

## Efficient Engine-Driven Heat Pump for the Residential Sector

### Introduction

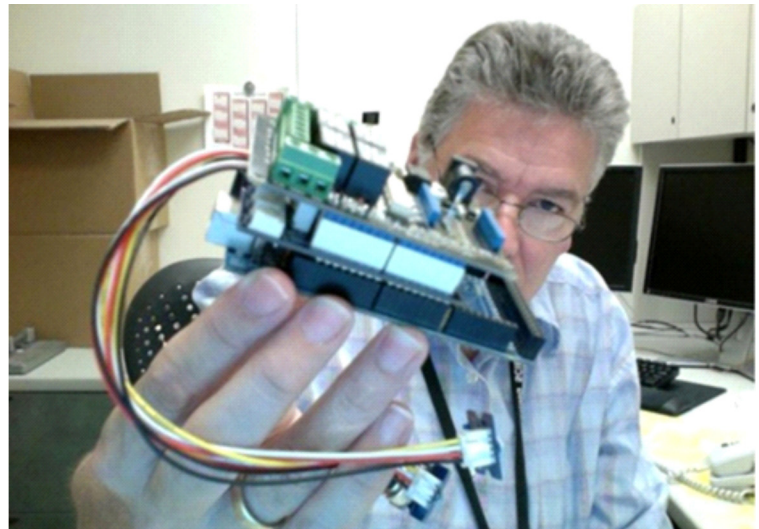
Building on previous work on an 11-ton packaged natural gas heat pump, this project will develop hardware and software for engine and system controls for a residential gas heat pump system that will provide space cooling, heating, and hot water.

Various electric heat pump systems are used to provide heating and cooling for a wide range of buildings, from commercial facilities to single family homes. The market for heat pumps is significant. For example, according to the U.S. Energy Information Administration's 2009 Residential Energy Consumption Survey, 9.8 million American homes are heated by electric heat pumps.

To operate a conventional electric heat pump system, fuel is first converted to energy at a power plant where the waste heat is typically discharged to the environment. Electrical energy is then transmitted over power lines and converted to mechanical energy by the heat pump motor. In this process, energy is converted twice, with waste heat loss each time. Overall system energy efficiency will increase significantly if fuel conversion is located closer to the site where energy is used to drive a heating and cooling system and if waste heat from the system is captured and utilized to supplement the heat produced by the vapor compression system.

The project team, led by Southwest Gas Corporation, previously developed an 11-ton packaged gas heat pump system that uses an internal combustion engine to drive a vapor-compression heat pump that utilizes the waste heat generated by the engine to enhance the heating of indoor air. The system incorporates a variable speed natural gas engine, which significantly improves part-load efficiency of the system. Accompanying system controls allow the engine to operate at desired design parameters, preventing excessive wear on engine parts and the compressors. The new system was introduced commercially in 2010 and received the National Society of Professional Engineers' 2010 New Product Award and R&D Magazine's 2011 R&D 100 Award.

The current research project aims to develop hardware and software for engine and system controls for a residential gas heat pump. In the residential application, waste heat will be utilized for domestic hot water production in addition to supplementing the heating capacity and defrosting in low ambient temperature installations. Once the controls are developed, the residential gas heat pump system will be field-tested in multiple locations in 2013.



Project partners are developing intelligent system control hardware and software for the residential gas heat pump.

*Photo courtesy of Oak Ridge National Laboratory*

### Benefits for Our Industry and Our Nation

The developed 11-ton packaged natural gas system and the residential gas heat pump provide many economic, environmental, and operational benefits, including:

- Reduces overall energy costs to the consumer
- Saves primary energy by using recovered waste heat
- Reduces peak electricity demand by 80%
- Reduces greenhouse gas emissions by 20–30%
- Saves water by reducing consumption at central power generating plants for electricity production

### Applications in Our Nation's Industry

The developed 11-ton packaged natural gas heat pump can be used to provide heating and cooling in small- and medium-sized buildings, such as big box stores, restaurants, warehouses, and other commercial buildings. The residential unit now under development aims to bring an economically viable combined heating and cooling option to the residential sector.

### Project Description

This project will develop a natural gas heat pump system for the residential sector. The system will incorporate an internal combustion engine that drives a vapor-compression heat pump. Waste heat generated by the engine will be used for domestic water heating and/or supplement the heating capacity at low ambient temperatures.

## Barriers

The project aims to overcome the following technology barriers:

- Development of cost-effective controls and appropriate control algorithms for the multi-function heat pump system
- Added system complexity when compared to traditional heat pump systems
- Need to avoid excessive wear on engine and compressors under extreme operating conditions
- Higher first cost when compared to traditional heat pump systems
- Additional space required for internal combustion engine
- Attenuation of inherent low frequency internal combustion sound
- Need to comply with local and federal emission regulations in a cost-effective manner

## Pathways

The project will build on system concepts and technical solutions developed for the 11-ton natural gas packaged heat pump. The same overall approach will be applied to a smaller system that is appropriate for the residential sector.

Research activities for the residential system are divided into three separate tasks: 1) system controls development, 2) engine controls development, and 3) system testing.

In the first task, candidate approaches for the supervisory control system will be evaluated, and the most promising candidates will be tested for functionality and reliability. In addition, appropriate algorithms for system control will be developed and optimized by evaluating field data from early prototypes.

In the second task, engine controller technology and software algorithms will be evaluated. The best suited technology will be incorporated into the system design, with the goal of maximizing value, performance, and reliability.

Prior to system testing, baseline performance testing will be conducted at the selected field test sites. The new system with the developed controller boards and algorithms will first be tested in laboratory conditions, followed by field testing at several different locations in Las Vegas, NV.

## Milestones

- System control hardware developed
- Algorithm for system control software developed
- Engine control system developed
- Laboratory testing of the new residential heat pump system
- Field testing of the new heat pump

## Commercialization

As with the 11-ton packaged natural gas heat pump aimed at the commercial sector, there is much interest in the residential gas heat pump and several options are being explored as to the best way to distribute and market the product. Southwest Gas will promote the new system in its service territory.

## Project Partners

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