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Commercial Absorption Heat Pump Water Heater: Beta Prototype Evaluation

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MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

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ABSTRACT

The Beta version of the Commercial Absorption Heat Pump (CAHP) water heater was evaluated in the environmental chambers at Oak Ridge National Laboratory. Ambient air conditions ranged from 17 to 75 ^{o}F and inlet water temperatures ranged from 100 to 120^{o}F in order to capture trends in performance. The unit was operated under full fire (100%) and partial fire (55%). The unit was found to perform at 90% of the project goal at the design conditions of 47^{o}F ambient and 100^{o}F water temperatures. The trends across the full range of environmental conditions were as expected for ambient air temperatures above 32^{o}F. Below this temperature and for the full fire condition, frost accumulated on the evaporator coil. In future work a defrost strategy will be enabled, the unit will be thoroughly cleaned of an oil contamination and the rectifier will be reconfigured in order to meet the design goals and have a field test unit ready in early 2017.

1. INTRODUCTION

This document presents the results of our evaluation of the 140 kBtu/h commercial absorption heat pump water heater Beta prototype unit. The Beta is the third generation configuration in this project. The lab breadboard test system was the first prototype and was a culmination of intense modeling efforts by Stone Mountain Technologies, Inc. (SMTI) and ORNL. The second prototype was named the Alpha and consisted of many of the breadboard components, improvements to a number of heat exchangers and assembled as a package unit. The Beta contains a number of further improvements over the Alpha. It is considerably smaller than the Alpha prototype with a 30% reduction in volume as well as a 23% smaller footprint. Five of the eight heat exchangers in the Beta are smaller and less costly. The evaporator fan, motor and venturi design were all upgraded. The solution pump was also improved.

Figure 1: Beta unit in the environmental chamber at ORNL

2. RESULTS & DISCUSSION

The performance of the Beta is described in terms of the gas input based Coefficient of Performance (COP_{gas}) and the heat load duty. The former is defined as

$$COP_{gas} = \frac{Sensible\ water\ heat\ load}{Maximum\ energy\ available\ from\ the\ natural\ gas}$$

$$= \frac{\dot{m}_w c_{pw}(water\ temperature\ increase)}{\dot{V}_{gas} h_{hv}}$$

where

$\dot{m}_w$	water mass flow rate, lb/h
c_{pw}	specific heat capacity, Btu/lb ^oF
$\dot{V}_{gas}$	volumetric flow of gas to the burner, ft^3/h
h_{hv}	natural gas higher heating value, Btu/ft^3

and temperatures are in ^oF.

Figures 2 and 3 are plots of COP_{gas} and heat duty for a range of ambient (17-75^{o}F) and hydronic (100-120^{o}F) temperatures investigated by ORNL with the unit operating at 100% firing rate. The plots show that the system performance experiences the expected trends for the range of conditions investigated. Performance decreases with increased hydronic temperature and decreased ambient temperature. The data recorded at the 47/100^{o}F design point indicates that the system is performing at 90% of design COP_{gas} (~1.32 vs. the design goal of 1.45) and design water heating output or heat duty (~126 kBtu/h vs. design goal of 140 kBtu/h). Figure 2 also contains 47/100^{o}F and 47/105^{o}F data recorded at SMTI. The data has slightly higher COP values than the experimental data recorded at ORNL. Airflow blockage through the evaporator to simulate lower ambient temperatures led to secondary effects that contributed to this discrepancy.

Curve fits to the 75, 60 and 47^{o}F data all follow the same slope while curve fits to the 32 and 17^{o}F data follow a slightly different slope due to frost accumulation on the coil (see Figure 4). A future defrost mechanism will alleviate this problem.

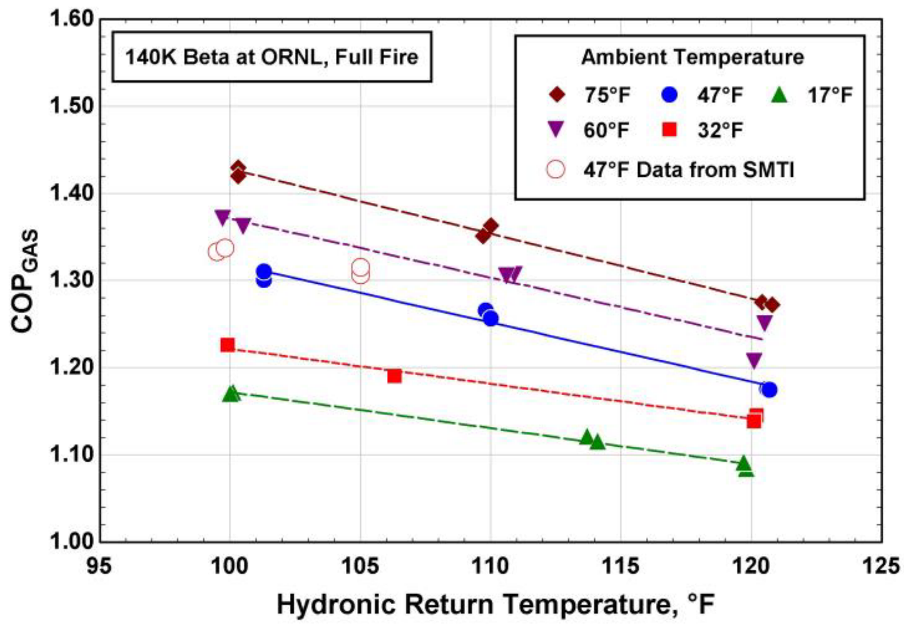

Figure 2. COP_{gas} vs ambient air and hydronic temperatures

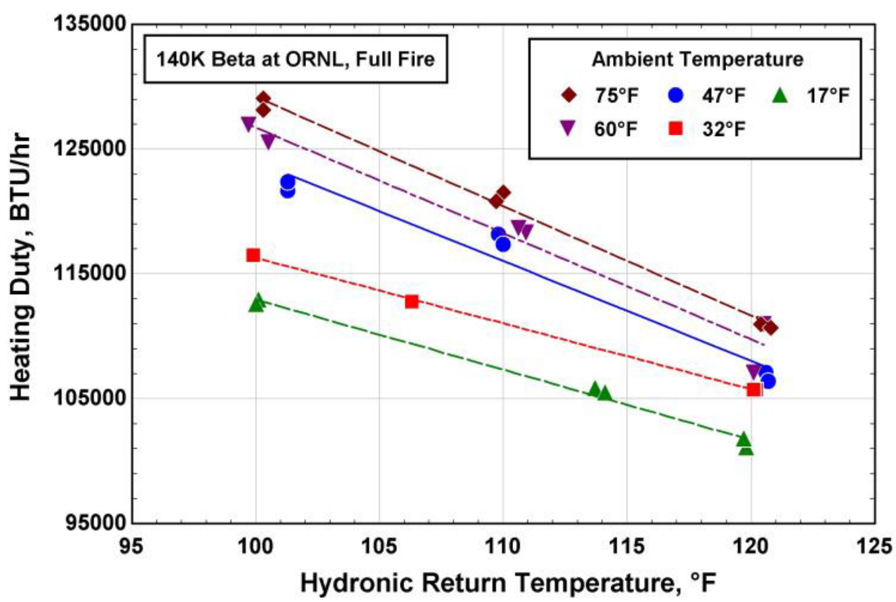

Figure 3. Heating load vs ambient and hydronic temperatures

Figure 4. 140k Beta unit with a frosted evaporator coil

The unit was also investigated at a reduced firing rate of 55% (54 kBtu/h) for a range of ambient air (17-60^{o}F) and hydronic (100-120^{o}F) temperatures. This testing was performed to evaluate system performance and heating duty at lower firing rates and demonstrate capacity modulation characteristics.

Figures 5 and 6 show performance trends similar to those experienced during the 100% fire testing. At the design conditions of 47/100^{o}F the system provides a COP_{gas} of ~1.32. The impact on performance due to the accumulation of frost is less noticeable for the 55% firing rate data. This is expected as the heat transferred by the evaporator is reduced by roughly 50% compared to that at full firing rate and the time required for frost to accumulate would be longer.

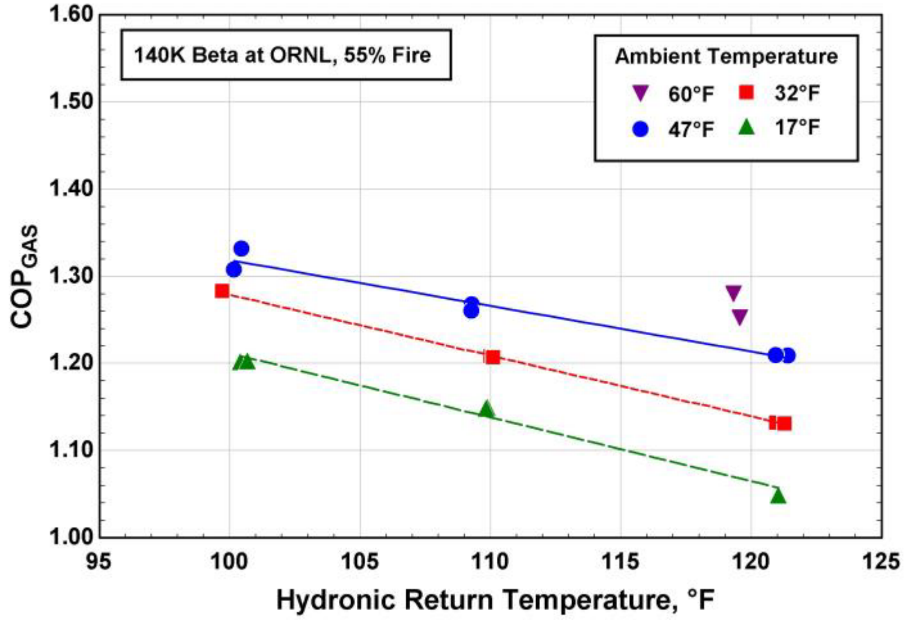

Figure 5. COP_{gas} vs ambient air and hydronic inlet temperatures

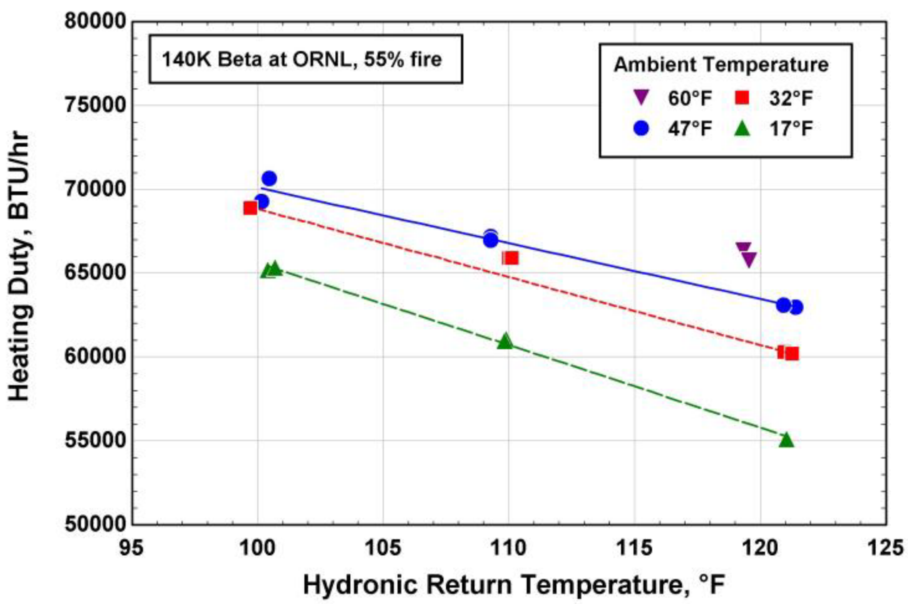

Figure 6. Heating load vs ambient air and hydronic inlet temperatures

3. FUTURE PLANS

The Beta unit was returned to SMTI to undergo a thorough cleaning to remove any oil that contaminated the system during an incident with a vacuum pump at SMTI. The current rectifier will be removed and an alternative design (similar to the one used on the Breadboard system) will be investigated. Performance is expected to be much closer to design once the refrigerant purity is resolved. Implementation and testing of the desired defrost strategy will also be performed. A field test unit will be ready for testing early in 2017