BONNEVILLE POWER ADMINISTRATION

Emerging Technologies

Nyle e60A R513a HPWH Feasibility Study

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Nyle e60A HPWH Feasibility Study

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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 use of energy in multifamily new construction in the Northwest. Nyle's e60A heat pump water heater (HPWH) will provide for a fully packaged, energy efficient, cost effective and grid responsive option for heating domestic water. Not only will the e60A help Bonneville meet its energy efficiency goals and but it also can assist Bonneville's resource plan goals to reduce electrical usage peaks.

This study is the first step in Bonneville's Technology Innovation Model (TIM) – assessing certifications, system components, performance, cost, constructibility, and maintenance – and we believe the e60A is ready to move on to Applications testing.

Codes and Certifications: Nyle has designed the e60A to meet code requirements for delivering potable water and plans to obtain a UL listing in 2021. However, the e60A will need to be tested per DOE CFR specifications before equipment efficiency (COP_h) can be reported. The DOE CFR and UL testing can pose a financial barrier to entry for commercial HPWH products in the United States, including this one. DOE CFR testing, required by law to report equipment efficiency, specifies test conditions so stringent that an extremely specialized lab is required to run the test, which can be costly. In addition, the test design points lead to test results that give little insight into the energy performance of installed equipment. UL testing guarantees product safety but is significantly more expensive than equivalent standards used in Europe, which could make it financially challenging for small US-based manufacturers to enter the market.

Performance: The e60A will be capable of producing hot water above the typical domestic water setpoint of 120°F for thermal storage and run down to temperatures well below freezing. Further testing will be performed to understand capacity and efficiency at different air and water conditions.

Cost: Nyle plans to develop a fully packaged system which will reduce overall cost and improve system reliability and performance. The unit and packaged system will be produced at a competitive cost, with expectation that it will be less expensive than many of its competitors.

Constructibility: To provide reliable installations with persistent energy savings and demand response capability, Nyle will offer packaged systems. The packaged system is expected to make product installations more comfortable for plumbing contractors to install.

Maintenance: The most important Maintenance items for the e60A heat pump and heat pump system are cleaning air-filters, water strainers, and flushing the potable water heat exchanger.

Background

Purpose

This Feasibility Study is meant to test the Nyle e60A's ability to meet the multifamily water heating needs in the PNW efficiently. The e60A is the smallest in a series of HPWHs Nyle plans to offer from 60 and 360 kBtu/hr nominal capacities. Because the design is similar for each product in the series, this study can be considered representative of the entire series. However, each product should undergo its own Applications Testing to ensure no unique issues are present before being installed in a building.

This study is the first step in the TIM, which is designed to take a technology through a series of stage gates representing different areas of inquiry to ensure that 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**

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.**
2. **Temperature maintenance of circulating water. Approximately one-third of energy is used to maintain the water temperature in the distribution piping.**

HPWHs have the potential to reduce the energy used for water heating by approximately a factor of three if properly designed.

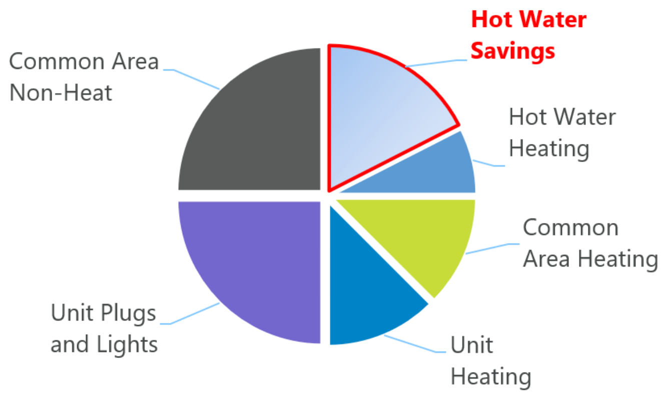

Figure 1. Multifamily energy savings with heat pump water heater.

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]
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 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.

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]

Single-pass systems heat water in one pass and require a high-temperature lift to operate efficiently, whereas multi-pass units heat water in several passes with low lift and can accept warmer water temperatures. Single-pass and multi-pass are shown in figures 2 and 3 respectively.

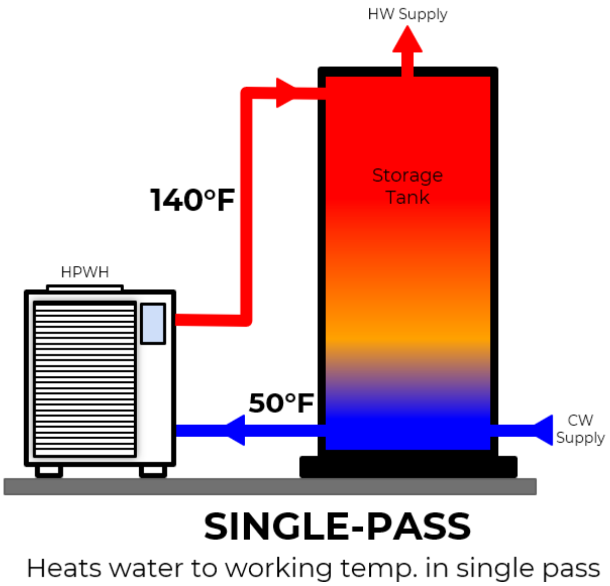

Figure 2. Single-pass HPWH

System Configuration

The Nyle e60A 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+. The similarity in refrigerant properties allows Nyle to model their design of existing R134a product lines while achieving a higher performance and better market fit to increase market penetration.

R513a also offers some advantages over CO2. For example, R513A can heat water at higher incoming water temperatures more efficiently than CO2. This allows R513A equipment to heat both entering city water and circulating water, whereas CO2 equipment is best used only heating entering city water.

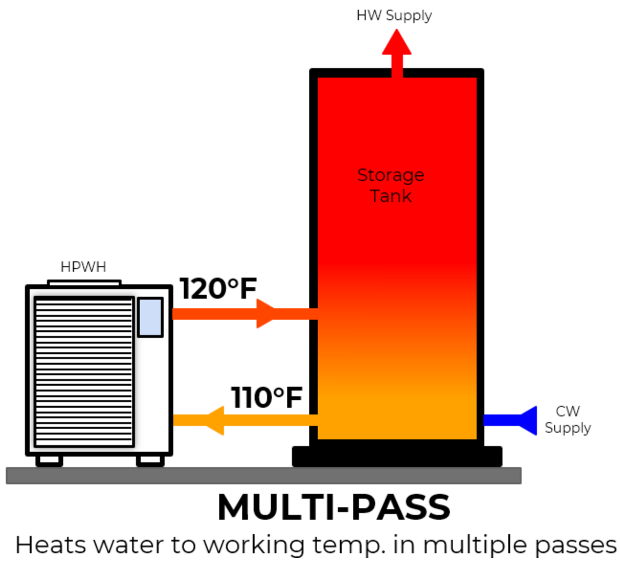

Figure 3. Multi-pass HPWH

There are no other known R513a HPWHs in production, although this new refrigerant is meant to be a drop-in replacement for existing R134a product lines.

Current Installations

The Nyle e60A HPWH is currently in the prototype and testing phase. There are no current installations.

Codes and Standards

This section reviews the Nyle e60A compliance with federal, state, and local energy codes and standards. The Energy Code addresses operational efficiencies and controls, the Mechanical Code addresses allowable refrigerant charge, the Plumbing Code addresses condensate management and drinking water quality standards, and the Electrical Code addresses the design of electrical connections.

Nyle must comply with the following codes to have a viable product in the Pacific Northwest and California.

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)

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)

Federal Safe Drinking Water Act

The SDWA requires all products in contact with potable water be tested through NSF 372 to prove they are lead-free, meaning they contain less than 0.025% lead at wetted surfaces. The Nyle e60A will comply with SDWA NSF 372.

Energy Code

Minimum performance of water heating equipment is covered in table C404.2 of energy codes based on the IECC. HPWH equipment drawing less than or equal to 24 amps must be tested per DOE 10 CFR Part 430 to show compliance. Depending on the voltage, the e60A may draw more or less than 24 amps.

TEST PROCEDURES

All HPWH equipment must be tested per DOE CFR 430 or 431 before an official heating coefficient of performance (COPh) can legally be published.

DOE 10 CFR Part 430 requires the dry-bulb (DB) temperature be maintained at 67.5 °F ±1 °F (19.7 °C ±0.6 °C) and relative humidity (RH) be maintained at 50% ±2% throughout the test. DOE 10 CFR Part 431 requires air conditions be maintained at 80.6 °F DB and 71.2 °F wet-bulb (WB) temperatures.

Tolerances required by DOE tests are extremely difficult for testing labs to meet, especially with regards to humidity – which typically has little impact on performance.

Because temperature has a significant impact on HPWH performance, the different temperatures (67.5°F vs 80.6°F) used in the DOE tests may cause confusion when attempting to compare equipment. Additionally, these representations do not reliably reflect the HPWH performance in the field – which will significantly depend on the climate in which the HPWH is installed.

Alternatively, the California Energy Commission (CEC) has developed self-reported test procedures designed to provide a holistic understanding of HPWH performance by creating a performance map for use in the CA Energy Code software. The performance map accounts for the effects of air conditions and incoming water temperature on heat pump capacity and efficiency. Nyle plans to test the e60A per CEC test procedures to create performance maps for inclusion in California energy compliance software[1].

[1]Current DOE CFR tests are a financial barrier to manufacturers because they include unnecessarily tight tolerances that need a specialized lab to perform. Additionally, by only testing equipment at a single ambient condition, tests do not accurately represent equipment efficiencies when installed. Energy codes will have a difficult time regulating HPWH performance with test procedures that do not accurately represent efficiencies. Alternatively, the DOE test can be updated to a procedure similar to the one developed by California Energy Commission that reflects equipment performance more holistically and manufacturers can run at lower cost. An updated DOE tests will create a clearer market with less barriers for both regulators and manufacturers.

Mechanical Code

The e60A must be UL certified to be accepted under the mechanical code by local Authorities Having Jurisdiction (AHJs). UL 1995 will be replaced with UL 60335-2-40 as of January 1, 2024. Products certified under UL 1995 will not be grandfathered into the new standard and will eventually need to be tested to the new UL standard.

Nyle has opted to test equipment under the new UL 60335-2-40 in 2021. This will allow the e60A to be available immediately without additional testing in future.

A skid sold and delivered as a single piece of pre-wired equipment will also need to be UL or ETL listed.

As a 508A certified panel shop, Nyle can more easily provide UL certification for packaged skid systems.

Plumbing Code

The UPC plumbing has two requirements that e60A must address (similar requirements exist in the IPC):

The first is UPC 603.5.4, which requires double-wall heat exchangers to protect potable water from the heat transfer medium by providing a space between the two walls that is vented to the atmosphere. The e60A utilizes a SWEP BPHE that is certified for potable water usage and vents to the atmosphere.

The UPC also requires NSF certification for products in contact with potable water – UPC sections 415.1, 417.1, 604.1, 604.9, 606.1, 607.2, and 608.2. NSF is used to show the product is lead-free and meets the Federal SDWA Section 1417.

NSF compliance applies to the e60A heat exchanger and any other components that come in contact with potable water. Nyle has confirmed that all applicable components will be NSF certified.

System Component Assessment

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

The e60A has a refrigerant circuit with an air-to-refrigerant evaporator, a compressor, a water-to-refrigerant condenser, and an expansion valve. It includes a fan to pull air through the evaporator and a pump to move water through the condenser. When the product is provided as a packaged system, additional components — some from third party manufacturers — must be provided. This additional equipment includes storage tanks, an expansion tank, a tempering valve, temperature maintenance equipment or a swing tank, and a fully integrated controls system. As part of the applications testing and demonstration project, the packaged system design will be finalized with schematic piping designs, specifications for components, and connection details.

System Configuration

This feasibility study is focused on the e60A single-pass configuration. In single-pass configuration, the e60A is designed for high lift, meaning the inlet and outlet water temperature delta is large. It efficiently heats incoming city water (40 °F to 70 °F) to a hot storage water temperature (130 °F to 160 °F).

Nyle will accomplish this using a swing-tank system subsequently under Swing Tank.

> *The best system design strategy for single-pass systems is to separate the primary and temperature maintenance heating loads.*

The primary heating load is the heat required to warm cold incoming city water. The temperature maintenance load is the heat required to keep circulation water hot. As the water recirculates through the building, the hot water piping loses heat to its surroundings and the water cools. If water is sent to the building at 125 °F, it may return at a temperature closer to 115 °F. Separating these two loads allows the primary single-pass HPWH to only heat incoming city water to a storage temperature above the building's hot water setpoint temperature.

A temperature-maintenance tank and additional equipment are needed to maintain recirculating loop temperature during periods of low hot water use. The temperature-maintenance tank provides secondary storage and isolates the primary storage thus preventing recirculation temperature losses and maintains thermal stratification. Two methods exist for configuring the temperature maintenance system: (1) Swing Tank, shown in Figure 4 and (2) Parallel Loop Tank, shown in Figure 5. The e60A will be introduced to market with the option of operating in a swing tank or a parallel loop configuration.

Swing Tank

The swing tank design uses an unstratified tank in series with the primary storage tanks. The swing tank temperature fluctuates between the hot storage water temperature (140 °F to 180 °F) and the hot water setpoint (~120 °F). As water is used, the hot storage water flows into the swing tank adding heat. During periods of

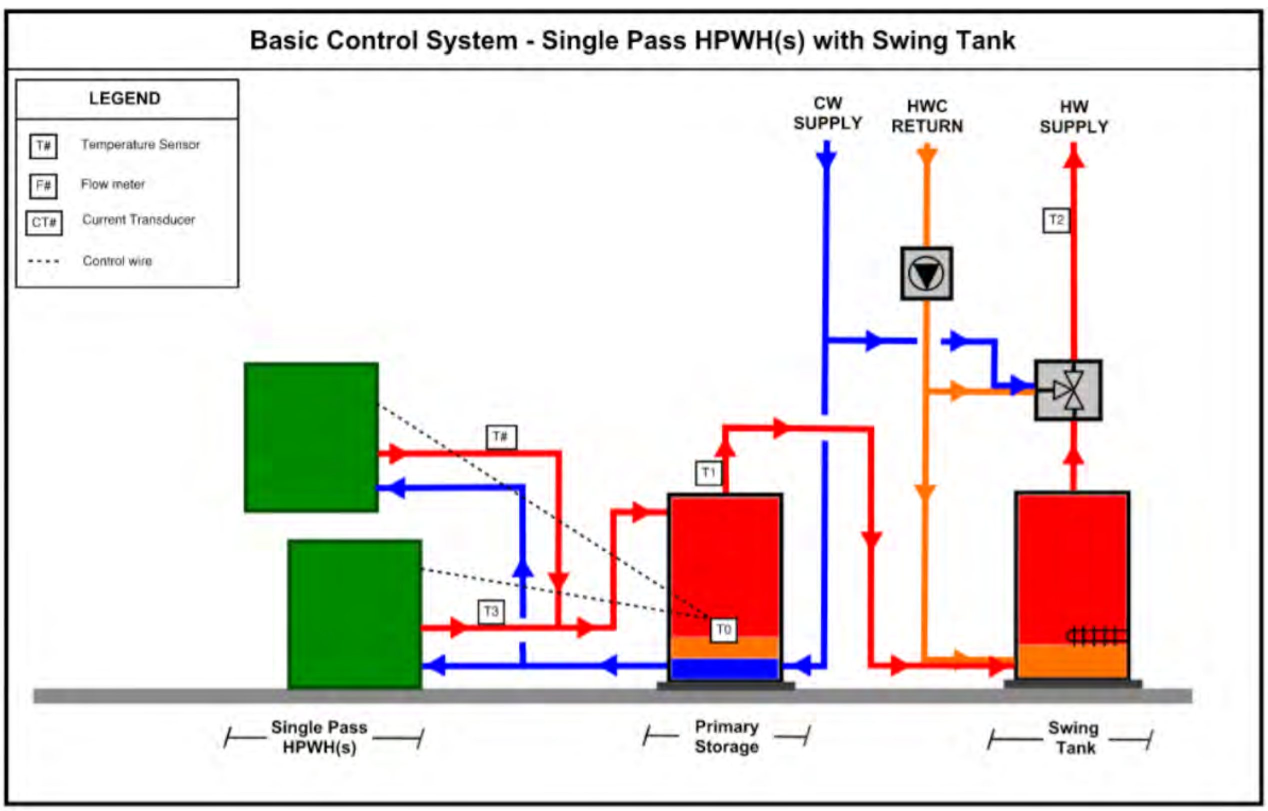

Figure 4. Swing Tank Configuration

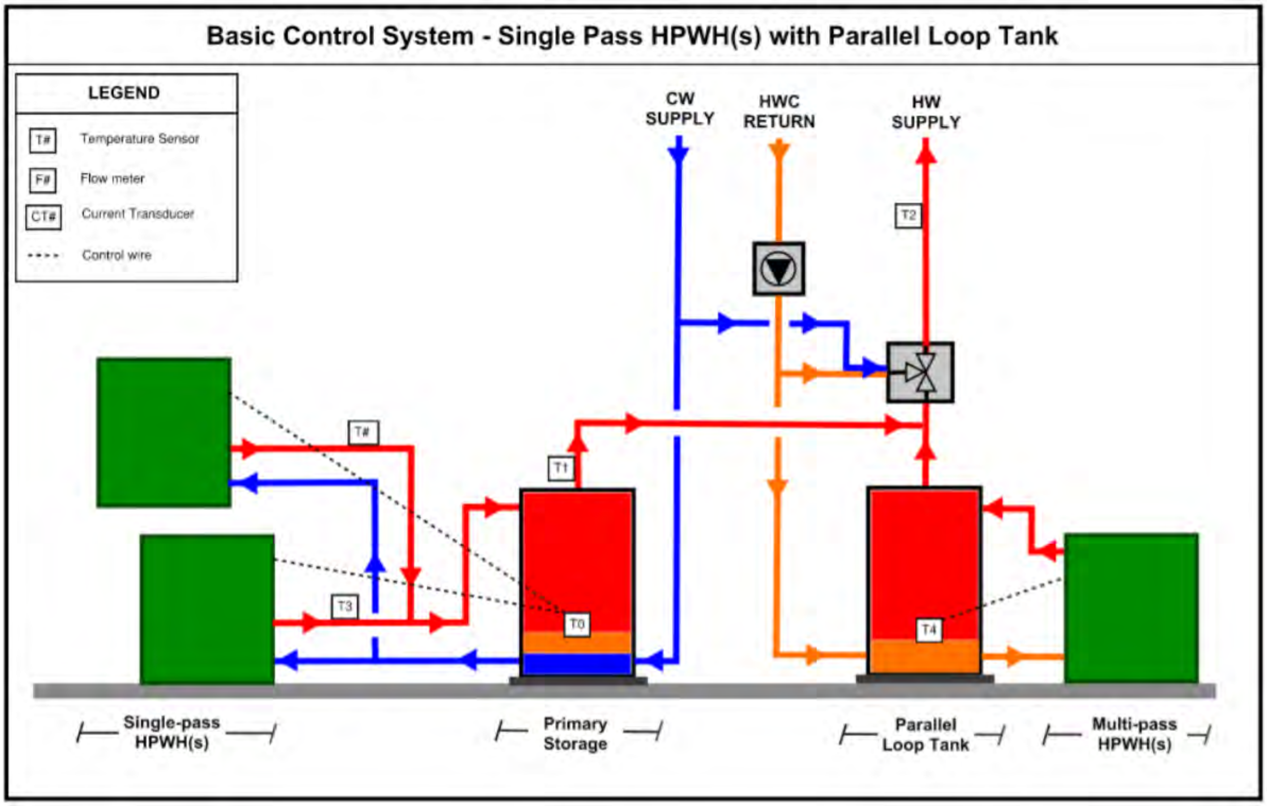

Figure 5. Parallel Loop Tank Configuration

heavy use, temperature in the swing tank will be at its highest because hot storage water entering the tank will increase the swing tank temperature. During periods of low usage, temperature in the swing tank will slowly drop. If the temperature becomes too low, an electric resistance heating element will turn on to ensure hot water will always be available to serve the building. The swing tank systems allow for a significant portion of the temperature maintenance heating to be accomplished through the primary single-pass heat pump, which increases efficiency.

Another option for a swing tank configuration is shown in appendix A. In this configuration, an electric water heater is used to provide backup heating for the heat pumps and the swing tank. Nyle will test this configuration during Applications Testing and plans to build a packaged system around it. Advantages of this option are discussed under *Engineering, Plumbing*.

Parallel Loop Tank

When using a parallel loop tank design, the recirculation losses are reheated using a separate multi-pass heat pump. This configuration uses a heat pump for both the primary and recirculation heating. In a parallel loop tank configuration, the primary storage temperature can be kept lower if desired. A lower primary storage water temperature can allow heat pumps to operate more efficiently but may require a larger storage volume. In this configuration, more heat pumps are needed, which adds cost. Additionally, without any electric resistance in the system, the parallel loop tank system capacity is significantly reduced in cold weather.

Nyle does not plan to use this configuration in the initial product offering to reduce cost and to provide more capacity in cold climates.

Potable Water Heat Exchanger

The e60A does not require a secondary heat exchanger to interface with potable water since the double-wall brazed plate heat exchanger (BPHE) built into the heat pump is certified for use with potable water.

High temperature combined with variable city water quality can cause scale that builds up in the heat exchanger. Scale buildup reduces performance and increases pressure drop through the heat exchanger. The BPHE operates under highly turbulent flow and is thus generally self-cleaning. However, buildup should be periodically manually removed to increase heat exchanger life, ensure setpoints are met, and increase efficiencies. The closed system "Cleaning in Place" method allows buildup to be flushed from the heat exchanger without disassembly.

Multiple Units

Multiple e60A units can be installed to meet the demand of large buildings. Units are designed so they may be arranged side-by-side without any side clearance needed between units. Zero side clearance is a major advantage and creates a modular system where units can be added to meet the building load while taking up less area.

Each unit will have an onboard microprocessor controls platform to allow communication with the other units in the system. Units in a system will be connected by a standard Ethernet cable. Units should be connected in a full loop for redundancy. If the cable breaks or is disconnected at any point, two-way communication will allow the remaining connected units to continue to communicate. The network of units can be connected to other systems using BACnet or Modbus.

The control system will stage units ON and OFF to balance the run time of each unit. One unit in the system will be the designated "primary" and control other units based on run times and thermal storage temperatures. If the "primary" unit malfunctions for any reason, software will automatically assign another unit as primary.

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. The e60A is meant for outdoor or buffer space installations. It resembles any other air-to-water heat pump or air-cooled chiller type 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 siting, architects will need to coordinate with the mechanical or plumbing engineer to identify an appropriate location.

Space requirements

Figure 4 shows unit dimensions, and Figure 5 shows an isometric view of the unit.

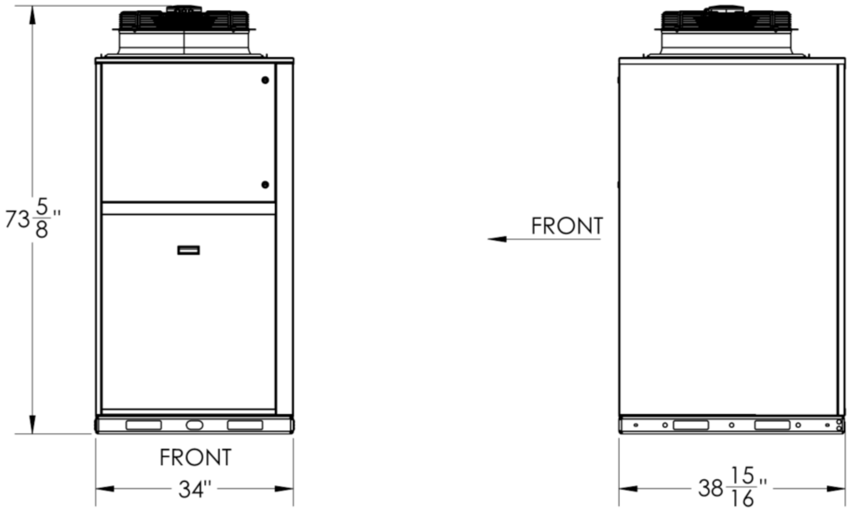

Figure 6. Unit Dimensions

The unit is relatively tall and narrow: just over 6 feet. Its dimensions are 73″ H X 34″ W X 38″ D. The unit pulls air through the evaporator on the back and discharges it out the top. The electrical panel is located on the front. The unit will require ~30″ back and top clearance to allow for airflow and 36″ of front clearance for electrical panel access.

Figure 7. Model Image of Unit

Zero side clearance allows units to be set side by side when multiple are needed. The Installation and Operations Manual will provide the necessary clearances to allow for proper airflow and maintenance once they are confirmed.

Because of the potential size of major components, such as storage tanks, it is important to identify equipment that will be too large to fit through doors early so architects and designers can plan appropriately for installation and replacement equipment. Nyle will need to finalize all individual components needed for a fully designed hot water system. Nyle will need to include installation instructions for the fully packaged system for drop-in installations. Design options should account for the number and size of apartment units being served. Layouts should consider various heat pump and storage tank arrangements. The architect and plumbing engineer will need to consult with Nyle to ensure space is allocated for the equipment.

Acoustics

Sound data for the e60A is not yet available. Sound testing will be performed alongside applications testing near the end of 2021.

Like other HPWHs, the unit should be installed away from bedroom windows and outdoor amenity spaces. When installed on a rooftop, an acoustic screen wall can be used to both reduce sound transmission and obscure equipment.

Allowable sound power levels at property lines vary by jurisdiction. Nyle 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 air intakes face into the prevailing wind. The preferred orientation for air intake is perpendicular to prevailing winds. In snowy climates, units should be elevated above snow accumulation.

The electrical panel will be located inside a NEMA 3R rated minimum enclosure, with the option for a NEMA 4X rated enclosure for additional protection from corrosion and extreme environments. Additional corrosion protection for internal components is available for a marine environment.

Like all HPWHs, capacity decrease with outdoor air temperature 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 e60A weighs approximately 775 pounds. It includes a reciprocating 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 the e60A is provided as part of a packaged system that includes thermal storage and a temperature maintenance system, the package 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

When e60A units are located indoors, mechanical engineers are responsible for providing ducted connections. Nyle will need to provide flanged connections to allow ductwork to be easily installed on the air inlet and outlet. Guidelines for duct dimensions and length, and/or static pressure should be included in the installation manual. Additionally, guidelines for selecting a booster fan should be provided. The e60A should have an additional contact for controlling a booster fan, which will be fed by a separate electrical connection for power.

Electrical

The e60A will be available for 208-volt (V) 3-phase (PH) and 460-V 3-PH. It 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 and is therefore the section applicable to the e60A.

Overcurrent, short circuit, and/or ground fault protection are not built into the unit and would typically be provided in the local disconnect or as part of the panel serving the device. Best practice is to install overcurrent, short circuit, and/or ground fault protection in the local disconnect within the line of sight (see NEC 440). Each unit should be provided with its own dedicated circuit.

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.

Plumbing

Plumbing engineers are typically tasked with selecting water heating equipment. However, the e60A is a more complex than the typical gas or electric water heater. Maximizing the potential of the e60A requires a system with thermal storage tanks for primary hot water storage and a swing tank to manage recirculated water.

Typically, plumbing engineers do not have the expertise, time or funds to design the complex custom system needed to support the HPWHs like the e60A. As a result, the e60A may be applied improperly and waste energy, or it might not be used at all because the plumbing engineer will specify an option that they are more comfortable designing around. It is therefore imperative for Nyle to offer complete system design support through their distribution channels.

Ductwork connections on the e60A are a unique advantage that sets it apart from other HPWHs currently on the market. Especially in cold climates, ductwork allows the e60A to be installed inside and avoid complications from wind and snow. Additionally, if ducted, the e60A can pull air directly from building exhaust. This will allow the unit to capture otherwise wasted heat from air leaving the building and operate more efficiently in cold temperatures.

CAPACITY

Plumbing engineers have support for sizing both the HPWHs and the thermal storage. Nyle distribution channels plan to help customer with the sizing process using a custom Nyle tool or the Ecosizer.

After required equipment sizes are known, engineers will need to select the number of HPWHs based on capacity. The e60A is designed to provide 60,000 Btu/hr (5 tons) of heating at the DOE test point. However, because capacity typically drops with temperature, engineers will need to select the appropriate number of heat pumps based on the capacity at a design temperature. Unlike electric resistance heaters, the amount of heat that can be provided using a HPWH changes with outdoor air temperature. Change in capacity based on outdoor temperature (the performance map) will be recorded during subsequent stages of the TIM and product development.

REDUNDANCY

Ecotope recommends that an e60A system be capable of integrating with electric resistance water heaters as a form of redundancy. Electric resistance capacity is less efficient and costs less than HPWH capacity. The electric resistance water heater in the packaged system should be piped in parallel with the HPWHs so that it can also store heat in the primary storage tanks – shown in appendix A.

ELECTRIC RESISTANCE SUPPLEMENTAL HEATING

When electric resistance heating is used for redundancy, it can also kick on during extremely cold weather periods to reduce the number of heat pumps that must be purchased to meet the load.

> *Nyle projects the unit will be capable of operation down to 10 °F, without heat being provided from a back-up source.*

As outdoor air temperature drops, HPWH capacity and efficiency also drop. To provide a system that optimizes first costs, energy savings, and cold-climate performance, Nyle plans to provide some electric resistance heating integrated into its packaged system. Appendix A illustrates a schematic design of a Nyle e60A and an electric resistance water heater for both HPWH backup and swing tank heating. Nyle will carry this design into applications testing to further optimize the system design.

In cold climates, Nyle may allow the electric resistance to supply primary heat on the coldest days. On many projects, this will substantially reduce first costs by allowing the purchase of fewer heat pumps without significantly impacting energy usage.

Figure 8 shows graphically when heat pumps would be supplemented by electric resistance heating in a mild climate.

The plot shows “Combined Capacity of (N) Heat Pumps”. This is the total capacity from 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 day. Notice that combined HPWH capacity does not meet the demand on the coldest day shown 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.

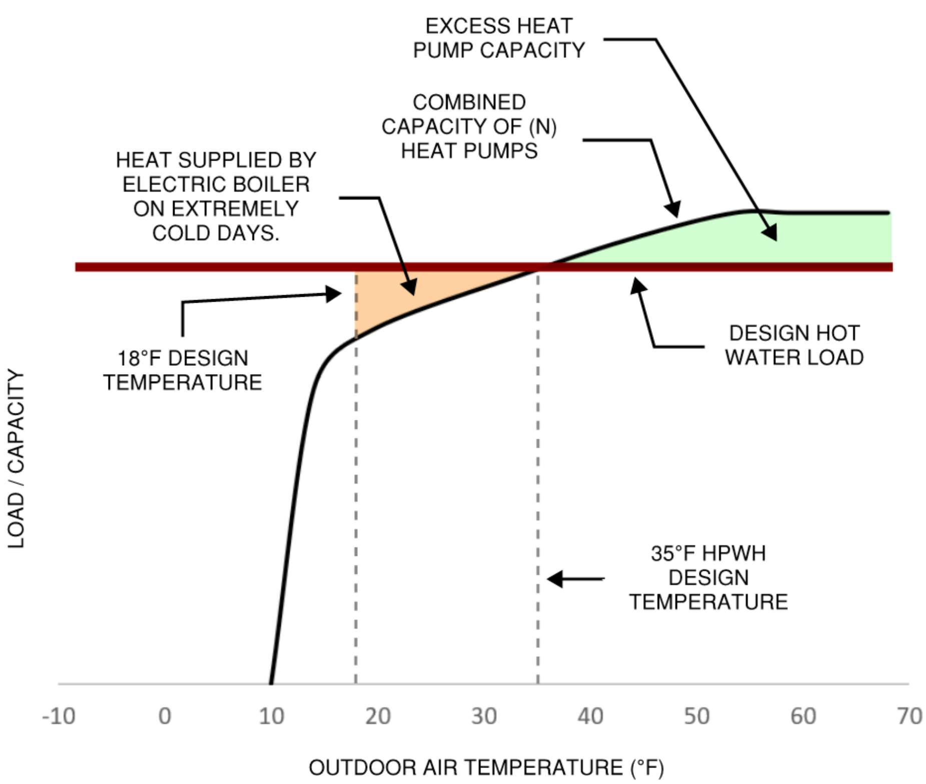

Figure 8. Mild Climate Sizing Method

Figure 9 shows how electric resistance heating can be leveraged in cold climates. In cold climates, where design temperatures are below 10 °F, Nyle will provide full electric resistance back up. However, the capacity required compared to a typical electric resistance system will be significantly reduced by the amount of thermal storage present.

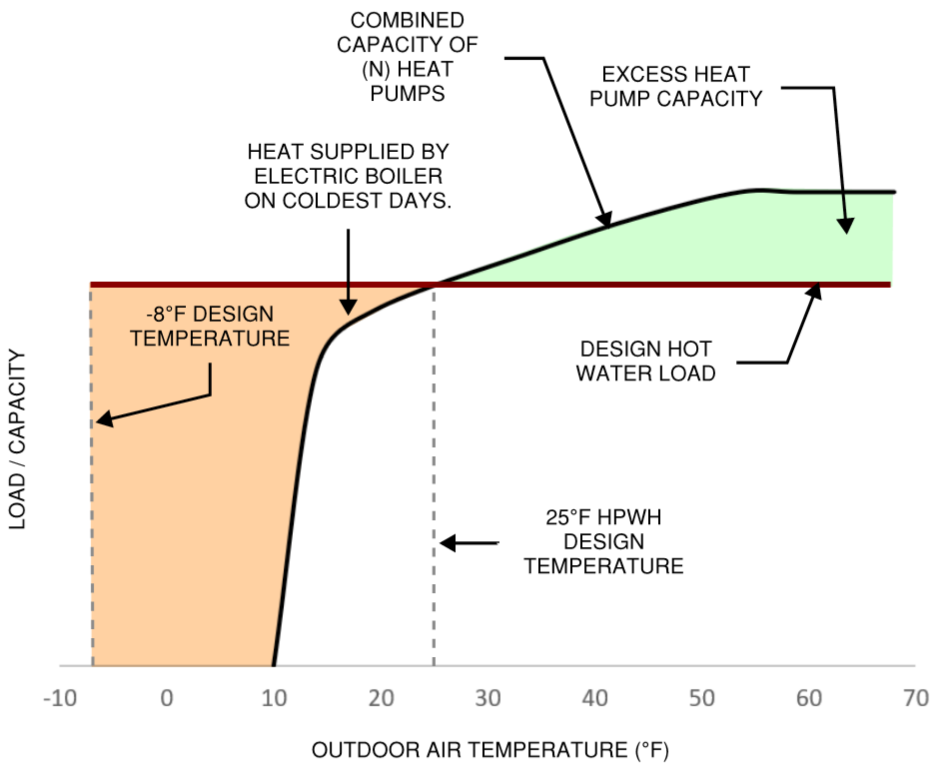

Figure 9. Cold Climate Sizing Method

If electric resistance heating is used for redundancy the system could also leverage electric resistance for demand response in some areas. When electricity is being produced at a low cost with renewable energy, clean electric resistance can be used to reach elevated setpoints or charge the thermal storage system more rapidly.

> ***A parallel electric water heater can allow the same resistance elements to provide swing tank heating, redundancy, trim heating in low-ambient conditions, and increase setpoint under EcoPort (CTA-2045) "advanced load-up" commands.***

When a parallel electric resistance water heat is used, as shown in appendix A, a single electric resistance water heater can be used for multiple purposes.

FREEZE PROTECTION

The e60A will be offered with and without a cold weather package, which includes electric resistance defrost elements and heat trace on internal components. For the cold weather package, all internal water piping, the condenser, and condensate drip pan in the e60A are wrapped with heat trace. In emergency situations, with an extended power outage, the unit can be shut down, drained of water, and filled with an antifreeze solution by maintenance personnel to prevent damage.

In addition to internal heat trace, heat trace should be located on any outdoor connected potable water piping and condensate piping in cold climates. Contact closures on the heat pump can be used to control heat trace on connected piping.

DEFROST

If HPWH evaporator coils freeze then a defrost cycle must initiate to allow heat transfer at the evaporator. Nyle plans to program the e60A to check if frost has built up on the evaporator coil by measuring current to the evaporator fan. As frost builds up on the coil, the static pressure required to move air through the coil will increase and thus change amperage to the fan. This method is common in refrigeration cases, but less common in outdoor heat pumps. Nyle should pay close attention to fluctuations in static pressure through the fan due to changes in outdoor conditions, such as wind, as well as ducted applications, to make sure defrost operates properly.

The e60A can operate at low temperatures. However, at low temperatures both reduced capacity and the need for defrost reduce useful heat output. Shorter defrost cycles enable the equipment to produce heat more of the time, which correlates to increased capacity at lower temperatures. Although electric resistance defrost can increase energy usage, it can also allow for faster defrost and increased capacity at low temperatures. [iii]

All the following conditions must be met before the unit enters a defrost mode.

- Amperage draw of the condenser fan indicates frost build up.
- Refrigerant temperature is below freezing and below the outdoor air wet bulb temperature.
- Cumulative compressor operation has exceeded a time limit to prevent cycling.

During defrost, the heat pump will turn-off the evaporator fan, shut-off the compressor, and engage electric resistance heating coils within the evaporator to melt the ice. Nyle is also considering adding spring loaded dampers to the outside of the evaporator coil. When the fan is not operating, dampers will close. Dampers will prevent wind from interfering with the defrost cycle and decrease defrost cycle time and increase efficiency.

CONDENSATE

In a typical cold-climate installation, the unit will be mounted on a curb. Under the curb, the surface will be sloped 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.

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 properly, the e60A should provide long-term quality performance. A fully packaged system will allow for reduced installation costs, consistent operation, and standardized maintenance.

To provide visibility to system operation, Nyle HPWHs will offer internet and utility connectivity as a standard feature. This will enable web monitoring, system optimization, error alerting and demand response through a standard EcoPort (CTA 2045) connection.

Demand response will allow the e60A to significantly reduce operating costs in some areas. Nyle has partnered with Packetized Energy to provide demand response capable of meeting the needs of any building owner and utility. In addition to the Packetized proprietary demand response platform, equipment will be able to communicate through EcoPort (CTA-2045) and OpenADR. Controls will meet Joint Appendix 13 (JA13) requirements for California.

Nyle needs to demonstrate that load shifting controls operate efficiently. Current codes, standards, and cloud providers (such as Packetized Energy) are focused on demand response for unitary residential electric resistance water heaters. These systems typically only use setpoint control to "Load Up" a storage system. For owners to see the most return on investment, control strategies for swing tank systems will need to use staging control in the primary system and setpoint control in the swing tank. Primary staging control will change the sensing location in the primary storage where the heat pump turns on and off. Swing tank setpoint "load up" temporarily increases the temperature setpoint of the swing tank.

End Users

End Users are concerned with consistent delivery of hot water. The key to consistent delivery of hot water in a HPWH system is properly sized components and redundancy. Engineers should always have at least N+1 redundancy with hot water generating equipment.

Availability, Cost and Constructibility Assessment

The availability, cost, and construction assessment evaluates challenges associated with acquiring and installing the product.

Availability

Over the past decade, Nyle has expanded manufacturing capabilities to provide more products at a shorter lead time for the growing HPWH market. Investments in production and testing have enabled the company to meet the growing demand and project timelines. Nyle is expected to be able to ramp up production in accordance with market demand.

Investments in engineering and manufacturing capabilities were made in part with capital provided by Maine Venture Fund (MVF), a state-sponsored venture capital fund. Nyle has recently repurchased shares from MVF allowing the venture capital company to invest in other dynamic Maine companies. Recently Nyle was awarded a grant of $142,981 from the Maine Technology Asset Fund 2.5 (MTAF2.5) program. The grant will enable them to expand capabilities and support continued job growth.

Construction Schedule

When provided as part of a package system, there will be little impact on the construction schedule. As with VRF systems, a packaged HPWH system should be straightforward and easy for contractors to install on schedule and within budget.

Retrofit Feasibility

HPWHs are good retrofit candidates for replacing either electric resistance or gas central water heating systems. If replacing a gas boiler, then the project engineer needs to determine if sufficient electrical capacity is available or if an electrical upgrade is needed to power the HPWH. If replacing electric resistance tanks then, some tanks can be removed to make room for the HPWHs on existing electrical breakers. In many instances, some of the existing water heaters can be repurposed providing swing tanks for the HPWH. The largest challenge on many projects will be finding a location for the unit outdoors and additional space for the storage tanks.

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

Nyle sells products through a network of manufacturers' representatives across North America and provides them with extensive training. Training is broken into three courses: Overview, Applications and System Selection and Installation, and Operation and Maintenance. Nyle provides this training throughout the year through live webinars and then provides access to these videos via an online library accessible on their website. One-on-one training and project support sessions with engineers are available upon request.

Nyle factory technicians are deployed around the world to support system startups and annual service contracts.

Warranties for the e-Series will be tiered with a standard one-year warranty and extended warranties available. The Advanced Water Heating Specification 8.0 includes warranty requirements for heat pumps to meet Tier qualification. Nyle will reference it when determining cost and warranty.

Maintenance

Maintenance requirements for the e60A are comparable to other HPWHs. Nyle 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

Nyle is investing in a low-GWP, demand response capable heat pump system notable and essential to the decarbonization of buildings. Nyle must still make significant investment to create a fully packaged product that responds consistently and can be easily installed. Nyle is based in the Maine, so to serve a Northeast market, the e60A must be capable of operating in extremely low outdoor temperatures.

Overall, the e60A has enormous potential to provide energy savings and load shifting when included as part of a well-designed packaged system. It is recommended to move the e60A forward in the TIM to Application Testing, which will determine if the product is ready for a demonstration project. Applications testing is expected to start in November or December of 2021.

Citations

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[ii]Heller, Jonathan, K. Geraghty, and S. Oram. Multifamily Billing Analysis: New Mid-rise Buildings in Seattle. December 2009. Prepared by Ecotope for Seattle Department of Planning and Development

[iii]Kashif Nawaz, Ahmed Elatar, Brian Fricke. A Critical Literature Review of Defrost Technologies for Heat Pumps and Refrigeration Systems. ORNL, March 31, 2018

Appendix A: Nyle eC60A Packaged System Diagram