A Contractor’s Introduction to Gas-Fired Heat Pump Water Heaters

A gas-fired heat pump water heater (GHPWH) uses the heat of combustion to drive a thermodynamic cycle that draws heat from the ambient air and transfers it to water in an indirect storage tank in addition to the heat provided by combustion of natural gas or propane. The result is a highly efficient (COP of around 1.5) water heating system that reduces energy use, utility costs, and carbon emissions. Unlike electric heat pump water heaters, a GHPWH will normally consist of a heat pump installed outdoors connected hydronically to an indirect storage tank installed in the mechanical room. Depending on the daily hot water use, a conventional gas water heater (storage or tankless) is recommended downstream of the indirect tank to handle peak loads. Additional specifications are provided in Table 1.

Figure 1: Gas Heat Pump Water Heater Prototype, Courtesy of SMTI

Why Use a Gas-fired Heat Pump Water Heater?

GHPWHs present a unique opportunity for plumbing contractors to provide a high-efficiency solution to customers that can save them 40% or more on operating costs over their aging water heaters. This is especially important for commercial foodservice facilities in California, which typically experience high gas water heating operating costs. Although the equipment and installation cost will be higher for a GHPWH compared to typical storage gas water heaters, the reduction in operation cost provides a favorable return on investment (ROI). The equipment’s simple payback time for an average medium-sized full-service restaurant would be about two years, offering savings around $2,500 per year. Commercial GHPWHs also present a unique opportunity to reduce space cooling costs and improve thermal comfort by directing cold air from the evaporator into the conditioned space.

Table 1: Commercial GHPWH Specifications

Technology Developer	Stone Mountain Technologies, Inc.
Heat Pump Output	80,000 Btu/hr
Gas Input	54,000 Btu/hr
Efficiency	COP of 1.5
Tank Size	100 gallon suggested
Max Supply Water	140°F
Hot Water Daily Supply	>4,500 gal/day
Supplemental Cooling	2.0 RT
Emissions	≤ 14 ng NOx/J
Installation	Heat pump outside, hydronically connected to indirect tank (inside), and optional cooling fan coil (inside).
Gas Piping	3/4”
Estimated Heat Pump Cost	$5,000
Total Installed Cost	$10,000 - $13,000

The initial cost will be reduced when rebate incentives become available. The GHPWH could receive a rebate as high as $2,000 with its average savings of ~400 therms/yr. This rebate estimate is based on current $100 rebates provided for 0.67 UEF (EnergyStar) water heaters, which equates to a rebate value of $5/therm of natural gas saved. The GHPWH also meets all California South Coast Air Quality Management District's Ultra Low NOx emission requirements (by meeting Rule 1146.2 <14 ng NOx/J output threshold).

How Does it Work?

GHPWHs work similarly to an electric heat pump, but the thermodynamic cycle is not a vapor-compression cycle. The compression is done in the liquid phase by a small pump instead of in the gas phase by a compressor in what is called a single-effect absorption cycle.

The single-effect absorption cycle is presented in Figure 2. The GHPWH is based on the vapor absorption refrigeration cycle, using an ammonia-water working fluid pair, where an absorbent (water) is used as a carrier for the refrigerant (ammonia). Though the refrigerant is still compressed by an electromechanical pump like in electric heat pump water heaters, it is compressed as a liquid which requires significantly less energy. Thermal energy from the 54,000 Btu/hr (15.8 kW) gas burner is required to drive the refrigerant vapor from its absorbed state in the desorber.

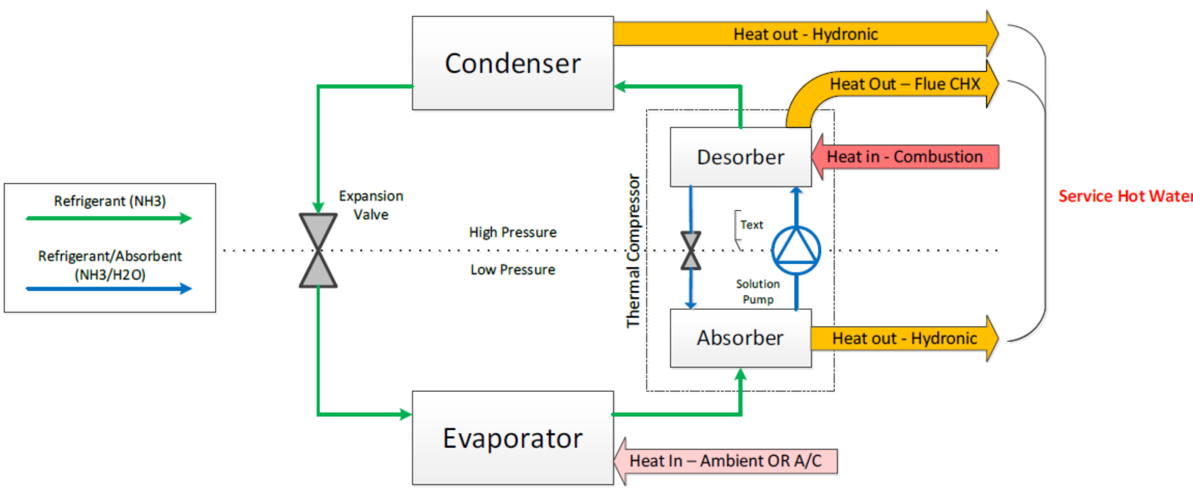

Figure 2: Single Effect Absorption Cycle, Courtesy of SMTI

The GHPWH heats stored water using a combination of energy from natural gas and energy that is extracted from the outside ambient air. Optionally, the cooling load from the evaporator can be directed to the indoor space, which cools the room in which the hydronic fan-coil is installed. If indoor cooling is not desired, the heat pump automatically connects the evaporator to the outdoor air so it can operate year-round. This means that a GHPWH provides water heating whenever needed, whether space cooling is required or not. Unlike electric heat pump water heaters, the GHPWH can also continue operating even down to very low ambient temperatures (-40°F).

The cooling capacity from a GHPWH is approximately half that of an electric heat pump water heater as more than 50% of water heating is achieved through the heat of combustion. This means the GHPWH heating-cooling capacity ratio is more closely aligned with the building needs and will not over cool the indoor space while generating hot water.

What Can I Expect for Installation and Maintenance?

The following is required to install a GHPWH:

1. 110-120V single phase electrical service from a 15 amp breaker to power the various electric components in the heat pump
2. ½ or ¾" gas piping connection to the heat pump depending on length of the run
3. A condensate drain line
    a. Depending on the host site requirements and local regulations, condensate disposal may require a condensate pump and/or neutralization
    b. The drain line should be made of PVC and at least ½" in diameter
4. An indirect storage tank (typically installed in the mechanical room) connected via a hydronic loop to the heat pump. A tank with a storage capacity of at least 100 gallons is recommended and the size of the internal heat exchanger should be matched to the heat pump capacity.
5. Optionally, a hydronic fan-coil installed indoors to provide "free" cooling. The fan-coil is connected to the heat pump via a second hydronic loop.
6. Standard water heater plumbing for hot and cold water to and from the indirect storage tank
7. Portable flue gas combustion analyzer to dial in the excess air for the 100% sealed pre-mix, ultra-low NOx combustion system

For most applications the heat pump will provide the "base load", while a conventional gas-fired storage or tankless water heater covers the peak load (or will be used to increase the delivered hot water temperature above 140˚F, if required). This "base load – peak load" strategy ensures the heat pump utilization is maximized, which improves the cost-effectiveness. A heat pump sized to handle the peak loads would be much larger and more expensive.

If the installation currently uses two gas-fired storage tank water heaters, the indirect storage tank connected to the heat pump can replace <u>one</u> of the two existing water heaters, with the second remaining to handle the peak load.

Condensate Drainage

The GHPWH is a condensing appliance which will generate flue gas condensate during operation. This condensate will need to be directed to a suitable drain (perhaps via a condensate nuetralizer if required by local codes) or directly into the ground per the manufacuter's instructions. If installed in a location subject to freezing temperatures and the condensate is directed to a drain, heat tracing may be required.

Clearances and Space Requirements

Since the GHPWH is a **<u>heat pump</u>** which draws part of the heat delivered from the ambient air, a minimum of 24 inches of clearance is required around all four sides of the heat pump. The fan which draws air over the outdoor coil should not be obstructed to provide adequate air flow. The heat pump can be installed anywhere outside the facility (roof or ground) as long as there is adequate gas service and ventilation.

Figure 3 shows an example diagram showing an outdoor/indoor installation of a GHPWH in a commercial facility. It shows the heat pump unit installed outdoors, connected via hydronic loop to an indirect storage tank installed in the mechanical room. Cold water is first directed to the indirect storage tank and then to the conventional gas water heater for final heating. The recirculation loop return (if used) should be directed back to the conventional water heater. An (optional) chilled water loop is installed between the heat pump outside and a hydronic fan-coil inside. This is similar to how mini-split air conditioners are installed, where an evaporator fan-coil is placed inside, connect via refrigerant lines to the outdoor condensing unit.

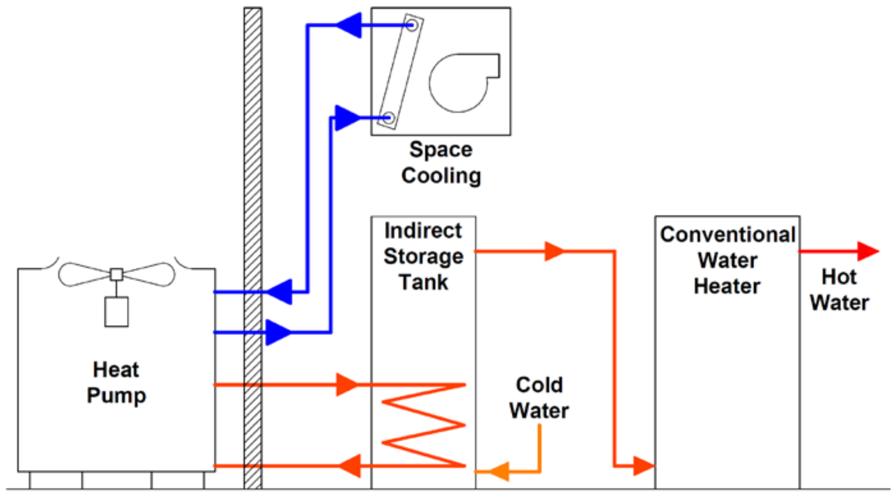

Figure 3: GHPWH System Components Schematic

GHPWH Maintenance and Considerations

It is recommended that the GHPWH receive periodic maintenance inspections to ensure proper function. The system controls will monitor heat pump performance and notify customers of possible maintenance requirements.

Other examples of possible but less frequent maintenance requirements would include:

1. Cleaning or replacing the air filter in the hydronic fan-coil (cooling) unit
2. Checking / cleaning the condensate neutralizer
3. Checking / cleaning the outdoor heat exchanger on the heat pump
4. Checking / cleaning / replacing a flame sense rod or ignitor, located at the burner. This is accessible near the gas inlet to the GHP.
5. Checking the pressure and glycol concentration of the hydronic loops connecting the heat pump to the indirect storage tank and (optional) cooling fan-coil

The heat pump section is factory sealed with the refrigerant charge and should not require maintenance over the lifetime of the water heater. The amount of ammonia refrigerant used is 10 lbs., well below of the allowable limit per safety standards.

Conclusion

GHPWH systems offer a unique opportunity to transform the commercial water heating market with a very high-efficiency gas product. The relatively straightforward installation requirements and competitive lifetime cost make it a strong new option to current high-efficiency gas products in the market, such as tankless and condensing water heaters. The slightly higher installed cost is offset by the large reduction in energy use over the lifespan of the water heater. The low maintenance requirements provide confidence that the customer can reliably meet their hot water needs without the need for frequent maintenance or intervention.

Further Resources

A full project report to the California Energy Commission demonstrating a commercial GHPWH at two restaurants in the Los Angeles basin is expected to be posted online in early 2021 here: https://www.energy.ca.gov/energy-rd-reports-n-publications.