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Emerging Technologies

Lochinvar Veritus HPWH Feasibility Study and Applications Testing

October 2023

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

OAT .... Outdoor Air Temperature
HPWH .... Heat Pump Water Heater
EAT .... Exhaust Air Temperature
IWT .... Incoming Water Temperature
NSF .... National Sanitation Foundation
SDWA .... Safe Drinking Water Act
IECC .... International Energy Conservation Code
COP .... Coefficient of Performance
PLC .... Programmable Logic Controller
BPHE .... Brazed Plate Heat Exchanger
WB .... Wet-bulb
DB .... Dry-bulb
RH .... Relative humidity

Executive Summary

Domestic water heating is the largest single energy use in multifamily new construction in the Northwest. Lochinvar's Veritus heat pump water heater (HPWH) is available as a fully packaged, energy-efficient, cost-effective, and grid-responsive option for heating domestic water. This report details the Veritus Feasibility Analysis and Applications Testing conducted by Ecotope and proves the product is ready for demonstration in the Pacific Northwest.

The Veritus will help Bonneville Power Administration meet the energy efficiency goals outlined in its resource plan.[i] When Veritus implements load shift controls, the system will also be a grid resource.

Codes and Certifications: Lochinvar designed the Veritus to meet potable water code requirements, has obtained a UL listing through UL 60335-2-40, and is tested per DOE CFR specifications for the rated nameplate equipment efficiency (COP_h).

Performance: Veritus will be capable of producing hot water up to 160°F at 35°F and 140°F at 23°F. Lochinvar has completed performance maps for all its HPWHs. In addition to making domestic hot water, Veritus can provide hydronic space heating.

Market Delivery: Lochinvar can provide the product as part of a fully packaged system, which will reduce overall costs and improve system reliability and performance. The packaged system will include the Veritus, Thermal-Stor Tanks, controls, and other auxiliary components needed for a hot water system. The packaged system will be sold as a skid or a package of parts for site installation. Veritus will also be sold separately as a stand alone heat pump product.

Constructability: The packaged system, especially the skidded system, is expected to simplify product installations for plumbing contractors. The Veritus is a 460-volt 3-phase product, but Lochinvar will supply a step-up transformer when required at an additional cost.

Maintenance: The Veritus heat pump system requires the following maintenance items: regular cleaning of the evaporator and water strainers, and flushing of the potable water heat exchanger.

Background

Market Landscape

Domestic water heating is the largest single use of energy in Northwest multifamily new construction, responsible for 25 to 30 percent of the energy use of a typical apartment building. In new apartments, domestic water heating typically has an Energy Use Intensity (EUI) of 8-10 kBtu/SF/yr.

Water heating can be divided into two distinct loads: 1) the heating of cold city water entering the system and 2) temperature maintenance of circulating water. Approximately one-third of the energy is used to maintain the water temperature in the distribution piping. Veritus will be able to provide all the heating for both entering city water and temperature maintenance.

HPWHs can reduce the energy used for water heating by approximately a factor of three if adequately designed. Figure 1 shows an energy use pie chart of a typical multifamily building and the savings that can be expected from a correctly designed and operated HPWH system. Heating DHW with central heat pumps can reduce the total energy usage by about 7 kBtu/SF/yr (EUI), or roughly 17 percent of the total building energy use.[ii]

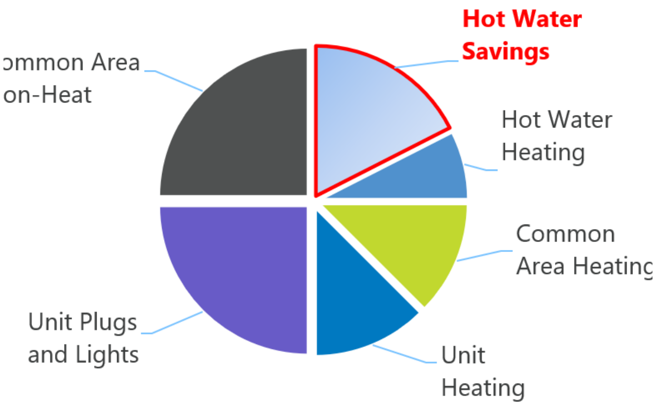

Figure 1. Multifamily energy savings with heat pump water heater.

In addition to overall energy savings, HPWH systems naturally allow for load shifting. A typical HPWH system is designed with less capacity and more storage than a traditional electric or gas water heater system and runs 12-16 hours a day to meet the hot water demand. When sized and controlled correctly, the 12-16 hour run period can avoid peak times and flatten the overall grid load.

Domestic Hot Water HPWH System Design

HPWHs can be single-pass or multi-pass and come as a standalone unit or be integrated into a tank as a unitary system. Single-pass systems heat water in a single cycle through the heat pump, quickly raising the temperature of cold city water and storing it as hot water. In contrast, multi-pass units heat water in several cycles through the heat pump, incrementally increasing the water temperature each time. Although the Veritus can operate in both single-pass and multi-

Heating DHW with central heat pumps can reduce the total energy usage by about 7 kBtu/SF/yr (EUI), or roughly 17 percent of the total building energy use.

pass, single-pass operation is recommended for most installations for the following reasons:

- Single-pass allows for better storage stratification (an important design factor).
- When water is heated in a single-pass, the water is immediately usable after it is heated which makes them superior at recovering from depleted storage.
- Lochinvar's THERMAL-STOR™ tank[a], designed for HPWH systems, will only work as intended with a single-pass configuration.

a https://www.lochinvar.com/products/storage-tanks/thermal-stor/

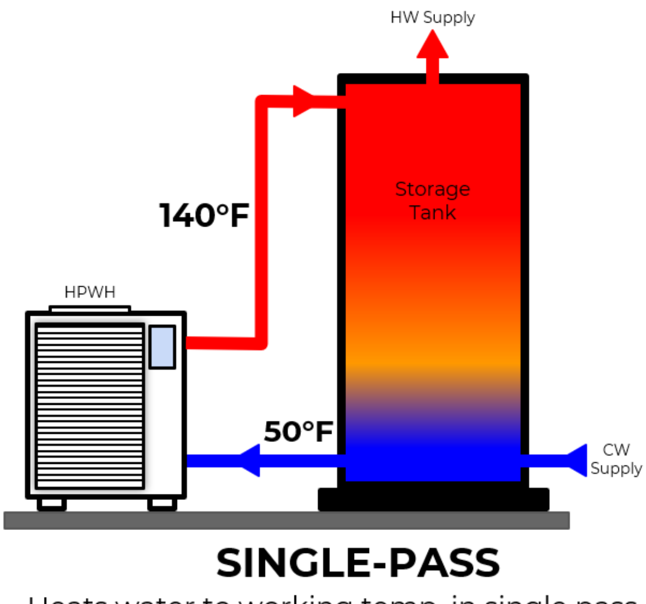

Figure 2. Single-pass HPWH.

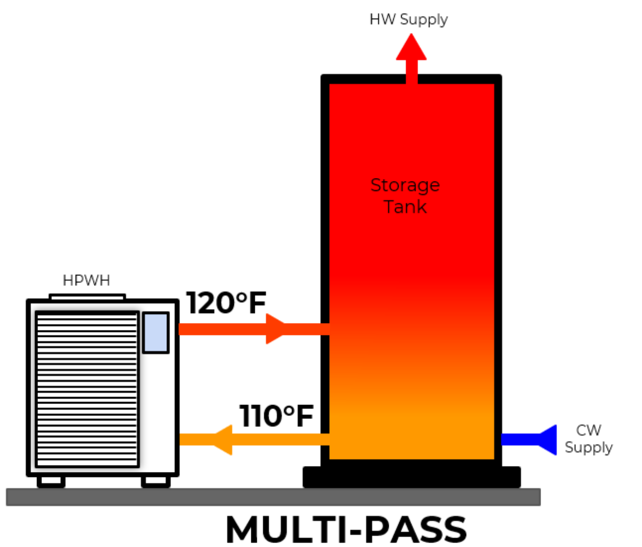

Figure 3. Multi-pass HPWH.

- All HPWHs theoretically operate slightly more efficiently in a single-pass configuration.

Single-pass and multi-pass are shown in Figures 2 and 3, respectively.

Refrigerant

The Lochinvar Veritus uses R513a refrigerant, an HFC/HFO blend with similar properties to the commonly used R134a – but with a significantly reduced global warming potential (GWP) of 631 versus 1300+.

Refrigerant policy in the United States is complex and needs clarification, making it difficult for manufacturers to plan. R513a is a temporary solution and will likely be phased out in the coming decades. Natural refrigerants, such as CO_2 (R744) and C_3H_8 (R290), offer non-toxic, low GWP solutions that eliminate the risks of HFC/HFO refrigerants. Manufacturers use R744 widely in the U.S., but it has several disadvantages[b].

R290 (commonly know as propane) is likely the long-term natural refrigerant solution for air-to-water heat pumps, able to efficiently serve both space and domestic water heating applications. However, while it is available in the rest of the world, UL 60335-2-40 prevents its use in the United States due to flammability[c]. As a boiler manufacturer, Lochinvar is comfortable designing and manufacturing equipment that safely uses flammable gasses and would use R290 if it could UL (or ETL) certify a product using it.

Purpose

This Feasibility Study examines the Lochinvar Veritus's ability to efficiently meet the multifamily water heating needs in the PNW. The Veritus is the smallest in a series of HPWHs Lochinvar plans to offer from 60 and 350 kBtu/hr nominal capacities. Because the design is similar for each product in the series, this study can represent the entire series.

This report includes the first and second steps in the Technology Innovation Model (TIM), which is designed to take a technology through a series of stage gates representing different areas of inquiry to ensure that

b As a natural refrigerant, R744 is futureproofed from complex refrigerant policy and operates more efficiently in cold temperatures than available synthetic refrigerants. However, R744 cannot heat high incoming water temperatures efficiently which prevents it from being used as Single-pass Return-to-Primary (SP RTP). Additionally, the high pressures at which it operates present manufacturing and maintenance challenges.

c R290 is a natural refrigerant that has the advantages and none of the disadvantages of CO_2 refrigerant; for example, it can be used in SP RTP configuration. While R290 is available in the rest of the world, UL 60335-2-40 restricts its use in the United States by severely limiting its allowable charge – even in outdoor installations – due to flammability. UL 60335-2-40 prevents Lochinvar and the United States from manufacturing and deploying the most efficient and sustainable heat pump systems.

the product can be safely and cost-effectively applied in a manner that ensures performance and savings in the marketplace.

Key stage gates for the TIM include:

1. Feasibility Study
2. Applications Testing
3. Demonstration Project
4. Measurement and Verification (M&V)
5. Design Guidelines

Veritus is ready for a demonstration project.

Current Installations

In the Spring of 2023, Lochinvar installed the first Veritus for testing piped as a multi-pass configuration in a cafeteria. A gas boiler was piped in as backup. Figures 4, 5, and 6 below show the installation.

Figure 4. Rooftop insallation.

Lochinvar has two other pilot installations: one at the Cleveland Zoo and the other at Cal Poly Pomona. The Cleveland Zoo installation serves a washdown system with two large loads per day and the Pomona installation serves classrooms with lab sinks.

Figure 5. Multipass piping into tank.

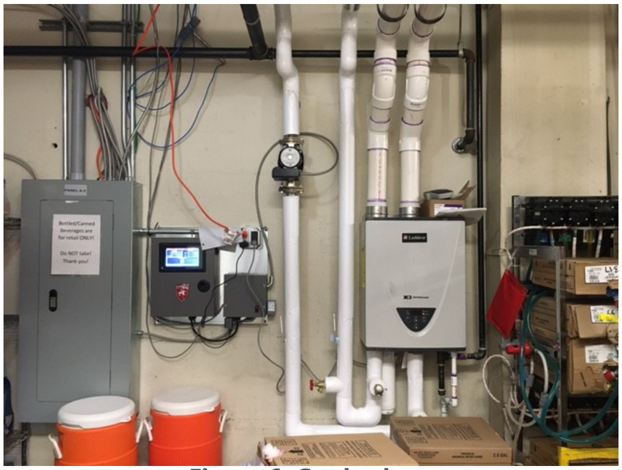

Figure 6. Gas backup.

Codes and Certifications

As a 508A-certified panel shop, Lochinvar can more easily provide UL certification for packaged skid systems.
Lochinvar complies with the following codes, allowing it to be installed in the Pacific Northwest and California.

Codes

FEDERAL LAW

- The Safe Drinking Water Act (SDWA) Section 1417

ENERGY CODE

- International Energy Conservation Code (IECC) (Includes Idaho and Montana)
- Washington State Energy Code (WSEC)
- Oregon Energy Efficiency Specialty Code (OEESC)
- Title 24 (in California)[d]

MECHANICAL CODE

- International Mechanical Code (IMC)

PLUMBING CODE

- Uniform Plumbing Code (UPC)
- International Plumbing Code (IPC)

ELECTRICAL CODE

- National Fire Protection Agency (NFPA) 70 – National Electrical Code (NEC)

In addition to the codes listed above, Lochinvar has achieved and OSHPD pre-approval for seismic safety.

d California Title 24 prescriptive code currently only allows swing tank systems or products listed on the Northwest Energy Efficiency Alliance (NEEA) Qualified Products List (QPL). The Nova will be most efficient in return to primary (not swing tank) configuration and therefore it is critical that Lochinvar list the product on the QPL for ease of adoption in California. Lochinvar is already in the process of listing.

To comply with the mechanical code, the Veritus has been UL listed. A full-system skid, sold and delivered as a single piece of pre-wired equipment, also needs a UL or ETL listed. Lochinvar works with a panel provided that is UL 508A certified to provide packaged skid systems.

System Component Assessment

System Component Assessment identifies the equipment needed for a complete water heating system deployment.

Figure 7 shows internal components, including a fan, evaporator, condenser, compressor, and reversing valve. The reversing valve is used during defrost to flip the evaporator and condenser and melt ice off the refrigerant to air coil.

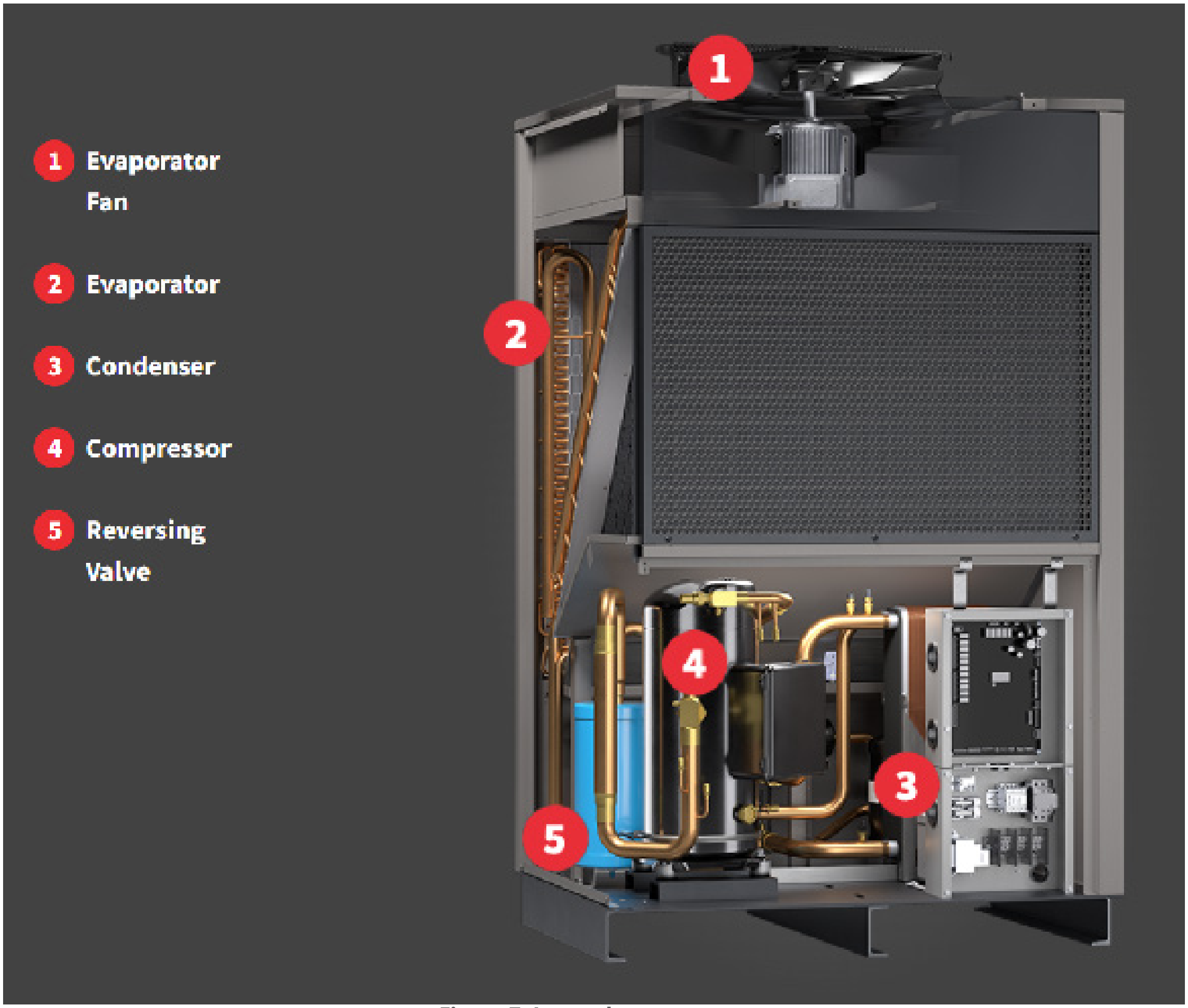

Figure 7. Internal components.

For a complete central water heating system, controls, thermal storage, and recirculation equipment – including pump and mixing valve – are also required. Lochinvar will supply all components when equipment is purchased as part of a packaged system. Figure 8 shows the single-pass return-to-primary schematic that will be used. Figure 9 shows Lochinvar's SMART TOUCHTM control panel used to monitor and control the HPWH system. The control panel includes an EcoPort (CTA-2045) to receive TOU pricing and demand response requests for load shifting.

System Configuration – Return to Primary

Veritus is designed to operate with variable incoming water temperature. It can target a high outlet water temperature even with variable inlet water temperature, allowing it to operate as a single-pass (SP) return-to-primary (RTP) system shown in Figure 8.

Lab testing performed at Pacific Gas and Electric's (PG&E) laboratory in California

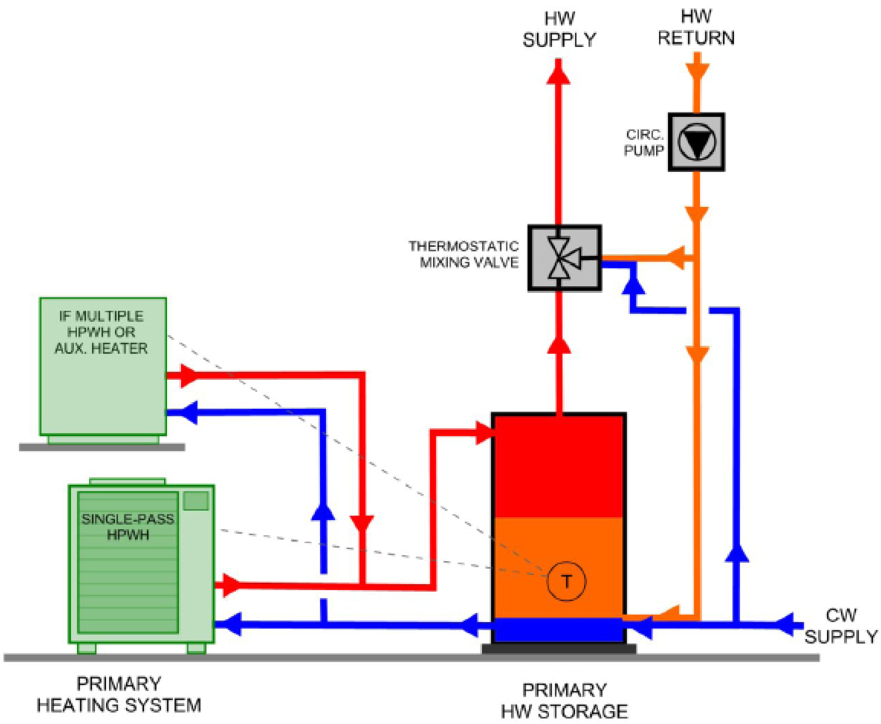

Figure 8. Return to primary system schematic.

Figure 9. Central Control Panel.

confirms that, when possible, SP RTP is the most efficient configuration for central heat pump water heating[e]. Additionally, SP RTP is easier to work with for designers, installers, and facilities staff because its piping design is simpler than swing tank and parallel loop tank configurations. In SP RTP, all incoming water and recirculation return water is piped back to the same thermal storage tanks.

Multiple Units

Multiple Veritus units can be installed in a space-efficient way to meet the demand for large buildings. Units are designed so they may be arranged side-by-side, with minimal

e While SP RTP is the most efficient configu-ration, it does not work efficiently with most R744-based refrigerant systems due to complications in the R744 refrigerant cycle. It cannot heat high incom-ing or variable water temperatures efficiently (e.g., multi-pass or SP RTP), and the high pressures at which it operates present manufacturing and mainte-nance challenges.

clearance needed between units. Multiple units can draw water from two manifold inlet and outlet water pipes. Manifold piping allows for only two wall penetrations when multiple Veritus are installed.

When multiple units are installed, one main unit is connected to the control panel. All the other units are connected to the main unit with shielded, twisted pair wire using serial communication.

Performance Assessment

The Performance Assessment confirms the equipment will have adequate performance to gain acceptance from designers and users.

Architecture

Unit installation location impacts the site's architectural design and acoustics. Veritus is meant for outdoor or buffer space installations. It resembles other air-to-water heat pumps or air-cooled chiller types of mechanical equipment. When installed in a visible location, the architect may want to provide a screen wall to obscure it from view. In large buildings in the Northwest, an allocated space in an open parking garage with sufficient airflow may be a suitable location to buffer winter temperatures.

Similar to any equipment locating, architects will need to coordinate with the mechanical or plumbing engineer to identify an appropriate location.

Space requirements

Unit dimensions vary by model and are provided in Lochinvar's design literature. Units should be installed with ~30″ back and top clearance to allow for airflow and evaporator coil cleaning. 36″ front clearance should be provided for maintenance access to components. In addition to clearances, units should be designed in a way that allows for future removal and replacement when equipment reaches end of life.

Because of the potential size of major components, such as storage tanks, it is important to identify equipment too large to fit through standard doors early so architects and designers can plan appropriately for installation and replacement equipment. Lochinvar's Thermal Stor™ tank includes R-30 insulation and does not include a size that will fit through a standard door.

Acoustics

Lochinvar measured Veritus acoustics in their factory, recording the average db from 4 sensors placed 10 feet away from each side of the unit. Veritus produces 63 and 76 db when operating at 80°F and 23°F respectively. Like other HPWHs, the unit should be installed away from bedroom windows and outdoor amenity spaces. An acoustic screen wall can reduce sound transmission and obscure equipment.

Allowable sound power levels at property lines vary by jurisdiction. Lochinvar aims to have the lowest possible sound power level to increase flexibility when locating the unit.

Climate

As with any heat pump product, it's important to consider weather, such as wind and snow. Designers should avoid placing units so that the air intake faces into the prevailing wind. The preferred orientation for air intake is perpendicular to prevailing winds. When installed outdoors in locations that receive snow, units should be elevated above the snow line and provided an alcove to shelter them from snow build-up that will chock airflow to the evaporator.

Like all HPWHs, capacity decreases with outdoor air temperature, which must be considered in cold climates. This is discussed under Engineering, Plumbing.

Engineering

Engineering performance is broken into structural, mechanical, electrical, and plumbing performance.

Structural

The Veritus weights vary from 900 to 3,200 pounds by model. Refer to Lochinvar's documentation for the exact weight by model[iii]. The unit includes a scroll compressor and axial fan that may require vibration isolation depending on the installation location and facility vibration requirements. Like other major mechanical components, the unit must be securely bolted to prevent it from falling in seismic or wind events.

When thermal storage is included, the entire system for a 100-unit building may weigh over 15 kips, including water weight. Structural engineers should be notified early in the design process where the thermal storage will be located so they can plan accordingly.

Mechanical

In unique cases where the units are located indoors, the mechanical engineer will be responsible for designing ducted connections. A booster fan, interlocked with unit operation, is required, as well as a source of makeup air. Lochinvar is working with a third party to provide fan sizing and ductwork designs for engineers. The third party will select and provide the fan and ductwork connections, reducing the potential for error with custom designed systems.

In cold climates, ductwork allows the Veritus to be installed inside and avoid complications from wind and snow. Additionally, if ducted, Veritus can pull air directly from building exhaust, allowing the unit to capture wasted heat from air leaving the building and operate more efficiently in cold temperatures.

Electrical

Veritus will be available in 460-V 3-PH only. However, Lochinvar will provide a step-up transformer for buildings that only include 208V – which is common in multifamily.
The unit must be hardwired, and the circuit feeding the device must comply with the National Electrical Code (NEC). Article 440 of the NEC applies to all devices that include hermetic refrigerant compressors. This is the section applicable to Veritus.

In addition to equipment requirements, electrical connections for auxiliary equipment – heat trace, pumps, electronic mixing valves, etc. – will be required. For a packaged system, all electrical points should be clearly identified for ease of field installation or included on a single point of connection in a skidded system.

Plumbing

Plumbing engineers are typically tasked with selecting water heating equipment. However, Veritus is more complex than the typical gas or electric water heater.
Funding to update Ecosizer to size single-pass

return-to-primary systems is needed as soon as possible to support the industry.
Typically, plumbing engineers do not have the expertise or budget the time or resources to design the complex custom system needed to support HPWHs like Veritus. As a result, the Veritus may be misapplied and waste energy or overlooked in favor of a more familiar option. Lochinvar must offer complete system design support through its distribution channels.

CAPACITY

Lochinvar must support its distribution network with sizing support for Veritus. While most HPWH systems currently use Ecosizer for system sizing, the tool does not currently support sizing SP RTP. Funding to update Ecosizer[f] to size single-pass return-to-primary systems is needed as soon as possible to support the industry.

After the equipment heating capacity is known, engineers must select the model and number of Veritus required to meet the capacity. Unlike electric resistance heaters, the heat that can be provided using a HPWH changes with outdoor air temperature. Engineers must select the appropriate number of heat pumps based on the capacity at a design temperature (a low temperature the heat pump will likely experience). Veritus has published performance maps on Lochinvar's website, which show changes in heating capacity based on outdoor air temperature. However, defrost derate is not included in performance maps. A 20% defrost derate should be applied to capacity below 40°F until Lochinvar gives further guidance.[g]

The Veritus can operate down to 23°F with a COP of ~2.4. At 23°F the unit's capacity is ~45% lower than its rated capacity.

REDUNDANCY

As a form of redundancy, Ecotope recommends the Veritus system be capable of integrating electric resistance water heaters, which are less efficient but cost less than HPWH capacity. An electric resistance water heater specified in such packaged systems should be piped in parallel with the HPWHs, allowing it to store heat in the primary storage tanks – as shown in Appendix A.

ELECTRIC RESISTANCE SUPPLEMENTAL HEATING

Electric resistance heating can also supplement heating capacity during extremely cold weather, reducing the heat pumps required to meet the load.

As outdoor air temperature drops, HPWH capacity and efficiency also drop. In cold climates, Lochinvar may allow the electric resistance to supply primary heat on the coldest days. On many projects, this will substantially reduce first costs by enabling the purchase of fewer heat pumps without significantly impacting energy usage. Figure 10 shows graphically when heat pumps would be supplemented by electric resistance heating in a mild climate.

The plot shows the "Combined Capacity of (N) Heat Pumps." This is the total capacity of one or more HPWHs to serve a building's domestic hot water demand. The "Design Hot Water Load" is also shown, illustrating the capacity needed to meet the highest demand

f https://ecosizer.ecotope.com/sizer/

g No test standards are currently written to quantify defrost derate. NEEA plans to incorporate a test in version 9.0 of the Advanced Water Heating Specification (AWHS). A test to quantify defrost will give designers and installers confidence in equipment capacity in defrost conditions.

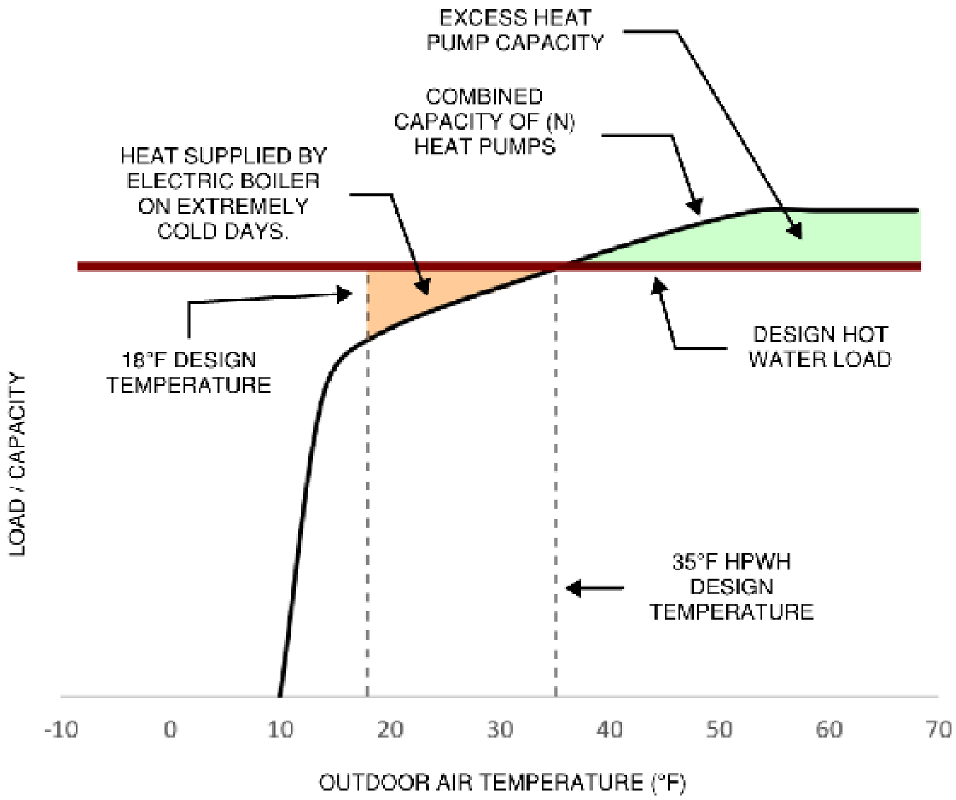

Figure 10. Mild Climate Sizing Method

day. Notice that combined HPWH capacity does not meet the demand on the coldest day, indicated by the "Design Temperature." The "HPWH Design Temperature" refers to the temperature at which the HPWH can supply the entire hot water load. Below this temperature, on high water use days, electric resistance heat may be required to provide some of the heating.

Lochinvar is not targeting cold climates initially. A phase two product will be developed specifically for cold climates. The cold climate will likely use a different refrigerant and have design changes in the refrigeration cycle.

FREEZE PROTECTION

The Veritus heats water down to 25°F, making it an excellent product for mild climates but not optimal for cold climates. The risk of freezing is low in mild climates but freeze protection still must be provided, especially on the condensate drain pan and line. Lochinvar has a condensate drain pan heater included on the unit that turns on during freezing conditions.

In addition to internal heat trace, heat trace should be located on any outdoor connected potable water piping and condensate piping in cold climates. Controls built into the Veritus system can be used to energize heat trace when required.

DEFROST

If HPWH evaporator coils freeze, then a defrost cycle must be initiated to allow heat transfer at the evaporator. Veritus uses a reverse cycle defrost in which the reversing valve (Figure 7) changes position and flips the evaporator and condenser in the refrigerant cycle. By reversing the refrigerant cycle, the unit cools the water flowing through it and heats the evaporator coil, which melts the ice off.

Reverse cycle defrost has the advantage of shorter defrost cycle times – which are beneficial for decreasing defrost derate. However, the disadvantage of reverse cycle defrost is that cold water flows to the top of the thermal storage system during defrost, which may disrupt stratification. The applications test memo in Appendix B describes the potential consequences of returning cold water to the top of a stratified thermal storage tank. During the demonstration project, Ecotope will provide recommended design solutions and observe the consequences of the defrost cycle as currently designed.

CONDENSATE

In a typical cold-climate installation, the unit will be mounted on a curb. Under the curb, the surface slopes toward a drain. Condensate will drain directly out of the bottom of the unit onto the surface below. In warmer climates, where freezing is not an issue, the condensate can be piped from the unit using a pipe sloped at a minimum of 1′ per 100′. In cold climates, condensate can be piped if desired, but only if the engineer coordinates heat trace to be installed on the condensate piping.

Owners – Cost, Demand Response

Owners want a product that is affordable to install, performs consistently, requires little maintenance, meets green building targets, and reduces energy costs. When designed and maintained correctly, Veritus should provide long-term quality performance. A fully packaged system will allow for reduced installation costs, consistent operation, and standardized maintenance.

In key markets, such as California, time-of-use and real-time pricing are starting to drive utility charges. Lochinvar provides an EcoPort connection. Controls to allow for load flexibility, and the ability to operate on a customizable schedule to maximize value for customers and reduce the payback period are in development.

End Users

End Users are concerned with the consistent delivery of hot water. The key to consistently delivering hot water in a HPWH system is appropriately sized components and redundancy. Engineers should design with at least N+1 redundancy with hot water generating equipment. Consistent proper sizing of SP RTP systems would benefit from an updated Ecosizer.
Reverse cycle defrost may also affect reliable hot water delivery through de-stratifying the storage tanks. Defrost will be investigated during the demonstration project with M&V.

Cost and Constructability Assessment

The Cost and Construction Assessment confirms challenges associated with acquiring and installing the product.

Availability

Lochinvar's factory in Lebanon, Tennessee, will be able to produce thousands of heat pumps a year and easily meet demand.

Construction Schedule

Lochinvar expects short lead times – up to 6 weeks – for Veritus. Additionally, providing it as part of a package system will reduce the need for coordination between building trades.

Retrofit Feasibility

HPWHs are good retrofit candidates for replacing electric resistance or gas central water heating systems.
If replacing a gas boiler, the project engineer must determine if sufficient electrical capacity is available or if an electrical upgrade is needed to power the HPWH. Because heat pump systems require a small amp draw compared to electric resistance, there is often room on existing panels. Flue gas piping from gas boilers can often be replaced with supply and return pipe for the outdoor HPWH.

In some cases, it is tempting to replace gas heaters with HPWHs piped the same way – as a multi-pass system. This design may look straightforward, but differences in how gas and HPWH systems are sized, designed, and operated often make this approach work poorly.

If replacing electric resistance tanks, then there will be room in the electrical panel. However, pipe routing will need to be determined.

The most significant challenge on many projects is finding a location for the unit outdoors and indoor space for the storage tanks. However, Veritus's ability to operate as a return-to-primary system reduces the footprint needed for the storage system.

Maintenance Assessment

Maintenance assessment is broken into two sections: customer service and maintenance. Customer service assesses the ability of the manufacturer to aid Northwest customers. Maintenance addresses upkeep requirements performed by the owner to ensure product longevity.

Customer Service

Lochinvar sells products through a network of manufacturer's representatives across North America and provides them with extensive training. Training includes commissioning, applications/design training, and product specific training – including maintenance and troubleshooting.

Lochinvar provides a 1 year parts and compressor warranty as a standard with an extended 5 year warranty option.

Maintenance

Maintenance requirements for the Veritus are comparable to other HPWHs. Lochinvar will outline a maintenance plan in the owner's manual, which should be followed to ensure equipment longevity. Maintenance will likely not be any more extensive than what's needed for a gas or electric resistance system.

Conclusions and Recommendations

The single-pass return-to-primary configuration and Lochinvar's ability to provide a packaged system will give Veritus a significant advantage in installation ease and efficiency. The system is ready for a demonstration project, but Lochinvar must develop an Installation and Operations Manual and train their distribution network before product launch. Ideally, a demonstration project can be provided during 2024 to provide learning that can be included in the product launch. Three areas that will be investigated and improved during the demonstration project include:

1. Thermal Stor™ tanks are too wide to work in many retrofit applications. A storage tank for HPWH retrofits will need to be designed for the demonstration project.

2. Investigation of defrosts impact on tank stratification and design that can be used to limit impact.

3. Single-pass return-to-primary sizing and design considerations. SP RTP sizing needs to be added to Ecosizer. A demonstration project will help develop and test sizing methodology.

Works Cited

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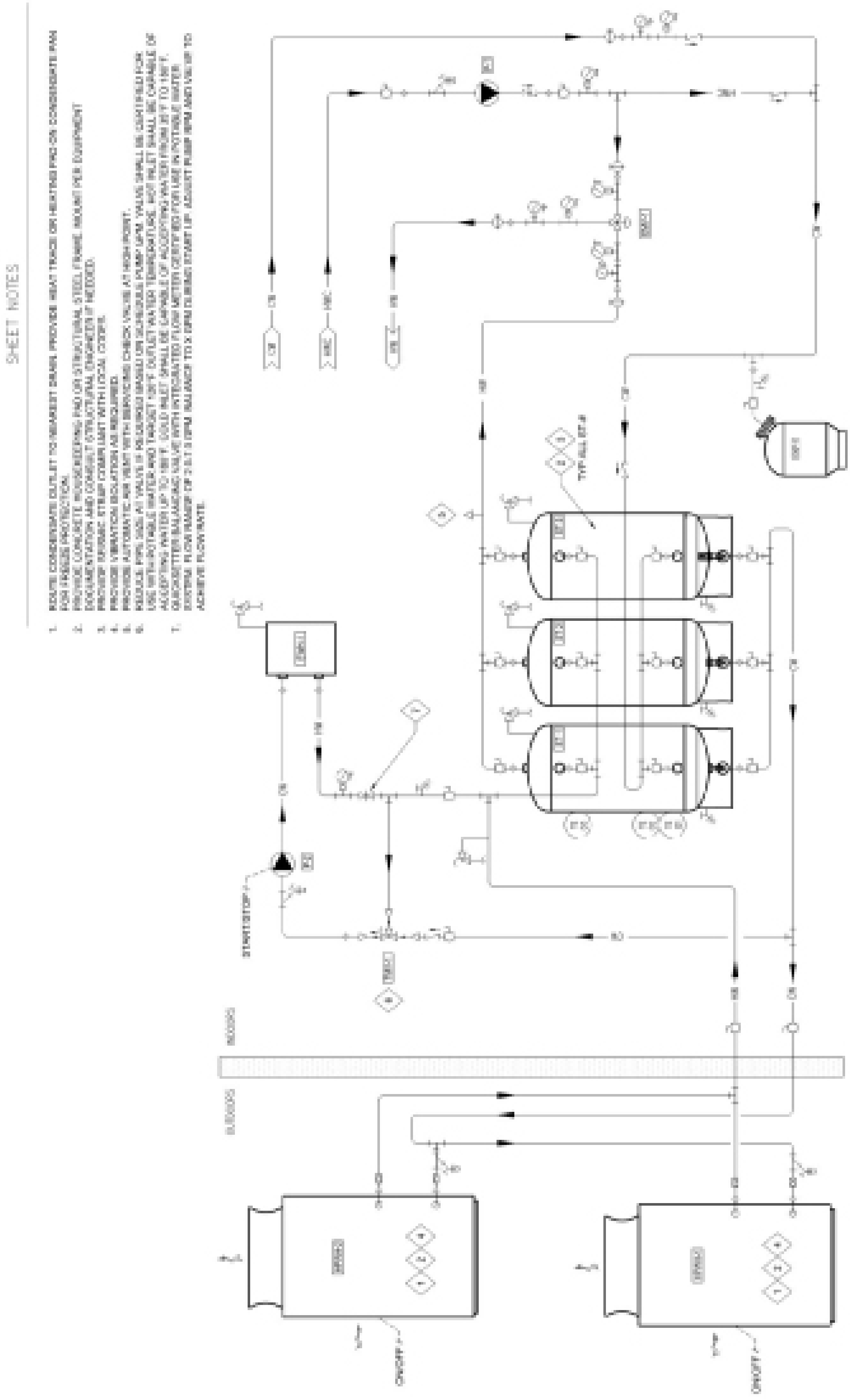
Appendix A



Appendix B- Application Test Memo

To: Erik Boyer, BPA
Robert Weber, BPA

From: Scott Spielman, Ecotope

Cc: Lochinvar

Subject: Veritus R513A Application Testing

Date: February 28, 2023

Applications testing for the Veritus R513A HPWH was performed on February 20th and 21st, 2023 at the Lochinvar factory. This memo outlines finding from the testing. A test procedure is included in the appendix.

Excecutive Summary

Applications testing of the Veritus included three major tests: (1) Functional Testing, (2) Swing Tank Testing, (3) Return to Primary Testing. The test procedure is included in the appendix. The following three high level take aways are a result of testing:

- The Veritus can operate efficiently and effectively in single pass return to primary (RTP). Single pass RTP will maximize system COP and be simpler for contractors to install. Ecotope recommends the product be added to the QPL as single pass RTP to allow it to be used through T24 as a Tier 3 product.

- The Veritus is the first HPWH Ecotope has worked with that uses reverse cycle defrost. This defrost method appears to be effective. However, if defrost water is piped into the top of the primary storage volume, cold water falling through the tank will dramatically reduce stratification – both cooling the top or the tank and warming the bottom of the tank. Ecotope highly recommends defrosts impact on stratification be carefully observed during the demonstration project. The approach to handling defrost may vary depending on climate.

    - In warm climates where defrost is rare, the current approach of piping defrost water to the top of the tank may be acceptable.

    - In cool, wet climates, like Seattle, where defrost can account for up to 20% of runtime on cold, high humidity days, two control valves may need to be added to prevent cold defrost water from entering the top of the storage tank.

- Internal controls operating Veritus refrigerants cycle, condenser pump, and control valve appear robust. However, the controls which integrate with the external system to decide when to turn the Veritus ON/OFF were unclear during testing. Ecotope recommends Lochinvar provide an explanation of controls – including how Veritus outlet water setpoint, tank ON setpoint, and tank OFF setpoint.

- Understanding of current controls may be especially valuable for LOAD UP before a load shifting SHED.

Day 1

The Lochinvar team used the swing tank configuration in the appendix to set up the Veritus lab test. When testing began on Monday, the storage tank had a uniform temperature of about 110°F. To create a stronger stratification layer, which would be observed during subsequent tests, the testing team did the following steps:

- Drew city water from the tank and closed the valve to the HPWH.

- Set the Veritus to heat only the primary tank to 140°F.

This allowed cold water to enter the bottom of the tank and hot water to exit and enter the top of the tank. The figure below shows the stratification developing in the tank.
The team also discussed the need to simplify and make the controls more understandable for the user. This can be achieved simply by adding multiple setpoint for:

Figure 2-1. Formation of tank stratification. Note the difference in scale on the two images.

- A HPWH outlet temperature

- Two tank temperature setpoints for turning the Veritus ON and OFF. Tank temperature setpoint can use the same, or different temperature sensors if multiple sensors are available in the thermal storage system.

These controls are essential for commissioning agents to verify the system performance. Using a single system temperature setpoint has caused problems for other manufacturers in the field. Additionally, the current controls will not be adequate for receiving incentives through CA SGIP program for load shifting.

Next, the team performed a swing tank heating operation by switching the valving over to the swing tank mode. However, the Veritus experienced a flow loss, which resulted in a refrigerant cycle overheating. The unit automatically shut off and entered a time delay mode to prevent further overheating. This mode is a standard safety feature for overheating due to low condenser water flow. While the swing tank simulation was not performed, the result simulated a severe clogged strainer scenario, which is one of the functional test requirements. The Veritus controls functioned properly, except for the lack of an alarm. The Veritus is being updated with alarming capabilities, and a low condenser flow alarm will be added.

During this test, it was noted that the water pump, which drives flow through the condenser, is located outside the Veritus. The pump will be sold with the Veritus but is installed externally. It will receive a signal from the onboard Veritus controls to turn ON/OFF and modulate. A control valve, which is internal to the Veritus, is also used to modulate flow.

While troubleshooting the swing tank flow issue, team performed functional testing on the Veritus unit under restricted airflow and power outage conditions. Cardboard and insulation were used to block the airflow to the evaporator, which reduced the heat absorption and lowered the superheat of both evaporators (Evap1 Spr, Evap2 Spr). The condenser subcooling (Sub Cooling) also increased as a result of less heat being pulled into the evaporator. The expansion valve (EEV 1) adjusted by closing slightly to limit the refrigerant flow and restore the superheat and subcooling values. As a result, the compressor worked harder against the more closed expansion valve, moving less refrigerant for the same electrical draw. Although it was not explicitly measured, this likely reduced the COP and the capacity of the unit. While the Veritus unit operated well to restore refrigerant conditions, no alarm was triggered.

Ecotope recommend the team work towards adding low level alarms to indicate when the system efficiency is compromised to indicate a need for maintenance. This test substantially reduced airflow to the evaporator within a matter of minutes. In the field it could take years to build up enough debris on the evaporator to justify maintenance. Alarming capabilities that can tracked slow reduction in performance, provider reasonable estimates for the causes, and remind owners to provide maintenance are valuable and should be developed. Ecotope can provide beta versions of this type of alarming during the M&V study. Intensive computational processes can then be simplified for additions to onboard controls.

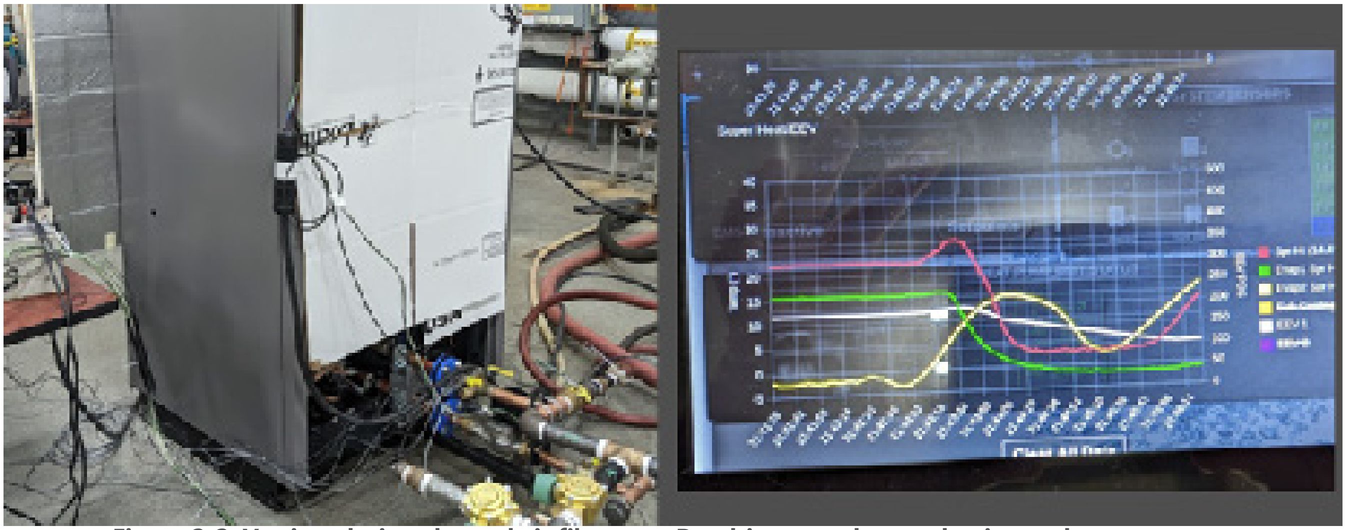


Figure 2-2. Vertitus during clogged air filter test. Resulting superheat reduction and recovery..png

Loss of power, or power outage, was tested by cutting power to the unit while it was running. The unit came back on and began heating without a delay.

It was discovered that the swing tank configuration was not working because a control valve with integrated check valve had been put into the system backwards. The valve was flipped, and swing tank operation was demonstrated manually. However, the system controls were unable to perform swing tank operation, which would require Veritus controls to trigger ON/OFF based on a call for heat by the swing tank or primary storage.

Day 2

For day two testing, the team configured the Veritus system to return to primary mode. First, the team ran defrost testing on the single primary storage tank. The Veritus was operated in reverse cycle and control valves were adjusted to direct cold, defrost water to the storage tank's bottom. Next, defrost water was directed into the tank's top. The test results were clear and decisive. Directing defrost water to the tank's top poses a high risk of de-stratifying the storage tank. This can impair the HPWH system's ability to meet hot water demand, especially in cold climates where defrost is required.

Furthermore, when storage tanks are piped in series rather than parallel, the stratification in the "hottest" tank will be degraded rapidly if defrost water is sent to the same outlet as the hot water. **Ecotope will keep a careful eye on defrost and stratification during the demonstrations project. Ecotope will make sure if defrost creates stratification issues, the hardware and controls are in place to adjust as needed during demonstration.**

Figure 2-3. Storage tank configured with multiple inlet ports. During defrost testing, first the bottom port was used for defrost return, then the top port was used.

Figure 2-4. The left figure shows the storage tank at the end of the first defrost test, where the defrost water was piped back into the bottom of the tank. The storage tank is extremely well stratified for delivering hot water at 120°F. The right figure shows the storage tank at the end of the second defrost test. Almost no hot water is available above 120°F.

Time	0:00	3:00	6:00	9:00	12:00	15:00
T1	136	136	135	134	134	133
T2	135	133	128	112	107	103
T3	135	127	123	110	105	102
T4	129	125	121	109	104	102
T5	90	116	116	106	102	99
T6	72	73	73	103	102	101
% Charge	83%	79%	75%	21%	21%	21%

Table 2-1. Tank temperatures during the second defrost test – return to top defrost testing. Note the dramatic reduction of % charge at minute 9 when 120°F stratification layer is destroyed.

The last test run was return to primary testing. For this test the team had to set up and balance the recirculation system to a ~5° deltaT at 10 GPM recirculation flow. Balancing the system proved difficult with more recirc water going back to the primary storage tank than desired. Eventually the system was balanced and the team was able to observe the Veritus operating in return to primary.

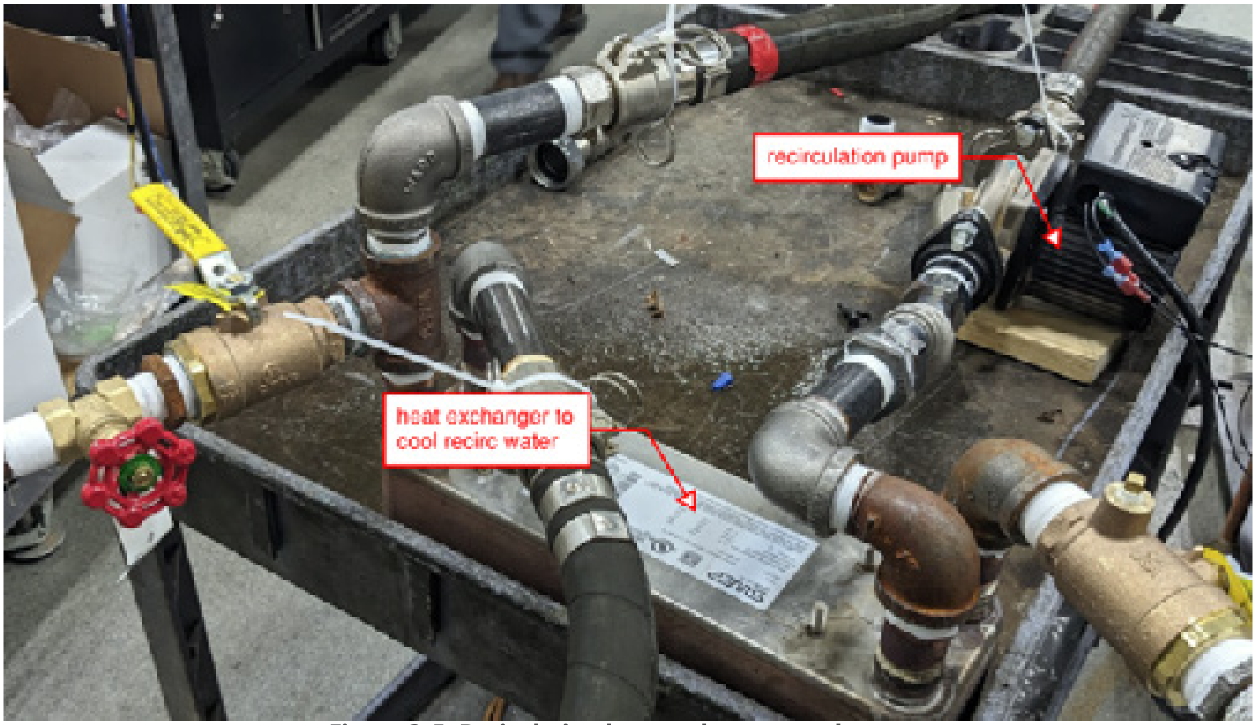


Figure 2-5. Reciculation heat exchangers and pumps