Residential Multi-Function Gas Heat Pump

Efficient Engine-Driven Heat Pump for the Residential Sector

Introduction

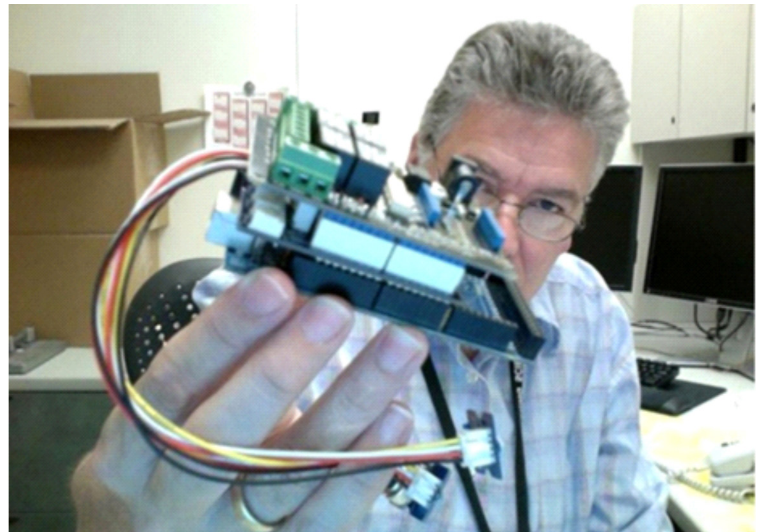
Building on previous work on an 11-ton packaged natural gas heat pump, this project developed hardware and software for engine and system controls for a residential gas heat pump system that provides space cooling, heating, and hot water.

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. 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. 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, significantly improving 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—introduced commercially in 2010—received the National Society of Professional Engineers' 2010 New Product Award and R&D Magazine's 2011 R&D 100 Award.

This research project aimed 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. Demonstration units were field tested at multiple locations between 2014 and 2015.



Project partners developed 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 residential gas heat pump provides 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 natural gas heat pump aims to bring an economically viable combined heating and cooling option to the residential sector.

Project Description

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

Barriers

The project aimed to overcome the following technology barriers:

- Development of cost-effective controls and appropriate control algorithms for the multi-function heat pump system
- Higher 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 engine sound
- Need to comply with local and federal emission regulations in a cost-effective manner

Pathways

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

Research activities for the residential system were 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 were evaluated, and three of the most promising candidates were designed and prototyped: 1) the utilization of low-cost micro-controllers as the basis of the system, 2) the utilization of a low-cost programmable logic controller (PLC), and 3) a custom designed control board. The three approaches were tested in the field and found to provide varying levels of reliability and cost savings while providing essentially the same level of control performance. In the second task, software algorithms and a new engine control system board were evaluated.

Prior to system testing, baseline performance testing was conducted at the selected field test sites. The new system with the developed controller boards and algorithms was first 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 systems
- Field testing of the new heat pumps
- Commercial configuration identified

Commercialization

There is much interest in the residential gas heat pump, and several options were being explored as to the best way to distribute and market the product. Southwest Gas had planned to promote the new system in its service territory. However, fundamental and excessive costs related to the manufacture of the unit's mechanical systems led to a decision by Southwest Gas to suspend further development of the technology at this time.

Spin-Off Activities

The micro-controller technology acquired for this research was successfully adapted to facilitate machine monitoring and prognostics. Specifically, significant cost savings—two orders of magnitude cheaper than conventional methods—were achieved in very high-speed vibration monitoring.

Project Partners

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