

# INTEGRATION OF AN ABSORPTION CHILLER SYSTEM IN A SUPERMARKET HEATING, COOLING AND POWER SYSTEM

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## 1 ABSTRACT

The objective of this investigation was to integrate a pre-engineered Combined Cooling, Heating and Power (CCHP) system into a supermarket application. The CCHP system, which consists of four natural gas-fired microturbines and a double effect absorption chiller/heater, provides electrical power, space conditioning, and sub-cooling of a refrigeration loop to reduce electric power demand. In addition, the exhaust heat from the chiller is used to regenerate a solid desiccant wheel that provides dehumidification of the retail space. Results of an energy analysis indicate that the CCHP system will provide a 65% reduction in grid electric demand. This paper will present a description of the CHP system, detail how it was integrated into the supermarket application, and describe the benefits of using CCHP systems in this application.

**Key Words: Combined Cooling, Heating and Power (CCHP or CHP), absorption chiller, waste heat recovery, Thermally Activated Technology (TAT)**

## 2 INTRODUCTION

Combined Cooling Heating and Power (CCHP) systems include an electric generator and a means for utilizing the waste heat from the generator. Typically the waste heat is used to heat hot water or to drive a thermally activated technology (TAT) device such as an absorption chiller [1, 2]. CHP systems offer the potential for high fuel utilization and low emissions. These systems can provide high value, especially when used in applications where the equipment is required to operate continuously (base-loaded applications) [3]. In addition to economic value, CCHP systems provide higher fuel utilization than central power plants, resulting in reduced use of fossil fuels. The U.S. Department of Energy has identified CCHP systems as an important part of the U.S. energy strategy [4, 5].

In the current work, a commercially available, pre-engineered CCHP system was applied to a supermarket application. Supermarkets have a significant electric base load due to the refrigeration system. They also require seasonal space cooling or heating and dehumidification. The challenge was to develop and implement a thermal and mechanical integration of a CCHP system in a supermarket application. Following a description of the CCHP system, this paper will describe the integration of the system into the supermarket, including a description of the skid that was assembled and delivered to the site. Analytical results showing the predicted energy savings will also be presented.

### 3 CCHP SYSTEM

The CCHP system used in this work is a commercially available product known as the PureComfort™ 240M. The system, pictured in Figure 1, is pre-engineered to properly combine four 60 kWe microturbines and a double-effect absorption chiller driven by the microturbine exhaust heat. The system includes a diverter valve to bypass the exhaust flow around the chiller when additional chilling capacity is not required or desired, preventing unfavorable concentrations of chiller fluids. The requisite ducting and fuel gas boosters are included in the standard product. The double-effect chiller can be operated to provide either chilled water for space cooling or hot water for space heating. The electric output and cooling and heating capacities of the PureComfort™ 240M system have been documented [6] and are presented in Table 1.

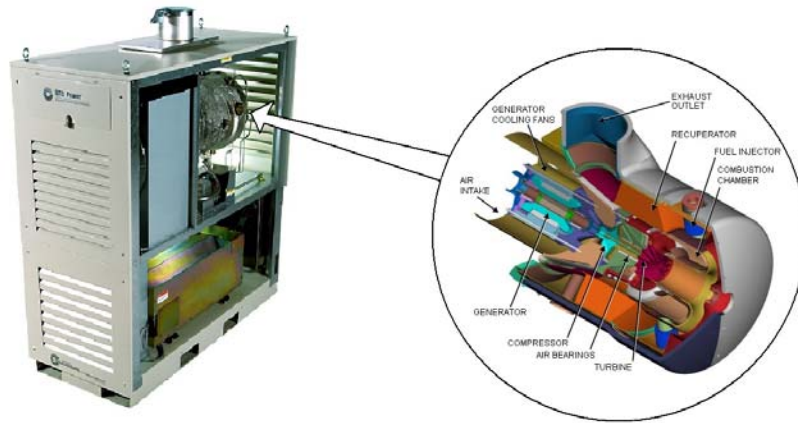


**Figure 1. PureComfort™ 240M**

**Table 1. PureComfort™ 240M Performance**

|   |   |
|---|---|
| Gross/Net<br>Electric Power<br>[kW <sub>e</sub> ] | <b>59 °F:</b> 240/229<br><b>95 °F:</b> 213/202<br><b>32 °F:</b> 240/229 |
| Cooling Power<br>[kW <sub>c</sub> /RT]            | <b>95 °F:</b> 420/120<br><b>59 °F:</b> 585/167                          |
| Heating Power<br>[kW <sub>t</sub> /MBH]           | <b>32 °F:</b> 295/1005<br><b>59 °F:</b> 339/1155                        |

Each microturbine in the PureComfort™ 240M system includes a recuperated turbine engine that drives a generator at speeds up to 96,000 rpm (see Figure 2). A solid-state power electronics package housed in the turbine enclosure converts the high frequency power from the generator into Direct Current, and then converts the DC into standard three phase alternating current.



**Figure 2. 60 kW Microturbine**

The exhaust of the microturbine is used to drive a double effect absorption chiller/heater shown in Figure 3. The chiller/heater provides either chilled water at 44 F or hot water at 140 F. An option for 170 F hot water is also available. Control of the energy input to the chiller is accomplished using a diverter valve to regulate the flow of microturbine exhaust to the chiller. The position of the valve, located in the ducting between the microturbines and the chiller, is determined by the chiller controller to maintain the chilled water temperature set point. Any exhaust not required to maintain the chilled water set point is vented through a bypass. When the chiller is not being used, an air seal blower located in the diverter valve provides a slight positive pressure inside the valve to prevent hot exhaust gas from entering the chiller.

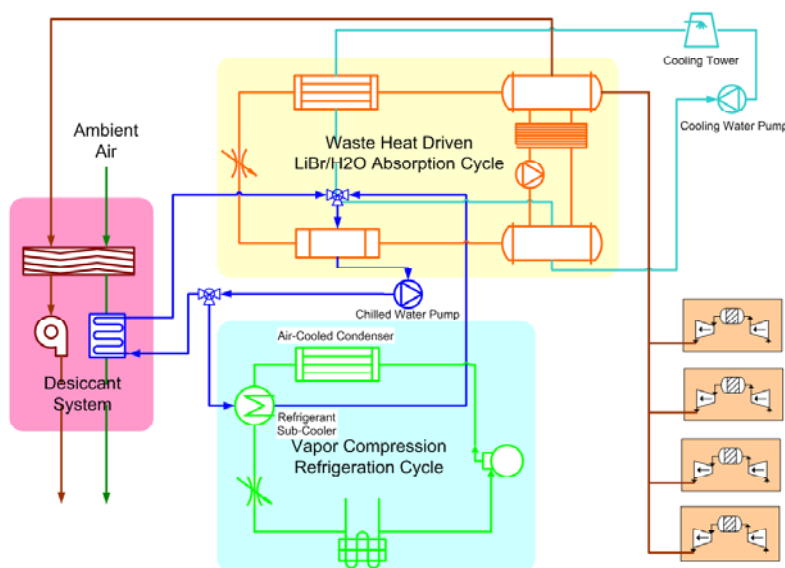


**Figure 3. Waste Heat Driven Absorption Chiller**

## 4 INTEGRATION WITH SUPERMARKET

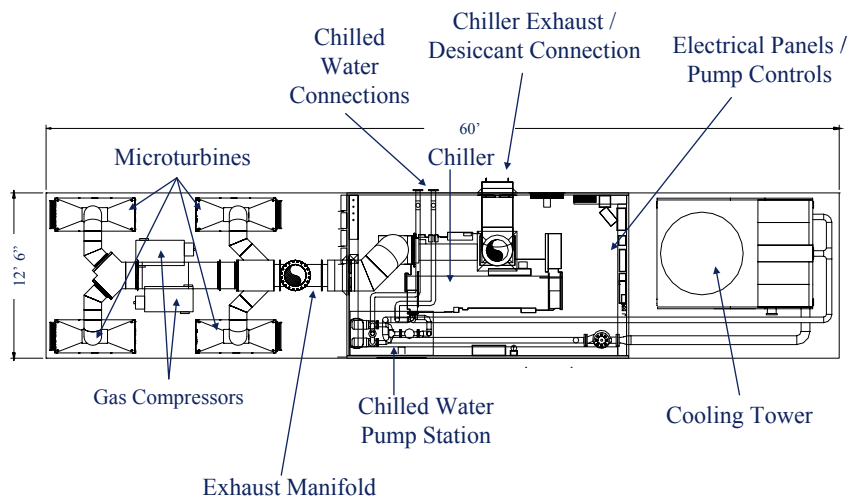
The PureComfort™ 240M system provides electricity and either chilled or heated water, and is designed for easy integration into commercial buildings. Application of this system to supermarkets presented new challenges and opportunities. In addition to requiring electrical power and seasonal space cooling or heating, the supermarket application also required refrigeration and dehumidification. The refrigeration load is traditionally provided by electric driven vapor compression. A solid desiccant wheel that is regenerated by a natural gas fired burner is used to dehumidify the retail space.

An analysis of the supermarket energy requirements was conducted to determine the most effective way to integrate the PureComfort™ 240M with existing systems. The results of the analysis indicated that, in addition to space cooling, the chilled water output from the CCHP system could be used to sub-cool the refrigeration loop, thereby reducing the refrigeration electric power demand. Furthermore, the exhaust heat from the chiller has sufficient thermal energy to regenerate the solid desiccant wheel. Therefore, the CCHP system can reduce the electric power required by the refrigeration system and the energy needed to regenerate the desiccant wheel. The integration of the PureComfort™ system into the supermarket is shown schematically in Figure 4.



**Figure 4. PureComfort™ 240M Integration with Supermarket System**

In addition to thermal integration with the supermarket, mechanical integration of the PureComfort™ 240M system was also required. The central portion of the store's roof was determined to be the best location for the CCHP system. For this reason, and the desire to minimize on-site installation efforts, a skidded assembly of the PureComfort™ 240M was designed. The skid included the standard PureComfort™ 240M components as well as a cooling tower and circulating pumps. A housing was added to provide a weather-proof enclosure for the chiller and pumps. The final skid design is depicted in Figure 5 showing the layout of the microturbines, fuel gas boosters, chiller with outdoor enclosure, cooling tower, and ductwork.

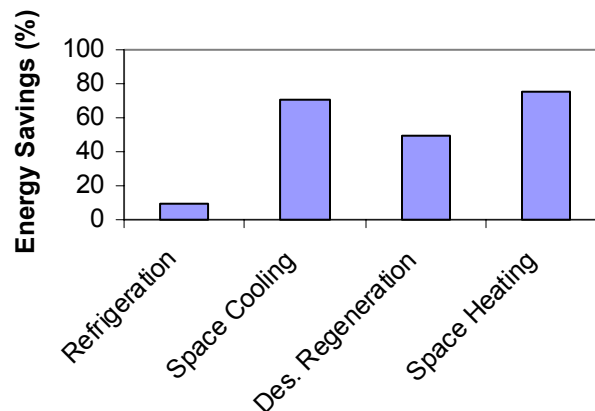


**Figure 5. PureComfort™ Skid Design**

The PureComfort™ 240M skid was installed and commissioned at a supermarket. Data have been acquired and are being analyzed. Preliminary analysis of the data indicates the system working as designed.

## 5 CHP BENEFITS IN SUPERMARKET APPLICATIONS

Based on its high utilization efficiency, the PureComfort™ system provides significant energy savings over conventional equipment. These savings result from the use of efficient microturbines combined with effective utilization of the waste heat contained in the exhaust flow. Results of an analysis of energy use in supermarkets indicated that the PureComfort™ 240M provides a 65 percent reduction in grid electric demand. Details of the energy savings are presented in Figure 6 as a percentage of the annual energy required for each system. The calculated energy savings would provide approximately \$140,000 per year in target markets, or about 40 percent of the annual energy cost for a supermarket.



**Figure 6. Predicted Annual Energy Savings**

In addition to energy savings, the PureComfort™ 240M system also provides environmental benefits. The microturbines are ultra-low NO<sub>x</sub> devices at full power. This attribute, coupled with high fuel utilization, results in significantly lower emissions than traditional systems utilizing grid electricity and traditional equipment. Another environmental benefit is that the chiller/heater utilizes water as the refrigerant, thereby avoiding the use of substances that lead to global warming or depletion of the ozone layer.

## 6 CONCLUSIONS

A commercially available, pre-engineered CHP system was applied to a supermarket application. The system, known as the PureComfort 240M, includes four 60 kWe microturbines and a double-effect absorption chiller driven by the microturbine exhaust heat. The CHP system was integrated into the supermarket so as to provide electricity, space heating and cooling, refrigerant subcooling, and regeneration of a solid desiccant. Analytical results indicate that the system will reduce the electrical demand from the grid by 65 percent, resulting in a 40 percent reduction in annual energy cost. The system was packaged for outdoor installation, mounted on a single skid, and installed at a customer site. Data from the system have been acquired and will be analyzed and presented at a future time.

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## ACKNOWLEDGEMENTS

The authors would like to gratefully acknowledge the support and significant interaction with Ron Fiskum at the Department of Energy and Robert DeVault at Oak Ridge National Laboratory.