-retrofit and instead relied on Senseware data to determine if the heat pumps were meeting load.

Table 3: Pre-retrofit Dwelling Unit Fixture Hot Water Temperature and Flow

Building	Unit ID	Temp °F Sink-Kitchen	GPM Sink-Kitchen	Temp °F Sink- Bath	GPM Sink-Bath	Temp °F Tub/Shower - Bath	GPM Tub/Shower - Bath
A	1	144	1.31	144	1.31	153	3.4
A	2	155	1.69	147	0.94	157	3.0
A	3	152	1.00	144	0.94	118	3.4
A	4	147	1.88	146	1.31	151	3.4
B	2	130	1.69	138	1.20	146	3.4
B	3	142	1.25	137	1.08	145	3.8
B	4	135	1.25	124	0.56	145	4.1

Table 4: Post-retrofit Dwelling Unit Fixture Hot Water Temperature and Flow

Building	Unit ID	Temp °F Sink-Kitchen	GPM Sink-Kitchen	Temp °F Sink- Bath	GPM Sink-Bath	Temp °F Tub/Shower-Bath*	GPM Tub/Shower-Bath*
A	1	125	3.0	125	2.0	N/A	N/A
A	4	126	2.2	125	1.7	N/A	N/A
B	3	126	3.6	128	1.2	N/A	N/A

*Due to COVID-19, TRC chose not to enter the unit bathrooms to minimize the amount of time in the units

As shown in Table 3 and Table 4 above, TRC expected a drop in temperatures after the retrofit as the original temperatures were too high. After the property manager installed a thermostatic mixing valve, hot water delivery temperatures in the residential units of quadplexes A and B no longer exceeded 130°F.

The increase in flow rate measurements after the retrofit is due to implementing a more accurate testing methodology by using a digital flow meter instead of a flow bag as we used for the pre-retrofit measurements. TRC determined the original flow rates to be unreliable and could not determine if flow rate changes occurred after the retrofit. However, the results of the survey coupled with no reported tenant complaints, implies there were no major changes in water supply experienced by the tenants since the retrofit.

Table 5 below illustrates the average daily hot water load for each quadplex as calculated from the post-retrofit monitored hot water use. TRC verified with the property manager that tenants typically do their laundry in their bathtubs as opposed to using the on-site laundry facilities. This contributes to the high average hot water use compared to expected hot water use per Title 24 estimates as seen in Table 5.

Table 5: Post-retrofit Average Estimated Daily Hot Water Load

Building	Number of Units	Expected Unit Daily HW Use per CA Title 24 (gals)*	Ave Unit Daily HW Use (gals)	Ave Laundry Daily HW Use (gals)	Ave Total Building Daily HW Use (gals)
A	4	41.9	71.87	2.77	290.3
B	4	34.6	88.92	21.77	377.5

*Expected daily HW demand calculated with reported occupancy of participating units using CA Title 24 algorithms

3.2 Data Analysis Results

The following results are based upon the HPWH system operation during the months of February through August 2020. The post-retrofit M&V period does not include a full year of monitoring, but TRC assumed consistent use to extrapolate results for an entire year. TRC anticipates that the assumption of consistent use is valid as long as no additional retrofits are completed on the buildings and the current occupants remain throughout the monitoring period.

3.2.1 Post-retrofit Hot Water Supply Adequacy

Prior to the retrofit, hot water delivery temperatures in the residential units of Quadplex A often exceeded 130°F in all but one location and 150°F in 5 of 12 locations. High delivered hot water temperature poses a safety and liability risk for occupants and owners, respectively. By using a thermostatic mixing valve in the retrofit system installation, occupants and owners are protected from these risks. The property owner installed a thermostatic mixing valve during the retrofit, therefore bringing delivered hot water temperatures below 130°F.

TRC monitored the output hot water temperature downstream of the mixing valve to estimate hot water supply adequacy. TRC found instances when hot water downstream of the mixing valve fell below 100°F. Usually, these instances would indicate inadequate supply when coincident with significant hot water demand. TRC found that the output hot water temperature often dips below 100°F without significant hot water demand. Such low temperatures without coincident hot water demand is consistent with thermal loss in the distribution system and mixing valve and is not an indication that the HPWH cannot meet the load. TRC reviewed specific periods of low output hot water temperature but found no clear evidence of coincidence with significant hot water demand. Therefore, TRC determined the HPWH was able to deliver at least 120°F hot water during periods of demand.

3.2.2 Laundry Gas Use Baseline

TRC monitored the post-retrofit washing machine hot water use to estimate the pre-retrofit gas used by the baseline gas-fired water heater. TRC assumed that the use of the laundry before and after the retrofit remained consistent. This allowed TRC to use the post-retrofit gas data, which only includes the laundry, to extract the gas use of the pre-retrofit water heater from the historical utility data. TRC also assumed that the total hot water use before and after the retrofit was consistent.

During the monitoring period of February through August 2020, the laundry hot water use was largely insignificant with respect to the tenant hot water use, 0.5% and 3% at A and B, respectively. The TRC analysis team originally assumed that laundry hot water would be a more significant portion of the overall hot water use. However, low laundry use is consistent with anecdotal evidence gathered from the property owner/management:

- Immediately following monitoring system installation, Gaddi Grove property ownership notified TRC of a plan to eliminate the common laundry in each of the buildings due to low historical use.

- During verification of unexpected high dwelling unit hot water use, TRC learned from conversations with the property owner/management that some residents handwash laundry in the bathroom tub.

TRC believes the limited post-retrofit laundry use is consistent with pre-retrofit laundry use based on this information. Furthermore, TRC determined that the laundry hot water load from the initial period is too small to build a pre-retrofit laundry hot water usage profile and adjust the pre-retrofit analysis.

3.2.3 Pre-retrofit Analysis

This section provides a snapshot of the domestic hot water system performance prior to the retrofit. TRC calculated the Total Annual Natural Gas Consumption and Average System Efficiency of the pre-retrofit water heaters based upon historic natural gas usage and current hot water demand (See Table 6 below).

Table 6: Pre-retrofit System Performance Analysis

Pre-Retrofit	Quadplex A	Quadplex B	Data Source
Total Annual Natural Gas Consumption (Therms/yr)	1152.65	1195.84	PG&E Billing Data
Total Annual Natural Gas Consumption (kBtu/yr)	115,265	119,584	PG&E Billing Data
Total Annual Hot Water Use (gal/yr)	124,284	173,698	Senseware (Estimate based on data collected Feb 20 through August 20)
Total Annual Natural Gas Cost ($/yr)	$1,871.27	$1,958.81	PG&E Billing Data
Average NG Rate* ($/kBtu)	$0.0162	$0.0164	PG&E Billing Data
Average Cost per Gallon ($/gal)	0.0151	0.0113	PG&E Billing Data
Average Gas Water Heater Efficiency (kBtu/gal)	0.92	0.68	

*All natural gas bills include fixed service fees which are not dependent upon the amount of gas used. Likewise, the cost per therm of natural gas used varies throughout the year. As a result, the average cost for each building varies when converted to $/kBtu.

The TRC analysis team noted that the pre-retrofit gas use data indicates seasonal variation in both buildings. As shown in Figure 5 and Figure 7 there is more gas use in the winter months than summer months. There is currently not enough post-retrofit data available to definitively determine the potential cause. Currently there are three hypotheses regarding the increased gas use for water heating:

1) Lower inbound temperature of water supplied by the City of Sacramento during winter months
2) Increased resident hot water use during the winter months
3) Operational loss due to exposure to cold outdoor air temperature through the laundry room

TRC's post-retrofit analysis accounts for the first two hypothesized causes of seasonal variation. Impacts from cold outdoor air temperature through the laundry room is no longer possible due to a new insulated wall in that location.

3.2.4 Post-retrofit Analysis

This section provides a snapshot of the heat pump water heater system performance over the monitoring period. As explained above, TRC assumed that the laundry and hot water use before and after the retrofit are consistent. Table 7 below summarizes the analysis. Total Annual Electricity Use is calculated using the expected monthly hot water load and the Average HPWH Efficiency. The Average HPWH Efficiency was calculated based upon the monitored average daily hot water use and average daily energy use by the HPWH, using the following formula:

$$Average\ HPHW\ Efficiency\ \left(\frac{kBtu}{gallon}\right) = \frac{E_i\ \times \mathrm{C}}{HW}$$

Where,

E_i = daily average energy consumption, Wh/Day

C = conversion factor, 3.412 kBtu/Wh

HW = daily average hot water use, gallons/day

Table 7 below summarizes the interim analysis. Total Annual Electricity Use is calculated using the expected monthly hot water load and the Average HPWH Efficiency. The Average HPWH Efficiency was calculated based upon the monitored average daily hot water use and average daily energy use by the HPWH.

The Coefficient of Performance (COP) was calculated from the Average Daily Energy Consumption and the Average Daily Heating Output of each HPWH using the following formula:

$$Coefficient\ of\ Performance\ (COP) = \frac{E_i\ \times \mathrm{C}}{E_o}$$

Where,

E_i = daily average energy consumption, Wh/Day

E_o = average daily heating output, kBtu/day

C = conversion factor, 3.412 kBtu/Wh

Table 7: Post-retrofit System Performance Analysis

Post-Retrofit	Quadplex A	Quadplex B	Data Source
Total Annual Electricity Use (kWh/yr)	5,530	6,500	Senseware (Estimate based on data collected February 2020 through August 2020)
Total Annual Electricity Use (kBtu/yr)	18,870	22,190	Senseware (Estimate based on data collected February 2020 through August 2020)
Total Annual Hot Water Use (gal/yr)	114,080	164,180	Senseware (Estimate based on data collected February 2020 through August 2020)
Total Annual Electricity Cost ($/yr)	$636.16	$903.51	SMUD Billing Data
Average Electric rate*#+ ($/kWh)	0.115	0.139	SMUD Billing Data
Average Cost per Gallon ($/gal)	.00557	.00550	
Average HPHW Efficiency (kBtu/gal)	0.16	0.13	
Average HPHW COP	3.06	3.14	

*All electric bills include a "System Infrastructure Fixed Charge" which applies prior to the incremental increase associated with the post-retrofit electricity consumption.
#The discrepancy in the electric rate is due to usage in Quadplex B during on-peak hours.

+The analysis uses the incremental rate, which does not include fixed charges in the blended rate.

4 Results

4.1 HPWH Retrofit Energy and Cost Savings

TRC analyzed both energy savings and cost savings from the monitoring data. TRC expected significant annual energy savings from the increased efficiency as shown in Table 8 below:

Table 8: Pre- and Post-Retrofit Energy Efficiencies

	Units	Quadplex A	Quadplex B
Gas Water Heater Efficiency	kBtu/gal	1.04	0.71
HPWH Efficiency	kBtu/gal	0.15	0.14
Efficiency Gain	kBtu/gal	0.89	0.57

Annual energy savings, cost savings, and net green-house gas (GHG) reductions are summarized in Table 9 below.

Table 9: HPWH Retrofit Savings

	Units	Quadplex A	Quadplex B
Annual Energy Input Savings	kBtu/yr	96,390	97,390
Annual Cost Savings	$/yr	$1,230	$1,060
Net GHG Emission Reduction	lb CO_2/yr	10,380	10,340

Based upon the monitoring periods, replacing the natural gas-fired domestic hot water system with an electricity-based HWPH system resulted in a site energy use reduction of approximately 96,900 kBtu/yr per building. The kBtu/yr reduction is based upon calculated monthly hot water use and the associated energy (kBtu) consumed by the pre-retrofit and post-retrofit systems based upon each system's in situ kBtu/gal shown above in Table 6 and Table 7, respectively.

Overall GHG emissions reduction is expected to exceed 10,000 lbs CO_2/yr per building. The GHG emissions reduction is calculated using the estimated annual energy use of each system and the emission factor for the associated utility (PG&E Natural Gas = 0.117 lbCO_2/kBtu and SMUD Electric = 0.56108 lbCO_2/kWh).[1]

TRC estimates the energy savings achieved for the HPWH retrofit for buildings A and B is 96,390 kBtu/yr and 97,390 kBtu/yr respectively. The annual cost savings associated with the energy savings are estimated to be $1,230/yr for Quadplex A and $1,060/yr for Quadplex B and were calculated using the following formula:

$$Annual\ Cost\ Savings = (NGC\ \times NGR) - (EU \times ER)$$

[1] https://planning.saccounty.net/PlansandProjectsIn-Progress/Documents/Climate%20Action%20Plan/2015%20Greenhouse%20Gas%20Emissions%20Inventory%20and%20Forecasts_Rev.pdf

Where,

NGC = baseline annual natural gas use, kBtu/yr

NGR = average NG blended rate, $/kBtu

EU = post-retrofit annual HPWH electric use, kWh/yr

ER = average electric blended rate, $/kWh

4.2 HPWH Performance

TRC's analysis indicates a HPWH coefficient of performance (COP) of approximately 3.0-3.2 during the February through August 2020 monitoring period. Based on the manufacturer's literature, TRC expected COPs of 3.75-4.75 based upon the average OAT (Ambient Temp °F) at A and B (60.3°F and 54°F, respectively). The manufacturer's test results shown in Figure 12 appear to be greater than the in-situ COPs by 0.75-1.25. TRC does not know the cause of the apparent underperformance, which may be a function of limited data. Another issue TRC noticed during a site visit on August 25, 2020 was the temperature setpoint of the mixing valve was set near 140°F which was not following the manufacturer guidelines. The tank and mixing valve temperature settings were adjusted by the field engineer to meet manufacturer guideline of 120°F. However, as this adjustment was made late in the monitoring period, TRC did not capture the effect the temperature adjustment had on the COP.

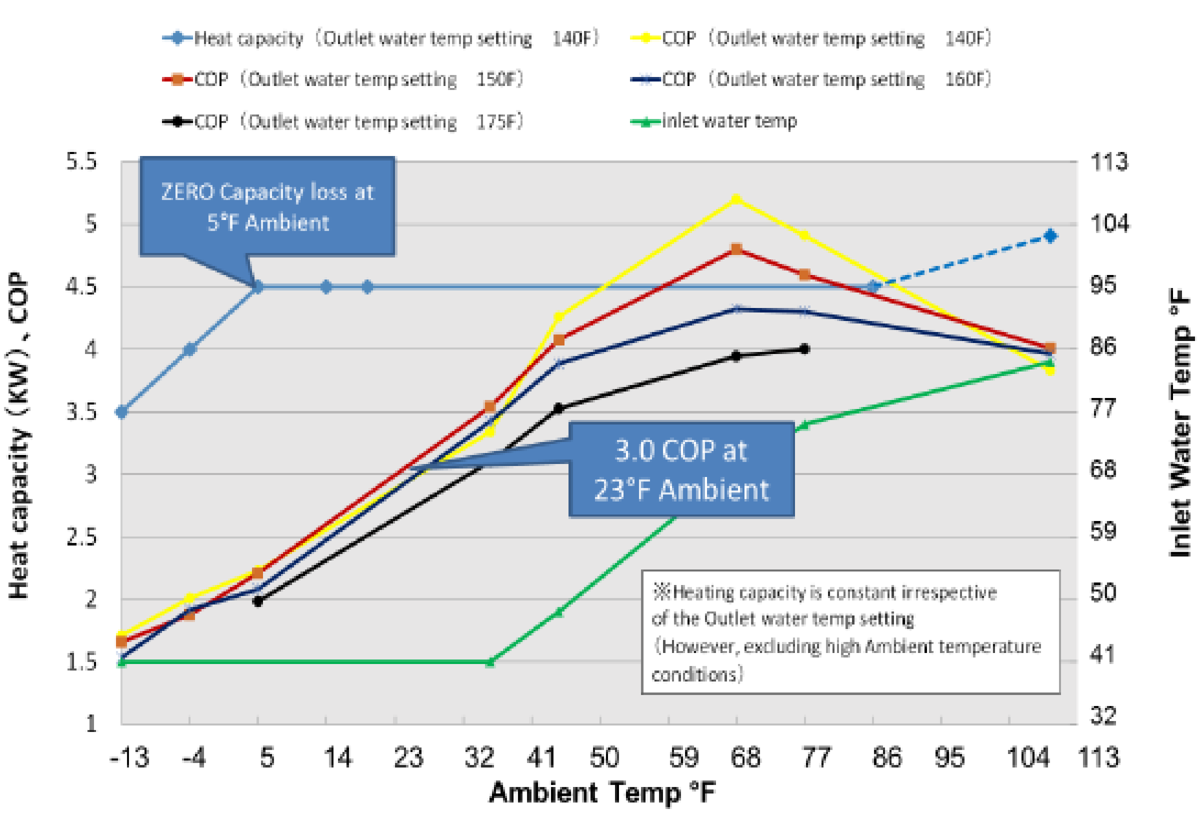


Figure 12: Sanden SanCO$_2$ Expected HPWH Performance

5 Single Heat Pump Analysis

The purpose of the single heat pump analysis is to determine if a single SANCO$_2$ heat pump water heater can meet the hot water (HW) demand of Quadplex A in the Gaddi Grove community without exceeding manufacturer recommended run time of 16 consecutive hours in a 24-hour period. The sections below provide the data collection procedure, usage and performance analysis and cost savings.

5.1 Data Collection Summary

During the single HP study monitoring period (August 2020 - October 2020), TRC collected the same data as described above in Section 2. TRC staff shutdown, isolated and adjusted one of the two previously installed SANCO$_2$ heat pump water heaters per the Sanden Installation Guide (See Appendix 7.2) on August 26, 2020.

To facilitate our analysis and monitoring of this test case, we added alarms within the Senseware platform to notify us if the system was not meeting its operational requirements. The alarms notified TRC staff when:

- Storage tank temperatures dropped below 120°F as this implied that the tank had been depleted of hot water
- The heat pump ran more than 16 hours in a 24-hour period. TRC included a daily run-time totalizer at 16 hours

Material cost for the HPWs and storage tanks are based on the December 2020 price list provided by the equipment manufacturer Sanden. Labor, ancillary materials & maintenance costs were estimated with the most recent RSMeans cost data.

TRC gathered the electricity consumption using temporary power meters for seven months with two operating HPWHs prior to converting to a single HPWH (Aug 26, 2020). Quadplex A’s electricity consumption ranged from 429kWh to 640 kWh with peak usage in March 2020 (See Figure 13 below). Post-single HPWH conversion electricity consumption at Quadplex A did not exceed 475 kWh during the monitoring period of August 2020 – October 2020 (See Figure 11).

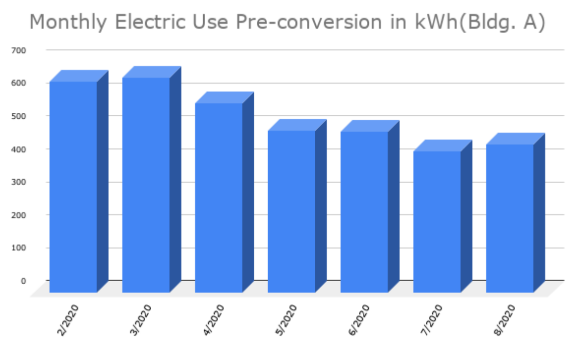


Figure 13: Quadplex A Dual HP Electricity Consumption

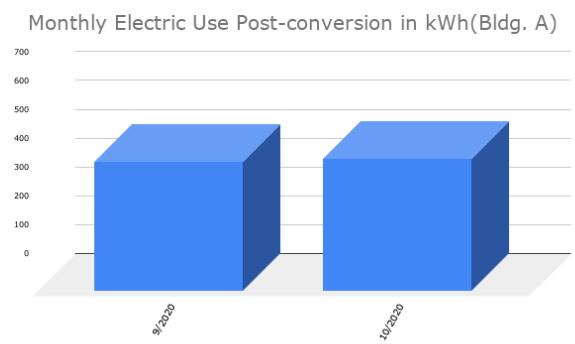


Figure 14: Quadplex A Single HP Conversion Electricity Consumption

5.2 Results

5.2.1 Hot Water Adequacy

The single heat pump was able to meet the HW demand of the quadplex throughout the monitoring period as demonstrated by tank temperature maintained above a critical temp of 125 °F, with the exception of four instances. During these 4 instances, the tank temperature fell below the critical temperature, each instance lasting for 1 to 4 hours as shown in Table 10. The complete monitored period data is presented in Figure 15.

Table 10: Critical Tank Temperature Occurrences (<125 F)

Occurrence	Time	Tank Temperature Range	Total HW Use (Gallons)	HPWH2 (Energy Consumption), kWh
4-Sep	10 PM to 11 PM	122 F to 140 F	54	968
7-Sep	8 PM to 10 PM	112 F to 141 F	121	1,836
11-Sep	12 AM to 1AM	114 F to 138 F	100	1,887
23-Oct	7 PM to 11 PM	112 F to 140 F	159	2,892

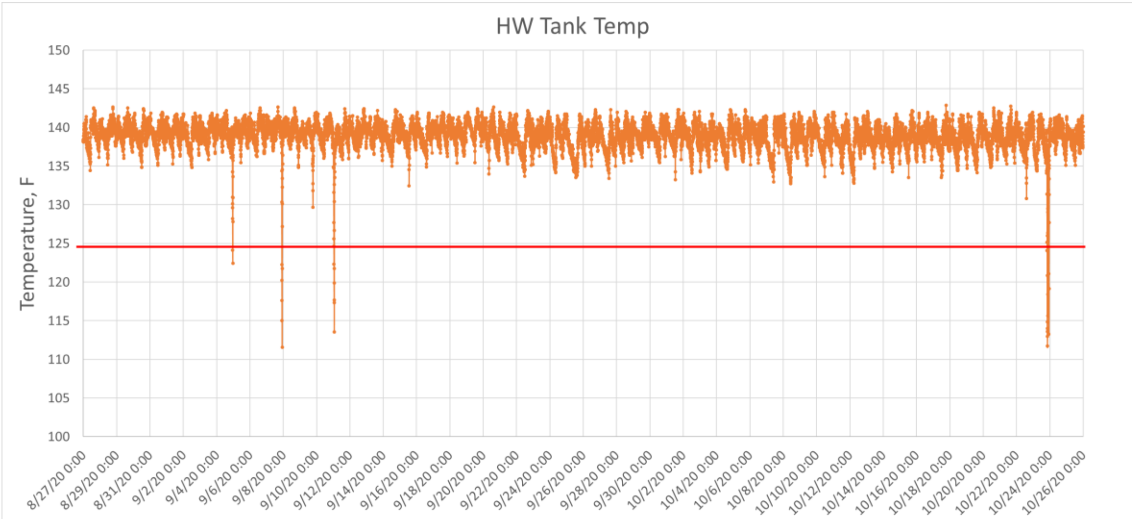


Figure 15: Graph Showing Critical Tank Temperature Occurrences

From the monitored data, the TRC team ascertained the following findings regarding the critical temperature occurrences:

- All four occurrences happened between 8 PM and 1AM.
- Average daily hot water use per unit in Quadplex A is 72 gallons. The expected hot water demand of per CA Title 24 is 41.9.
- As can be seen in Table 10 above, each occurrence lasted for 1 to 4 hours, where there was a sudden surge in usage in multiple units either simultaneously or overlapping with high usage. At the end of each occurrence, the tank temperature recovered to storage temperature (>140 F) within 17 hours.
- Of the 17,880 HW gallons used during the monitoring period, only 2.4% (433.6 gallons) of HW were used during critical tank temperature occurrences.
- Since the period of these occurrences is small compared to the total monitoring period, TRC concluded that the single heat pump met HW demand for Quadplex A during most of the summer monitoring period.

5.2.2 Performance

TRC's analysis indicates a coefficient of performance (COP) of approximately 3.23 during the single heat pump setup measured August 2020 to October 2020 as compared to a COP of 3.06 from the two heat pump setup measured February 2020 to July 2020.

The Coefficient of Performance (COP) was calculated from the Average Daily Energy Consumption and the Average Daily Heating Output of each HPWH using the following formula:

$$Coefficient\ of\ Performance\ (COP) = \frac{E_i \times C}{E_o}$$

Where,

E_i = daily average energy consumption, Wh/Day

E_o = average daily heating output, kBtu/day

C = conversion factor, 3.412 kBtu/Wh

Given the numerous variables between the two monitoring periods which include changes in seasonal outdoor air temperature, tank set point temperature, mixing valve temperature, and number of operating heat pumps, TRC could not attribute the marginal change in COP to one particular factor.

Table 11 below shows the performance comparison between the two setups.

Table 11: System Performance Comparison Quadplex A

Monitoring Period	# of Active HPWH	COP	Consumption (kWh/day)	Avg Daily Run Time (hours)*#
February - August	2	3.06	14,092	8.20
August-October	1	3.23	11,797	10.84

*The run time is calculated based on the instances when the HPWHs are operating (Watt readings >10 from trends). During Feb to August both HPWHs operated simultaneously.
#Manufacturer recommended run time of less than 17 hours every 24. 71% duty cycle.

Based on the data analysis of both hot water adequacy and system performance, TRC determined the single HPWH system was able to meet the HW demand of Quadplex A for the summer monitoring period. However, this data does not include cold winter months where the average daily run times may increase due to increased hot water use and lower inlet water temperatures. In order to confirm the adequacy of the single heat pump setup during winter months, TRC recommends analyzing the system performance during at least two standard winter months such as December & January.

5.2.3 Cost Savings

As expected, the installation cost of a single heat pump is less than the dual heat pump system. TRC estimated a savings of approximately $5,000 (36%) as seen in Table 12 below.

Table 12: Two HPWH vs One HPWH - Installation Cost Comparison

HP Quantity	HP (Materials)	Tank (Materials)	Ancillary (Materials)	Total Cost Material	Cost Labor	Permit & Engineering	Total
2	$6,150	$2,340	$800	$9,290	$4,490	$500	$13,780
1	$3,075	$2,340	$500	$5,915	$2,894	$500	$8,809
Savings	$3,075	$0	$300	$3,375	$1,596	$0	$4,971

Table 13: Bldg A Single Heat Pump Operation Cost Comparison

Results	2 HP	1 HP	Standard Unit (Nat Gas)	Data Source
Total Annual Electric Use (kBtu/yr)	5,530.63	5,188.89	115,265.0	Estimate based on SMUD Billing Data and Senseware (collected February 2020 through August 2020)
Total Annual Operations Cost ($/yr)	$636.16	$596.85	$1,871.27	Estimate based on SMUD Billing Data and Senseware (collected February 2020 through August 2020)
Estimated Annual Maintenance * Cost ($/yr)	$300	$150	$150	RS Means and Billing Data
Total Annual Operating Cost ($/yr)	$936.16	$746.85	$2,021	RS Means and Billing Data
Estimated Lifetime Operating Cost (EUL)** ($)	$14,042.41	$11,202.78	$30,315	Estimated lifetime cost based on the National Residential Efficiency Measures Database

*Estimated annual maintenance costs includes "flush" only.

**Estimated Useful Life (EUL) of 15 years used to calculate lifetime operating costs.

Table 13 above shows the expected bill impacts of running one heat pump as opposed to two heat pumps, and a standard natural gas unit. While the table suggest a reduction in total annual electric use for one heat pump compared to two, TRC also adjusted the tank and mixing valve temperatures which could affect the heat pump's electrical consumption and could not conclusively determine energy savings and operational cost savings for a single heat pump system compared to a dual heat pump system. To evaluate these potential savings, TRC recommends a longer monitoring period with a single heat pump without other system changes. TRC did find the single heat pump was able to meet demand during the summer monitoring period and estimates a 36% installation cost reduction for a single heat pump system compared to a dual heat pump system.

5.3 Recommended Future Work

TRC continued to monitor heat pump performance data and receive Senseware alerts beyond the conclusion of the monitoring period and observed the alerts for run times greater than 16 hours were becoming more frequent as seen in Table 14 below.

Table 14: Single Heat Pump Run Times

Date	Duration (Hrs)	Avg OAT (F)
10/22/2020 11:47	17.5	72
10/23/2020 18:54	19.7	68
10/26/2020 15:08	17.6	68
10/29/2020 19:38	17.8	66
11/6/2020 10:08	18.6	62
11/7/2020 0:00	21.3	62

TRC concluded the seasonal drop in outdoor air temperature is contributing to lower inlet water temperatures which is causing the heat pump to operate for longer periods to achieve the desired hot water temperature. As demonstrated in Table 14 above, TRC started observing OAT in the 60s and low 70s. For comparison, the average OAT during the August 26 – October was 80°F. TRC does not have evidence indicating recent significant changes in occupancy, or water usage are contributing to longer run times.

As a result, TRC recommends SMUD perform a single heat pump study at least through December and January to determine hot water adequacy and what the appropriate solution is for instances where a single heat pump cannot deliver hot water within the manufacturer recommended run times.

6 Appendix A: Data Collection

6.1 Data Analysis Spreadsheets

The workbooks were too large to embed in the document. These will be provided as a separate file to SMUD.

6.2 Pre-Retrofit Survey Results

Building #	Unit ID	How many people live in the unit?	How long have you lived in the unit? Is there any seasonal fluctuation in occupancy?	How would you describe the occupancy schedule like (e.g. occupied 24/7, just morning/ evening/ nights on weekdays, etc)?	What are the age range(s) of the tenant?	Any dogs or cats? Do you use hot water for pet bathing?	How many total showers, on average, are there each day?	How many total baths, on average, are there each day?	Would you describe showers as short (less than 5-mins), medium (6-12 mins), or long (over 12 mins)?	How many loads of laundry does your family wash per week?	Do you use a dishwasher, handwash, or combination?	If you use a dishwasher, about how often do you run it?
A	1	5	6	Evening	(2) 0-12; (1) 13-18; (2) 30-39	No	1	1	Medium	5	Handwash	0
A	2	3	4 years 2 months	24/7	(1)0-12; (1) 19-29; (1) 50-59	No	3 to 4	1	Medium	1 to 2	Handwash	0
A	3	4	2	Evening	(3) 13-18; (1) 60+	No	1	1	Medium	2	Handwash	0
A	4											
B	1											
B	2	3	4	24/7	0-12; 50-59	No	3	3	Medium and long	3	Handwash	0
B	3	6	3	24/7	(2) 0-12; (2) 13-18; (2) 30-39	No	1	1	Medium	0	Handwash	0
B	4	1	3	NA	60+	No	1	1	NA	NA	Handwash	0

Building #	Unit ID	How long does it typically take for your water to get hot?	Do you have problems with hot water running out?	Are there any water pressure issues? For example, water pressure drops when others are using other water, too.	How important is water preservation to you?	Do you think your household uses more water than the average home?	If water costs doubled would your usage change?	On a scale from 1-10 how satisfied are you with hot water at your home?	Are there any other hot water used that are not included here?
A	1	1 minute	No	No	very important	Normal	Yes	9	No
A	2	<1 minute	No	No	Important	No	No	10	No
A	3	1 minute	No	No	very important	No	Yes	8	No
A	4								
B	1								
B	2	not long	No	No	very important	No	Yes	9	No
B	3	2 minutes	Yes	No	NA	No	Yes	9	No
B	4	Does not get hot	Yes	Ok	Important	NA	Yes	Ok sometimes	No

6.3 Post-Retrofit Survey Results

Building	Unit ID	How many people live in the unit?	How long have you lived in the unit?	Has the number of people living in your apartment changed in 2020?	How would you describe the time a day that people are home? (circle any that apply)	What are the ages of the people living in the unit?	How many total showers, on average, are taken each day in your home? (circle one)	How long is a typical shower? (circle one)	How many total baths, on average, are there each day? (circle one)	How many loads of laundry does your family wash per week? (circle one)
A	1	1	3-4 years	No	Evening	60	1	5 Mins	1	0
A	2	6	3-4 years	No	24/7	(2)0-12; (2) 13-18; (1) 40-49; (1) 30-39	1	12 Mins+	1	7+
A	3	4	3-4 years	No	24/7	(2) 13-18; (1) 19-29; (1) 60+	4 to 5	6-12 mins	4+	1 to 2
A	4									
B	1									
B	2									
B	3	3	5+ years	No	24/7	(1)0-12; (1) 19-29; (1) 50-59	2 to 3	6-12 mins	1	1 to 2
B	4	5	5+ years	No	Evening	(2)0-12; (1) 13-18; (2) 30-39	4 to 5	6-12 mins	3	3 to 4

Building	Unit ID	How long does it typically take for your water to get hot? (circle one)	Do you ever run out of hot water? (circle one)	Are there any water pressure issues? For example, water flow drops when others are using other water, too. (circle one)	On a scale from 1-5, how important is saving water to you? (circle one)	Do you think your houshold uses more water than the average home? (circle one)	On a scale from 1-10, how satisfied are you with the hot water at your home? (circle one)	If you got a monthly water bill, how would your water use change? (circle one)
A	1	Less than 1 minute	No	No	5	No	10	No Response
A	2	1-2 minutes	No	No	5	Don't Know	7	Reduce as much as possible
A	3	1-2 minutes	No	No	5	No	10	Reduce a little
A	4							
B	1							
B	2							
B	3	Less than 1 minute	No	No	4	No	10	No Change
B	4	Less than 1 minute	No	No	5	Don't Know	9	No Change

7 Appendix B: Other References

7.1 Sanden SanCO_2 Technical Manual

Sanden SANCO$_2$

Heat Pump Water Heater

Technical Information

October 2017

SANDEN Technical Book

Advisory note:
Basic knowledge of hot water, refrigeration, electricity and thermodynamics is required to fully understand this material.

Thank you for your attention, the Sanden Technical team.

John Miles
General Manager

Maho Ito
Manager

David Hale
Technical Support

Sanden International (USA), Inc.
47772 Halyard Dr.
Plymouth MI 48170

Phone: 1-844-SANDCO_2 / 1-844-726-3236

Email: info@sandenwaterheater.com

Website: www.sandenwaterheater.com

Table of Contents

SANCO$_2$

SANCO$_2$ is a customized CO_2 Heat Pump Water Heater (HPWH) that Sanden has designed to meet the North American market needs.

It is based on the Eco Cute units, which is a widely accepted and commonly used water heater in Japan and were first introduced to the market in 2001.

An Eco Cute is a HPWH that uses carbon dioxide as a refrigerant. “Cute” translates to hot water in Japanese which is pronounced Kyuto.

Since 2011, Sanden has collaborated with local utility companies to conduct laboratory and field testing to ensure that the technology will transfer to the North American market without problems.

Why CO_2?

Carbon dioxide is a unique refrigerant that does not contribute to global warming.

The Global Warming Potential (GWP) of carbon dioxide is 1, compared to the GWP of the typically used HPWH’s refrigerants such as R134a – GWP of 1,430 and R410a – GWP of 2,086.

CO_2 is used as the benchmark to measure Global Warming, so these numbers translate that 1lb of CO_2 released into the atmosphere will contribute 1lb of Global Warming Potential, 1lb of R134a will contribute 1,430lbs of Global Warming Potential for 100 years.

SANCO$_2$ utilizes a 22 oz. of CO_2 refrigerant which is charged and stored inside of a closed loop system with an operating pressure range of 600 psi to 1,600 psi.

Carbon dioxide rarely achieves its liquid state. After being compressed and heated, the CO_2 refrigerant becomes as dense as liquid, while still remaining as a gas (transcritical state), substantially increasing the transfer of heat between itself and the water, especially in low ambient conditions.

In addition to the refrigerant attributes mentioned above, carbon dioxide extracts heat even at very low temperatures. The unit operates down below -20°F without a back-up heating element, and will deliver a maximum water temperature of 160°F at those very low ambient temperatures.

Cont.

Think of it this way – the outside air will transfer heat to the CO_2 through an evaporator, the CO_2 is then heated through compression, the heat from CO_2 is transferred to the cold water through a double wall heat exchanger, and the hot water is pumped from the unit.

In the unlikely event of a refrigerant leak, the system can be recharged with CO_2 as would a normal HVAC system, however we recommend contacting Sanden Technical Support for information on this procedure.

What advantages are there?

Energy Efficiency

- SANCO$_2$ is 4 x more efficient than traditional electric water heaters. It uses much less energy to heat water faster
- SANCO$_2$ is more efficient in field testing than integrated HPWH's

High Performance

- Greater first hour rating than all HPWH's:
- 83 Gallon tank – FHR 115 gallons
- 43 Gallon tank – FHR 71 gallons
- Temperature set-point between 130 and 175°F, delivering hotter water than all other residential electric water heaters
- Faster recovery after hot water draw, approximately 18 GPH delivered to the top of the tank

Extended Operating Range

- Hot water production down to -20°F and below
- No need for back up electric element in the storage tank

Flexible Installation

- Heat Pump is installed outside, so no energy stealing from the space or cold airflow issues to overcome
- Tank can be installed almost anywhere in the home, power is not required or a large space requirement around the tank
- Heat pump has an extremely small footprint and a low operating noise level making it suitable for installation almost anywhere

High Quality with Low Maintenance

- Long Life Stainless Steel Tank with a 15 year prorated warranty
- No anode rods to replace or air filters to clean

Environmentally Friendly

- Minimal impact on global warming

Applications - Residential

Sizing
Sizing of the system to the home is **EXTREMELY IMPORTANT.**

43 Gallon Tank:
First hour delivery (FHR): 71 gallons. This tank size is suitable for families of 2 to 4 members.

83 Gallon Tank:
First hour delivery (FHR): 115 gallons. This tank size is suitable for families of 5+ or larger users of DHW.

Heat Pump Outdoor Installation
The outdoor unit can be installed in various locations including: directly outside of a home, a garage, basement, mechanical room, or a rooftop.

When mounting the unit, ensure no obstacles that can prevent air flow obstruct the unit.

If wall mounted installation is desired, the outdoor unit can be installed either high on a wall or low on a wall, but should be accessible in the event of maintenance. In areas with high snowfall, the unit must be installed above the anticipated snowline.

Heat pump Indoor Installation
To remove any ambient issues, locating the condenser inside of a building can be a viable alternative as long as the minimum 800 CFM (cubic feet per minute) ventilation requirements are met and can be maintained throughout use.

Tank Installation
The Storage tank must be installed upright.

Installation clearances are 2” around the tank- no airflow is required so closet installation is possible.

No power is required for the tank, just water connections to the home and heat pump plus a control wire connection to the heat pump.

Maximum Distance
The distance between the heat pump and tank must be within the maximum limits of the system.

Gen3; GS3-45HPA; 50ft total length including 16ft vertical separation

Gen2; GUS-A45HPA; 25ft total length including 10ft vertical separation

Applications - Multi-family Buildings

Multiple Units in a Central system
In most multi-residential applications, multiple heat pump units as well as tank units can be connected together to increase efficiency, hot water output, and recovery.

Sizing
When sizing for multi-residential applications, the following information is required to determine the number of heat pumps and tanks. Both the heat pump and tank unit are scalable depending on hot water usage.

- Number of apartments per building
- Number of apartments on each floor
- Number of bedrooms per apartment
- Number of bathrooms per apartment
- Number of kitchens per floor
- Number of laundry rooms per floor
- Expected number of residents per building
- Expected demography of residents (professional, family, senior)

Installation
As per residential applications, the heat pumps and tanks can be installed indoor and/or outdoor depending on a building design, location, and climate.

Installation location specifics must be as per the residential application.

Important
<u>It is very important to install multiple heat pumps and tanks using a plumbing schematic developed in consultation with Sanden.</u>

<u>Detailed planning and a meticulous installation is required, especially with multiple units piped together so that the entire installed system will function as it is intended.</u>

Applications - Light Commercial

Sizing
The Sanden heat pump can be used for light commercial applications, such as schools, restaurants, farms and small businesses.

The following information is required for water heater sizing:
- Daily hot water usage
- Peak hot water usage and time
- Hot water usage type, for example dish washing, agricultural or hair dressing
- List of appliances that use hot water
- Number of appliances, bathrooms, shower rooms and kitchens that use hot water
- Delivered hot water temperature
- Expected hot water draw pattern

Installation
Like residential applications, heat pumps and tanks can be installed indoor and/or outdoor depending on a building design, location, and climate.

Installation location must be as per the residential application.

Important
It is very important to install multiple heat pumps and tanks using a plumbing schematic developed in consultation with Sanden.

Detailed planning and a meticulous installation is required, especially with multiple units piped together so that the entire installed system will function as it is intended.

Applications – Combination Heating and DHW

It is permitted to use the $SANCO_2$ system to provide some limited capacity heating (radiant, fan coil, etc.) in certain areas of North America, when combined with a minimum of 25 gallons per day usage of DHW.

It is NOT permitted to use the $SANCO_2$ system to provide heating as its only function.

Sizing
Maximum heating capacity must be less than 8,000 BTU/h.
Minimum design ambient temperature must be above 27°F.
Tank size must be the 83 gallon tank.
DHW usage – minimum 25 gallons per day.

Installation
Like residential applications, the heat pumps and tanks can be installed indoor and/or outdoor depending on a building design, location, and climate.
Installation location specifics must be as per the residential application.

Important
Per your local code, potable and non-potable water may need to be separated. Check with your local code authority to determine if separation, and/or use of a double wall heat exchanger is required.

In applications requiring separation between potable and non-potable water, Sanden mandates the use of a Taco X-block system.

It is very important to install a combination system using the plumbing schematic developed by Sanden.

Particular importance must be given to the location of the heating system return water pipe from the X-block to the tank, lower return water temperatures should return to the bottom of the tank.

Detailed planning and a meticulous installation is required, especially with multiple units piped together so that the entire installed system will function as it is intended.

Unit Operation

As hot water is drawn from the top of the tank for showers etc., cold water enters the bottom of the tank from the city or well cold water supply feed.

The incoming cold water and stored hot water do not fully mix inside the tank (unlike other water heaters), this helps maintain a higher average tank temperature and is called stratification.

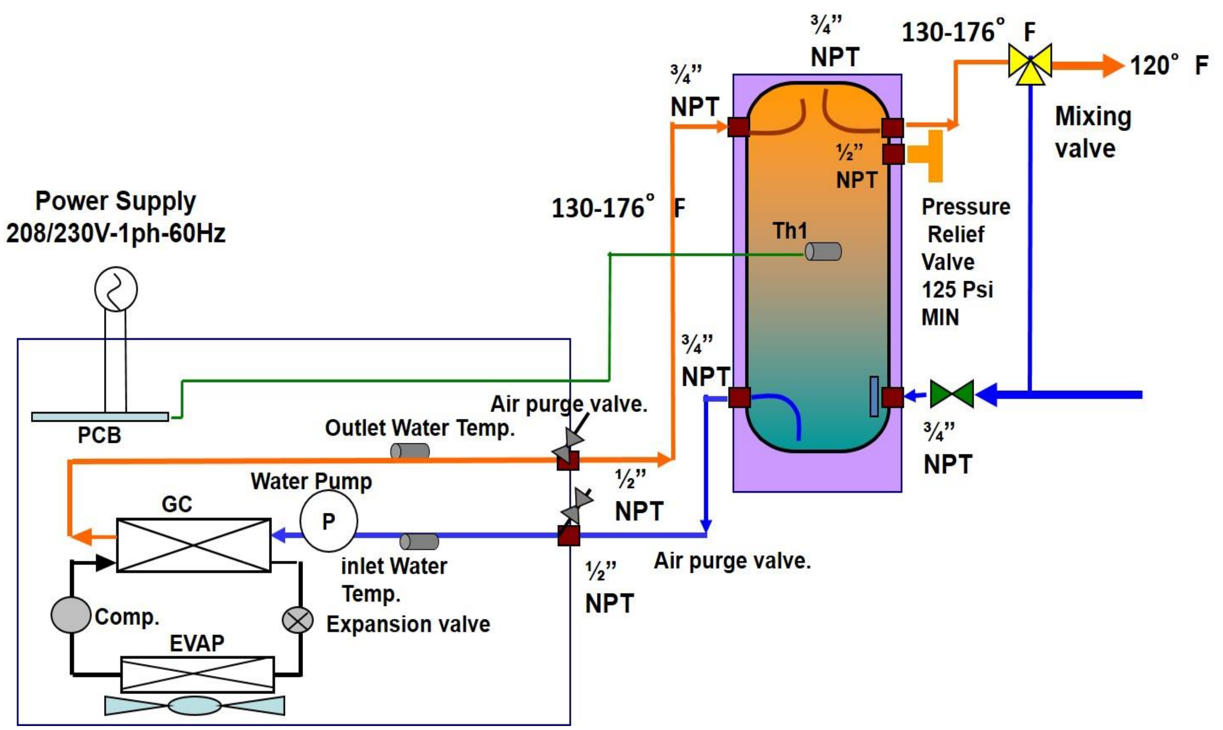
As more hot water is drawn from the tank, the volume of cold water increases, however the tank still remains stratified. When the tank temperature sensor measures the water temperature below 113°F, the heat pump control will start the unit.

The variable speed pump pulls the cold water into the heat pump, and using the heat from the ambient air the water is heated to the user selected water temperature set-point and the returned to the top of the tank.

Heating continues until the water entering the heat pump heat exchanger is 122°F, at which point the heat pump will cycle off and the tank is now completely full of hot water.

The SANCO$_2$ unit will produce hot water at temperatures between 130°F and 176°F depending on set-point chosen.

Therefore, it is mandatory to install the supplied Honeywell AM101 mixing valve and set the delivered water temperature to the home at the customer's requirement.



Hot Water Recovery

The $SANCO_2$ system capacity is rated at a minimum of 4.5Kw (15,400 Btu/h) at all ambient temperatures above 5°F.

Below 5°F, total capacity is reduced, the amount of reduction will depend on the outdoor temperature.

Above 5°F, the Hot water recovery for a Sanden system is equivalent to any 4.5Kw electric water heater, however depending on user set-point selected and incoming water temperature this recovery rate can alter.

Gallons per Minute (GPM)						
	Incoming Water Temperature					
Heat Pump Set Point	40	45	50	55	60	65
130	0.34	0.36	0.39	0.41	0.44	0.47
140	0.31	0.32	0.34	0.36	0.39	0.41
150	0.28	0.29	0.31	0.32	0.34	0.36
160	0.26	0.27	0.28	0.29	0.31	0.32
165	0.25	0.26	0.27	0.28	0.29	0.31
175	0.23	0.24	0.25	0.26	0.27	0.28
Gallons per Hour (GPH)						
	Incoming Water Temperature °F					
Heat Pump Set Point °F	40	45	50	55	60	65
130	20.5	21.7	23.1	24.6	26.4	28.4
140	18.5	19.5	20.5	21.7	23.1	24.6
150	16.8	17.6	18.5	19.5	20.5	21.7
160	15.4	16.1	16.8	17.6	18.5	19.5
165	14.8	15.4	16.1	16.8	17.6	18.5
175	13.7	14.2	14.8	15.4	16.1	16.8

This table shows the recovery flow for a single heat pump unit.

The flow rate given is the flow from the heat pump to the tank, not flow into the home/appliance. The recovery rate is the same for an 83 or 43 gallon tank.

In multiple heat pump systems, simply multiply the GPH by the number of heat pumps to calculate system recovery flow.

Cont.

Sanden recommends that the heat pump set-point should be at a minimum of 150°F for the combination of maximum hot water production and system efficiency.

This setting will increase the total delivered recovery of the tank as the hot water from the tank will be mixed with cold water to provide the lower delivered water temperature to the home, to prevent scalding and potential injury.

The ratio of hot water and cold water used can be calculated using this formula which was developed by ASPE.

Heat pump set-point and average tank temperature 150°F

Incoming Cold Water Temp	130°F Mixed Delivered Water Temp	125°F Mixed Delivered Water Temp	120°F Mixed Delivered Water Temp	115°F Mixed Delivered Water Temp	110°F Mixed Delivered Water Temp
40°F	0.82	0.77	0.73	0.68	0.64
45°F	0.81	0.76	0.71	0.67	0.62
50°F	0.80	0.75	0.7	0.65	0.6
55°F	0.79	0.74	0.68	0.63	0.58
60°F	0.78	0.72	0.67	0.61	0.56

For example:
A 3 GPM hot water flow into the home with the mixing valve set for a temperature of 120°F, and a cold incoming water temperature of 50°F will need 2.1 GPM of tank water and 0.9 GPM of cold water.

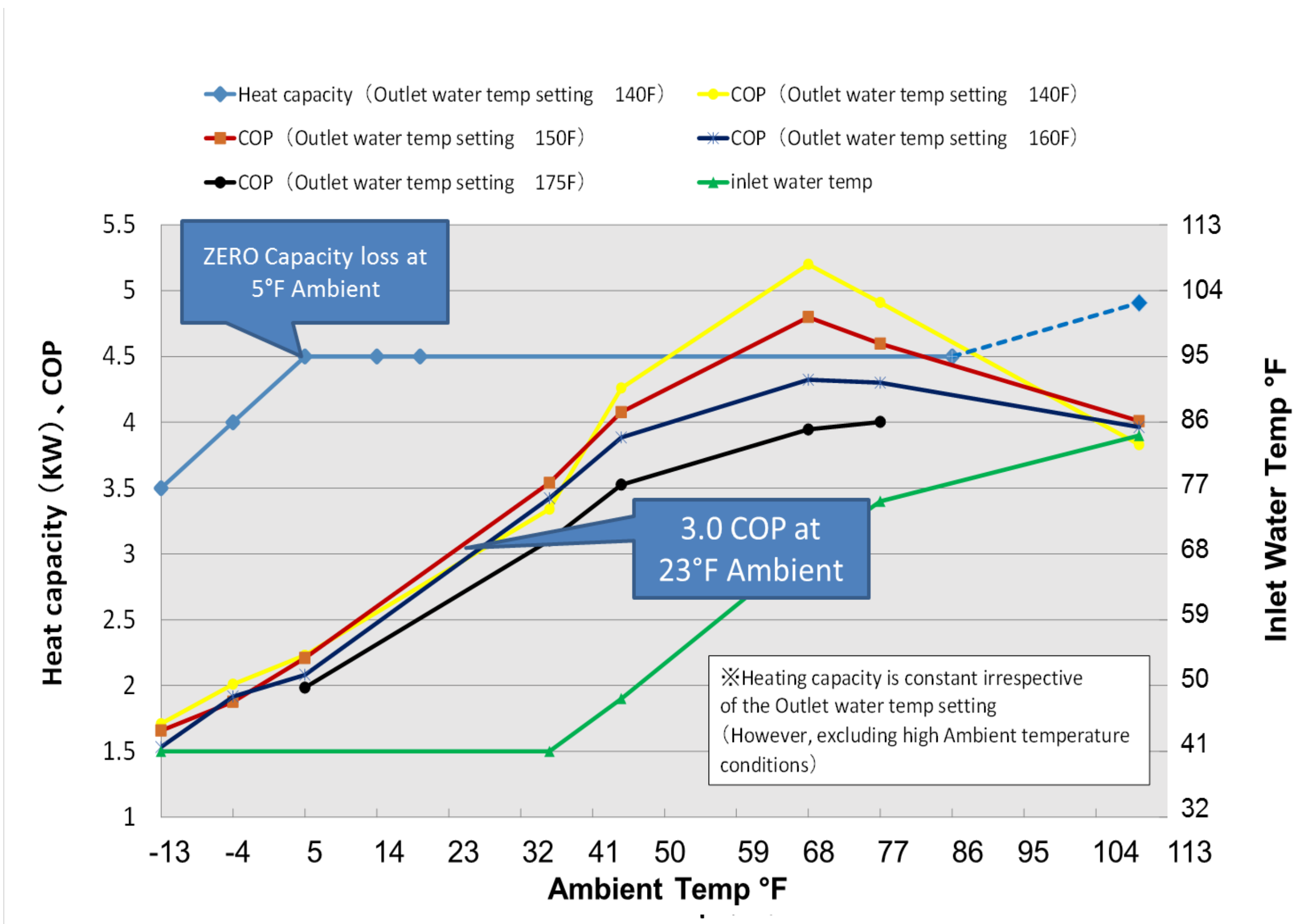
This reduction in water usage from the tank results in greater hot water production from the tank and increased recovery rate of the DHW system when viewed as a whole.

Efficiency, Capacity vs Ambient

Unit efficiency is affected by delivered water temperature and outdoor ambient
Unit capacity is ONLY affected by outdoor ambient.

Annual efficiency can be approximated using the system Coefficient of Performance at the various ambient temperatures.

Coefficient of Performance (COP) is calculated by dividing capacity by power input.



SANCO$_2$ can always make 160 DegF Hot Water (depending on set point) at all Outside Air temps

As can be seen, at 5°F ambient the system COP over 2.0, which rises to over 4.0 at 67°F ambient.

Pre-Installation Check List

1. Unit application sizing and plumbing planning
Refer to this manual for information on the sizing and requirements/limitations for the specific application required.
If in doubt, call technical support for advice.

2. Electrical Requirements
The outdoor unit should be fed with mains power from the breaker and local disconnect (per NEC code). Wire sizing should be calculated based on Minimum Circuit Ampacity and wire length.

The unit has a 16ft thermistor cable as standard, use a 16-2 AWG shielded wire to extend the thermistor cable from the heat pump unit to the tank.

Ensure the breaker size and voltage is correct for the system.
Sanden units do not have start components for the compressor, and therefore they rely on the correct power and amperage supply to start:

Unit	Power Supply	Breaker Size
GS3-45HPA-US	208/230V-1Ph-60Hz	15 Amps
GUS-A45HPA	208/230V-1Ph-60Hz	15 Amps

Voltage tolerance is 187V to 253V.

3. Pipe Length and Sizes
Ensure that the maximum piping lengths are observed or the system will not operate correctly and will likely experience premature failure of its components.

Do not upsize or alter the piping length from those published as Sanden cannot guarantee operation with incorrectly installed pipe.

For a GS3-A45HPA unit the pipe length should not extend more than 50 feet in length with 16 feet in height or elevation, with a maximum of 6 bends in each pipe run between the tank and heat pump unit.

Water supply to the tank, and from the tank to the building MUST be a minimum of ¾” and should be either copper or PEX piping, depending on local code requirements

The piping size between the heat pump and tank unit MUST be ½” diameter and should be either copper or PEX piping.

Cont.

ALL piping external to the building or in an unconditioned space **MUST** have a minimum ¾” thick closed cell insulation with all joints taped, ensuring none of the system piping is exposed.

4. Water Quality
Water with high concentrations of chloride that exceed 0.1 ounces per gallon (200mg/litre) can cause corrosion and subsequent failures, and thus the warranty will be no longer valid for the heat pump unit and tank unit.

No warranty coverage is given on the heat pump unit and tank unit where the PH is less than 6.0.

Supply water with a PH less than 6.0 may be treated to raise the PH and it is recommended that an analysis of the supply water be conducted before connecting the heat pump unit to the system.

Changing, or alternating, from one water supply to another can have a detrimental effect on the operation and/or life expectation of the water tank, PR valve, water heating circulation and the heat exchanger in the system and should be tested to ensure it meets the warranty requirements in the installation manual.

5. Tank Unit Positioning
If installing the tank unit indoors or in an enclosed space, leave at least 2” of clearance around the back and sides of the tank.

Sanden tanks have all of the connections on the sides of the tank, not the top of the tank like the majority of the North American water heaters.

Ensure adequate clearance for the connections and piping to the tank and the piping for the supplied mixing valve is maintained.

6. Outdoor Unit Positioning
Ensure that a minimum distance of 6” behind the unit and 12” in front of the unit is maintained, otherwise, the condenser airflow could be affected. Ensure adequate access for service and setting panel operation is provided.

Access to the unit can be obtained by removing the top cover and front cover of the condensing unit and all valve and electrical connections are on the RHS of the outdoor unit when looking at the condenser fan.

Sanden recommends a minimum of 18” separation when stacking the units vertically and 24” for RHS service access.

7. Error Codes
Errors occur typically because the system has either: too little flow of water from the tank to the heat pump, incorrect voltage to the system, and/or has not been purged of air in the water on start up.

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Installation Tips

Condensate
As the unit is taking heat from the outside air, the coil on the unit will be colder than the ambient temperature. This means that depending on the humidity level of the outside air, the unit will produce condensate as it removes water vapor from the air.
The quantity of condensate will depend on the current humidity level

It is very important that this condensate be drained away from the outdoor unit and the outdoor unit be raised a minimum of 4" from the ground.

This is particularly important in areas exposed to freezing weather as the melted condensate from defrost could create a slip and fall hazard.

Defrosting of the outdoor coil occurs to remove frost buildup on the coil, the unit will calculate when to defrost based on operating conditions.

The unit is supplied with a 5/8" drain hose connector for a hose to drain away the condensate (this can be found in the base of the heat pump packaging).

Tank Connections
All tank connections are ¾", this is designed to allow flexibility in the tank installation due to site conditions.
For the heat pump piping, 2 x ¾" to ½" reducers are required.

Multiple heat pump systems
For systems with multiple heat pumps attached to a single tank, every heat pump requires its own individual thermistor.

The thermistor should be securely fitted in the thermistor well and secured with silicon or thermal paste.

If using several thermistors, push the first thermistor(s) as deep into the well as it will possibly go, then follow up by inserting additional thermistor(s).

Only one thermistor can go through the terminal block on the tank, with the other thermistors wired directly to the other heat pump units' thermistor wire.

Existing Tanks
Sanden tanks have been developed to maximize performance and efficiency.

For correct unit operation, it is important that the heat pump receives cold water, therefore we do not permit existing water heaters or tanks to be used.

Freeze Protection

The basic design for a Sanden system requires piping potable water to the heat pump.

Eco Cute systems are designed to be able to lift water temperatures over 100°F quickly and efficiently, having a heat exchanger in the storage tank and a closed loop type system will significantly reduce performance and efficiency.

This results in water being potentially exposed to freezing outdoor temperatures, so strategies are set up both in installation and the unit control system to minimize the potential of a freeze-up.

1. **Minimal Water Piping Outdoors** – Plan your job site and unit location to penetrate into the building adjacent to the heat pump
   Use ¾" minimum thick closed cell insulation on the external piping
   Tape joints and ensure that none of the system piping is exposed

2. **Control Logic** – Two stages of freeze protection built into the control logic.

   Stage 1; Unit measures Inlet water temperature or outlet water temperature below 39°F (4°C), with an outside air temperature less than 30°F (-1°C)

   Stage 2; If the outside air temperature is at or below the temperatures in the table below, freeze protection will be triggered based on timing, not inlet & outlet water temperatures.

   Timing starts once the compressor has cycled off in normal operation, unless power is lost to the unit, in which case the timing will restart at zero when power is restored.

Outside Air Temperature	Interval time
LESS THAN -16 DegC (3 DegF)	1 Hour
BETWEEN -12 DegC (10 DegF) & -16 DegC (3 DegF)	3 Hours
BETWEEN -1 DegC (30 DegF) & -12 DegC (10 DegF)	4 Hours

When the freeze protection cycle starts initially the water pump will operate, then the compressor will start 3 minutes later.
Water will be heated to the set-point temperature and the compressor will continue to operate until the return water to the heat exchanger reaches 122°F.

Once the compressor stops the timing will begin again and based on the ambient temperature freeze protection will begin again after the appropriate time period has passed.

3. **Trace Heat** - To protect the piping between the tank and heat pump, we recommend that trace heat be installed in applications where the winter design ambient is below 30°F.

   Self-regulating trace heat 6W per foot is recommended.
   Sanden provides as an optional extra a 6ft length of trace heat cable,
   Part # FG2-6L.

   This length is designed to install on both the hot and cold water pipes attached to the unit and connected to the mains voltage wiring for the unit.

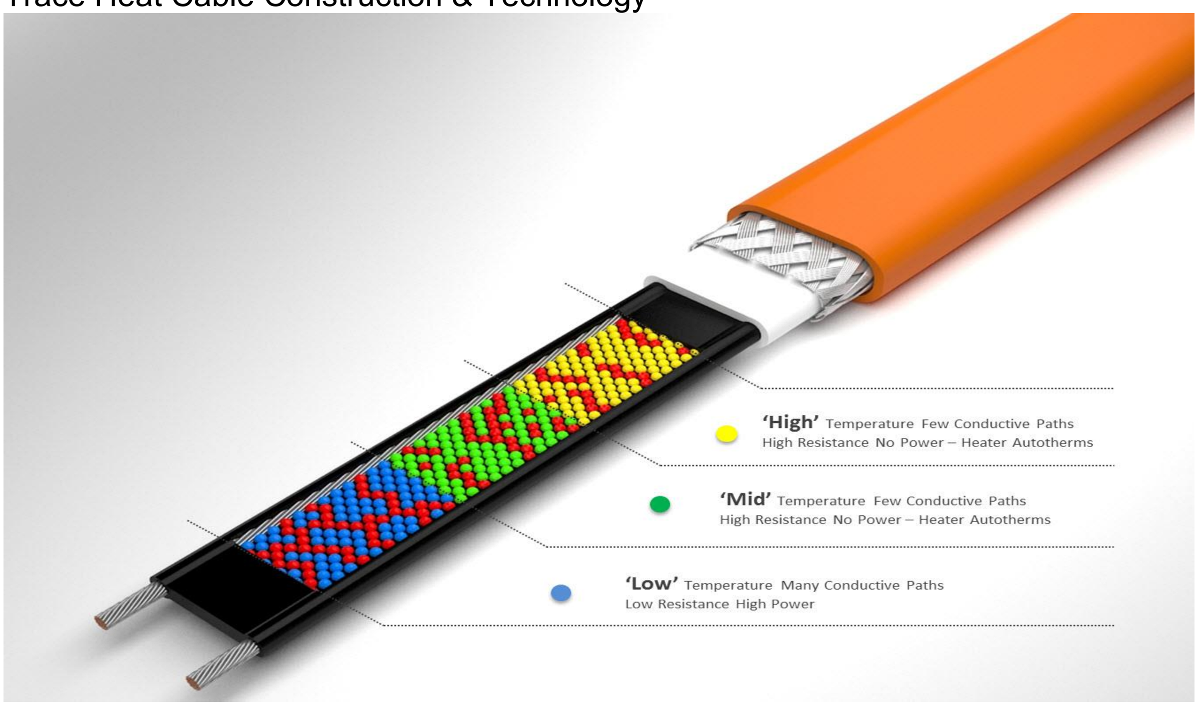
   The Sanden trace heat cable selected will regulate based on the exact temperature down to the inch that the cable senses.

   Sanden recommends that the trace heat cabling start at the top connection set, then wrap around the hot water supply piping (under the insulation) and cross over to the cold water inlet piping inside the building (minimizes the length of cable exposed to the air, then finish at the bottom connection set.

   Follow the instructions provided in the trace heat kit for detailed information on the cable instruction.

   Field testing has shown that when correctly installed, self-regulating trace heat will use less than 0.3% of the total energy consumed by the Sanden unit.

Trace Heat Cable Construction & Technology



4. **Power Outage**

If the mains power is cut to the system for whatever reason, it is acceptable to run the unit using a generator.

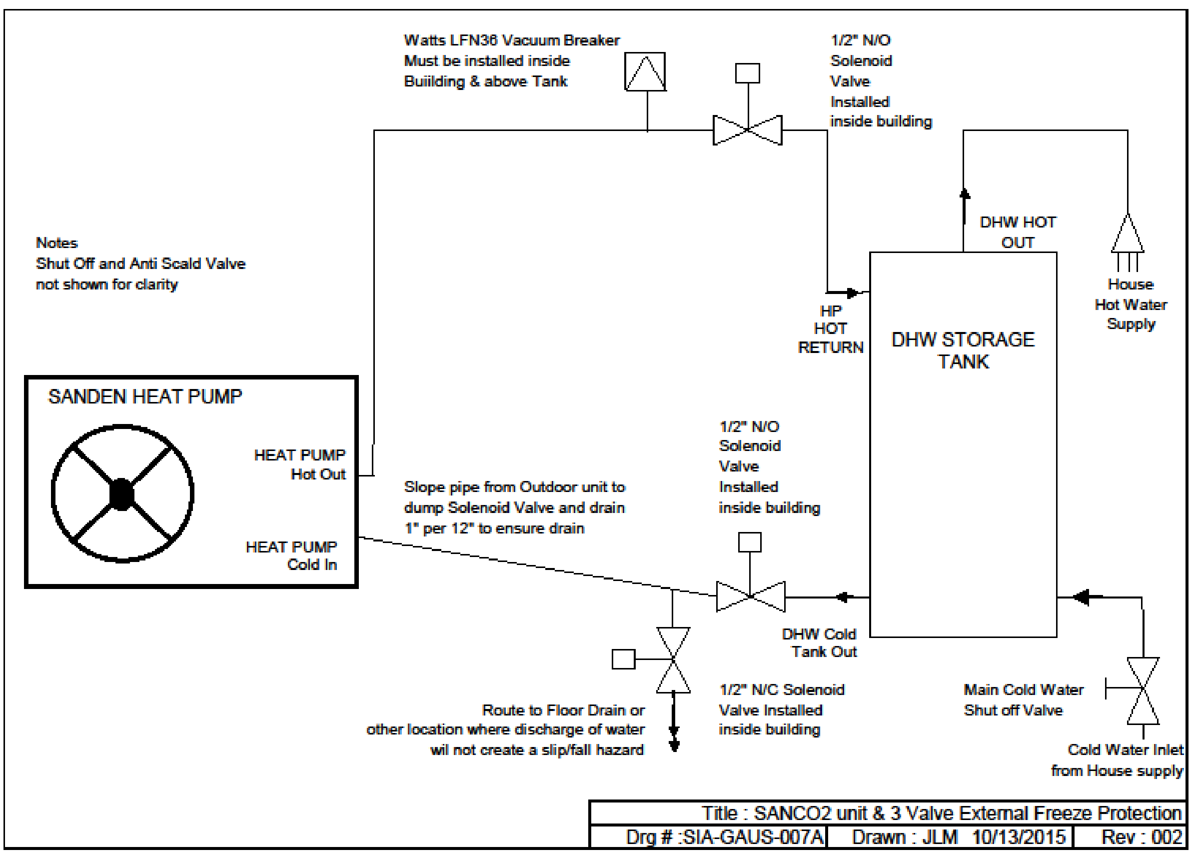
The unit will consume a maximum of approximately 2.5kw at -20°F ambient, so ensure that the generator is sized correctly.

However, without backup power there is a risk of the 0.6 gallons of water contained in the outdoor unit and the approximate maximum of 1 gallon of water in the interconnect piping may freeze.

Sanden has conducted tests where the unit has been left without power for 24 hours in a 25°F ambient and no freezing was reported.

The water in the outdoor unit and piping can be drained manually using the air bleed screws, however the tank will need to be isolated before draining.

An automatic system based on a drain back philosophy is available using three solenoid valves and a vacuum breaker to both isolate the tank and to drain down the outdoor unit and piping on power being cut.



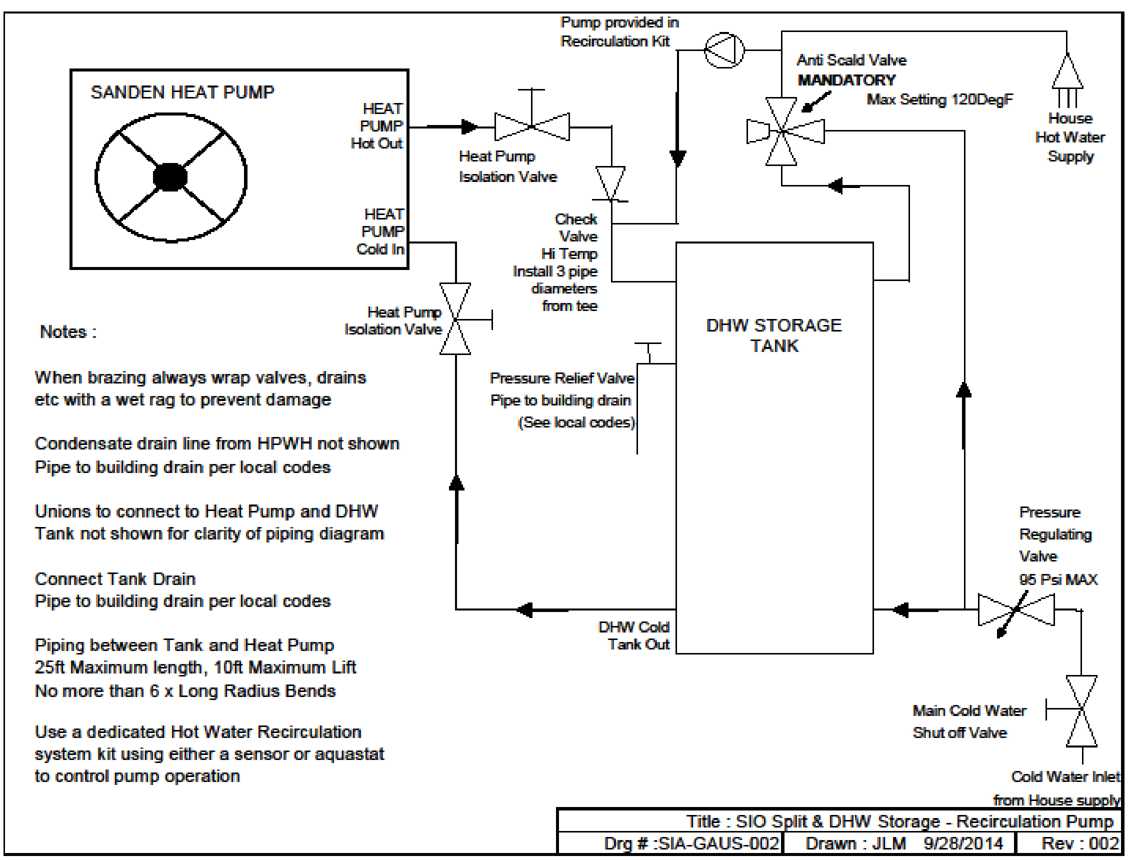
Recirculation

These types of systems are often used to ensure hot water is available at the furthest fixture from the storage tank.

Multiple types of recirculation systems are available commercially.
Sanden only permits the use of systems that use either a sensor or an aquastat to control the pump. Timer systems are not permitted.

The recirculation system should only operate to clear the plug of cold water from the piping, typically this plug is less than 2 gallons in a residential application.
For commercial recirculation applications – please contact technical support.

Pipe Size	Water Volume per Foot of pipe	Water Volume per 50ft of pipe
½"	0.01	0.5
¾"	0.02	1.2
1"	0.04	2.1



Heat Pump Control Modes

Time Setting
As part of the water heating cycle logic refers to the current time, it is necessary to set the clock on the controller before starting to use the product.

Commissioning Mode
After the mode is selected, press the Enter key to select an option mode from the five modes described below.

Heat Setting Mode
Set the heating mode to either ON (unit runs) or OFF (unit cannot operate).

Temperature Setting Mode
The water temperature settings available are 130°F, 140°F, 150°F, 160°F, 165°F and 175°F (55°C, 60°C, 65°C, 70°C, 75°C and 80°C)

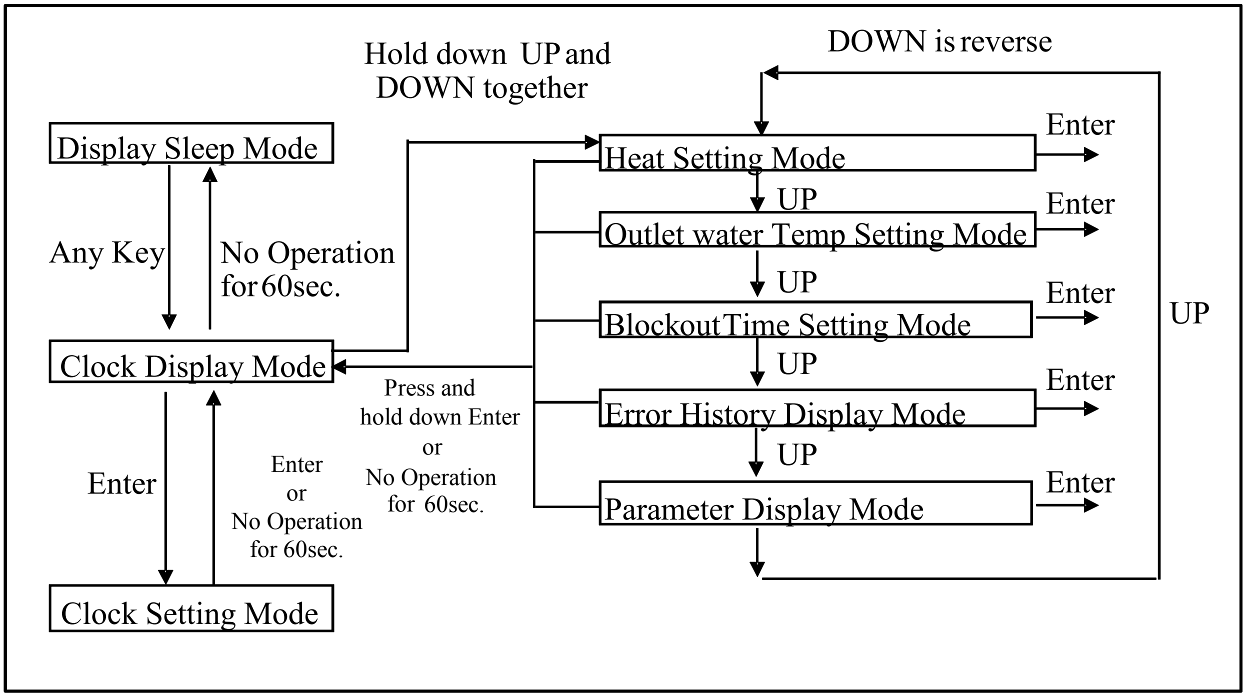
Block Out Time Setting
This mode is used to set a single block out time that prevents the heat pump unit operation within that chosen time period.

Error History
This records all errors that have occurred on the system and can be used for troubleshooting after an error code has been cleared by cycling the power to the unit.

Parameter Display
This displays all of the values currently measured by the unit's temperature sensors and can be used for troubleshooting and general unit performance questions.

Setting Panel Location
The setting panel is located under the top cover and the display can be viewed through the window above the water fitting side of the heat pump and is used to navigate and select between the modes listed above.

Cont.

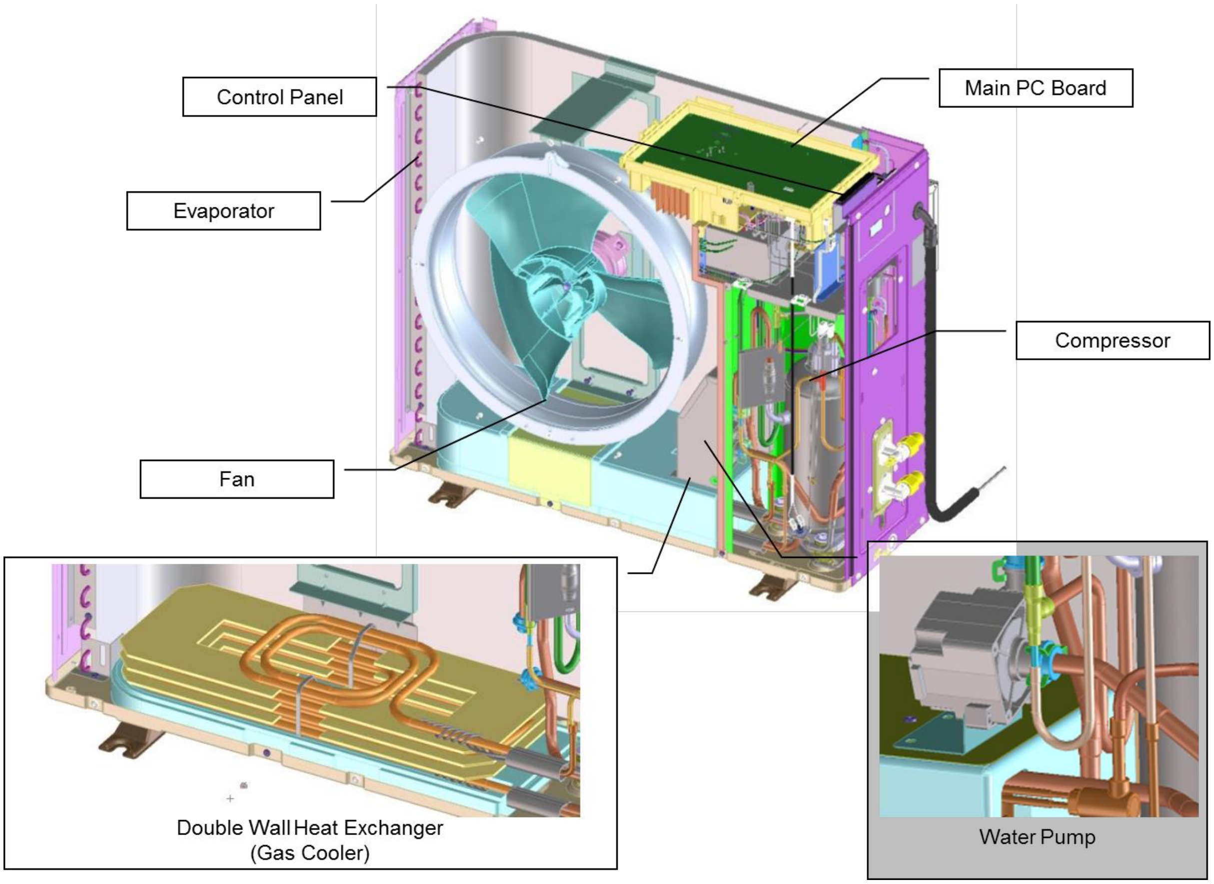


Parameters
In the parameter mode, the system will display control values used by the unit.

When a temperature value is displayed, it will show as °C x 10 for example 0580 = 58°C or when converted 136°F. To convert use this formula; °F = (°C x 1.8) +32

Parameter	What is being measured
00	Tank Temperature : Shown as °C multiplied by 10
01	Compressor Operating Time (Defrost & Freeze Protection) : Hour
02	Compressor Starting Frequency : Hz
03	Control Software Rev #
04	HP Outlet Water Temperature : Shown as °C multiplied by 10
05	HP Inlet Water Temperature : Shown as °C multiplied by 10
06	Discharge Line Temperature : Shown as °C multiplied by 10
07	Ambient Temperature : Shown as °C multiplied by 10
08	Compressor Operating Frequency : Hz
09	Fan Motor Speed : RPM
10	Pump Rotational Speed : RPM

Inside the Heat Pump



Variable Speed Fan
The fan speed is based on the ambient temperature for maximum capacity & efficiency.

Water Pump
Water flow is controlled by a variable speed water pump located inside the heat pump, the flow rate is varied to maintain the set-point supply temperature.

PCB
The PCB constantly monitors and adjusts the operation of the heat pump to maintain capacity, efficiency and reliability

Setting/Operation Panel
Used to navigate through each setting for the heat pump unit.

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Error Codes

Outdoor Unit Self Diagnosis
The outdoor unit has a built-in self-diagnostic system that will register 82 different faults based on the sensors and control logic of the outdoor unit.

The setting panel on the unit will display the numerical value of the error code with a red light. All of the error codes are listed in the Installation and Owners Manuals provided with the unit- and cause the heat pump to shut down simultaneously.

Inadequate Flow
Restricted water flow to and from the heat pump will ultimately result in an error code.

If this issue arises, make sure the pipe size is correct, the pipe length/lift is inside the maximum, check the heat pump piping for blockage or kinking, look for freezing if in a cold climate, ensure all water shut off valves are open, and ensure water is supplied to the system from the building.

System Communication
A system control error show up occasionally on a heat pump unit.

For a communication/system control error - Error Code 40 to 82 – perform the following checks:

- Check that all wire connections are firmly attached to the PCB.
- Check the unit for proper voltage at various points.

Clearing Errors
To clear an error code after it has been corrected, turn off power to the unit and wait 3 minutes before restarting.

The error code will now be accessible in the Error History mode.

Error Code	Error Explanation
E000	No error code reported
E001	HP Water Outlet Over Temperature 1
E002	HP Water Outlet Over Temperature 2
E003	HP Outlet Temp thermistor detection error
E004	HP Discharge Over Temperature 1
E005	HP Discharge Over Temperature 2
E006	HP Discharge Temperature Thermistor detection error
E007	High Pressure Error
E008	High Ambient Temperature Defrost Drive error
E009	HP Defrost thermistor detection error
E011	HP Inlet Temp thermistor wire break or reading value = -22°F
E012	HP Outlet Temp thermistor wire break or reading value = -22°F
E013	HP Discharge temp thermistor wire break or reading value = -24°F
E014	HP Defrost thermistor wire break or reading value = -58°F
E015	HP Ambient Temp thermistor wire break or reading value = -58°F
E016	Tank thermistor wire break or reading value = -22°F
E021	HP Inlet Temp thermistor wire break or reading value = 212°F
E022	HP Outlet Temp thermistor short circuit or reading value = 302°F
E023	HP Discharge thermistor short circuit or reading value = 302°F
E024	HP Defrost Temp thermistor short circuit or reading value = 212°F
E025	HP Ambient Temp thermistor wire break or reading value = 212°F
E026	Tank thermistor short circuit or reading value = 248°F
E031	Fan Motor Locked
E032	Fan Motor Revolution error
E034	Water Pump locked

Error Code	Error Explanation
E041	INV Compressor Start error
E042	INV Communication error
E050	INV Transient Over Current error at Converter
E051	INV Transient Over Current error at Inverter
E052	INV Transient Over Current Software error at Inverter
E053	INV Transient Over Current Software error at Converter
E054	INV Temperature Sensor error
E055	INV Heatsink Temperature error
E056	INV Overload Detection error
E057	INV Power Supply Low Voltage error
E058	INV Power Supply Over Voltage error
E059	INV Inverter Current Detection error
E060	INV Transient Power Cutoff Detection error
E061	INV Transient Power Cut off Detection error 1
E062	INV Transient Power Cut off Detection error 2
E063	INV Control Circuit Board Power Supply error
E064	INV Transient Voltage Drop Detection error
E065	INV Motor Operation Detection error
E066	INV Converter Current Detection error
E080	Outlet Water Temperature Rise error
E081	Compressor Overload Protection
E082	Compressor Low Current Protection

Error Code Explanation

<table>
<tr><th>Code</th><th>Error</th><th>Corrective Action</th></tr>
<tr><td>E001</td><td>HP water outlet over temperature 1
Temp Sensor reading 187°F</td><td rowspan="2">1. Check the heat pump piping for blockage/debris
2. Check piping size, length, kink, excessive number of bends
3. Check outdoor piping is not sitting in the sun without insulation and preheating the water
4. Check for frozen pipes
5. Ensure mains water supply is ON
6. Ensure all shut off valves are open
7. Check the water circulation pump is running, replace the pump if not
8. Make sure each unit has its own separate tank thermistor.</td></tr>
<tr><td>E002</td><td>HP water outlet over temperature 2</td></tr>
</table>

Code	Error	Corrective Action
E003	HP outlet temperature thermistor detection error reading < 86°F when compressor has been running for 30 minutes	1. Check if the thermistor is out of the mounting pocket on the water outlet pipe
E004	HP discharge over temperature 1 Temp sensor reading of 266°F	1. Check & replace the discharge temp thermistor 2. Reconnect the expansion valve PCB connector, check to ensure connection 3. Replace the expansion valve (together with PCB), or the entire heat pump unit 4. Refrigerant flow blocked – replace unit
E005	HP discharge temperature Thermistor detection error 2	(shared with E004)
E006	HP Discharge temperature thermistor detection error reading < 113°F when compressor has been running for 30 minutes	1. Check if the thermistor is out of the mounting pocket on the water outlet pipe 2. Check if the Expansion Valve Coil or wiring has become disconnected or not connected properly 3. Check resistance on Expansion Valve Coil, should be 46Ω across wires 4. Refrigerant Leak – Check for signs of oil, replace HP
E007	High Pressure Switch Open Refrigerant Pressure > 2000 Psig	1.Check wiring on the High Pressure switch – check switch continuity 2.Check piping for blockage and/or freeze up preventing flow in or out of the unit 3.Ensure all isolation valves are open & tank is completely filled 4.Check water pump for operation (parameters) ensure power wiring is connected to PCB 5.Check all the air is bled from the heat pump 6.Check if inlet or outlet temp, discharge sensor have fallen out of their wells 7.Check Expansion Valve Coil power connection and Coil Resistance

Code	Error	Corrective Action
E008	High Ambient Defrost Drive – Unit is trying to defrost in an Ambient Temperature > 68°F	1. Check if the Evaporator air flow is blocked or recirculating 2. Check Evaporator Coil for dirt and debris 3. Check Ambient Temperature sensor resistance/connection 4. Check Defrost Temperature resistance /connection
E009	HP Defrost Thermistor detection error not sensing 37°F or less with at least 30 minutes of compressor operation	1. Check if the Defrost thermistor has fallen out of its well on the Evaporator coil 2. Check Resistance and Connection of the Defrost thermistor

E011	HP Inlet Temp thermistor wire break or reading value = -22°F
E012	HP Outlet Temp thermistor wire break or reading value = -22°F
E013	HP Discharge temp thermistor wire break or reading value = -24°F
E014	HP Defrost thermistor wire break or reading value = -58°F
E015	HP Ambient Temp thermistor wire break or reading value = -58°F
E016	Tank thermistor wire break or reading value = -22°F
E021	HP Inlet Temp thermistor wire break or reading value = 212°F
E022	HP Outlet Temp thermistor short circuit or reading value = 302°F
E023	HP Discharge thermistor short circuit or reading value = 302°F
E024	HP Defrost Temp thermistor short circuit or reading value = 212°F
E025	HP Ambient Temp thermistor wire break or reading value = 212°F
E026	Tank thermistor short circuit or reading value = 248°F

- These codes are all based on the 5 temperature sensors on the unit and tank sensor not giving a value back to the outdoor PCB.
- All these sensors are resistance based, so they can be checked with a multimeter and the resistance reading checked vs ambient, water temperature and the parameter value in the PCB.
- Apart from the tank thermistor, all other thermistors are provided in a single assembly.

GS3-45HPA & GUS-A45HPA Thermistor Values

Inlet Water Temperature Thermistor, Outlet Water Temperature Thermistor

Temp (°F)	14	32	50	68	86	104	122	140	158	176	194	212
Temp (°C)	-10	0	10	20	30	40	50	60	70	80	90	100
Resistance (kΩ)	37.5	23.7	15.5	10.3	7.0	4.9	3.5	2.5	1.9	1.4	1.1	0.8

Ambient Temperature Thermistor

Temp (°F)	14	32	50	68	86	104	122	140	158	176	194	212
Temp (°C)	-10	0	10	20	30	40	50	60	70	80	90	100
Resistance (kΩ)	12.00	7.20	4.45	2.83	1.85	1.24	0.84	0.59	0.42	0.31	0.23	0.17

Defrost Temperature Thermistor

Temp (°F)	14	32	50	68	86	104	122	140	158	176	194	212
Temp (°C)	-10	0	10	20	30	40	50	60	70	80	90	100
Resistance (kΩ)	9.39	6.00	3.94	2.64	1.82	1.27	0.91	0.66	0.49	0.37	0.28	0.22

Discharge Temperature Thermistor

Temp (°F)	14	32	50	68	86	104	122	140	158	176	194	212
Temp (°C)	-10	0	10	20	30	40	50	60	70	80	90	100
Resistance (kΩ)	276.0	162.0	98.3	61.5	39.5	26.1	17.6	12.1	8.5	6.1	4.5	3.3

Tank Temperature Thermistor

Temp (°F)	14	32	50	68	86	104	122	140	158	176	194	212
Temp (°C)	-10	0	10	20	30	40	50	60	70	80	90	100
Resistance (kΩ)	54.6	32.4	19.9	12.5	8.1	5.3	3.6	2.5	1.8	1.3	0.9	0.7

Code	Error	Corrective Action
E031	Fan motor locked	1. Reconnect the connector, check if it is off the PCB 2. Check motor will spin, if not replace the fan motor 3. Check to make sure that nothing is stopping the fan from rotating – not much torque available 4. Check fan is not being affected by winds – install a baffle if needed 5. Check parameters to see motor speed
E032	Fan motor revolution error	
E034	Water circulation pump locked or circulating below 150 RPM	1. Check the heat pump piping for debris or valves being closed 2. Confirm that the connector for the water circulation pump is connected to the PCB correctly 3. Replace the water circulation pump
E041 ~ E066	System control error – Solution – Replacement PCB or possibly Replacement Unit	Replace the PCB - These are the eccentric error codes that are seen with inverter drive units – such as IPM Overcurrent. Always perform the 3 system checks: Incoming voltage must be 187V to 253V – 1 Ph. Check power wiring at the terminals for loose wires. Check wiring to the compressor from PCB. Check compressor resistance. RED-WHT WHT-BLU BLU-RED 0.802 0.802 0.802
E080	Outlet Water Temperature Rise, unit is not hitting set point water & water pump is running continuously	1.Check power wiring voltage may be down causing reduced operation 2.Check piping for blockage and/or freeze up preventing flow in or out of the unit 3.Ensure all isolation valves are open & tank is completely filled 4.Check water pump for operation (parameters) ensure power wiring is connected to PCB 5.Check all the air is bled from the heat pump 6.Check if inlet or outlet temp, discharge sensor have fallen out of their wells 7.Check Expansion Valve Coil power connection and Coil Resistance should be 46Ω

Code	Error	Corrective Action
E081	Compressor Overload Protection, high load and high current draw on the compressor	1.Check power wiring, voltage may be down causing high current draw, make sure power does not get cut off in operation 2.Check piping for blockage and/or freeze up preventing flow in or out of the unit 3.Ensure all isolation valves are open & tank is completely filled 4.Check compressor wiring is connected to PCB 5.Check all the air is bled from the heat pump 6.Check if inlet or outlet temp, discharge sensor have fallen out of their wells 7.Check Expansion Valve Coil power connection and Coil Resistance should be 46Ω
E082	Compressor Low Current Protection, low load and low current draw on the compressor	1.Check power wiring, voltage may be high causing low current draw, make sure power does not get cut off during operation 2.Check piping for blockage and/or freeze up preventing flow in or out of the unit 3.Ensure all isolation valves are open & tank is completely filled 4.Check compressor wiring is connected to PCB 5.Check all the air is bled from the heat pump 6.Check if inlet or outlet temp, discharge sensor have fallen out of their wells 7.Check Expansion Valve Coil power connection and Coil Resistance should be 46Ω

Maintenance

Split systems are very easy to maintain, in reality they are not very different to the maintenance on a Central A/C or heat pump system, and can be placed on a similar maintenance schedule.

1. Heat Pump
If the heat pump unit is installed outdoors, it will be exposed to the elements.

Remove the top and side covers of the unit and check the evaporator for any dirt or debris.

On the Gen2 unit, there is a filter on the cold water inlet connection – periodically, it needs to be removed and the filter cleaned.

Check for leaks of any kind from pipes and tears in insulation.

To clean the unit, simply blow away the debris with an air hose or spray the unit down with a water hose, coil cleaning solutions can be used without problem.

2. System
Draw water from the tank via a faucet: check the delivered mixed temperature vs customer requirement. Adjust the mixing valve if needed.

Draw water from the tank to start the heat pump. Check the unit parameter mode to check delivered water temperature vs set-point.

Check error history. Note any recent or new error codes

If drain down freeze protection system is installed, cycle the power to check valve operation – restart system and ensure unit operation.

3. Tank
Open the pressure relief valve to prevent sticking, ensure water is discharged.

Check the thermistor connection in to the thermistor well and the wiring connection to the terminals (both sides of the terminal).

Warranty Information

The Sanden warranty is 10 years on the Heat Pump refrigeration circuit, 10 years on all other parts, 15 years (prorated after 10 years) on the tank, and 3 years on labor costs.

Warranty support first starts with the distributing company.
Initially, they should be able to provide information on the correct application, shipping and handling procedures for the product and general installation advice.

Always check the product packaging prior to leaving the distributor, note any damage and return the product to the distributor if necessary – DO NOT install damaged units and attempt to claim as a warranty.

Should a problem occur with the product, the distributor will be the first point of contact in the warranty process. A warranty claim can be filed either online or a request for a form can be sent to *info@sandenwaterheater.com.*

Following proper procedures will expedite warranties.

A warranty claim form should be filled out completely and will be reviewed by a Sanden Technical Support employee. After review, the claim will be processed and filed. If it is not filled out correctly, additional time may be required to complete the information required.

If a claim is determined to be valid, Sanden may contact the contractor or technician to review the installation. When approved, warranty parts will be expedited at Sanden's expense.

Please complete the information on the warranty claim form as completely as possible before submitting to expedite the warranty process.

Heat pump serial numbers are CCXXXXX- The entire serial number is requested when completing a claim.

On the tank unit, the serial number is located underneath the pressure relief valve and is SWLXXXX.

Once warranty repair is complete, unless specifically requested that the part be returned to Sanden, the failed component can be field scrapped.

Glossary

Uniform Energy Factor

A water heater's energy efficiency is determined by the energy factor (UEF), which is based on the amount of hot water produced per unit of energy consumed over a typical day. The higher the energy factor, the more efficient the water heater.

First Hour Rating

First Hour Rating is a calculated amount used to explain the performance abilities of a water heater within the first hour of use when recovered to the thermostat setting. In other words, when determining the first hour rating, you will start with a fully heated tank of water.

Tank Unit	UEF	First Hour Rating
SAN-83SSAQA	4.10	111 Gallons
SAN-43SSAQA	3.09	71 Gallons

Notes

Manual Notes

Thank you for reading this manual, we hope it has been informative.

Please note that all Sanden units are subject to continuous improvement and specifications can change without notice.

Always check the information supplied with the unit before installation.

All sizing guides contained in this manual are suggestions only, based on our experience and knowledge, please perform an accurate DHW load analysis prior to selecting and installing your Sanden HPWH system.

We hope you enjoy the hot water produced from your Sanden SANCO$_2$ unit.

John, Maho & David

7.2 Sanden $SanCO_2$ Installation Manual

SANDEN
Delivering Excellence

Installation manual

Sanden Heat Pump Water Heater with Natural Refrigerant (CO2)

Covering model numbers for residence

<u>Heat Pump Unit GS3-45HPA-US</u>

※<u>This manual is for TO BE USED by the installing Contractor only.</u>

This appliance is not to be installed by unqualified and unlicensed **pers**ons, please read and understand this manual prior to installing and operating the unit.

Contents

Note: Every care has been taken to ensure accuracy in preparation of this publication. No liability can be accepted for any consequences that may arise as a result of its application.

Introduction

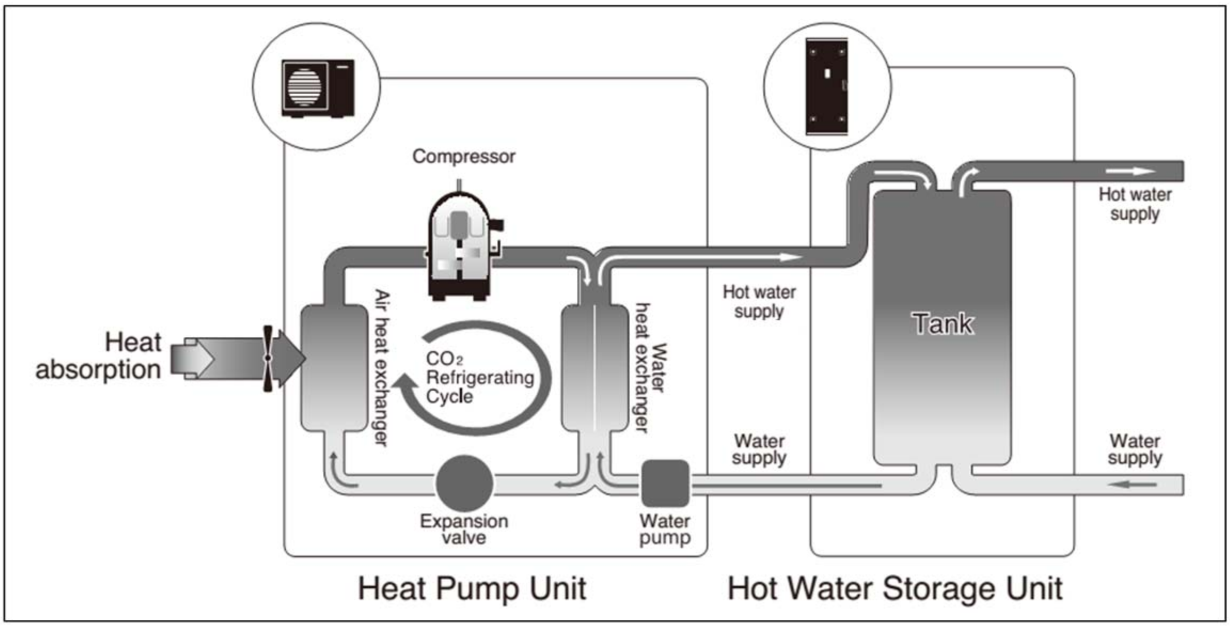
The Sanden SANCO$_2$ Heat Pump Water Heater System has been designed using the latest refrigeration technology to remove the heat from the air to heat water. The refrigerant we use is CO_2 which does not contribute to global warming so it allows us to help keep a clean healthy earth for future generations.

By using CO_2 as the refrigerant, we have produced one of the most energy efficient units currently available. It is even more efficient when connected to demand response power and the noise level is so low it will operate unobtrusively at any time.

How it works

The Sanden SANCO$_2$ Heat Pump Water Heater System heats water by transferring the heat from the surrounding air to the water using a refrigerant. The refrigerant is heated by a heat exchanger that absorbs heat from the surrounding air (Figure 1).

Figure 1: Heat Pump Water Heater System



Note:
The unit must have a minimum of 5 hours continuous power available at all time to allow the unit to operate without affecting reliability.

Installation details

This Sanden SANCO$_2$ Heat Pump Water Heater System must be installed by licensed personnel in accordance with local building codes:

- Installing contractor should be licensed by applicable state/province and municipal authorities to install an Electrical & Plumbing product.

- The unit has been designed for heating potable domestic hot water. Any other usage, such as use for DHW in combination with space heating requires both a heat exchanger suitable for local codes to be installed on the system to separate potable and non-potable water and consultation with Sanden.

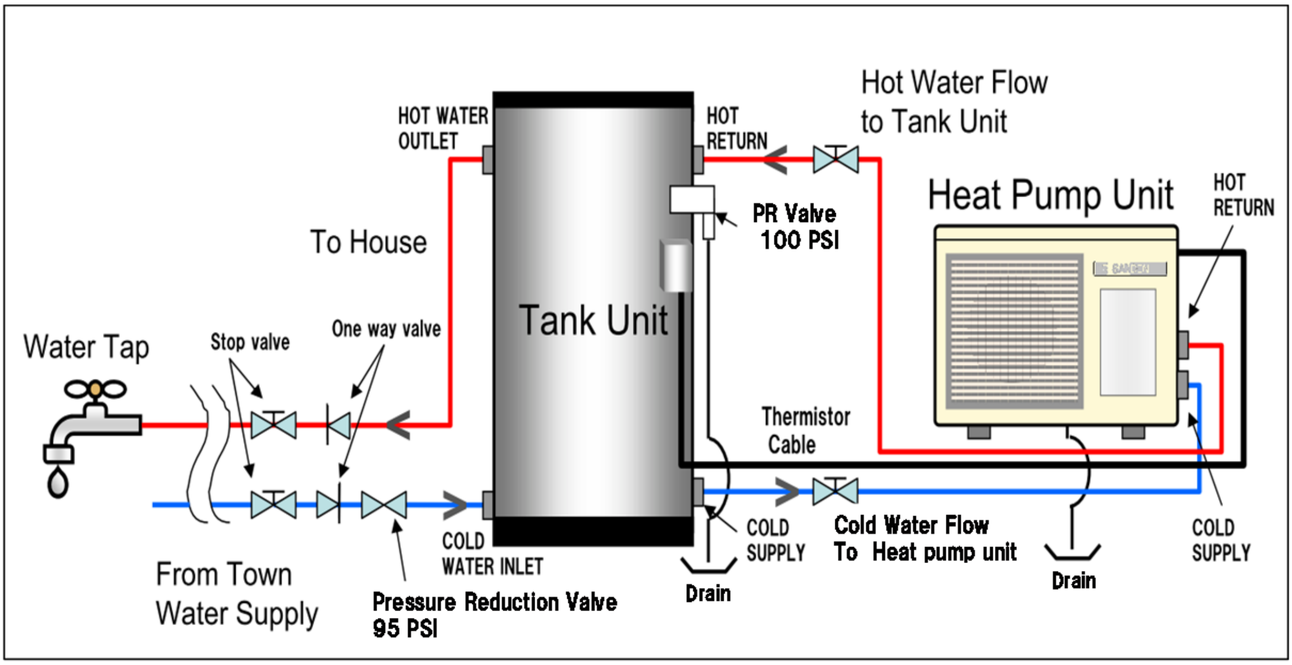
- The unit is designed to operate when connected to the water supply with a maximum operating pressure of 95PSI (655 kPa). To ensure the mains pressure does not exceed this, first check incoming cold water mains pressure, and then a pressure regulating device must be connected to the water supply line.

- ⚠ **DANGER** This system delivers hot water exceeding 120 ^{o}F (50 ^{o}C). Installation of a temperature tempering device is **<u>MANDATORY</u>** to avoid potential scalds and burns.

- The unit must be stored and transported in an upright position. Failure to do so may render the unit faulty. Such failure is not covered under any warranty agreements.

Failure to comply with the above conditions will void the warranty.

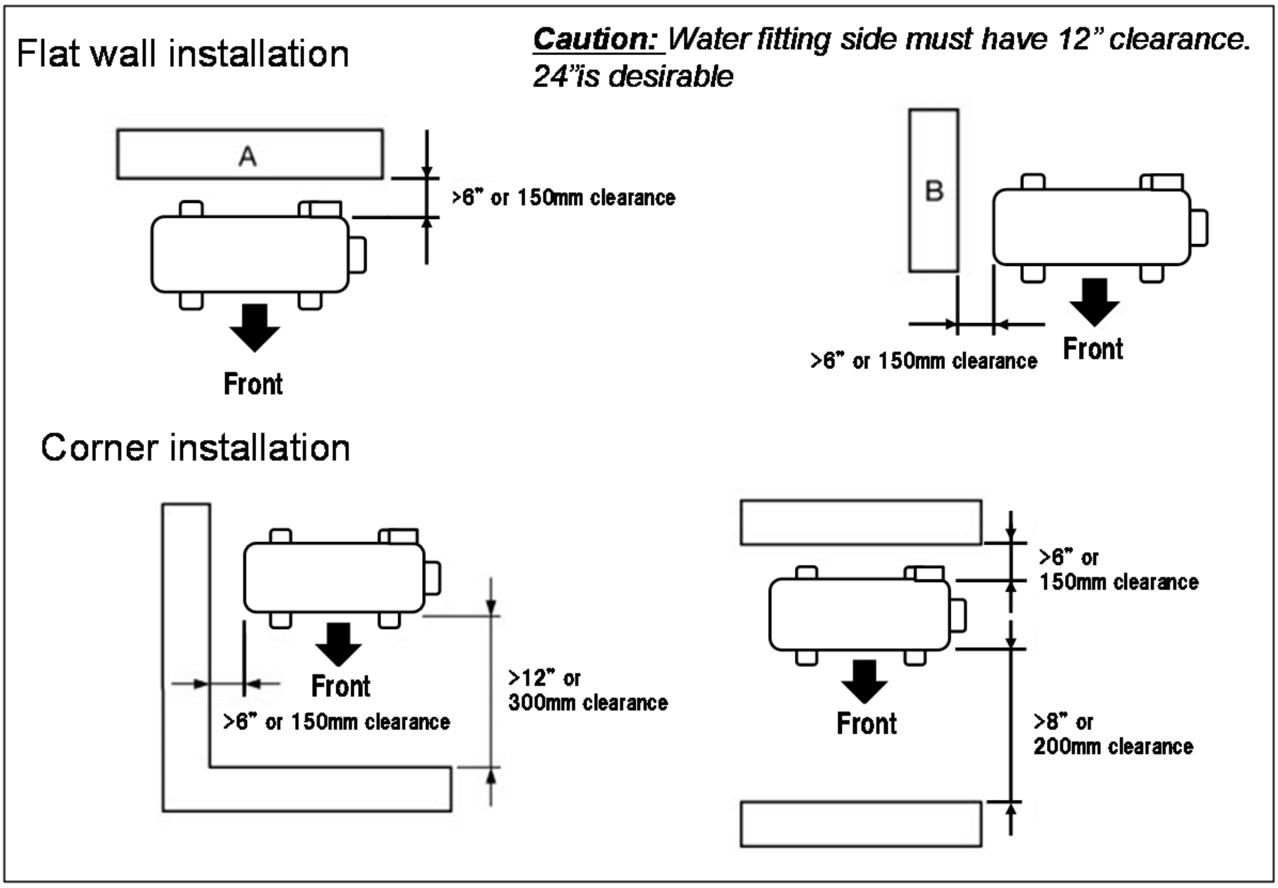
Figure 2: Typical installation layout



Installation location

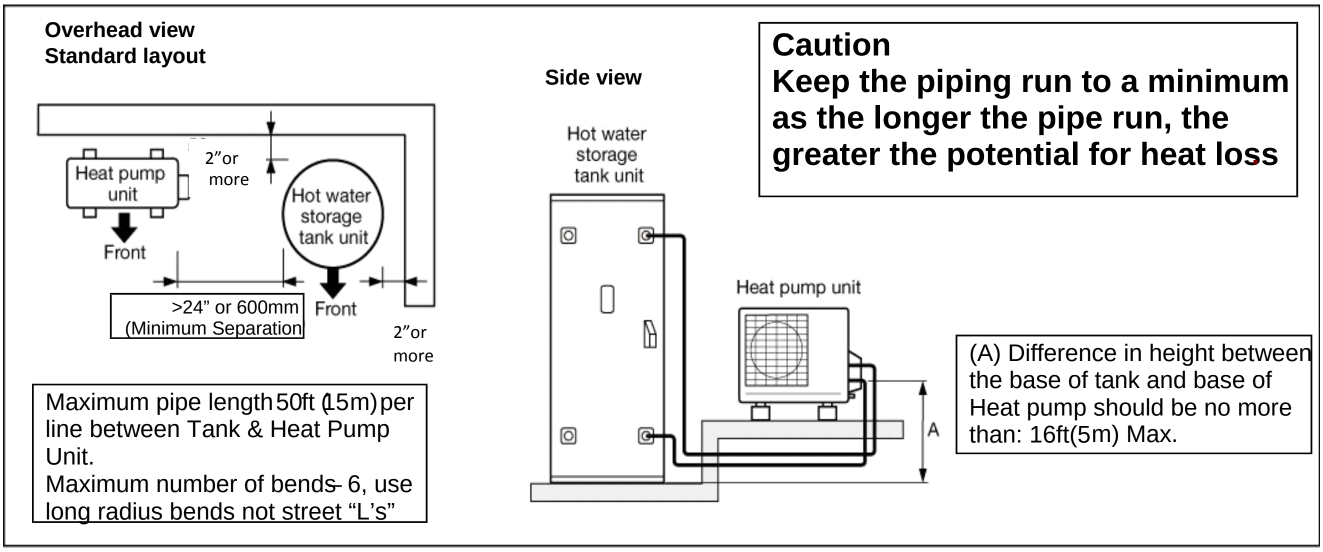
- For the most efficient operation of the heat pump unit, the optimum location is the warmest side of the property and there should be sufficient space for the air to circulate through the unit.
- The tank unit should be located as close as possible to the most frequently used hot water outlet such as a bathroom. It may be located either outside or inside. The heat pump unit must be located outside and as close as practicable to the tank unit but not further than 50ft (15m) away from the tank.
- Ensure sufficient clearance around the heat pump unit to allow air to circulate and provide adequate space for service maintenance of the unit (Figure 3).
- Although the heat pump unit is very quiet, it is preferable to avoid installing it directly below a bedroom window.
- Install the heat pump unit in an area which allows sufficient ventilation. Poor ventilation may cause the unit to short cycle and this could increase power consumption by more than 10%.
- Do not install the heat pump unit in a confined space without making provision for intake or exhaust airflow for the unit.
- If the heat pump unit is installed facing a wall, exhaust air may stain the wall.

Figure 3: Restrictions on where the heat pump unit can be installed (overhead view)



※1 Unit should have a minimum of 18" or 500mm space above the unit to ensure correct operation
2 Discharge Air blowing against a wall/obstacle in front of the unit may stain the wall/obstacle
3 If the unit is not able to operate with adequate airflow due to obstacles and reduced clearances, Then heating output will be reduced by approx. 10% and power consumption increased by approx.10%
4 For optimum operation install the unit per the above or in a location with no obstacles

Figure 4: Restrictions on installation with the space between the tank unit and the heat pump unit



Heat pump Unit Installation

- The surface to which the heat pump unit is installed must be firm, preferably a concrete pad or block. If the surface is firm there is no need to fix the unit to a base surface, unless there is a likelihood of high wind or local vibration.
  If the heat pump unit and tank unit are to fixed, appropriate fixing devices for the weight/expected duty should be used. It is permissible to install the Heat Pump on the side of a wall provide an adequate support is used.
  Note: For California installation the Tank section water heater must be braced, anchored, or strapped to avoid falling or moving during an earthquake. For Tank size over 52 Gallons (236l) consult your local building jurisdiction for appropriate bracing designs.
  Note: For Florida installation the Heat Pump unit should be installed in accordance with all local codes regarding Hurricane winds.

- Use appropriately treated lumber or pre-fabricated "pump ups" to raise the Heat Pump unit 4"-6" from the ground – this will allow defrost condensate to drain. In areas with significant snowfall ensure unit is mounted above the anticipated snowfall depth.

- A Pressure Relief (PR) valve **MUST** be installed during the installation of the tank unit. This is installed in a defined point near the top of the tank unit. The PR Valve must have clear drainage where escaping steam or water can flow freely. PR Valve setting should be 100 Psig.

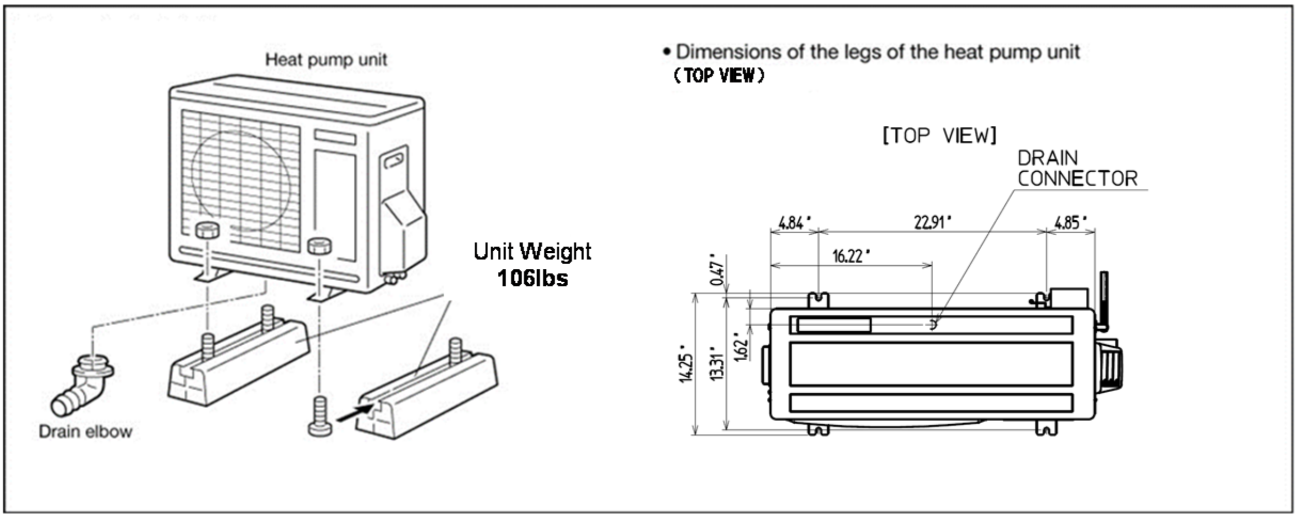
- The installation site must be well drained so that any water accumulating (such as rain or pipe leakage) will drain away and not enter the heat pump unit and the tank unit.

- Supply water pressure must be a minimum of 29 PSI (200 kPa) to ensure Heat Pump unit operation – If pressure is below 29 PSI install a booster pump to water supply.

Note:
The entire system is set up and fully functional when supplied. Once all the water and electric connections have been made, the system will operate automatically provided that mains power is available.

The only adjustments to the unit are to set the desired hot water supply temperature & set the current time on the operation panel under the top housing cover, especially if the block out time setting is desired. See Set point adjustment, current time setting, and block out time section on page 19.

Figure 5: Heat pump installation example and dimensions



- Attach the drain elbow to the drain opening located on the bottom of the heat pump unit. The drain elbow is included in the installation kit for the heat pump unit.

- Attach a drain hose with 5/8 inch (16mm) of inner diameter to the drain elbow to guide the drained water to an appropriate drain.

Water Piping Installation – Heat Pump Unit & Tank

- All piping that connects to the water supply must be installed by a licensed contractor.

- The water supplied to the system must comply with the potable water quality standard. Use of water that does not comply with this standard could result in a malfunction of the system.

-

Description	PH	TDS (Total Dissolved Solids)	Total Hardness (calcium Ion concentration)	Aluminium	Chlorides	Copper	Iron	Manganese	Zinc
Maximum Levels	6.0 to 9.0	Up to 500 ppm	Up to 200ppm or 12 grains hardness	Up to 0.2 ppm	Up to 200 ppm	Up to 1.0 ppm	Up to 0.3 ppm	Up to 0.05 ppm	Up to 5 ppm

- The water supply must have a pressure of 29 PSI (200 kPa) or higher.

- A drain trap must be installed on the drain pipe if water is to be drained to a drain pan.

- This product cannot be connected to a solar water heater.
- The piping must be insulated with ¾" to 1" closed cell insulation.
- Self Regulating Heat tape (3-5W per foot) must be installed on both Water Lines to the Heat Pump to protect the water piping in areas with freezing temperatures.
- If the piping needs brazing, make sure that all flux and flux splatter is wiped away with a wet cloth. When brazing, ensure connections are protected using a wet cloth.
- As the hot-water supply pipe will expand and contract, use sleeves when penetrating through concrete walls or slabs.
- With buried piping, an outer cover will need to be used that has had both ends sealed to avoid any ingress of rain.
- Use only heat-resistant and corrosive-resistant material to seal the pipe joints.
- Cutting and wrenching the piping material may result in oil and dust adhering to it. After processing, clean the material with a mild detergent before doing any piping work and smooth the edges to remove any scratches and burrs. (After flowing water through it verify whether any debris has accumulated on the filter of the faucet and heat pump unit pipe.)
- When using PTFE sealing tape, ensure that no tape is sticking out of the threads.
- Any heat-resistant PVC piping use is **<u>NOT</u>** recommended due to high outlet water temperature for between the heat pump and the tank as well as the tank and the mixing valve.
- Follow the manufacturer's instruction manual for the type of bond, amount to be applied, curing time, and other specifications.
- If any bond or flux has entered the tank unit and the hot water has a chemical/acrid smell, take the following countermeasures.

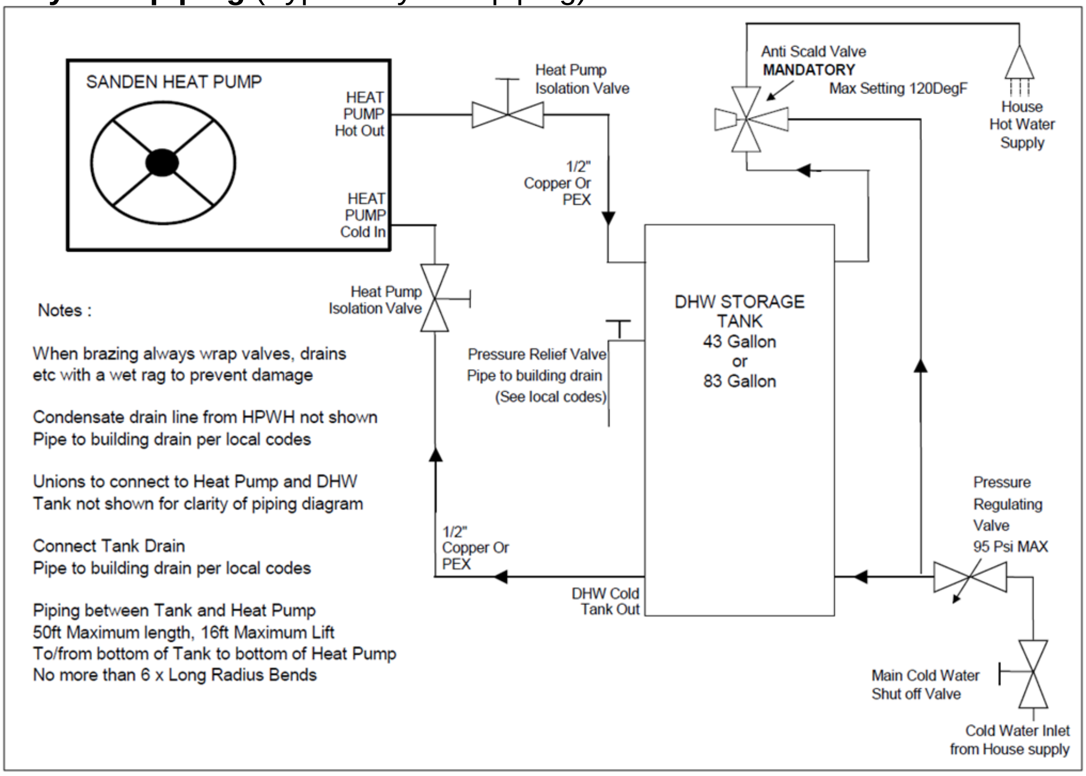
  a) After heating the water in the tank unit, drain it and clean inside the tank unit. Fill the tank unit with 26 gallons (100 litres) of water and exchange twice.
  b) Clean or change the filter.
  c) Fill up the tank unit.
  d) Drain water from the relief valve for one to two minutes.
  e) Run water from all the hot water supply faucets in the house for about ten minutes to clean inside the pipes.

Heat Pump Unit Water piping

ALL PIPING BETWEEN HEAT PUMP & TANK SHOULD BE ½" NO EXCEPTIONS

- Connect the heat pump unit COLD supply to the tank unit fitting marked Cold Supply. – ½" NPT Connection (Certain early units may use ½" BSP connections).
- Connect the heat pump unit HOT return to the tank unit fitting marked Hot Return – ½" NPT Connection (Certain early units may use ½" BSP connections).
- Connect the mains water supply to the lower fitting on the tank unit marked Cold Water Inlet.
- Connect the hot water supply pipe to the top of the tank unit marked Hot Water Outlet.
- Install the PR valve to the fitting on the tank unit marked PR valve, pipe from PR valve directly to a Building drain; do not install any shut off valve between PR valve and Building drain.
- Run water through the pipe(s) to remove any debris inside before connecting the pipe(s).
- After all the piping connections are completed, run water through the system.
- Remove the air from the system according to the instructions below on Page 15.
- Make sure all the necessary devices are mounted to the pipes as shown in diagram. If the heat pump unit piping is kinked or clogged or the air inside was not removed during the test operation, temperature of the supplied hot water may become inconsistent.

Figure 6: System piping (Typical System piping)



Mains Power/Electrical Installation

⚠ **DANGER**

- All Electrical Wiring should be done in accordance with the latest edition of the National Electrical Code (NEC) and all local State/Province and Municipality codes.
- The power requirement for the system is a dedicated 15 amp circuit fitted with a circuit breaker. This circuit may be connected to constant power or off-peak power.
- A local disconnect should be installed adjacent to the Heat Pump unit in accordance to NEC and local codes.
- **Installation of this system must be carried out only by a qualified installation technician (electrical, HVAC or plumbing).**

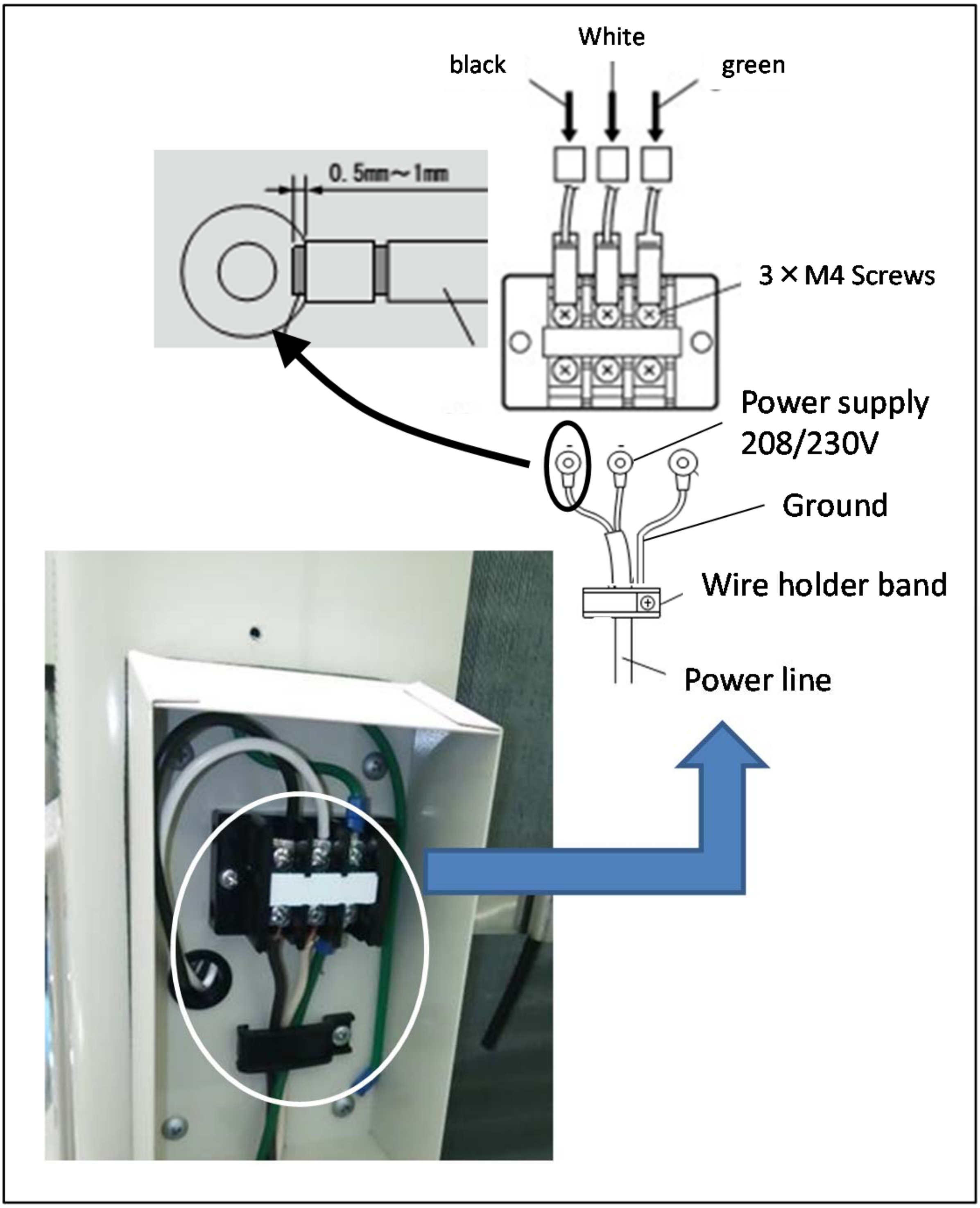
Electrical connections

- Breaker size and wiring must be sized per NEC rules for the rating plate amperage, MCA and MOP or Max Circuit Breaker.
- **Power Supply is 208/230V-1Ph-60Hz**
- **Verify that the tank unit is full of water and the water shut off valves are open before turning on the power.**

How to connect Main Power

- Remove the terminal block cover (Philips head screwdriver required)
- Connect the power wiring to the terminal block per the wiring diagram/manual.
- Ensure ground wire is connected.
- Secure the field power supply wiring below the terminal block with the screw clamp fitting.
- Re attach the terminal block cover to the heat pump unit.

Figure 7: Main Power Connection



How to connect Tank thermistor cable to Heat Pump unit

- The thermistor cable and conduit length are provided to cover 16.5 feet between the tank and the Heat Pump.

- If the units are located closer, the thermistor cable and conduit may be cut to the desired length (Figure 8).

- If the units are further apart, the thermistor cable may be extended by connecting an 18-2 AWG Shielded wire to the existing thermistor cable – connections are not polarity sensitive.

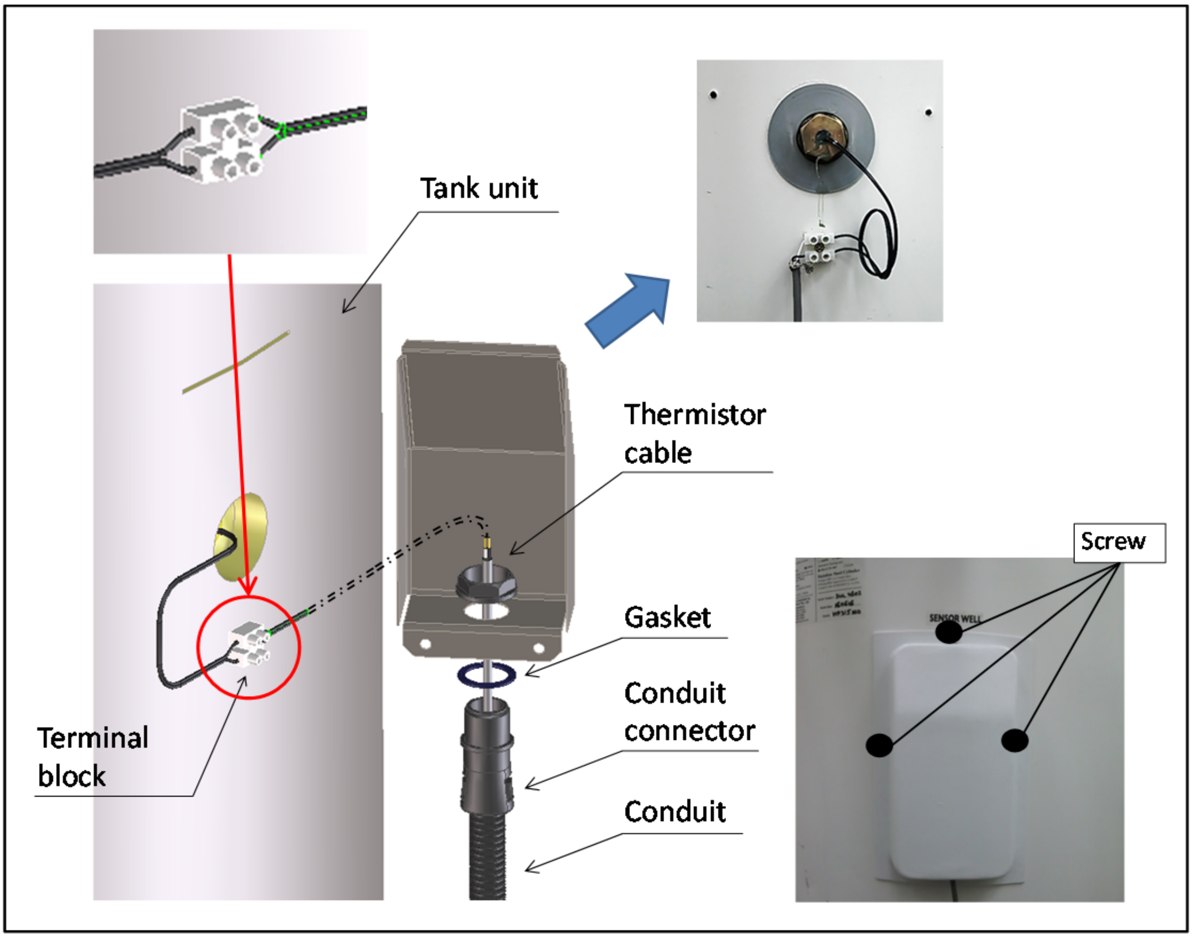
- Attach the conduit connector to the conduit end. Push the conduit into the opening on the connector until the conduit does not go any further. Pull the conduit several times to ensure the connector is fixed properly to the conduit.

- Unscrew and carefully remove the terminal block cover on the tank. Do not use unnecessary force to remove the cover as this could pull and break the cable coming out of the tank unit.

- Attach the connector on the end of the thermistor conduit coming from the heat pump unit side to the opening on the bottom of the cover on the tank unit.
  Confirm the gasket is adhered to the thread of the conduit connector before attaching the connector to the cover. If the gasket is not present, there is a risk of water getting inside the cover and this may result in a malfunction of the terminal block.

- Connect the thermistor cables to the bottom of the terminal block.
  Replace the terminal block cover back onto the tank unit and tighten the screws.

Figure 8: Connecting tank unit thermistor cable – GAUS Tanks shown as example



System operation using continuous Power Supply

- If the block out time function is selected (setting is covered on Page 18) the unit will not operate during the block out times – this function is typically used on installations that have time of use electricity tariffs.
- The water heating cycle operation starts automatically when the residual hot water in the tank unit is less than 40 gallons (150 litres).
- The system will not run if the electrical power supply is cut off. However, the system will automatically start operation, once the electric power supply is restored.

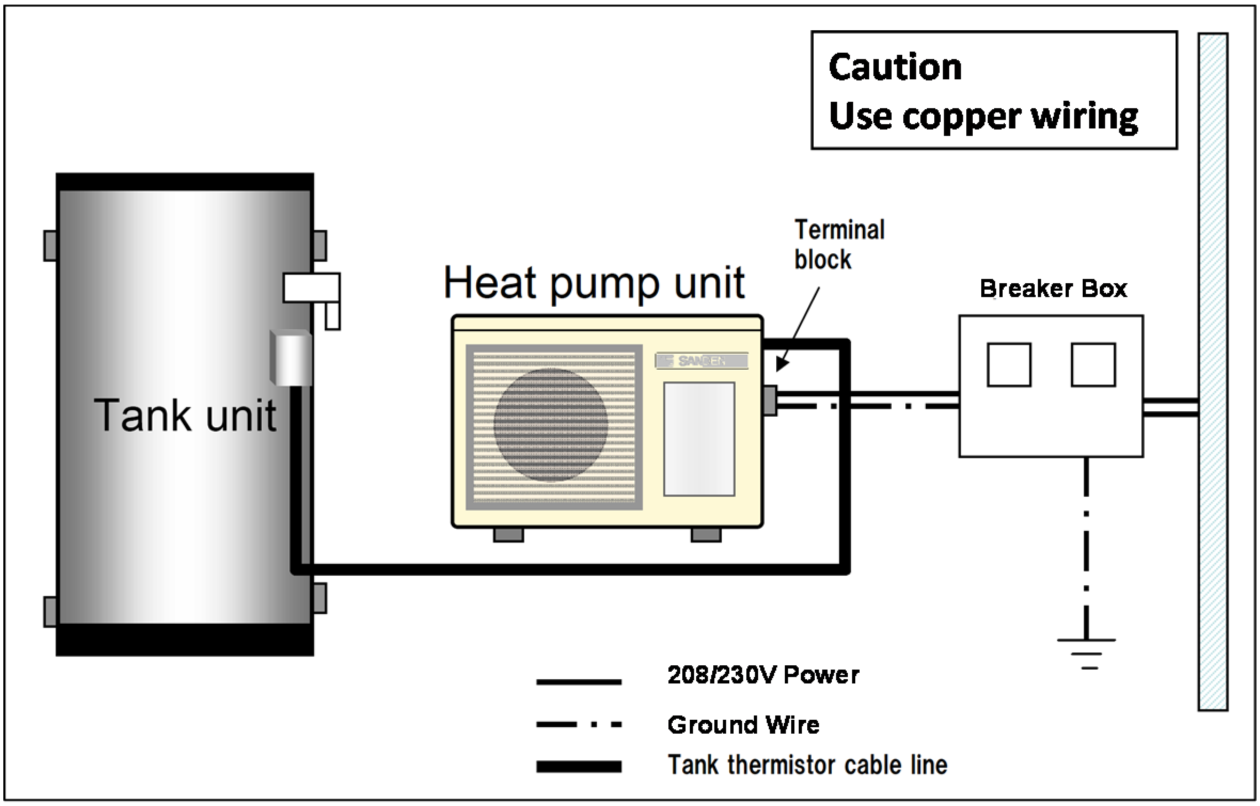
System operation if connected to Demand Response Power

- There are no special settings for the Demand Response. The system will run once power becomes available and the temperature in the tank drops below the set point of the tank thermistor.
- If connecting the unit to Demand Response power ensure that the power supply provides a minimum of 5 hours continuous power, as it can take at least four hours to fill the tank unit with hot water.
  If the ambient temperature is lower than 50°F (10°C) this can be longer.

- If the unit is connected to Demand Response power and hot water consumption has been higher than normal, hot water might not be available until the next power supply cycle.

- Daily frequency and amount of hot water consumption may also affect the duration of the heating cycle operation.

Figure 9: Outline of electrical system connections



The basic system installation is now complete; the unit is now ready for initial water filling, air purge and then start up Check the Installation against the Installation Check list provided at the end of this manual

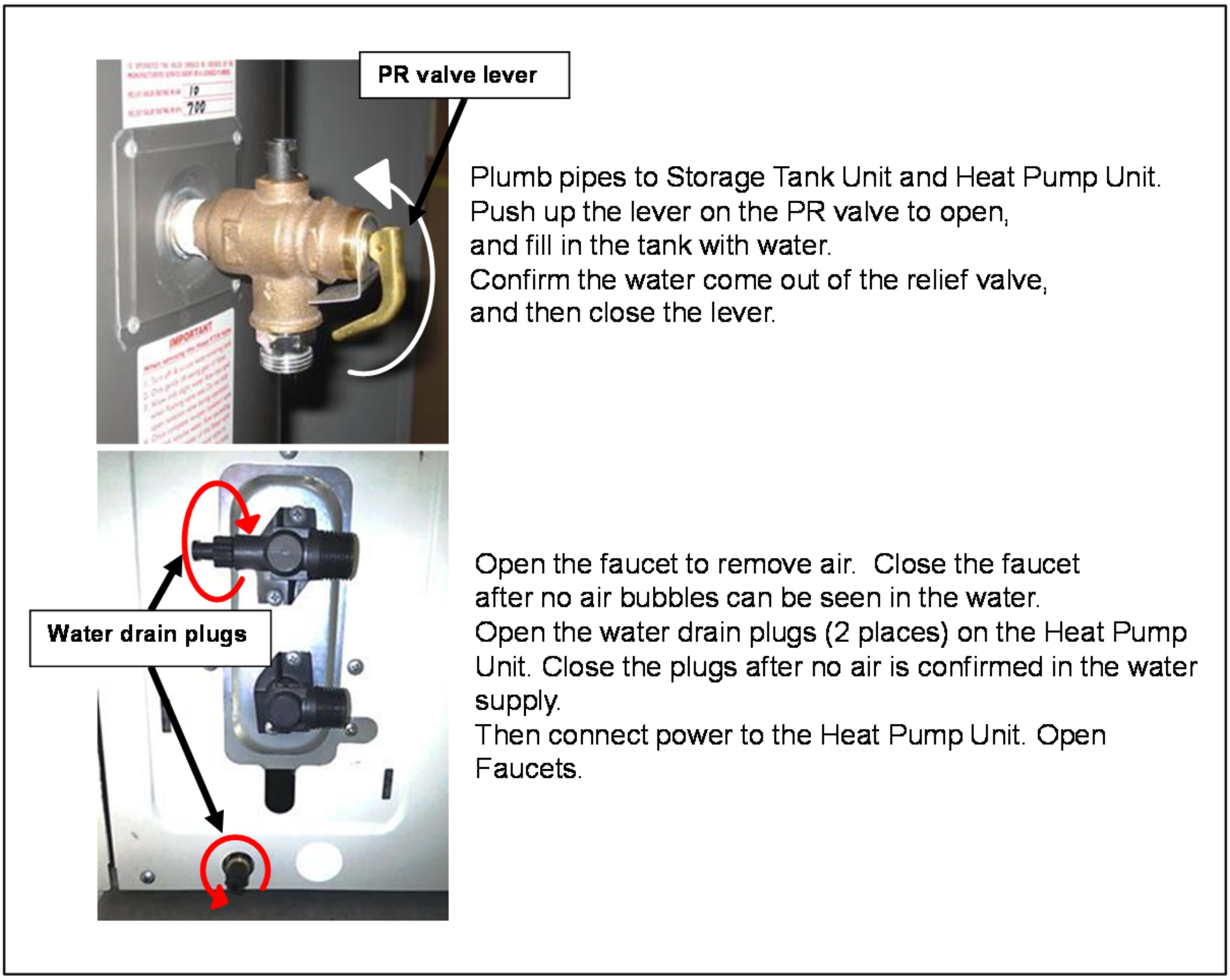
Ensure that the work site is tidy; Sanden International recommends the use of Slim Duct or Fortress product to cover water piping on the outside of the house.

Filling the System & Purging Air

The following steps must be taken to ensure all air is removed from the system. Incorrect purging of air may cause the water temperature to vary during operation, and lead to possible error codes.

- Ensure that all piping to tank unit and heat pump unit are installed and connections are tight, then open the Cold Water Supply Valve to the system.
- Push up the lever on the PR valve to open, and fill the tank unit with water. Confirm that water comes out of the relief valve, and then close the lever.
- Open the hot water faucets to remove air from the house piping system.
- Close the faucets after no air is seen in the water.
- Open the water drain plugs (two places) on the heat pump unit. Close the plugs after no air is seen in the water or a steady stream of water is present.
- Supply power to the heat pump unit and leave the hot water faucets open for 3 minutes. Close the faucets after no air can be seen in the water.

Figure 10: Air removal process

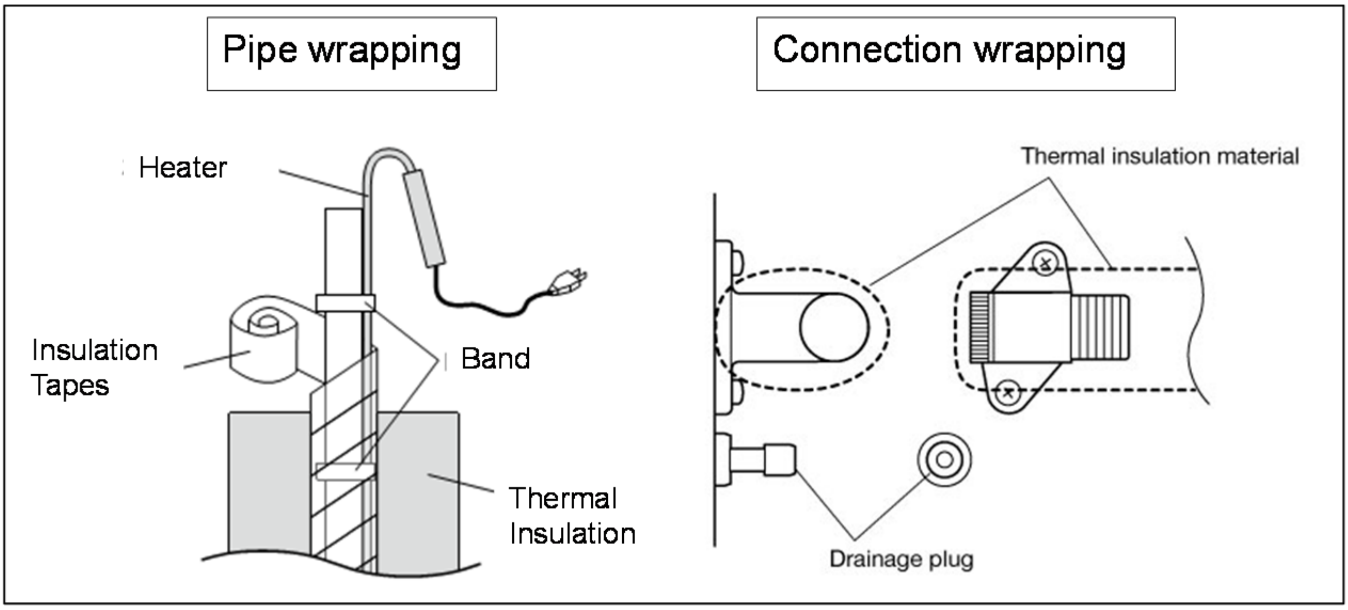


Freeze protection

- Even if the water pipes have been insulated, the piping can freeze if the surrounding temperature falls below freezing (32^{o}F). This could cause damage to the equipment and piping so make sure the appropriate freeze protection measures are taken.
- Follow the instructions in the installation manual provided with the freeze protection heat tape.
- After completion of the piping, inspect the plumbing for any water leaks from the joints before installing freeze protection.
- Wrap the freeze protection heater around the pipes, up to the water connectors of the Heat Pump unit.
- Ensure the freeze protection heaters are connected to a **24 hours continuous power supply.**
- It is important to fully explain the use and operation of the freeze protection heater to the customer.
- **When turning off the power, because the unit will not be in use, ALL water must be drained from the unit and piping**.

> Note: Heat tape that uses the outside temperature to energize, may not maintain the temperature of the pipes correctly. It is important to use a heat tape that directly senses the pipe's temperature.

Figure 11: Details on wrapping thermal insulation around the piping connector



Unit Operation

Time setting

This product contains a built-in clock.
As part of the water heating cycle logic refers to the current time, it is necessary to set the clock before starting to use the product. The current time can be set in the Clock Setting Mode as described below.

Note:
There is no need to adjust the time setting for the daylight saving period. Even if the installation is conducted during the daylight saving period, the clock setting to the ordinary time (not daylight saving time) is preferable.

1. Switching to Clock Setting Mode
   With the display reading 000X (X being the time elapsed from starting the unit) Press the "Enter" key to switch to the Clock Setting Mode.
   Time Display starts flashing once the mode is switched.
2. Setting the Clock
   The time setting can be adjusted by pressing "Up" and "Down" keys. Fast forward and rewind are available by pressing and holding down either the Up or Down key.
3. Confirming Time Setting
   After the clock is adjusted to the current time, press the Enter key to confirm the setting. The time display stops flashing once the setting is finished.

Caution

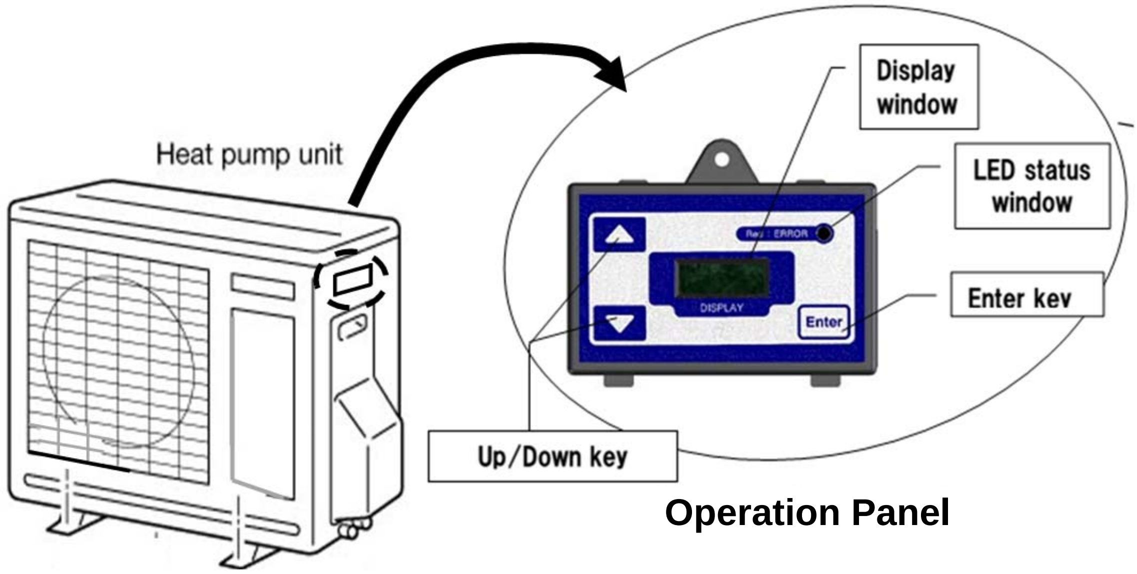
The setting automatically cancels when no panel operation is performed for more than 60 seconds in the Clock Setting Mode. If this occurs, changes made will not be reflected to the setting. If the clock setting is rewound to a time that is earlier than the time when a heating cycle is triggered, the system will start the heating cycle.

Note:

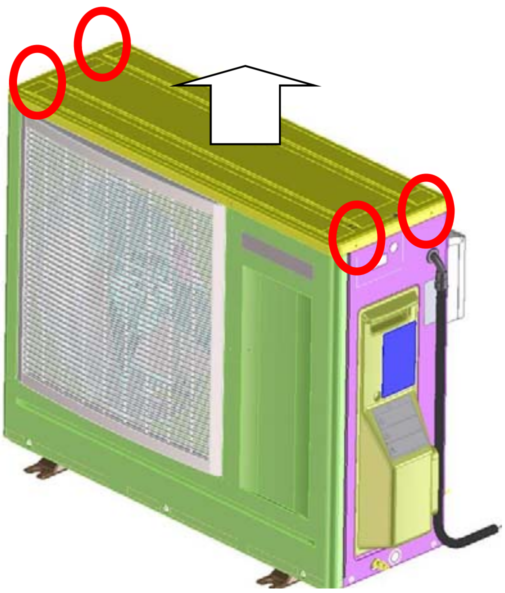
IF NO BUTTONS ARE PRESSED ON THE CONTROL PANEL FOR MORE THAN 60 SECONDS, THE DISPLAY GOES TO SLEEP AND THE PANEL IS BLANK EXCEPT FOR THE OPERATION STATUS LIGHT
GREEN IS NORMAL, RED IS AN ERROR

SLEEP MODE IS TURNED OFF WHEN ANY BUTTON IS PRESSED (UP, DOWN or ENTER).

Figure 12: How to operate the controller

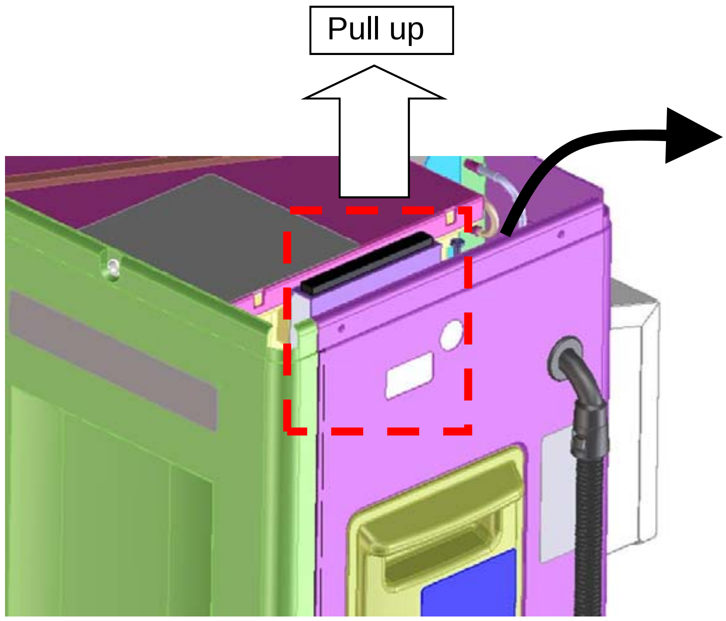


Operation Panel



How to remove the operation panel

1. Remove Top Panel (4 screws)
2. Pull up Operation Panel



Operation Panel

Commissioning Mode

Commissioning mode is a function to check the heat pump unit status and to check and perform other settings. It should generally be assumed that the owner does not operate this function. The following modes can be found in this mode.

Heat setting mode
Set the heating mode to either ON (Unit Runs) or OFF (Unit cannot operate)

Outlet water temperature setting mode
Set the Outlet Hot water temperature 130～175°F

Block out time setting mode (Time of use)
Set the block out time

Error history display mode
Check the history of any errors that may have occurred.

Parameter display mode
Check the values measured by the thermistors in the unit.

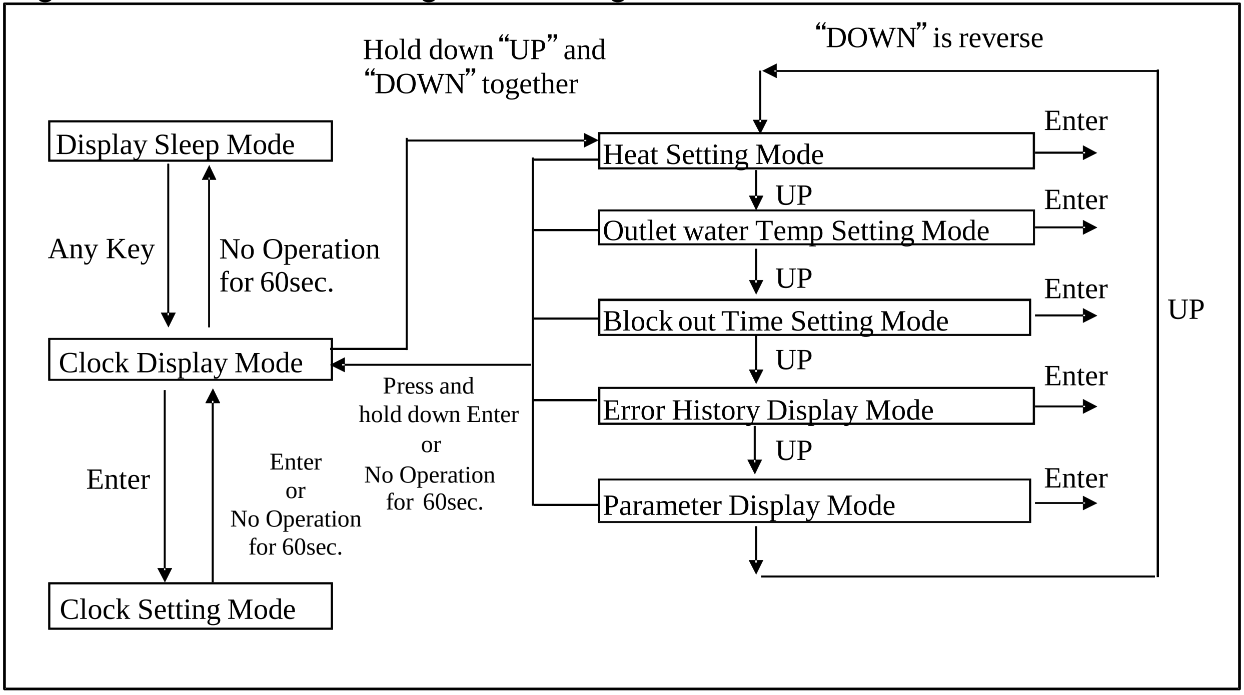
How to switch to Commissioning Mode

Press and hold down the Up and Down keys together to enter the Commissioning mode.

After the mode is selected, press the Enter key to select an option mode from the six described above.

To exit Commissioning maintenance mode, either press and hold down the Enter key, or do not touch the control panel for more than 60 seconds so it goes to sleep.

Figure 13 Commissioning mode diagram



Heat Setting

Enter into Commissioning Mode
First option is the Heat Setting – Press Enter one more time to access this
Use UP/DOWN arrow keys to toggle between Heat On and Heat Off
Press Enter to confirm choice

To bypass the Heat Setting simply press the UP key to access the next parameter in the Commissioning menu

Temperature Setting

Enter into Commissioning Mode
First option is the Heat Setting –
Press the UP Key to access Temperature Setting then Press Enter to access
Use UP/DOWN arrow keys to toggle between the various Temperature Settings
Press Enter to confirm choice

Settings available 130, 140, 150, 160, 165, 175°F

To bypass the Temperature setting simply press the UP key to access the next parameter in the Commissioning menu

Block Out Time Setting

Enter into Commissioning Mode
First option is the Heat Setting
Second option is Temperature Setting–
Press the UP Key to access Block Out Time then Press Enter to access

This mode is used to set the block out time that prevents the heat pump unit operation within the chosen time period.

Block out times are used if the customer has a time of use tariff or wants to take advantage of Solar PV production

'bo' and '00XX' (00 = Out Beginning time, XX = Out end time) are displayed. (Initial setting = 00 o'clock for both start and end)

Adjust set block out Beginning time

Press Up or Down key and '00' (start time) in '00XX' starts flashing and 'XX' (end time) illuminates. Now the block out Beginning time can be adjusted. Setting can be performed only in hour increments, not in minutes. Time is displayed in Military time not AM/PM

Set block out Beginning time

Press the Enter key to set the desired time setting. After the start time is set, the start time display stops flashing. The end time display NOW starts flashing.
THIS TIME WILL THE TIME WHEN THE HEAT PUMP IS FIRST PREVENTED FROM OPERATING EVEN IF THE TANK IS COLD

Adjust block out end time

Set to the desired end time by using Up and Down keys. Setting can be performed only in hour increments, not in minutes. Time is displayed in Military time not AM/PM

Set block out end time

Press enter key to set the desired time setting. After the end time is set, the start time and end time are displayed for two seconds, then it starts to display 'bo' and '00XX' (00 = start time, XX = end time) sequentially.
THIS TIME WILL THE TIME WHEN THE HEAT PUMP IS NOW ALLOWED TO OPERATE BASED ON TANK TEMPERATURE

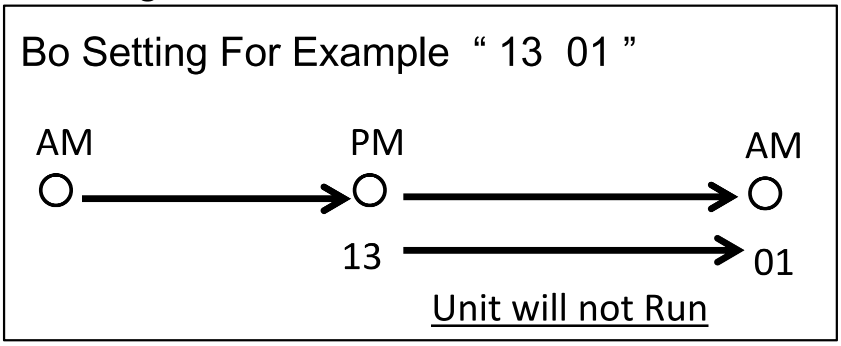
Go back to clock display mode

Press Enter key to go back to the clock display mode. It will automatically go back to the clock display mode when no panel operation is performed for more than 60 seconds. Block out time setting mode cannot be set unless the end time setting is confirmed.

Cancel block out setting

To cancel the block out setting, set both beginning and end times to '00'. Setting to other than '00' (01 ~ 23) will be interpreted as a setting error and the end time will flash. Make sure to set both times to '00' when cancelling the block out time setting.

※Example setting



To bypass the Block Out Time, simply press the UP key to access the next parameter in the Commissioning menu

Error History

Enter into Commissioning Mode
First option is the Heat Setting
Second option is Temperature Setting
Third option is Block Out Time –
Press the UP Key to access Error History then Press Enter to access

This records all errors that have occurred on the system, this can be used for troubleshooting after an error code has been cleared by cycling the power to the unit.

The most recent error code is displayed first, previous error codes can be seen by pressing the DOWN key

To bypass the Error History simply press the UP key to access the next parameter in the Commissioning menu

Parameter Display

Enter into Commissioning Mode
First option is the Heat Setting
Second option is Temperature Setting
Third option is Block Out Time
Fourth option is Error history –
Press the UP Key to access Parameter Display then Press Enter to access

This displays all of the values currently measured by the unit’s temperature sensors, this can be used for troubleshooting and general unit performance questions.

All values will be in °C and will displayed 10 x larger than the actual value e.g. 58°C will be displayed as 0580 (°F conversion x 1.8 +32)

When first entering this mode the display will cycle between no00 and the actual data value ****, to access the other data points use the DOWN key

No.00	Tank TH A temp
No.01	Factory Default Value
No.02	Factory Default Value
No.03	Factory Default Value
No.04	Outlet water temp
No.05	Inlet water temp
No.06	Factory Default Value
No.07	Ambient temp
No.08	Factory Default Value
No.09	Factory Default Value
No.10	Factory Default Value

To bypass the Parameter Display, simply press the UP key to return the first option mode in the Commissioning menu

To Exit Commissioning Mode, do not press any key for 60 seconds and Control will default to sleep mode and revert to the current time display when awoken.

Error Codes

When an error has occurred, a red LED on the operation panel turns on and an error code is displayed on the LED display. The panel does not revert to the display sleep mode while the error code is shown.

Figure 14 Error Code example

After a component is replaced or the inspection is completed, turn the breaker OFF for a period of 3 minutes before restarting to confirm the error does not re-occur.

Below is the list of the error codes. If the corrective action does not solve the error problem, a malfunction of the PCB is highly likely.

Error code	Error contents	Corrective action
E001	HP water outlet over temperature 1	- Check the heat pump piping for blockage/debris - Check for any piping bend, blockage or kinking - Check pipes are not frozen - Ensure mains water supply is available - Ensure all shut off valves are open - If the water circulation pump is not working, replace the pump - In areas with hard water ensure Gas Cooler is not scaled up, descale if necessary
E002	HP water outlet over temperature 2	
E003	HP outlet temperature thermistor detection error	- Check if the thermistor is out of the mounting pocket on the water outlet pipe
E004	HP discharge over temperature 1	- Replace the discharge temp thermistor - Reconnect the expansion valve PCB connector, check to ensure connection - Replace the expansion valve (together with PCB), or the entire heat pump unit
E005	HP discharge over temperature 2	
E006	HP discharge temperature Thermistor detection error	
E007	High pressure side error	- Check the heat pump piping for any blockage - Check for any piping bend, blockage or kink - Check if the pipes are frozen - Ensure mains water supply is available - Ensure all shut off valves are open - If the water circulation pump is not

		working, replace the pump - In areas with hard water ensure Gas Cooler is not scaled up, descale if necessary
E008	High ambient temperature defrost drive error	- Remove debris from the evaporator coil (e.g. leaves, grass, snow) - Replace the ambient temperature thermistor - Replace the defrost thermistor
E009	HP defrost thermistor detection error	- Check if the thermistor is mounted in position on the evaporator - Replace the defrost thermistor
E011	HP inlet temperature thermistor wire break	- Check the thermistor connectors on the main PCB in the heat pump unit for any disconnect, wire breakage or short circuit - Measure resistance of the specific thermistor indicated by the error code
E012	HP outlet temperature thermistor wire break	
E013	HP discharge temperature thermistor wire break	
E014	HP defrost temperature thermistor wire break	
E015	HP ambient temperature thermistor wire break	
E016	Tank thermistor wire break	
E021	HP inlet temperature thermistor wire short circuit	
E022	HP outlet temperature thermistor wire short circuit	
E023	HP discharge temperature thermistor wire short circuit	
E024	HP defrost temperature thermistor wire short circuit	
E025	HP ambient temperature thermistor wire short circuit	
E026	Tank thermistor short circuit	
E031	Fan motor locked	- Reconnect the connector, check if it is off the PCB - Ensure Fan Blade is not caught on debris or snow/ice build-up inside the unit - Replace the fan motor
E032	Fan motor revolution error	
E034	Water circulation pump locked	- Check the heat pump piping for blockage or kinking - Confirm that the connector for the water circulation pump is connected to the PCB correctly - Replace the water circulation pump - In areas with hard water ensure piping is not scaled up, descale if necessary
E040 ～ E082	System control error	Replace the PCB (In the case of E080, check the heat pump piping for blockage/debris, any piping bend, blockage or kinking and pipes are not frozen)

Note:
1. After a component is replaced or the inspection is completed, turn the breaker OFF for a period of 3 minutes before restarting to confirm the error does not re-occur.

2. If the corrective actions above do not solve the error problem, a malfunction of the PCB is highly likely.

Water Supply Quality (Supplemental)

Chloride and PH

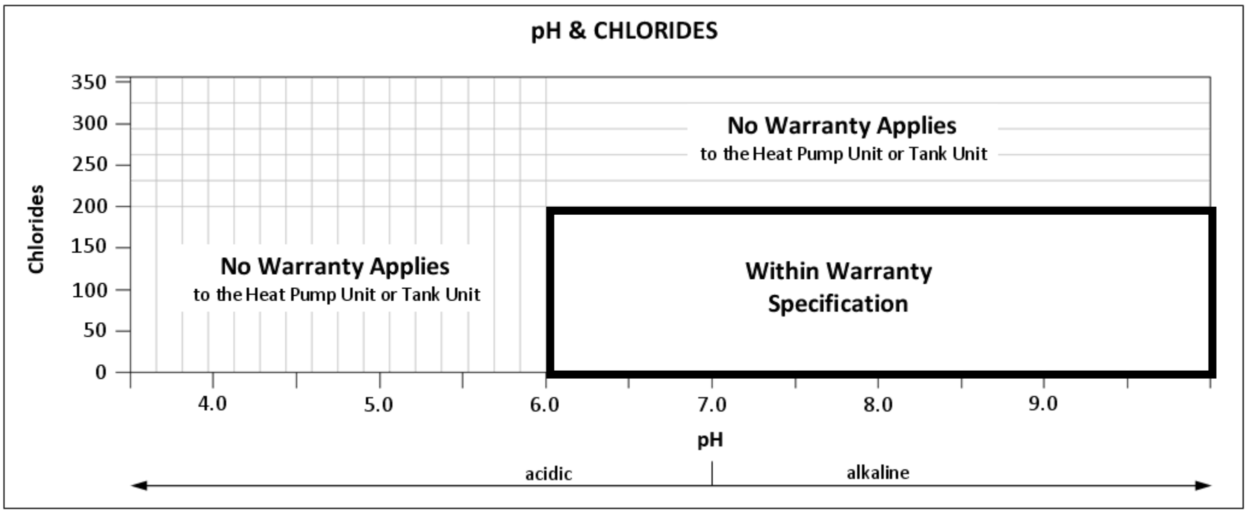
In areas with a high concentration of chloride in the water, that water can cause corrosion and subsequent failures. Where the chloride level exceeds 0.1 ounces per gallons (200 mg/litre), the warranty is no longer valid on to the heat pump unit and tank unit.

PH is a measure of whether the water is alkaline or acid. In an acidic water supply, the water can attack the parts and cause them to fail.

No warranty coverage is given on the heat pump unit and tank unit where the PH is less than 6.0.

Supply Water with a PH less than 6.0 may be treated to raise the PH.
It is recommended that an analysis of the Supply Water be conducted before connecting the Heat pump unit to the system.

Figure 15



Change of water supply

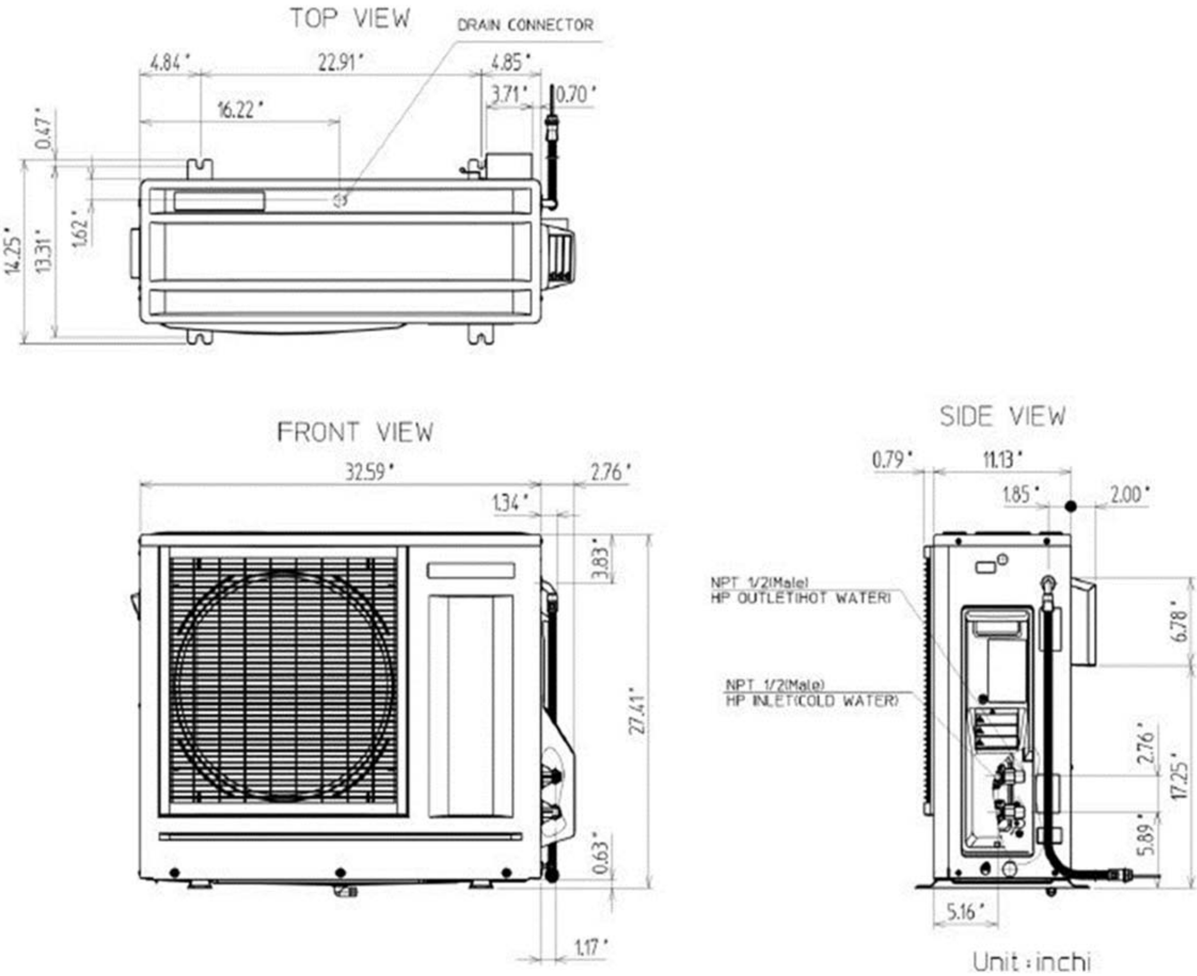
Changing, or alternating, from one water supply to another can have a detrimental effect on the operation and/or life expectation of the water tank, PR valve, water heating circulation and the heat exchanger in the system.

Where there is a changeover from one water supply to another, for example, a rainwater tank supply, desalinated water supply, public recirculated water supply or water brought in from another supply, then water chemistry information should be sought from the supplier or the water should be tested to ensure it meets the warranty requirements in this installation manual.

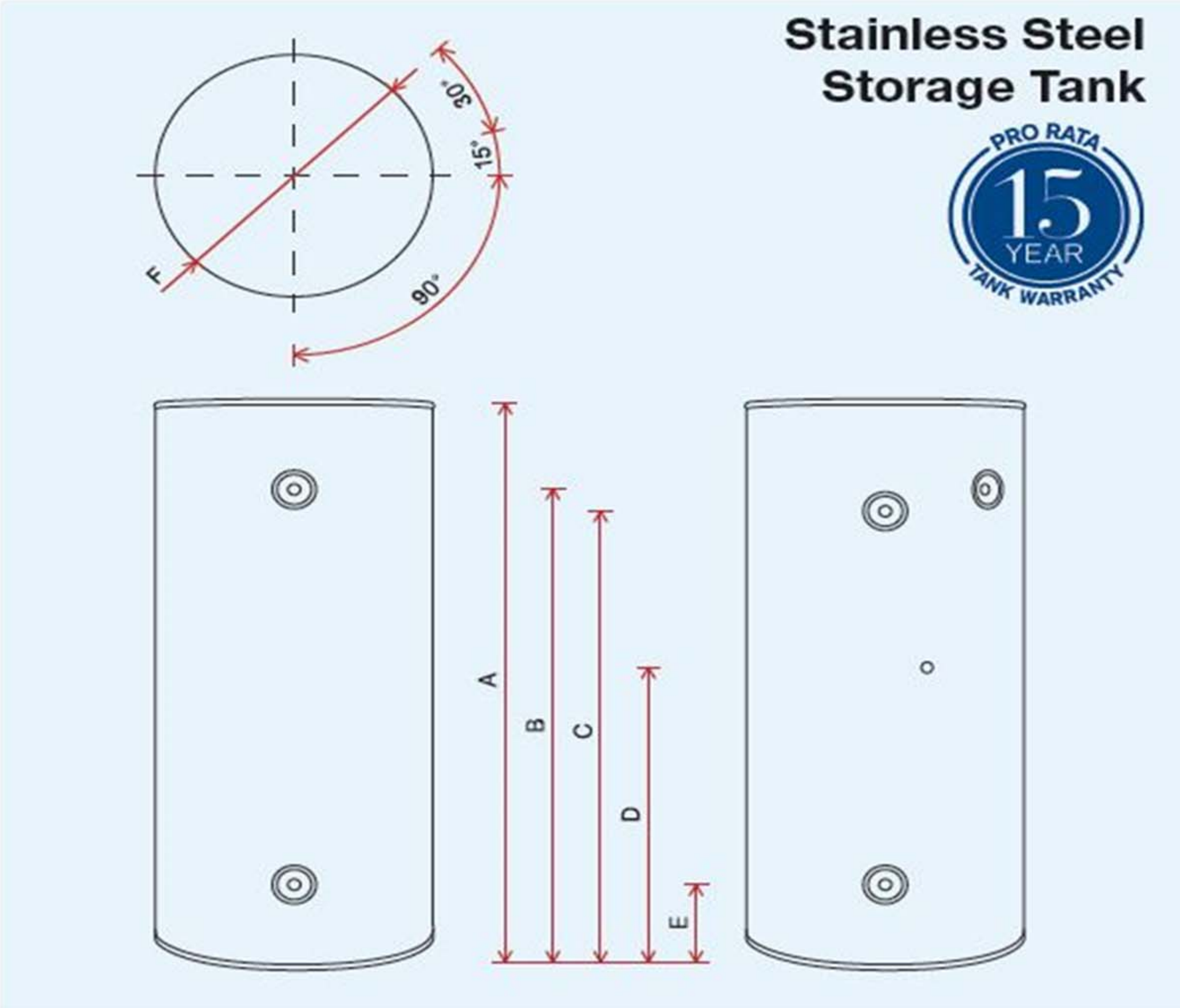
Technical data

Specifications	GS3-45HPA-US
Performance	
Energy Factor - 43 Gal System	3.09
First Hour Rating - 43 Gal System	71 Gallons
Energy Factor - 83 Gal System	3.84
First Hour Rating - 83 Gal System	101 Gallons
Nom Heating Capacity (Btu/h)	15,400 Btu/h
Nom Heating Capacity (kw)	4.5kw
Heating COP	5.0
Water Temperature Setting	130 to 175 DegF
Refrigerant Type	R744 (CO_2)
Refrigerant Charge (Oz)	22oz
Power Voltage	208/230v-1Ph-60Hz
Breaker Size	15A
MCA (Amps)	13.0A
Compressor RLA/LRA (Amps)	7.5/9.8A
Fan Motor RLA/Watts	0.3A / 70W
Pump RLA/Watts	0.2A / 30W
Noise Level (DbA)	37
Weight (lbs)	106lbs
Storage Tank	
GAUS-160QQTA/SAN-43SSAQA	43 Gallons
GAUS-315EQTD/SAN-83SSAQA	83 Gallons
Tank Connection Sizes	
Cold Water Inlet	3/4" NPT
Hot Water Outlet	3/4" NPT
Cold Water to Heat Pump	3/4" NPT
Hot Water Return from Heat Pump	3/4" NPT
Press Relief Valve Setting	100 Psig
Pipe Size - Tank to Heat Pump	
Size	1/2" & 1/2"
Max Pipe Length	50ft
Max Vertical Separation of	16ft
Certifications	
Safety	ETL & ETLc
Performance	AHRI
ARI Certification reference #	TBA
Warranty - System	3 Years Labor
Heat Pump	10 Years Parts
Tank	15Yrs Limited Lifetime

GS3-45HPA-US Dimensions

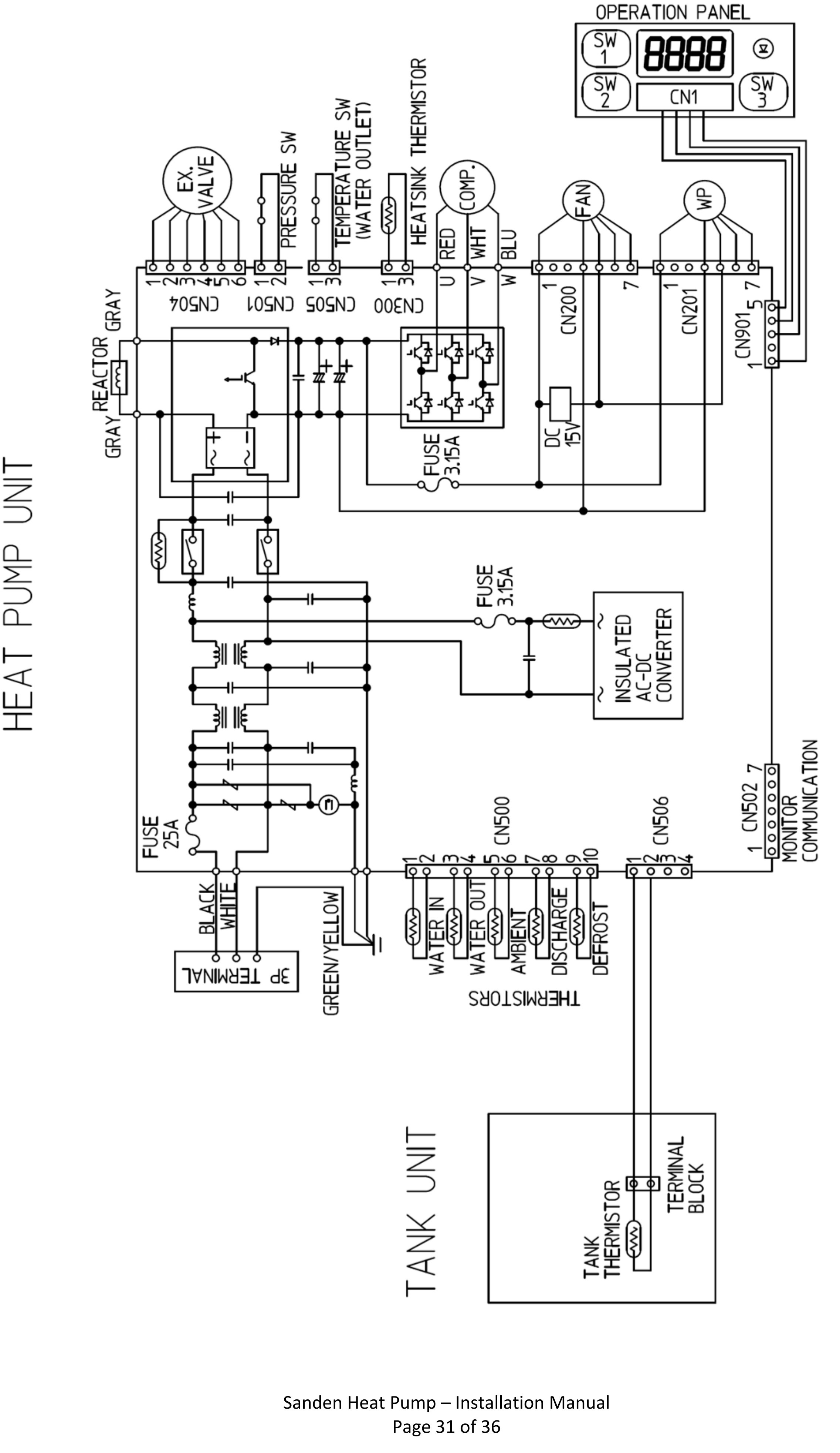


Stainless Steel Tank Dimensions



	Tank Model No:	GAUS-160QTA	GAUS-315EQTD	SAN-43SSAQA	SAN-83SSAQA
A	Height	47-1/4"	58-5/8"	38-1/8"	68-7/8"
B	Hot Water Outlet & PR Valve	37-3/8"	49-5/8"	29-1/2"	60-1/4"
C	Heat Pump Return	37-3/8"	49-5/8"	29-1/2"	60-1/4"
D	Sensor Port	17-1/8"	37"	9-3/4"	40 3/8"
E	Cold Water Inlet / Cold Water to HP	8-1/4"	7-7/8"	8-3/4"	8-3/4"
F	Diameter	22-1/2"	26-3/4"	24-1/2"	24-1/2"
	Weight (lbs)	88 lbs	154 lbs	88 lbs	115 lbs
	Tank Capacity (gallons)	43 gallons	83 gallons	43 gallons	83 gallons

Wiring Diagram



Warranty Policy

Warranty Conditions

1. The Sanden Heat Pump Water Heater System must be installed in accordance with the installation instructions supplied with the Heat Pump Water Heater System, and in accordance with all relevant statutory/local requirements of the state/province/municipality in which the water heater is installed.
2. Where a failed component or Heat Pump Water Heater System is replaced under warranty, the balance of the original warranty period will remain effective. The replaced part or Heat Pump Water Heater System does not carry a new warranty.
3. Where the Heat Pump Water Heater System is installed in a position that does not allow safe, ready access, the cost of accessing the site safely, including the cost of additional materials handling and/or safety equipment, shall be the owner's responsibility.
4. The warranty only applies to the Heat Pump Water Heater System and original or genuine (company) component replacement parts and therefore does not cover any plumbing or electrical parts supplied by the installer and not an integral part of the Heat Pump Water Heater System. Such parts would include pressure regulating valve, isolation valves, check valves, electrical switches, pumps or fuses.
5. The Heat Pump Water Heater System must be sized to supply the hot water demand in accordance with the guidelines in the Sanden Heat Pump Water Heater System literature.
6. This warranty is for parts only, any and all labor costs associated with diagnosis, removal of the faulty part and installation of replacement parts will solely be the owner’s responsibility.

Warranty Exclusions

1. Repair and replacement work will be carried out as set out in the Sanden Heat Pump Water Heater System warranty. However the following exclusions may void the warranty and may incur additional service charges and/or cost of parts:
2. Accidental damage to the Heat Pump Water Heater System or any component, including: Acts of God, failure due to misuse, incorrect installation, attempts to repair the water heater other than by a Sanden accredited service agent or the Sanden service department.
3. Where it is found there is nothing wrong with the Heat Pump Water Heater System; where the complaint is related to excessive discharge from the temperature and/or the pressure relief valve due to high water pressure; where there is no flow of hot water due to faulty plumbing; where water leaks are related to plumbing and not the Heat Pump Water Heater System or its components; where there is a failure of electricity or water supplies; where the supply of electricity or water does not comply with relevant codes or acts.
4. Where the Heat Pump Water Heater System or its component has failed directly or indirectly as a result of excessive water pressure.
5. Overflow vent drain has not been installed or blocked or corroded
6. Where the Heat Pump has rusted as a result of a corrosive atmosphere
7. Where the unit fails to operate or fails as a result of ice formation in the piping to or from the Heat Pump Water Heater System.
8. Where the Heat Pump Water Heater System is located in a position that does not comply with the Heat Pump Water Heater System installation instructions or relevant statutory requirements, causing the need for major dismantling or removal of cupboards, doors or walls, or use of special equipment to bring the Heat Pump Water Heater System to floor or ground level or to a serviceable position.

9. Repair and/or replacement of the Heat Pump Water Heater System due to scale formation above 200ppm (water hardness) in the waterways or the effects of either corrosive water or water with a high chloride or low PH level when the water heater has been connected to a scaling or corrosive water supply or a water supply with a high chloride or low PH level as outlined in the Owner's Guide and Installation Manual.
10. Warranty service is provided to the original owner of the equipment only.

    Subject to any statutory provisions to the contrary, this warranty excludes any and all claims for damage to furniture, carpets, walls, foundations or any other consequential loss either directly or indirectly due to leakage from the Heat Pump Water Heater System, or due to leakage from fittings and/or pipe work of metal, plastic or other materials caused by water temperature, poor Workmanship or other modes of failure.
11. Internet purchase

    Any Sanden parts that are purchased on the internet are not eligible for the warranty term. The parts must be purchased through Sanden certified distributors/contractors.

Warranty period

Subject to the Warranty Conditions and Exclusions stated above, your Sanden Heat Pump Water Heater System is warranted in a Residential application as follows:

Heat pump unit – Sanden warrants all parts & labor on the SANCO$_2$ system for a period of 3 years from date of installation and a further 7 years on Parts only excluding shipping costs. Labor costs are paid directly to the servicing contractor per the payment cost schedule published by Sanden and revised from time to time at Sanden's requirement.

Tank unit – Sanden warrants that the tank will be free from defects for 10 years at 100% replacement, and for a further 5 years under a pro-rated scale, culminating in warranty end after Fifteen years from date of installation

Check sheet

Safety items

Action	Completed
Fix the legs of the tank unit in place with anchor bolts if necessary.	
The floor has been properly waterproofed and properly drained.	
The earth leakage breaker can be turned off with the test button.	
Earth (ground) work is implemented.	
The tank unit is installed on a level sturdy surface.	
There are no gas containers or flammable materials anywhere near the unit.	
The wiring between the tank unit and the heat pump unit is properly connected.	

Heat Pump & Tank

Action	Completed
A concrete base block is installed (if necessary).	
An inspection space is retained in accordance with the installation manual	

Water Piping

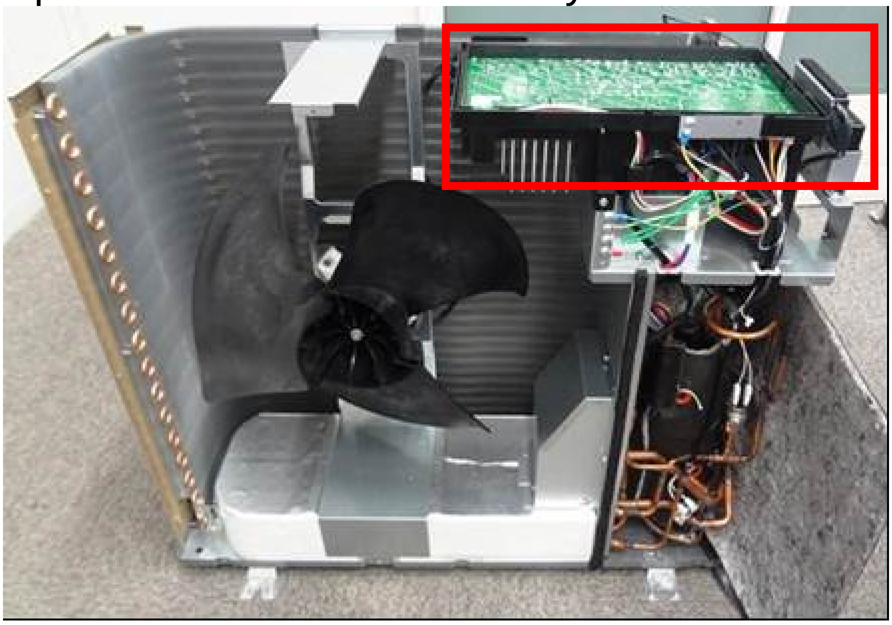
Action	Completed
A dedicated water supply shut off valve is installed	
The piping for the hot water supply has been properly insulated.	
There is no water leaking from the water supply/hot water supply and heat pump pipes.	
In areas subject to snap freezes, protection is provided.	
Union joints are used so that the parts can be easily removed.	
Piping is installed from the drain outlet on both PR Valve & Heat Pump drain	
The filter in the pressure-reducing valve is clean.	
Independent pipes, not a twin tube, are used for the heat pump unit pipes (insulated, UV stabilised)	
Mixing/Anti Scald valve is installed and the setting is correct	
Pressure reduction valve (95PSI) has been fitted to the cold water supply	
During draining of the tank, water does not overflow from the drain.	

Installed By…………………………………………………… Date…………………………………

Inspected By ………………………………………………… Date…………………………………

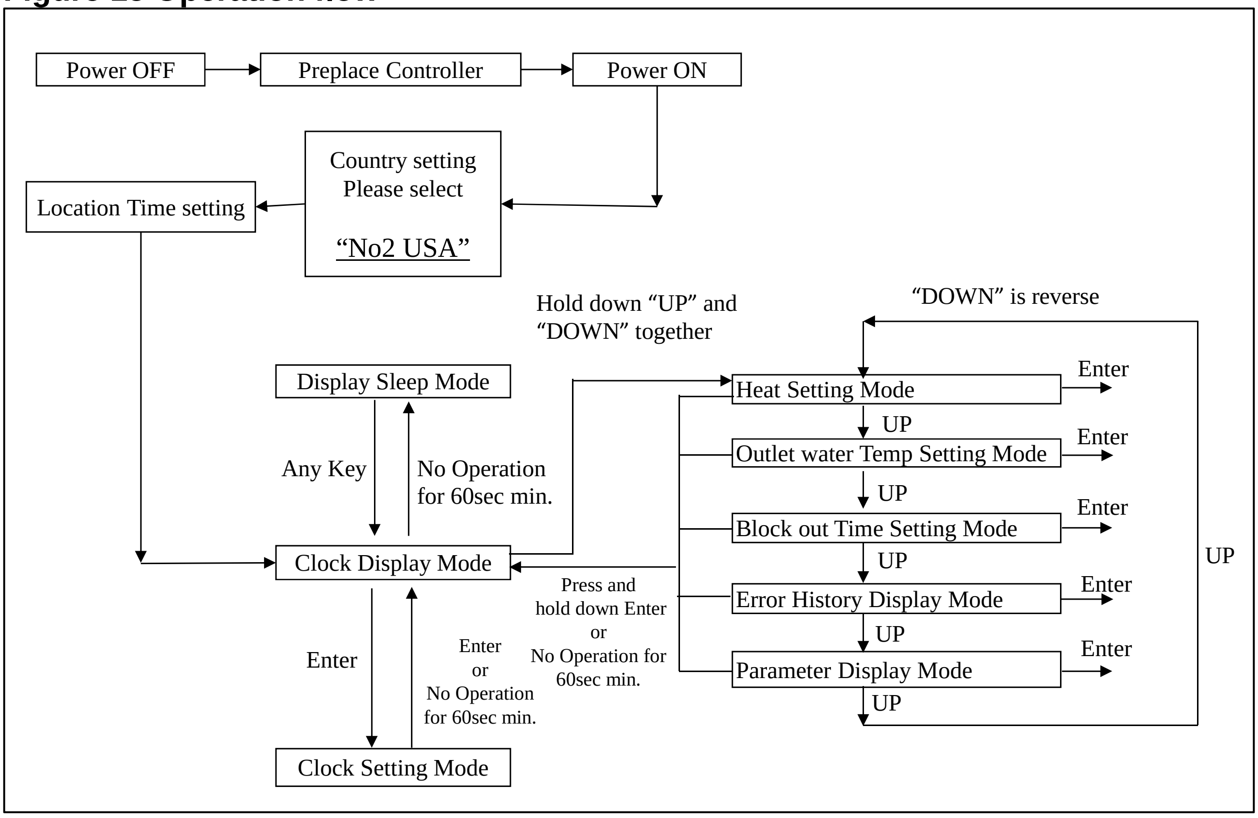
Replace controller assembly

Please replace the controller assembly box.



After PCB replace, Panel operation flow

Figure 15 Operation flow



Memo

7.3 ECO_2 Systems $SanCO_2$ Price List

SANCO$_2$ Heat Pump Water Heaters

List Pricing DECEMBER 2020

Capacity	Type	Model #	Description	List Price
43 Gallon System	Heat Pump Water Heater	GS4-45HPC	Gen4, 4.5kw/15,400 Btu/h Heat Pump Water Heater Unit, CO_2 Refrigerant, 208/230V-1Ph-60Hz 15A Power Supply and 3 Year Labor & 10 Year Parts Warranty	$ 3,075.00
	Storage Tank	SAN-43SSAQA	43 Gallon Stainless Steel Tank, R12 Insulation includes Anti Scald Valve & 125 Psig ASME approved Pressure Relief Valve and 15 Year Limited Lifetime Warranty	$ 1,750.00
	System			**$ 4,825.00**

Capacity	Type	Model #	Description	List Price
83 Gallon System	Heat Pump Water Heater	GS3-45HPC	Gen4, 4.5kw/15,400 Btu/h Heat Pump Water Heater Unit, CO_2 Refrigerant, 208/230V-1Ph-60Hz 15A Power Supply and 3 Year Labor, 10 Year Parts Warranty	$ 3,075.00
	Storage Tank	SAN-83SSAQA	83 Gallon Stainless Steel Tank, R12 Insulation includes Anti Scald Valve & 125 Psig ASME approved Pressure Relief Valve and 15 Year Limited Life Warranty	$ 1,909.00
	System			**$ 4,984.00**

Capacity	Type	Model #	Description	List Price
119 Gallon System	Heat Pump Water Heater	GS4-45HPC	Gen4, 4.5kw/15,400 Btu/h Heat Pump Water Heater Unit, CO_2 Refrigerant, 208/230V-1Ph-60Hz 15A Power Supply and 3 Year Labor, 10 Year Parts Warranty	$ 3,075.00
	Storage Tank	SAN-119GLBK	119 Gallon Glass lined Tank, High R value Insulation includes Anti Scald Valve & 150 Psig ASME approved Pressure Relief Valve and 10 Year Warranty	$ 2,340.00
	System			**$ 5,415.00**

Eco2 Systems LLC, PO Box 1358, Walled Lake MI 48390 Tel : 1-844 726 3262 or 213 400 7758

www.eco2waterheater.com

As of December 1st 2020

7.4 Data Communication – Additional Details

The mesh network completes the seamless routing of data from many nodes (contact closure, pulse, Modbus, or BACnet) to and from the client site. The mesh network is auto-configuring and self-healing, providing network resilience in the event of node failure. All meters and sensors (nodes) are connected to the mesh network via communication bridges.

The gateway includes onboard data backup and SSL encrypted data communication to cloud-based Senseware servers. The gateway communicates using a dedicated cellular modem that is completely independent of any site network.

Senseware's online dashboard (dashboard) includes a user interface that monitors incoming data to ensure appropriate quality and identifies potential issues with the metering system. Throughout the current monitoring period, no dashboard notifications indicating measurement issues or system failures were identified.

The Senseware subscription can be turned over to the building ownership at the conclusion of the M&V period. However, TRC recommends that the site consider various data acquisition system options for collecting usage data for billing purposes.