Final Report Certification
for
CRADA Number CRNL-04-0694

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Between

UT-Battelle, LLC

and

Lennox Industries, Inc.
(Participant)

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3. By the signature below, the Participant has no objection to the public distribution of the final report due to patentable information.

For the Participant:

Robert Uselton
(Name)

Senior Principal Engineer, Lennox Industries, Inc.
(Title)

Feb 27, 2007
(Date)

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Hybrid Heat Pumps Using Selective Water Sorbents (SWS)

November 30, 2006

Prepared by
M. R. Ally
Senior Research Staff

UT-BATTELLE

ORNL-XXXX

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CRADA No. ORNL-04-0694

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HYBRID HEAT PUMPS USING SELECTIVE WATER SORBENTS (SWS)

M. R. Ally

November 2006

Prepared by
OAK RIDGE NATIONAL LABORATORY
P.O. Box 2008
Oak Ridge, Tennessee 37831-6285
managed by
UT-Battelle, LLC
for the
U.S. DEPARTMENT OF ENERGY
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Abstract

The development of the ground-coupled and air-coupled Heating Ventilation and Air-Conditioning (HVAC) system is essential in meeting the goals of Zero Energy Houses (ZEH), a viable concept vigorously pursued under DOE sponsorship. ORNL has a large Habitat for Humanity complex in Lenoir City where modern buildings technology is incorporated on a continual basis. This house of the future is planned for lower and middle income families in the 21st century. The work undertaken in this CRADA is an integral part of meeting DOE's objectives in the Building America program.

SWS technology is a prime candidate for reducing the footprint, cost and improve the performance of ground-coupled heat pumps. The efficacy of this technique to exchange energy with the ground is a topic of immense interest to DOE, builders and HVAC equipment manufacturers. If successful, the SWS concept will become part of a packaged ZEH kit for affordable and high-end houses.

Lennox Industries entered into a CRADA with Oak Ridge National Laboratory in November 2004. Lennox, Inc. agreed to explore ways of using Selective Water Sorbent materials to boost the efficiency of air-coupled heat pumps whereas ORNL concentrated on ground-coupled applications. Lennox supplied ORNL with heat exchangers and heat pump equipment for use at ORNL's Habitat for Humanity site in Lenoir City, Tennessee. Lennox is focused upon air-coupled applications of SWS materials at the Product Development and Research Center in Carrollton, TX.

Statement of Objectives

The objective of this project is to jointly develop and test residential heat pumps employing Selective Water Sorbents (SWS). The technical objective is to develop appropriate SWS material(s), specific system components, and perform computer simulations necessary to generate the technical information for developing an engineering design of a prototype unit. SWS uses the difference in water vapor pressure between itself and the environment (ground or air) to transport water with a high latent heat of vaporization. SWS also has the added property of being able to absorb about 7 to 8 times its own weight of water, thereby making water storage very efficient. Water is released when the temperature of the SWS is such that its water vapor pressure is slightly above the environment. Water is absorbed by the SWS when its temperature is slightly below that of its environment, or if it comes into contact with condensed water. These properties of SWS materials can be exploited for engineering a new generation of highly cost-effective and more efficient ground-coupled heat pumps that can also offer peak electricity demand reductions.

Benefits to the Funding DOE Office's Mission

The President's national energy plan (NEP) specifically calls for improvements in the energy efficiency of residential and commercial buildings and of energy-using equipment in these buildings. EERE's Building Technologies (BT) Program has embraced the

program goal of developing technologies and design approaches that enable net-zero energy houses (ZEHs) at low incremental cost by 2025. A net zero energy building is a residential or commercial building with greatly reduced needs for energy through efficiency gains, with the balance of energy needs supplied by renewable technologies. In 2003, the most recent year for which data is available, residential buildings accounted for 37% of the nation's consumption of electricity (DOE 2005 Buildings Energy Data Book, August 2005, Summary Table 5). Space heating and cooling accounted for almost 4 quads, or a little over 28%, of that electric use (Ibid, Table 1.2.3). Heat pumps are one of the most prevalent and energy efficient means by which to use electricity for space heating and cooling – in 2004 over 2 million heat pumps were shipped by U.S. manufacturers (Ibid, Table 5.6.1).

This CRADA supports the overall Building Technologies' Program goal of producing ZEHs by 2025. Central to this goal are substantial reductions in energy use by enhancing the energy efficiency of equipment used to provide space heating, cooling, dehumidification and ventilation as well as hot water, at low incremental cost. This project will increase the efficiency of air-coupled heat pumps at low cost and reduce the cost of ground-coupling heat pumps.

Relationship to Other DOE Projects:

The CRADA directly supports other parallel activities within the BT program such as integrated heat pump (IHP) development, and development of advanced HVAC and water heating (WH) options. Indeed, any technology which relies on heat rejection or extraction from ambient air or the ground can potentially be enhanced by this technology (e.g., stand alone air-conditioners and refrigerators).

Technical Discussion of Work Performed by All Parties

The work performed by all parties including intellectual property is summarized below.

Status of intellectual property is as follows:

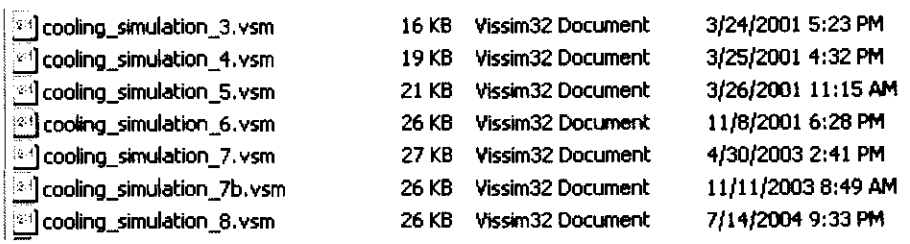
CRADA (ORNL-04-0694; November 9 2004-November 9 2006).
ORNL Background Intellectual Property:

- "Super Energy Saver Heat Pump with Dynamic Hybrid Phase Change," ID-1298, S-1011886.
- 4-Way Valve to Achieve Subcooling and Desuperheating discussed with Lennox, dated 2/16/04.
- Intellectual Property augmented February 16, 2003 by e-mail notification to potential CRADA partner.
- Design algorithm for air-coupled system to Lennox Inc., April 27, 2005
- SWS Data to Lennox, Inc. June 08, 2005

- Schematic of ground-coupled system to Lennox. Inc., July 8, 2005
- Schematic of ground-coupled system to Lennox Inc., July 08, 2005

Participant's Background Intellectual Property:

- Lennox Industries Invention Record "Hybrid Earth-Coupled Heat Pump", dated November 12, 2001
- Computer Simulation Programs:



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- Lennox Industries Invention Record "Hybrid Heat Pump Incorporating Thermal Ballast", dated February 12, 2004 (Page 40 of Robert Uselton's Engineering Notebook, RBU11)

Commercialization Possibilities

This concept is still under development under the DOE's Buildings Technology Program. Results to date are very encouraging. Our R&D program has received continual support form DOE headquarters to further study the technical feasibility of implementing this novel ground-coupled concept. Commercialization possibilities are not limited to the CRADA partner, although under the CRADA terms, they shall have first choice for the air-coupled version, but we are open to negotiate with interested parties on the ground-coupled version, which is an enabling technology for the near zero energy homes (NZEH).

Plans for Future Collaboration

Following computer simulations of the ground-coupled version, we plan to complement our intellectual property portfolio, apply for patents, and invite companies especially those with a background and interest in ground-coupled systems for further collaborations, technology transfer, and licensing.

Conclusions

The ground-coupled technology that we are developing is unique and offers a very attractive cost-performance alternative for residential homeowners to lower their utility bills by using the ground as an efficient thermal source or sink for heating and cooling, respectively. ORNL has a credible NZEH program and this technology is an enabling technology to reach that goal. The positive element in this technology is that it can be

retrofitted in existing homes. It represents an effective and inexpensive solution to the problems of greenhouse gases and global warming.