ABSTRACT

Kung, Yi-Shu. Ph.D., Purdue University, May 2015. An Integrated System of Vapor-compression Chiller and Absorption Heat pump: Experiment, Modeling, and Energy and Economic Evaluation. Major Professor: Ming Qu.

Buildings currently consume 41% of the primary energy in the United States. Among the 41% primary energy, approximate 50% are used for building heating, cooling, and water heating. Improving the efficiencies of the devices for building heating and cooling has potentials to reducing the energy consumptions. This research aims to find one solution for building energy efficiency through investigating an Integrated System of an Integrated Compression-Absorption Subcooling System (ICASS) Based upon the principle of subcooling effect, the ICASS can improve the efficiency of the cooling device but also achieve additional useful heating sources potentially used for space heating and domestic hot water. The ICASS utilizes thermal energy as a part of power inputs to reduce the dependency of electricity so that it can reduce the peak power demand. Due to the improved system efficiency and the availability of heating source, the ICASS could also improve the cost effectiveness of the system.

The objectives of this research include:

Objective 1: To develop the thermodynamic and heat transfer models of the ICASS for system design and performance evaluation.

Objective 2: To test the performances of a test bed for data analysis and model validation. The data collected from the test bed will also contribute the fields of vapor-compression refrigeration system (VCRS) and absorption heat pump (AHP).

Objective 3: To conduct both energy and exergy analysis of the ICASS based on the validated models.

Objective 4: To evaluate the energy and economic benefits and to discover the commercial potentials of the ICASS.

In order to predict the potential improvements of the ICASS, an integration of a VC and a single-effect lithium bromide AHP was modeled in the Engineering Equation Solver (EES) as a case study according to the engineering fundamentals and scientific principles.

A test bed was constructed following the design models of ICASS. The test bed is located in the Herrick Labs at Purdue University, West Lafayette, IN. The VCRS, AHP, and ICASS were tested at different operation conditions and the system performances were recorded. Experimental data collected was also used to develop, adjust, and validate the models of VCRS, AHP, and ICASS.

The validated models of VCRS, AHP, and ICASS were extended for system sensitivity analyses and overall system performance prediction when ICASS is used to various applications. The sensitivity analyses were able to identify the key parameters, which most influence the system performance. Since the ICASS utilizes both electricity and thermal energy as the energy inputs, exergy analysis was conducted to calculate the exergy efficiency and determine the irreversibilites of the system to address the potentials of the improvements. To compare the performance of ICASS with other equivalent systems, the separated systems of VCRS, absorption chiller, AHP, and water heater were used to identify the benefits due to the ICASS. The results showed that ICASS consumed the less energy by providing same heating and cooling than the equivalent systems. Finally, building energy simulations were carried out to evaluate the economic performance of the ICASS when it is applied to the full service restaurant. The simulation results indicated that the applications with high cooling demands are favorable for ICASS and the higher heating demands, the higher the savings.